U.S. Fish & Wildlife Service

Ecological Services
Anchorage Field Office

Rpt. #2 of 2
cont.

Technical Report WAES-TR-98-03

Habitat Conservation

Contaminants Survey: Bear Creek Well Number 1

Alaska Peninsula / Becharof National Wildlife Refuge

Endangered Species

by:
Sonce de Vries
Mark Giger

Environmental Contaminants

July 1998

Acknowledgments

The Contaminants staff in the Anchorage Field Office wishes to thank the Becharof Refuge staff for their enthusiastic support during the planning and execution of the field survey. In particular, Ron Hood, Refuge Manager, Rick Poetter, Assistant Refuge Manager, and Janice Collins, Secretary were very helpful with logistics and field support. "Moose" Mumma and Gary Terry provided equipment and technical support on a number of occasions. A particular vote of thanks goes to cooperative student Joan (Christian) Dean, who provided steadfast support in the field and unflagging optimism when things got tough. Jerry Grey, pilot, demonstrated consummate flying skill and added a pleasant personality to the group. Last, but not least, many thanks to John Gerlach and Johanna Young, students with the RAP Program, who provided willing hands and good company during long days in the field.

Executive Summary

In 1988, the U.S. Fish and Wildlife Service (Service) funded a contaminants project with the following objectives : 1) conduct a reconnaissance-level field inspection of abandoned oil and gas exploration sites on the Alaska Peninsula/ Becharof National Wildlife Refuge, 2) identify and map abandoned physical remains of oil exploration activities and 3) collect soil samples for organochlorine, petroleum, and metal analysis.

During the field survey, several sites warranting further study were identified. One such site was Bear Creek Well No., drilled as an exploration well by the Humble Oil and Refining Company (now Exxon) in the 1950s and abandoned for lack of commercial potential. The well pads still contained a large amount of wood and metal from buildings and machinery used during the exploration drilling.

In early 1990, Refuge Manager Ronald Hood proposed to the Exxon officials involved in the *Exxon Valdez* oil spill cleanup that Exxon remove both the debris at the Bear Creek Well No. 1 site and the old culverts under the access road. Exxon complied, removing the debris and most of the culverts during 1990 and 1991.

In 1993 Service personnel performed soil sampling at the well pads to identify any residual contamination left after Exxon's abandonment of the site. Some petroleum and metal residues of concern were found on the pads. Also, the remains of the reserve pit were found to be eroding into a stream which flows into Bear Creek, an important salmon spawning stream. The reserve pit residues contained significant amounts of barium (identified in an earlier report), petroleum, zinc, and a trace of polychlorinated biphyenls.

It is recommended that this site be investigated further to determine the extent of the contamination related to the well pads and the reserve pit and the ecological risk associated with this site.

Table of Contents

Appendix A

Schematic Drawings of Sampling sites at Bear Creek Well No. 1

Appendix B

Contaminants data from Bear Creek Well No. 1

List of Maps and Tables

Introduction

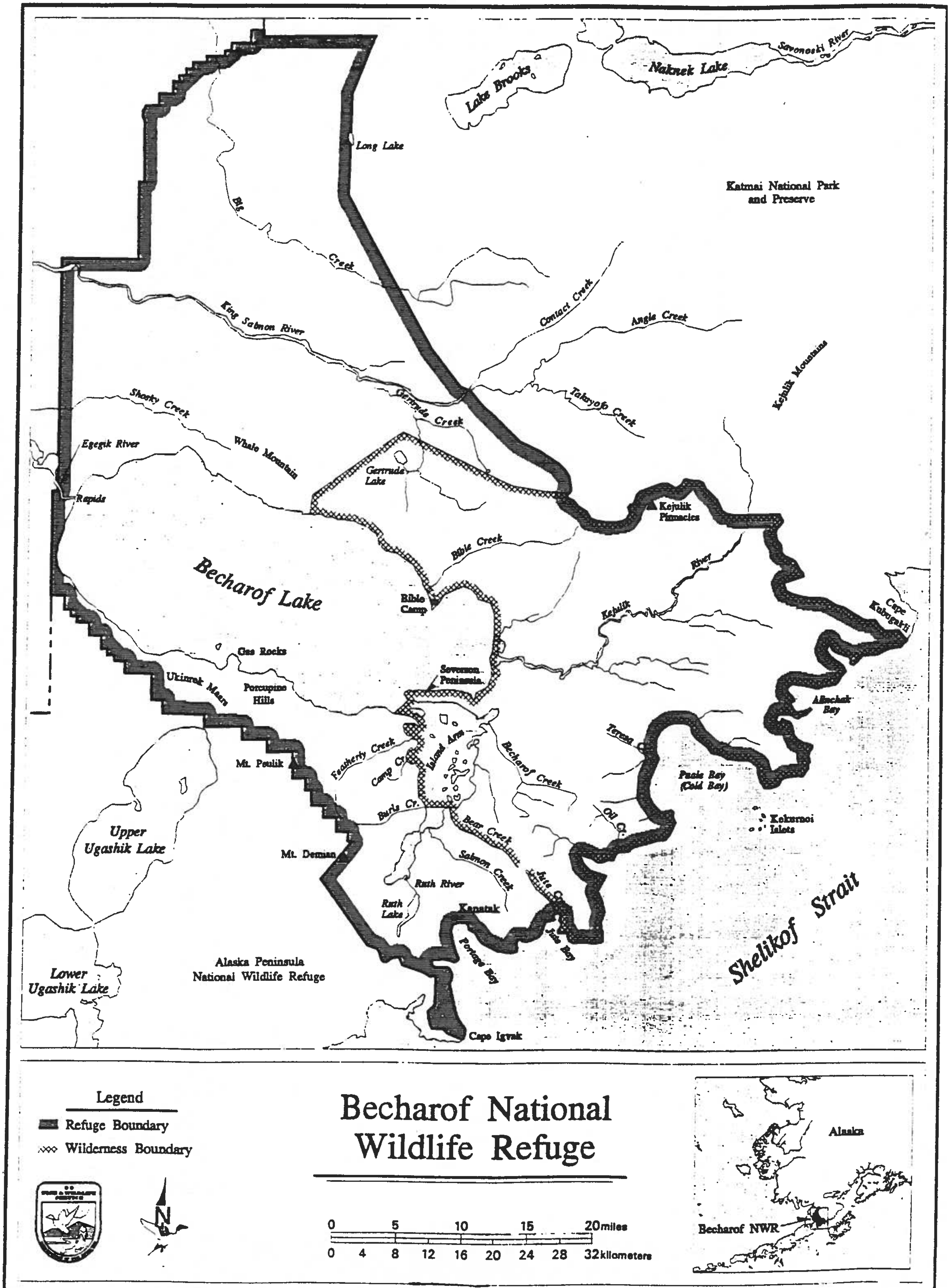
History and Purpose of the Refuge

Becharof National Wildlife Refuge, located on the Alaska Peninsula in southwestern Alaska (Map1), was created by the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). The purposes of the refuge as described in Section 302(2)(B) of ANILCA include:

(1) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, brown bears, salmon, migratory birds, the Alaska Peninsula caribou herd and marine birds and mammals;
(2) to fulfill the international treaty obligations of the United States with respect to fish, wildlife, and their habitats;
(3) to provide, in a manner consistent with the purposes set forth in subparagraphs (1) and (2), the opportunity for continued subsistence uses by local residents; (and)
(4) to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in subparagraph (1), water quality and necessary water quantity within the refuge (USFWS, 1985).

Study Area

Bear Creek, part of the Egegik River watershed, flows northwest into the Island Arm of Becharof Lake and is part of the southwest wilderness boundary within the refuge, as designated under ANILCA Section 702(4). The Egegik River watershed is critical for four of the five species of Pacific salmon that spawn on the refuge. The Alaska Department of Fish and Game estimates 834,000 adult sockeye or red salmon (*Onchorhynchus nerka*) return to Becharof Lake annually and it is estimated that eighty-five percent of these salmon spawn in the Island Arm area


Becharof National Wildlife Refuge
Legend
Refuge Boundary
Wilderness Boundary
0 5 10 15 20 miles
0 4 8 12 16 20 24 28 32 kilometers
Alaska
Becharof NWR
Naknek Lake
Lake Brooks
Savonoski River
Long Lake
Katmai National Park and Preserve
Big Creek
King Salmon River
Contact Creek
Angle Creek
Kejulik Mountains
Takayofo Creek
Gertrude Creek
Shosky Creek
Whale Mountain
Egegik River
Rapids
Gertrude Lake
Kejulik Pinnacles
Bible Creek
Kejulik River
Becharof Lake
Bible Camp
Cape Kubugakli
Gas Rocks
Severson Peninsula
Ukinrek Maars
Porcupine Hills
Island Arm
Featherly Creek
Camp Cr.
Becharof Creek
Teresa
Aliuchak Bay
Puale Bay (Cold Bay)
Mt. Peulik
Burls Cr.
Oil Cr.
Kekurnoi Islets
Upper Ugashik Lake
Bear Creek
Mt. Demian
Salmon Creek
Jute Cr.
Ruth River
Ruth Lake
Kanatak
Jute Bay
Shelikof Strait
Portage Bay
Alaska Peninsula National Wildlife Refuge
Lower Ugashik Lake
Cape Igvak

of the lake. These salmon are vital to the maintenance of the large population of brown bears (*Ursus arctos*) and bald eagles (*Haliaeetus leucoephalus*) that inhabit the area, not to speak of their commercial value to the Bristol Bay fishery. Becharof Lake's Island Arm is rated among the highest quality fish and wildlife habitats on the Alaska Peninsula and it has been identified as having "special value" to the refuge under Section 304(g) of ANILCA (USFWS, 1985).

History of Petroleum Exploration

From 1957 to 1959, a consortium of oil companies composed of Humble Oil and Refining Company (Humble), now part of Exxon, and the General Petroleum Corporation. (now Mobil Oil) conducted an oil and gas exploration program on what is now the Becharof National Wildlife Refuge. As part of this program, a heavy-duty access road with culverts was built by Humble from Island Bay on Shelikof Strait to the Bear Creek Well No. 1 exploration well and beyond. The Bear Creek well was completed by March 1959. No commercial quantities of oil or gas were found (Bascle, et al. 1987). The well was abandoned by Humble and the drill rig, associated equipment, and all consumables were leased to General Petroleum. According to Exxon, all demobilization and cleanup obligations at the Bear Creek well were assumed by General Petroleum.

General Petroleum continued their exploratory program further inland through 1959 but found no commercial quantities of oil and gas. The exploration program was abandoned by 1960. Demobilization was accomplished by General Petroleum through the Bear Creek/Island Bay area.

Study Background

Overflights of the refuge in the 1980s revealed a number of sites where debris from abandoned exploration sites remained. Several sites were visited and some were sampled in 1987. The sites visited included the Bear Creek No. 1 well site. The site was found to contain considerable debris remaining from the exploration work and an abandoned reserve pit which was eroding into a small tributary to Bear Creek on the east side of the site. The reserve pit, as observed in the cutbank eroded by the creek, appeared to contain drill mud, drums, and assorted trash. Samples were taken and analyzed for aluminum, arsenic, barium, cadmium, chromium, copper, lead, magnesium, manganese, nickel, selenium, silver, tin, and zinc. The results, as reported in (the) "Report of Findings: Becharof National Wildlife Refuge Contaminants Study" (Jackson, 1991), revealed concentrations of barium, considered to be diagnostic of reserve pits, ranging up to 4420 ppm dry wt. This concentration is well above the mean of 811 ppm reported for Alaskan stream and lake sediments in The Geochemical Atlas of Alaska (Los Alamos National Laboratory, 1983). All other metals in the reserve pit were within normal background concentrations.

The refuge, coordinating with the Bureau of Land Management as the regulator of subsurface leasing for oil and gas on federal lands, began requesting Exxon, as the driller of the Bear Creek No. 1 well, to submit cleanup plans for the area. Exxon representatives visited the site in 1990 and agreed to remove the culverts under the access road which were collapsing and blocking fish passage and also to remove the wood and metal debris at the well site. Much of this work was performed in August 1990 but the amount of debris and culverts made it impossible to complete the entire removal at that time. The work of clearing the well site was completed in 1991. However, the abandoned reserve pit was not removed and many collapsing culverts remain in place on the access road.

Potential Impacts from Abandoned Oil and Gas Exploration Sites

Oil and gas exploration has the potential to contaminate the environment with a variety of chemical compounds. The most probable contaminants are refined petroleum products used to power vehicles and equipment. However, other contaminants such as crude oil, metals, and halogenated (ie. chlorinated) compounds may be present due to their use in well drilling and site operations (e.g., drilling mud, batteries for machinery and auxiliary power, pesticides, and solvents used in maintenance shops, etc.).

Petroleum

Crude oil and refined petroleum products are made up of a complex mixture of chemical compounds. Even when the toxicity of individual compounds is known, it is difficult to determine what the toxic effect to the environment will be due to the additive, synergistic, or antagonistic effects of the various compounds. In addition, crude oil and refined petroleum products can have diverse effects on organisms within the same ecosystem (Overton, et. al., 1994).

The light-end fractions of petroleum hydrocarbons (C6-C10) consisting primarily of benzene, toluene, ethylbenzene and xylenes (BTEX) and naphthalene are the most toxic and abundant compounds present during the initial stages of spills or releases. It is in these early stages of a spill that acute toxic effects are most common. As petroleum weathers, these single-ring, lower molecular weight compounds, being more volatile, soluble, and/or biodegradable, are lost, leaving behind the less acutely toxic, multi-ring, higher molecular weight compounds such as polycyclic aromatic hydrocarbons (PAHs) (Overton, et. al., 1994).

PAHs are more persistent in the environment and have the potential to create chronic toxicity problems. At least one known human carcinogen, benzo(a)pyrene, has been identified as a mutagen (Overton, et. al., 1994). There is also evidence implicating PAHs as an inducer of cancerous and precancerous lesions (Eisler, 1987).

Petroleum products also contain trace amounts of metals including aluminum, nickel, chromium, lead, vanadium, and zinc. Although some of these metals are required as essential micronutrients by living systems, they may also become toxic to living organisms at relatively low levels of exposure.

Drilling Mud

Drilling mud is another source of potential contamination at oil and gas exploration sites. Drill mud components, primarily bentonite and chemical additives, are brought to drill sites in powder form. The dry materials are then mixed with various fluids to make "mud", which is introduced to the well casing while drilling to provide lubrication, remove formation cuttings, and to prevent blowouts. The used mud, often mixed with downhole cuttings from drilling, was not carefully managed in the early days of exploration. It could have been placed in a sump near the drill rig or it might have been deposited in a convenient nearby stream as appears to be the case at this site.

The most commonly used components of water-based drilling mud are barite, caustic soda, bentonite clays, and lignosulfonates. Of these, soda and lignosulfonates are usually considered the most toxic compounds.

Another potential source of contamination associated with drill mud are hydrocarbons (ie. diesel fuel or crude oil) added to the drill muds on occasion to compensate for specific down-hole conditions.

Drill mud may also be a source of metals to the environment. Though drilling mud was only one of a number of potential sources, Newbury (1979) reported an increase in metals, notably zinc, cadmium, and lead, in the sediment around a number of offshore drilling rigs. Woodward et. al. (1988), in a study of five well pads and their reserve pits on the North Slope of Alaska, measured an increase in common and trace elements in ponds adjacent to reserve pits. Concentrations of barium, chloride, chromium, potassium, sulfate, and zinc in pond water and of copper, chromium, iron, and lead in pond sediments were higher in ponds adjacent to the reserve pits than in control ponds. Cuttings from the well may be an additional source of metals depending on the geochemistry of the formation drilled.

Other Contaminants

Halogenated aromatic compounds, such as polychlorinated biphenyls (PCBs), and organochlorine (OCs) compounds, may also be present at older exploration sites. PCBs and a number of OCs (eg. DDT) are no longer manufactured for use in the U.S. but, due to their earlier widespread use and resistance to degradation, they are still found in the environment.

PCBs are closely related to pesticides in their chemical, physical, and toxicological properties. Unlike pesticides, they were never intended to become part of the environment. Most were used in "closed" systems such as electrical transformers and capacitors. PCBs were also used as lubricants, fluids in vacuum pumps and compressors, and heat transfer and hydraulic fluids. PCBs are mixtures of various isomers and were identified most commonly under the trade name "Aroclor" on the basis of the percent chlorine present. For example, Aroclor 1254, is a mixture of isomers with an average chlorine content of 54 percent by weight. Since there are 209 PCB isomers, and these isomers differ in physical, chemical, and biological properties, evaluation of the potential environmental impacts from a particular PCB product is complicated. PCBs also biomagnify in food chains; and since the late 1960's, they have been linked increasingly to adverse reproductive and developmental effects in a variety of fish-eating birds and mammals (Eisler, 1986) .

In some parts of the world, OC-containing pesticides may have been used around exploration sites to reduce disease-carrying insects. The properties that make OCs effective pesticides (low volatility, chemical stability, lipid solubility, slow rates of biotransformation and degradation) also make them a problem for wildlife and humans. Pesticide persistence in the environment, and their ability to bioconcentrate and biomagnify within various food chains, can result in significant body burdens in some species. In many cases, these body burdens have been found to be detrimental to reproductive success and even lethal to many species (Ecobichon, 1991).

Objective

The objective of the Bear Creek Well No.1 site study was to perform soil sampling of the well pad to determine if the above described contaminants were present at levels that could pose a threat to fish and wildlife on the Refuge.

Site Location

Bear Creek Well No. 1 is located in the upper portion of the Bear Creek drainage within the wilderness area of the Becharof National Wildlife Refuge: Section 36, Township 29 South, Range 41 West, Karluk (C6) Quadrangle (Map 2). The well site is located on a steep slope on the north side of Bear Creek, approximately four miles northeast of Island Bay on the Shelikof Strait. The pads excavated into the hillside are flanked by two surface water drainages, one of which is located very close to the edge of the well pad. Both streams probably receive subsurface drainage from the site before flowing into Bear Creek approximately ½ mile away.

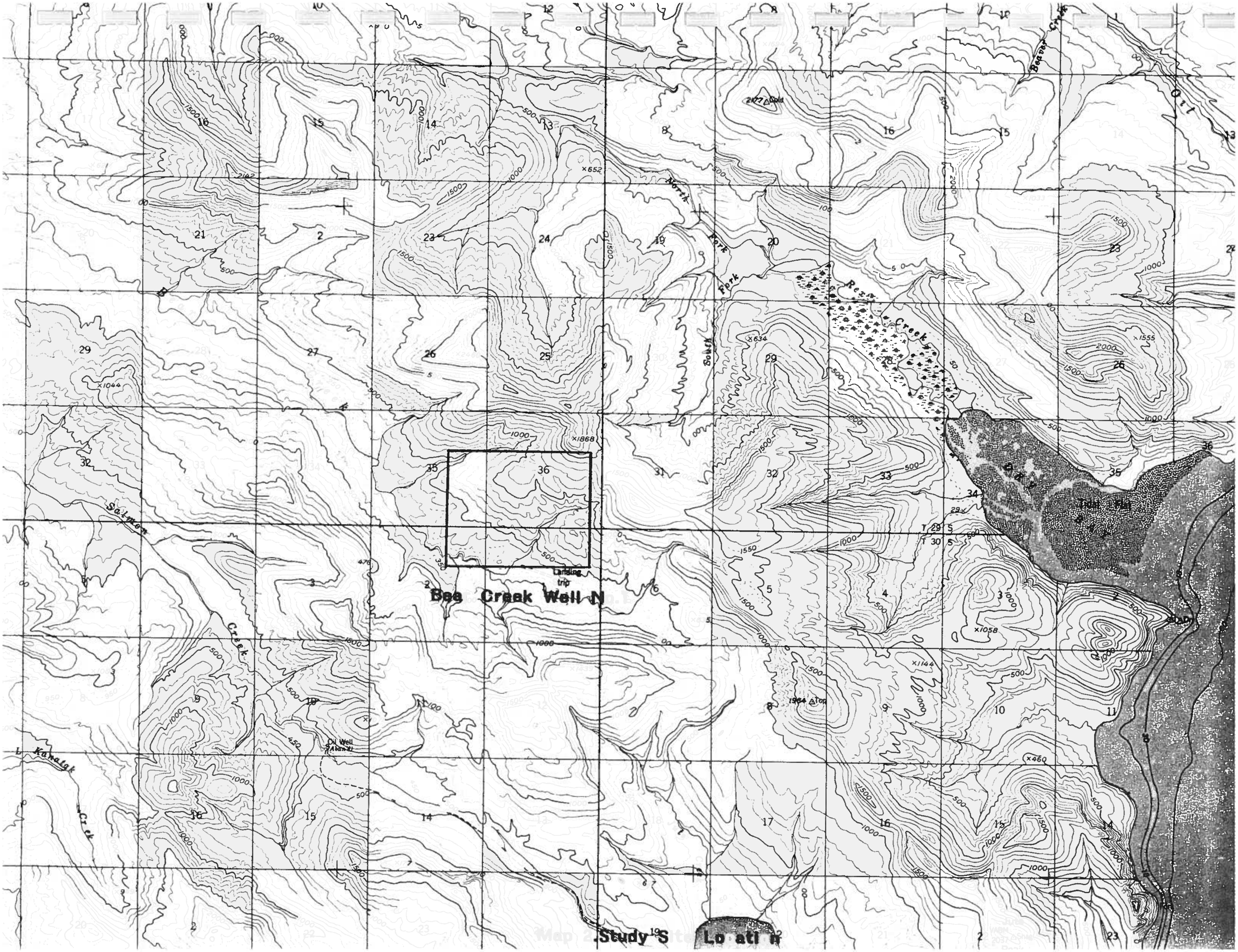
Methods and Materials

Field Procedures

Four areas at the Bear Creek Well No. 1 site were investigated. One was the well pad (approximately three hectares), the second was the housing pad (approximately three hectares), the third was the shop pad (approximately one hectare), and the fourth was an upslope control site (approximately one hectare) used to establish background concentrations. Because the pads appeared to have been cleared and graded during the Exxon cleanup, leaving no trace of the original surface or building locations, sampling was random rather than biased.

The well (see schematic of sampling pattern in Appendix A1), housing (Appendix A2) and shop pads (Appendix A3), and the control site (Appendix A4) were gridded into squares 25 meters on a side and samples were taken at the grid intersections. All measurements were made from the well survey monument on the well pad. No fixed monuments for use as reference points were available for the other three areas.

Two soil auger samples were collected from each grid point intersection. The surface material (0 to 20 cm.) was composited into one sample and the second



Map 2. Study Site Location

(subsurface) sample was composited from material collected between 80-100 cm. In several instances the deeper samples could not be collected because of the large number of coarse fragments. No alternative deep samples were collected.

Nineteen sampling sites were selected on the well pad from which 25 samples were collected for OC, PCB, and PAH analyses and nine samples were collected for metals analyses. Twenty-four sampling sites were selected on the housing pad from which 40 samples were collected for OC, PCB, and PAH analyses and 12 samples were collected for metals analyses. Seven sampling sites were selected on the shop pad from which nine samples were collected for OC, PCB, and PAH analyses and three samples were collected for metals analyses.

A control site was selected northeast of the well pad across a drainage bordering the east side of the well pad and up a short steep slope. A grid system like the one used for selecting sampling sites on the pads was used to identify sampling points. Nine sampling sites were selected in the control area from which 17 samples were collected for OC, PCB, and PAH analyses and seven samples were collected for metals analyses.

Soil samples were collected using a stainless steel hand auger and a stainless steel shovel. The equipment was decontaminated between samples with a scrub brush and water brought from Refuge headquarters at King Salmon. Supplemental wash water was collected up gradient of the site from the drainage on the west side. All equipment was decontaminated before collecting the surface sample and decontaminated again before collecting the deeper sample. Each composite sample was mixed in a stainless steel bowl that was decontaminated between each sample with Alconox and water and rinsed with acetone. The sample was stirred with a clean stainless steel spoon and an aliquot was transferred either to a pre-cleaned IChem Series 300 labeled glass jar for chlorinated hydrocarbon and PAH analyses or to a ziplock bag for metal analyses.

Fifteen sediment sampling locations (Appendix A5) were also selected from the drainages on both sides of the pads and from Bear Creek. Samples for OC, PCB, and PAH analyses and metals analyses were collected at each location. Each sample was an aliquot of a composite of three scoops of sediment taken with a decontaminated stainless

1) Analyte concentrations must be at least 2x the PQL[1]

2) At least 50% of the duplicates for the analyte must have a relative percent difference <20%,

3) At least 50% of the spike recoveries for the analyte must be within the range of 80-120%

4) At least 50% of the test blanks for the analyte must be non detect for the PQL

All values passing this screening are reviewed against the literature to identify contaminants of concern. It is recognized that the choice of values at only twice the practical quantitation limit is extremely conservative. However, the object of the types of preliminary contaminant investigations done by the Service is to identify problems which require further investigation either by the Service or by others. The intent is to draw attention to the presence of substances which <u>may</u> present a threat to fish and wildlife.

A complete set of raw data is available in the files at the Anchorage Field Office.

Results and Discussion

Appendix B presents the analytical results for the site. The Appendix includes data on metals and polycyclic aromatic hydrocarbons for soil and sediment samples collected from the well (Tables B1), housing (Tables B2), and shop pads (Tables B3), the control site (Tables B4), and for the streams bordering the site (Tables B5).

Quality Assurance/Quality Control

Table 1 lists all the analytes screened for at the Bear Creek Well No. 1 site. It also denotes analytes that do not warrant further discussion because they did not pass the

---

[1]The practical quantitation limit (PQL) is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

steel scoop and mixed in a clean container. Samples were handled the same as those collected from the pads.

Soil and sediment samples were frozen the day of collection and kept frozen during transport to Anchorage and the laboratory.

Equipment and container blanks also were collected during sampling. Duplicates were collected for ten percent of the samples.

Analytical Procedures

Samples were analyzed by the Geochemical & Environmental Research Group, Texas A&M.

Organic and pesticide compounds in soil and sediment samples were extracted in a Soxhlet extraction apparatus; the extracts were then treated with copper to remove sulfur. The extracts were eluted through alumina/silica gel columns to obtain the AH, PAH, OC, and PCB fractions, which were analyzed by gas chromatography.

Organic and pesticide compounds in water samples were extracted with methylene chloride in a separatory funnel and separated using alumina/silica gel columns. The fractions were analyzed by gas chromatography.

Metals in soil and sediment samples were determined by three techniques, depending on concentration and element. Mercury was determined by cold vapor atomic absorption spectrometry; arsenic, selenium, cadmium, and lead were determined by graphite furnace; the remaining elements were determined by atomic emission using an argon plasma.

Quality Assurance / Quality Control Screening

The raw data collected during this study was reviewed against criteria developed by the Environmental Contaminants Group in the Service's Anchorage Field Office. All values must pass the initial screening criteria as follows:

Table 1. Analytes tested for in soil and sediment samples collected June 1992 at Bear Creek Well No. 1, Alaska Peninsula/Becharof National Wildlife Refuge.

Metals	PAH	OC	PCB	
Aluminum	<2x 1,2,5,6-dibenzanthracene	<2x aldrin	<2x PCB# 100	<2x PCB# 201
Arsenic	1,2-benzanthracene	<2x hexachlorobenzene	<2x PBC# 101	<2x PCB# 205
<2x Cadmium	1,6,7-trimethyl-naphthalene	<2x heptachlor	<2x PCB# 105	<2x PCB# 206
Chromium	1-methylnaphthalene	<2x alpha BHC	<2x PCB# 107/108/144	<2x PCB# 209
Copper	1-methylphenanthrene	<2x alpha chlordane	<2x PCB# 110/77	<2x PCB# 22
B Iron	2,6-dimethylnaphthalene	<2x beta BHC	<2x PCB# 118/108/149	<2x PCB# 24
<2x Mercury	2-methylnaphthalene	<2x cis-nonachlor	<2x PCB# 126	<2x PCB# 25
Manganese	C1-fluoranthenes & pyrenes	<2x delta BHC	<2x PCB# 128	<2x PCB# 26
Nickel	C1-phenanthrenes & anthracenes	<2x dieldrin	<2x PBC# 129	<2x PCB# 28
Lead	C1-chrysenes	<2x endrin	<2x PCB# 136	<2x PCB# 29
<2x Selenium	C1-dibenzothiophenes	<2x gamma BHC	<2x PCB# 137	<2x PCB# 31
Zinc	C1-fluorenes	<2x gamma chlordane	<2x PCB# 138	<2x PCB# 33
	C1-naphthalenes	<2x heptachlor epoxide	<2x PCB# 141	<2x PCB# 37/42
	C2-phenanthrenes & anthracenes	<2x mirex	<2x PCB# 146	<2x PCB# 40
	C2-chrysenes	<2x o,p'-DDD	<2x PCB# 149	<2x PCB# 41/64
	C2-dibenzothiophenes	<2x o,p'-DDE	<2x PCB# 15	<2x PCB# 44
	C2-fluorenes	<2x o,p'-DDT	<2x PCB# 151	<2x PCB# 45
	C2-naphthalenes	<2x oxychlordane	<2x PCB# 153	<2x PCB# 46
	C3-phenanthrenes & anthracenes	<2x p,p'-DDD	<2x PCB# 156/171/202	<2x PCB# 47/48
	C3-chrysenes	<2x p,p'-DDE	<2x PCB# 158	<2x PCB# 49
	C3-dibenzothiophenes	<2x p,p'-DDT	<2x PCB# 16/32	<2x PCB# 50
	C3-fluorenes	<2x toxaphene	<2x PCB# 167	<2x PCB# 52
	C3-naphthalenes	<2x trans-nonachlor	<2x PCB# 170	<2x PCB# 60/56
	C4-phenanthrenes & anthracenes		<2x PCB# 172	<2x PCB# 66
	<2x C4-chrysenes		<2x PCB# 174	<2x PCB# 7
	C4-naphthalenes		<2x PCB# 177	<2x PCB# 70
	<2x acenaphthalene		<2x PCB# 178	<2x PCB# 74
	acenaphthene		<2x PCB# 18	<2x PCB# 8
	anthracene		<2x PCB# 180	<2x PCB# 82
	benzo(a)pyrene		<2x PCB# 183	<2x PCB# 83
	<2x benzo(b)fluoranthene		<2x PCB# 185	<2x PCB# 84
	benzo(e)pyrene		<2x PCB# 187/182/159	<2x PCB# 85
	benzo(g,h,i)perylene		<2x PCB# 188	<2x PCB# 87
	<2x benzo(k)fluoranthene		<2x PCB# 189	<2x PCB# 88
	biphenyl		<2x PCB# 191	<2x PCB# 92
	chrysene		<2x PCB# 194	<2x PCB# 97
	dibenzothiophene		<2x PCB# 195	<2x PCB# 99
	fluoranthene		<2x PCB# 196	<2x PCB# unk
	fluorene		<2x PCB# 200	PCB-total
	<2x indeno(1,2,3-cd)pyrene			
	naphthalene			
	perylene			
	phenanthrene			
	pyrene			

<2x Analyte did not meet quality assurance criteria for detection limits.

B Analyte did not meet quality assurance criteria for blanks.

QA/QC screen for any of the sample sites. Iron was eliminated due to blank interference. Cadmium, mercury and selenium were less than 2x the PQL. All of the organochlorines, with the exception of total PCBs , were also eliminated since they were less than 2x the PQL.

Several of the PAHs (1,2,5,6-dibenzanthracene, C4-chrysenes, acenaphthalene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3,-cd) pyrene) were not present at greater than 2x the PQL at any of the sampling areas and were eliminated from consideration. All other PAHs met the criteria for at least some of the sample areas and were reviewed to identify potential problems.

Soil Samples

Metal values measured in soils on the pads and in the control area were compared to the values for the geometric mean value of each element presented in Table 3 in the Element Concentrations in Soils and Other Surficial Materials in Alaska (Gough, 1988).

Aluminum, ranging from 15,050 to 21,746 ppm for all samples including the control area, was low compared to the geometric mean of 62,000 ppm in Alaska soils.

Arsenic, with a geometric mean of 6.7 ppm in Alaska, varied on site from 6.74 - 13.90 ppm. The values appear to be high but, since the control area values ranged from 9.41 to 13.03 ppm, they are not considered significant.

Chromium, with a geometric mean of 50 ppm in Alaska, ranges from 22.04 to 41.21 ppm for the site, including the control, placing these soils at below average concentrations for the state.

Copper, with a geometric mean of 24 ppm in Alaska, ranges from 51.96 to 73.94 ppm on site. Control sites values were actually higher, ranging from 62.43 to 83.65 ppm. Therefore, while these values are above average, they are not considered significant.

Manganese, ranging from 515.320 to 1709.00 ppm for all samples including the control, was low compared to the geometric mean of 5,100 ppm for Alaska soils.

Nickel, with a geometric mean of 24 ppm in Alaska, ranged from 20.32 to 35.11

ppm for pad soils. The control site values were slightly higher, ranging from 23.39 to 38.09 ppm. Therefore, while these values are slightly elevated, they are within the range for background concentrations at this site.

Lead, with a geometric mean of 12 ppm in Alaska, ranged from 10.93 to 181.97 ppm on the well pad. No lead above 2x PQL was found on the shop and housing pads. The control site values were also below 2x the PQL. Therefore, lead on the well pad should be investigated further.

Zinc, with a geometric mean of 70 ppm in Alaska, ranged from 94.10 to 145.10 ppm on the pads. Control site values ranged from 106.20 to 138.40 ppm. These values are elevated above the mean but, compared with the control site concentration, do not appear to be significant.

Individual polycyclic aromatic hydrocarbon constituents from soils on the pads were summed for each sample and compared to the summed concentrations for the control site. Values for all of the well pads ranged from 0.07 ppm to 4.89 ppm. The sum of PAH concentrations for the control site ranged from 0.02 ppm to 0.59 ppm. Therefore, the total PAHs on the well pads were generally above background concentrations, most significantly on the shop pad. A higher level of contamination from petroleum would be expected where equipment was routinely maintained. Since there was very little organic matter in evidence at this site, it is assumed that any hydrocarbons measured were probably from anthropogenic sources and may be a contaminant of concern for wildlife. While no mammalian receptors were observed on site, it was a nesting area for semipalmated plovers (*Charadrius semipalmatus)*

<u>Sediment Samples</u>

Metal concentrations in all sediment samples, excepting SD08 and SD09, from drainages around the Bear Creek Well No. 1 site were within the range of sediment background levels for metals in Alaska reported by Los Alamos National Laboratory (1983).

Concentrations of total PAHs for all sediment samples, excepting SD08 and SD' 09, ranged from 1.66 ppm to 54.11 ppm. The upper value may indicate deposition remaining from exploration activities, natural background or a combination.

Samples SD08 and SD09, taken from the stream cutbank which appears to intersect reserve pit materials near the edge of the well pad, were distinctly different from the rest of the stream bed sediment samples. The material was pinkish-mauve in color, greasy in texture, and smelled strongly of hydrocarbons. There was at least several cubic yards of this material, interspersed with such trash as hard hats, cans, and boots, exposed in the drainage. Despositional areas of the same material were also located in the stream bed downstream from the apparent reserve pit materials.

The metal suite analyzed for in these sediments was identical to that for the soils on the pads (Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, and Zn). Cadmium, iron, mercury, and selenium were eliminated on quality assurance considerations. All other elements, with the exception of zinc, appeared to be within normal background ranges for most of the sediment samples. However, the zinc concentrations in SD08 (354.1 ppm) and in SD09 (361.1 ppm) were significantly (3x or more) above the concentrations measured up gradient from the well pad, from the other stream sediment samples, and the well pad soils. While the values are still below the maximum concentration of 2700 ppm reported for Alaska, they are significantly above other values detected on this site.

Sample SD09 also contained the only concentration of total PCBs (0.05 ppm) to be identified well above the detection limit in any of the samples taken during the site investigation.

The sum of PAH concentrations in SD08 was 153.47 ppm; in SD09 it was 41.09 ppm. These high values for PAHs plus the very strong odor of hydrocarbons noted by the samplers suggest that total petroleum hydrocarbons in the material could be much higher.

Recommendations

Concentrations of lead in soil samples collected from the pads at Bear Creek Well No. 1 are elevated and should be investigated further. No other metals analyzed for appear to be of concern.

Polycyclic aromatic hydrocarbons on all the well pads were elevated compared to the control, particularly on the shop pad. Further investigation to determine whether these are contaminants of concern for wildlife is recommended.

The exposed debris-laden material located in the drainage next to the well pad appears to be the remains of a reserve pit/ dump site used during the drilling of this exploratory well. The current analyses, indicating elevated PAHs, PCBs, and zinc, coupled with the elevated barium measured in the earlier investigation, confirms this assumption.

The barium, total PAHs, PCBs, and zinc in this material are a concern, particularly when these contaminants, and possibly others, are entering the surface water drainage intersecting this abandoned reserve pit/dump and moving downstream to enter Bear Creek, a critical red salmon spawning habitat on the Refuge. It is recommended that the situation be investigated further do determine if there is a risk to biological receptors from this debris.

References

Bascle, R., Evans, D., Seidlitz, A. and J. Burkowski. 1987. Alaska Peninsula/Becharof National Wildlife Refuges oil and gas assessment. U.S. Bureau of Land Management, Division of Mineral Resources, Alaska.

Dames & Moore. 1978. Drilling fluid dispersion and biological effects of study for Lower Cook Inlet. C.O.S.T. Well. Prepared for Atlantic Richfield Company, Anchorage, Alaska. 309 pp.

Ecobichon, D. J. 1991. Toxic effects of pesticides. *Pp* 565-622 *in* Amdur, M. O., Doull, J. and C. D. Klaassen (eds). Casarett and Doull's toxicology: the basic science of poisons. McGraw-Hill, Inc., New York. 1033 pp.

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

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). 81 pp.

Gough, L. P., Severson, R. C. and H. T. Shacklette. 1988. Element concentrations in soils and other surficial materials of Alaska. U.S. Geological Survey Professional Paper 1458. 53 pp.

Jackson, R. 1991. Report of findings: Becharof National Wildlife Refuge Contaminants Study. Ecological Services, U. S. Fish and Wildlife Service, Anchorage, Alaska. 35 pp.

Los Alamos National Laboratory, 1983. The geochemical atlas of Alaska: Los Alamos, Los Alamos National Laboratory Publication, GJBX 32 (83), La-9897-MS,UC-51, 57 pp.

Newbury, T. K. 1979. Possible accumulation of heavy metals around offshore oil production facilities in the Beaufort Sea. Arctic 32(1), 42-45.

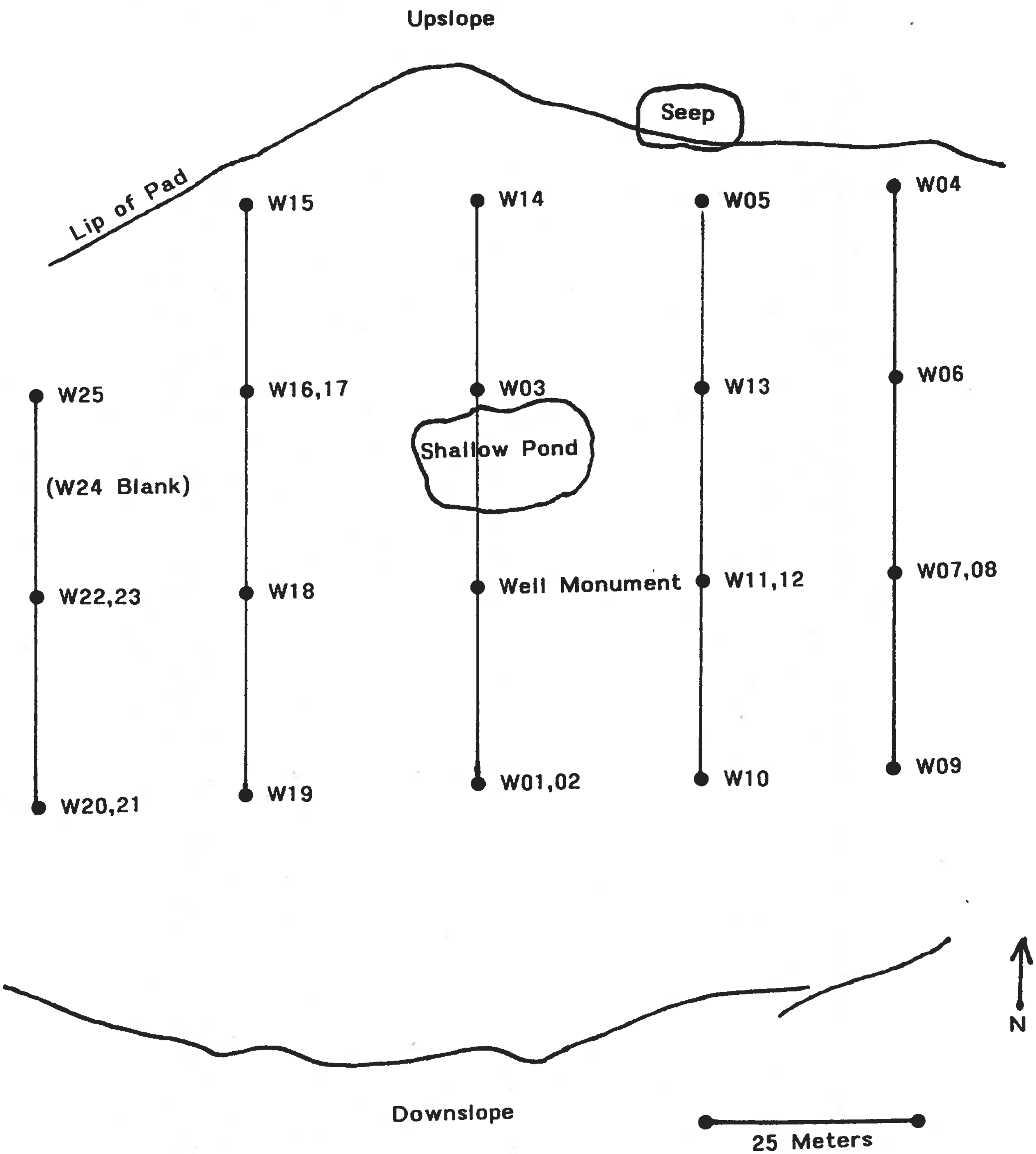
Overton, E. B., W. D. Sharp, and P. Roberts. 1994. Toxicity of Petroleum. *Pp* 133-156 *in* Cockerham, L. G. and B. S. Shane (eds). Basic environmental toxicology. CRC Press, Boca Raton, Florida. 627 pp.

USFWS. 1985. Becharof National Wildlife Refuge Comprehensive Conservation Plan. Environmental Impact Statement. Wilderness Review. U.S. Fish and Wildlife Service, Anchorage, Alaska. 255 pp.

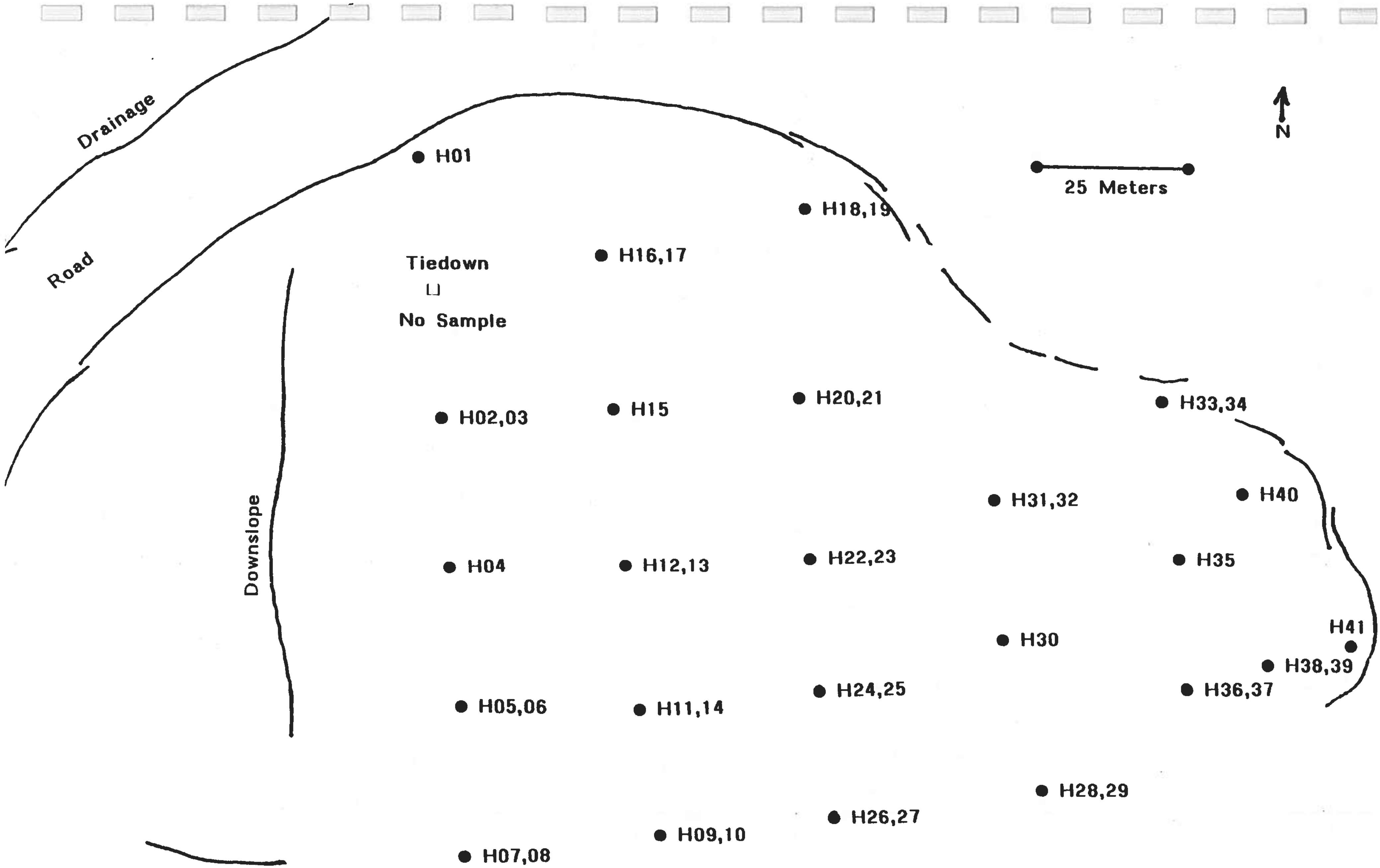
Woodward, D. F., Snyder-Conn, E., Riley R. G., and T. R. Garland. 1988. Drilling fluids and the Arctic tundra of Alaska: Assessing contamination of wetlands habitat and the toxicity to aquatic invertebrates and fish. Arch. Environ. Contam. Toxicol. 17, 683-697.

Appendix A

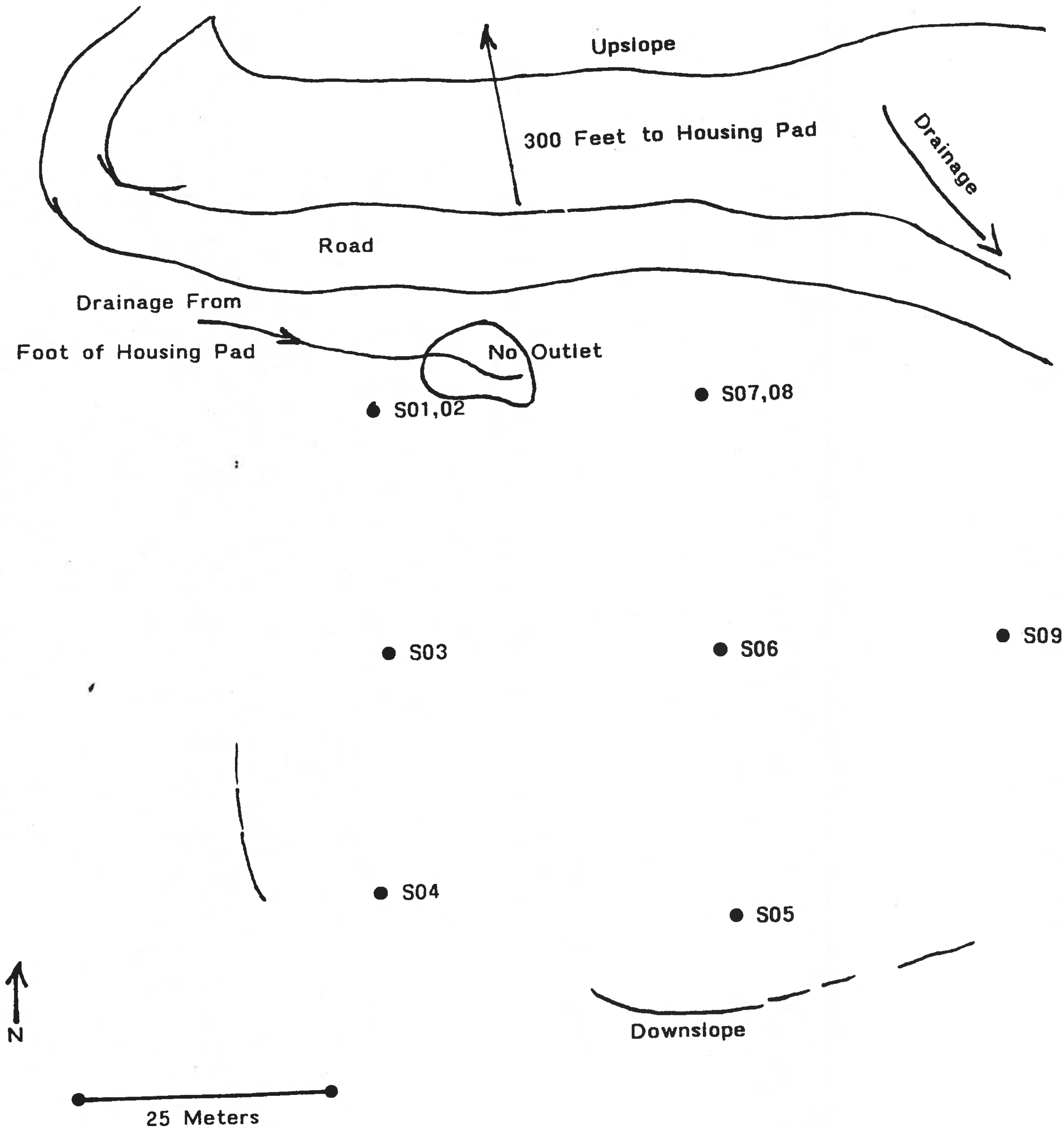
Schematic Drawings of Sampling Sites at Bear Creek Well No. 1



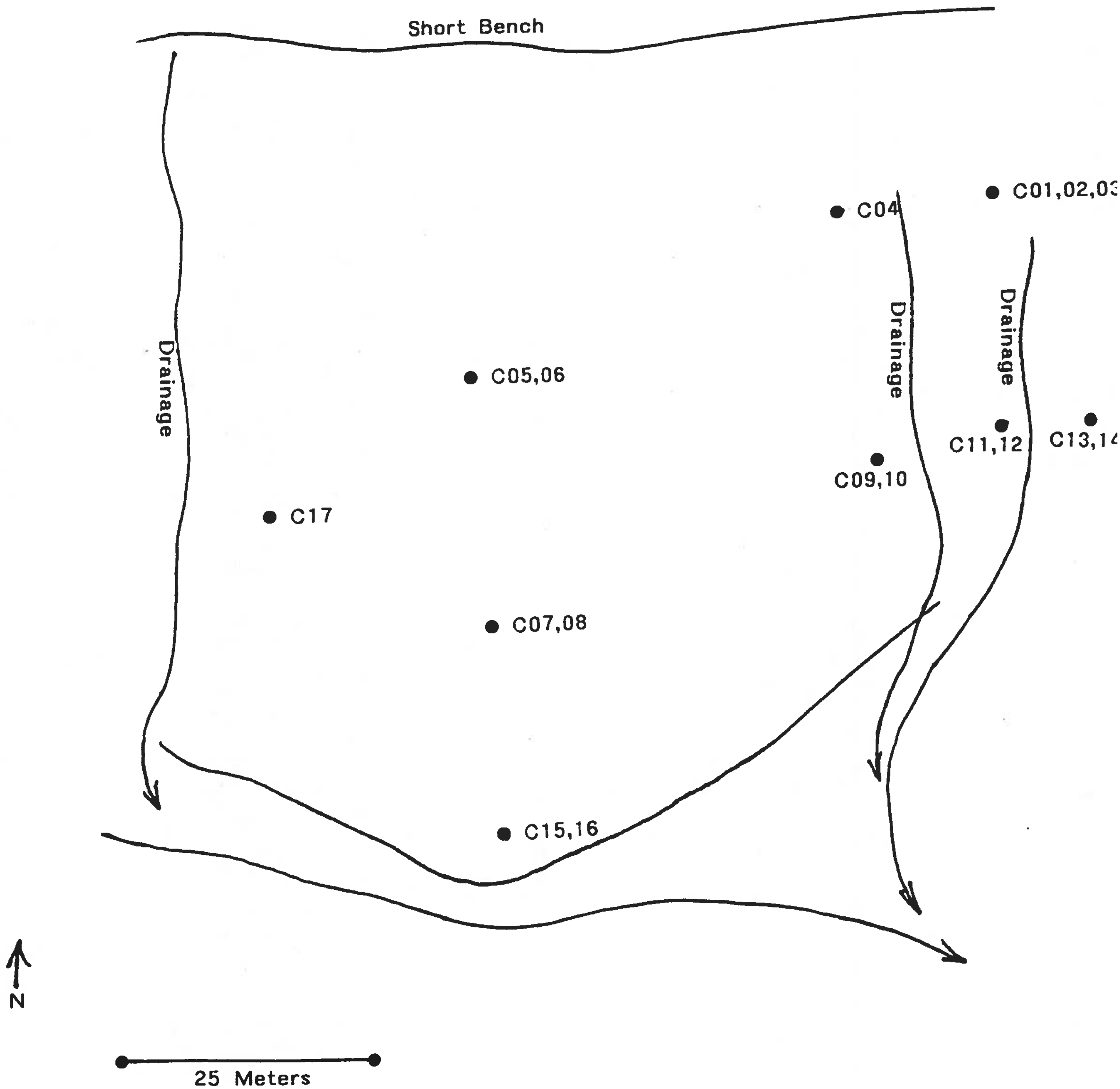
A1. WELL PAD SAMPLING SITES



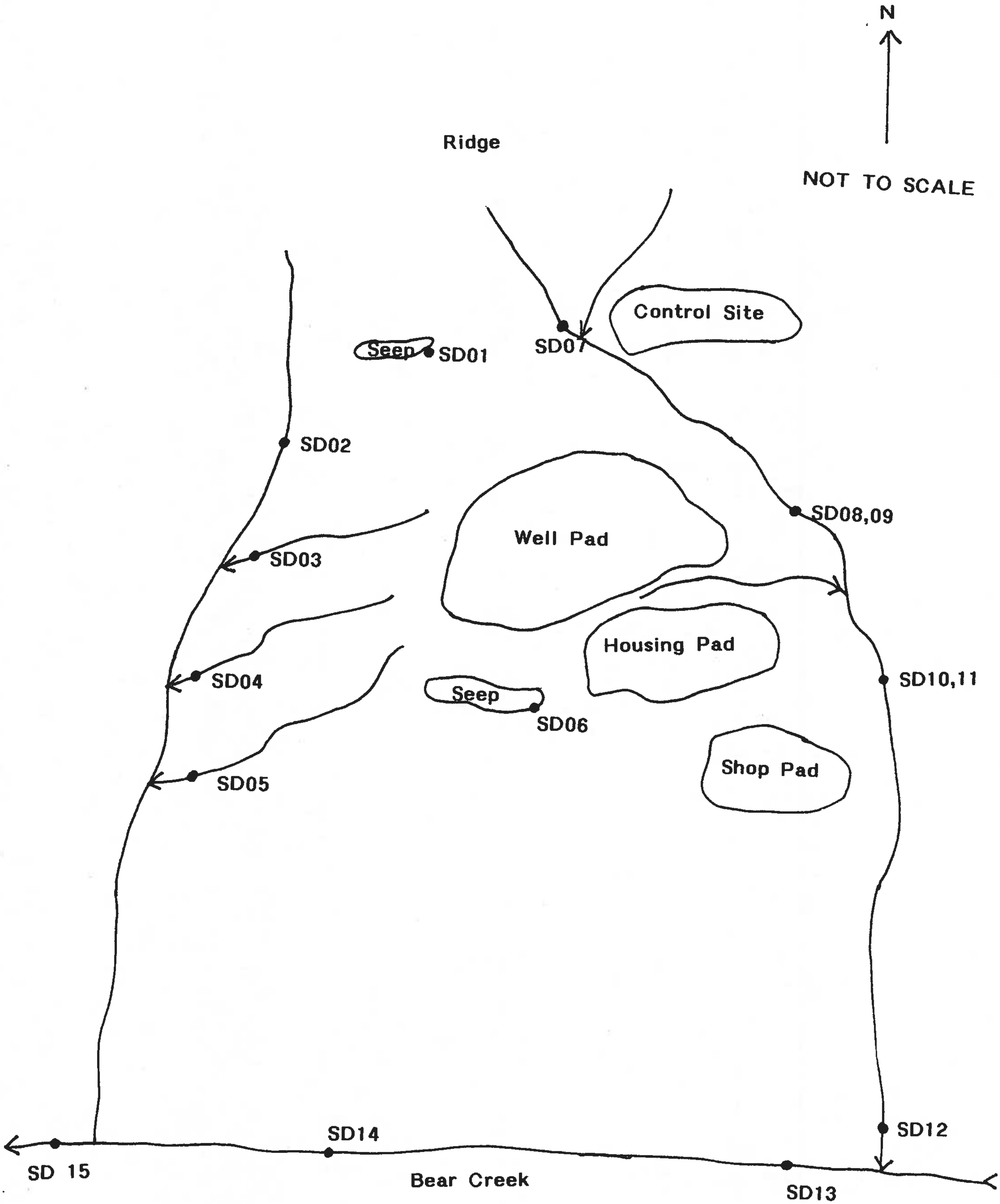
A2. HOUSING PAD SAMPLING SITES



A3. SHOP PAD SAMPLING SITES



A4. CONTROL SAMPLING SITES



A5. SEDIMENT SAMPLING SITES

Appendix B

Contaminants data from Bear Creek Well No. 1

Concentrations (ppm dry weight)

(-) indicates a concentration <2x the detection limit

B1. Well Pad: Metals

Metal	Sample #								
	W03	W06	W07	W10	W13	W16	W19	W23	W24
Aluminum	20404.00	19307.00	19583.00	19899.00	17480.00	18809.00	19335.00	20640.00	-
Arsenic	9.04	10.69	9.48	9.02	6.74	7.61	11.32	11.53	-
Chromium	37.51	32.39	28.61	30.91	25.16	30.56	35.26	36.24	-
Copper	65.58	64.44	58.05	63.61	51.96	63.53	71.89	71.71	-
Manganese	610.40	575.20	778.70	588.10	490.00	592.10	686.00	712.50	-
Nickel	30.90	27.91	28.94	26.09	20.32	27.30	32.39	35.11	-
Lead	28.44	-	-	10.93	181.97	16.92	-	-	-
Zinc	145.10	106.40	102.80	109.10	94.00	144.80	118.70	125.60	-

Note: sample W24 was a container blank.

B1. Well Pad: Polycyclic Aromatic Hydrocarbons

PAH	Sample #								
	W01	W02	W03	W04	W05	W06	W07	W08	W09
1-methylnaphthalene	0.090	0.129	0.565	0.039	-	0.023	-	-	0.043
1-methylphenanthrene	0.022	0.031	0.036	0.026	-	0.026	-	0.036	-
2,6-dimethylnaphthalene	0.106	0.187	0.114	0.032	-	0.020	-	-	0.029
2-methylnaphthalene	0.132	0.204	0.723	0.042	-	0.030	-	0.023	0.059
C1-fluoranthenes & pyrenes	-	-	0.040	0.029	0.045	-	-	-	0.022
C1-phenanthrenes & anthracenes	0.062	0.078	0.107	0.074	0.122	0.056	0.064	0.020	0.106
C1-chrysenes	-	-	0.043	0.029	0.056	-	-	-	0.029
C1-dibenzothiophenes	-	-	-	-	-	-	-	-	-
C1-fluorenes	-	-	0.036	-	-	-	-	-	-
C1-naphthalenes	0.108	0.089	0.342	0.231	0.079	0.034	0.038	-	0.034
C2-phenanthrenes & anthracenes	0.059	0.085	0.095	0.069	0.122	0.048	0.066	0.032	0.086
C2-chrysenes	-	-	0.049	0.032	0.065	-	0.020	-	0.022
C2-dibenzothiophenes	-	0.027	0.020	-	-	0.020	0.020	0.022	-
C2-fluorenes	0.036	0.043	0.083	0.041	0.055	0.028	0.033	-	0.035
C2-naphthalenes	0.089	0.065	0.432	0.255	0.100	0.033	0.039	0.014	0.040
C3-phenanthrenes & anthracenes	0.050	0.073	0.077	0.054	0.094	0.043	0.054	0.027	0.061
C3-chrysenes	-	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	0.027	-	-	-	-	-	-	-
C3-fluorenes	0.050	0.063	0.079	0.049	0.067	0.036	0.047	0.027	0.050
C3-naphthalenes	0.073	0.074	0.251	0.162	0.120	0.044	0.054	0.023	0.052
C4-phenanthrenes & anthracenes	0.020	0.038	0.044	0.031	0.040	0.020	0.025	-	0.029
C4-naphthalenes	0.061	0.083	0.212	0.105	0.115	0.043	0.051	0.029	0.054
benzo(g,h,i)perylene	-	-	-	-	0.020	-	-	-	-
biphenyl	-	-	0.025	-	-	-	-	-	-
chrysene	-	-	-	-	0.025	-	-	-	0.023
naphthalene	0.025	-	0.087	0.052	-	-	-	-	-
perylene	0.023	-	0.058	0.024	0.050	-	-	-	-
phenanthrene	0.041	0.050	0.055	0.037	0.054	0.043	0.031	-	0.041
pyrene	-	-	0.020	-	0.024	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	1.047	1.346	3.593	1.413	1.253	0.547	0.542	0.253	0.815

B1. Well Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	W10	W11	W12	W13	W14	W15	W16	W17
1-methylnaphthalene	0.056	0.056	0.100	0.048	0.100	0.139	0.053	0.048
1-methylphenanthrene	-	0.022	0.028	-	0.047	0.028	0.040	0.044
2,6-dimethylnaphthalene	0.055	0.035	0.092	0.038	0.089	0.244	0.040	0.060
2-methylnaphthalene	0.078	0.091	0.143	0.070	0.113	0.244	0.053	0.062
C1-fluoranthenes & pyrenes	-	0.040	0.031	0.034	0.065	0.090	0.046	0.098
C1-phenanthrenes & anthracenes	0.073	0.060	0.077	0.089	0.241	0.205	0.109	0.146
C1-chrysenes	-	0.030	0.040	0.029	0.071	0.093	0.045	0.096
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-fluorenes	-	-	-	-	0.034	0.035	0.022	0.036
C1-naphthalenes	0.097	0.138	0.150	0.242	0.304	0.198	0.379	0.114
C2-phenanthrenes & anthracenes	0.055	0.082	0.068	0.075	0.176	0.170	0.109	0.150
C2-chrysenes	-	0.041	0.042	0.031	0.070	0.102	0.049	0.144
C2-dibenzothiophenes	-	0.027	-	0.024	0.027	0.022	0.020	-
C2-fluorenes	0.033	0.064	0.042	0.050	0.120	0.097	0.081	0.071
C2-naphthalenes	0.075	0.143	0.087	0.203	0.384	0.238	0.434	0.164
C3-phenanthrenes & anthracenes	0.042	0.093	0.054	0.060	0.110	0.131	0.079	0.125
C3-chrysenes	-	-	-	-	-	0.025	-	0.031
C3-dibenzothiophenes	-	0.030	-	-	0.021	-	-	-
C3-fluorenes	0.042	0.107	0.054	0.059	0.107	0.102	0.094	0.079
C3-naphthalenes	0.074	0.133	0.102	0.130	0.356	0.282	0.269	0.224
C4-phenanthrenes & anthracenes		0.056	0.035	0.032	0.058	0.078	0.042	0.086
C4-naphthalenes	0.061	0.220	0.088	0.109	0.217	0.193	0.152	0.180
benzo(g,h,i)perylene	-	-	0.023	-	0.023	0.024	-	0.031
biphenyl	-	-	-	-	-	-	0.020	-
chrysene	-	-	-	-	0.032	0.038	0.021	0.025
naphthalene	0.041	0.037	0.031	0.044	0.047	0.036	0.089	-
perylene	-	0.033	0.057	0.049	0.058	0.103	0.065	0.186
phenanthrene	0.045	0.034	0.058	0.058	0.142	0.106	0.056	0.066
pyrene	-	0.025	-	-	0.036	0.050	0.024	0.042
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.827	1.597	1.402	1.474	3.048	3.073	2.391	2.308

B1. Well Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	W18	W19	W20	W21	W22	W23	W24	W25
1-methylnaphthalene	0.038	0.068	0.055	0.042	0.041	-	0.138	0.150
1-methylphenanthrene	0.027	0.045	0.042	0.030	0.041	-	0.044	0.026
2,6-dimethylnaphthalene	0.038	0.060	0.054	0.039	0.040	-	0.153	0.258
2-methylnaphthalene	0.044	0.090	0.069	0.048	0.051	-	0.200	0.246
C1-fluoranthenes & pyrenes	0.059	0.031	0.063	0.050	0.045	0.051	-	0.074
C1-phenanthrenes & anthracenes	0.144	0.088	0.150	0.132	0.111	0.135	-	0.172
C1-chrysenes	0.074	0.030	0.040	0.048	0.046	0.062	-	0.084
C1-dibenzothiophenes	-	0.023	0.059	-	0.027	0.024	-	0.032
C1-fluorenes	-	-	0.023	0.020	-	-	-	0.037
C1-naphthalenes	0.104	0.084	0.156	0.123	0.093	0.089	-	0.396
C2-phenanthrenes & anthracenes	0.144	0.086	0.133	0.111	0.104	0.120	-	0.153
C2-chrysenes	0.099	0.031	0.046	0.049	0.055	0.070	-	0.196
C2-dibenzothiophenes	0.033	0.031	0.046	0.027	0.041	0.037	-	0.046
C2-fluorenes	0.070	0.053	0.077	0.076	0.064	0.066	-	0.116
C2-naphthalenes	0.131	0.103	0.149	0.140	0.117	0.110	-	0.412
C3-phenanthrenes & anthracenes	0.126	0.068	0.115	0.084	0.084	0.100	-	0.139
C3-chrysenes	0.021	-	-	-	-	-	-	0.064
C3-dibenzothiophenes	0.027	0.024	0.038	0.024	0.032	0.030	-	0.035
C3-fluorenes	0.089	0.066	0.093	0.097	0.079	0.094	-	0.135
C3-naphthalenes	0.170	0.145	0.192	0.192	0.185	0.178	-	0.375
C4-phenanthrenes & anthracenes	0.073	0.038	0.065	0.049	0.047	0.058	-	0.078
C4-naphthalenes	0.131	0.123	0.168	0.150	0.160	0.151	-	0.281
benzo(g,h,i)perylene	0.028	-	-	0.023	0.021	0.027	-	0.029
biphenyl	-	-	-	-	-	-	-	0.025
chrysene	0.030	-	-	0.023	-	0.027	-	0.039
naphthalene	0.021	0.020	0.038	0.022	-	-	-	0.052
perylene	0.097	0.022	0.041	0.050	0.053	0.107	-	0.118
phenanthrene	0.065	0.049	0.076	0.069	0.052	0.070	-	0.088
pyrene	0.029	0.021	0.033	0.027	0.025	0.027	-	0.037
	-----	-----	-----	-----	-----	-----	-----	-----
Total	1.912	1.399	2.021	1.745	1.614	1.633	0.535	3.893

Note: sample W24 was a container blank.

B2. Housing Pad: Metals

Metal	Sample #					
	H01	H04	H07	H10	H15	H19
Aluminum	18816.00	15729.00	21746.00	16266.00	17911.00	16154.00
Arsenic	10.92	13.90	12.02	10.78	11.60	10.22
Chromium	31.38	30.31	39.13	28.01	35.15	26.72
Copper	69.18	65.69	68.93	72.12	73.94	65.62
Manganese	688.40	1709.00	782.30	709.80	721.70	701.90
Nickel	26.05	22.78	30.49	25.19	27.39	27.51
Lead	-	-	-	-	-	-
Zinc	107.00	109.30	121.10	117.30	124.90	108.50

Metal	Sample #					
	H23	H27	H30	H34	H37	H40
Aluminum	15363.00	19323.00	17365.00	16020.00	17880.00	16298.00
Arsenic	11.14	12.31	12.62	11.40	12.27	10.25
Chromium	28.93	32.04	31.72	30.01	34.63	26.62
Copper	66.02	75.35	70.84	62.34	68.37	66.66
Manganese	592.00	796.60	885.40	665.90	615.40	744.50
Nickel	29.05	28.34	29.69	27.70	27.75	28.18
Lead	-	-	12.83	-	-	-
Zinc	104.80	120.20	253.40	100.30	106.60	113.10

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons

PAH	Sample #							
	H01	H02	H03	H04	H05	H06	H07	H08
1-methylnaphthalene	-	0.123	-	-	-	-	-	-
1-methylphenanthrene	-	0.054	-	-	-	-	-	-
2,6-dimethylnaphthalene	-	0.062	-	-	-	-	-	-
2-methylnaphthalene	-	0.163	-	-	-	-	-	-
C1-fluoranthenes & pyrenes	-	-	0.070	-	-	-	0.022	0.022
C1-phenanthrenes & anthracenes	0.068	0.032	0.155	0.039	0.047	0.044	0.034	0.036
C1-chrysenes	-	-	0.051	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.052	0.021	0.287	0.025	0.024	-	-	-
C2-phenanthrenes & anthracenes	0.057	0.030	0.160	0.033	0.045	0.044	0.048	0.044
C2-chrysenes	-	-	0.072	-	-	-	-	-
C2-dibenzothiophenes	-	-	0.020	-	-	-	-	-
C2-fluorenes	0.027	-	0.060	0.019	0.021	0.020	-	-
C2-naphthalenes	0.047	0.024	0.201	-	0.019	-	-	-
C3-phenanthrenes & anthracenes	0.035	0.019	0.123	0.021	0.028	0.030	0.037	0.033
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-	-
C3-fluorenes	0.040	0.022	0.105	0.027	0.032	0.034	0.033	0.029
C3-naphthalenes	0.064	0.019	0.228	-	0.021	-	-	-
C4-phenanthrenes & anthracenes	0.021	-	0.091	-	0.018	0.019	0.024	0.021
C4-naphthalenes	0.031	-	0.121	0.018	0.019	-	-	-
chrysene	-	-	0.025	-	-	-	-	-
naphthalene	-	-	0.086	-	-	-	-	-
perylene	-	-	0.112	-	-	0.019	-	-
phenanthrene	0.062	0.034	0.104	0.042	0.034	0.034	-	-
pyrene	0.024	-	0.044	-	-	0.021	0.025	0.021
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.528	0.603	2.115	0.224	0.308	0.265	0.223	0.206

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H09	H10	H11	H12	H13	H15	H16	H17
1-methylnaphthalene	-	-	-	-	0.086	0.031	-	-
1-methylphenanthrene	-	-	0.036	0.048	0.044	0.057	0.034	0.037
2,6-dimethylnaphthalene	-	-	-	-	0.089	-	-	0.020
2-methylnaphthalene	-	-	-	-	0.136	-	-	0.026
C1-fluoranthenes & pyrenes	-	-	-	-	-	0.028	-	-
C1-phenanthrenes & anthracenes	0.039	0.028	0.032	0.141	0.166	0.156	0.195	0.132
C1-chrysenes	-	-	-	-	0.022	0.032	-	-
C1-dibenzothiophenes	-	-	-	0.030	0.039	0.026	0.040	0.028
C1-naphthalenes	-	-	-	-	0.025	0.220	0.023	-
C2-phenanthrenes & anthracenes	0.052	0.040	0.036	0.171	0.185	0.141	0.241	0.143
C2-chrysenes	-	-	-	-	0.021	-	-	-
C2-dibenzothiophenes	-	-	-	0.065	0.075	0.048	0.094	0.055
C2-fluorenes	0.021	-	-	0.068	0.116	0.078	0.090	0.071
C2-naphthalenes	-	-	-	-	0.035	0.185	0.024	-
C3-phenanthrenes & anthracenes	0.039	0.031	0.029	0.086	0.096	0.068	0.117	0.066
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	0.051	0.061	0.032	0.076	0.043
C3-fluorenes	0.039	0.023	0.025	0.128	0.200	0.145	0.174	0.127
C3-naphthalenes	-	-	0.021	-	0.047	0.145	0.025	-
C4-phenanthrenes & anthracenes	0.025	-	-	0.031	0.042	0.025	0.044	0.026
C4-naphthalenes	-	-	-	0.031	0.077	0.094	0.042	0.040
chrysene	-	-	-	-	-	0.028	-	-
naphthalene	-	-	-	-	-	0.075	-	-
perylene	-	-	-	-	0.071	-	-	-
phenanthrene	-	-	-	0.053	0.053	0.104	0.058	0.041
pyrene	-	-	-	0.034	-	0.046	0.021	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.215	0.122	0.179	0.937	1.686	1.764	1.298	0.855

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H18	H19	H20	H21	H22	H23	H24	H25
1-methylnaphthalene	-	-	-	-	0.020	-	-	-
1-methylphenanthrene	0.033	-	0.041	-	-	-	-	-
2,6-dimethylnaphthalene	-	-	-	-	0.022	-	-	-
2-methylnaphthalene	-	-	0.027	-	0.028	-	-	-
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.121	0.123	0.042	0.058	0.037	0.052	0.044	0.036
C1-chrysenes	-	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.044	-	0.028	0.032	0.024	0.050	0.033	0.020
C2-phenanthrenes & anthracenes	0.121	0.134	0.038	0.041	0.033	0.044	0.038	0.027
C2-chrysenes	-	-	-	-	-	-	-	-
C2-dibenzothiophenes	0.042	-	-	0.025	-	0.031	0.022	-
C2-fluorenes	0.092	0.071	0.022	0.022	-	0.024	-	-
C2-naphthalenes	0.044	-	0.034	-	0.028	0.051	0.034	0.026
C3-phenanthrenes & anthracenes	0.062	0.073	0.027	0.029	0.023	0.030	0.027	0.022
C3-chrysenes	-	0.052	-	-	-	0.027	-	-
C3-dibenzothiophenes	0.033	-	-	0.022	-	-	-	-
C3-fluorenes	0.139	0.128	0.040	0.026	0.019	0.030	0.031	-
C3-naphthalenes	0.035	0.025	0.030	0.062	0.035	0.070	0.035	0.043
C4-phenanthrenes & anthracenes	0.024	0.030	-	-	-	-	-	-
C4-naphthalenes	0.042	0.040	0.027	0.049	0.033	0.065	0.032	0.031
chrysene	-	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-	-
perylene	0.019	0.022	-	0.021	-	-	-	-
phenanthrene	0.078	0.040	0.037	0.047	0.026	0.037	0.035	0.026
pyrene	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.929	0.738	0.393	0.434	0.328	0.511	0.331	0.231

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H26	H27	H28	H29	H30	H31	H32	H33
1-methylnaphthalene	-	-	-	-	-	0.047	-	0.035
1-methylphenanthrene	-	0.024	-	-	-	0.022	0.021	-
2,6-dimethylnaphthalene	-	0.022	-	-	-	0.041	-	0.026
2-methylnaphthalene	-	0.024	-	-	-	0.065	-	0.042
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.027	-	0.061	0.033	0.058	0.030	0.031	0.062
C1-chrysenes	-	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.021	-	0.036	-	0.036	0.028	0.022	0.020
C2-phenanthrenes & anthracenes	0.025	-	0.039	0.031	0.046	0.020	0.025	0.040
C2-chrysenes	-	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	-	-	-	-
C2-fluorenes	-	-	0.027	-	0.021	-	-	-
C2-naphthalenes	0.030	-	0.046	0.025	0.046	0.030	0.028	0.038
C3-phenanthrenes & anthracenes	-	-	0.027	0.020	0.034	-	-	0.025
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-	-
C3-fluorenes	0.020	-	0.034	-	0.030	-	-	0.025
C3-naphthalenes	0.027	-	0.041	0.032	0.046	0.027	0.031	0.045
C4-phenanthrenes & anthracenes	-	-	-	-	0.021	-	-	-
C4-naphthalenes	0.023	-	0.033	0.031	0.042	0.025	0.031	0.041
chrysene	-	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-	-
perylene	-	-	-	-	-	-	-	-
phenanthrene	0.021	-	0.049	-	0.044	0.027	0.025	0.045
pyrene	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.194	0.070	0.393	0.172	0.424	0.362	0.214	0.444

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H34	H35	H36	H37	H38	H39	H40	H41
1-methylnaphthalene	-	-	-	-	-	-	-	0.042
1-methylphenanthrene	-	-	-	-	-	-	-	-
2,6-dimethylnaphthalene	-	-	-	-	-	-	-	0.031
2-methylnaphthalene	-	-	-	-	-	-	-	0.073
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.046	0.063	0.032	0.025	0.036	0.054	0.050	0.051
C1-chrysenes	-	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.027	0.079	0.020	-	-	0.022	0.025	-
C2-phenanthrenes & anthracenes	0.042	0.046	0.028	0.023	0.035	0.039	0.046	0.038
C2-chrysenes	-	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	0.022	-	0.022	-
C2-fluorenes	0.025	0.023	-	-	0.020	-	0.023	-
C2-naphthalenes	0.044	0.085	0.027	0.024	0.034	0.034	0.042	0.041
C3-phenanthrenes & anthracenes	0.033	0.030	0.020	-	0.025	0.022	-	0.026
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-	-
C3-fluorenes	0.029	0.028	-	-	0.027	0.026	0.030	0.027
C3-naphthalenes	0.056	0.082	0.036	0.037	0.047	0.049	0.076	0.053
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	-	-
C4-naphthalenes	0.052	0.066	0.033	0.036	0.039	0.046	0.043	0.048
chrysene	-	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-	-
perylene	-	-	-	-	-	-	-	-
phenanthrene	0.031	0.044	0.025	-	0.022	0.036	0.035	0.043
pyrene	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.385	0.546	0.221	0.145	0.307	0.328	0.392	0.473

C3. Shop Pad: Metals

Metal	Sample #		
	S01	S05	S09
Aluminum	16376.00	15415.00	15050.00
Arsenic	10.93	10.11	12.70
Chromium	23.13	28.76	29.01
Copper	55.84	63.39	63.90
Manganese	669.00	1333.90	1398.60
Nickel	21.81	26.15	27.52
Lead	-	-	-
Zinc	94.10	101.10	98.70

B3. Shop Pad: Polycyclic Aromatic Hydrocarbons

PAH	Sample #								
	S01	S02	S03	S04	S05	S06	S07	S08	S09
1-methylnaphthalene	-	-	0.058	0.070	0.040	0.044	0.026	0.038	0.831
1-methylphenanthrene	-	-	0.051	0.020	0.019	-	-	0.025	-
2,6-dimethylnaphthalene	-	0.024	0.056	0.058	0.031	0.035	0.022	0.025	0.153
2-methylnaphthalene	-	0.022	0.080	0.104	0.055	0.068	0.042	0.055	1.013
C1-fluoranthenes & pyrenes	-	-	-	0.027	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.050	0.082	0.095	0.156	0.084	0.073	0.071	0.060	0.075
C1-chrysenes	-	-	-	0.049	-	0.022	-	-	0.020
C1-dibenzothiophenes	-	-	0.024	-	-	-	-	-	-
C1-naphthalenes	0.145	0.136	0.115	0.137	0.183	0.093	0.119	0.068	0.090
C2-phenanthrenes & anthracenes	0.035	0.052	0.075	0.095	0.046	0.045	0.065	0.046	0.059
C2-chrysenes	-	-	-	0.045	-	-	-	-	-
C2-dibenzothiophenes	-	0.022	0.038	-	-	-	0.025	-	-
C2-fluorenes	0.025	0.047	0.032	0.034	0.024	0.025	0.032	0.026	0.029
C2-naphthalenes	0.097	0.113	0.113	0.140	0.132	0.074	1.636	0.049	0.067
C3-phenanthrenes & anthracenes	0.026	0.033	0.057	0.059	0.030	0.034	0.056	0.036	0.040
C3-dibenzothiophenes	-	-	0.029	-	-	-	0.022	-	-
C3-fluorenes	0.034	0.049	0.044	0.044	0.029	0.031	0.045	0.032	0.039
C3-naphthalenes	0.082	0.106	0.119	0.114	0.088	0.065	1.380	0.038	0.058
C4-phenanthrenes & anthracenes	-	-	0.033	0.037	-	-	0.028	-	0.028
C4-naphthalenes	0.062	0.080	0.110	0.080	0.061	0.045	1.243	0.034	0.048
chrysene	-	-	-	0.040	-	-	-	-	-
naphthalene	0.062	0.047	0.039	0.035	0.034	0.027	0.036	0.031	0.026
perylene	-	-	-	0.031	-	-	-	-	-
phenanthrene	0.037	0.063	0.062	0.109	0.080	0.052	0.040	0.046	0.045
pyrene	-	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.655	0.876	1.230	1.484	0.936	0.733	4.888	0.609	2.621

B4. Control Site: Metals

Metal	Sample #						
	C1	C2	C5	C6	C9	C12	C16
Aluminum	14663.00	19120.00	13635.00	13708.00	13818.00	12679.00	20608.00
Arsenic	9.83	13.03	9.41	9.86	10.63	11.00	9.82
Chromium	26.30	29.90	25.27	22.04	23.69	26.02	40.21
Copper	68.20	73.09	75.66	65.42	62.43	70.28	83.65
Manganese	721.90	803.40	891.20	622.50	628.50	515.30	661.90
Nickel	30.19	27.87	32.25	28.10	23.39	29.75	38.09
Lead	-	-	-	-	-	-	-
Zinc	109.40	112.80	116.10	111.60	106.20	115.20	138.40

B4. Control Site: Polycyclic Aromatic Hydrocarbons

PAH	Sample #								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
1-methylphenanthrene	-	-	-	-	-	-	-	-	-
2-methylnaphthalene	-	-	-	-	-	-	-	-	0.024
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.030	0.021	-	0.043	0.044	0.026	0.043	0.030	0.057
C1-chrysenes	-	-	-	-	-	-	-	-	-
C1-naphthalenes	-	-	-	0.020	-	-	-	-	0.023
C2-phenanthrenes & anthracenes	0.040	0.027	0.022	0.028	0.035	0.027	0.045	0.033	0.042
C2-fluorenes	-	-	-	-	-	-	-	-	-
C2-naphthalenes	-	-	-	-	-	-	-	-	0.023
C3-phenanthrenes & anthracenes	0.026	-	-	-	0.023	0.019	0.028	0.021	0.021
C3-fluorenes	0.023	-	-	0.019	0.025	0.019	0.024	-	0.028
C3-naphthalenes	-	-	-	-	0.022	-	-	-	-
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	0.021	-	-
C4-naphthalenes	-	-	-	-	0.022	-	-	-	-
phenanthrene	-	-	-	0.037	0.033	-	0.027	-	0.053
pyrene	0.022	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.141	0.048	0.022	0.147	0.204	0.091	0.188	0.084	0.271

PAH	Sample #							
	C10	C11	C12	C13	C14	C15	C16	C17
1-methylphenanthrene	0.031	0.025	-	-	0.029	-	0.023	-
2-methylnaphthalene	0.027	-	-	-	-	-	-	-
C1-fluoranthenes & pyrenes	-	0.022	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.042	0.084	0.067	0.041	0.029	0.078	0.048	0.071
C1-chrysenes	-	-	-	-	-	0.023	-	-
C1-naphthalenes	-	0.045	-	-	-	0.033	-	0.035
C2-phenanthrenes & anthracenes	0.043	0.078	0.060	0.044	0.034	0.065	0.045	0.053
C2-fluorenes	-	0.032	0.020	-	-	0.029	-	0.026
C2-naphthalenes	-	0.038	-	-	-	0.036	-	0.032
C3-phenanthrenes & anthracenes	0.024	0.041	0.032	0.027	0.021	0.034	0.024	0.027
C3-fluorenes	0.021	0.046	0.030	0.026	-	0.044	0.021	0.041
C3-naphthalenes	-	0.032	-	-	-	0.034	-	0.029
C4-phenanthrenes & anthracenes	-	0.024	0.022	-	-	0.021	-	0.022
C4-naphthalenes	-	0.023	-	-	-	0.027	-	0.023
phenanthrene	0.023	0.069	0.047	0.023	-	0.063	0.029	0.056
pyrene	-	0.026	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.211	0.585	0.278	0.161	0.113	0.487	0.190	0.415

B5. Sediment Samples: Metals

Metal	Sample #							
	SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08
Aluminum	16423.00	12716.00	18988.00	16960.00	20177.00	17569.00	18359.00	5293.00
Arsenic	3.90	2.33	5.47	11.22	10.99	1.85	12.15	3.11
Chromium	16.77	11.56	20.01	24.57	36.66	16.94	24.76	12.47
Copper	35.27	31.04	46.70	65.91	69.06	41.35	64.53	20.32
Manganese	524.30	454.00	654.00	772.60	662.90	533.60	498.00	225.70
Nickel	12.51	9.81	17.41	26.18	27.57	13.39	21.71	5.19
Lead	-	-	-	-	-	-	-	75.13
Zinc	75.30	61.00	91.00	135.00	106.00	73.20	1D5.00	354.10

Metal	Sample #						
	SD09	SD10	SD11	SD12	SD13	SD14	SD15
Aluminum	8665.00	20504.00	18870.00	19035.00	13491.00	17020.00	19093.00
Arsenic	3.23	8.23	7.38	9.87	4.01	8.22	7.04
Chromium	13.17	30.83	21.86	29.45	12.91	21.45	23.38
Copper	28.80	62.05	41.31	62.59	30.00	54.55	48.79
Manganese	260.20	780.70	316.40	625.50	361.60	522.40	411.50
Nickel	6.56	21.75	13.33	23.01	8.00	18.61	20.15
Lead	41.92	-	-	11.44	-	-	-
Zinc	361.10	88.70	74.60	124.10	53.60	94.90	88.30

B5. Sediment Samples: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #						
	SD09	SD10	SD11	SD12	SD13	SD14	SD15
1-methylnaphthalene	0.310	0.229	1.383	1.406	0.547	1.015	0.043
1-methylphenanthrene	-	-	-	0.023	0.041	0.041	0.023
2,6-dimethylnaphthalene	0.056	0.040	0.340	0.273	0.172	0.279	0.029
2-methylnaphthalene	0.386	0.308	1.674	1.625	0.662	1.206	0.057
C1-fluoranthenes & pyrenes	-	-	-	-	-	0.024	0.020
C1-phenanthrenes & anthracenes	0.609	-	-	0.027	0.074	0.183	0.124
C1-chrysenes	0.097	-	-	-	-	0.038	0.028
C1-dibenzothiophenes	0.262	-	-	-	-	-	-
C1-fluorenes	0.449	-	-	-	-	-	-
C1-naphthalenes	2.642	0.791	0.701	2.234	3.034	1.201	1.190
C2-phenanthrenes & anthracenes	0.953	-	-	0.024	0.051	0.103	0.078
C2-chrysenes	0.164	-	-	-	-	0.028	0.023
C2-dibenzothiophenes	0.513	-	-	-	-	-	-
C2-fluorenes	1.314	-	-	-	0.031	0.058	0.048
C2-naphthalenes	7.834	0.172	0.144	0.807	8.190	0.416	0.551
C3-phenanthrenes & anthracenes	0.774	-	-	-	0.028	0.049	0.043
C3-chrysenes	-	-	-	-	-	-	-
C3-dibenzothiophenes	0.381	-	-	-	-	-	-
C3-fluorenes	1.090	-	-	-	0.033	0.061	0.052
C3-naphthalenes	14.098	0.030	0.029	0.156	0.178	0.180	0.159
C4-phenanthrenes & anthracenes	0.350	-	-	-	-	0.023	0.020
C4-naphthalenes	8.038	-	-	0.065	0.070	0.097	0.073
acenaphthene	0.031	-	-	-	-	-	-
anthracene	0.033	-	-	-	-	-	-
biphenyl	0.059	-	-	0.028	0.028	0.023	0.028
chrysene	0.054	-	-	-	-	0.025	-
naphthalene	0.436	0.094	0.097	0.280	0.372	0.154	0.306
perylene	0.029	-	-	-	-	-	-
phenanthrene	0.055	-	-	-	0.044	0.125	0.075
pyrene	0.075	-	-	-	-	-	-
Total	41.092	1.664	4.368	6.948	13.555	5.329	2.970

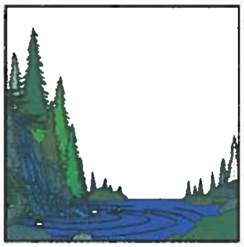
B5. Sediment Samples: Polycyclic Aromatic Hydrocarbons

PAH	Sample #							
	SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08
1-methylnaphthalene	0.735	0.678	2.690	1.029	0.044	0.816	13.961	1.331
1-methylphenanthrene	-	-	0.035	-	0.028	-	0.266	0.146
2,6-dimethylnaphthalene	0.146	0.162	0.754	0.230	0.038	0.170	19.841	4.322
2-methylnaphthalene	0.868	0.774	2.869	1.227	0.060	0.986	17.586	1.673
C1-fluoranthenes & pyrenes	-	-	-	0.039	-	-	-	-
C1-phenanthrenes & anthracenes	-	-	0.027	0.091	-	-	0.026	1.098
C1-chrysenes	-	-	-	0.040	-	-	-	0.173
C1-dibenzothiophenes	-	-	-	-	-	-	-	0.211
C1-fluorenes	-	-	-	-	-	-	-	1.067
C1-naphthalenes	2.061	1.600	2.125	3.871	2.256	1.826	1.705	36.732
C2-phenanthrenes & anthracenes	-	-	0.023	0.076	-	-	0.020	0.906
C2-chrysenes	-	-	-	0.047	-	-	-	0.234
C2-dibenzothiophenes	-	-	-	-	-	-	-	0.192
C2-fluorenes	-	-	-	0.056	-	-	-	1.228
C2-naphthalenes	0.457	0.373	0.548	1.242	0.575	0.409	0.360	56.987
C3-phenanthrenes & anthracenes	-	-	-	0.056	-	-	-	0.716
C3-chrysenes	-	-	-	-	-	-	-	0.030
C3-dibenzothiophenes	-	-	-	-	-	-	-	0.030
C3-fluorenes	-	-	-	0.060	-	-	-	0.622
C3-naphthalenes	0.067	0.070	0.108	0.340	0.122	0.059	0.060	29.133
C4-phenanthrenes & anthracenes	-	-	-	0.035	-	-	-	0.345
C4-naphthalenes	0.020	0.022	0.042	0.127	0.038	0.022	0.022	9.164
acenaphthene	-	-	-	-	-	-	-	0.326
anthracene	-	-	-	-	-	-	-	0.040
biphenyl	-	-	0.023	0.055	0.021	-	-	3.380
chrysene	-	-	-	0.020	-	-	-	0.070
naphthalene	0.299	0.223	0.302	0.464	0.295	0.217	0.275	2.518
perylene	-	-	0.096	-	-	-	-	-
phenanthrene	-	-	-	0.051	-	-	-	0.731
pyrene	-	-	-	0.020	-	-	-	0.065
	-----	-----	-----	-----	-----	-----	-----	-----
Total	4.653	3.902	9.642	9.176	3.477	4.505	54.122	153.470

U.S. Fish & Wildlife Service

Ecological Services
Anchorage Field Office

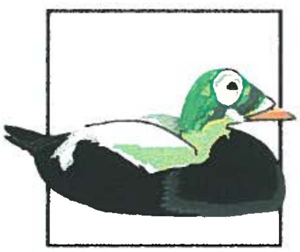
Technical Report WAES-TR-98-03



Habitat Conservation

Contaminants Survey: Bear Creek Well Number 1

Alaska Peninsula / Becharof National Wildlife Refuge



Endangered Species

by:
Sonce de Vries
Mark Giger

Environmental Contaminants

May 1998

Acknowledgments

The Contaminants staff in the Anchorage Field Office wishes to thank the Becharof Refuge staff for their enthusiastic support during the planning and execution of the field survey. In particular, Ron Hood, Refuge Manager, Rick Poetter, Assistant Refuge Manager, and Janice Collins, Secretary were very helpful with logistics and field support. "Moose" Mumma and Gary Terry provided equipment and technical support on a number of occasions. A particular vote of thanks goes to cooperative student Joan (Christian) Dean, who provided steadfast support in the field and unflagging optimism when things got tough. Jerry Grey, pilot, demonstrated consummate flying skill and added a pleasant personality to the group. Last, but not least, many thanks to John Gerlach and Johanna Young, students with the RAP Program, who provided willing hands and good company during long days in the field.

Executive Summary

In 1988, the U.S. Fish and Wildlife Service (Service) funded a contaminants project with the following objectives : 1) conduct a reconnaissance-level field inspection of abandoned oil and gas exploration sites on the Alaska Peninsula/ Becharof National Wildlife Refuge, 2) identify and map abandoned physical remains of oil exploration activities and 3) collect soil samples for organochlorine, petroleum, and metal analysis.

During the field survey, several sites warranting further study were identified. One such site was Bear Creek Well No., drilled as an exploration well by the Humble Oil and Refining Company (now Exxon) in the 1950s and abandoned for lack of commercial potential. The well pads still contained a large amount of wood and metal from buildings and machinery used during the exploration drilling.

In early 1990, Refuge Manager Ronald Hood proposed to the Exxon officials involved in the *Exxon Valdez* oil spill cleanup that Exxon remove both the debris at the Bear Creek Well No. 1 site and the old culverts under the access road. Exxon complied, removing the debris and most of the culverts during 1990 and 1991.

In 1993 Service personnel performed soil sampling at the well pads to identify any residual contamination left after Exxon's abandonment of the site. Some petroleum and metal residues of concern were found on the pads. Also, the remains of the reserve pit were found to be eroding into a stream which flows into Bear Creek, an important salmon spawning stream. The reserve pit residues contained significant amounts of barium (identified in an earlier report), petroleum, zinc, and a trace of polychlorinated biphyenls.

It is recommended that this site be investigated further to determine the extent of the contamination related to the well pads and the reserve pit and the ecological risk associated with this site.

Table of Contents

Appendix A

Schematic Drawings of Sampling sites at Bear Creek Well No. 1

Appendix B

Contaminants data from Bear Creek Well No. 1

List of Maps and Tables

Introduction

History and Purpose of the Refuge

Becharof National Wildlife Refuge, located on the Alaska Peninsula in southwestern Alaska (Map1), was created by the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). The purposes of the refuge as described in Section 302(2)(B) of ANILCA include:

(1) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, brown bears, salmon, migratory birds, the Alaska Peninsula caribou herd and marine birds and mammals;

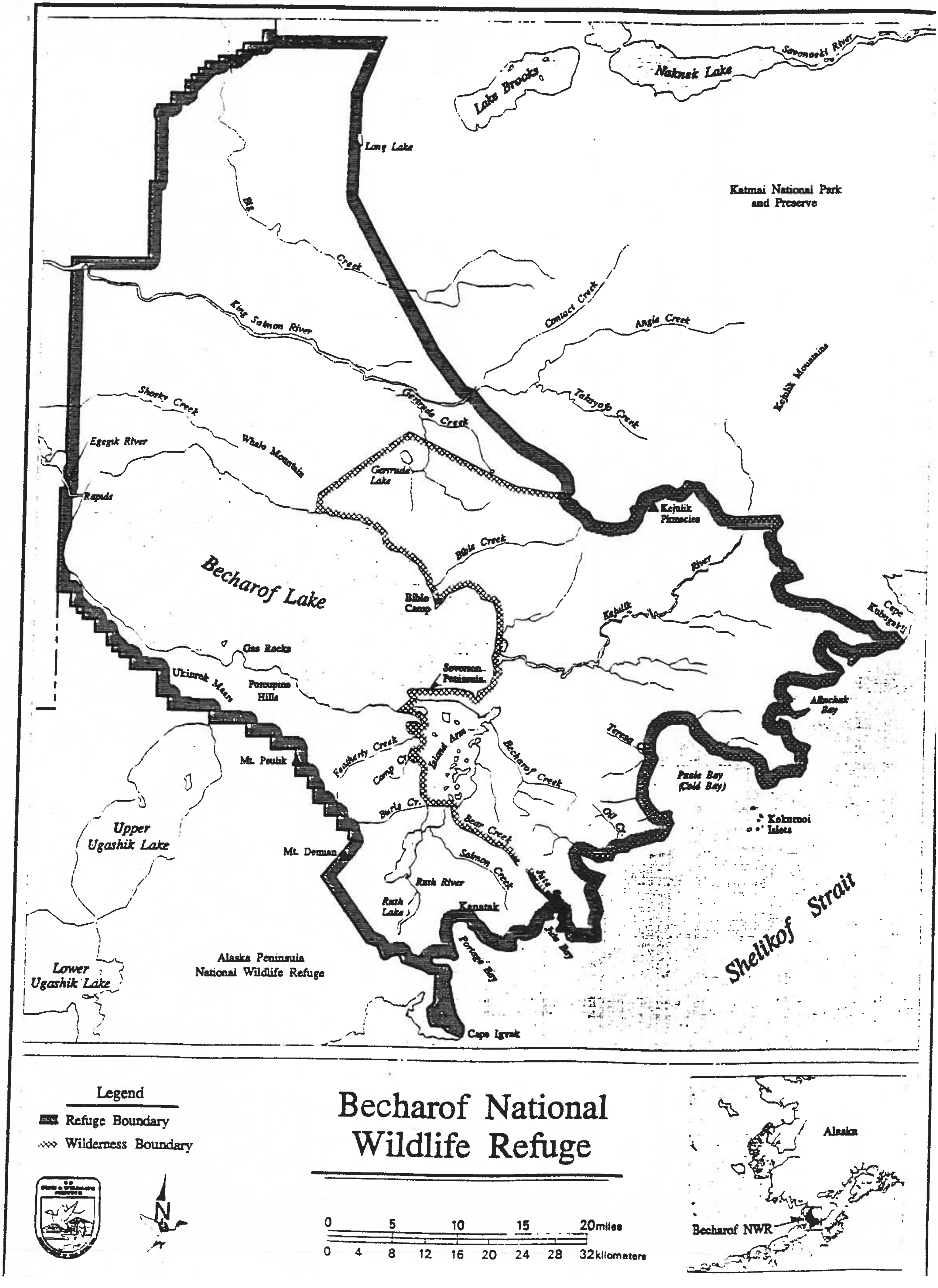
(2) to fulfill the international treaty obligations of the United States with respect to fish, wildlife, and their habitats;

(3) to provide, in a manner consistent with the purposes set forth in subparagraphs (1) and (2), the opportunity for continued subsistence uses by local residents; (and)

(4) to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in subparagraph (1), water quality and necessary water quantity within the refuge (USFWS, 1985).

Study Area

Bear Creek, part of the Egegik River watershed, flows northwest into the Island Arm of Becharof Lake and is part of the southwest wilderness boundary within the refuge, as designated under ANILCA Section 702(4). The Egegik River watershed is critical for four of the five species of Pacific salmon that spawn on the refuge. The Alaska Department of Fish and Game estimates 834,000 adult sockeye or red salmon (*Onchorhynchus nerka*) return to Becharof Lake annually and it is estimated that eighty-five percent of these salmon spawn in the Island Arm area


Savonoski River
Naknek Lake
Lake Brooks
Long Lake
Katmai National Park
and Preserve
Big
Creek
King Salmon River
Contact Creek
Angle Creek
Kejulik Mountains
Takayofo Creek
Gertrude Creek
Shosky Creek
Whale Mountain
Egegik River
Rapids
Gertrude
Lake
Kejulik
Pinnacles
Bible Creek
Becharof Lake
Bible
Camp
Kejulik
River
Cape
Kubugakli
Gas Rocks
Severson
Peninsula
Ukinrek Maars
Porcupine
Hills
Alinchak
Bay
Featherly Creek
Camp Cr.
Island Arm
Becharof Creek
Tereva Cr.
Mt. Peulik
Puale Bay
(Cold Bay)
Kekurnoi
Islets
Burls Cr.
Oil Cr.
Upper
Ugashik Lake
Bear Creek
Mt. Denman
Salmon Creek
Jute
Ruth River
Ruth
Lake
Kanatak
Jute Bay
Shelikof Strait
Portage Bay
Lower
Ugashik Lake
Alaska Peninsula
National Wildlife Refuge
Cape Igvak
Legend
Refuge Boundary
Wilderness Boundary
Becharof National
Wildlife Refuge
0 5 10 15 20 miles
0 4 8 12 16 20 24 28 32 kilometers
Alaska
Becharof NWR

of the lake. These salmon are vital to the maintenance of the large population of brown bears (*Ursus arctos*) and bald eagles (*Haliaeetus leucoephalus*) that inhabit the area, not to speak of their commercial value to the Bristol Bay fishery. Becharof Lake's Island Arm is rated among the highest quality fish and wildlife habitats on the Alaska Peninsula and it has been identified as having "special value" to the refuge under Section 304(g) of ANILCA (USFWS, 1985).

History of Petroleum Exploration

From 1957 to 1959, a consortium of oil companies composed of Humble Oil and Refining Company (Humble), now part of Exxon, and the General Petroleum Corporation. (now Mobil Oil) conducted an oil and gas exploration program on what is now the Becharof National Wildlife Refuge. As part of this program, a heavy-duty access road with culverts was built by Humble from Island Bay on Shelikof Strait to the Bear Creek Well No. 1 exploration well and beyond. The Bear Creek well was completed by March 1959. No commercial quantities of oil or gas were found (Bascle, et al. 1987). The well was abandoned by Humble and the drill rig, associated equipment, and all consumables were leased to General Petroleum. According to Exxon, all demobilization and cleanup obligations at the Bear Creek well were assumed by General Petroleum.

General Petroleum continued their exploratory program further inland through 1959 but found no commercial quantities of oil and gas. The exploration program was abandoned by 1960. Demobilization was accomplished by General Petroleum through the Bear Creek/Island Bay area.

Study Background

Overflights of the refuge in the 1980s revealed a number of sites where debris from abandoned exploration sites remained. Several sites were visited and some were sampled in 1987. The sites visited included the Bear Creek No. 1 well site. The site was found to contain considerable debris remaining from the exploration work and an abandoned reserve pit which was eroding into a small tributary to Bear Creek on the east side of the site. The reserve pit, as observed in the cutbank eroded by the creek, appeared to contain drill mud, drums, and assorted trash. Samples were taken and analyzed for aluminum, arsenic, barium, cadmium, chromium, copper, lead, magnesium, manganese, nickel, selenium, silver, tin, and zinc. The results, as reported in (the) "Report of Findings: Becharof National Wildlife Refuge Contaminants Study" (Jackson, 1991), revealed concentrations of barium, considered to be diagnostic of reserve pits, ranging up to 4420 ppm dry wt. This concentration is well above the mean of 811 ppm reported for Alaskan stream and lake sediments in The Geochemical Atlas of Alaska (Los Alamos National Laboratory, 1983). All other metals in the reserve pit were within normal background concentrations.

The refuge, coordinating with the Bureau of Land Management as the regulator of subsurface leasing for oil and gas on federal lands, began requesting Exxon, as the driller of the Bear Creek No. 1 well, to submit cleanup plans for the area. Exxon representatives visited the site in 1990 and agreed to remove the culverts under the access road which were collapsing and blocking fish passage and also to remove the wood and metal debris at the well site. Much of this work was performed in August 1990 but the amount of debris and culverts made it impossible to complete the entire removal at that time. The work of clearing the well site was completed in 1991. However, the abandoned reserve pit was not removed and many collapsing culverts remain in place on the access road.

Potential Impacts from Abandoned Oil and Gas Exploration Sites

Oil and gas exploration has the potential to contaminate the environment with a variety of chemical compounds. The most probable contaminants are refined petroleum products used to power vehicles and equipment. However, other contaminants such as crude oil, metals, and halogenated (ie. chlorinated) compounds may be present due to their use in well drilling and site operations (e.g., drilling mud, batteries for machinery and auxiliary power, pesticides, and solvents used in maintenance shops, etc.).

Petroleum

Crude oil and refined petroleum products are made up of a complex mixture of chemical compounds. Even when the toxicity of individual compounds is known, it is difficult to determine what the toxic effect to the environment will be due to the additive, synergistic, or antagonistic effects of the various compounds. In addition, crude oil and refined petroleum products can have diverse effects on organisms within the same ecosystem (Overton, et. al., 1994).

The light-end fractions of petroleum hydrocarbons (C6-C10) consisting primarily of benzene, toluene, ethylbenzene and xylenes (BTEX) and naphthalene are the most toxic and abundant compounds present during the initial stages of spills or releases. It is in these early stages of a spill that acute toxic effects are most common. As petroleum weathers, these single-ring, lower molecular weight compounds, being more volatile, soluble, and/or biodegradable, are lost, leaving behind the less acutely toxic, multi-ring, higher molecular weight compounds such as polycyclic aromatic hydrocarbons (PAHs) (Overton, et. al., 1994).

PAHs are more persistent in the environment and have the potential to create chronic toxicity problems. At least one known human carcinogen, benzo(a)pyrene, has been identified as a mutagen (Overton, et. al., 1994). There is also evidence implicating PAHs as an inducer of cancerous and precancerous lesions (Eisler, 1987).

Petroleum products also contain trace amounts of metals including aluminum, nickel, chromium, lead, vanadium, and zinc. Although some of these metals are required as essential micronutrients by living systems, they may also become toxic to living organisms at relatively low levels of exposure.

Drilling Mud

Drilling mud is another source of potential contamination at oil and gas exploration sites. Drill mud components, primarily bentonite and chemical additives, are brought to drill sites in powder form. The dry materials are then mixed with various fluids to make "mud", which is introduced to the well casing while drilling to provide lubrication, remove formation cuttings, and to prevent blowouts. The used mud, often mixed with downhole cuttings from drilling, was not carefully managed in the early days of exploration. It could have been placed in a sump near the drill rig or it might have been deposited in a convenient nearby stream as appears to be the case at this site.

The most commonly used components of water-based drilling mud are barite, caustic soda, bentonite clays, and lignosulfonates. Of these, soda and lignosulfonates are usually considered the most toxic compounds.

Another potential source of contamination associated with drill mud are hydrocarbons (ie. diesel fuel or crude oil) added to the drill muds on occasion to compensate for specific down-hole conditions.

Drill mud may also be a source of metals to the environment. Though drilling mud was only one of a number of potential sources, Newbury (1979) reported an increase in metals, notably zinc, cadmium, and lead, in the sediment around a number of offshore drilling rigs. Woodward et. al. (1988), in a study of five well pads and their reserve pits on the North Slope of Alaska, measured an increase in common and trace elements in ponds adjacent to reserve pits. Concentrations of barium, chloride, chromium, potassium, sulfate, and zinc in pond water and of copper, chromium, iron, and lead in pond sediments were higher in ponds adjacent to the reserve pits than in control ponds. Cuttings from the well may be an additional source of metals depending on the geochemistry of the formation drilled.

Other Contaminants

Halogenated aromatic compounds, such as polychlorinated biphenyls (PCBs), and organochlorine (OCs) compounds, may also be present at older exploration sites. PCBs and a number of OCs (eg. DDT) are no longer manufactured for use in the U.S. but, due to their earlier widespread use and resistance to degradation, they are still found in the environment.

PCBs are closely related to pesticides in their chemical, physical, and toxicological properties. Unlike pesticides, they were never intended to become part of the environment. Most were used in "closed" systems such as electrical transformers and capacitors. PCBs were also used as lubricants, fluids in vacuum pumps and compressors, and heat transfer and hydraulic fluids. PCBs are mixtures of various isomers and were identified most commonly under the trade name "Aroclor" on the basis of the percent chlorine present. For example, Aroclor 1254, is a mixture of isomers with an average chlorine content of 54 percent by weight. Since there are 209 PCB isomers, and these isomers differ in physical, chemical, and biological properties, evaluation of the potential environmental impacts from a particular PCB product is complicated. PCBs also biomagnify in food chains; and since the late 1960's, they have been linked increasingly to adverse reproductive and developmental effects in a variety of fish-eating birds and mammals (Eisler, 1986).

In some parts of the world, OC-containing pesticides may have been used around exploration sites to reduce disease-carrying insects. The properties that make OCs effective pesticides (low volatility, chemical stability, lipid solubility, slow rates of biotransformation and degradation) also make them a problem for wildlife and humans. Pesticide persistence in the environment, and their ability to bioconcentrate and biomagnify within various food chains, can result in significant body burdens in some species. In many cases, these body burdens have been found to be detrimental to reproductive success and even lethal to many species (Ecobichon, 1991).

Objective

The objective of the Bear Creek Well No.1 site study was to perform soil sampling of the well pad to determine if the above described contaminants were present at levels that could pose a threat to fish and wildlife on the Refuge.

Site Location

Bear Creek Well No. 1 is located in the upper portion of the Bear Creek drainage within the wilderness area of the Becharof National Wildlife Refuge: Section 36, Township 29 South, Range 41 West, Karluk (C6) Quadrangle (Map 2). The well site is located on a steep slope on the north side of Bear Creek, approximately four miles northeast of Island Bay on the Shelikof Strait. The pads excavated into the hillside are flanked by two surface water drainages, one of which is located very close to the edge of the well pad. Both streams probably receive subsurface drainage from the site before flowing into Bear Creek approximately ½ mile away.

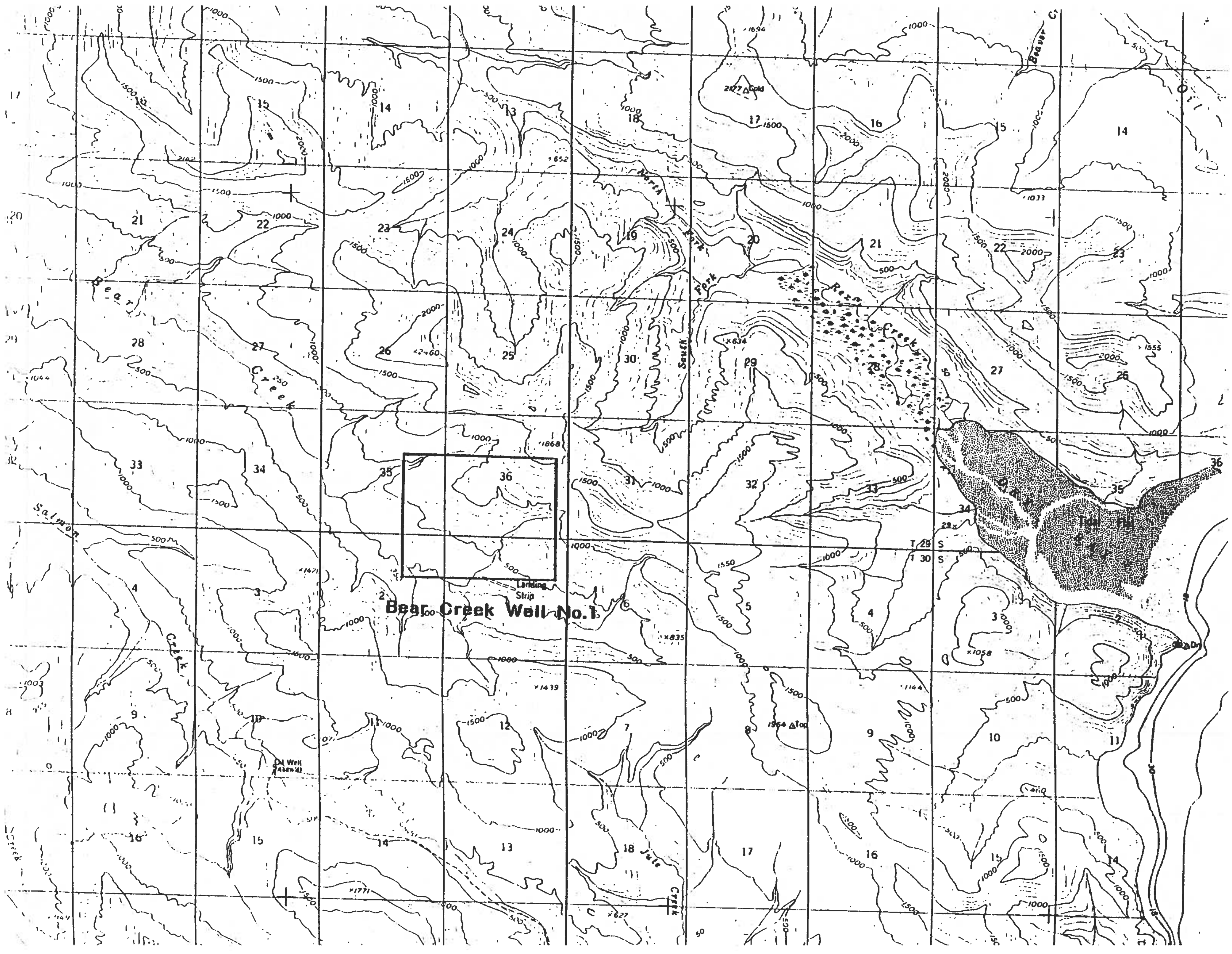
Methods and Materials

Field Procedures

Four areas at the Bear Creek Well No. 1 site were investigated. One was the well pad (approximately three hectares), the second was the housing pad (approximately three hectares), the third was the shop pad (approximately one hectare), and the fourth was an upslope control site (approximately one hectare) used to establish background concentrations. Because the pads appeared to have been cleared and graded during the Exxon cleanup, leaving no trace of the original surface or building locations, sampling was random rather than biased.

The well (see schematic of sampling pattern in Appendix A1), housing (Appendix A2) and shop pads (Appendix A3), and the control site (Appendix A4) were gridded into squares 25 meters on a side and samples were taken at the grid intersections. All measurements were made from the well survey monument on the well pad. No fixed monuments for use as reference points were available for the other three areas.

Two soil auger samples were collected from each grid point intersection. The surface material (0 to 20 cm.) was composited into one sample and the second



Bear Creek
Salmon Creek
North Fork
South Fork
Bear Creek
Jute Creek
Oil
Beaver C.
Tidal Flat
T 29 S
T 30 S
Landing Strip
Bear Creek Well No.1
Oil Well (Abnd)
2127 △ Cold
1964 △ Top

(subsurface) sample was composited from material collected between 80-100 cm. In several instances the deeper samples could not be collected because of the large number of coarse fragments. No alternative deep samples were collected.

Nineteen sampling sites were selected on the well pad from which 25 samples were collected for OC, PCB, and PAH analyses and nine samples were collected for metals analyses. Twenty-four sampling sites were selected on the housing pad from which 40 samples were collected for OC, PCB, and PAH analyses and 12 samples were collected for metals analyses. Seven sampling sites were selected on the shop pad from which nine samples were collected for OC, PCB, and PAH analyses and three samples were collected for metals analyses.

A control site was selected northeast of the well pad across a drainage bordering the east side of the well pad and up a short steep slope. A grid system like the one used for selecting sampling sites on the pads was used to identify sampling points. Nine sampling sites were selected in the control area from which 17 samples were collected for OC, PCB, and PAH analyses and seven samples were collected for metals analyses.

Soil samples were collected using a stainless steel hand auger and a stainless steel shovel. The equipment was decontaminated between samples with a scrub brush and water brought from Refuge headquarters at King Salmon. Supplemental wash water was collected up gradient of the site from the drainage on the west side. All equipment was decontaminated before collecting the surface sample and decontaminated again before collecting the deeper sample. Each composite sample was mixed in a stainless steel bowl that was decontaminated between each sample with Alconox and water and rinsed with acetone. The sample was stirred with a clean stainless steel spoon and an aliquot was transferred either to a pre-cleaned IChem Series 300 labeled glass jar for chlorinated hydrocarbon and PAH analyses or to a ziplock bag for metal analyses.

Fifteen sediment sampling locations (Appendix A5) were also selected from the drainages on both sides of the pads and from Bear Creek. Samples for OC, PCB, and PAH analyses and metals analyses were collected at each location. Each sample was an aliquot of a composite of three scoops of sediment taken with a decontaminated stainless steel scoop and mixed in a clean container. Samples were handled the same as those collected from the pads.

Soil and sediment samples were frozen the day of collection and kept frozen during transport to Anchorage and the laboratory.

Equipment and container blanks also were collected during sampling. Duplicates were collected for ten percent of the samples.

Analytical Procedures

Samples were analyzed by the Geochemical & Environmental Research Group, Texas A&M.

Organic and pesticide compounds in soil and sediment samples were extracted in a Soxhlet extraction apparatus; the extracts were then treated with copper to remove sulfur. The extracts were eluted through alumina/silica gel columns to obtain the AH, PAH, OC, and PCB fractions, which were analyzed by gas chromatography.

Organic and pesticide compounds in water samples were extracted with methylene chloride in a separatory funnel and separated using alumina/silica gel columns. The fractions were analyzed by gas chromatography.

Metals in soil and sediment samples were determined by three techniques, depending on concentration and element. Mercury was determined by cold vapor atomic absorption spectrometry; arsenic, selenium, cadmium, and lead were determined by graphite furnace; the remaining elements were determined by atomic emission using an argon plasma.

Quality Assurance / Quality Control Screening

The raw data collected during this study was reviewed against criteria developed by the Environmental Contaminants Group in the Service's Anchorage Field Office. All values must pass the initial screening criteria as follows:

1) Analyte concentrations must be at least 2x the PQL[1]

2) At least 50% of the duplicates for the analyte must have a relative percent difference <20%,

3) At least 50% of the spike recoveries for the analyte must be within the range of 80-120%

4) At least 50% of the test blanks for the analyte must be non detect for the PQL

All values passing this screening are reviewed against the literature to identify contaminants of concern. It is recognized that the choice of values at only twice the practical quantitation limit is extremely conservative. However, the object of the types of preliminary contaminant investigations done by the Service is to identify problems which require further investigation either by the Service or by others. The intent is to draw attention to the presence of substances which <u>may</u> present a threat to fish and wildlife.

A complete set of raw data is available in the files at the Anchorage Field Office.

Results and Discussion

Appendix B presents the analytical results for the site. The Appendix includes data on metals and polycyclic aromatic hydrocarbons for soil and sediment samples collected from the well (Tables B1), housing (Tables B2), and shop pads (Tables B3), the control site (Tables B4), and for the streams bordering the site (Tables B5).

<u>Quality Assurance/Quality Control</u>

Table 1 lists all the analytes screened for at the Bear Creek Well No. 1 site. It also denotes analytes that do not warrant further discussion because they did not pass the

[1]The practical quantitation limit (PQL) is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

Table 1. Analytes tested for in soil and sediment samples collected June 1992 at Bear Creek Well No. 1, Alaska Peninsula/Becharof National Wildlife Refuge.

Metals	PAH	OC	PCB	PCB
Aluminum	<2x 1,2,5,6-dibenzanthracene	<2x aldrin	<2x PCB# 100	<2x PCB# 201
Arsenic	1,2-benzanthracene	<2x hexachlorobenzene	<2x PBC# 101	<2x PCB# 205
<2x Cadmium	1,6,7-trimethyl-naphthalene	<2x heptachlor	<2x PCB# 105	<2x PCB# 206
Chromium	1-methylnaphthalene	<2x alpha BHC	<2x PCB# 107/108/144	<2x PCB# 209
Copper	1-methylphenanthrene	<2x alpha chlordane	<2x PCB# 110/77	<2x PCB# 22
B Iron	2,6-dimethylnaphthalene	<2x beta BHC	<2x PCB# 118/108/149	<2x PCB# 24
<2x Mercury	2-methylnaphthalene	<2x cis-nonachlor	<2x PCB# 126	<2x PCB# 25
Manganese	C1-fluoranthenes & pyrenes	<2x delta BHC	<2x PCB# 128	<2x PCB# 26
Nickel	C1-phenanthrenes & anthracenes	<2x dieldrin	<2x PBC# 129	<2x PCB# 28
Lead	C1-chrysenes	<2x endrin	<2x PCB# 136	<2x PCB# 29
<2x Selenium	C1-dibenzothiophenes	<2x gamma BHC	<2x PCB# 137	<2x PCB# 31
Zinc	C1-fluorenes	<2x gamma chlordane	<2x PCB# 138	<2x PCB# 33
	C1-naphthalenes	<2x heptachlor epoxide	<2x PCB# 141	<2x PCB# 37/42
	C2-phenanthrenes & anthracenes	<2x mirex	<2x PCB# 146	<2x PCB# 40
	C2-chrysenes	<2x o,p'-DDD	<2x PCB# 149	<2x PCB# 41/64
	C2-dibenzothiophenes	<2x o,p'-DDE	<2x PCB# 15	<2x PCB# 44
	C2-fluorenes	<2x o,p'-DDT	<2x PCB# 151	<2x PCB# 45
	C2-naphthalenes	<2x oxychlordane	<2x PCB# 153	<2x PCB# 46
	C3-phenanthrenes & anthracenes	<2x p,p'-DDD	<2x PCB# 156/171/202	<2x PCB# 47/48
	C3-chrysenes	<2x p,p'-DDE	<2x PCB# 158	<2x PCB# 49
	C3-dibenzothiophenes	<2x p,p'-DDT	<2x PCB# 16/32	<2x PCB# 50
	C3-fluorenes	<2x toxaphene	<2x PCB# 167	<2x PCB# 52
	C3-naphthalenes	<2x trans-nonachlor	<2x PCB# 170	<2x PCB# 60/56
	C4-phenanthrenes & anthracenes		<2x PCB# 172	<2x PCB# 66
	<2x C4-chrysenes		<2x PCB# 174	<2x PCB# 7
	C4-naphthalenes		<2x PCB# 177	<2x PCB# 70
	<2x acenaphthalene		<2x PCB# 178	<2x PCB# 74
	acenaphthene		<2x PCB# 18	<2x PCB# 8
	anthracene		<2x PCB# 180	<2x PCB# 82
	benzo(a)pyrene		<2x PCB# 183	<2x PCB# 83
	<2x benzo(b)fluoranthene		<2x PCB# 185	<2x PCB# 84
	benzo(e)pyrene		<2x PCB# 187/182/159	<2x PCB# 85
	benzo(g,h,i)perylene		<2x PCB# 188	<2x PCB# 87
	<2x benzo(k)fluoranthene		<2x PCB# 189	<2x PCB# 88
	biphenyl		<2x PCB# 191	<2x PCB# 92
	chrysene		<2x PCB# 194	<2x PCB# 97
	dibenzothiophene		<2x PCB# 195	<2x PCB# 99
	fluoranthene		<2x PCB# 196	<2x PCB# unk
	fluorene		<2x PCB# 200	PCB-total
	<2x indeno(1,2,3-cd)pyrene			
	naphthalene			
	perylene			
	phenanthrene			
	pyrene			

<2x Analyte did not meet quality assurance criteria for detection limits.

B Analyte did not meet quality assurance criteria for blanks.

QA/QC screen for any of the sample sites. Iron was eliminated due to blank interference. Cadmium, mercury and selenium were less than 2x the PQL. All of the organochlorines, with the exception of total PCBs, were also eliminated since they were less than 2x the PQL.

Several of the PAHs (1,2,5,6-dibenzanthracene, C4-chrysenes, acenaphthalene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3,-cd) pyrene) were not present at greater than 2x the PQL at any of the sampling areas and were eliminated from consideration. All other PAHs met the criteria for at least some of the sample areas and were reviewed to identify potential problems.

Soil Samples

Metal values measured in soils on the pads and in the control area were compared to the values for the geometric mean value of each element presented in Table 3 in the Element Concentrations in Soils and Other Surficial Materials in Alaska (Gough, 1988).

Aluminum, ranging from 15,050 to 21,746 ppm for all samples including the control area, was low compared to the geometric mean of 62,000 ppm in Alaska soils.

Arsenic, with a geometric mean of 6.7 ppm in Alaska, varied on site from 6.74 - 13.90 ppm. The values appear to be high but, since the control area values ranged from 9.41 to 13.03 ppm, they are not considered significant.

Chromium, with a geometric mean of 50 ppm in Alaska, ranges from 22.04 to 41.21 ppm for the site, including the control, placing these soils at below average concentrations for the state.

Copper, with a geometric mean of 24 ppm in Alaska, ranges from 51.96 to 73.94 ppm on site. Control sites values were actually higher, ranging from 62.43 to 83.65 ppm. Therefore, while these values are above average, they are not considered significant.

Manganese, ranging from 515.320 to 1709.00 ppm for all samples including the control, was low compared to the geometric mean of 5,100 ppm for Alaska soils.

Nickel, with a geometric mean of 24 ppm in Alaska, ranged from 20.32 to 35.11

ppm for pad soils. The control site values were slightly higher, ranging from 23.39 to 38.09 ppm. Therefore, while these values are slightly elevated, they are within the range for background concentrations at this site.

Lead, with a geometric mean of 12 ppm in Alaska, ranged from 10.93 to 181.97 ppm on the well pad. No lead above 2x PQL was found on the shop and housing pads. The control site values were also below 2x the PQL. Therefore, lead on the well pad should be investigated further.

Zinc, with a geometric mean of 70 ppm in Alaska, ranged from 94.10 to 145.10 ppm on the pads. Control site values ranged from 106.20 to 138.40 ppm. These values are elevated above the mean but, compared with the control site concentration, do not appear to be significant.

Individual polycyclic aromatic hydrocarbon constituents from soils on the pads were summed for each sample and compared to the summed concentrations for the control site. Values for all of the well pads ranged from 0.07 ppm to 4.89 ppm. The sum of PAH concentrations for the control site ranged from 0.02 ppm to 0.59 ppm. Therefore, the total PAHs on the well pads were generally above background concentrations, most significantly on the shop pad. A higher level of contamination from petroleum would be expected where equipment was routinely maintained. Since there was very little organic matter in evidence at this site, it is assumed that any hydrocarbons measured were probably from anthropogenic sources and may be a contaminant of concern for wildlife. While no mammalian receptors were observed on site, it was a nesting area for semipalmated plovers *(Charadrius semipalmatus)*

Sediment Samples

Metal concentrations in all sediment samples, excepting SD08 and SD09, from drainages around the Bear Creek Well No. 1 site were within the range of sediment background levels for metals in Alaska reported by Los Alamos National Laboratory (1983).

Concentrations of total PAHs for all sediment samples, excepting SD08 and SD 09, ranged from 1.66 ppm to 54.11 ppm. The upper value may indicate deposition remaining from exploration activities, natural background or a combination.

Samples SD08 and SD09, taken from the stream cutbank which appears to intersect reserve pit materials near the edge of the well pad, were distinctly different from the rest of the stream bed sediment samples. The material was pinkish-mauve in color, greasy in texture, and smelled strongly of hydrocarbons. There was at least several cubic yards of this material, interspersed with such trash as hard hats, cans, and boots, exposed in the drainage. Despositional areas of the same material were also located in the stream bed downstream from the apparent reserve pit materials.

The metal suite analyzed for in these sediments was identical to that for the soils on the pads (Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, and Zn). Cadmium, iron, mercury, and selenium were eliminated on quality assurance considerations. All other elements, with the exception of zinc, appeared to be within normal background ranges for most of the sediment samples. However, the zinc concentrations in SD08 (354.1 ppm) and in SD09 (361.1 ppm) were significantly (3x or more) above the concentrations measured up gradient from the well pad, from the other stream sediment samples, and the well pad soils. While the values are still below the maximum concentration of 2700 ppm reported for Alaska, they are significantly above other values detected on this site.

Sample SD09 also contained the only concentration of total PCBs (0.05 ppm) to be identified well above the detection limit in any of the samples taken during the site investigation.

The sum of PAH concentrations in SD08 was 153.47 ppm; in SD09 it was 41.09 ppm. These high values for PAHs plus the very strong odor of hydrocarbons noted by the samplers suggest that total petroleum hydrocarbons in the material could be much higher.

Recommendations

Concentrations of lead in soil samples collected from the pads at Bear Creek Well No. 1 are elevated and should be investigated further. No other metals analyzed for appear to be of concern.

Polycyclic aromatic hydrocarbons on all the well pads were elevated compared to the control, particularly on the shop pad. Further investigation to determine whether these are contaminants of concern for wildlife is recommended.

The exposed debris-laden material located in the drainage next to the well pad appears to be the remains of a reserve pit/ dump site used during the drilling of this exploratory well. The current analyses, indicating elevated PAHs, PCBs, and zinc, coupled with the elevated barium measured in the earlier investigation, confirms this assumption.

The barium, total PAHs, PCBs, and zinc in this material are a concern, particularly when these contaminants, and possibly others, are entering the surface water drainage intersecting this abandoned reserve pit/dump and moving downstream to enter Bear Creek, a critical red salmon spawning habitat on the Refuge. It is recommended that the situation be investigated further do determine if there is a risk to biological receptors from this debris.

References

Bascle, R., Evans, D., Seidlitz, A. and J. Burkowski. 1987. Alaska Peninsula/Becharof National Wildlife Refuges oil and gas assessment. U.S. Bureau of Land Management, Division of Mineral Resources, Alaska.

Dames & Moore. 1978. Drilling fluid dispersion and biological effects of study for Lower Cook Inlet. C.O.S.T. Well. Prepared for Atlantic Richfield Company, Anchorage, Alaska. 309 pp.

Ecobichon, D. J. 1991. Toxic effects of pesticides. *Pp* 565-622 *in* Amdur, M. O., Doull, J. and C. D. Klaassen (eds). Casarett and Doull's toxicology: the basic science of poisons. McGraw-Hill, Inc., New York. 1033 pp.

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

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). 81 pp.

Gough, L. P., Severson, R. C. and H. T. Shacklette. 1988. Element concentrations in soils and other surficial materials of Alaska. U.S. Geological Survey Professional Paper 1458. 53 pp.

Jackson, R. 1991. Report of findings: Becharof National Wildlife Refuge Contaminants Study. Ecological Services, U. S. Fish and Wildlife Service, Anchorage, Alaska. 35 pp.

Los Alamos National Laboratory, 1983. The geochemical atlas of Alaska: Los Alamos, Los Alamos National Laboratory Publication, GJBX 32 (83), La-9897-MS,UC-51, 57 pp.

Newbury, T. K. 1979. Possible accumulation of heavy metals around offshore oil production facilities in the Beaufort Sea. Arctic 32(1), 42-45.

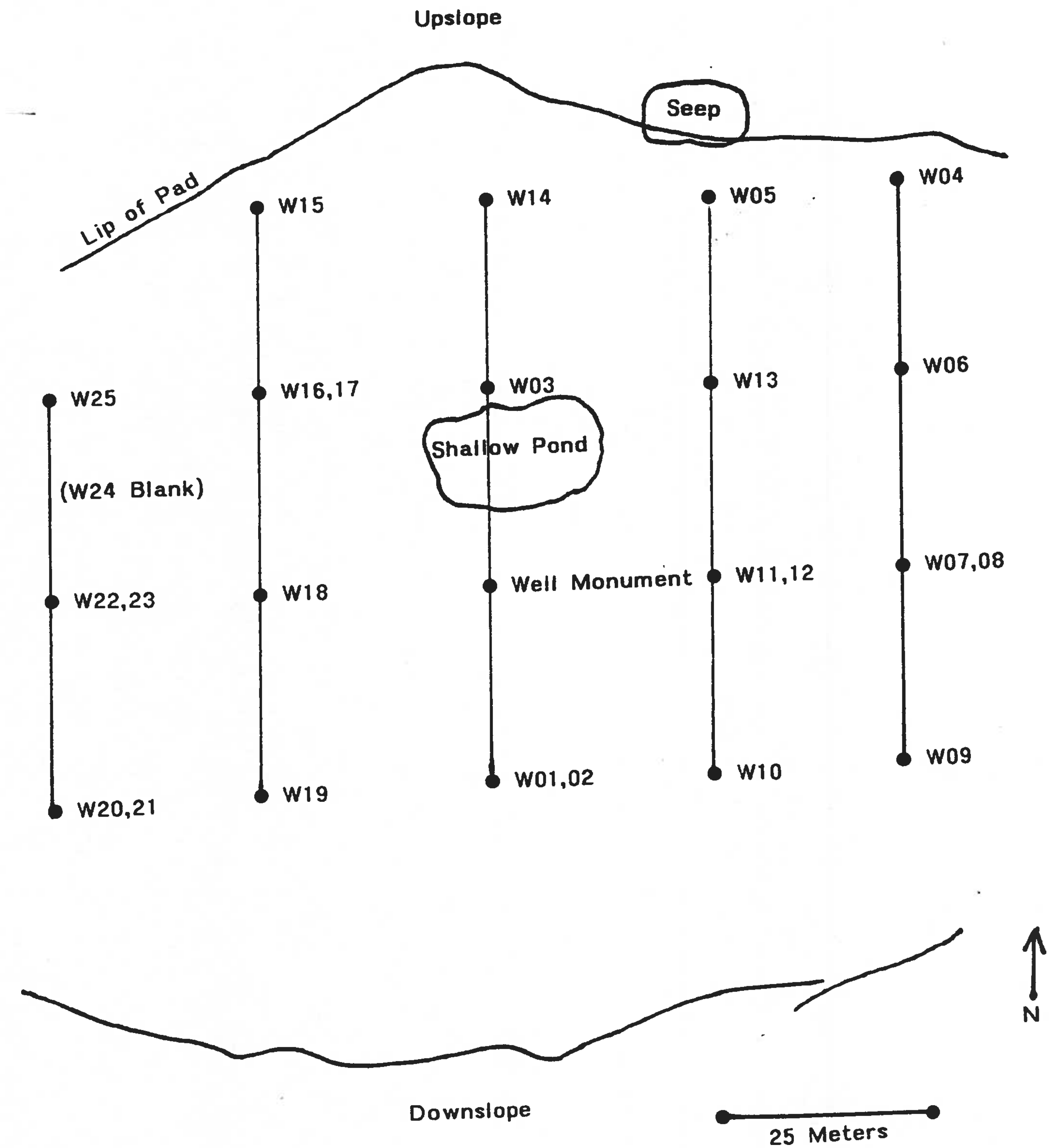
Overton, E. B., W. D. Sharp, and P. Roberts. 1994. Toxicity of Petroleum. *Pp* 133-156 *in* Cockerham, L. G. and B. S. Shane (eds). Basic environmental toxicology. CRC Press, Boca Raton, Florida. 627 pp.

USFWS. 1985. Becharof National Wildlife Refuge Comprehensive Conservation Plan. Environmental Impact Statement. Wilderness Review. U.S. Fish and Wildlife Service, Anchorage, Alaska. 255 pp.

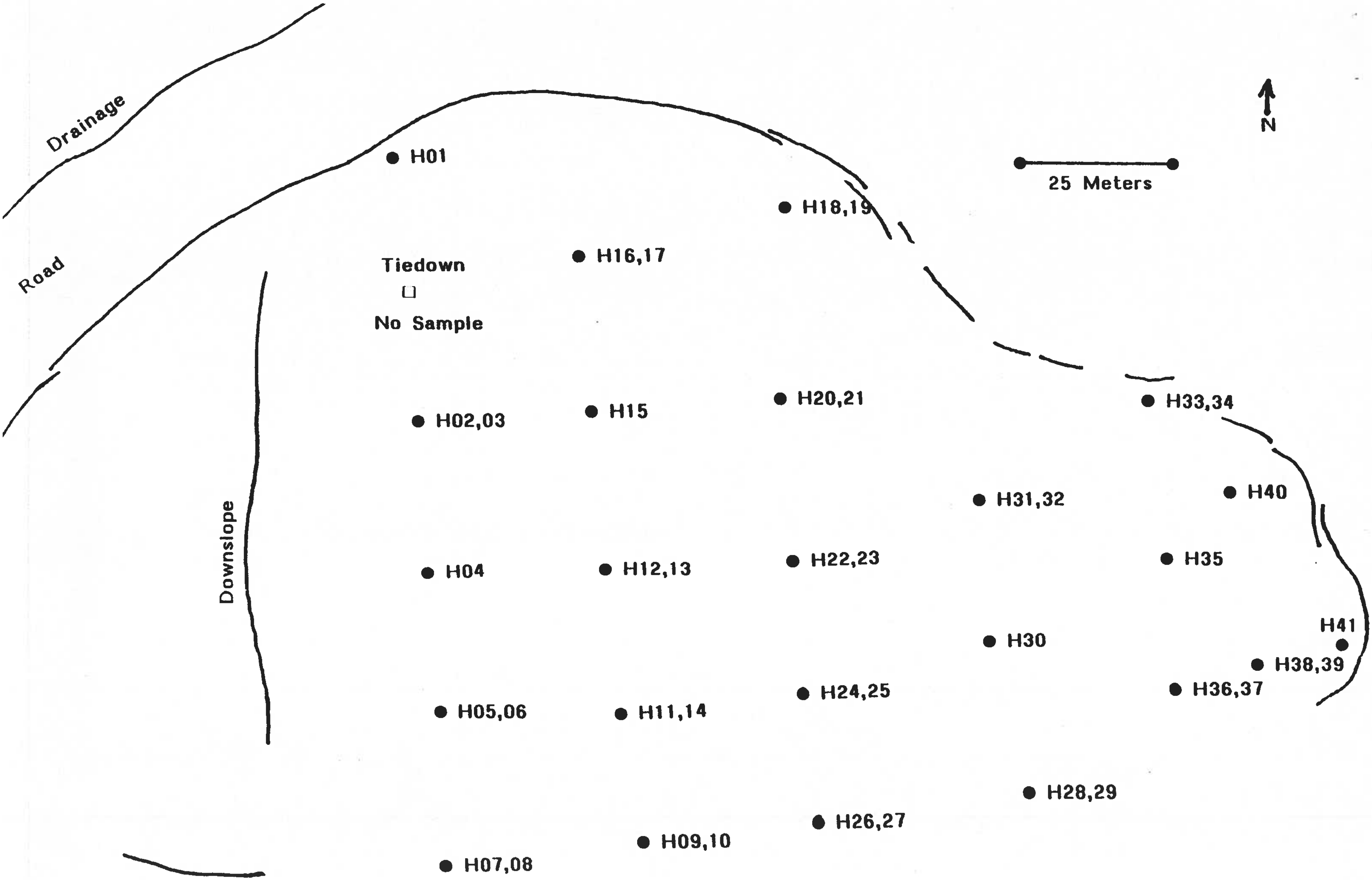
Woodward, D. F., Snyder-Conn, E., Riley R. G., and T. R. Garland. 1988. Drilling fluids and the Arctic tundra of Alaska: Assessing contamination of wetlands habitat and the toxicity to aquatic invertebrates and fish. Arch. Environ. Contam. Toxicol. 17, 683-697.

Appendix A

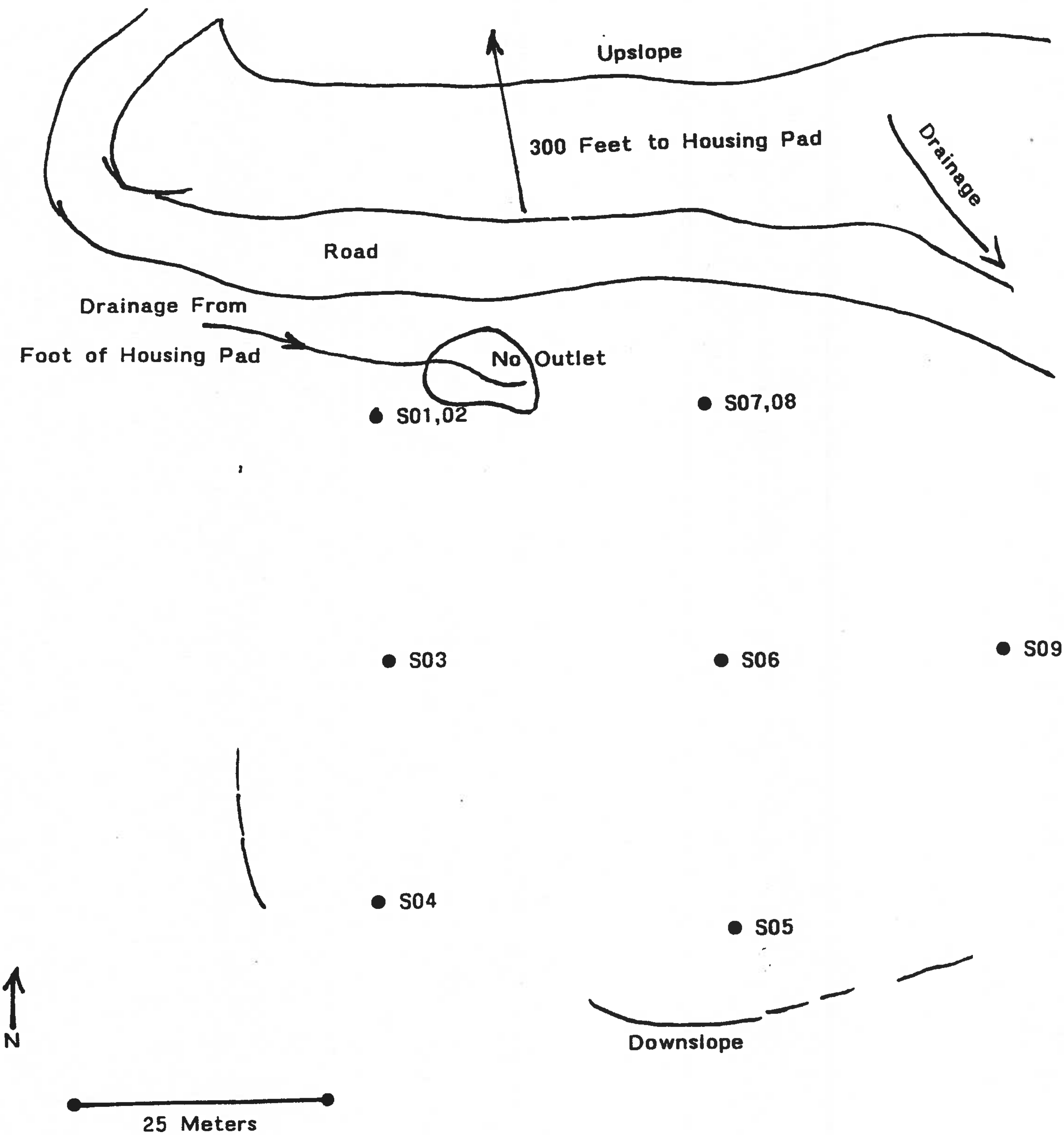
Schematic Drawings of Sampling Sites at Bear Creek Well No. 1



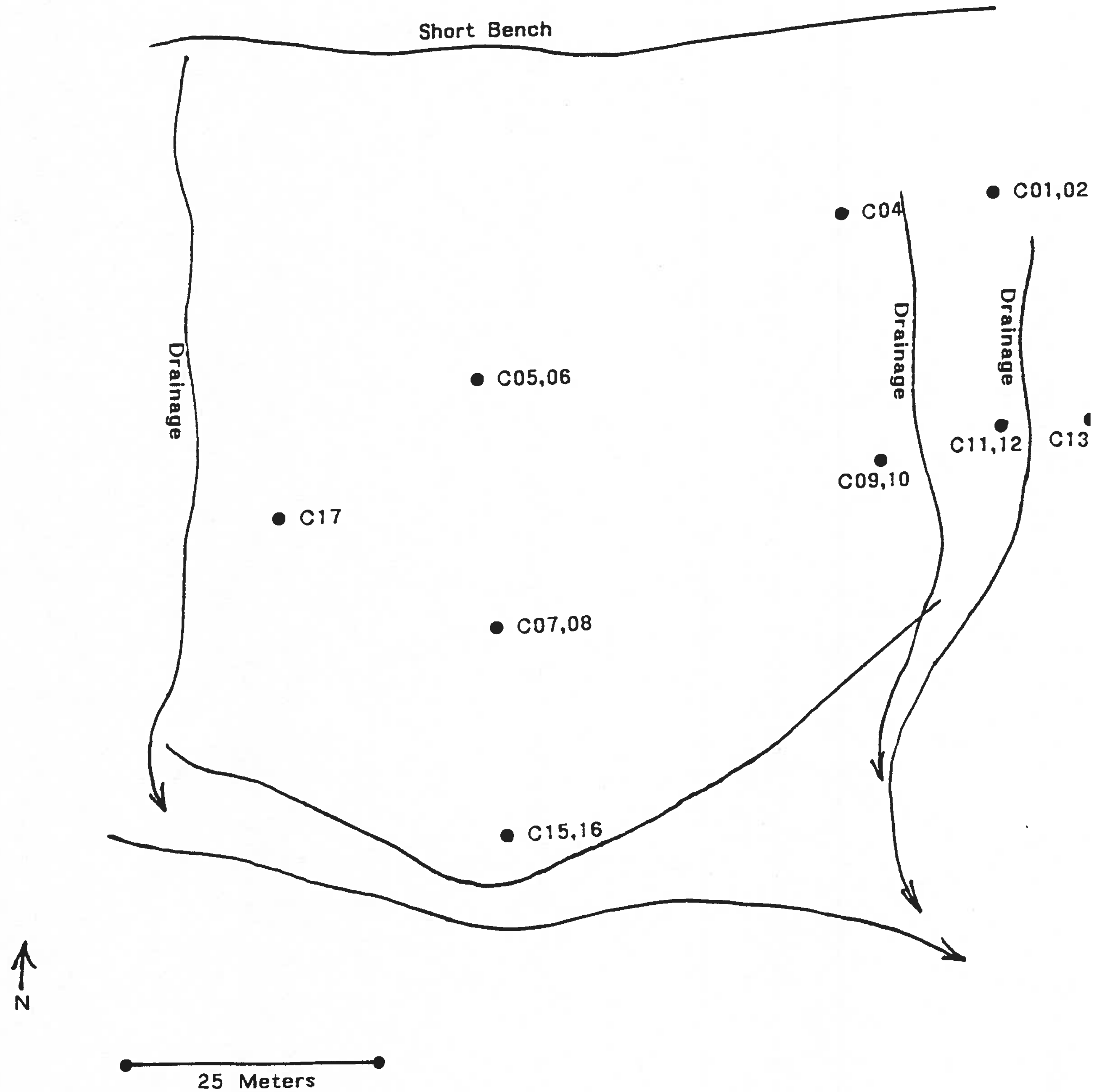
A1. WELL PAD SAMPLING SITES



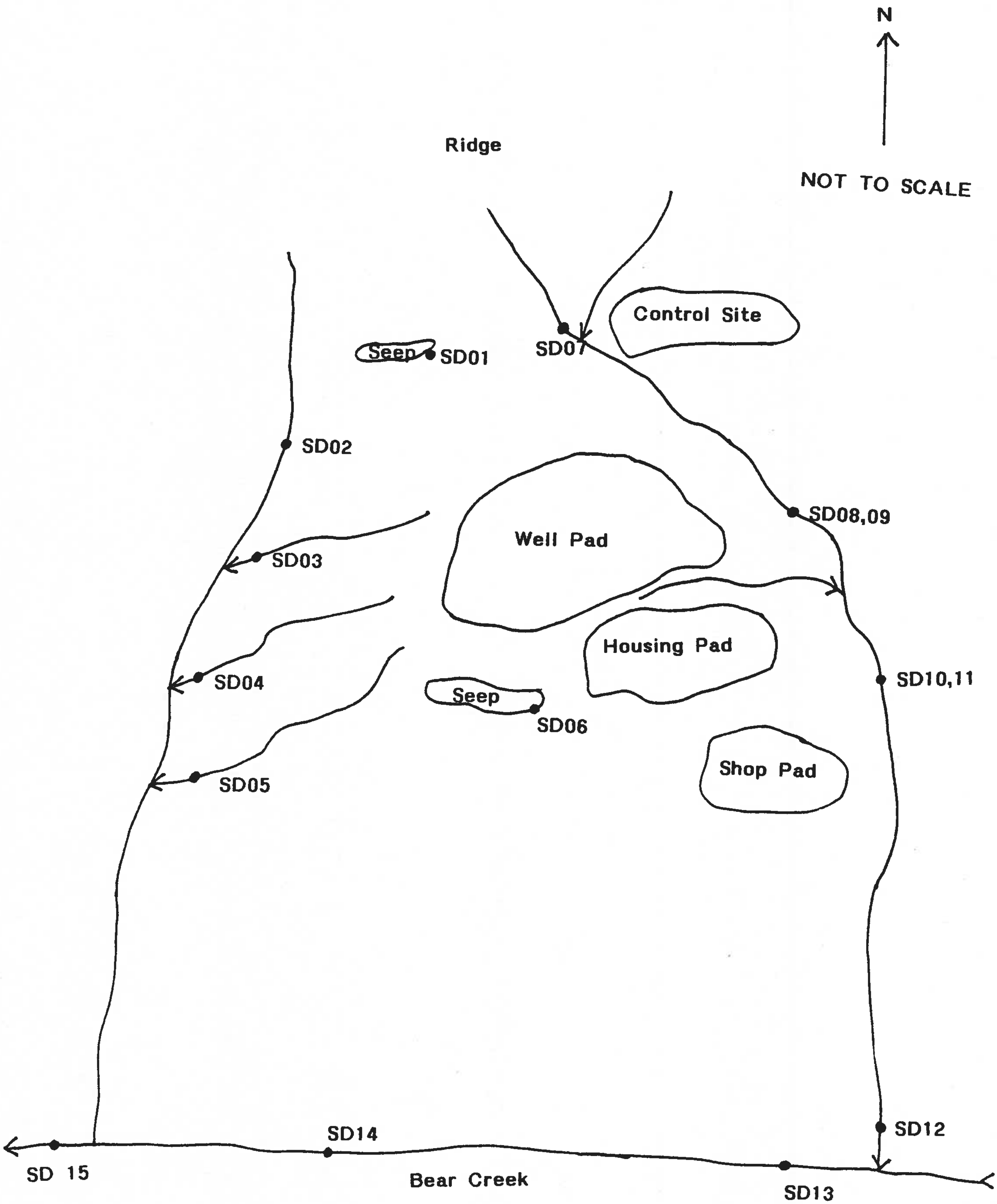
A2. HOUSING PAD SAMPLING SITES



A3. SHOP PAD SAMPLING SITES



A4. CONTROL SAMPLING SITES


N
NOT TO SCALE
Ridge
Control Site
Seep
SD01
SD07
SD02
SD08,09
Well Pad
SD03
Housing Pad
SD04
SD10,11
Seep
SD06
Shop Pad
SD05
SD12
SD14
SD 15
Bear Creek
SD13

Appendix B

Contaminants data from Bear Creek Well No. 1

Concentrations (ppm dry weight)

(-) indicates a concentration <2x the detection limit

B1. Well Pad: Metals

Metal	Sample #							
	W03	W06	W07	W10	W13	W16	W19	W23	W24
Aluminum	20404.00	19307.00	19583.00	19899.00	17480.00	18809.00	19335.00	20640.00	-
Arsenic	9.04	10.69	9.48	9.02	6.74	7.61	11.32	11.53	-
Chromium	37.51	32.39	28.61	30.91	25.16	30.56	35.26	36.24	-
Copper	65.58	64.44	58.05	63.61	51.96	63.53	71.89	71.71	-
Manganese	610.40	575.20	778.70	588.10	490.00	592.10	686.00	712.50	-
Nickel	30.90	27.91	28.94	26.09	20.32	27.30	32.39	35.11	-
Lead	28.44	-	-	10.93	181.97	16.92	-	-	-
Zinc	145.10	106.40	102.80	109.10	94.00	144.80	118.70	125.60	-

Note: sample W24 was a container blank.

B1. Well Pad: Polycyclic Aromatic Hydrocarbons

PAH	Sample #								
	W01	W02	W03	W04	W05	W06	W07	W08	W09
1-methylnaphthalene	0.090	0.129	0.565	0.039	-	0.023	-	-	0.043
1-methylphenanthrene	0.022	0.031	0.036	0.026	-	0.026	-	0.036	-
2,6-dimethylnaphthalene	0.106	0.187	0.114	0.032	-	0.020	-	-	0.029
2-methylnaphthalene	0.132	0.204	0.723	0.042	-	0.030	-	0.023	0.059
C1-fluoranthenes & pyrenes	-	-	0.040	0.029	0.045	-	-	-	0.022
C1-phenanthrenes & anthracenes	0.062	0.078	0.107	0.074	0.122	0.056	0.064	0.020	0.106
C1-chrysenes	-	-	0.043	0.029	0.056	-	-	-	0.029
C1-dibenzothiophenes	-	-	-	-	-	-	-	-	-
C1-fluorenes	-	-	0.036	-	-	-	-	-	-
C1-naphthalenes	0.108	0.089	0.342	0.231	0.079	0.034	0.038	-	0.034
C2-phenanthrenes & anthracenes	0.059	0.085	0.095	0.069	0.122	0.048	0.066	0.032	0.086
C2-chrysenes	-	-	0.049	0.032	0.065	-	0.020	-	0.022
C2-dibenzothiophenes	-	0.027	0.020	-	-	0.020	0.020	0.022	-
C2-fluorenes	0.036	0.043	0.083	0.041	0.055	0.028	0.033	-	0.035
C2-naphthalenes	0.089	0.065	0.432	0.255	0.100	0.033	0.039	0.014	0.040
C3-phenanthrenes & anthracenes	0.050	0.073	0.077	0.054	0.094	0.043	0.054	0.027	0.061
C3-chrysenes	-	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	0.027	-	-	-	-	-	-	-
C3-fluorenes	0.050	0.063	0.079	0.049	0.067	0.036	0.047	0.027	0.050
C3-naphthalenes	0.073	0.074	0.251	0.162	0.120	0.044	0.054	0.023	0.052
C4-phenanthrenes & anthracenes	0.020	0.038	0.044	0.031	0.040	0.020	0.025	-	0.029
C4-naphthalenes	0.061	0.083	0.212	0.105	0.115	0.043	0.051	0.029	0.054
benzo(g,h,i)perylene	-	-	-	-	0.020	-	-	-	-
biphenyl	-	-	0.025	-	-	-	-	-	-
chrysene	-	-	-	-	0.025	-	-	-	0.023
naphthalene	0.025	-	0.087	0.052	-	-	-	-	-
perylene	0.023	-	0.058	0.024	0.050	-	-	-	-
phenanthrene	0.041	0.050	0.055	0.037	0.054	0.043	0.031	-	0.041
pyrene	-	-	0.020	-	0.024	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	1.047	1.346	3.593	1.413	1.253	0.547	0.542	0.253	0.815

B1. Well Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	W10	W11	W12	W13	W14	W15	W16	W17
1-methylnaphthalene	0.056	0.056	0.100	0.048	0.100	0.139	0.053	0.048
1-methylphenanthrene	-	0.022	0.028	-	0.047	0.028	0.040	0.044
2,6-dimethylnaphthalene	0.055	0.035	0.092	0.038	0.089	0.244	0.040	0.060
2-methylnaphthalene	0.078	0.091	0.143	0.070	0.113	0.244	0.053	0.062
C1-fluoranthenes & pyrenes	-	0.040	0.031	0.034	0.065	0.090	0.046	0.098
C1-phenanthrenes & anthracenes	0.073	0.060	0.077	0.089	0.241	0.205	0.109	0.146
C1-chrysenes	-	0.030	0.040	0.029	0.071	0.093	0.045	0.096
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-fluorenes	-	-	-	-	0.034	0.035	0.022	0.036
C1-naphthalenes	0.097	0.138	0.150	0.242	0.304	0.198	0.379	0.114
C2-phenanthrenes & anthracenes	0.055	0.082	0.068	0.075	0.176	0.170	0.109	0.150
C2-chrysenes	-	0.041	0.042	0.031	0.070	0.102	0.049	0.144
C2-dibenzothiophenes	-	0.027	-	0.024	0.027	0.022	0.020	-
C2-fluorenes	0.033	0.064	0.042	0.050	0.120	0.097	0.081	0.071
C2-naphthalenes	0.075	0.143	0.087	0.203	0.384	0.238	0.434	0.164
C3-phenanthrenes & anthracenes	0.042	0.093	0.054	0.060	0.110	0.131	0.079	0.125
C3-chrysenes	-	-	-	-	-	0.025	-	0.031
C3-dibenzothiophenes	-	0.030	-	-	0.021	-	-	-
C3-fluorenes	0.042	0.107	0.054	0.059	0.107	0.102	0.094	0.079
C3-naphthalenes	0.074	0.133	0.102	0.130	0.356	0.282	0.269	0.224
C4-phenanthrenes & anthracenes		0.056	0.035	0.032	0.058	0.078	0.042	0.086
C4-naphthalenes	0.061	0.220	0.088	0.109	0.217	0.193	0.152	0.180
benzo(g,h,i)perylene	-	-	0.023	-	0.023	0.024	-	0.031
biphenyl	-	-	-	-	-	-	0.020	-
chrysene	-	-	-	-	0.032	0.038	0.021	0.025
naphthalene	0.041	0.037	0.031	0.044	0.047	0.036	0.089	-
perylene	-	0.033	0.057	0.049	0.058	0.103	0.065	0.186
phenanthrene	0.045	0.034	0.058	0.058	0.142	0.106	0.056	0.066
pyrene	-	0.025	-	-	0.036	0.050	0.024	0.042
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.827	1.597	1.402	1.474	3.048	3.073	2.391	2.308

B1. Well Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	W18	W19	W20	W21	W22	W23	W24	W25
1-methylnaphthalene	0.038	0.068	0.055	0.042	0.041	-	0.138	0.150
1-methylphenanthrene	0.027	0.045	0.042	0.030	0.041	-	0.044	0.026
2,6-dimethylnaphthalene	0.038	0.060	0.054	0.039	0.040	-	0.153	0.258
2-methylnaphthalene	0.044	0.090	0.069	0.048	0.051	-	0.200	0.246
C1-fluoranthenes & pyrenes	0.059	0.031	0.063	0.050	0.045	0.051	-	0.074
C1-phenanthrenes & anthracenes	0.144	0.088	0.150	0.132	0.111	0.135	-	0.172
C1-chrysenes	0.074	0.030	0.040	0.048	0.046	0.062	-	0.084
C1-dibenzothiophenes	-	0.023	0.059	-	0.027	0.024	-	0.032
C1-fluorenes	-	-	0.023	0.020	-	-	-	0.037
C1-naphthalenes	0.104	0.084	0.156	0.123	0.093	0.089	-	0.396
C2-phenanthrenes & anthracenes	0.144	0.086	0.133	0.111	0.104	0.120	-	0.153
C2-chrysenes	0.099	0.031	0.046	0.049	0.055	0.070	-	0.196
C2-dibenzothiophenes	0.033	0.031	0.046	0.027	0.041	0.037	-	0.046
C2-fluorenes	0.070	0.053	0.077	0.076	0.064	0.066	-	0.116
C2-naphthalenes	0.131	0.103	0.149	0.140	0.117	0.110	-	0.412
C3-phenanthrenes & anthracenes	0.126	0.068	0.115	0.084	0.084	0.100	-	0.139
C3-chrysenes	0.021	-	-	-	-	-	-	0.064
C3-dibenzothiophenes	0.027	0.024	0.038	0.024	0.032	0.030	-	0.035
C3-fluorenes	0.089	0.066	0.093	0.097	0.079	0.094	-	0.135
C3-naphthalenes	0.170	0.145	0.192	0.192	0.185	0.178	-	0.375
C4-phenanthrenes & anthracenes	0.073	0.038	0.065	0.049	0.047	0.058	-	0.078
C4-naphthalenes	0.131	0.123	0.168	0.150	0.160	0.151	-	0.281
benzo(g,h,i)perylene	0.028	-	-	0.023	0.021	0.027	-	0.029
biphenyl	-	-	-	-	-	-	-	0.025
chrysene	0.030	-	-	0.023	-	0.027	-	0.039
naphthalene	0.021	0.020	0.038	0.022	-	-	-	0.052
perylene	0.097	0.022	0.041	0.050	0.053	0.107	-	0.118
phenanthrene	0.065	0.049	0.076	0.069	0.052	0.070	-	0.088
pyrene	0.029	0.021	0.033	0.027	0.025	0.027	-	0.037
	-----	-----	-----	-----	-----	-----	-----	-----
Total	1.912	1.399	2.021	1.745	1.614	1.633	0.535	3.393

Note: sample W24 was a container blank.

B2. Housing Pad: Metals

Metal	Sample #					
	H01	H04	H07	H10	H15	H19
Aluminum	18816.00	15729.00	21746.00	16266.00	17911.00	16154.00
Arsenic	10.92	13.90	12.02	10.78	11.60	10.22
Chromium	31.38	30.31	39.13	28.01	35.15	26.72
Copper	69.18	65.69	68.93	72.12	73.94	65.62
Manganese	688.40	1709.00	782.30	709.80	721.70	701.90
Nickel	26.05	22.78	30.49	25.19	27.39	27.51
Lead	-	-	-	-	-	-
Zinc	107.00	109.30	121.10	117.30	124.90	108.50

Metal	Sample #					
	H23	H27	H30	H34	H37	H40
Aluminum	15363.00	19323.00	17365.00	16020.00	17880.00	16298.00
Arsenic	11.14	12.31	12.62	11.40	12.27	10.25
Chromium	28.93	32.04	31.72	30.01	34.63	26.62
Copper	66.02	75.35	70.84	62.34	68.37	66.66
Manganese	592.00	796.60	885.40	665.90	615.40	744.50
Nickel	29.05	28.34	29.69	27.70	27.75	28.18
Lead	-	-	12.83	-	-	-
Zinc	104.80	120.20	253.40	100.30	106.60	113.10

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons

PAH	Sample #							
	H01	H02	H03	H04	H05	H06	H07	H08
1-methylnaphthalene	-	0.123	-	-	-	-	-	-
1-methylphenanthrene	-	0.054	-	-	-	-	-	-
2,6-dimethylnaphthalene	-	0.062	-	-	-	-	-	-
2-methylnaphthalene	-	0.163	-	-	-	-	-	-
C1-fluoranthenes & pyrenes	-	-	0.070	-	-	-	0.022	0.022
C1-phenanthrenes & anthracenes	0.068	0.032	0.155	0.039	0.047	0.044	0.034	0.036
C1-chrysenes	-	-	0.051	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.052	0.021	0.287	0.025	0.024	-	-	-
C2-phenanthrenes & anthracenes	0.057	0.030	0.160	0.033	0.045	0.044	0.048	0.044
C2-chrysenes	-	-	0.072	-	-	-	-	-
C2-dibenzothiophenes	-	-	0.020	-	-	-	-	-
C2-fluorenes	0.027	-	0.060	0.019	0.021	0.020	-	-
C2-naphthalenes	0.047	0.024	0.201	-	0.019	-	-	-
C3-phenanthrenes & anthracenes	0.035	0.019	0.123	0.021	0.028	0.030	0.037	0.033
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-	-
C3-fluorenes	0.040	0.022	0.105	0.027	0.032	0.034	0.033	0.029
C3-naphthalenes	0.064	0.019	0.228	-	0.021	-	-	-
C4-phenanthrenes & anthracenes	0.021	-	0.091	-	0.018	0.019	0.024	0.021
C4-naphthalenes	0.031	-	0.121	0.018	0.019	-	-	-
chrysene	-	-	0.025	-	-	-	-	-
naphthalene	-	-	0.086	-	-	-	-	-
perylene	-	-	0.112	-	-	0.019	-	-
phenanthrene	0.062	0.034	0.104	0.042	0.034	0.034	-	-
pyrene	0.024	-	0.044	-	-	0.021	0.025	0.021
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.528	0.603	2.115	0.224	0.308	0.265	0.223	0.206

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H09	H10	H11	H12	H13	H15	H16	H17
1-methylnaphthalene	-	-	-	-	0.086	0.031	-	-
1-methylphenanthrene	-	-	0.036	0.048	0.044	0.057	0.034	0.037
2,6-dimethylnaphthalene	-	-	-	-	0.089	-	-	0.020
2-methylnaphthalene	-	-	-	-	0.136	-	-	0.026
C1-fluoranthenes & pyrenes	-	-	-	-	-	0.028	-	-
C1-phenanthrenes & anthracenes	0.039	0.028	0.032	0.141	0.166	0.156	0.195	0.132
C1-chrysenes	-	-	-	-	0.022	0.032	-	-
C1-dibenzothiophenes	-	-	-	0.030	0.039	0.026	0.040	0.028
C1-naphthalenes	-	-	-	-	0.025	0.220	0.023	-
C2-phenanthrenes & anthracenes	0.052	0.040	0.036	0.171	0.185	0.141	0.241	0.143
C2-chrysenes	-	-	-	-	0.021	-	-	-
C2-dibenzothiophenes	-	-	-	0.065	0.075	0.048	0.094	0.055
C2-fluorenes	0.021	-	-	0.068	0.116	0.078	0.090	0.071
C2-naphthalenes	-	-	-	-	0.035	0.185	0.024	-
C3-phenanthrenes & anthracenes	0.039	0.031	0.029	0.086	0.096	0.068	0.117	0.066
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	0.051	0.061	0.032	0.076	0.043
C3-fluorenes	0.039	0.023	0.025	0.128	0.200	0.145	0.174	0.127
C3-naphthalenes	-	-	0.021	-	0.047	0.145	0.025	-
C4-phenanthrenes & anthracenes	0.025	-	-	0.031	0.042	0.025	0.044	0.026
C4-naphthalenes	-	-	-	0.031	0.077	0.094	0.042	0.040
chrysene	-	-	-	-	-	0.028	-	-
naphthalene	-	-	-	-	-	0.075	-	-
perylene	-	-	-	-	0.071	-	-	-
phenanthrene	-	-	-	0.053	0.053	0.104	0.058	0.041
pyrene	-	-	-	0.034	-	0.046	0.021	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.215	0.122	0.179	0.937	1.686	1.764	1.298	0.855

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H18	H19	H20	H21	H22	H23	H24	H25
1-methylnaphthalene	-	-	-	-	0.020	-	-	-
1-methylphenanthrene	0.033	-	0.041	-	-	-	-	-
2,6-dimethylnaphthalene	-	-	-	-	0.022	-	-	-
2-methylnaphthalene	-	-	0.027	-	0.028	-	-	-
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.121	0.123	0.042	0.058	0.037	0.052	0.044	0.036
C1-chrysenes	-	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.044	-	0.028	0.032	0.024	0.050	0.033	0.020
C2-phenanthrenes & anthracenes	0.121	0.134	0.038	0.041	0.033	0.044	0.038	0.027
C2-chrysenes	-	-	-	-	-	-	-	-
C2-dibenzothiophenes	0.042	-	-	0.025	-	0.031	0.022	-
C2-fluorenes	0.092	0.071	0.022	0.022	-	0.024	-	-
C2-naphthalenes	0.044	-	0.034	-	0.028	0.051	0.034	0.026
C3-phenanthrenes & anthracenes	0.062	0.073	0.027	0.029	0.023	0.030	0.027	0.022
C3-chrysenes	-	0.052	-	-	-	0.027	-	-
C3-dibenzothiophenes	0.033	-	-	0.022	-	-	-	-
C3-fluorenes	0.139	0.128	0.040	0.026	0.019	0.030	0.031	-
C3-naphthalenes	0.035	0.025	0.030	0.062	0.035	0.070	0.035	0.043
C4-phenanthrenes & anthracenes	0.024	0.030	-	-	-	-	-	-
C4-naphthalenes	0.042	0.040	0.027	0.049	0.033	0.065	0.032	0.031
chrysene	-	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-	-
perylene	0.019	0.022	-	0.021	-	-	-	-
phenanthrene	0.078	0.040	0.037	0.047	0.026	0.037	0.035	0.026
pyrene	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.929	0.738	0.393	0.434	0.328	0.511	0.331	0.231

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H26	H27	H28	H29	H30	H31	H32	H33
1-methylnaphthalene	-	-	-	-	-	0.047	-	0.035
1-methylphenanthrene	-	0.024	-	-	-	0.022	0.021	-
2,6-dimethylnaphthalene	-	0.022	-	-	-	0.041	-	0.026
2-methylnaphthalene	-	0.024	-	-	-	0.065	-	0.042
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.027	-	0.061	0.033	0.058	0.030	0.031	0.062
C1-chrysenes	-	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.021	-	0.036	-	0.036	0.028	0.022	0.020
C2-phenanthrenes & anthracenes	0.025	-	0.039	0.031	0.046	0.020	0.025	0.040
C2-chrysenes	-	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	-	-	-	-
C2-fluorenes	-	-	0.027	-	0.021	-	-	-
C2-naphthalenes	0.030	-	0.046	0.025	0.046	0.030	0.028	0.038
C3-phenanthrenes & anthracenes	-	-	0.027	0.020	0.034	-	-	0.025
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-	-
C3-fluorenes	0.020	-	0.034	-	0.030	-	-	0.025
C3-naphthalenes	0.027	-	0.041	0.032	0.046	0.027	0.031	0.045
C4-phenanthrenes & anthracenes	-	-	-	-	0.021	-	-	-
C4-naphthalenes	0.023	-	0.033	0.031	0.042	0.025	0.031	0.041
chrysene	-	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-	-
perylene	-	-	-	-	-	-	-	-
phenanthrene	0.021	-	0.049	-	0.044	0.027	0.025	0.045
pyrene	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.194	0.070	0.393	0.172	0.424	0.362	0.214	0.444

B2. Housing Pad: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #							
	H34	H35	H36	H37	H38	H39	H40	H41
1-methylnaphthalene	-	-	-	-	-	-	-	0.042
1-methylphenanthrene	-	-	-	-	-	-	-	-
2,6-dimethylnaphthalene	-	-	-	-	-	-	-	0.031
2-methylnaphthalene	-	-	-	-	-	-	-	0.073
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.046	0.063	0.032	0.025	0.036	0.054	0.050	0.051
C1-chrysenes	-	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-	-
C1-naphthalenes	0.027	0.079	0.020	-	-	0.022	0.025	-
C2-phenanthrenes & anthracenes	0.042	0.046	0.028	0.023	0.035	0.039	0.046	0.038
C2-chrysenes	-	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	0.022	-	0.022	-
C2-fluorenes	0.025	0.023	-	-	0.020	-	0.023	-
C2-naphthalenes	0.044	0.085	0.027	0.024	0.034	0.034	0.042	0.041
C3-phenanthrenes & anthracenes	0.033	0.030	0.020	-	0.025	0.022	-	0.026
C3-chrysenes	-	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-	-
C3-fluorenes	0.029	0.028	-	-	0.027	0.026	0.030	0.027
C3-naphthalenes	0.056	0.082	0.036	0.037	0.047	0.049	0.076	0.053
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	-	-
C4-naphthalenes	0.052	0.066	0.033	0.036	0.039	0.046	0.043	0.048
chrysene	-	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-	-
perylene	-	-	-	-	-	-	-	-
phenanthrene	0.031	0.044	0.025	-	0.022	0.036	0.035	0.043
pyrene	-	-	-	-	-	-	-	-
Total	0.385	0.546	0.221	0.145	0.307	0.328	0.392	0.473

C3. Shop Pad: Metals

Metal	Sample #		
	S01	S05	S09
Aluminum	16376.00	15415.00	15050.00
Arsenic	10.93	10.11	12.70
Chromium	23.13	28.76	29.01
Copper	55.84	63.39	63.90
Manganese	669.00	1333.90	1398.60
Nickel	21.81	26.15	27.52
Lead	-	-	-
Zinc	94.10	101.10	98.70

B3. Shop Pad: Polycyclic Aromatic Hydrocarbons

PAH	Sample #								
	S01	S02	S03	S04	S05	S06	S07	S08	S09
1-methylnaphthalene	-	-	0.058	0.070	0.040	0.044	0.026	0.038	0.831
1-methylphenanthrene	-	-	0.051	0.020	0.019	-	-	0.025	-
2,6-dimethylnaphthalene	-	0.024	0.056	0.058	0.031	0.035	0.022	0.025	0.153
2-methylnaphthalene	-	0.022	0.080	0.104	0.055	0.068	0.042	0.055	1.013
C1-fluoranthenes & pyrenes	-	-	-	0.027	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.050	0.082	0.095	0.156	0.084	0.073	0.071	0.060	0.075
C1-chrysenes	-	-	-	0.049	-	0.022	-	-	0.020
C1-dibenzothiophenes	-	-	0.024	-	-	-	-	-	-
C1-naphthalenes	0.145	0.136	0.115	0.137	0.183	0.093	0.119	0.068	0.090
C2-phenanthrenes & anthracenes	0.035	0.052	0.075	0.095	0.046	0.045	0.065	0.046	0.059
C2-chrysenes	-	-	-	0.045	-	-	-	-	-
C2-dibenzothiophenes	-	0.022	0.038	-	-	-	0.025	-	-
C2-fluorenes	0.025	0.047	0.032	0.034	0.024	0.025	0.032	0.026	0.029
C2-naphthalenes	0.097	0.113	0.113	0.140	0.132	0.074	1.636	0.049	0.067
C3-phenanthrenes & anthracenes	0.026	0.033	0.057	0.059	0.030	0.034	0.056	0.036	0.040
C3-dibenzothiophenes	-	-	0.029	-	-	-	0.022	-	-
C3-fluorenes	0.034	0.049	0.044	0.044	0.029	0.031	0.045	0.032	0.039
C3-naphthalenes	0.082	0.106	0.119	0.114	0.088	0.065	1.380	0.038	0.058
C4-phenanthrenes & anthracenes	-	-	0.033	0.037	-	-	0.028	-	0.028
C4-naphthalenes	0.062	0.080	0.110	0.080	0.061	0.045	1.243	0.034	0.048
chrysene	-	-	-	0.040	-	-	-	-	-
naphthalene	0.062	0.047	0.039	0.035	0.034	0.027	0.036	0.031	0.026
perylene	-	-	-	0.031	-	-	-	-	-
phenanthrene	0.037	0.063	0.062	0.109	0.080	0.052	0.040	0.046	0.045
pyrene	-	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.655	0.876	1.230	1.484	0.936	0.733	4.888	0.609	2.621

B4. Control Site: Metals

Metal	Sample #						
	C1	C2	C5	C6	C9	C12	C16
Aluminum	14663.00	19120.00	13635.00	13708.00	13818.00	12679.00	20608.00
Arsenic	9.83	13.03	9.41	9.86	10.63	11.00	9.82
Chromium	26.30	29.90	25.27	22.04	23.69	26.02	40.21
Copper	68.20	73.09	75.66	65.42	62.43	70.28	83.65
Manganese	721.90	803.40	891.20	622.50	628.50	515.30	661.90
Nickel	30.19	27.87	32.25	28.10	23.39	29.75	38.09
Lead	-	-	-	-	-	-	-
Zinc	109.40	112.80	116.10	111.60	106.20	115.20	138.40

B4. Control Site: Polycyclic Aromatic Hydrocarbons

PAH	Sample #								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
1-methylphenanthrene	-	-	-	-	-	-	-	-	-
2-methylnaphthalene	-	-	-	-	-	-	-	-	0.024
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.030	0.021	-	0.043	0.044	0.026	0.043	0.030	0.057
C1-chrysenes	-	-	-	-	-	-	-	-	-
C1-naphthalenes	-	-	-	0.020	-	-	-	-	0.023
C2-phenanthrenes & anthracenes	0.040	0.027	0.022	0.028	0.035	0.027	0.045	0.033	0.042
C2-fluorenes	-	-	-	-	-	-	-	-	-
C2-naphthalenes	-	-	-	-	-	-	-	-	0.023
C3-phenanthrenes & anthracenes	0.026	-	-	-	0.023	0.019	0.028	0.021	0.021
C3-fluorenes	0.023	-	-	0.019	0.025	0.019	0.024	-	0.028
C3-naphthalenes	-	-	-	-	0.022	-	-	-	-
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	0.021	-	-
C4-naphthalenes	-	-	-	-	0.022	-	-	-	-
phenanthrene	-	-	-	0.037	0.033	-	0.027	-	0.053
pyrene	0.022	-	-	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.141	0.048	0.022	0.147	0.204	0.091	0.188	0.084	0.271

PAH	Sample #							
	C10	C11	C12	C13	C14	C15	C16	C17
1-methylphenanthrene	0.031	0.025	-	-	0.029	-	0.023	-
2-methylnaphthalene	0.027	-	-	-	-	-	-	-
C1-fluoranthenes & pyrenes	-	0.022	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.042	0.084	0.067	0.041	0.029	0.078	0.048	0.071
C1-chrysenes	-	-	-	-	-	0.023	-	-
C1-naphthalenes	-	0.045	-	-	-	0.033	-	0.035
C2-phenanthrenes & anthracenes	0.043	0.078	0.060	0.044	0.034	0.065	0.045	0.053
C2-fluorenes	-	0.032	0.020	-	-	0.029	-	0.026
C2-naphthalenes	-	0.038	-	-	-	0.036	-	0.032
C3-phenanthrenes & anthracenes	0.024	0.041	0.032	0.027	0.021	0.034	0.024	0.027
C3-fluorenes	0.021	0.046	0.030	0.026	-	0.044	0.021	0.041
C3-naphthalenes	-	0.032	-	-	-	0.034	-	0.029
C4-phenanthrenes & anthracenes	-	0.024	0.022	-	-	0.021	-	0.022
C4-naphthalenes	-	0.023	-	-	-	0.027	-	0.023
phenanthrene	0.023	0.069	0.047	0.023	-	0.063	0.029	0.056
pyrene	-	0.026	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----	-----
Total	0.211	0.585	0.278	0.161	0.113	0.487	0.190	0.415

85. Sediment Samples: Metals

Metal	Sample # SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08
Aluminum	16423.00	12716.00	18988.00	16960.00	20177.00	17569.00	18359.00	5293.00
Arsenic	3.90	2.33	5.47	11.22	10.99	1.85	12.15	3.11
Chromium	16.77	11.56	20.01	24.57	36.66	16.94	24.76	12.47
Copper	35.27	31.04	46.70	65.91	69.06	41.35	64.53	20.32
Manganese	524.30	454.00	654.00	772.60	662.90	533.60	498.00	225.70
Nickel	12.51	9.81	17.41	26.18	27.57	13.39	21.71	5.19
Lead	-	-	-	-	-	-	-	75.13
Zinc	75.30	61.00	91.00	135.00	106.00	73.20	105.00	354.10

Metal	Sample # SD09	SD10	SD11	SD12	SD13	SD14	SD15
Aluminum	8665.00	20504.00	18870.00	19035.00	13491.00	17020.00	19093.00
Arsenic	3.23	8.23	7.38	9.87	4.01	8.22	7.04
Chromium	13.17	30.83	21.86	29.45	12.91	21.45	23.38
Copper	28.80	62.05	41.31	62.59	30.00	54.55	48.79
Manganese	260.20	780.70	316.40	625.50	361.60	522.40	411.50
Nickel	6.56	21.75	13.33	23.01	8.00	18.61	20.15
Lead	41.92	-	-	11.44	-	-	-
Zinc	361.10	88.70	74.60	124.10	53.60	94.90	88.30

B5. Sediment Samples: Polycyclic Aromatic Hydrocarbons

PAH	Sample #							
	SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08
1-methylnaphthalene	0.735	0.678	2.690	1.029	0.044	0.816	13.961	1.331
1-methylphenanthrene	-	-	0.035	-	0.028	-	0.266	0.146
2,6-dimethylnaphthalene	0.146	0.162	0.754	0.230	0.038	0.170	19.841	4.322
2-methylnaphthalene	0.868	0.774	2.869	1.227	0.060	0.986	17.586	1.673
C1-fluoranthenes & pyrenes	-	-	-	0.039	-	-	-	-
C1-phenanthrenes & anthracenes	-	-	0.027	0.091	-	-	0.026	1.098
C1-chrysenes	-	-	-	0.040	-	-	-	0.173
C1-dibenzothiophenes	-	-	-	-	-	-	-	0.211
C1-fluorenes	-	-	-	-	-	-	-	1.067
C1-naphthalenes	2.061	1.600	2.125	3.871	2.256	1.826	1.705	36.732
C2-phenanthrenes & anthracenes	-	-	0.023	0.076	-	-	0.020	0.906
C2-chrysenes	-	-	-	0.047	-	-	-	0.234
C2-dibenzothiophenes	-	-	-	-	-	-	-	0.192
C2-fluorenes	-	-	-	0.056	-	-	-	1.228
C2-naphthalenes	0.457	0.373	0.548	1.242	0.575	0.409	0.360	56.987
C3-phenanthrenes & anthracenes	-	-	-	0.056	-	-	-	0.716
C3-chrysenes	-	-	-	-	-	-	-	0.030
C3-dibenzothiophenes	-	-	-	-	-	-	-	0.030
C3-fluorenes	-	-	-	0.060	-	-	-	0.622
C3-naphthalenes	0.067	0.070	0.108	0.340	0.122	0.059	0.060	29.133
C4-phenanthrenes & anthracenes	-	-	-	0.035	-	-	-	0.345
C4-naphthalenes	0.020	0.022	0.042	0.127	0.038	0.022	0.022	9.164
acenaphthene	-	-	-	-	-	-	-	0.326
anthracene	-	-	-	-	-	-	-	0.040
biphenyl	-	-	0.023	0.055	0.021	-	-	3.380
chrysene	-	-	-	0.020	-	-	-	0.070
naphthalene	0.299	0.223	0.302	0.464	0.295	0.217	0.275	2.518
perylene	-	-	0.096	-	-	-	-	-
phenanthrene	-	-	-	0.051	-	-	-	0.731
pyrene	-	-	-	0.020	-	-	-	0.065
	-----	-----	-----	-----	-----	-----	-----	-----
Total	4.653	3.902	9.642	9.176	3.477	4.505	54.122	153.470

B5. Sediment Samples: Polycyclic Aromatic Hydrocarbons cont...

PAH	Sample #						
	SD09	SD10	SD11	SD12	SD13	SD14	SD15
1-methylnaphthalene	0.310	0.229	1.383	1.406	0.547	1.015	0.043
1-methylphenanthrene	-	-	-	0.023	0.041	0.041	0.023
2,6-dimethylnaphthalene	0.056	0.040	0.340	0.273	0.172	0.279	0.029
2-methylnaphthalene	0.386	0.308	1.674	1.625	0.662	1.206	0.057
C1-fluoranthenes & pyrenes	-	-	-	-	-	0.024	0.020
C1-phenanthrenes & anthracenes	0.609	-	-	0.027	0.074	0.183	0.124
C1-chrysenes	0.097	-	-	-	-	0.038	0.028
C1-dibenzothiophenes	0.262	-	-	-	-	-	-
C1-fluorenes	0.449	-	-	-	-	-	-
C1-naphthalenes	2.642	0.791	0.701	2.234	3.034	1.201	1.190
C2-phenanthrenes & anthracenes	0.953	-	-	0.024	0.051	0.103	0.078
C2-chrysenes	0.164	-	-	-	-	0.028	0.023
C2-dibenzothiophenes	0.513	-	-	-	-	-	-
C2-fluorenes	1.314	-	-	-	0.031	0.058	0.048
C2-naphthalenes	7.834	0.172	0.144	0.807	8.190	0.416	0.551
C3-phenanthrenes & anthracenes	0.774	-	-	-	0.028	0.049	0.043
C3-chrysenes	-	-	-	-	-	-	-
C3-dibenzothiophenes	0.381	-	-	-	-	-	-
C3-fluorenes	1.090	-	-	-	0.033	0.061	0.052
C3-naphthalenes	14.098	0.030	0.029	0.156	0.178	0.180	0.159
C4-phenanthrenes & anthracenes	0.350	-	-	-	-	0.023	0.020
C4-naphthalenes	8.038	-	-	0.065	0.070	0.097	0.073
acenaphthene	0.031	-	-	-	-	-	-
anthracene	0.033	-	-	-	-	-	-
biphenyl	0.059	-	-	0.028	0.028	0.023	0.028
chrysene	0.054	-	-	-	-	0.025	-
naphthalene	0.436	0.094	0.097	0.280	0.372	0.154	0.306
perylene	0.029	-	-	-	-	-	-
phenanthrene	0.055	-	-	-	0.044	0.125	0.075
pyrene	0.075	-	-	-	-	-	-
	-----	-----	-----	-----	-----	-----	-----
Total	41.092	1.664	4.368	6.948	13.555	5.329	2.970