(1)

INSTALLATION RESTORATION PROGRAM

STAGE 1

KING SALMON AIRPORT
KING SALMON, ALASKA 99613

DTIC
ELECTE
DEC 0 6 1989
S D
D

PREPARED BY
CH2M HILL
2550 DENALI STREET — 8TH FLOOR
ANCHORAGE, ALASKA

AUGUST 29, 1989

FINAL TECHNICAL REPORT

PREPARED FOR
UNITED STATES AIR FORCE
ALASKAN AIR COMMAND
5099TH CEOS/CC
ELMENDORF AIR FORCE BASE, ALASKA 99506

OCCUPATIONAL AND ENVIRONMENTAL
HEALTH LABORATORY (AFOEHL/TS)
BROOKS AIR FORCE BASE, TEXAS 78235-5501

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

①

INSTALLATION RESTORATION PROGRAM

STAGE 1

FINAL TECHNICAL REPORT

FOR

KING SALMON AIRPORT

King Salmon, Alaska 99613

United States Air Force
Alaskan Air Command
5099th CEOS/CC
Elmendorf Air Force Base, Alaska 99506

August 29, 1989

PREPARED BY

CH2M HILL
2550 Denali Street, 8th Floor
Anchorage, Alaska 99503

CH2M HILL SOUTHEAST, INC.
Gainesville, Florida

CONTRACT NO. F33615-85-D-4535, DELIVERY ORDER NO. 005

JAMES WILLIAMS
AFOEHL TECHNICAL PROGRAM MANAGER

AIR FORCE OCCUPATIONAL & ENVIRONMENTAL HEALTH LABORATORY
TECHNICAL SERVICES DIVISION
BROOKS AIR FORCE BASE, TEXAS 78235-5501

NOTICE

This report has been prepared for the United States Air Force by CH2M HILL for the purpose of aiding in the implementation of a final remedial action plan under the Air Force Installation Restoration Program (IRP). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to an Air Force final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the IRP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this report, since subsequent facts may become known that may make this report premature or inaccurate. Acceptance of this report in performance of the contract under which it is prepared does not mean that the US Air Force adopts the conclusions, recommendations, or other views expressed herein, which are those of the contractor only and do not necessarily reflect the official position of the United States Air Force.

Copies of this report may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

NG:lw/CVR193/009 (pc)

A-1

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS N/A
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release; Distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) N/A	5. MONITORING ORGANIZATION REPORT NUMBER(S) N/A
6a. NAME OF PERFORMING ORGANIZATION CH2M HILL 6b. OFFICE SYMBOL *(If applicable)*	7a. NAME OF MONITORING ORGANIZATION AFOEHL/TSS
6c. ADDRESS *(City, State, and ZIP Code)* 2550 Denali Street, 8th Floor Anchorage, Alaska 99503	7b. ADDRESS *(City, State, and ZIP Code)* Brooks AFB, Texas 78235-5501
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOEHL/TSS 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-85-D-4535
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO

11. TITLE *(Include Security Classification)*
IRP Stage 1, Final Technical Report for King Salmon Airport

12. PERSONAL AUTHOR(S)
CH2M HILL

13a. TYPE OF REPORT Final	13b. TIME COVERED FROM ________ TO ________	14. DATE OF REPORT *(Year, Month, Day)* 89/08/29	15. PAGE COUNT 262 (Vol. I)

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Installation Restoration Program, IRP; inorganics, volatile organics, semivolatile organics, pesticides, contaminants, toxic, petroleum oils, lubricants, steel drums, groundwater quality, soil vapor gas, aquifer, geophysical survey, sampling, monitoring wells, remedial investigation (RI), feasibility study (FS), remedial action.

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Four investigation areas at King Salmon Airport were tested for over 146 inorganic, volatile organic, semivolatile organic, and pesticide contaminants. Of these 146, 31 potential contaminants of concern have been identified. These contaminants are addressed in this report because they exceed federal or state criteria for the protection of human health and the environment, are consistently present in site media (soil, sediment, surface, and groundwaters), and are potentially toxic to humans and the environment. Suggested actions and the rationale for each investigation area are presented. An extensive appendix of field data is included as a separate volume.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL James Williams	22b. TELEPHONE *(Include Area Code)* 800/821-4528	22c. OFFICE SYMBOL AFOEHL/TSS

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

PREFACE

This Final Technical Report for the Installation Restoration Program (IRP) Stage 1 for King Salmon AFS has been prepared under Contract F33615-85-D-4535 by CH2M HILL. This report presents the result of the Phase II/Phase IV, Stage I investigation. Contractor personnel key to the production of this report include Jacques Gusmano, John Martinsen, Paul McBeth, Scott McKinley, and Dixie Simon-Gilles, among others. CH2M HILL acknowledges the contributions of NORTEC, Tracer Research Corporation, and our drilling subcontractors in obtaining specific field data. An extensive appendix, bound separately, includes field data, forms, related reports, and biographies. James F. Williams served as AFOEHL Technical Program Manager.

ERRATA

"King Salmon Air Force Station," "King Salmon AFS," and "station" are names used inaccurately throughout the document. The correct designation should be "King Salmon Airport" for the U.S. Air Force facilities located on a state airport near King Salmon, Alaska.

CVR193/055

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

Page

CONTENTS (continued)

APPENDIXES (Bound together in a separate volume)

FIGURES

TABLES

Page

TABLES (continued)

EXECUTIVE SUMMARY

PROGRAM HISTORY

The Air Force Installation Restoration Program (IRP) was developed to 1) assess past hazardous waste disposal sites and spill sites at Air Force installations and 2) develop remedial actions consistent with the National Contingency Plan (NCP) for those sites that pose a hazard to human health and welfare or the environment.

The Air Force IRP consists of four phases:

- Phase I--Records Search and Installation Assessment
- Phase II--Confirmation and Quantification
- Phase III--Technology Base Development
- Phase IV--Operation Remedial Actions

The Air Force has combined Phase II and Phase IV to allow the remedial investigation and feasibility study to be conducted in parallel. This report presents the result of the Phase II/Phase IV, Stage 1 investigation conducted by CH2M HILL at the King Salmon Air Force Station (AFS) in King Salmon, Alaska.

SUMMARY OF FINDINGS

Four investigation areas at King Salmon AFS were tested for over 146 inorganic, volatile organic, semivolatile organic, and pesticide contaminants. Of these 146, 31 potential contaminants of concern have been identified. These contaminants are addressed in this report because they exceed federal or state criteria for the protection of human health and the environment, are consistently present in site media (soil, sediment, surface, and groundwaters), and are potentially toxic to humans and the environment.

LOCATION OF INSTALLATION AND INVESTIGATED SITES

King Salmon AFS is located approximately 340 miles southwest of Anchorage, Alaska, on the northwest corner of the Alaska Peninsula.

Past hazardous waste disposal and spill sites have been prioritized and grouped into four areas for the purposes of the Phase II/Phase IV, Stage 1 investigation. The location and identification of each area is shown in Figure 1. A brief description of each is presented in the following subsections.

Eskimo Creek Seep

The Eskimo Creek seep is a petroleum oils and/or lubricants (POL) seep emanating from the toe of a small bluff east of Building 603 along the west bank of Eskimo Creek. The primary source of the seep is unidentified but may be underground POL delivery systems spill sites, underground storage tanks, or POL tanks 11, 12, 13, or 14. Any of the foregoing potential sources could also be minor or secondary sources.

Naknek River Seep

The Naknek River seep is located along the north bank of the Naknek River near the deactivated POL tank farm. The likely source of this seep is soils contaminated by spills and releases from the tank farm, and potentially other unidentified tanks and delivery systems.

North Barrel Bluff

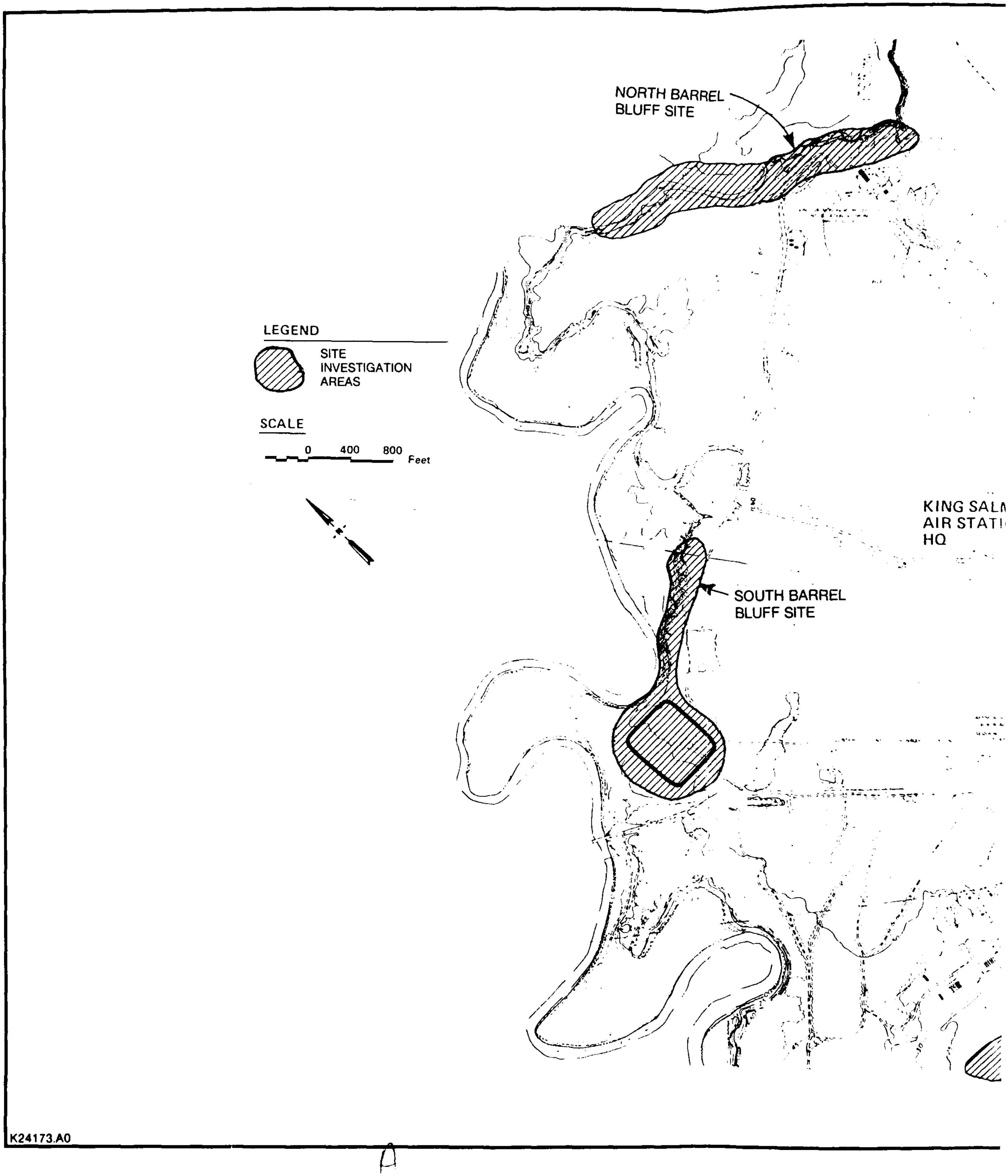
This site is outside the King Salmon AFS installation boundaries. The area has been used in the past to dispose of drums, metal, and wood debris. The most visible type of debris is 55-gallon steel drums. Estimates of the number of barrels at the site range from hundreds of thousands to one million. This debris is visible along the face of the bluff for approximately 2300 feet. Residual liquids within the drums at the time of disposal are a likely source of continuing releases to soil, surface, and groundwater. The contents of the drums have not been fully characterized. However, many of the drum labels indicate fuel oil or other organic products. Because this area was used as a dump, potentially any substance delivered to the base in drums could be present.

South Barrel Bluff

South Barrel Bluff is located south of North Barrel Bluff along the west bank of King Salmon Creek. South Barrel Bluff also includes part of a former landfill. This area has been used to dispose of drums, metal, and wood debris. The most visible debris at South Barrel Bluff is 55-gallon steel drums. The drums and other types of debris are visible along the face of the bluff for approximately 1,000 feet. Contents of the drums would be expected to be similar to those in the North Barrel Bluff.

TIME FRAME FOR FIELD INVESTIGATION ACTIVITIES

Field tasks completed as part of the Stage I investigation and their duration are shown in Figure 2.


NORTH BARREL BLUFF SITE
LEGEND
SITE INVESTIGATION AREAS
SCALE
0
400
800
Feet
KING SAL
AIR STAT
HQ
SOUTH BARREL BLUFF SITE
K24173.A0

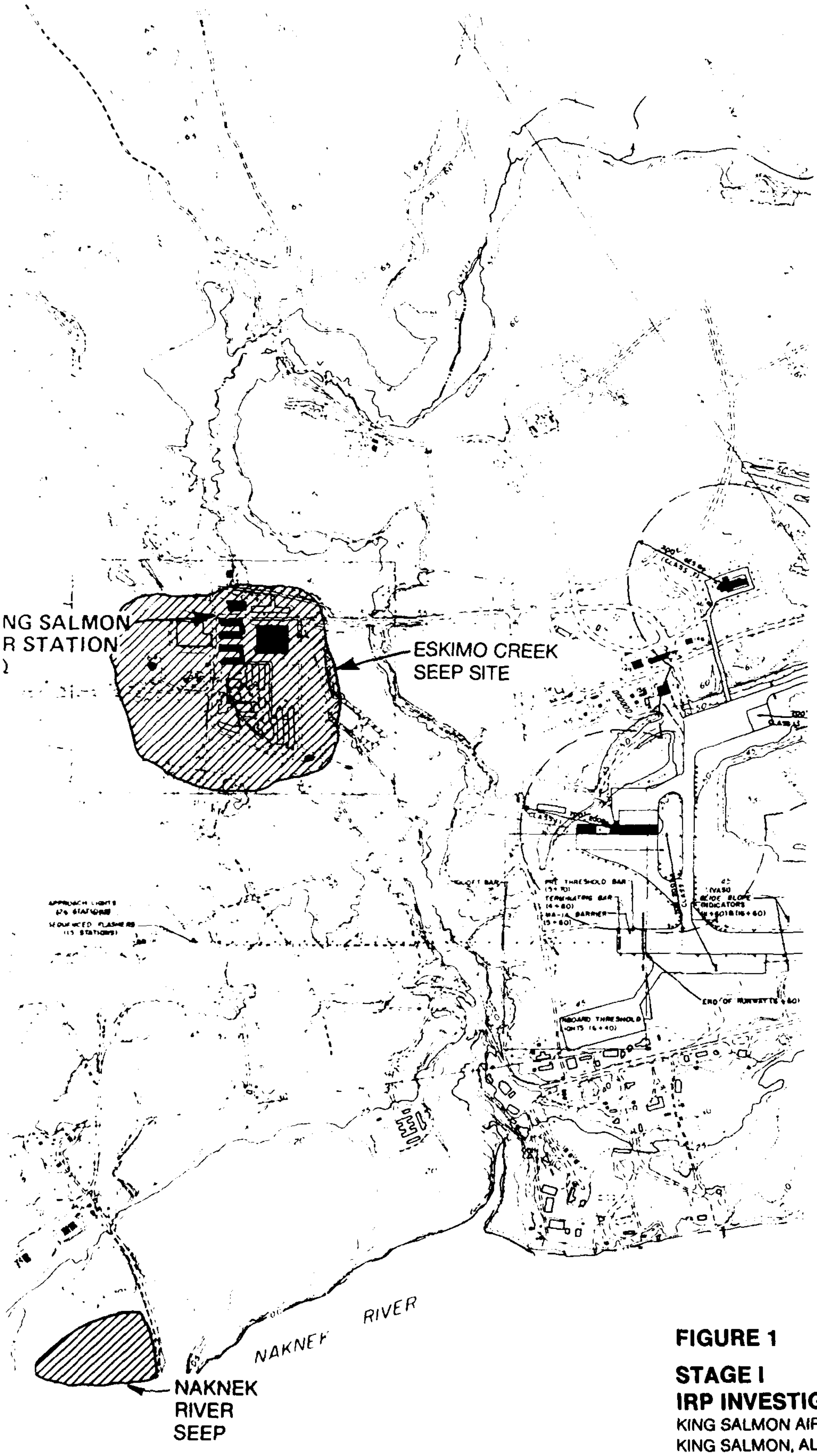


FIGURE 1

STAGE I
IRP INVESTIGATION AREAS
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

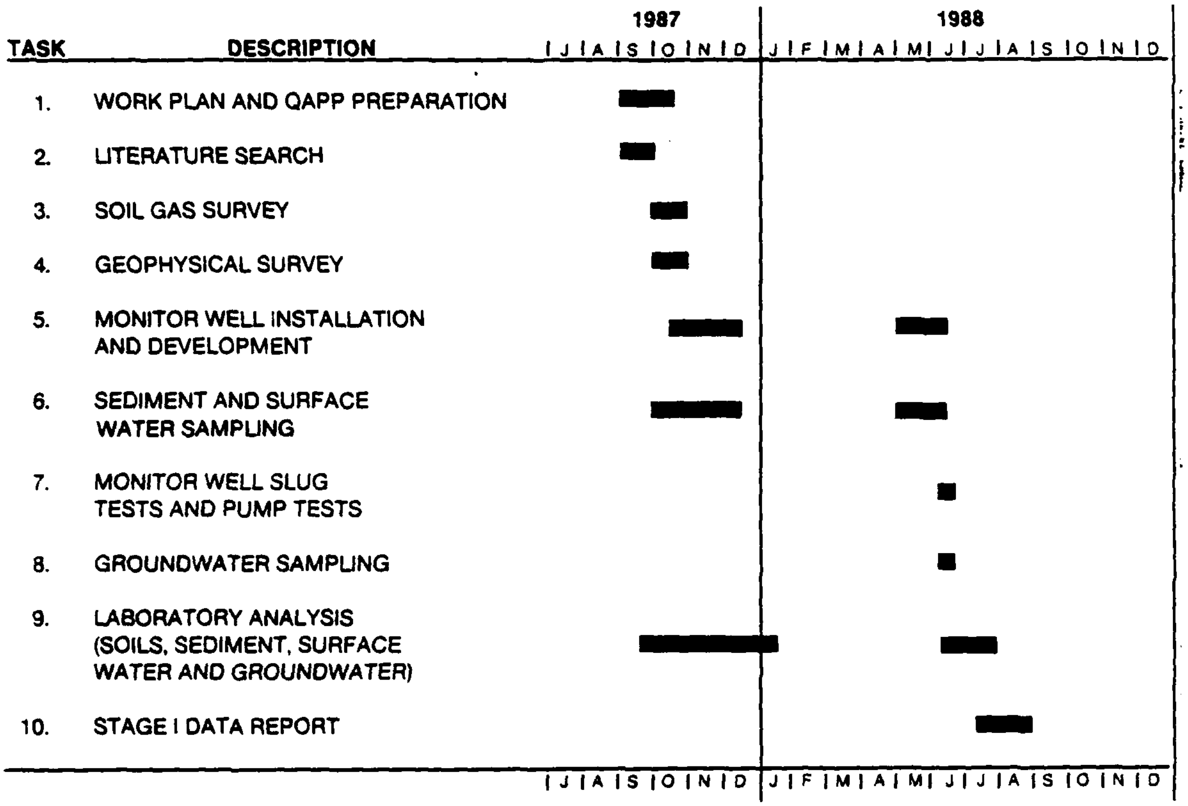


FIGURE 2

STAGE I
PROJECT SCHEDULE
TIMELINE FOR FIELD ACTIVITIES
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

FIELD INVESTIGATION, SUMMARY, AND RESULTS

Field work completed as part of the Stage 1 investigation includes:

- Soil gas survey at the Eskimo Creek and Naknek River seeps
- Geophysical surveys at the Eskimo Creek and Naknek River seeps, and North and South Barrel Bluffs
- Groundwater monitoring well installations, slug tests, pump tests, sampling, and analysis at the Eskimo Creek seep site
- Sediment and surface water sampling at the Naknek River seep and North and South Barrel Bluff sites

Table 1 shows the number and type of analyses performed. Summary details of these investigations for each area are provided in the following subsections.

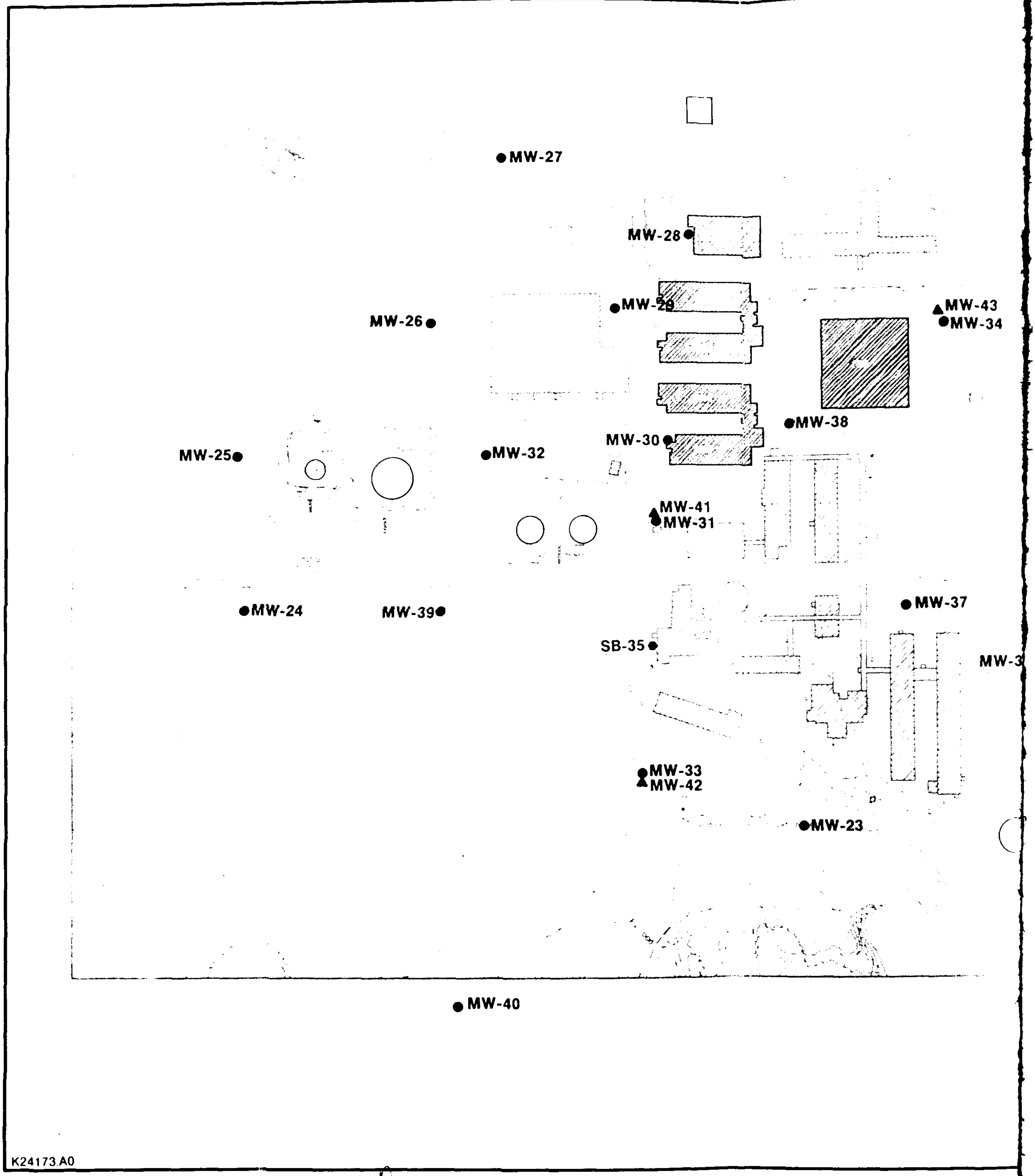
Eskimo Creek Seep

Groundwater Monitoring Wells. Seventeen shallow monitoring wells (30 to 40 feet deep), three deep monitoring wells (95 to 120 feet deep), and one soil boring (35 feet deep) were completed within the King Salmon AFS headquarters area. The three deep wells paired with shallow wells formed well nests, enabling hydrologists to estimate vertical hydraulic gradients. Stage 1 monitoring well and soil boring locations are shown in Figure 3.

The shallow monitoring well screens are 10 feet in length. These were generally positioned so that the center of the well screen intercepted the water table. This installation allowed "floater" constituent types to enter the monitoring well. The deep monitoring well screens are 10 to 20 feet in length. These were positioned in the aquifer where visible observations of hydraulic conductivity and well yield appeared to be the highest.

In situ slug tests were performed on each of the shallow wells. Pumping tests were performed on each of the deep wells to obtain estimates of the lateral hydraulic conductivity in the immediate vicinity of the subsurface zones penetrated by the monitoring well screens. Slug/bail test data were carefully evaluated because of the positioning of the shallow monitoring well screens above and below the water table.

These tests indicated an average hydraulic conductivity of 59 ft/day in the shallow aquifer zone and 25 ft/day in the intermediate aquifer zone. The vertical hydraulic gradient


MW-27
MW-28
MW-29
MW-26
MW-43
MW-34
MW-38
MW-30
MW-25
MW-32
MW-41
MW-31
MW-37
MW-24
MW-39
SB-35
MW-3
MW-33
MW-42
MW-23
MW-40

K24173.A0

A

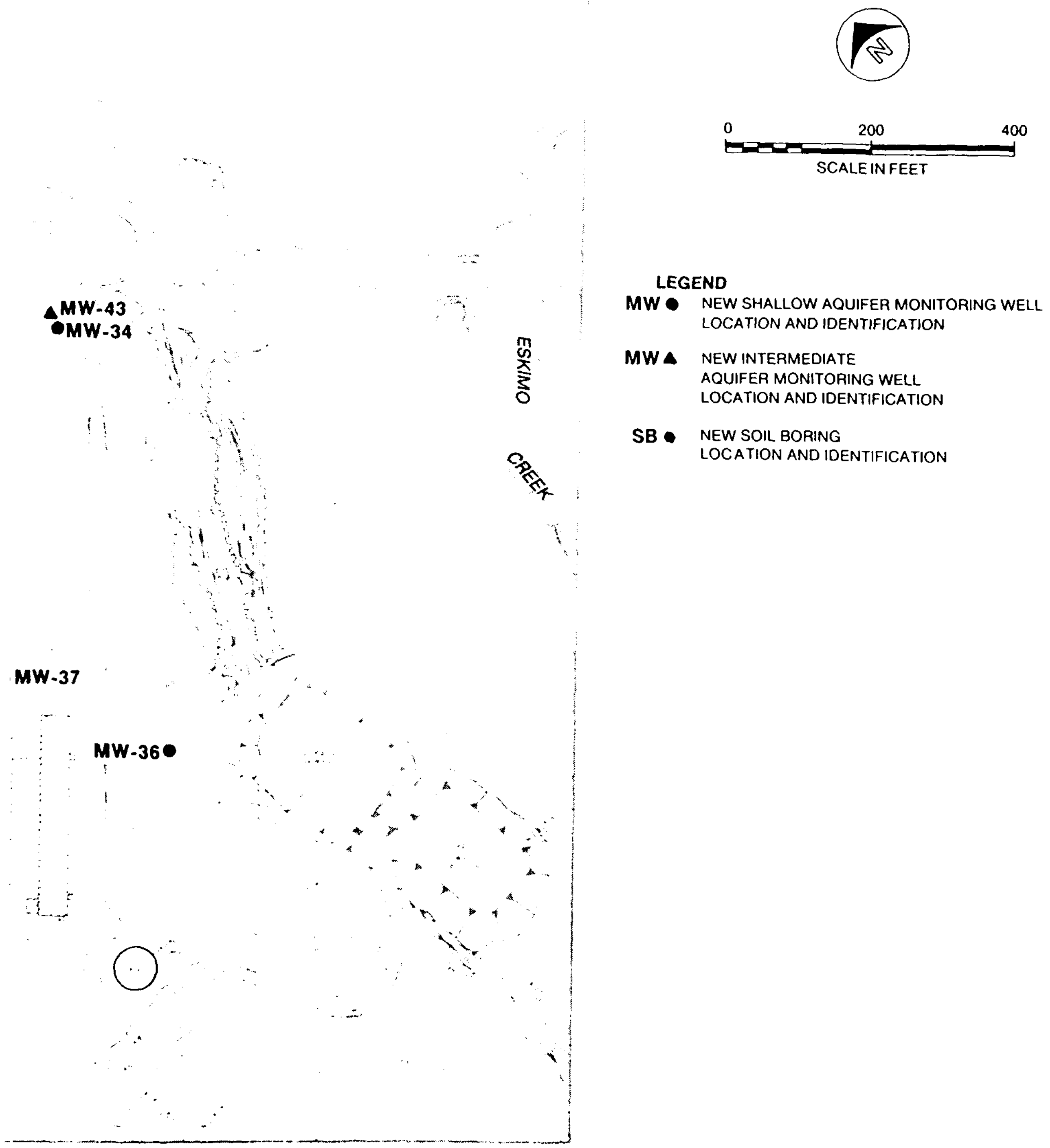


FIGURE 3

STAGE I
MONITORING WELL AND
SOIL BORING LOCATIONS
JUNE 1988
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

between the shallow and intermediate aquifers is estimated at 0.07 ft/day downward.

Shallow and intermediate aquifer groundwater flow directions are primarily from north to south across the site with localized variance in flow direction observed in the shallow aquifer. The vertical hydraulic gradient and groundwater flow directions have been estimated on the basis of a single round of groundwater measurements (May and June 1988) and may, therefore, not depict year-round conditions.

Groundwater Quality. Groundwater sampling and analyses were performed on each of the new monitoring wells, the station's two production wells (No. 4 and No. 5), and on eight existing US Corps of Engineers (USCOE) shallow wells. Table 1 shows the number and type of analyses performed.

Groundwater in the shallow aquifer contained measurable concentrations of aromatic volatiles, which include primarily benzene, toluene, and xylene. Detected concentrations of xylene were generally higher than concentrations of benzene and toluene. Benzene concentrations ranged from <1 to 77 µg/l, toluene from <1 to 130 µg/l, and xylene from <1 to 520 µg/l.

Total petroleum hydrocarbons were also detected in shallow aquifer groundwater at concentrations ranging from <1 to 5,666 mg/l. Figure 4 shows the estimated lateral extent of hydrocarbons detected in shallow groundwater.

Higher concentrations of the aromatic volatile constituents may be present in the USCOE wells. Several of these wells are located in areas where floating product has been observed. However, analyses for aromatic volatiles could not be performed on groundwater samples from these wells because the well construction method included the use of PVC cement, which is partially composed of aromatic volatile constituents.

Groundwater samples collected from the deep monitoring wells did not contain constituents for which analyses were performed. Analyses of groundwater samples collected from the two station production wells indicate total petroleum hydrocarbons concentrations of 6.5 and 27 mg/l.

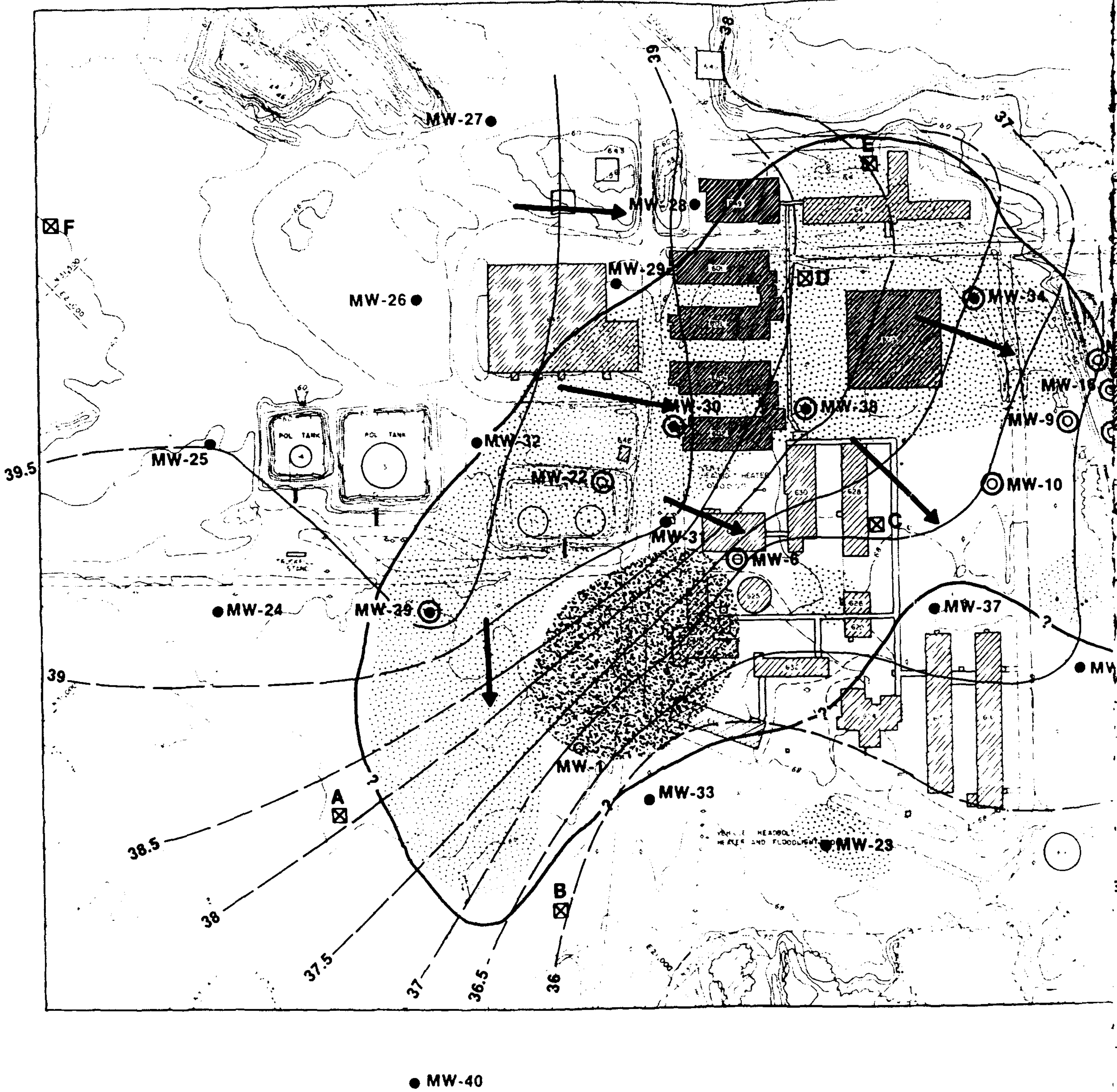
The source of these constituents is undetermined but may originate from lubricating fluids from the well pumps or from leakage along the well casing from the overlying contaminated portions of the shallow aquifer.

Soil Vapor Gas. The soil vapor gas study identified the presence of a total hydrocarbons plume beneath the headquarters area. Figure 4 shows the estimated lateral extent of this plume. Other localized hydrocarbon occurrences were

Table 1
NUMBER OF ANALYSES BY SITE

Parameter	Analytical Method	Eskimo Creek	USCOE Well	Naknek River Seep	North Barrel Bluff	South Barrel Bluff	Offsite Well	Development Water
Water Samples								
Alkalinity - Carbonate, Bicarbonate, & Hydroxide (Field Test)	A403	23	7	1	3	3	--	--
Common Anions (Chloride, Fluoride, Nitrate, Sulfate, Orthophosphate)	A429	23	7	1	3	3	--	--
Specific Conductance (Field Test)	E120.1	23	7	1	3	3	--	--
pH (Field Test)	E150.1	23	7	1	3	3	--	--
Total Dissolved Solids	E160.1	23	7	1	3	3	--	--
Temperature (Field Test)	E170.1	23	7	1	3	3	--	--
Lead	SW3005/ SW7421	23	7	--	--	--	--	2
Metal Screen (25 metals)	E200.7	2	0	1	3	3	1	--
Petroleum Hydrocarbons	E418.1	21	7	--	--	--	--	--
Purgeable Halocarbons	E601	2	--	1	3	3	1	--
Organochlorine Pesticides	E608	--	--	--	3	3	1	--
Extractable Priority Pollutants	E625	--	--	--	3	3	1	--
Purgeable Aromatics	SW5030/ SW8020	16	--	1	3	3	1	2
Soil Samples								
Petroleum Hydrocarbons	SW3550/ E418.1	18	--	--	--	--	--	--
Organochlorine Pesticides and PCBs	SW3550/ SW8080	--	--	--	3	--	--	--
Volatile Organic Compounds	SW5030/ SW8240	5	--	--	3	--	--	--
EPTOX Metals	40 CFR 261.24	5	--	--	--	--	--	--
Semivolatile Organic Compounds	SW3550/ SW8270	5	--	--	3	--	--	--
Soil Moisture Content	ASTM D2216	23	--	--	3	--	--	--

CVR193/041


MW-27
MW-28
MW-29
MW-26
F
D
E
MW-34
MW-16
MW-9
MW-30
MW-38
MW-32
MW-25
POL TANK
POL TANK
MW-22
MW-10
MW-31
C
MW-6
MW-37
MW-24
MW-39
MW-1
MW-33
MW-23
A
B
MW-40
39.5
39
38.5
38
37.5
37
36.5
36
38
37
?
C

1173 A0

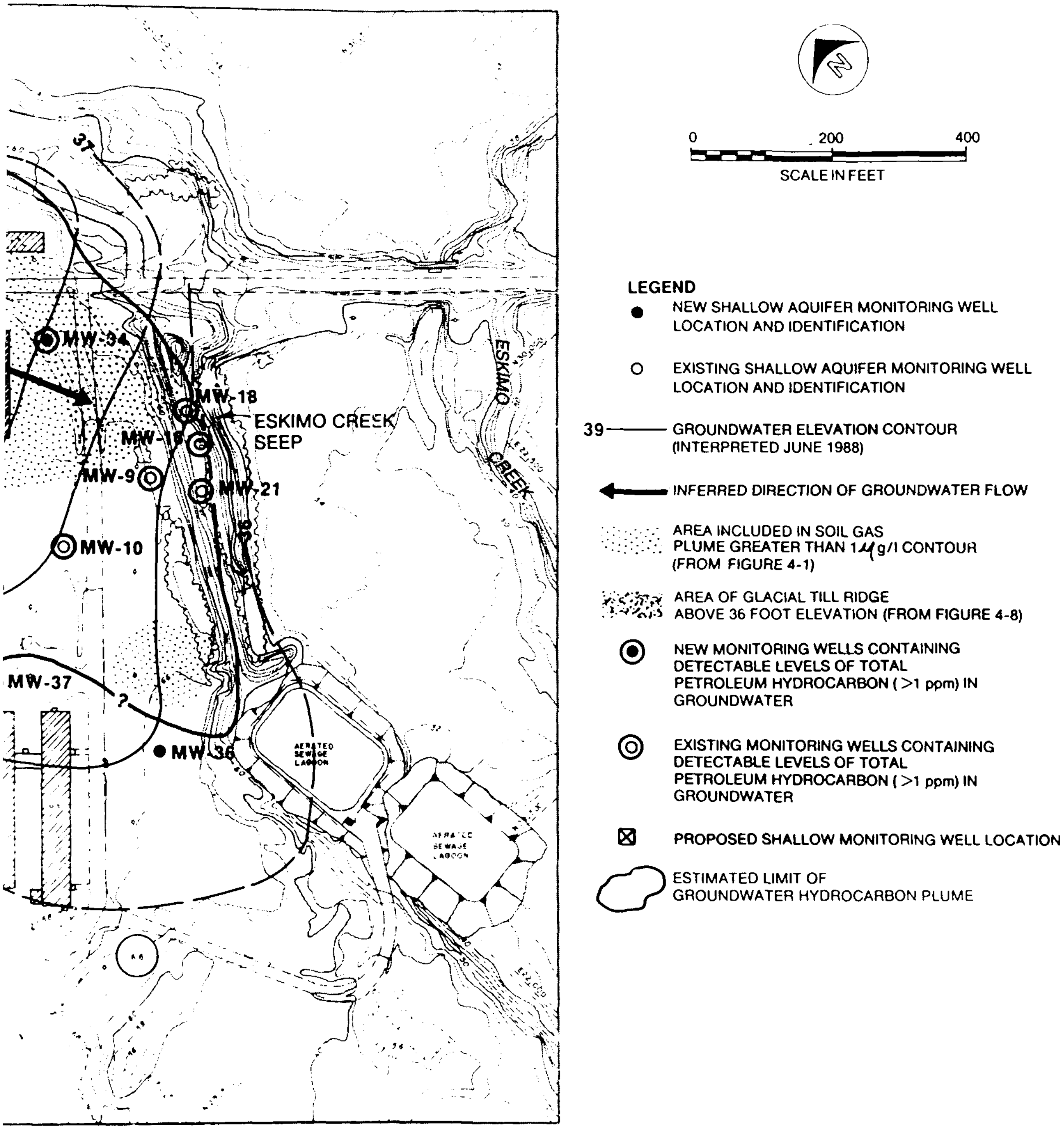


FIGURE 4

PLUME INTERPRETATION OF PETROLEUM HYDROCARBONS IN GROUNDWATER

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

also identified and are shown on Figure 4. These appeared to be separated from the main plume based on the existence of other soil gas points with low or nondetectable values.

Geophysical Survey. Geophysical survey data did not specifically identify the location of an underground storage tank possibly associated with a deactivated service station west of Building 624. The survey did identify several other "reflective" targets that could be pipes or other buried metallic objects.

Naknek River Seep

Field investigation activities completed at the Naknek River seep were limited to several soil gas sampling locations and a water sample from the seep. A total hydrocarbons concentration of 2,200 µg/l was observed at the riverbank in one of the soil gas sample locations. Several other soil gas sample locations were reported at less than method detection limits (0.03 µg/l).

The geophysical survey data collected at this site indicate that a disposal area may exist at the western end of the site. Partially buried drums observed at the site support this conclusion. Water samples collected from the seep on the north bank of the Naknek River identified the presence of xylene and 1,1,1-trichloroethane at concentrations of 15 µg/l and 85 µg/l, respectively.

North Barrel Bluff

Geophysical survey data collected at the North Barrel Bluff site indicate that buried and partially buried debris are concentrated along the face of the bluff in a section 50 to 100 feet wide and 2,300 feet long.

South Barrel Bluff

Data from geophysical surveys performed along the South Barrel Bluff indicate that the primary disposal areas are located along the face of the bluff beginning at a point east of the two residential homes and extending westward for approximately 1,000 feet. Other localized buried debris areas are located in a gully east of the two houses. Chlordane was detected in a surface water sample at a concentration of 0.2 µg/l.

RECOMMENDATIONS

Suggested activities and the rationale for each investigation area are presented in Table 2.

CVR193/060

Table 2
RECOMMENDATIONS FOR KING SALMON AFS

Suggested Activity	Rationale	Eskimo Creek Seep	Naknek River Seep	North Barrel Bluff	South Barrel Bluff
Review facility as-built drawings and historical aerial photographs	Determine location of buried and/or deactivated structures	X	X	X	X
Conduct soil gas survey	Delineate lateral extent of the total hydrocarbons detection observed in the Stage 1 investigation to assist in location of shallow monitoring wells		X		
Collect samples from shallow soil borings and surface sediment locations	Assess the nature and extent of present contamination in unsaturated and near-surface soils	X	X	X	X
Collect and analyze surface water samples		X			
Install shallow and/or intermediate monitoring wells and perform single well tests	Determine groundwater flow directions, estimates of aquifer parameters and provide groundwater samples for water quality characterization	X	X	X	X
Perform groundwater measurement and water quality sampling	Confirmation of results and investigation of seasonal affects	X	X	X	X
Analyze soil and water samples for expanded constituent list (priority pollutants)	Identify and quantify individual constituents not tested for in Stage 1	X	X	X	X
Select appropriate analytical methodologies to address data quality objectives	Assure detection limits are appropriate for risk analysis and site characterization	X	X	X	X
Identify and select background soil and groundwater locations	Correlate background concentrations with site concentrations for risk analysis assessment	X	X	X	X
Conduct geophysical survey	Identify small disposal areas not previously located and further delineate lateral extent of buried debris identified in Stage 1 reconnaissance investigation		X	X	X
Dig test pits with backhoe	Waste characterization			X	X
Construct perimeter fence	Reduce potential for human and/or wildlife exposures through physical contact			X	X

Table 2 (Continued)
RECOMMENDATIONS FOR KING SALMON AFS

Suggested Activity	Rationale	Eskimo Creek Seep	Naknek River Seep	North Barrel Bluff	South Barrel Bluff
Include residential water wells in groundwater sampling program	Identify potential health risks associated with a water supply in close proximity to disposal areas				X
Conduct shallow aquifer pumping test	Provide estimate of aquifer parameters for "pump and treat" remediation	X			

CVR193/061

I. INTRODUCTION

1.1 AIR FORCE INSTALLATION RESTORATION PROGRAM

The Installation Restoration Program (IRP) is a Department of Defense (DOD) program for assessing and remediating hazardous waste problems on military installations. The program is DOD's response to the requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA or "Superfund") which requires all federal agencies to fully comply with its procedural and substantive requirements. The program was formally designated as the DOD Superfund program on November 21, 1981.

1.1.1 Program Objectives

The objective of the Air Force IRP is to assess past hazardous waste disposal and spill sites on Air Force installations and develop remedial actions consistent with the National Contingency Plan (NCP) for those sites that are determined to pose a threat to human health and welfare or the environment. This program objective is derived from the overall objective of the National Contingency Plan (NCP) (40 CFR - 300.68i), i.e., to select "a cost-effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment." Future actions at King Salmon AFS must meet the requirements of CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA), and the NCP.

The NCP is currently under revision, in response to SARA. These revisions are expected to conform to the guidelines established in SARA as well as the Interim Guidance on Superfund Selection of Remedy (December 24, 1986), which supersedes portions of the NCP until its revisions are complete.

Two major provisions of SARA affect selection of treatment technologies. They pertain to regulatory requirements and permanence of treatment. Provisions regarding preference for technologies that will effect permanent remedies are stated in Section 121(b)(1) of SARA:

> "...The President shall conduct an assessment of permanent solutions and alternative treatment technologies or resource recovery technologies that, in whole or in part, will result in permanent and significant decrease in the toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant..."

The importance of applicable or relevant and appropriate requirements (ARARs) are defined in SARA and outlined in the Interim Guidance memorandum:

> "...Section 300.68 of the NCP specifically refers to ARARs in regard to the development of alternatives. SARA incorporates this requirement into statutory law while adding the provision that remedial actions also attain state requirements more stringent than federal requirements if they are also applicable or relevant and appropriate..."

1.1.2 Organization of Installation Restoration Program

The Air Force has developed its Installation Restoration Program to comply with federal regulations. The IRP was previously organized into four sequential phases, described below:

- o Phase I--Records Search. In this phase, past disposal sites which may be hazardous are identified. This phase constitutes a preliminary assessment of the hazards at each installation. Sites are identified from a review of base records and interviews with current and former base employees. Hazards and potential hazards are assessed based on material disposed and a review of regional geological and hydrogeological factors. Sites are then ranked and those with the highest hazard potential are recommended for additional investigation in Phase II. This phase does not include sampling and analysis.

- o Phase II--Confirmation. In this phase field and laboratory data are collected and analyzed to identify the nature and extent of the contamination at sites identified in Phase I. Sites requiring remedial action are identified and programmed for further work.

- o Phase III--Technology Base Development. Contaminants identified in Phase II are further evaluated to determine if they can be treated with known technologies. If no treatments are identified, treatment technologies are developed in this phase.

- o Phase IV--Operations. This is the action phase of the IRP. Remedial actions are recommended, then designed, built, and executed.

The Air Force has modified its IRP to make it similar to the EPA's Remedial Investigation/Feasibility Study (RI/FS) program. It has combined Phase II and a portion of Phase IV in order to conduct the remedial investigation and feasibility study in parallel, where possible, instead of in serial fashion. With this approach, preliminary remedial alternatives can be identified and screened as information on the nature and extent of contamination is obtained. The early identification of remedial alternatives that are potentially applicable to the King Salmon sites will contribute to the definition of further data requirements, including data required to assess the feasibility of the preliminary remedial alternatives (e.g., treatability and incineration characteristics).

1.2 DESCRIPTION AND HISTORY OF INSTALLATION

The primary mission of the 5071st Combat Support Squadron (CSS), based at King Salmon AFS, is twofold. The installation is a forward operating base supporting aircraft deployed at the direction of the Commander of the 21st Tactical Fighter Wing (TFW) based at Elmendorf Air Force Base in Anchorage, Alaska, and is also a surveillance radar installation.

The Phase I report provided the following concise narrative of the history of the installation:

> King Salmon Airport was constructed by the Civil Aeronautics Authority [now Federal Aviation Administration (FAA)] as part of an overall airfield construction program in Alaska during the early 1940s. The field was completed and turned over to the U.S. Army in 1941. The airfield became an advance staging base and fuel stop for aircraft deploying to and from the Aleutian Islands. It was returned to the control of the FAA in 1945. The FAA turned it over to the State of Alaska in 1959. The State continues to operate the airport with the Air Force as its major tenant.
>
> The Alaskan Air Command (AAC) began using the airport in 1948 as a Forward Operating Base. The installation has provided operational and maintenance support to the aircraft on alert. King Salmon AFS was also one of the original ten aircraft control and warning (AC&W) sites constructed as part of a permanent air defense system in Alaska during the early 1950s. King Salmon became operational as a ground controlled intercept site in 1951. It was converted to a North American Air Defense (NORAD) Control Center in 1953.
>
> Communications were initially provided by a high frequency radio system. A White Alice Communications System, tropospheric scatter and microwave relay equipment site was activated at King Salmon in 1957. It was

deactivated in 1979 and replaced by an Alascom-owned-and-operated satellite earth terminal.

In 1977, the AAC implemented a base support contract with RCA Services as part of an Air Force-wide effort to reduce remote tours. Twenty-eight military positions were eliminated. The remaining 63 positions were primarily in operations. Installation of Joint Surveillance System (JSS) equipment was completed in 1982, enabling radar and beacon data to be transmitted via satellite to the Region Operations Control Center (ROCC). This further reduced the number of personnel required at the installation.

1.3 IRP PHASE I RECORDS SEARCH

The Phase I records search for King Salmon AFS, completed in September 1985 by Engineering-Science, identified 17 sites containing potentially hazardous materials. In addition to the 17 specific sites, the Phase I records search also indicated a need for follow-up monitoring of drinking water supply wells at the installation and in the adjacent community. The Phase I Records Search was performed by completing the following tasks:

- Identification of Past Waste Management Practices
- Evaluation of Site-Specific Background Information
- Prioritization of each site using a hazard assessment rating methodology (HARM)
- Selection of sites from the HARM list, that pose the greatest potential hazard to human health and the environment

Each task is discussed briefly in the following subsections.

1.3.1 Past Waste Management Practices

The Phase I investigation reviewed past and present activities at King Salmon AFS resulting in the generation, accumulation, and disposal of hazardous wastes.

The sources of hazardous waste at King Salmon AFS have been grouped into the following categories:

- Industrial Operations (Shops)
- Waste Accumulation Areas
- Fuels Management
- Spills and Leaks
- Pesticide Utilization
- Fire Protection Training

Table 1-1
PAST AND PRESENT WASTE MANAGEMENT PRACTICES

Category	Location (Building)	Type of Waste or Stored Material	1985 Rate of Generation	Disposal Site	
				Pre-1983	Post-1983
INDUSTRIAL OPERATIONS					
POL Maintenance	642	Contaminated JP-4[a]	500 gal/yr	FPTA	FPTA
		Contaminated Diesel Fuel	400 gal/yr	FPTA/Road Oiling	INC/DRMO[b]
Liquid Fuels Operations	177	Contaminated JP-4	240 gal/yr	FPTA	INC/DRMO[b]
Refuel Maintenance	149	Contaminated JP-4	300-600 gal/yr	Dry Well	INC/DRMO[b]
		Contaminated Diesel Fuel	120-180 gal/yr	Dry Well	INC/DRMO[b]
		Lubricating Oil & Hydraulic	440 gal/yr	Dry Well	INC/DRMO[b]
		Fluid PD-680	30 gal/hr	Dry Well	INC/DRMO[b]
Radar	Mar Tower	Gearbox Oil	20 gal/yr	Road Oiling	INC/DRMO[b]
Vehicle/ Equipment Maintenance	636	Lubricating Oil & Hydraulic	500 gal/yr	Road Oiling	INC/DRMO[b]
		Fluid Paints & Thinners	20 gal/yr	Road Oiling	INC/DRMO[b]
		Battery Acid	90 gal/yr	Neutralized/ Sanitary Sewer	Neutralized/ Sanitary Sewer
		PD-680	55 gal/yr	Road Oiling	INC/DRMO[b]
Power & Heating Plant	638, 642	Lubricating Oil	860 gal/yr	Road Oiling	INC/DRMO[b]
		Ethylene Glycol/Water	500 gal/yr	Road Oiling	DRMO[b]
		Diesel Fuel (Parts Cleaning)	200 gal/yr	Road Oiling	INC/DRMO[b]
Barrier Maintenance	638	Lubricating Oil	60 gal/yr	Road Oiling	INC/DRMO[b]
Aircraft Maintenance Shops	160	PD-680	25-50 gal/yr	FPTA/Road Oiling	FPTA
		Lubricating Oil	300-400 gal/yr	FPTA/Road Oiling	FPTA
		Compressor Oil	50 gal/yr	FPTA/Road Oiling	FPTA
		Brake Fluid	2 gal/yr	FPTA/Road Oiling	FPTA
		Hydraulic Fluid	50 gal/yr	FPTA/Road Oiling	FPTA
		Contaminated JP-4	700 gal/yr	FPTA/Road Oiling	FPTA
Oil-Water Separators	Various Locations	Sludge	Not reported	Not reported	DRMO

Table 1-1
(Continued)

Category	Location (Building)	Type of Waste or Stored Material	1985 Rate of Generation	Disposal Site	
				Pre-1983	Post-1983
WASTE ACCUMULATION AREAS					
Waste Accumulation Area No. 1 (Active)	(See Figure 1-2)	Waste Oils Shop Wastes Spent Solvents	Approximately 5,500 gal.	DRMO	DRMO
Waste Accumulation Area No. 2 (Inactive)	(See Figure 1-2)	Not Reported	Not Reported	Not Reported	Not Applicable
Waste Accumulation Area No. 3 (Inactive)	(See Figure 1-2)	Not Reported	Not Reported	Not Reported	Not Applicable
FUELS MANAGEMENT					
Above Ground & Below Ground Tanks	Various Locations	Diesel, AVGAS, JP-4, MOGAS, Isopropyl Alcohol	62 Tanks with a total capacity of approx. 5,500,000 gal	Not Applicable	Not Applicable
Pipelines	Various Locations			Not Applicable	Not Applicable
POL Tanks 11, 12, 13, 14	(See Figure 1-2)	Diesel Fuel	1,049,000 gal	Not Applicable	Not Applicable
POL Tank Farm (Nos. 2, 3, 4, 5, 6, 7, 22, 23, 24, 25, 30, 28)	Naknek River Seep (See Figure 1-2)	Diesel Fuel Isopropyl Alcohol	450,000 gal 100,000 gal	Not Applicable	Not Applicable
Deactivated POL Tank (No. 27)	Unnumbered, near Naknek River Seep (See Figure 1-2)	Unknown	50,000 gal	Not Applicable	Not Applicable

Table 1-1
(Continued)

Category	Location (Building)	Type of Waste or Stored Material	1985 Rate of Generation	Disposal Site	
				Pre-1983	Post-1983
POL Tank (No. 1)		Diesel Fuel	427,000 gal	Not Applicable	Not Applicable
SPILL AND LEAKS					
Eskimo Creek Seep	Approx. 1,100 ft. SSW of center of POL tanks 11, 12, 13, 14 cluster at Eskimo Creek (Figure 1-2)	Diesel Fuel	Quantity unknown, but volume over time sufficient to discolor surface soil, stress vegetation, and be recoverable in test pit	(First observed in 1977)	Underlying soil, shallow groundwater, Eskimo Creek sediments and surface water
Naknek River Seep	Naknek River bank near POL tank No. 700 (Figure 1-2)	Uncharacterized Petroleum Product (Active tanks in vicinity of seep store diesel fuel, isopropyl alcohol, and MOGAS)	Observable flow in 1984, but 1985 Phase 1 report noted sheen only, and May 1987 site visit (CH2M and OEHL personnel) noted soil discoloration only	Not Applicable	Underlying soil, ground surface, shallow aquifer, and surface water in seep
PESTICIDE UTILIZATION	Fogging inside various buildings	Malathion fogging in past years	Phase I report judged quantities to be small enough to warrant no further investigation	Not Applicable	Not Applicable
FIRE PROTECTION TRAINING					
FPTA No. 1 (1980-Present)	(Figure 1-2)	Contaminated and noncontaminated JP-4, Aqueous Film Forming Foam (AFFF)	50-ft.-diameter pit, 400-500 gal/month	Incineration	Incineration[b]
FPTA No. 2 (1979-Present)	(Figure 1-2)	Wood debris, contaminated fuels, AFFF, halon, potassium bicarbonate	Areal extent/volume of pit not reported, practice burns once/month	Incineration	Incineration[b]

Table 1-1
(Continued)

Category	Location (Building)	Type of Waste or Stored Material	1985 Rate of Generation	Disposal Site	
				Pre-1983	Post-1983
FIRE PROTECTION TRAINING (Continued)					
FPTA No. 3 (Until Late 1970s)	(Figure 1-2)	Wood debris, contaminated fuels, AFFF, halon, potassium bicarbonate	Areal extent/volume of pit not reported, practice burns once/month	Incineration	Not Applicable
FPTA No. 4 (Until Late 1970s)	(Figure 1-2)	Waste oil, spent solvents, contaminated fuels, auto bodies	50-ft.-diameter pit	Incineration	Not Applicable

---

Key: MAR=Minimally Attended Radar
DRMO=Defense Reutilization and Management Office
INC=Incineration
FPTA=Fire Protection Training Area

[a] Contaminated JP-4--Waste fuel that has been contaminated with other materials.

[b] Beginning in 1986, King Salmon no longer incinerates waste POL products. This waste is now shipped to DRMO at Elmendorf AFB.

Source: Phase I Report (Engineering Science)

CVR193/016

Table 1-1 summarizes the past and present waste management activities at King Salmon AFS for those activities involving hazardous materials or generating hazardous wastes.

1.3.2 Site-Specific Background Information

After a review of the past waste generation and disposal practices at King Salmon AFS, the Phase I investigation identified the 17 sites (Figure 1-1) as being potentially contaminated with hazardous materials. The Alaskan Air Command (AAC) prioritized these 17 sites based on hazard assessment ranking methodology (HARM) scores (Table 1-2). In ranking each site, the AAC also considered restoration activities accomplished at the site to date and the location sequencing of work tasks over the duration of the King Salmon IRP.

Table 1-2
PHASE I SITE IDENTIFICATION
AND HARM RANKING SCORE

Phase I Site No.	Site Name	HARM Score
1	Fuel Seepage at Eskimo Creek	86
2	POL Tanks No. 11, 12, 13, 14	72
3	Fuel Seepage at Naknek River	71
4	Building 1959 Dry Well	65
5	Dump	63
6	Road Oiling	61
7	Waste Accumulation Area No. 2	61
8	Landfill No. 1	60
9	Landfill No. 2	60
10	Fire Protection Training Area No. 1	59
11	Fire Protection Training Area No. 2	59
12	Fire Protection Training Area No. 3	59
13	Fire Protection Training Area No. 4	59
14	Waste Accumulation Area No. 3	59
15	Landfill No. 3	57
16	Landfill No. 5	57
17	White Alice Site	55

Six of the highest priority sites from Table 1-2 were selected for investigation during the Stage 1 investigation (Table 1-3).

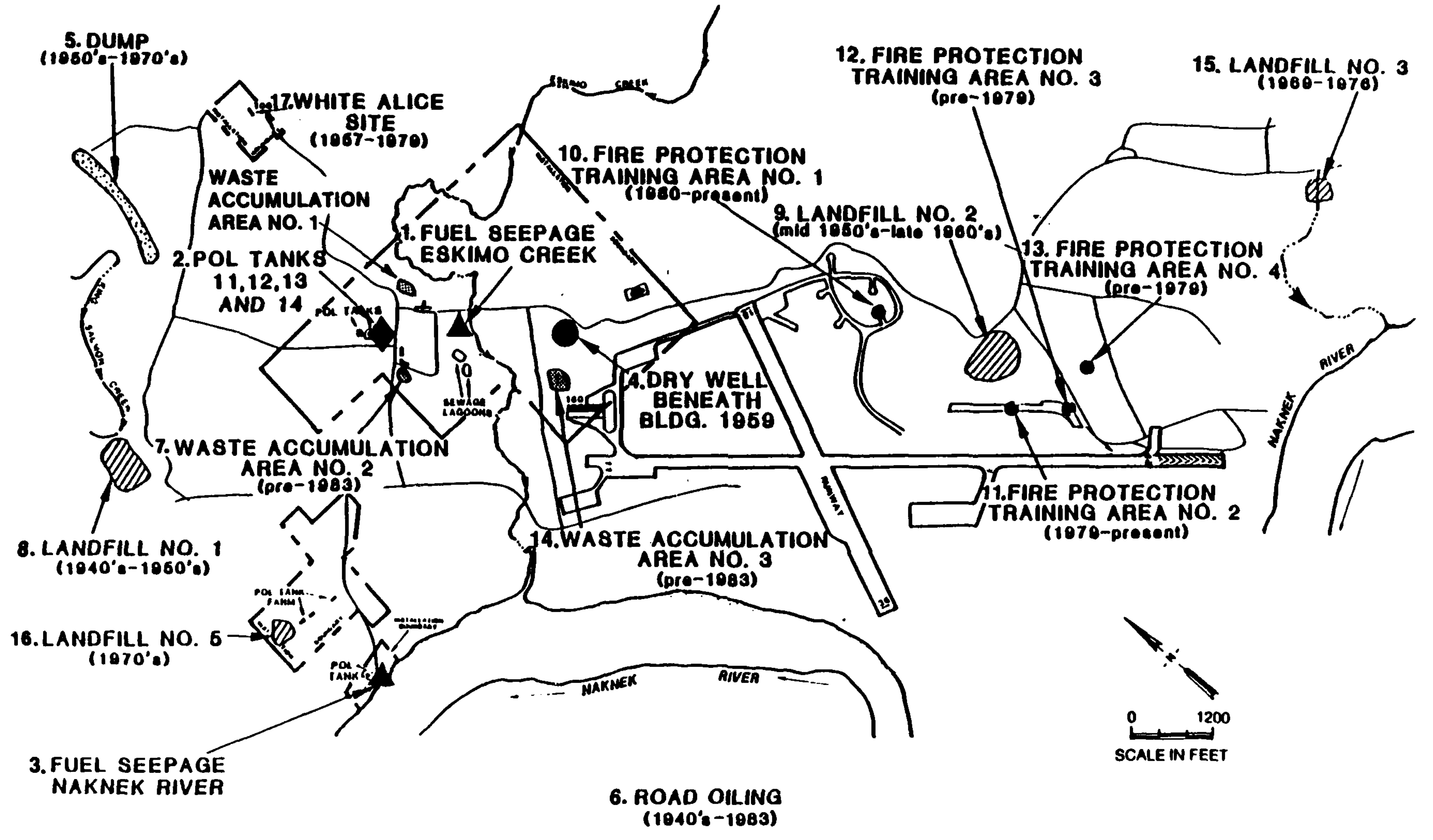


FIGURE 1-1

PHASE I SITES RECOMMENDED FOR INSTALLATION RESTORATION PROGRAM
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

K24173.A0
SOURCE: ES Engineering Science

Table 1-3
PHASE I SITES SELECTED FOR
INVESTIGATION IN STAGE 1

Phase I Site No.	Phase I Site Name	Stage 1 Site Name
1	Fuel Seepage at Eskimo Creek	Eskimo Creek Seep
2	POL Tanks No. 11, 12, 13, 14	
3	Fuel Seepage at Naknek River	Naknek River Seep
5	Dump	North Barrel Bluff
8	Landfill No. 1	South Barrel Bluff
17	White Alice Site	North Barrel Bluff

Figure 1-2 shows the approximate location of each site. These six sites were combined to form four sites, on the basis of location and potential waste characteristics for purposes of the initial efforts performed under this scope of work. The four operable units are identified in Figure 1-3. As additional information is obtained, the boundaries and grouping of these units may be redefined for purposes of design of the initial remedial measure and development of preliminary alternative remedial actions. Table 1-4 identifies the types of waste believed to exist at each of these sites and potential migration pathways for contamination associated with the sites. A discussion of each site follows.

1.3.2.1 Eskimo Creek Seep

The Eskimo Creek seep is a diesel fuel seep located east of Building 603 at Eskimo Creek. The source of this seep may be any of several active facilities in the vicinity of the seep, past spills, and/or associated with active or abandoned portions of the installation's liquid fuel system underground pipelines.

The installation power plant, motor pool, POL Tanks 11, 12, 13, and 14 and fuel lines are all potential sources associated with the management of large quantities of diesel fuel. Leaks and spills from any of these sources may have contributed to fuel oil contamination of the shallow groundwater allowing the oil to migrate along the water table to the point where it emerges as a seep at Eskimo Creek. This seepage of POL was first observed in the mid-1970s when the

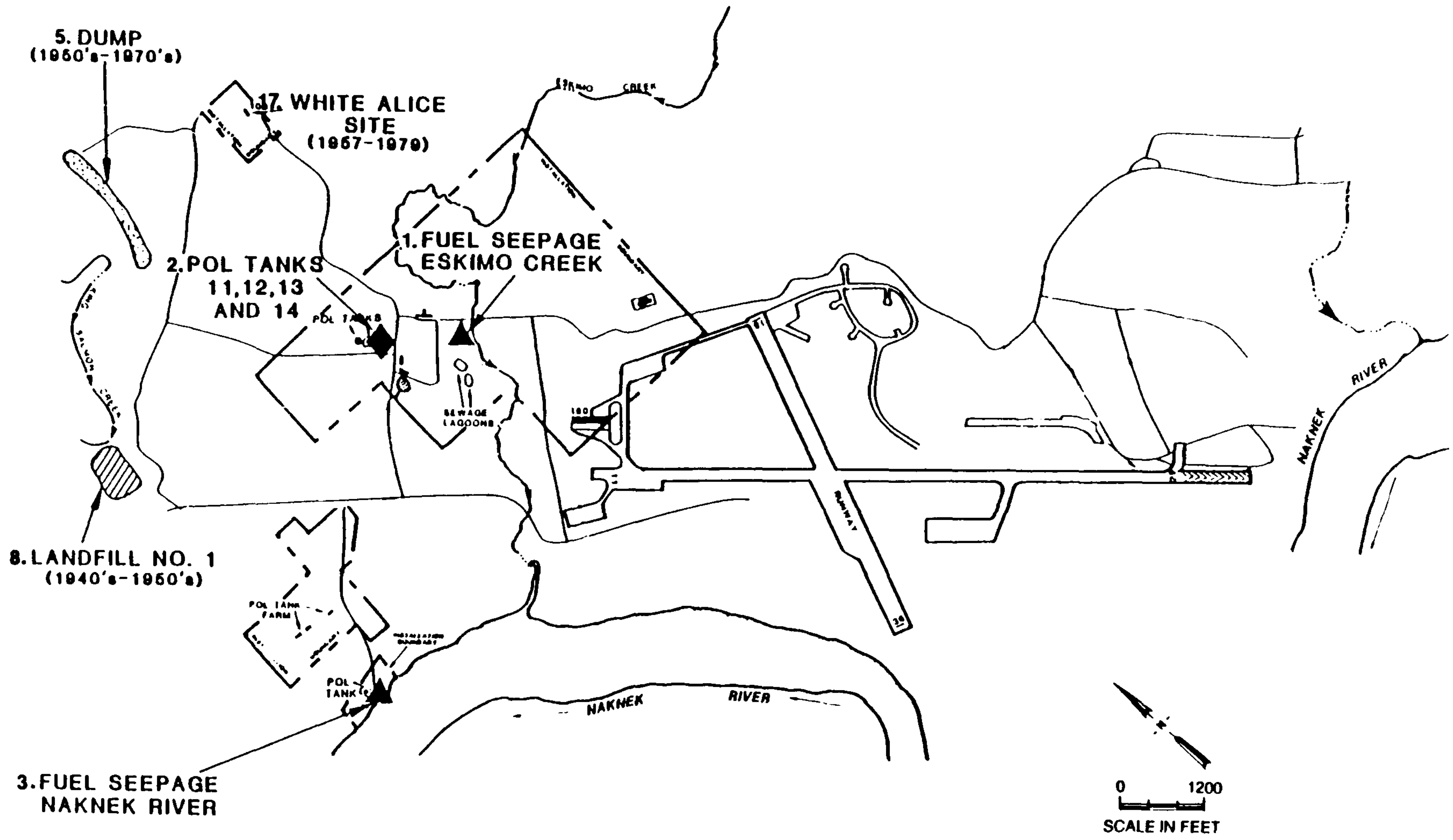


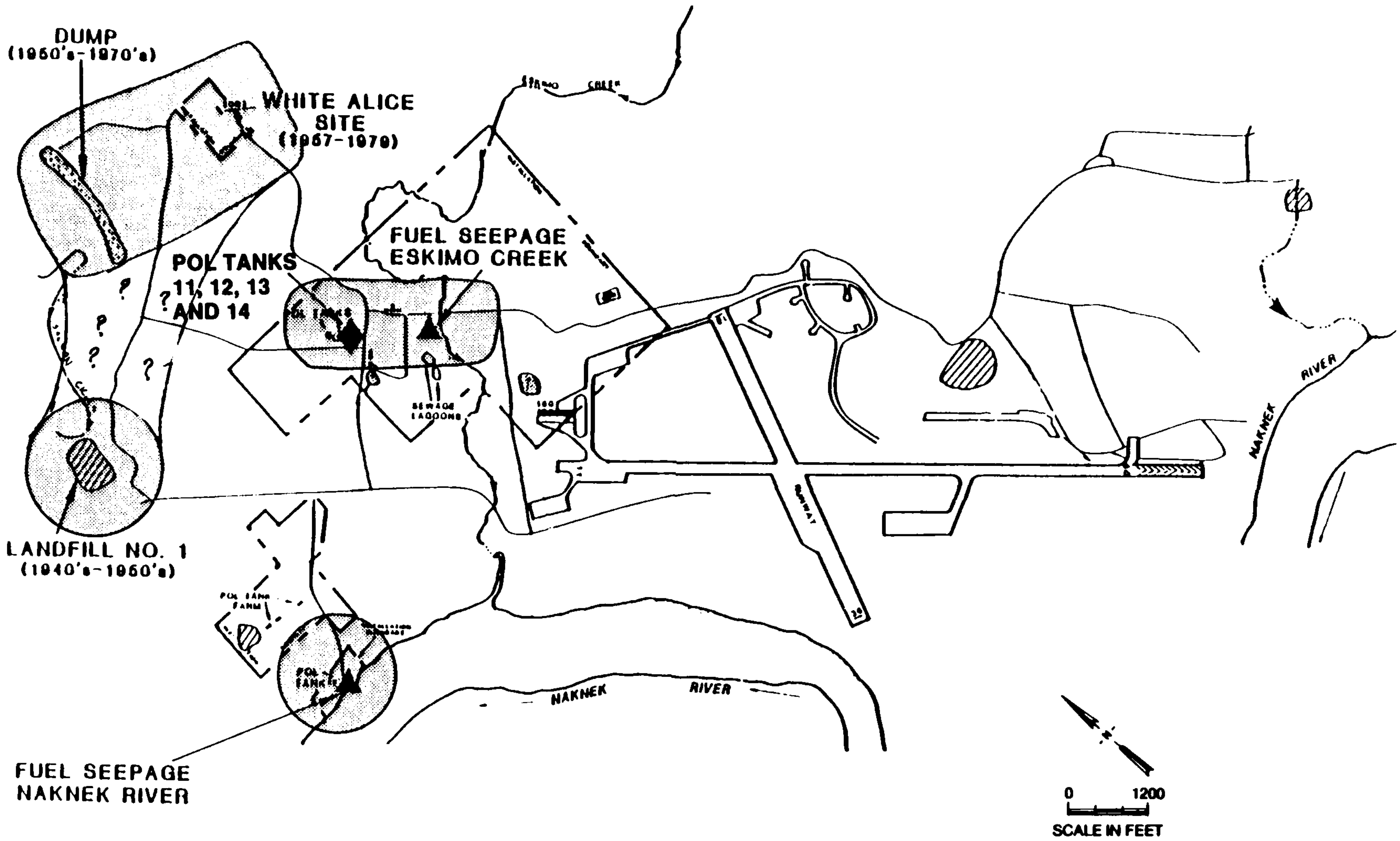
FIGURE 1-2

STAGE I IRP SITES RECOMMENDED FOR INVESTIGATION

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

K24173.A0
SOURCE: ES Engineering Science



NOTES:

1. QUESTION MARKS (?) INDICATE UNCERTAINTY WHETHER DUMP OR LANDFILL EXTENDS INTO THIS AREA.
2. AN ADDITIONAL BARREL DUMP SITE HAS BEEN REPORTED DIRECTLY NORTH AND ADJACENT TO THE WHITE ALICE SITE

K24173.A0
SOURCE: ES Engineering Science

FIGURE 1-3

STAGE I INVESTIGATION AREAS

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

Table 1-4
STAGE 1--WASTE TYPES BY SITE

Site	Waste Type	Potential Migration Pathways
Eskimo Creek Seep	Diesel Fuel	Shallow groundwater migration; shallow groundwater communication with deeper groundwater/drinking water supply; surface water (Eskimo Creek, Naknek River); aquatic life and food chain; direct contact with contaminated surface soils and sediments; direct contact with surface water
Naknek River Seep	Petroleum products (not otherwise specified, but possibly diesel fuel, isopropyl alcohol, MOGAS, or unknown contents of unnumbered deactivated POL tank)	Shallow groundwater migration; shallow groundwater communication with deeper groundwater/drinking water supply; surface water (Naknek River); aquatic life and food chain; direct contact with contaminated surface soils and sediments; direct contact with surface water
North Barrel Bluff	Discarded drums (mostly empty, but 10 percent of capacity estimated to contain liquid products and wastes); wood and metal debris	Leachate migration to surface water (bog, King Salmon Creek, Naknek River) by surface runoff or shallow groundwater transport; aquatic life and food chain; leachate migration to shallow groundwater; shallow groundwater communication with deeper aquifer and drinking water supply; direct contact with debris; volatilization of contaminants to ambient air
South Barrel Bluff	Discarded drums (mostly empty, but 10 percent of capacity estimated to contain liquid products and wastes); wood and metal debris; shop wastes (paints, thinners, etc.); refuse	Leachate migration to surface water (bog, King Salmon Creek, Naknek River) by surface runoff or shallow groundwater transport; aquatic life and food chain; leachate migration to shallow groundwater; shallow groundwater communication with deeper aquifer and drinking water supply; direct contact with debris; volatilization of contaminants to ambient air

CVR193/044

rate was reportedly as much as 10 gallons per day. The visible seepage was reportedly the greatest when the water table was high, and nearly stopped during the winter low-water period. Recently the reported flow rate has been lower, approaching 1 to 2 gallons per month during winter months.

The Phase 1 report indicates that analytical results of samples from the Eskimo Creek site show the POL contamination is a type of diesel fuel that was not used at the installation after 1973, thus implying that the fuel entered the ground prior to that date.

In April 1987, CH2M HILL and USAFOEHL personnel visited the Eskimo Creek seep site and measured 0.6 foot of petroleum product in a monitoring culvert adjacent to Building 648 and 0.3 foot of petroleum product in U.S. Corps of Engineers Monitoring Well 22. In addition, U.S. Corps of Engineers Monitoring Wells 9 and 18 showed noticeable petroleum odors, but no other wells contained measurable floating product.

1.3.2.2 Naknek River Seep

The Naknek River seep is located immediately south of Landfill No. 5 and the nearby POL tank farm. The facility Master Plan dated January 1975 also depicts a deactivated 50,000-gallon tank (No. 27) at the POL tank farm and POL tanks and diesel fueling facilities within 400 feet of the Naknek River seep. The Master Plan indicates that five of the tanks at the tank farm were scheduled for deactivation on September 1, 1978. According to the Phase I investigation, the first report of this seep occurred in 1984 when a "fuel/water mixture" was observed flowing down the embankment toward the Naknek River in the vicinity of the King Salmon AFS POL tanks nearest the river. A 6-foot-deep excavation along the crest of the embankment exposed oil on the shallow groundwater surface, and the Phase I report described an oily film on the water surface at the time of the site visit for that investigation.

When CH2M HILL and USAFOEHL personnel viewed this site in April 1987, some soil discoloration was observed at the embankment, but no flow of fuel/water was observed.

1.3.2.3 North Barrel Bluff

This site is outside the King Salmon AFS installation boundaries and is comprised of two Phase I sites: the dump and the former White Alice site. The dump was described in the Phase I report as consisting of drums, metal, and wood debris extending along the valley of King Salmon Creek from the White Alice site to Landfill No. 1. However, the CH2M HILL Presurvey Report described two separate exposed barrel dumps along the King Salmon Creek Bluff, the northern one being associated with the White Alice site and the southern one associated with Landfill No. 1.

Estimates of the number of barrels at those dumps range from hundreds of thousands to one million, with the number of barrels containing liquid estimated to be approximately 10 percent. During 1984, approximately 2,000 drums were removed from the site, and some of the remaining barrels were covered with soil. The drums were buried at Landfill No. 4 pending permission regarding disposal, and may have contained residual liquids.

1.3.2.4 South Barrel Bluff

This site is southwest of the previously described North Barrel Bluff site, on the east bank of King Salmon Creek. The site includes Landfill No. 1, a closed and covered landfill that was probably operated from the 1940s to the mid--1970s. Similar to the North Barrel Bluff, this dump also consists of drums, metal, and wood debris. The areal extent of the barrel bluff sites cannot be determined by visual inspection, since both sites are partially covered with soil.

1.4 KING SALMON AIRPORT PROJECT OBJECTIVES

The current study is Stage 1 of the combined Phase II/IV remedial investigation and feasibility study for the operable unit sites at King Salmon Airport. In addition to remedial investigation tasks, this Stage 1 effort includes feasibility study tasks through development of preliminary alternative remedial actions. Also included in this study is design of a Conceptual Remedial Measure (CRM) for the petroleum product seep at Eskimo Creek. Following the RI/FS tasks, a work plan will be prepared to determine if any additional confirmation and feasibility studies are needed, as well as remedial actions that can be implemented in 1988-89 work for King Salmon Airport.

This IRP Stage 1 work for King Salmon Airport was performed as authorized by Contract No. F33615-85-D-4535, Delivery Order No. 0006.

The purpose of the Phase II/IV, Stage 1 work conducted in 1987 and 1988 was to (1) collect and evaluate field data to define to site hydrogeology, (2) confirm the presence or absence of contamination within the specified areas of investigation, and (3) determine the extent of contamination at each of the King Salmon Airport operable unit sites and recommend remedial action for each. The specific Stage 1 tasks identified were:

1. Conduct a literature search to determine the geological, hydrogeological, and environmental settings for this investigation

2. Perform a soil gas survey and drill monitoring wells, taking soil samples for analyses, to delineate the petroleum, oil, and lubricants (POL) contaminant plume in the vicinity of Tanks 11, 12, 13, and 14 and the Eskimo Creek seep

3. Determine the nature and extent of contamination of groundwater in the vicinity of POL Tanks 11, 12, 13, and 14 and the Eskimo Creek seep

4. Determine the nature and extent of surface water contamination of Eskimo Creek resulting from the POL seep

5. Design a Conceptual Remedial Measure (CRM) to contain/intercept the POL seep at Eskimo Creek

6. Determine the nature of the petroleum product seep at Naknek River

7. Define the horizontal and vertical extent of barrels and other debris at the North Barrel Bluff

8. Determine whether the wetland area that lies between King Salmon Creek and the face of the North Barrel Bluff and the surface waters of King Salmon Creek downstream of the barrel bluff have been contaminated by liquids from the barrels and debris disposed at this site

9. Determine the horizontal and vertical extent of the barrels and other debris at the South Barrel Bluff and Landfill No. 1

10. Determine whether surface water in King Salmon Creek is contaminated downstream of the South Barrel Bluff

11. Perform a qualitative risk assessment to determine the potential environmental or health hazards associated with those contaminants found

12. Develop preliminary alternative remedial actions for the sites addressed in this scope of work

13. Develop data quality objectives (DQOs) necessary to perform the detailed evaluation of remedial alternatives and to conduct the quantitative risk assessment required in any future IRP work on these sites

1.5 PROJECT TEAM ORGANIZATION

The CH2M HILL project team organization and assignments are shown in Figure 1-4. Detailed biographies are provided in Appendix J.

CVR193/015

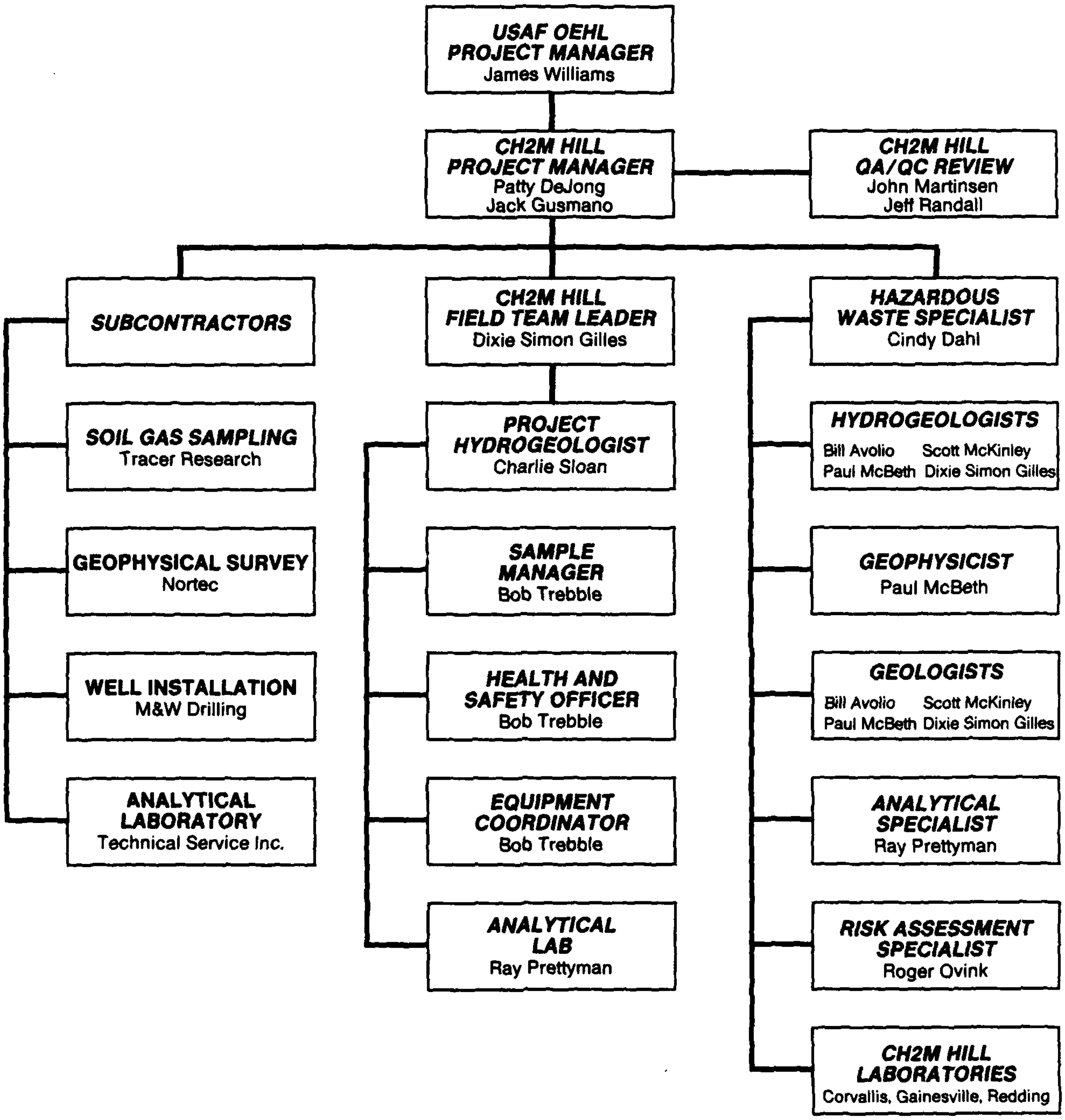


FIGURE 1-4

PROJECT ORGANIZATION
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

K24173.A0

II. ENVIRONMENTAL SETTING

2.1 GEOGRAPHIC SETTING

2.1.1 Physiography

King Salmon Airport is located on an 86-acre site in the central portion of Section 23, Township 17 S, Range 45 W, Seward Meridian. Figure 2-1 provides a location map and Figure 2-2 shows a detailed vicinity map. The installation is on the northwestern section of the Alaska Peninsula approximately 340 miles southwest of Anchorage, Alaska. This area is generally characterized by glaciated zones bounded by well defined moraines, with some gully development along morainal ridges. Many kettle basins containing lakes are present throughout the area. Most area drainage is not fully integrated.

The Naknek River lies to the south of King Salmon Airport. Eskimo Creek flows through the central portion of the base, and King Salmon Creek lies to the northwest.

Ground surface elevations on the base range from 30 feet mean sea level (MSL) along the banks of the Eskimo Creek, to 68 feet MSL within the central portion of the base headquarters area.

2.1.2 Vegetation

Vegetation at King Salmon consists primarily of scattered white spruce with ericacous shrubs. Trees are sparse, and most of the vegetation is short. The floodplains of Eskimo and King Salmon Creek are wetlands. They contain a variety of shrubs, herbs, grasses, and sedges rooted in a continuous matrix of lichens and mosses. Depressions typically nurture grasses and sedges while raised hummocks and hills foster crowberry, birch, willow, and blueberry. Summer blooms include lousewart, violet, buttercup, and other wild flowers (Alaska Department of Community and Regional Affairs, 1982).

2.1.3 Cultural Geography

2.1.3.1 Land Use

Land development at King Salmon began in the 1930s when an air navigation silo was built. During World War II, an Air Force base was constructed. The Federal Aviation Administration (FAA) maintained the base throughout the war. The King Salmon Airport remains today one of the major military installations in western Alaska. Other facilities at King Salmon include a road between the town and Naknek, a post office, an Alaska Department of Fish and Game (ADFG)

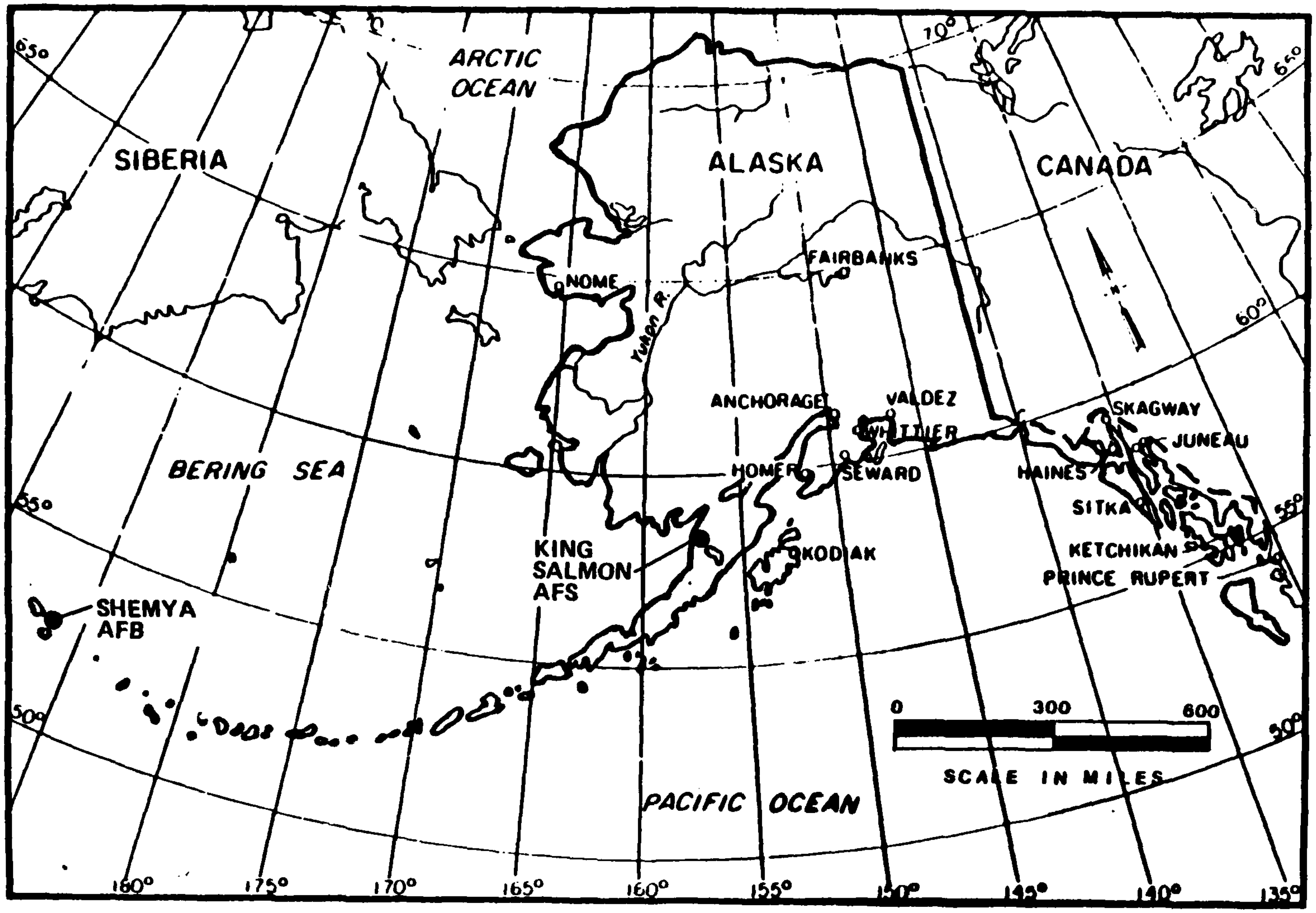


FIGURE 2-1

LOCATION MAP
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

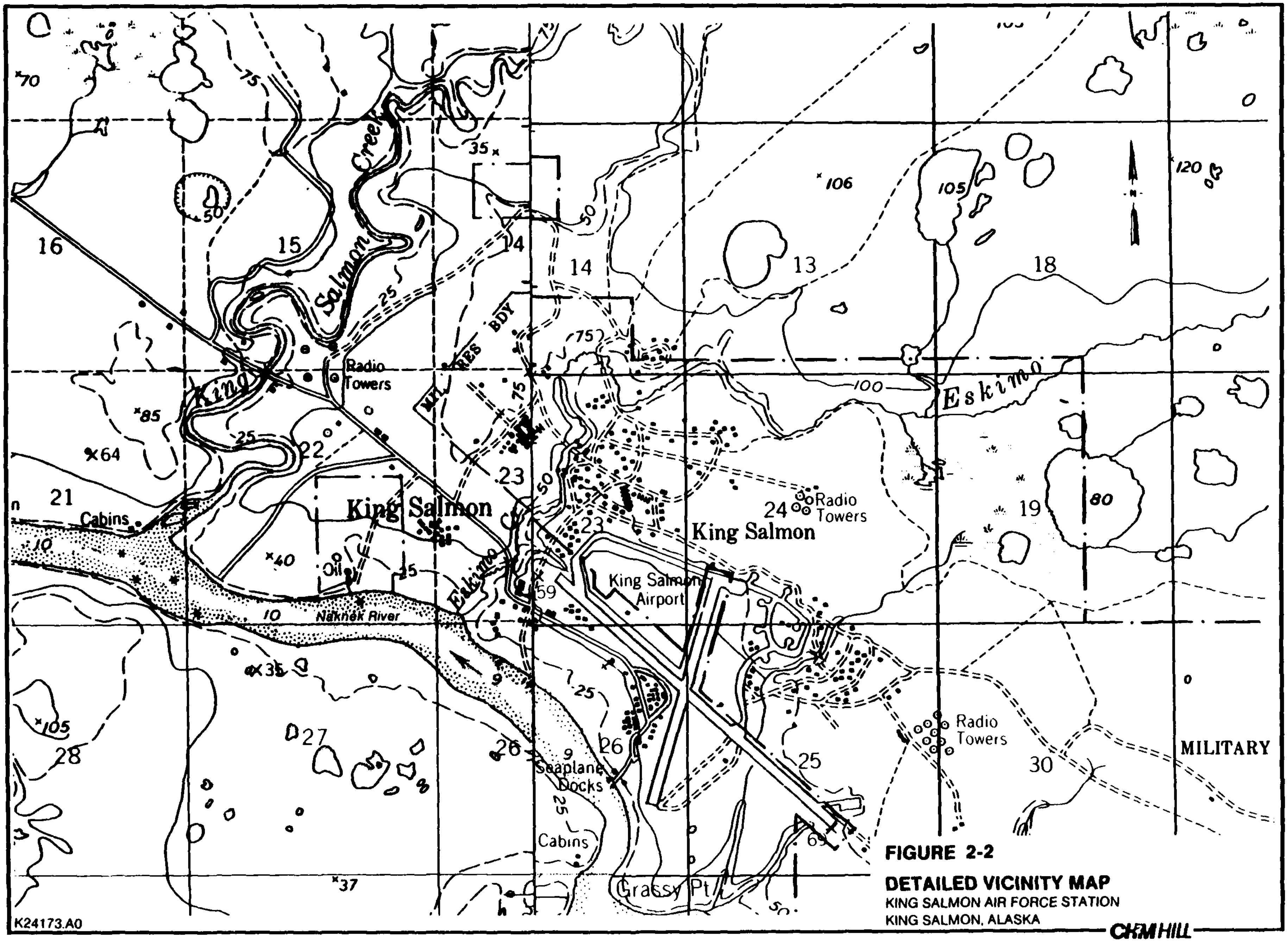


FIGURE 2-2

DETAILED VICINITY MAP

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

office, a weather bureau office, inns, stores, and private businesses.

Three of the largest landowners in the King Salmon area are the federal government, the State of Alaska, and Paug-vik, Inc. (Naknek's native village corporation). The State of Alaska has claimed 1.56 acres for the King Salmon Airport and 12.55 acres on the Naknek River for use by the ADFG. The U.S. Fish and Wildlife Service (USFWS) owns 8.24 acres on the Naknek River adjacent to the parcel occupied by the ADFG. The National Park Service (NPS) has a King Salmon office situated on 11.43 acres. Much of the land is owned by the federal government for use by the Air Force and FAA.

The Alaska Native Claims Settlement Act (ANCSA) (1971) does not acknowledge King Salmon as a native village. Consequently, a native village corporation has not been established for King Salmon. Interim conveyance and patents to land around King Salmon have been provided to Paug-vik, Inc.

Pursuant to the Native Allotment Act of 1906, the Secretary of the Interior may provide up to 160 acres of land to individual natives with the stipulation that the claimant occupies and uses the allotment continuously. By 1982, natives had filed 24 active claims and 2 patented claims near King Salmon. With the passage of ANCSA, new claims were not accepted between 1971 and 1982. Provision for the approval of pending claims was established by the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. Claims are not approvable under ANILCA in cases where protests have been filed. Certificates of claim approval are issued when claims are officially surveyed (Alaska Department of Community and Regional Affairs, 1982).

2.1.3.2 Demography

In 1980, the population at King Salmon was predominantly white and male. The distribution by race was 81.1 percent white, 8.6 percent black, 5.9 percent native, 0.9 percent Asian, and 3.4 percent other races. Males outnumbered females by a ratio of 3.7 to 1 (Alaska Department of Community and Regional Affairs, 1982).

A 1980 Census Bureau survey documented 43 civilian families and 75 households at King Salmon. Since station personnel reside at the installation on unaccompanied assignments, their families remain at home. In 1987, this Air Force station accommodated 275 military personnel and 19 civilians on assignments related to the military (USAF, 1987).

2.1.3.3 Population Density

In 1980 more military personnel resided at King Salmon than civilians: 340 military personnel resided at King Salmon Airport; 205 civilians lived in the village. The civilian population has grown to more than 300, while the military personnel now numbers fewer than 300.

The summer population frequently increases with the seasonal influx of NPS, ADFG, and local hotel and restaurant employees. Additionally, many people pass through King Salmon enroute to fishing and cannery jobs on the coast or to sport fishing and hunting trips (Alaska Department of Community and Regional Affairs, 1982).

2.1.3.4 Age Distribution

A 1980 U.S. Census Bureau survey recorded most of the inhabitants at King Salmon were between the ages of 22 and 44 years. The median age was 27.1 years. Age distribution is shown in Table 2-1.

2.1.3.5 Education Level

The Bristol Bay School District provides education to residents of North and South Naknek and King Salmon. Children attending preschool through grade 12 commute daily to Naknek. Some students pursue higher education. No information is presently available on the education of King Salmon residents (Alaska Department of Education, 1987).

The education level of Air Force personnel at King Salmon reflects that of the Air Force in general. Air Force personnel typically have high school educations. Officers are required to have a baccalaureate degree.

2.1.3.6 Socioeconomics

The economy of King Salmon is based primarily on employment related to government, transportation, and fishing. The U.S. government provides the largest, most stable source of employment. Civilians holding government jobs work for the U.S. Air Force, the FAA, USFWS, NPS, and the U.S. Postal Service. The King Salmon installation is self-contained and does not contribute substantially to the local economy. Occasionally, some military personnel seek part-time employment with local flying services, restaurants, and canneries.

Table 2-1
KING SALMON AGE DISTRIBUTION

Age (Years)	Total	Female
Under 1	-	-
1-2	5	2
3-4	5	2
5	5	1
6	5	5
7-9	18	9
10-13	14	9
14	4	2
15	8	6
16	3	2
17	1	-
18	5	4
19	3	1
20	8	1
21	37	1
22-24	103	16
25-29	119	15
30-34	81	14
35-44	76	16
45-54	31	6
55-59	4	-
60-61	4	2
62-64	3	2
65-74	3	1
75-84	-	-
85 and over	1	1

Source: U.S. Census Bureau, 1980

The State of Alaska provides year-round and summer jobs in King Salmon. Most state workers are based in King Salmon and work throughout the Bristol Bay Borough. Major state employers include the Department of Public Safety (DPS), ADFG, and the Department of Transportation and Public Facilities (DTPF).

Commercial flying services employ much of the local work force. Airline employers include Peninsula Airways, King Flying Service, and Mark Air. Hotels and restaurants provide a few additional jobs. A few residents seek employment with the Bristol Bay red salmon fishery, sport fishing lodge operations, a construction company, a car rental business, and miscellaneous small enterprises.

2.1.3.7 Public Health and Welfare

The Camai Medical Center at Naknek is the only health clinic serving King Salmon.

2.2 GEOLOGY

2.2.1 Geomorphlogy

King Salmon AFS is located in an area exhibiting the characteristics of past intense glaciation during Pleistocene time (between 10,000 and 1.6 million years ago). Glacial activity is significant on the Alaska Peninsula in that glacier advance and retreat eroded the uplands into block-like groups of mountains with rounded crests separated by U-shaped valleys and low passes. The mountain ridges that rose above the ice sheet remained angular and sharp in appearance. The retreat and melting of the large glaciers produced great quantities of outwash sediment, which has resulted in the filling of many basin and lowland areas.

Alaska's generally cold climatic regime has produced a subsurface condition termed "permafrost," a combination of geological, hydrologic, and meteorologic characteristics that produce perennially frozen ground. Permafrost occurs in both unconsolidated sediments and bedrock. The occurrence of permafrost in Alaska is mapped as areas of continuous permafrost, discontinous permafrost, and no permafrost. King Salmon AFS is located in the zone of discontinous permafrost (Figure 2-3).

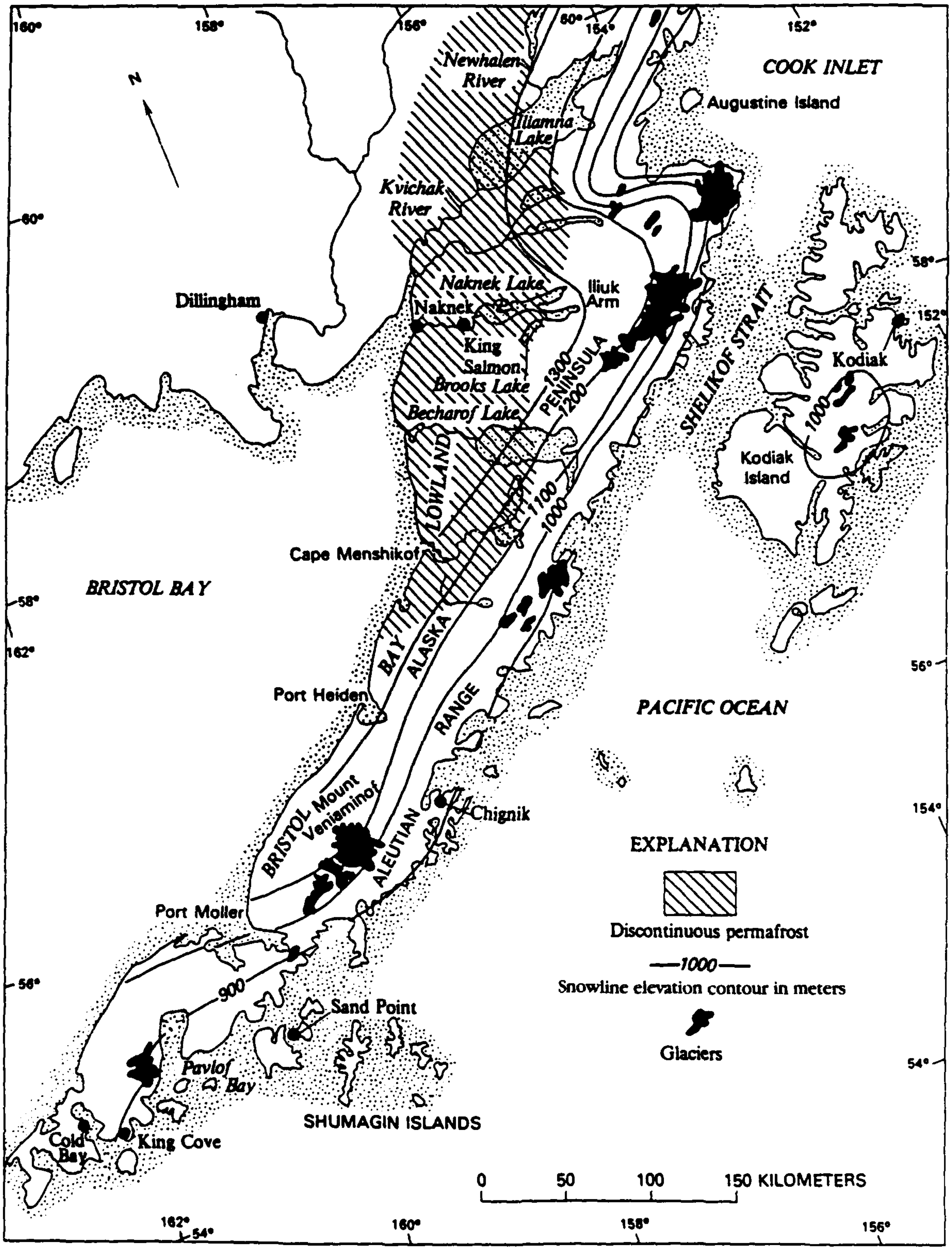


FIGURE 2-3

SNOWLINE, GLACIERS AND AREAS OF DISCONTINUOUS PERMAFROST ON THE ALASKA PENINSULA

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

K24173.A0

CH2M HILL

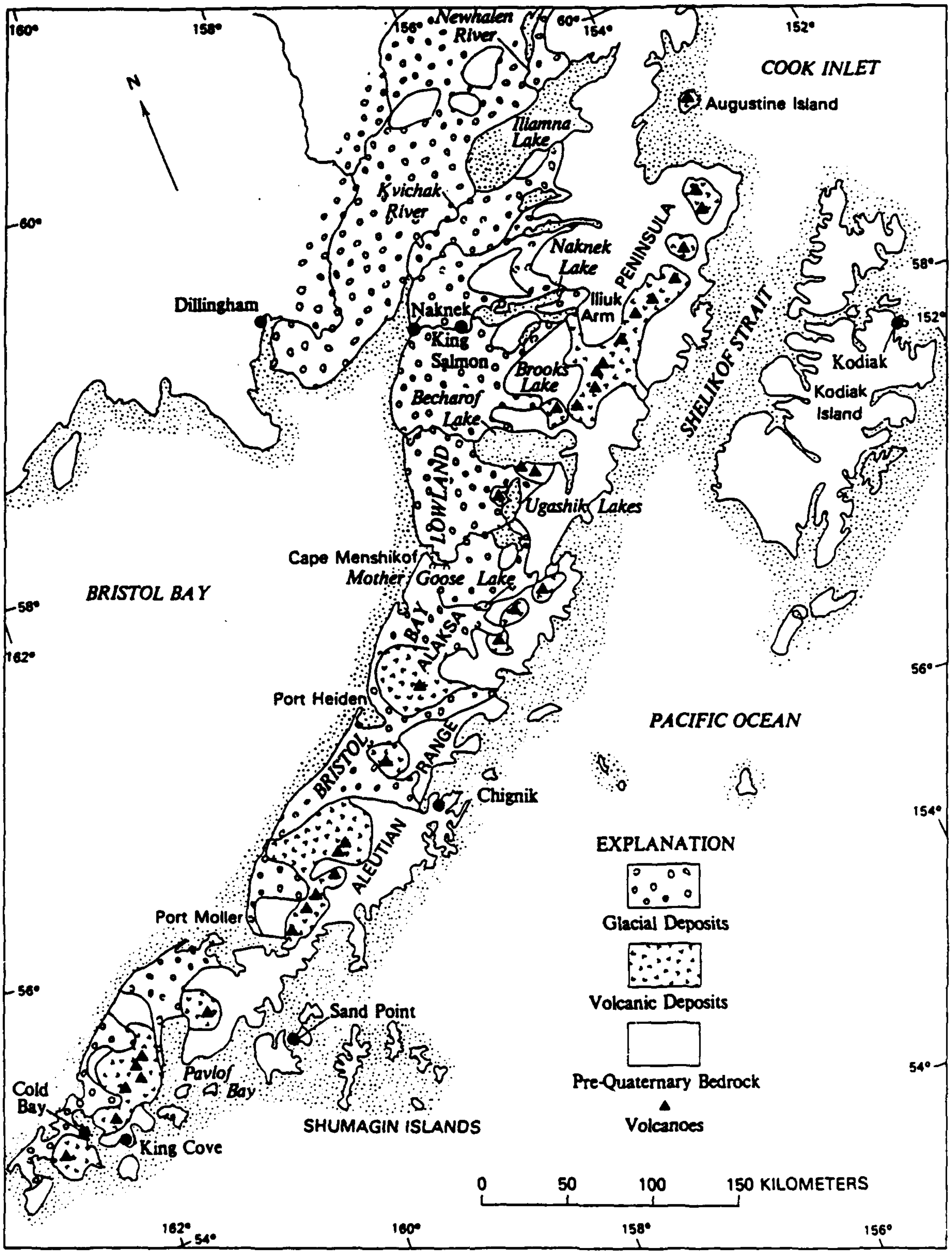


FIGURE 2-4

DISTRIBUTION OF QUATERNARY GLACIAL DEPOSITS, VOLCANOES AND VOLCANIC DEPOSITS ON THE ALASKA PENINSULA

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

K24173.A0

CH2M HILL

2.2.2 Bedrock Geology

Bedrock is not exposed in the vicinity of King Salmon AFS and underlies overburden materials at depths of several hundred feet.

2.2.3 Surficial Geology

In the lowland areas in the vicinity of King Salmon AFS, well-sorted recent alluvium is present, consisting primarily of sand, silt, and clay in stratified layers. Glaciofluvial sediments occur beneath the slopes and terraces overlooking the valleys of streams and rivers. These sediments are poorly to moderately well-sorted outwash and morainal materials (i.e., unconsolidated materials deposited by the melting glacier or by erosion of older moraines). The upland areas bordering or overlooking the site are underlain by glacial moraine and drift materials. These materials are mixed, unsorted, and generally unstratified clay, silt, sand, gravel, cobbles, and boulders arranged in a conspicuous arcuate pattern, usually about the larger lakes. Figure 2-4 shows geologic units which are surficially exposed on the Alaska Peninsula.

At King Salmon AFS, glacial outwash and sand deposits blanket the surface. The outwash sand ranges in thickness from about 20 to 40 feet and overlies silty glacial till.

2.3 HYDROGEOLOGY

2.3.1 Occurrence and Movement of Groundwater

The most productive groundwater sources are the unconsolidated alluvial aquifers of Alaska's major river valleys and the glacial outwash aquifers underlying coastal basins and some lowland areas. King Salmon is underlain by glacial outwash.

The primary source of recharge to the aquifers beneath King Salmon is precipitation. Additional sources of recharge to these aquifers include stream channels that lose flow (influent streams), lakes, topographic high points, and slopes of low hills.

Groundwater discharges from aquifers to springs, effluent streams, lakes, or bays. Groundwater discharge may also occur at topographic low points in the form of seepage, which may be evident by marshes or shallow ponds.

In areas of discontinuous permafrost, localized zones of permafrost may control or influence groundwater movement. Permafrost may act as a barrier to downward percolation and to lateral movement of groundwater and also may act as a confining layer to subpermafrost water.

The lower groundwater temperatures in Alaska also influence groundwater flow velocities. Groundwater existing under low temperature ranges (zero to 4.5°C) moves more slowly than groundwater in temperate regions due to increased viscosity.

Groundwater at King Salmon occurs in a near-surface shallow aquifer under unconfined conditions. The shallow aquifer is underlain by a low hydraulic conductivity unit termed the upper aquitard. Beneath the upper aquitard lies an intermediate aquifer where groundwater is present under confined conditions. In the shallow and intermediate aquifers beneath King Salmon Airport, groundwater flows to the south.

A more detailed discussion of the hydrogeology at King Salmon Airport is provided in Section IV.

2.3.2 Surface Water

Figure 2-5 shows the location and flow directions of the predominant surface water features in King Salmon, Alaska. In addition to those identified in Figure 2-5, there are several other unnamed tributaries with intermittent, seasonal flow. These tributaries ultimately discharge to the Naknek River.

Surface water discharge rates have been measured on Eskimo Creek and King Salmon Creek. Periods of measurement, mean annual flow, annual low and annual high flows for each creek are shown in Table 2-2.

Peak flows in Eskimo Creek appear to be associated with both snow-melt runoff and precipitation events. Minimum flows are probably also associated with drought periods between precipitation events and with winter low flows and may represent base flow contributions from the King Salmon shallow aquifer.

2.4 AMBIENT AIR QUALITY

King Salmon Airport is a remote military installation with a limited industrial base. Potential sources of airborne emissions in the King Salmon vicinity include:

- Exhaust from gasoline, diesel, propane, and aircraft engines
- Wood stoves
- Solid waste burning
- Emissions from cannery facilities

- Construction
- Sand dryer

With approximately 20 inches of rainfall per year and an annual average wind velocity of 9 mph, dilution and dispersion of airborne emissions results in overall acceptable air quality.

No records of previous or existing air sampling performed in the King Salmon vicinity are available.

Table 2-2
SURFACE WATER FLOW DATA

Recording Period	Mean Recorded Discharge (cfs)	Minimum Recorded Discharge & Day of Occurrence (cfs)	Maximum Recorded Discharge (cfs)
Eskimo Creek			
Oct 29/87	22.8[a]		
Oct/83 - Sept/84	14.1	3.8 (Aug 06)	94 (Jun 02)
Oct/82 - Sept/83	10.8	2.6 (July 20)	58 (Oct 01)
Oct/81 - Sept/82	11.9	3.2 (Feb 18)	103 (Jun 06)
Oct/80 - Sept/81	13.0	2.0 (Dec 13)	68 (Mar 14)
Oct/79 - Sept/80	16.66	1.5 (Jan 13)	53 (Nov 08)
King Salmon Creek			
Oct 28/87	310.5[b]	--	--

---

[a] Discharge measurement performed 100 feet downstream from culvert east of Eskimo Creek. (See data sheet Appendix D-5.)

[b] Discharge measurement performed between South and North Barrel Bluff sites. (See data sheet Appendix D-5.)

cfs = cubic feet per second

2.5 NATURAL RESOURCES

2.5.1 Mineral Resources

Active mining operations are not known to exist in King Salmon. An active sand and gravel operation is located north of King Salmon Airport. This facility produces sand, gravel, concrete,

A

P

and other mixtures for construction and road surface preparation. Estimates of annual production and known reserves at the sand and gravel facility were not available.

2.5.2. Environmental Resources

King Salmon is situated on the Naknek River, a very productive fish and wildlife area, on the Alaska Peninsula. The installation is near the Katmai National Park and Preserve. The Alaska Peninsula is an important state-managed habitat for large and small game animals, fish, and birds (Engineering Sciences, 1985). Wildlife and wildlife habitat are considered an important natural resource in the area.

Commercial and sport fish and their aquatic habitat are important natural resources. The Naknek River and its tributaries (including Eskimo Creek and King Salmon Creek) support an enormous stock of migratory and resident sport and commercial game fish. The Naknek River drainage supports one of the largest sockeye salmon runs in the world. Between 1977 and 1981, the Naknek River system received an average annual return of 1.4 million sockeye salmon. Drainage from the King Salmon installation flows into the Naknek River and on to Bristol Bay, one of the world's most productive fishing grounds, where over 40 million sockeye salmon have been recorded in a single season. Commercial fishermen from Alaska and other states congregate annually in Bristol Bay to harvest salmon and other fish. Additionally, thousands of nonresidents pass through King Salmon on their way to fishing and cannery jobs at Bristol Bay (Alaska Department of Community and Regional Affairs, 1982).

In addition to sockeye salmon, all other species of Pacific salmon return to the Naknek River, King Salmon Creek, and Eskimo Creek. These include pink, chum, coho, and chinook salmon. Eskimo and King Salmon Creeks are utilized by all these salmon species for spawning and rearing, but are used primarily by chinook salmon. The salmon spawning runs in the area begin in late May and extend through late September. Other local fish include trophy-size rainbow trout, arctic char, Dolly Varden, grayling, lake trout, whitefish, burbot, and northern pike. Sport fishermen from around the world come to the Naknek River system to enjoy some of the best fishing in the world. The local economy derives much of its support from sport fishing along the Naknek River and its tributaries and from commercial fishing in Bristol Bay (USAF, 1987).

2.6 CULTURAL RESOURCES

2.6.1 Archaeology

There are many prehistoric archaeological sites along the Naknek River. One site in particular is located at the end of King Salmon's main runway, between the runway and the river bank. The site was excavated by archaeologists in 1973. The remains of a house and other artifacts, estimated to be 1,500 to 2,000 years old, have been discovered. Some local people observed that extensions of the runway had disturbed some native houses, and workers on the runway have reported seeing trade beads and other artifacts (Dumond, 1981).

Eskimo shelters dating back to the early 1900s have been found on the banks of Eskimo Creek. Other local prehistoric sites have been identified on the bank of the Naknek River across from the mouth of King Salmon Creek, and upstream on the Naknek River in the vicinity of the confluence of Big Creek with the Naknek River. Other prehistoric sites are scattered, and abut the banks of the Naknek River between Kvichak Bay and Naknek Lake. These sites are estimated to date back 2,000 years or more (Dumond, 1981).

2.6.2 Human Resources

People residing at the King Salmon installation are primarily military personnel or persons authorized by the military to be there. These personnel are on "unaccompanied assignments," meaning families remain at home away from the base. The human resources at the installation are, therefore, military and largely temporary (USAF, 1987).

Most of the nonmilitary residents of King Salmon hold jobs in government, transportation, or fishing. Government or the public sector is the primary employer of civilians in King Salmon. The FAA has employed in excess of 33 people. While the Air Force station does not contribute substantially to the local economy, some military personnel seek part-time employment with the canneries, restaurants, and flying services. The USFWS, NPS, and U.S. Postal Service are other major governmental employers in King Salmon. The State of Alaska employs seasonal and full-time workers in King Salmon. Most of these employees work for the ADFG, the DTPF, or the DPS.

Part of the civilian work force in King Salmon is engaged in commercial fishing activities. Additionally, various small enterprises provide companies, car rental businesses, fur trapping, and other miscellaneous small businesses.

2.6.3 Existing Cultures

Native groups around the King Salmon and Bristol Bay area include the Athabascan, Kiatagmiut, Aglegmiut, Peninsula Eskimo, and Aleut. The Aglegmiut occupy the lower half of the Naknek River and most of the coastline around the north end of Bristol Bay. The Peninsula Eskimo inhabit the base of the Alaska Peninsula including land along Shelikof Strait, and the upper half of the Naknek River upon which King Salmon is located (Dumond, 1981).

The Peninsula Eskimo natives of King Salmon often claim to be Aleut; however, their dialect is Sugpiaq, the language of the Peninsula Eskimo. Consequently, anthropologists generally consider these natives to be Peninsula Eskimo (Dumond, 1981). Census information gathered in 1980 by the U.S. Census Bureau reflects the natives' desire to be labeled Aleut. The 1980 census recorded two Eskimos and 27 Aleuts at King Salmon.

2.7 BIOLOGY AND ECOLOGY

2.7.1 Flora

The land around the Naknek River resembles the arctic zone of the nearby Katmai National Park and Preserve, but it is classified as transitional between subarctic forest and moist tundra. North of Naknek, trees are more common; but south of Naknek, trees gradually taper off. Lichen and sphagnum heaths are widespread, interspersed with lichens, crowberry, low birches, and marsh blueberry. Lake and river shores have communities of sedges, willow forms, reed grasses, bluejoint, white spruce, balsam poplar, taller birches, and alder (Dumond, 1981). Flowering plants include monkshood, lousewart, violet, buttercup, and other wild flowers (Alaska Department of Community and Regional Affairs, 1982).

2.7.2 Fauna

One of the most prevalent terrestrial mammals is the brown bear, which feeds during the summer months on salmon in the rivers. The brown bear retreats from the Naknek River vicinity in the fall to feed on berries in the high country and, subsequently, to hibernate for the long winter. Moose frequent the area also. In the summer, moose range throughout the region, favoring high, well-drained areas of willow and alder and areas along rivers where forage is good. Deep winter snows typically drive moose out of the high country into lower areas where travel is easier and food is more available.

Other land mammals in the region include caribou, red fox, weasels, mink, beaver, muskrat, lynx, wolves, porcupine, lemmings, shrews, voles, arctic ground squirrels, tundra hares, snowshoe hares, land otter, and caribou.

The Naknek River and its tributaries annually support migrations of anadromous fish. These include sockeye, chinook, silver, chum, and pink salmon species. Resident fish include trophy-size rainbow trout, arctic char, Dolly Varden, grayling, lake trout, whitefish, burbot, and northern pike. King Salmon is a base for world-class sport fishing, and nearby Bristol Bay fosters one of the most productive commercial salmon fishery in the world.

Hundreds of thousands of waterfowl stop at Bristol Bay while migrating to and from distant nesting grounds. Most of the world's black brant population and virtually all of the world's population of emperor and Canada geese fly through the region. Mallards, gadwalls, pintails, green-winged teal, American widgeons, greater scaup, goldeneyes, buffleheads, oldsquaw, harlequins, scoters, and other ducks are known to nest at King Salmon. The Kvichak River is a major flyway for sandhill cranes and whistling swans. Snow geese, whitefronted geese, Canada geese, and loons stop there during their seasonal migrations. Some birds remain at King Salmon to nest and molt. Recent surveys have recorded 141 species of waterfowl, with a breeding population of 32 ducks and 1.2 swans for every square mile of lowlands.

Shorebirds use the same habitats and flyways as other waterfowl. They include rock and western sandpipers, ruddy turnstones, bar-tailed godwits, golden and black-billed plovers, dunlins, and phalaropes. Shorebirds nest on lake shores, coastal beaches, and tundra hummocks. Other species found on coasts and inland waters include glaucous-winged and mew gulls, arctic terns, and black-legged kittiwakes.

The protected bald eagle nests along the Naknek River and its tributaries. Other raptors that frequent the area include American and arctic peregrine falcons, ospreys, and short-eared owls. Many passerines, such as Lapland longspurs, snow buntings, swallows, Savanna sparrows, and dippers, are also present.

Wintering birds at King Salmon include white-tailed, willow, and rock ptarmigan and ravens. Seabirds move offshore in the winter, while most of the other bird species migrate to warmer climates (Alaska Department of Community and Regional Affairs, 1982).

2.7.3 Environmentally Sensitive Areas

The Alaska Peninsula supports a diverse variety of fish, birds, small game, and large game animals. The area is a state-managed habitat for wildlife and is considered to be one of the most significant in the state (Engineering Science, 1985).

King Salmon is located on the bank of the Naknek River. This river and its tributaries (including Eskimo Creek and King Salmon Creek) are rich in sport and commercial fish and ecologically link the project site with Bristol Bay. The Naknek River is one of Alaska's most important sport fishing areas. Drainage from the military installation at King Salmon is conveyed by King Salmon Creek, Eskimo Creek, and the Naknek River to Bristol Bay, site of one of the state's most productive commercial fisheries. The land, aquatic, and marine ecosystems are, therefore, interrelated. Activities at the King Salmon installation can affect the local environment, Naknek River, Eskimo Creek, King Salmon Creek, and possibly downstream environments (Bristol Bay). Because of Alaska's delicate environmental setting, the long-term impacts of pollutant discharge in the area could be severe. The potential impacts on public health are uncertain (Engineering Science, 1985).

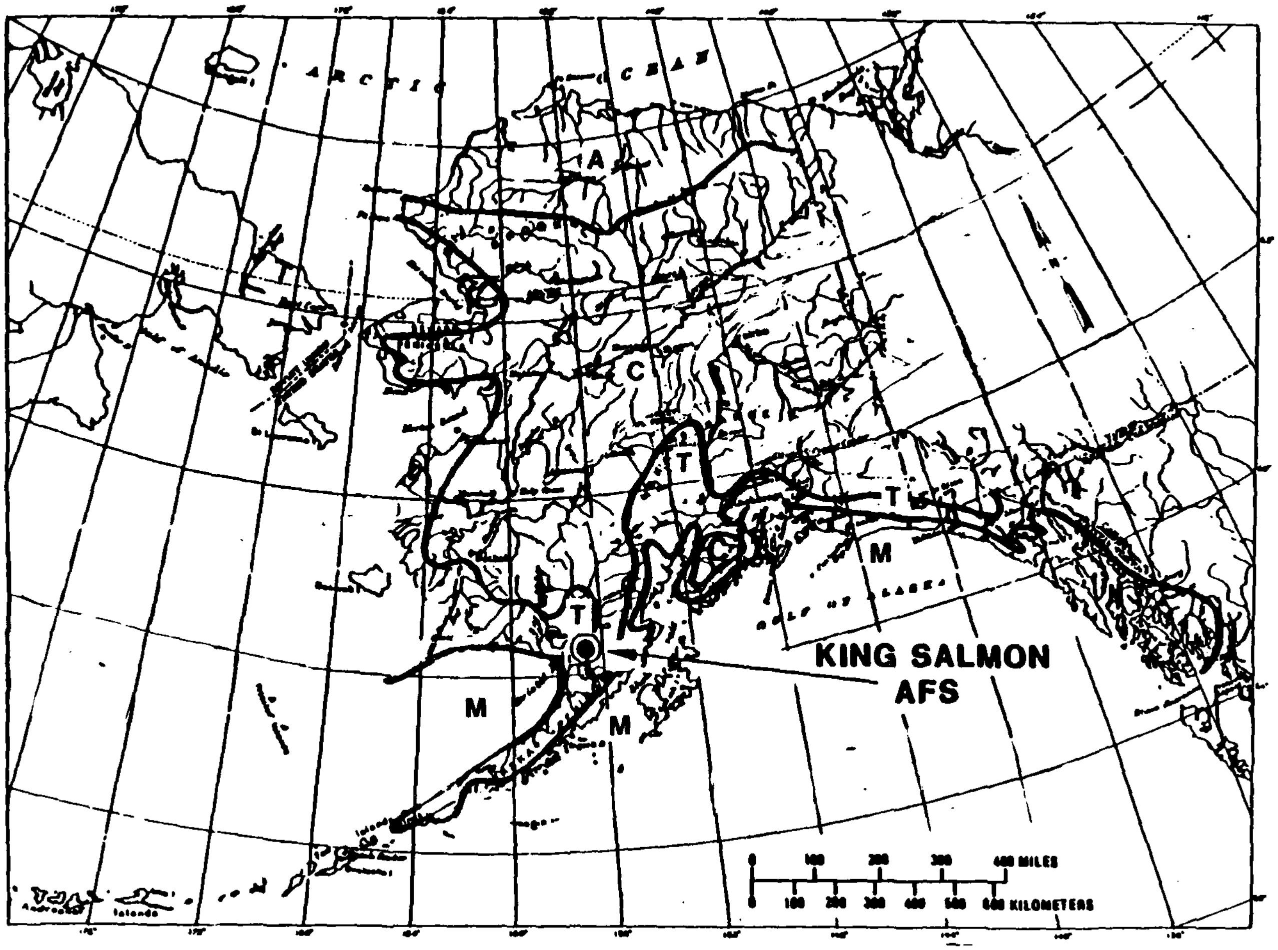
2.7.4 Endangered Species

The project area is within the nesting range of the American peregrine falcon and is in the migratory range of the arctic peregrine falcon. Both are considered endangered in Alaska.

2.8 CLIMATOLOGY/METEOROLOGY

Because of its enormous size, Alaska spans four distinct climatic zones, each of which has been established on the basis of temperature and precipitation characteristics. These areas include the arctic, continental, transitional, and maritime zones (Engineering Sciences, 1985). Figure 2-6 shows the location and boundaries of each climatic zone type. Because of its inland location, King Salmon lies on the border between the transitional and continental zones. The Alaska Peninsula has a subpolar maritime climate characterized by high winds, protracted cloud cover, frequent precipitation, and fog.

Rainfall varies significantly in Alaska: 5 inches fall during a typical year in the arctic climatic zone, while 300 inches fall during the average year in the southeastern maritime zone. This considerable spatial variation in rainfall across the state is due primarily to orographic



Legend
- A - ARCTIC
- C - CONTINENTAL
- T - TRANSITIONAL
- M - MARITIME

K24173.A0
SOURCE: ES Engineering Science

FIGURE 2-6

ALASKAN CLIMATIC ZONES
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

effects related to topography and exposure. Coastal mountainous areas receive the most rainfall and interior lowlands receive the least (Engineering Sciences, 1985).

Climatic data for King Salmon are summarized in Table 2-3. Climatic variables presented include temperature, precipitation, snowfall, and surface winds.

Table 2-3
CLIMATIC DATA FOR
KING SALMON AIR FORCE STATION

	Mean Annual	Monthly Recorded Minimum	Monthly Recorded Maximum
Temperature	33°F	-46°F (January)	88°F (June)
Precipitation	19.8 inches	0 inches (March, April November)	7.3 inches (September)
Snowfall	46 inches	0 inches (March, April November)	20 inches (March)
Surface Winds	9 mph	0	A

Note: A=High winds associated with severe storms can occur at any time. These high winds are called williwaws.
Source: Engineering Science, 1985.

2.81. Precipitation

Precipitation at King Salmon is slightly variable. The average annual precipitation at King Salmon is 19.8 inches. The months of July through October are typically the wettest, averaging above 2 inches of rainfall per month. The maximum monthly precipitation recorded was 7.3 inches in September. The months of March, April, and November have each passed at one time without measurable precipitation being recorded. The maximum 24-hour precipitation was 1.7 inches durint the month of September (11th Weather Squadron, Elmendorf AFB, AK, 1942-1982).

Winter snow depths average 46 inches annually. The highest monthly snowfall depth ever recorded was 20 inches in March. The maximum 24-hour snowfall depth was 11 inches during the month of March (Engineering Sciences, 1985). The position of the modern snowline is determined by the lowest point of firm snow as derived from 1:63,360 scale maps and aerial photographs and from the point where medial moraines on valley glaciers are covered by snow. These data indicate the snowline is lowest, 900 m, along the Pacific side of the peninsula and rises westward across the peninsula by about 100 m every 20 km.

2.8.2 Temperature

The weather at King Salmon is seasonally mild because of its proximity to the coast. The mean annual temperature is 33°F. Monthly average temperatures vary from 55°F in July to 12°F in December. The highest temperature ever recorded in King Salmon was 88°F in June; the coolest temperature was -46°F in January (Engineering Sciences, 1985).

2.8.3 Wind

2.8.3.1 Direction

Wind prevails typically from the north during the winter months and from the south to east in the summer. The annual prevailing wind direction is from the north.

2.8.3.2 Wind Speed/Velocity

Wind speeds at King Salmon are characteristically mild. The annual average wind speed is 9 miles per hour.

2.8.3.3 Seasonal Variability

Average monthly wind speeds are relatively uniform throughout the year. Wind speeds vary on the average between 8 and 10 miles per hour during any month of the year (Engineering Sciences, 1985). However, severe storms are common and can occur at any time, often accompanied by high winds known as "williwaws." These storms are spawned by the Aleutian Low Pressure area, and their northeastward circulation path takes them along the southeast side of the peninsula on their way across the north Pacific to Canada and the northwestern United States.

2.8.4 Evapotranspiration

Information on the seasonal variation of evapotranspiration is not available for the King Salmon area; however, the potential evapotranspiration has been estimated at 17.87 inches. The actual evapotranspiration has been estimated at 15.98 inches (Patrick, et. al., 1968).

III. FIELD INVESTIGATION PROGRAM

3.1 INTRODUCTION

Detailed planning efforts concerning the execution and control of the Stage 1 field activities were conducted during September 1987. The results of these efforts were the Work Plan, Quality Assurance Project Plan, and the Site Safety Plan. These documents are referred to frequently in the following text. Exceptions to the documents are discussed in detail.

The field investigation program for this study consisted of the following tasks:

- Soil gas survey
- Geophysical survey
- Monitoring well installation
- Environmental sampling
- Aquifer testing

Before proceeding with any task, the King Salmon AFS Point of Contact was notified. Base Civil Engineering Work Clearance Requests, AF Form 103, were prepared, submitted and approved for all soil boring/monitoring well locations.

3.2 SOIL GAS SURVEY

The soil gas survey was conducted on October 21, 1987 through October 31, 1987 by Tracer Research Corporation of Tucson, Arizona under the supervision of a CH2M HILL geologist. Drilling support was provided by M-W Drilling, Inc. of Anchorage, Alaska. Soil gas surveys provide a relatively inexpensive way of identifying areas containing volatile and semivolatile organic contaminants occurring in the soil or which have migrated upward through the soil from underlying contaminated groundwater.

Soil gas samples were collected by driving a hollow steel probe to a depth between 5 and 35 feet below the ground surface. The majority of samples were collected within a few feet of the water table. The probes were driven using the cat-head on a truck-mounted Acker MP4 drilling rig. Probes consisted of either 1.5-inch-diameter steel pipe or E-size drill rods. A volume of gas equal to 5 to 10 times the volume of the probe was evacuated using a vacuum pump. During the soil gas evacuation, samples were collected by inserting a syringe needle through a silicone rubber segment in the evacuation line down into the steel probe.

The soil gas samples were analyzed in the field with a Varian 3300 gas chromatograph equipped with a flame ionization detector and a Spectra Physics 4270 computing integrator. The samples were analyzed for benzene, toluene, xylene, and total hydrocarbons.

3.2.1 Eskimo Creek Seep

The soil gas survey at the Eskimo Creek seep site consisted of 49 probes advanced in the general area of the installation structures located west of Eskimo Creek. The locations of the soil gas probes are shown in Figure 3-1, Eskimo Creek Seep Soil Gas Probe Locations. The purpose of the soil gas survey in this area was to locate "hot spots" of volatile organic contamination and assist in determining locations for the monitoring wells.

3.2.2 Naknek River Seep

The soil gas survey at the Naknek River seep site consisted of two probes advanced near the seep. The purpose of the soil gas survey in this area was to assist in determining the lateral extent of contamination associated with the Naknek River seep. Three additional probes were advanced along the highway between the west entrance to the installation and the entrance to the Naknek River tank farm. The purpose of the soil gas survey in this area was to assist in determining whether or not POL tanks 11 through 14 were a possible source for the Naknek River seep.

The soil gas survey for the Naknek River seep was done on a time remaining basis and was not the primary purpose for use of the soil gas survey techniques at King Salmon AFS. The locations of the probes are shown in Figure 3-2, Naknek River Soil Gas Probe Locations.

3.2.3 North Barrel Bluff

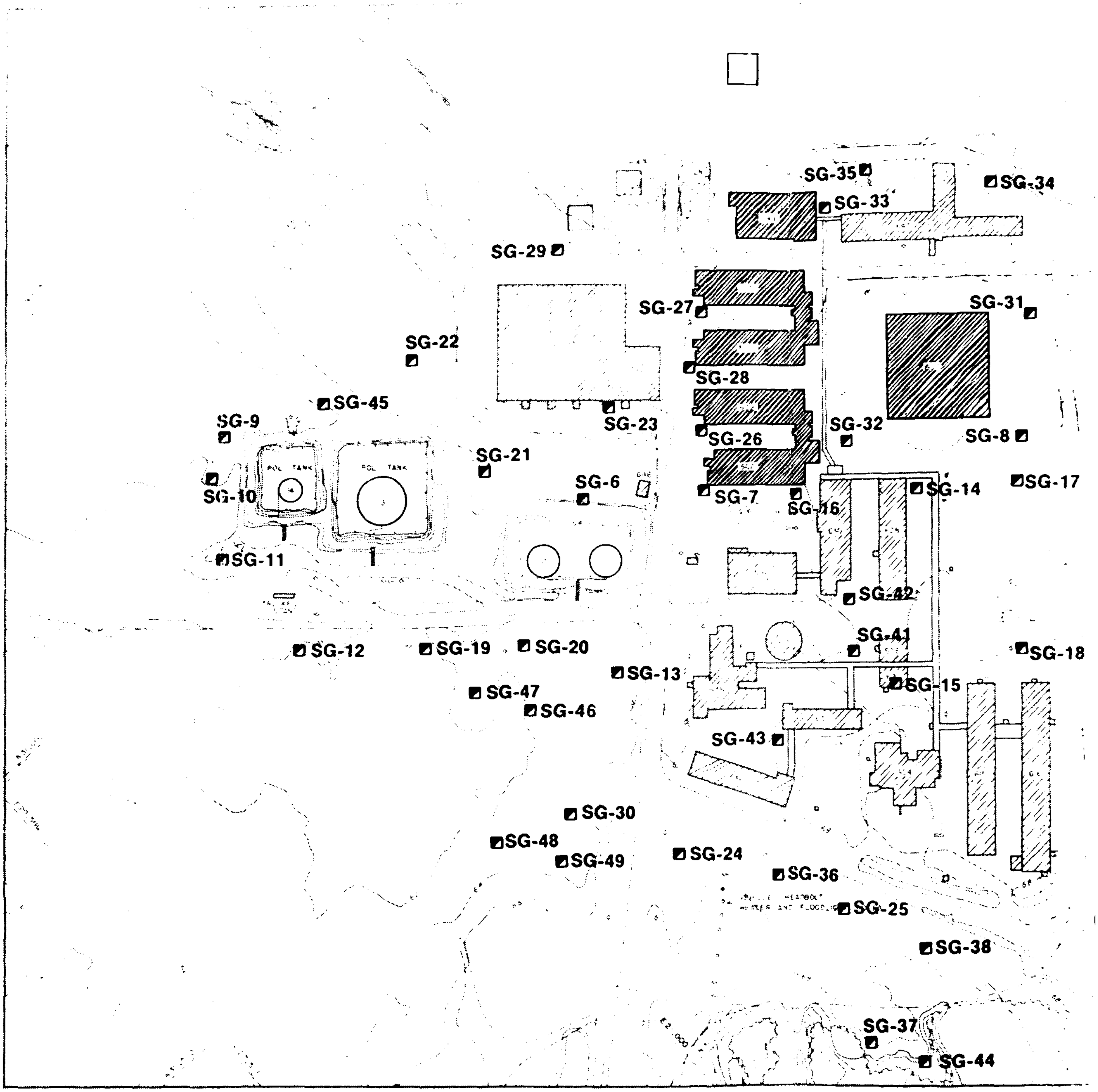
No soil gas surveys were conducted at the North Barrel Bluff site.

3.2.4 South Barrel Bluff

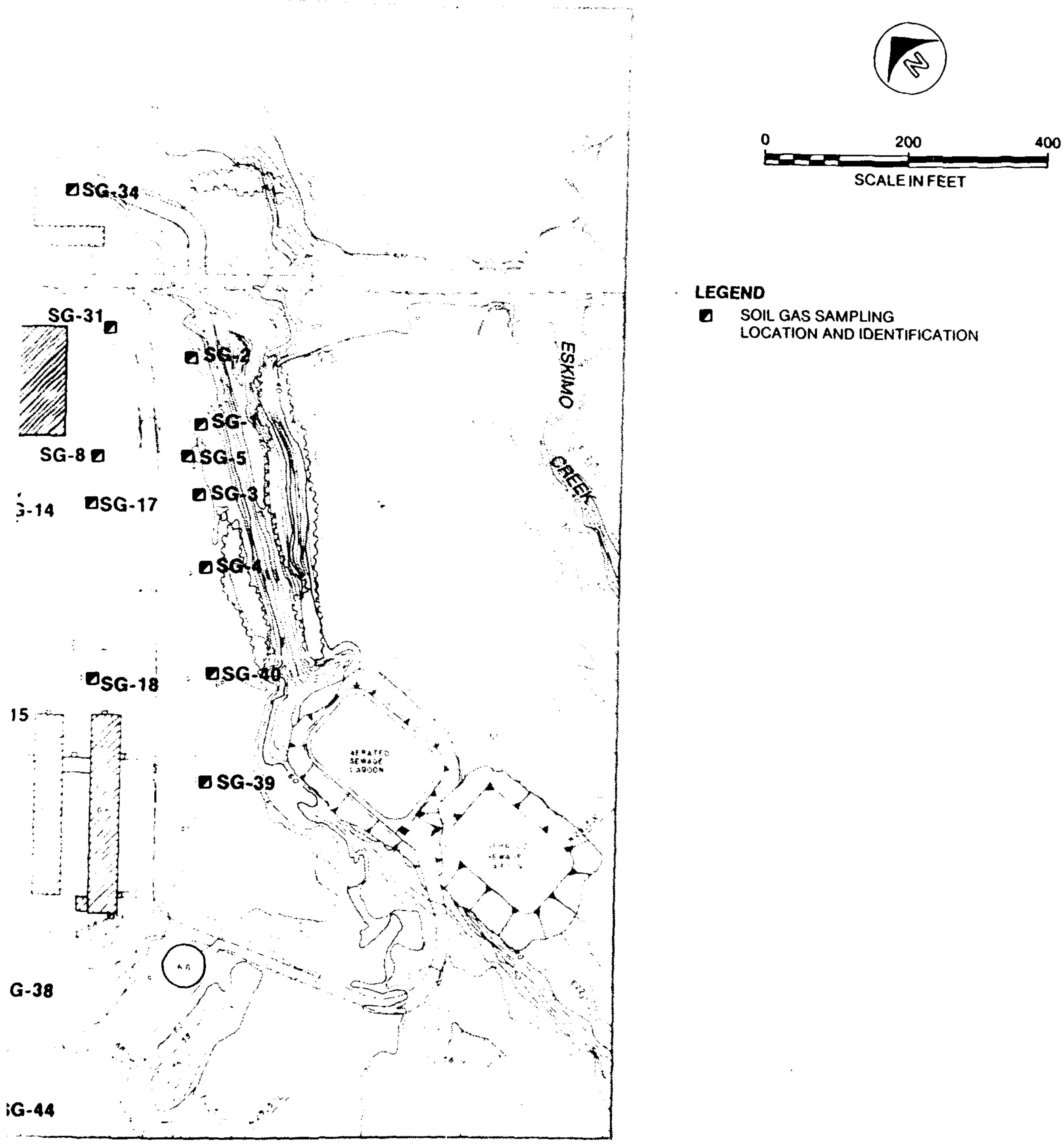
No soil gas surveys were conducted at the South Barrel Bluff and Landfill No. 1 site.

3.3 GEOPHYSICAL SURVEY

The geophysical survey was conducted October 21 through 31, 1987 by NORTEC, a division of ERT, of Anchorage, Alaska, under the supervision of a qualified CH2M HILL geologist. The following complementary geophysical techniques were used:


SG-35
SG-34
SG-33
SG-29
SG-27
SG-31
SG-22
SG-28
SG-45
SG-9
SG-23
SG-32
SG-8
SG-26
POL TANK
POL TANK
SG-21
SG-6
SG-10
SG-7
SG-16
SG-14
SG-17
SG-11
SG-42
SG-41
SG-12
SG-19
SG-20
SG-18
SG-13
SG-15
SG-47
SG-46
SG-43
SG-30
SG-48
SG-49
SG-24
SG-36
SG-25
SG-38
SG-37
SG-44

K24173.A0



LEGEND

▨ SOIL GAS SAMPLING LOCATION AND IDENTIFICATION

FIGURE 3-1

ESKIMO CREEK SEEP SOIL GAS PROBE LOCATIONS

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL


GNS

B

- Electromagnetic profiling using a Geonics EM-31DL Terrain Conductivity Meter with digital recorder

- Magnetic gradiometer surveying using an EDA OMNI IV Magnetometer/Gradiometer

- Ground penetrating radar (GPR) profiling using a GSSI System-GPR with a 120-MHz antenna

A detailed description of these techniques and their application to hazardous waste site investigations is provided by Benson (1982). Geophysical survey lines were established using fiberglass tapes, a Brunton compass, and a right-angle prism. Survey lines were tied to several BLM monuments, building corners, and/or subdivision rebar corner posts. Distances along survey lines are taped distances rather than true horizontal distances. The level of accuracy achieved was considered sufficient for the reconnaissance purposes of the geophysical investigation.

3.3.1 Eskimo Creek Seep

At the Eskimo Creek site, the investigations were directed toward identifying the source or sources of the contaminants observed at the Eskimo Creek seep. The following survey objectives were outlined:

- Characterize subsurface soils

- Map contaminant plume, if possible

- Explore for utilities and debris

- Check proposed monitoring well locations for hazards

Geophysical investigations conducted at this site were restricted to the use of the ground penetrating radar system due to cultural interferences (buildings, powerlines, radar dome, etc.) with the electromagnetic and magnetic methods. The radar dome proved to be the greatest interference and virtually eliminated the EM meter from the survey.

Two GPR grids were surveyed at the Eskimo Creek seep site. The geophysical survey grids are shown in Appendix I, Plate 4, Ground Penetrating Radar Trackline Map, Headquarters Area. The first was a detailed grid with a 10-foot line spacing in the vicinity of Buildings 636, 632, and 624. This area was reported by Air Force personnel to have been the location of a previous service station. The purpose of the geophysical survey in this area was to search for a possible buried fuel tank which may have been left in place when the service station was removed.

The larger grid was surveyed along several lines that paralleled the soil gas probe transects. The purpose of the geophysical survey in this area was to attempt to characterize subsurface soils, to search for evidence of a contaminant plume, and to explore for buried utilities and debris.

3.3.2 Naknek River Seep

Initially, a geophysical survey at the Naknek River seep Site was not planned. However, due to the reported presence of rows of buried drums at the site, a brief geophysical survey using both the Geonics EM-31DL Terrain Conductivity Meter and the OMNI IV Magnetometer/Gradiometer was performed. The survey grid is shown in Appendix I, Figure 2, Naknek River Tank Farm, Geophysical Anomaly Map. Instrument readings were taken at 25-foot intervals along the survey lines.

3.3.3 North Barrel Bluff

The geophysical investigation at the North Barrel Bluff site was directed primarily at defining the extent of the waste disposal areas. Most of the investigation was conducted using the conductivity meter and the magnetometer/gradiometer.

Most of the geophysical survey lines were conducted perpendicular to the bluff. Instrument readings were recorded at 25-foot intervals along the survey lines. Survey lines were carried down the face of the bluff when possible and onto the flood plain of King Salmon Creek. Many geophysical lines were terminated at the crest of the bluff because continuation of the line down the face of the bluff would require direct contact with the barrels, violating the site safety plan.

The location of the North Barrel Bluff survey lines are shown in Appendix I, Plate 2, Geophysical Anomaly Map, North Barrel Bluff Site.

Geophysical surveys were conducted at two other reported waste disposal areas near the North Barrel Bluff. The areas are shown in Appendix I, Plate 2, Geophysical Anomaly Map, North Barrel Bluff Site. The first was an area of disturbance south of the road between the north and south barrel bluffs. From aerial photographs, the area appears to have been cleared. The area was reported by a local contractor to have been a waste disposal area. The second area, southeast of the large existing building at the North Barrel Bluff, reportedly was used as a disposal area for debris resulting from demolition of several buildings in this vicinity. An abandoned buried tank was also reported to exist in this area.

Both areas were surveyed with the magnetometer and the conductivity meter.

3.3.4 South Barrel Bluff

The purpose of the geophysical survey at the South Barrel Bluff and Landfill No. 1 site was the same as for the North Barrel Bluff. A more closely spaced grid was established in this area because it is currently being developed as a residential housing area. Two houses have already been constructed within the zone of suspected waste disposal.

Most of the South Barrel Bluff survey lines were oriented in a north-south direction at approximately 45-degree angles to the crest of the bluff. The lines were surveyed with both the conductivity meter and the magnetometer/gradiometer. Instrument readings were recorded at 25-foot intervals.

The locations of the survey lines are shown in Appendix I, Plate 3, Geophysical Anomaly Map, South Barrel Bluff Site.

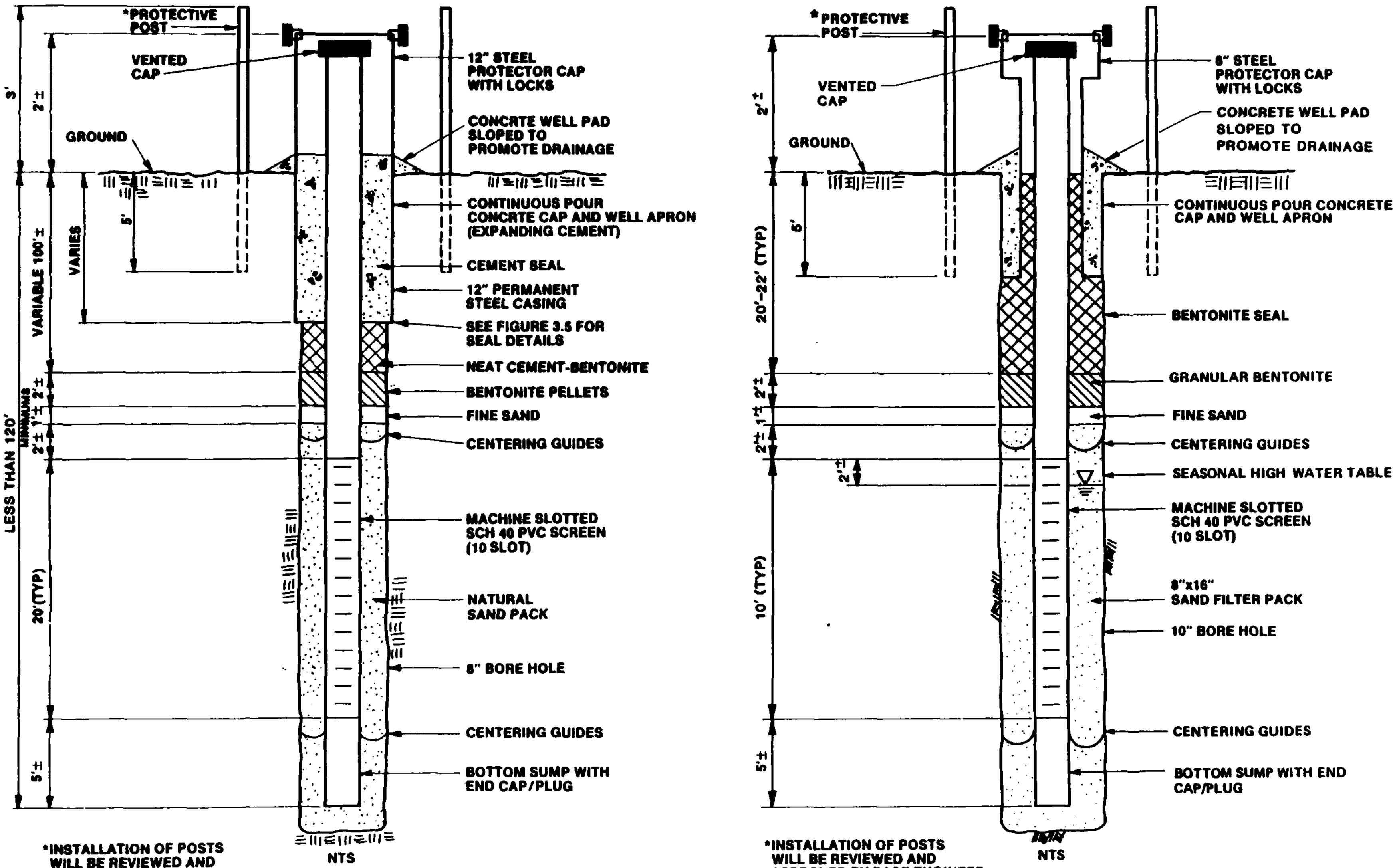
3.4 SUBSURFACE EXPLORATION AND MONITORING WELL CONSTRUCTION

The subsurface exploration was performed on November 4, 1987 through December 11, 1987 and on May 1, 1988 through June 10, 1988 by M-W Drilling, Inc. of Anchorage, Alaska, under the supervision of a qualified CH2M HILL geologist. Shallow borings were drilled with a truck-mounted Acker MP4 drilling rig equipped with 6-inch inside-diameter hollow-stem augers. Deep borings were drilled with a Schramm TA-60T truck-mounted air rotary drilling rig. Monitoring wells were constructed by M-W Drilling, Inc. under the supervision of a qualified CH2M HILL geologist. Monitoring well construction details are shown in Figure 3-3.

Initially, the subsurface exploration and monitoring well construction was scheduled to be completed in the fall of 1987. After the construction of 12 of the monitoring wells, work was suspended due to extremely cold weather and the nonavailability of an equipment decontamination area. The remainder of the work was completed in the spring of 1988.

Working in extremely cold weather presented unique problems such as:

- Organics in the soil did not volatize and therefore were not detected by the organic vapor analyzer (OVA).



*INSTALLATION OF POSTS WILL BE REVIEWED AND APPROVED BY BASE ENGINEER

4" MONITORING WELL

*INSTALLATION OF POSTS WILL BE REVIEWED AND APPROVED BY BASE ENGINEER

2" MONITORING WELL

FIGURE 3-3
TYPICAL MONITORING WELLS
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA
CH2M HILL

K24173.A0

- Removing frozen soil from the augers and drilling equipment approximately doubled the time required for decontamination.

- Water and bentonite slurry could not be brought to the drill site more than 10 to 15 minutes prior to use. Hoses and pumps had to be returned promptly to the heated decontamination area to avoid freezing and subsequent damage.

- During decontamination, the area became filled with steam, causing visibility problems. The doors to the area could not be left open because of the extreme cold.

Decontamination of the back of the drill rig, the augers and drill rods, soil sampling equipment, and all tools and equipment was done in accordance with the Statement of Work, Section 5.2.1.5 of the Work Plan and Section 1-7 of the QAPP. After completion of wells in visibly contaminated areas, all drilling equipment was washed with detergent prior to steam cleaning. (Detailed decontamination procedures are described in the QAPP, Section 1.7, and in the Sampling Plan.)

Subsurface soil samples were collected in accordance with the Statement of Work, Section 2.1 of the Work Plan, and Section 5.2.1.5 of the QAPP. Samples were collected at 5-foot intervals above the water table and at points of noticeable change in subsurface materials below the water table in all shallow borings.

Samples were obtained in general accordance with ASTM D1586, Penetration Testing and Split-Barrel Sampling. Exceptions were as follows:

- A 2-1/2-inch inside diameter sampler was used instead of a 1-3/8-inch inside diameter

- A 330-pound hammer was used instead of a 140-pound hammer

Samples were classified in general accordance with ASTM D2487. Sample classification and the results of the penetration test are shown in the boring logs presented in Appendix C-1.

Split-spoon samples were attempted in the deep borings but no samples were recovered because sample materials were primarily loose, saturated sands that could not be retained by the sampler. The sampler was pushed with the hydraulics on the drill rig instead of being driven with a hammer. Penetration test results were not obtained.

The split-spoon sampler was decontaminated in accordance with Section 2.1 of the Work Plan and Section 5.2.1.5 of the QAPP.

The monitoring wells were developed by bailing or pumping. Development of the wells continued until the temperature, pH, and specific conductivity measurements stabilized and turbidity was reduced. At least 10 well volumes of water were removed from each of the wells. Development records are provided in Appendix D-3.

Development water from wells suspected to be contaminated was collected in a 1,000-gallon water tank. Sampling and disposal of the development water is discussed under Section 3.9.1

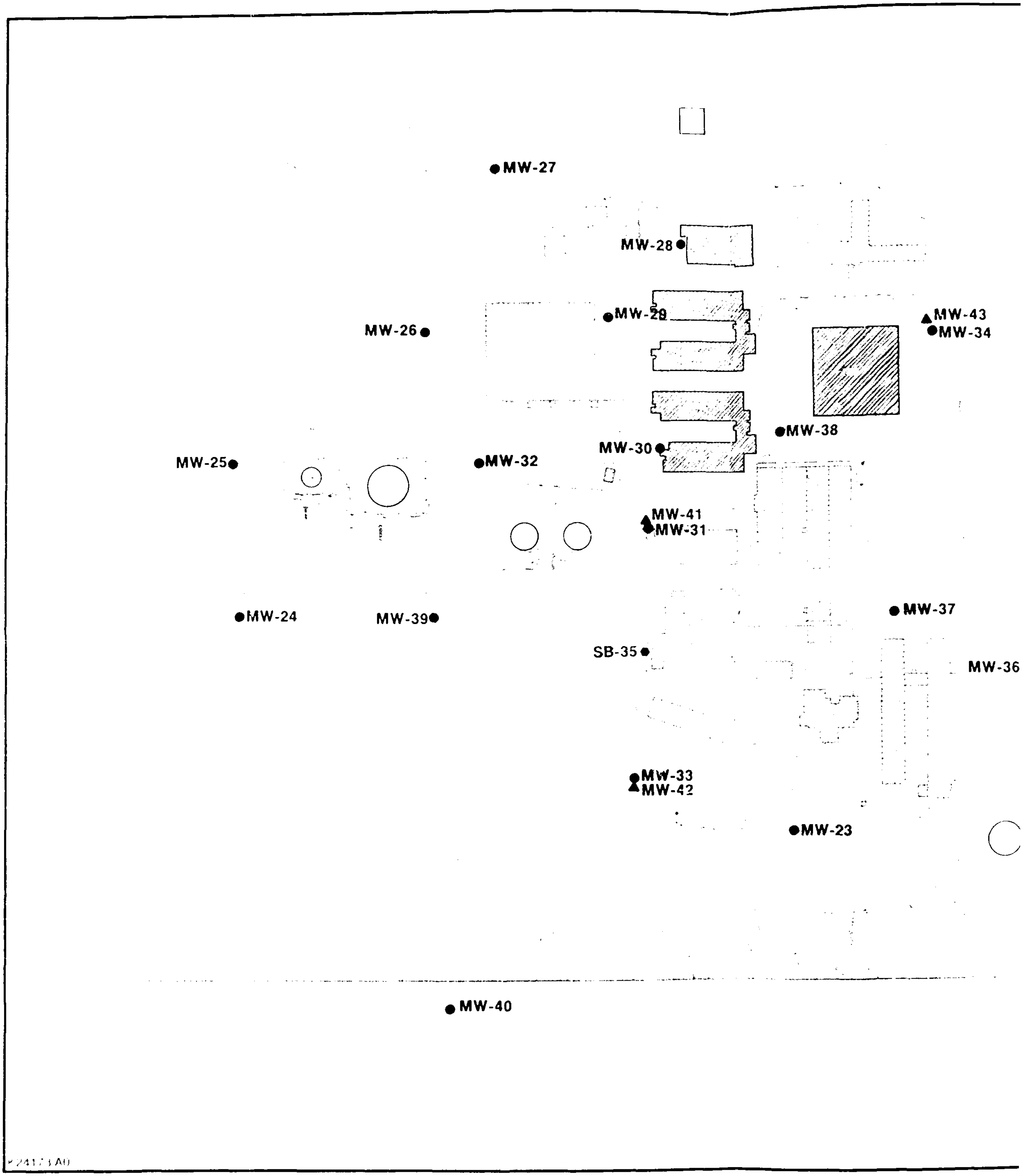
3.4.1 Eskimo Creek Seep

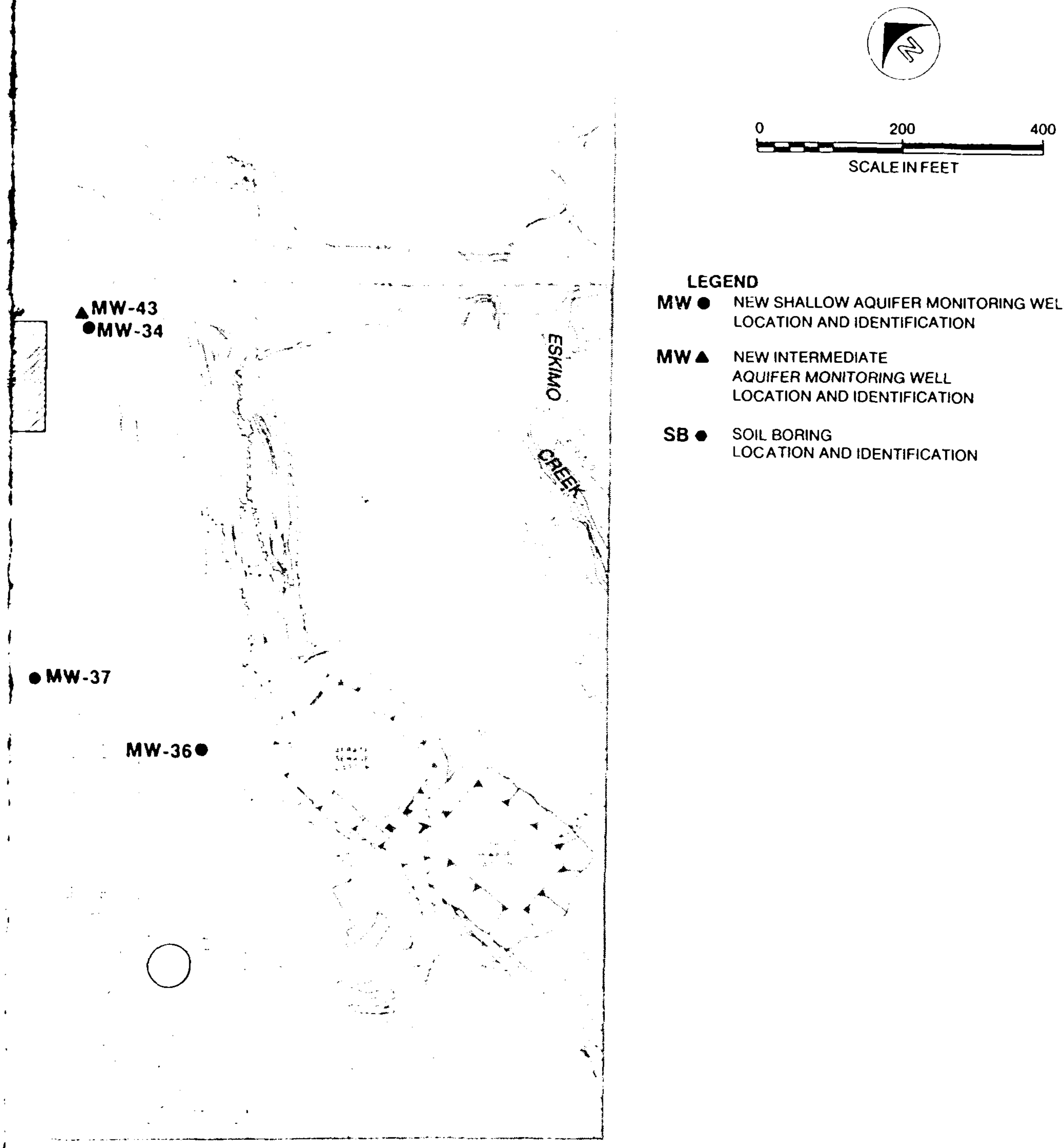
A total of 21 soil borings, 18 shallow and 3 deep, were drilled at the Eskimo Creek seep site. Monitoring wells were constructed in all of the soil borings except MW-35. When drilling the boring for MW-35, an abandoned fuel line was encountered. The boring was therefore abandoned. The locations of the monitoring wells are shown on Figure 3-4.

Shallow wells were constructed at the Eskimo Creek seep site in order to assess the extent of groundwater contamination in the upper aquifer and to further define the hydrogeology of the site. Deep wells were constructed for the purpose of exploring the intermediate aquifer for possible contamination. Deep wells were drilled next to shallow wells in order to determine the vertical gradient and assess the vertical extent of the contamination.

Initially, a shallow and deep well were to be constructed near both of the onsite production wells, KS4 and KS5. This nest of three wells, screened in the upper, intermediate, and deep aquifers, was intended to aid in determining the vertical gradients between the three aquifers. MW-31 and MW-41 were completed near KS5. A second nest was to consist of MW-35 and MW-42. However, during the drilling of MW-35, an abandoned 2-inch-diameter steel fuel line was encountered and ruptured at about 5 feet below the ground surface. The rupture was not discovered until the boring had been drilled to a depth of about 38 feet. The amount of fuel lost was estimated to be about 75 gallons. After base personnel were notified and the rupture repaired, the boring was abandoned by backfilling with tremied neat cement grout.

MW-42 was then moved to nest with MW-33. After completion of drilling at MW-42, the drilling subcontractor was unable to extract the temporary 8-inch-diameter casing. Because of


MW-27
MW-28
MW-29
MW-26
MW-43
MW-34
MW-38
MW-30
MW-25
MW-32
MW-41
MW-31
MW-24
MW-39
MW-37
SB-35
MW-36
MW-33
MW-42
MW-23
MW-40
P24173A0



LEGEND

MW ●	NEW SHALLOW AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION
MW ▲	NEW INTERMEDIATE AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION
SB ●	SOIL BORING LOCATION AND IDENTIFICATION

FIGURE 3-4

ESKIMO CREEK SEEP
NEW GROUNDWATER
MONITORING WELL AND
SOIL BORING LOCATIONS
JUNE 1988
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

damage to the end of the 8-inch casing during drilling of MW-41 without a drive shoe, the drilling subcontractor welded a drive shoe to the 8-inch casing prior to beginning drilling of MW-42. The difficulty in extracting the temporary 8-inch casing may be attributed to the drive shoe. A tool designed to cut the drive shoe from the casing was air freighted from Anchorage, Alaska. Attempts to cut the drive shoe off were unsuccessful. The drilling subcontractor still could not extract the casing even when using jacks capable of delivering 300 tons of lifting force to the casing. A joint decision between the CH2M HILL project hydrogeologist and OEHL was made to construct the well inside of the 8-inch casing. Well construction details for MW-42 are shown in the well construction log in Appendix C-1.

As specified in the Statement of Work, cuttings from MW-30, MW-31, MW-39, MW-40, MW-41, and MW-43 were contained in drums in compliance with Test Methods for Evaluating Solid Waste Physical/Chemical Methods, SW-846, 3rd Edition (US EPA, 1986). Cuttings from these wells showed visible signs of contamination and significant levels of contamination were indicated by the organic vapor analyzer.

3.4.2 Naknek River Seep

No borings or wells were completed at this site.

3.4.3 North Barrel Bluff

No borings or wells were completed at this site.

3.4.4 South Barrel Bluff

No borings or wells were completed at this site.

3.5 MONITOR WELL PROTECTIVE CASINGS, AND GUARD POSTS

Six-inch-diameter, locking, steel protective casings were cemented in place around the top of each 2-inch-diameter monitoring well. The protective casings extend to a depth of 3.5 feet below ground surface in MW-23 through MW-26 and to a depth of 5 feet below ground surface for the remaining monitoring wells. This additional depth was recommended due to the potential frost heave problems.

Monitoring well protective casings for MW-23 through MW-26 originally extended to a depth of 1 foot below ground surface. Frost heave damage was observed in the Spring of 1988. The protective casings had become loose and unstable. These protective casings were removed and reset at a 3.5-foot depth in 1988. The contractor was unable to remove concrete belo a depth of about 3.5 feet. Damage due to frost heave may still occur at these wells. To minimize damage, the PVC well casing was wrapped with polytheylene sheeting to prevent the concrete from adhering to the well casing.

During placement of the concrete for the surface seal and protective casing installation, a 2-foot by 2-foot cement surface pad was also constructed, using temporary forms to shape the concrete pads.

Three guard posts were installed around each well where vehicular damage was considered probable by the King Salmon AFS Point of Contact. The guard posts were constructed from 3-inch-diameter steel pipe. The pipe was placed in a 5-foot hole and backfilled with concrete. Approximately 2.5 feet extended above the ground surface. The pipes were then filled with concrete.

Five guard posts were placed around the three shallow-intermediate monitoring well nests.

Twelve-inch-diameter, locking, steel protective casings were placed around each 4-inch-diameter monitoring well. These protective casings also serve as a component of the aquifer seal and extend to depths ranging from 35 to 52 feet. Protective casings were painted bright yellow with the monitoring well identification painted on in black on the side of the protective casing.

3.6 CONSTRUCTION OF AQUIFER SEAL FOR DEEP MONITORING WELLS

Two King Salmon AFS production wells are located in the vicinity of shallow aquifer wells in which floating fuel product has been detected. Intermittent pumping of the production wells may result in a hydraulic head reduction in the deep wells, potentially causing downward leakage of these contaminants into lower aquifers. To determine whether there has been vertical movement of these contaminants from the shallow aquifer into deeper aquifers, three deep monitoring wells were installed at the King Salmon AFS site. These wells were screened in an intermediate aquifer that lies between the shallow aquifer and the deep aquifer in which the production wells are screened. To minimize the potential for migration of contaminants down the well during the installation procedure and after the installation was complete, an aquifer seal was constructed in the upper aquitard that lies between the shallow and intermediate aquifers. Figure 3-5 depicts the construction of the aquifer seal.

The construction of the aquifer seal was perfo[illegible] using the following methodology. A 12-inch-diameter cased borehole was advanced through the shallow aquifer into the upper aquitard. Drill cuttings from the upper aquitard were monitored for the presence of organic vapors using an OVA and/or HNU photoionization detector. The OVA was calibrated to methane

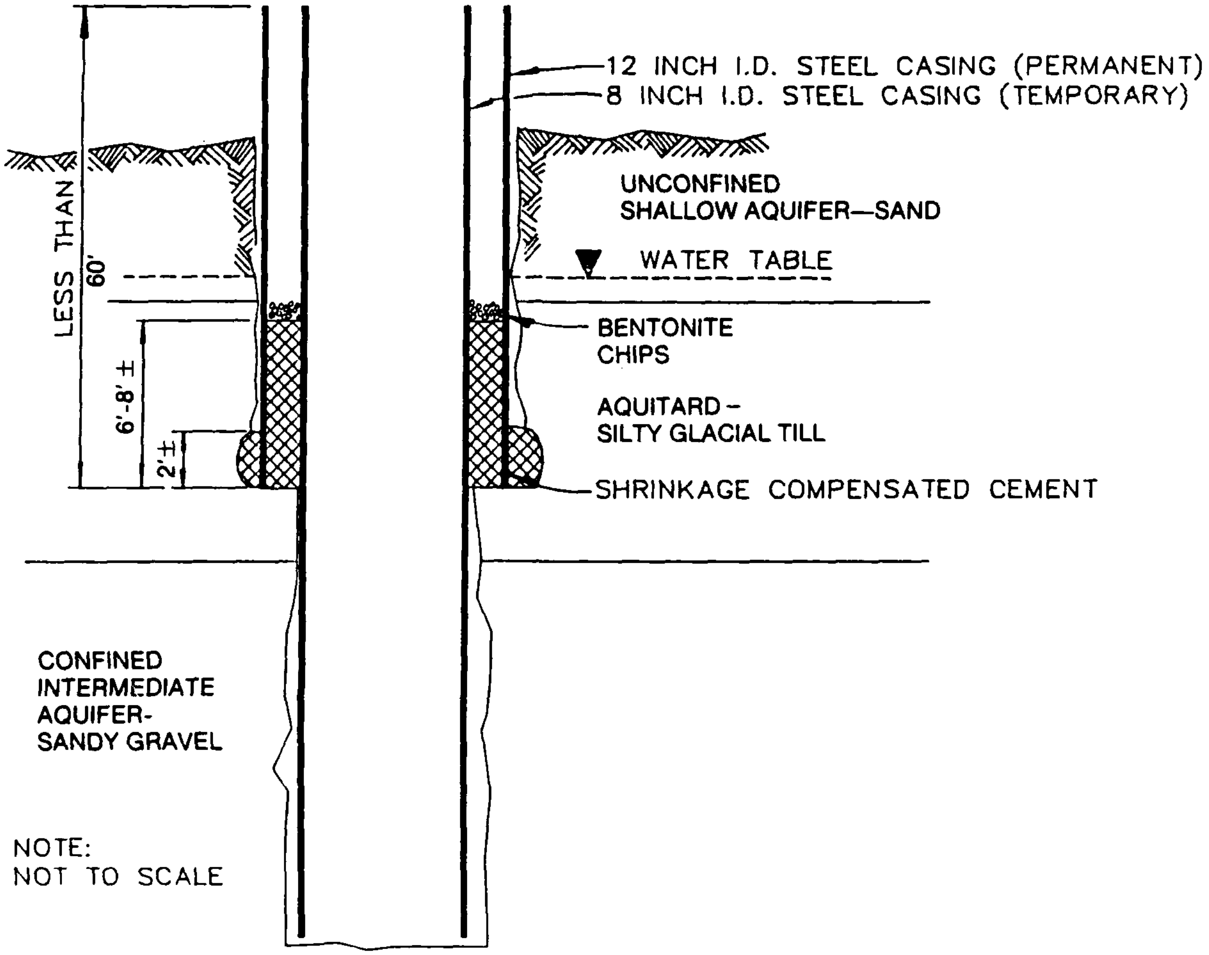


FIGURE 3-5

AQUIFER SEAL CONSTRUCTION DIAGRAM

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

K24173.A0

CH2M HILL

equivalents and the HNU was calibrated to benzene equivalents. The 12-inch-diameter cased borehole was advanced into the upper aquitard to a final depth at which OVA or HNU measurements on drill cuttings no longer indicated the presence of organic constituents.

The 12-inch borehole was then overreamed below the cased portion of the borehole creating a larger-diameter borehole. The overreaming was completed to a depth approximately 2 feet below the bottom of the 12-inch casing. The borehole was then dewatered and the drill bit and drill pipe removed from the hole. A shrinkage-compensated cement mixture consisting of the following components by approximate percent weight: water 33 percent, Portland Cement 61 percent, gypsum 5 percent, and bentonite 1 percent, was mixed and tremied into the bottom of the borehole. This sealing mixture typically filled the borehole from the bottom to a depth of 6 to 8 feet. After the sealing mixture was tremied into place, the 12-inch casing was advanced into the overreamed portion of the borehole. The seal was then allowed to stabilize for approximately 12 hours.

Construction of the 8-inch borehole then proceeded inside of the 12-inch casing. At total depth, the 4-inch well was built inside the annular space.

Upon completion of the monitoring well, the 8-inch casing was removed and the 12-inch casing left in place.

3.7 SURVEYING

At the conclusion of the Stage 1 field effort, all newly installed monitoring wells, existing USCOE wells, landfill wells, and the two King Salmon AFS production wells were surveyed for horizontal location and elevation to the King Salmon AFS site datum.

The surveying was performed by Coastal Surveyors/Ralph Mancuso and Associates, Naknek, Alaska. Locations for each monitoring well were established by measuring horizontal and zenith angles using an electronic theodolite, and measuring ground distances using electronic distance measuring equipment. Angles and distances were measured between points of known location and each monitor well location. This data was then trigonometrically transformed using standard survey data reduction techniques into a north and east coordinate location. Coordinate locations are given to the nearest 0.01 of a foot.

Elevations were determined for each monitoring well at a position marked at the top of the well casing. Elevation differences between known points and each monitoring well were measured using a differential leveling technique. The elevation differences were then arithmetically summed to obtain the measuring point elevation for each well. Elevations were calculated to the nearest 0.01 of a foot.

A coordinate and elevation listing for the King Salmon AFS monitoring wells is provided in Appendix E.

3.8 SAMPLING PROGRAM

The surface water and sediment sampling began on October 28, 1987, and was completed on November 2, 1987. Groundwater sampling began on June 5, 1988, and was completed on June 17, 1988. All sampling was performed by trained, experienced CH2M HILL personnel. The location, type of analyses, and number of samples were specified in the SOW. The actual number of samples collected at each site is summarized in Table 3-1, Number of Analyses by Site.

Sampling methodology and protocols are indicated on the analytical reports, in Appendix G, Analytical Data. Sample preservation methods, required containers, and holding times are shown in Table G-2, also in Appendix G.

Sampling was done in accordance with Annex C of the Statement of Work, Sections 1.5, 1.6, and 1.7 and Appendix A, Project Sampling Plan, of the Quality Assurance Project Plan, and Sections 5.2.1.4 and 5.2.1.5 of the Project Work Plan. Exceptions were as follows:

- A stainless steel bailer with a teflon ball valve was used to sample the USCOE wells. A 1-inch-diameter teflon bailer was not available. The use of the stainless steel bailer should have no affect on the results of the analyses performed on samples from the USCOE wells.

- Sampling of MW-6 and MW-23 was not performed immediately after purging. These wells were purged dry and were allowed to recover overnight prior to sampling. MW-1 did not recover after purging and was not sampled.

Samples were shipped under full chain-of-custody procedures by air freight to the laboratory. Copies of the completed chain-of-custody forms are included in Appendix F, Chain-of-Custody Forms.

Field quality assurance/quality control samples were as specified in Statement of Work, Appendix B, and in Section 1.4 of the QAPP. Exceptions were as follows:

- Trip blanks were not sent with every cooler containing volatile organic compound samples. Had this

Table 3-1
NUMBER OF ANALYSES BY SITE

Parameter	Analytical Method	Eskimo Creek	USCOE Well	Naknek River Seep	North Barrel Bluff	South Barrel Bluff	Offsite Well	Development Water
Water Samples								
Alkalinity - Carbonate, Bicarbonate, & Hydroxide (Field Test)	A403	23	7	1	3	3	--	--
Common Anions (Chloride, Fluoride, Nitrate, Sulfate, Orthophosphate)	A429	23	7	1	3	3	--	--
Specific Conductance (Field Test)	E120.1	23	7	1	3	3	--	--
pH (Field Test)	E150.1	23	7	1	3	3	--	--
Total Dissolved Solids	E160.1	23	7	1	3	3	--	--
Temperature (Field Test)	E170.1	23	7	1	3	3	--	--
Lead	SW3005/ SW7421	23	7	--	--	--	--	2
Metal Screen (25 metals)	E200.7	2	0	1	3	3	1	--
Petroleum Hydrocarbons	E418.1	21	7	--	--	--	--	--
Purgeable Halocarbons	E601	2	--	1	3	3	1	--
Organochlorine Pesticides	E608	--	--	--	3	3	1	--
Extractable Priority Pollutants	E625	--	--	--	3	3	1	--
Purgeable Aromatics	SW5030/ SW8020	16	--	1	3	3	1	2
Soil Samples								
Petroleum Hydrocarbons	SW3550/ E418.1	18	--	--	--	--	--	--
Organochlorine Pesticides and PCBs	SW3550/ SW8080	--	--	--	3	--	--	--
Volatile Organic Compounds	SW5030/ SW8240	5	--	--	3	--	--	--
EPTOX Metals	40 CFR 261.24	5	--	--	--	--	--	--
Semivolatile Organic Compounds	SW3550/ SW8270	5	--	--	3	--	--	--
Soil Moisture Content	ASTM D2216	23	--	--	3	--	--	--

CVR193/041

been done, the number of analyses would have exceeded the maximum number of analyses specified in Tables A-4 and A-5 of the Statement of Work.

- Equipment blanks were not collected for every day of groundwater sampling. Had this been done, the number of analyses would have exceeded the maximum number of analyses as specified in Tables A-4 and A-5 of the Statement of Work. Decontamination and sampling procedures were consistent throughout the groundwater sampling program. The results of the analyses on the equipment blanks are likely to be representative.

3.8.1 Sampling of Drummed Soil Cuttings and Development Water

In accordance with the Statement of Work, Section 5.2.1.5 of the Work Plan and Section 2.2 of the QAPP, the drums containing contaminated cuttings from the soil borings were sampled and tested for EP Toxicity Metals 40 CFR 261.24, volatile organic compounds, and semivolatile organic compounds. Exceptions were as follows:

- The drilling subcontractor supplied ten new DOT approved drums. Additional drums were obtained, with permission, from the King Salmon AFS Point of Contact. These drums had been used but appeared to be clean and in good condition. If the contents must be disposed of as hazardous waste, they may have to be transferred to new drums prior to shipment.

- Composite samples, one from each drum were not collected. In all, 21 drums were filled with contaminated soil from MW-30, MW-31, MW-38, MW-39, MW-41, and MW-43. Each drum could not be sampled without exceeding the maximum number of analyses (5) as specified in Table A-5 of the Statement of Work. If the drums must be disposed of as hazardous waste, the cost of retesting each drum within a group should be compared with the cost of disposing of all the drums. One highly contaminated drum within a group may indicate that the whole group must be disposed of as hazardous waste.

The drums from each well were grouped into one of five groups. Drums from MW-31 and MW-41 were grouped together because these two well are less than 10 feet apart. One composite sample for each group for a total of five samples was prepared. Drums were sampled by compositing discrete samples taken from the top to the bottom of each drum. The composite sample from each drum was composited with other samples collected from drums in the same group to form one composite sample per group of drums. The results of the analyses are presented in Section 4.1.4, Soils Investigation. The soils were determined not to be RCRA hazardous waste and were transferred to base engineering for ultimate disposal.

In accordance with the Modification to the Statement of Work, the development water was sampled and tested for purgeable aromatic compounds and lead. As discussed in Section 3.4, the development and purge water was contained in a 1,000-gallon water tank. After the tank was full, the water was sampled by dropping a 5-foot length of tygon tubing through the opening at the top of the tank. After the tube had filled, the top of the tube was plugged and the tube withdrawn. Care was taken to avoid sampling the sediment in the bottom of the tank or the floating product. The results of the analyses are presented in Appendix G, Analytical Data.

3.9 LABORATORY PROGRAM

All analyses were conducted in accordance with the standard methods specified in the Statement of Work. The CH2M HILL environmental laboratory in Corvallis, Oregon, was responsible for overall sample handling, custody, and documentation for the samples collected in the fall of 1987. The CH2M HILL environmental laboratory in Redding, California, was responsible for the samples collected in the spring of 1988. Analyses for total petroleum hydrocarbons were subcontracted to Technical Services, Inc., in Jacksonville, Florida.

Laboratory quality assurance/quality control data are presented in Appendix G, Analytical Data.

CVR193/017 (pc)

IV. RESULTS AND SIGNIFICANCE OF FINDINGS

4.1 DISCUSSION OF RESULTS

4.1.1 Soil Gas Investigation

This section summarizes the results of the soil gas investigation performed at the Eskimo Creek seep and Naknek River seep sites. The soil gas report is attached as Appendix I.

4.1.1.1 Eskimo Creek Seep

Maps showing soil gas sampling locations and concentrations for total hydrocarbons (Figures 3-1 and 4-1) are attached. Total hydrocarbon values represent the C3-C9 range reported in the attached soil gas report. This range is a hydrocarbon group that is analyzed by Tracer Research and is a function of the calibration of their flame ionization detectors.

Figure 4-1 indicates the distribution of total hydrocarbons in the soil gas. The highest concentration detected was at sampling location SG-6 (820 µg/l total), northeast and east of POL Tanks 11 and 12.

The extent of contamination from this point appears to include an area southwest of the tanks (west soil gas plume) and a much larger area southeast that includes the Eskimo Creek seep (east soil gas plume). This plume can be traced from the POL tanks through the center of the station to the Eskimo Creek seep. The plume also includes a large area that extends north of the Eskimo Creek seep.

Isolated areas of contamination around sampling locations SG-40, SG-41, and SG-25 appear to be unrelated to the main soil gas plumes. These locations may be isolated sources of groundwater or soil contamination from historically different events.

4.1.1.2 Naknek Seep

Two soil gas samples were analyzed at the Naknek seep (Figure 4 in Appendix I). Sample SGNS-1 located near the Naknek River bank showed a concentration of 2,200 µg/l total hydrocarbons. Sample SGNS-2 was located approximately 400 feet from the riverbank and did not contain detectable hydrocarbons (<0.03 µg/l). Three additional probes located along the abandoned pipeline between the station and Naknek River seep were also at less than detection levels.

4.1.2 Geophysical Investigation

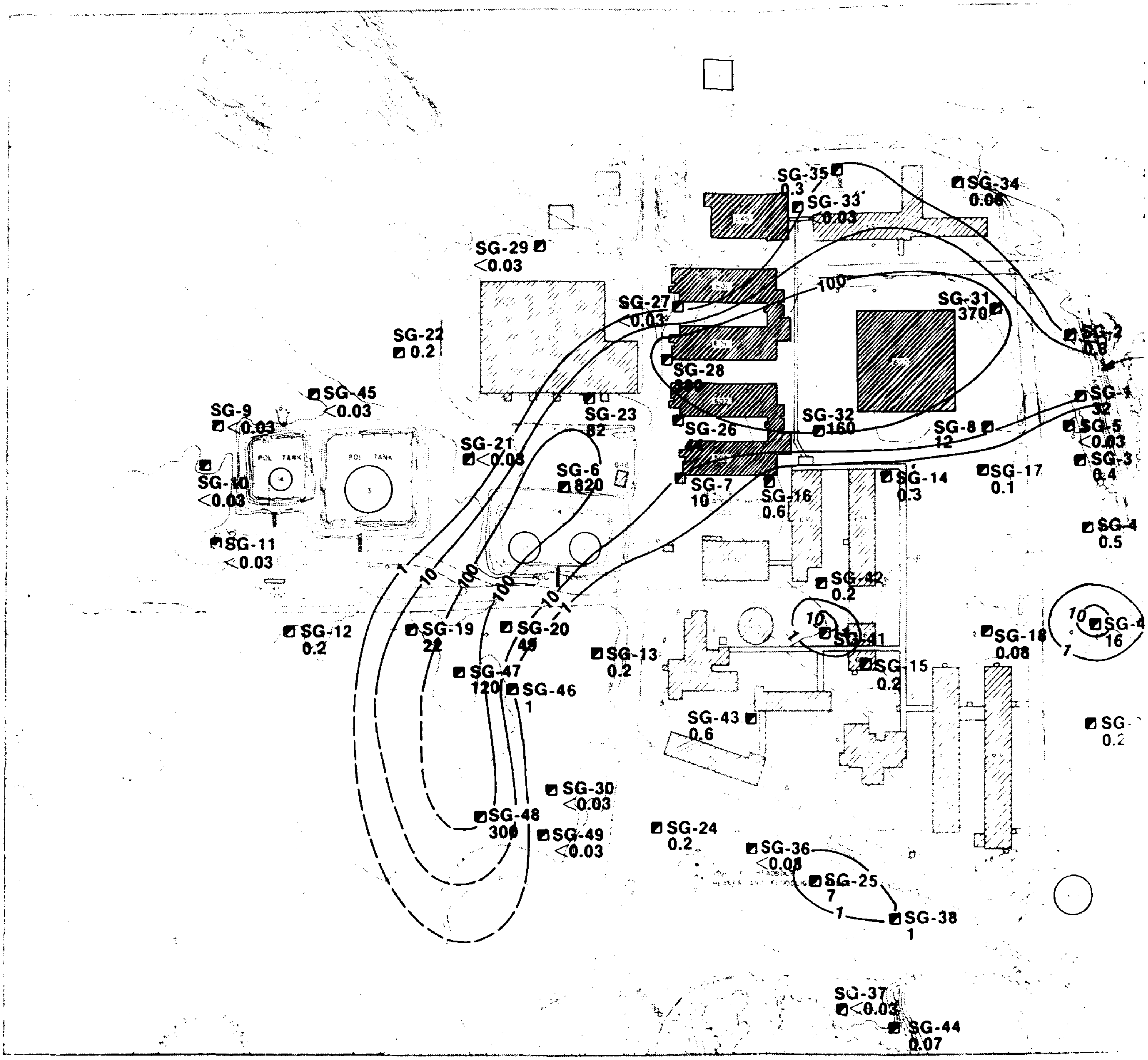
This section summarizes the results of the 10-day reconnaissance geophysical investigation conducted at King Salmon AFS. Four sites--Eskimo Creek seep, Naknek River seep, North Barrel Bluff, and South Barrel Bluff--were surveyed using combinations of electromagnetic conductivity, ground penetrating radar (GPR), and magnetics. The report is attached as Appendix I. Results for each site are described below.

4.1.2.1 Eskimo Creek Seep

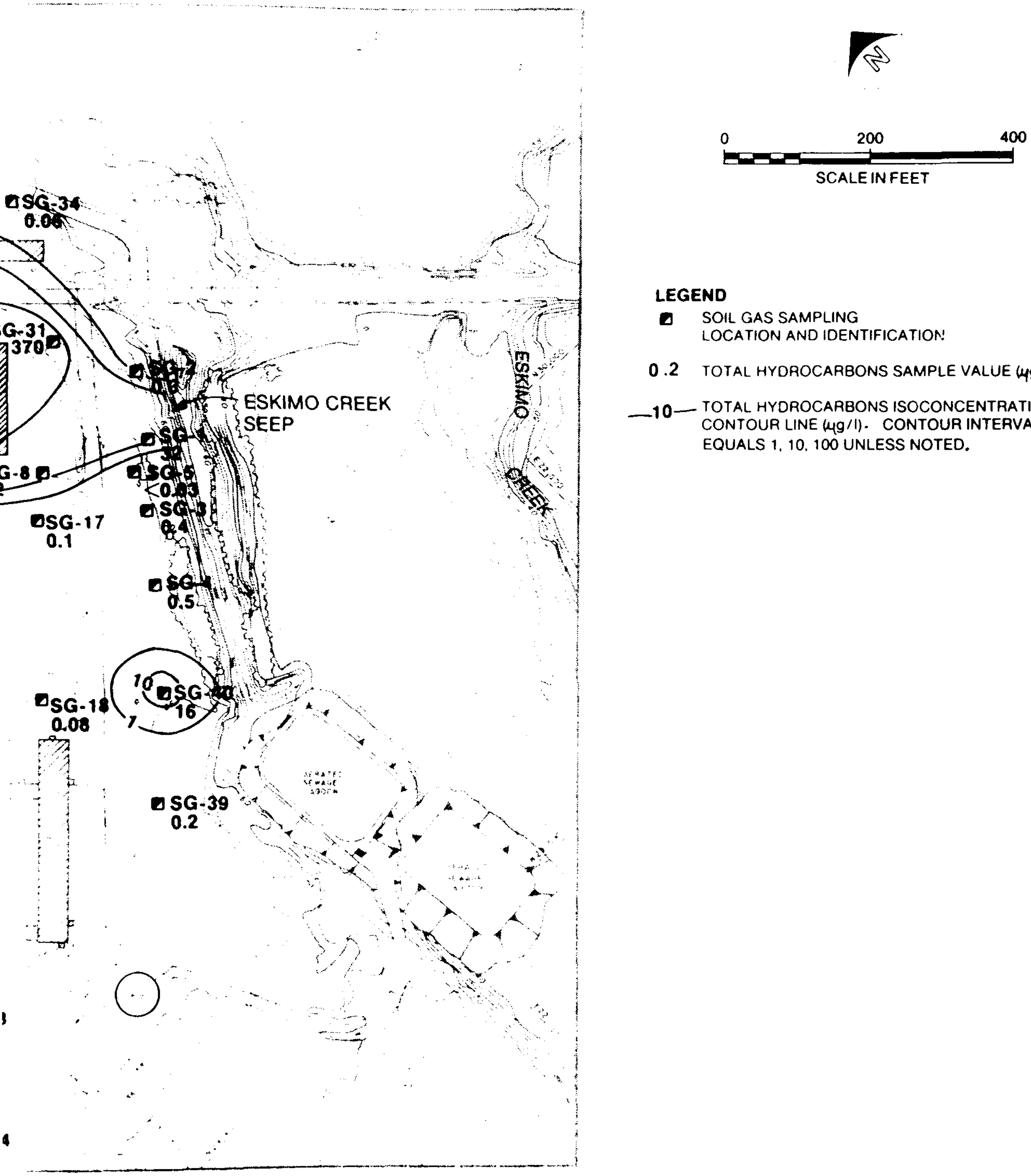
The detailed GPR grid survey over a former service station site (in the vicinity of Buildings 636, 632, and 624) failed to yield any strong radar reflections characteristic of a buried tank. A few hyperbolic reflections were identified, but these are believed to be caused by buried utilities rather than a large buried tank. The locations of these radar targets are indicated in Plate 4 (Appendix I), as well as on the radar records in Plates 15-26. Of these targets, the reflection most suggestive of a buried tank is a target about 10 feet in depth at Station 113N on Line 80E (Plate 23). This feature lies in the center of a 20-foot-wide zone suggesting trenching or disturbance, and Line 70E (Plate 22) just 10 feet to the west shows evidence of a subsurface slab that may be a concrete slab.

A ground penetrating radar (GPR) survey grid was conducted along soil gas probe transects on the Eskimo Creek seep bluff in the hope of providing useful soils data to correlate with the soil gas analyses. Cases are reported in the literature where it has been possible to detect the presence of hydrocarbon contamination in soils by observing a change in the character or "texture" of the GPR records caused by a contrast in subsurface dielectric properties in the zone of contamination. There have also been some sites where petroleum products floating on the water table have resulted in particularly strong radar reflections ("bright spots") at the water table depth.

The Headquarters Area GPR records were searched for changes in reflection signal "texture" that might be indicative of zones of contamination, particularly in the areas that indicated high soil gas hydrocarbon concentrations. Such GPR contrasts were not observed. Neither were strong water table reflections observed that might be indicative of the presence of hydrocarbons; over most of the site the water table was apparently deeper than the maximum effective penetration of the GPR signal (about 20 feet). Below that depth, no coherent returns appear on the GPR profiles, only noise and signal reverberations are present.


SG-35 0.3
SG-34 0.06
SG-33 <0.03
SG-29 <0.03
SG-27 <0.03
100
SG-31 370
SG-2 0.6
SG-22 0.2
SG-28 330
SG-45 <0.03
SG-9 <0.03
SG-23 82
SG-26 48
SG-32 160
SG-8 12
SG-1 32
SG-5 <0.03
SG-21 <0.03
SG-3 0.4
SG-10 <0.03
POL TANK
SG-6 820
SG-7 10
SG-16 0.6
SG-14 0.3
SG-17 0.1
SG-4 0.5
SG-11 <0.03
1
10
100
100
10
1
SG-42 0.2
10
1
SG-41
SG-12 0.2
SG-19 22
SG-20 48
SG-13 0.2
SG-18 0.08
10
SG-4 16
1
SG-47 120
SG-46 1
SG-15 0.2
SG-43 0.6
SG- 0.2
SG-30 <0.03
SG-48 300
SG-49 <0.03
SG-24 0.2
SG-36 <0.03
SG-25 7
1
SG-38 1
SG-37 <0.03
SG-44 0.07

4173 A0



LEGEND

▨	SOIL GAS SAMPLING LOCATION AND IDENTIFICATION
0.2	TOTAL HYDROCARBONS SAMPLE VALUE (µg/l)
—10—	TOTAL HYDROCARBONS ISOCONCENTRATION CONTOUR LINE (µg/l). CONTOUR INTERVAL EQUALS 1, 10, 100 UNLESS NOTED.

FIGURE 4-1

ESKIMO CREEK SEEP
SOIL GAS
TOTAL HYDROCARBONS
ISOCONCENTRATION
CONTOURS
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

4.1.2.2 Naknek River Seep

The results of the reconnaissance geophysical profiling near the Naknek River seep are summarized in Figure 2 of Appendix I. This area was targeted because partially buried drums were identified. Profile plots of the electromagnetic and magnetic data and listings of the data are provided in Appendix I.

The location of the anomalies indicative of major disposal suggest that drums are buried throughout the western end of the site, although additional profiling over a more thorough grid would be required to confirm this interpretation. Lines 100W, 300W, and 500W were surveyed to investigate suspicious cleared areas at the north side of the site, which were thought to possibly contain buried tanks. No metallic features were identified.

4.1.2.3 North Barrel Bluff

At North Barrel Bluff most of the waste disposal was confined to a narrow strip along the bluff edge, extending south no more than 50 to 100 feet. The grid of geophysical lines surveyed is summarized in Plate 2 of Appendix I. All lines were surveyed using both a terrain conductivity meter and a magnetometer. Selected lines were surveyed with ground penetrating radar.

The rumors of major burial pits extending hundreds of feet back from the bluff are not supported by the geophysical data. Lines 1100W and 634S extended well into the zones of surface disturbance evident on aerial photographs of the site, but no geophysical evidence of major debris burial was found. The baseline was also extended to the west so that a complete transect to the west end of the bluff could be obtained. No evidence of waste burial was observed along this profile.

Two additional areas across which reconnaissance profiles were surveyed did provide some evidence of waste disposal. Line MP-1 (Plate 2 of Appendix I) indicated that the disturbed area southeast of the South Barrel Bluff-North Barrel Bluff road does contain a substantial amount of metallic debris.

The two reconnaissance lines surveyed in the reported disposal area northeast of the school district building (Lines MP-2 and MP-2X, Plate 2) showed little evidence of waste disposal. Rapid profiling of this general area with a terrain conductivity meter indicated scattered occurrences of waste material, but not a large debris area. Additional work would be required in this area in order to determine if a large disposal pit exists.

The primary objective of delineating the extent of the major disposal areas at the North Barrel Bluff site was accomplished. The geophysical data provided little direct information toward the secondary objectives of exploring subsurface soil conditions outside the debris boundaries and searching for indications of possible contaminant plumes. Outside the disposal areas, both electromagnetic and magnetic data indicate that uniform soil conditions, as measured by those techniques, exist. The magnetic field data indicated higher total field readings on the terrace above the bluff than down on the flood plain of King Salmon Creek as illustrated by Line 1900W (Figure B4). This suggests that the outwash sands that comprise the terrace are possibly volcanic in origin and contain a significant proportion of magnitite.

4.1.2.4 South Barrel Bluff

The geophysical survey results for the South Barrel Bluff site are summarized in Plate 3 of Appendix I. All lines were surveyed using both the terrain conductivity meter and the magnetometer/gradiometer. In addition, Lines 421E and 500E were also profiled using the ground penetrating radar system.

Beginning at the west end of the South Barrel Bluff site, Lines 548S and 312W were surveyed across a cleared rectangular area, which is identified as "Landfill No. 1" in the presurvey report. The geophysical results indicated very little waste disposal on this portion of the site, except for some disturbance in the vicinity of a reinforced concrete foundation structure.

Plate 3 of Appendix E shows that most of the major waste disposal has apparently been concentrated between Lines 300E and 1280E. The two houses are apparently situated in close proximity to the waste disposal. Local residents report encountering debris when installing septic systems and drilling domestic water wells at these residences (the septic systems and wells are located adjacent to the houses).

A local contractor reported a disposal site between the main road and the bluff just east of the houses. A relatively closely spaced grid of geophysical lines was surveyed in this area to search for this reported deposit [Lines 1280E, 1380E, 1458E, 75N, and 100N (extension)]. The geophysical profiling indicated that the waste disposal in this area is confined to a former gully that cuts through the bluff (Plate 3 of Appendix E, Lines 1458E, 75N, and the Base Line). The geophysical results suggest that the material was deposited in the gully and covered over.

4.1.2.5 Conclusions of the Geophysical Investigation

The use of the electromagnetic conductivity and ground magnetic geophysical techniques proved to be very effective as rapid reconnaissance methods for delineating the limits of major waste disposal areas at the North Barrel Bluff site, the South Barrel Bluff site, and Naknek River seep. More precise definition of the boundaries of the disposal zones could be achieved at a future date by surveying profiles at a closer line spacing.

Geophysical profiling in the Eskimo Creek seep area using the ground penetrating radar was not successful in identifying the source of contamination at the Eskimo Creek seep. Further general profiling is not recommended in this area, although the GPR would be useful at this site for searching for specific targets such as utility lines, buried tanks, or drilling hazards associated with installation of groundwater monitoring wells.

4.1.3 Hydrogeologic Investigation

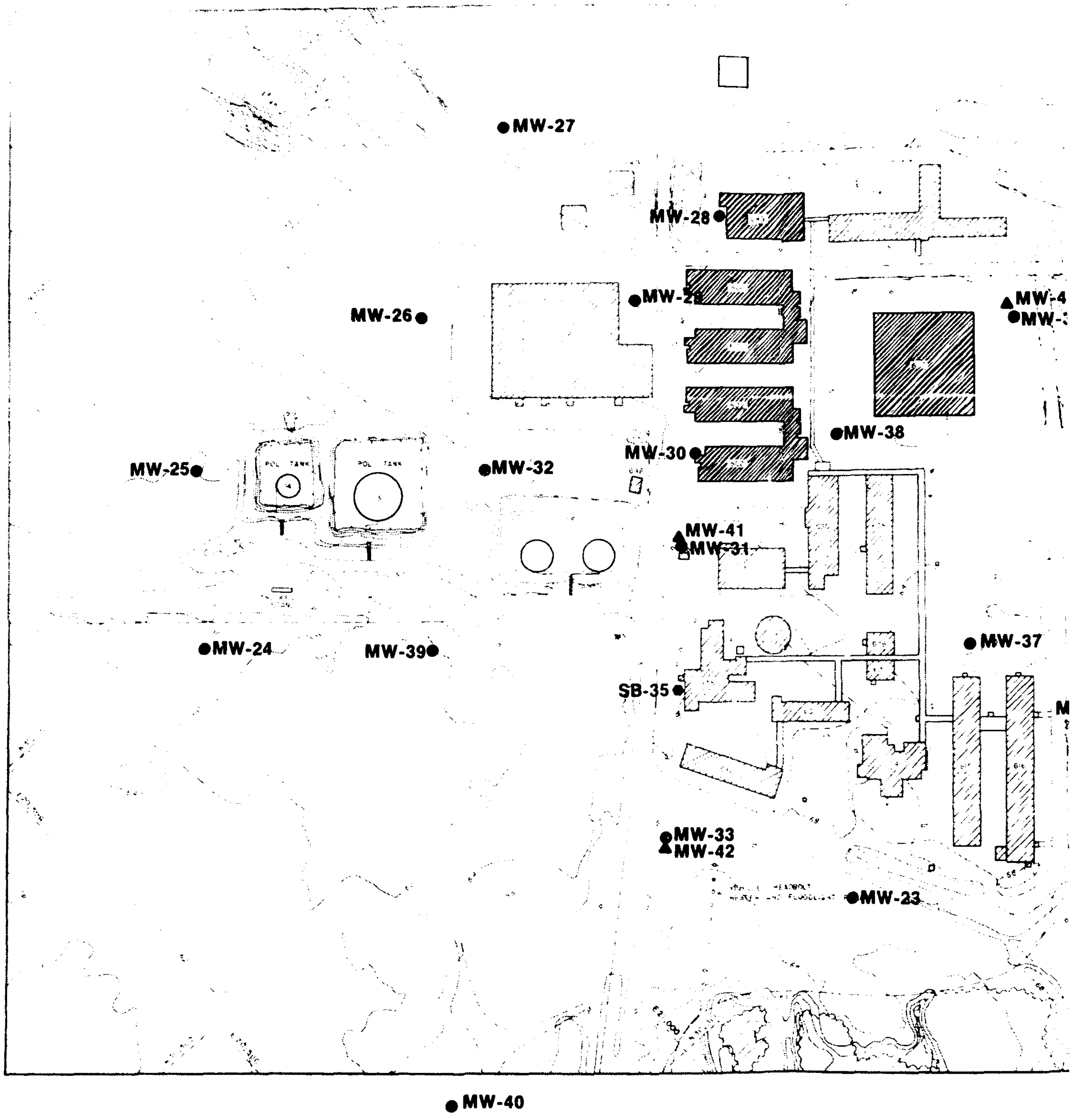
The current understanding of the site-specific geology for the Eskimo Creek seep and Barrel Bluff Areas is based on information from four investigations:

- Corps of Engineers oil contamination exploration, 1978
- Existing well logs (base and local residential)
- Corps of Engineers foundation report, 1985
- IRP Stage 1 investigation, CH2M HILL 1987-88

Boring logs from these investigations are presented in Appendix C-5. Well locations are presented in Figures 4-2 and 4-3 and well details are presented in Table 4-1. At the conclusion of the Stage 1 field investigation, existing wells completed during earlier investigations (whose location could be determined) were surveyed for horizontal location and vertical elevation. Each new well installed during this period also was surveyed. A summary of well coordinates and elevations is provided in Appendix E. The new survey indicates that several of the existing Corps well elevations previously reported on well logs were incorrect.

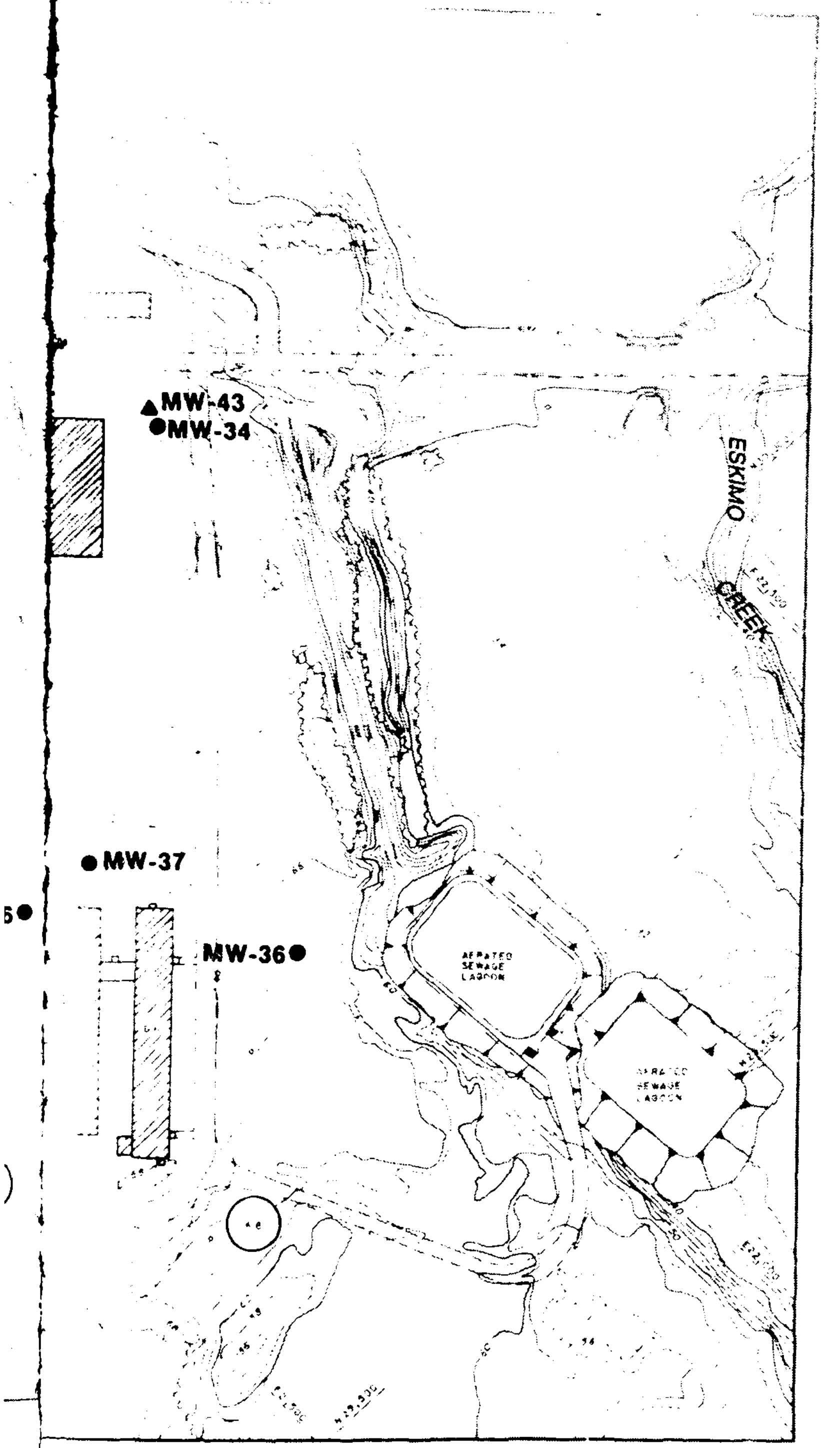
4.1.3.1 Geology

Site stratigraphy is illustrated in two cross sections. Figure 4-4 shows the locations of the cross sections and boring logs are presented in Appendix C-5. Section A-A' (Figure 4-5) illustrates the geology from northwest to south-


MW-27
MW-28
MW-29
MW-26
MW-4
MW-
MW-38
MW-30
MW-25
POL TANK
POL TANK
MW-32
MW-41
MW-31
MW-24
MW-39
MW-37
SB-35
M
MW-33
MW-42
MW-23
MW-40

K24173.A0

A



LEGEND

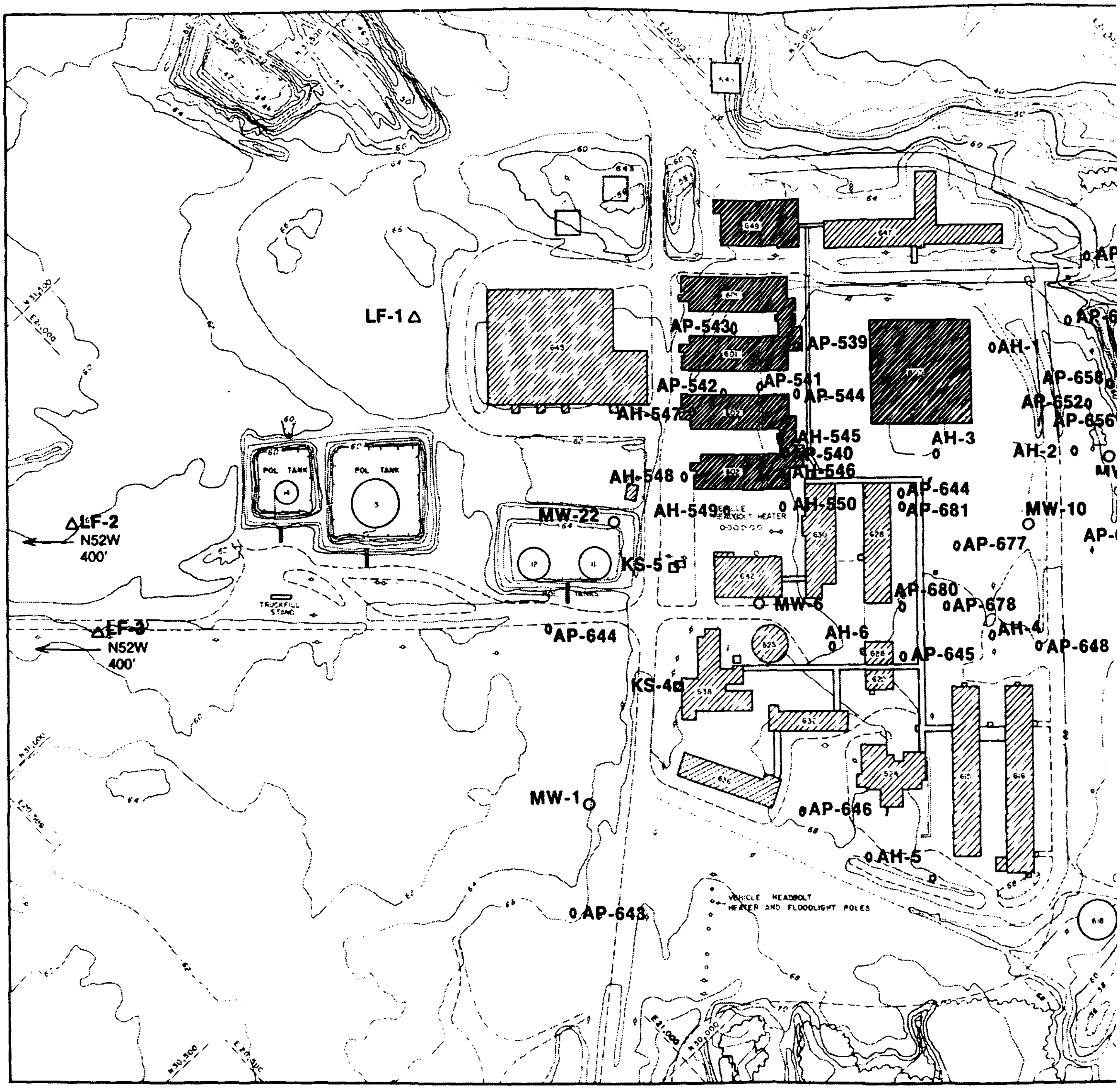
MW ●	NEW SHALLOW AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION
MW ▲	NEW INTERMEDIATE AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION
SB ●	SOIL BORING LOCATION AND IDENTIFICATION

FIGURE 4-2

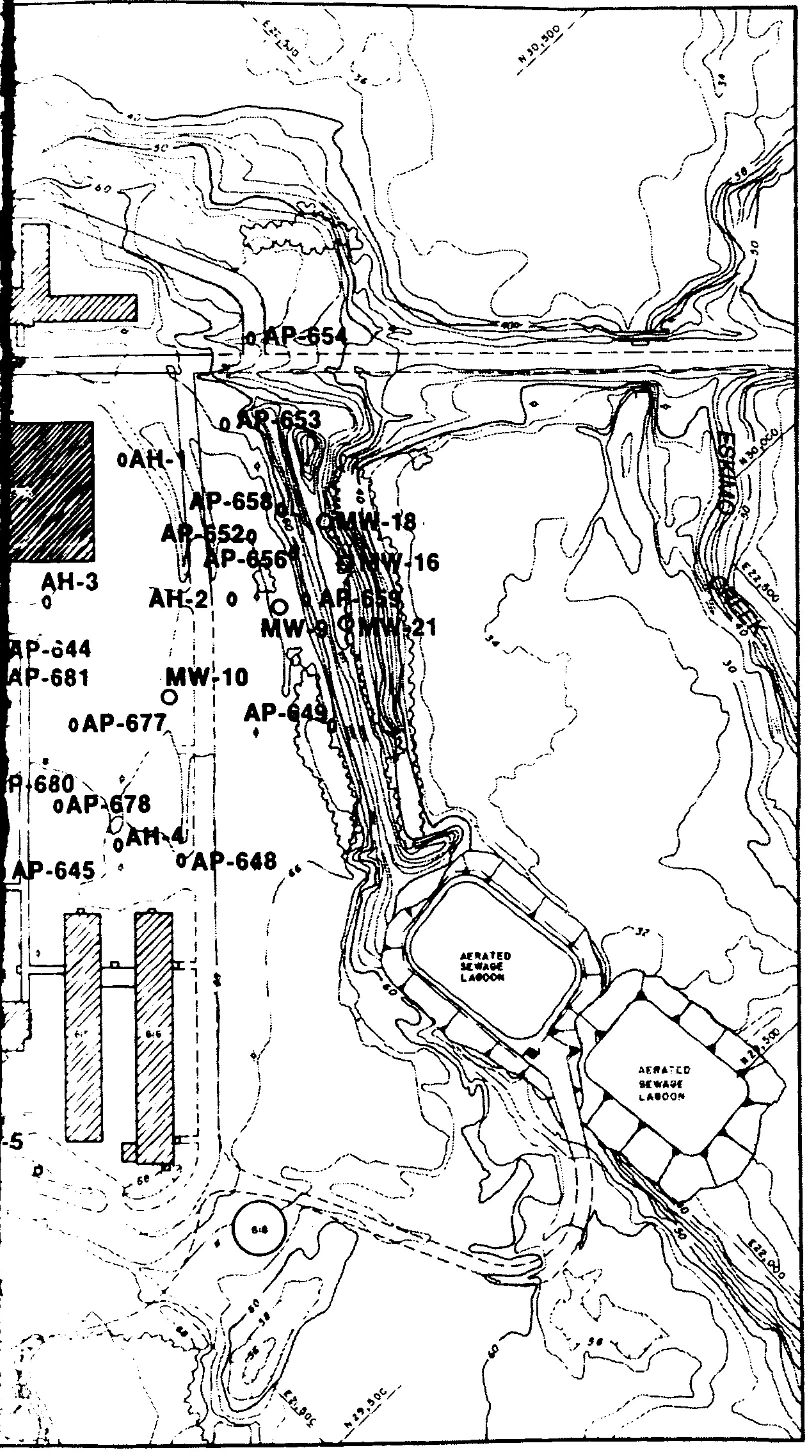
NEW GROUNDWATER MONITORING WELL AND SOIL BORING LOCATIONS

JUNE 1988
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL


LF-1
LF-2
N52W
400'
LF-3
N52W
400'
POL TANK
POL TANK
TRUCKFILL STAND
TANKS
AP-543
AP-539
AH-1
AP-658
AP-542
AP-541
AP-544
AP-652
AP-656
AH-547
AH-545
AP-540
AH-546
AH-3
AH-2
AH-548
AH-549
AH-550
AP-644
AP-681
MW-10
MW-22
AP-677
KS-5
MW-6
AP-680
AP-678
AH-4
AP-644
AH-6
AP-645
AP-648
KS-4
MW-1
AP-646
AH-5
AP-643
VEHICLE HEADBOLT HEATER AND FLOODLIGHT POLES
VEHICLE HEADBOLT HEATER

K24173.A0



0 200 400
SCALE IN FEET

LEGEND

0	EXISTING SOIL BORINGS
○	EXISTING MONITORING WELLS
□	EXISTING BASE PRODUCTION WELLS
△	EXISTING LANDFILL MONITORING WELLS
AH	CORPS OF ENGINEERS
AP	CORPS OF ENGINEERS
LF	AIR FORCE
MW	CH2M HILL

FIGURE 4-3

EXISTING MONITORING WELL AND SOIL BORING LOCATIONS

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

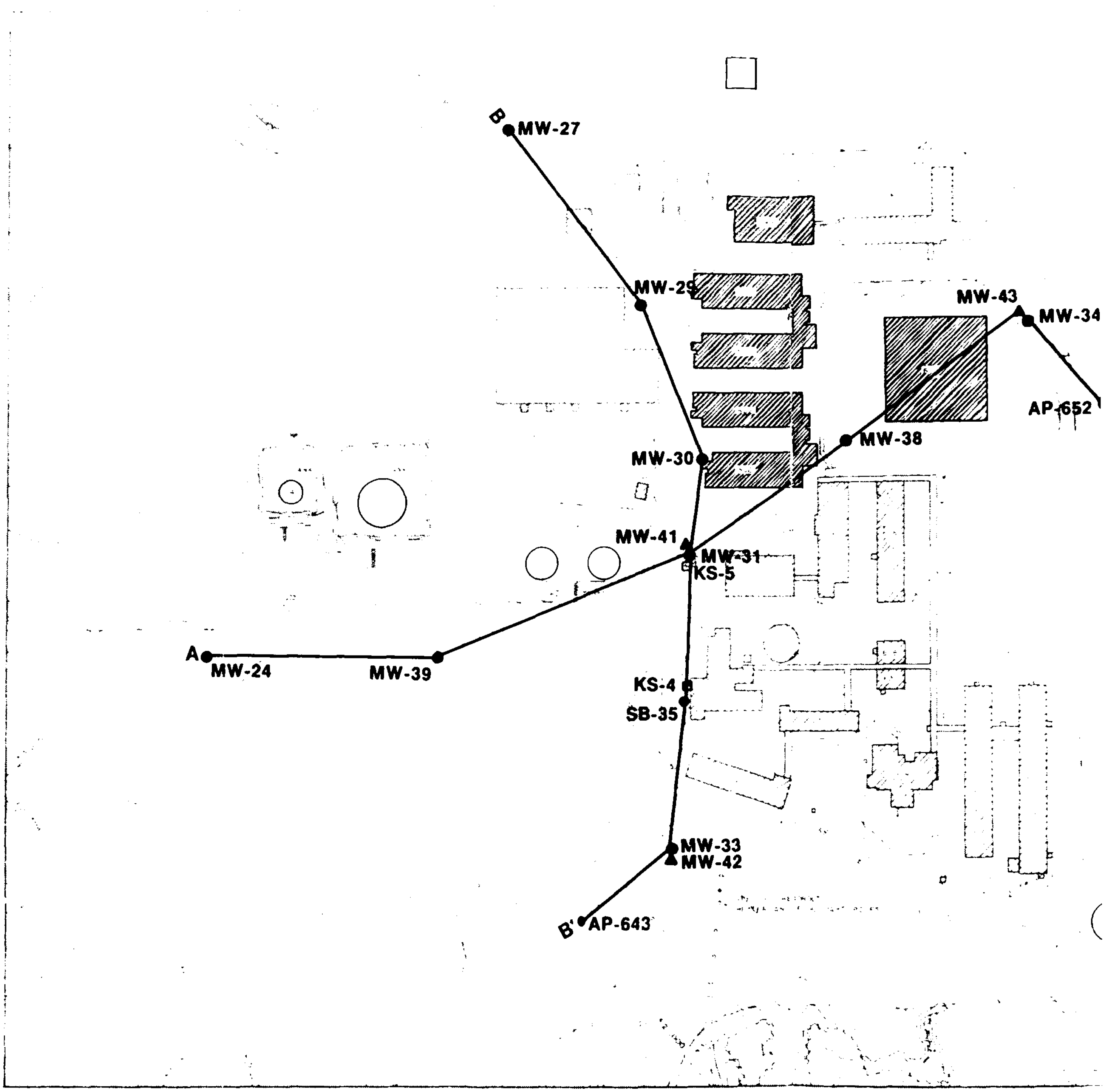
Table 4-1
MONITORING WELL CONSTRUCTION DETAILS

Well Number	Date Installed	Installed By	Well Diameter (inches)	Well Materials	Total Length (ft)	Wellhead Elevation (ft NGVD)	Well Casing Stickup (ft)	Protective Casing Stickup (ft)	Ground Elevation (ft NGVD)	Depth Below Ground Surface (ft)	Screened Interval Below Ground Surface (ft)	Sump Length (ft)
MW-23	11/07/87	CH2M	2	PVC	37.95	69.10	1.71	2.12	67.39	36.24	22.24 - 32.24	4
MW-24	11/07/87	CH2M	2	PVC	3[illegible].2	60.66	1.64	2.3	59.02	29.58	17.08 - 27.08	2.5
MW-25	11/09/87	CH2M	2	PVC	31.22	62.05	1.33	2.47	60.72	29.88	14.89 - 24.89	5
MW-26	11/10/87	CH2M	2	PVC	36.20	66.92	1.43	1.95	65.49	34.77	19.77 - 29.77	5
MW-27	11/13/87	CH2M	2	PVC	34.46	64.90	1.35	1.75	63.55	33.11	18.11 - 28.11	5
MW-28	11/15/87	CH2M	2	PVC	37.06	66.68	1.77	2.13	64.91	35.29	20.29 - 30.29	5
MW-29	11/17/87	CH2M	2	PVC	35.52	65.9	1.70	2.33	64.20	33.82	18.82 - 28.82	5
MW-30	11/19/87	CH2M	2	PVC	37.20	68.28	1.71	2.43	66.57	35.49	20.49 - 30.49	5
MW-31	11/20/87	CH2M	2	PVC	37.63	67.08	1.77	2.42	65.31	35.86	20.86 - 30.86	5
MW-32	11/21/87	CH2M	2	PVC	39.13	64.81	1.45	2.38	63.36	37.68	22.68 - 32.68	5
MW-33	11/23/87	CH2M	2	PVC	40.71	68.57	1.82	2.21	66.75	38.89	24.89 - 34.89	4
MW-34	12/09/87	CH2M	2	PVC	38.00	67.55	1.75	2.33	65.8	36.25	21.25 - 31.25	5
MW-36	05/08/88	CH2M	2	PVC	38.20	68.49	2.00	2.05	66.49	36.20	24.2 - 34.2	2
MW-37	05/10/88	CH2M	2	PVC	40.90	68.93	1.91	2.36	67.02	38.99	26.99 - 36.99	2.2
MW-38	05/12/88	CH2M	2	PVC	39.80	69.06	1.55	2.17	67.51	38.25	25.75 - 35.75	2.5
MW-39	05/13/88	CH2M	2	PVC	32.32	63.73	1.93	2.17	61.80	30.39	16.39 - 26.39	4
MW-40	06/08/88	CH2M	2	PVC	41.17	65.79	1.61	1.98	64.18	39.56	25.36 - 35.36	4.2
MW-41	05/13/88	CH2M	4	PVC	99.37	65.94	1.30	2.50	65.31	98.07	74.5 - 94.5	3.6
MW-42	06/11/88	CH2M	4	PVC	100.40	68.54	1.93	2.50	66.75	98.47	87.5 - 97.5	1
MW-43	06/11/88	CH2M	4	PVC	117.57	67.25	2.15	2.50	65.20	115.42	89.9 -109.9	5.5
MW-1	09/14/83	USCOE	1.5	PVC	30	64.74	1.79	2.24	62.95	28.21	23.31 - 28.21	na
MW-6	09/17/83	USCOE	1.5	PVC	35	66.34	0.99	1.55	65.35	34.01	29.01 - 34.01	na
MW-9	09/15/83	USCOE	1.5	PVC	35	66.02	0.36	0.80	65.66	34.64	29.64 - 34.64	na
MW-10	09/17/83	USCOE	1.5	PVC	35	68.70	1.96	2.31	66.74	33.04	28.04 - 33.04	na
MW-16	09/16/83	USCOE	1.5	PVC	30	59.14	1.19	1.84	57.95	28.81	18.81 - 28.81	na
MW-18	09/16/83	USCOE	1.5	PVC	30	59.43	2.05	2.57	57.38	27.95	17.95 - 27.95	na
MW-21	09/16/83	USCOE	1.5	PVC	30	60.41	0.64	1.01	59.77	29.36	19.36 - 29.36	na
MW-22	09/18/83	USCOE	1.5	PVC	35	64.30	0.93	1.27	63.37	34.07	29.07 - 34.07	na
LF-1	na	USAF	4	PVC	82.23	65.70	0.55	na	65.15	81.68	na	na
LF-2	na	USAF	4	PVC	40.55	63.24	3.0	na	60.34	37.55	na	na
LF-3	na	USAF	4	PVC	36.6	60.75	1.25	na	59.5	35.35	na	na
KS-4	1952	USAF	8	Steel	na	66.62	na	na	na	228	na	na
KS-5	1952	USAF	8	Steel		65.50	na	na	na	237	227 - 237	na

Notes:

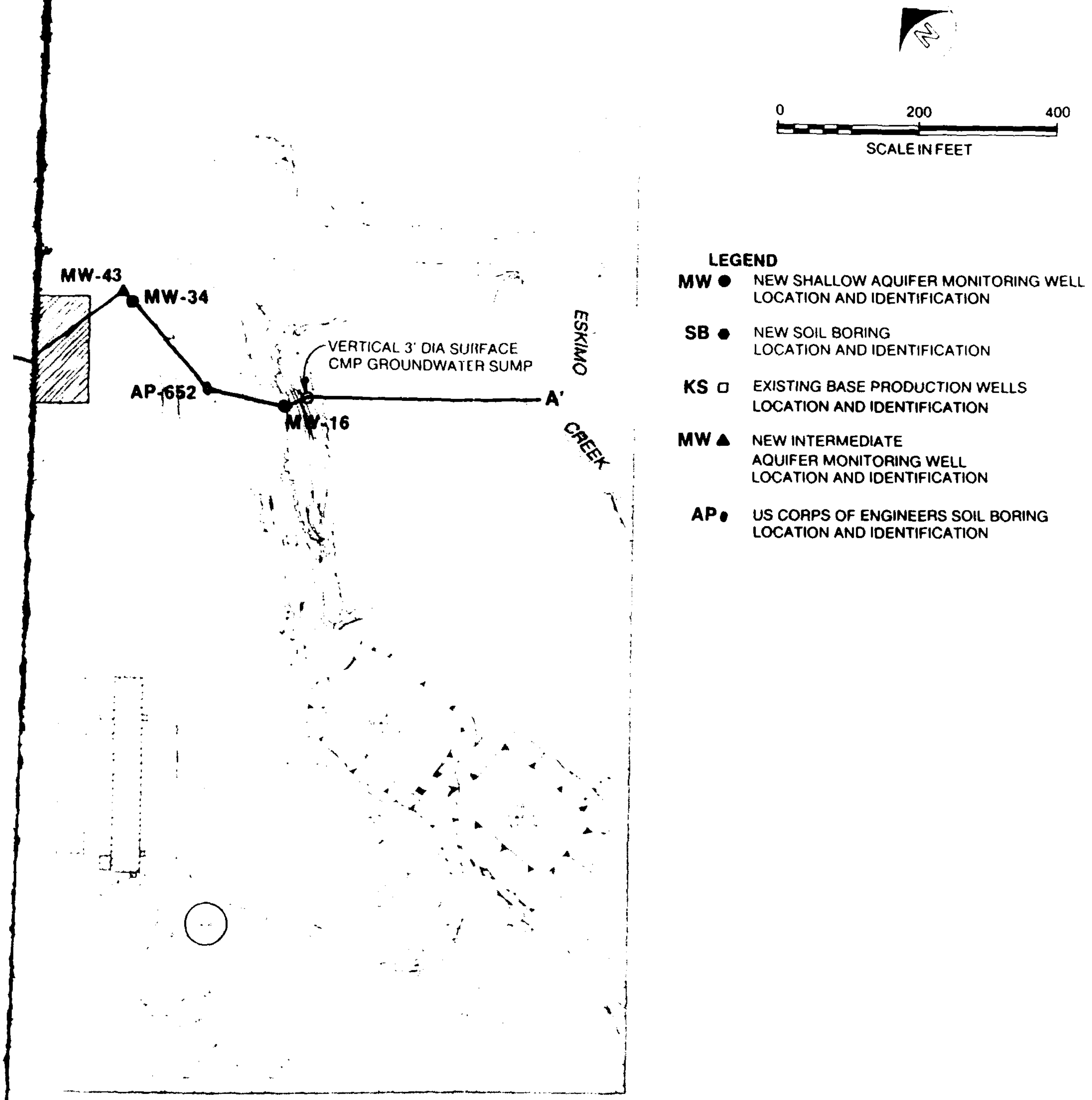
1. The screened interval given for ACOE wells is estimated from ACOE well logs and may not be accurate because survey data provded in the logs is apparently incorrect.
2. na = Not Available.

CVR51/040


B
MW-27
MW-29
MW-43
MW-34
AP-652
MW-38
MW-30
MW-41
MW-31
KS-5
A
MW-24
MW-39
KS-4
SB-35
MW-33
MW-42
B'
AP-643

K24173.A0

A



LEGEND

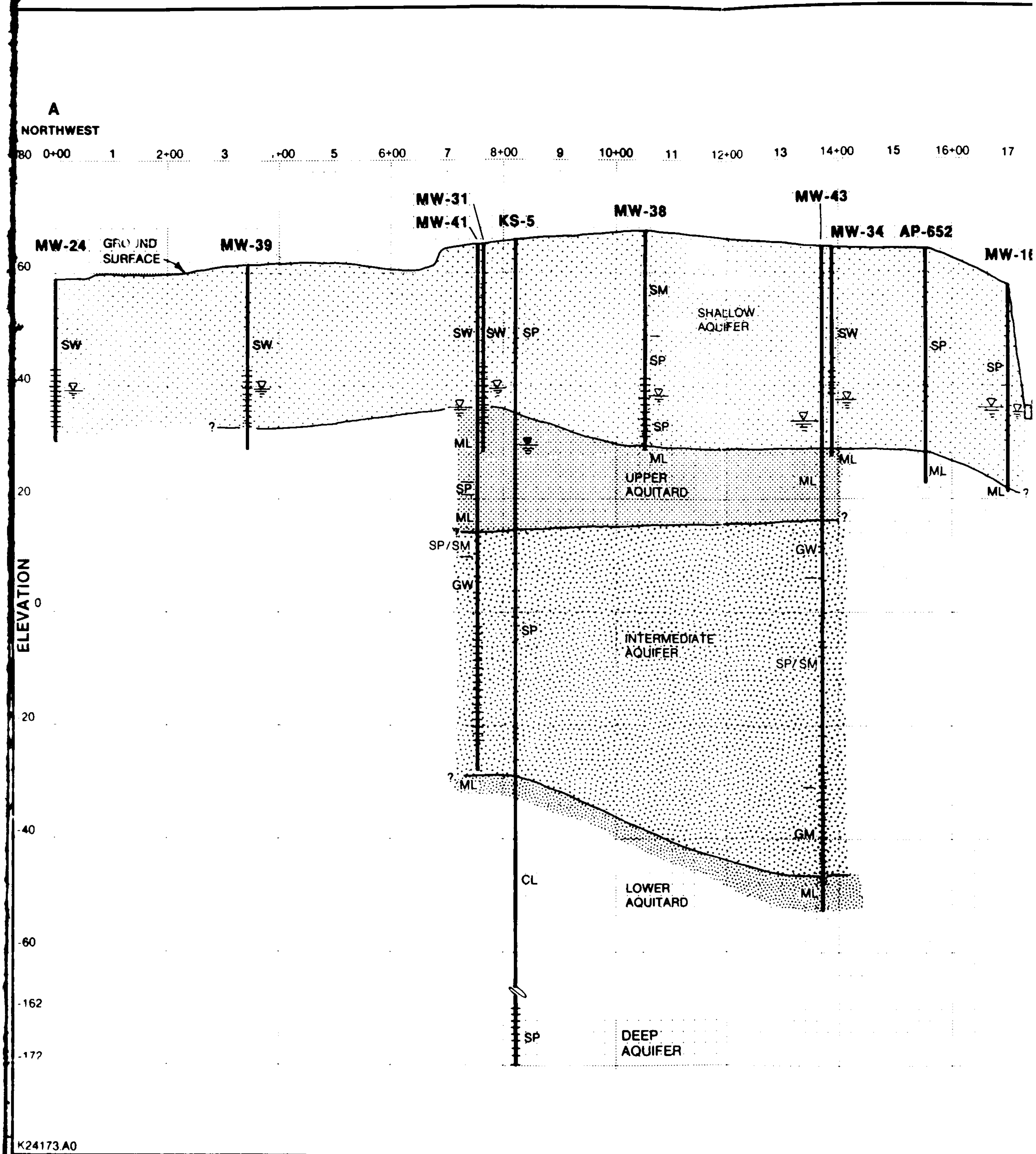
MW ●	NEW SHALLOW AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION
SB ●	NEW SOIL BORING LOCATION AND IDENTIFICATION
KS ☐	EXISTING BASE PRODUCTION WELLS LOCATION AND IDENTIFICATION
MW ▲	NEW INTERMEDIATE AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION
AP ●	US CORPS OF ENGINEERS SOIL BORING LOCATION AND IDENTIFICATION

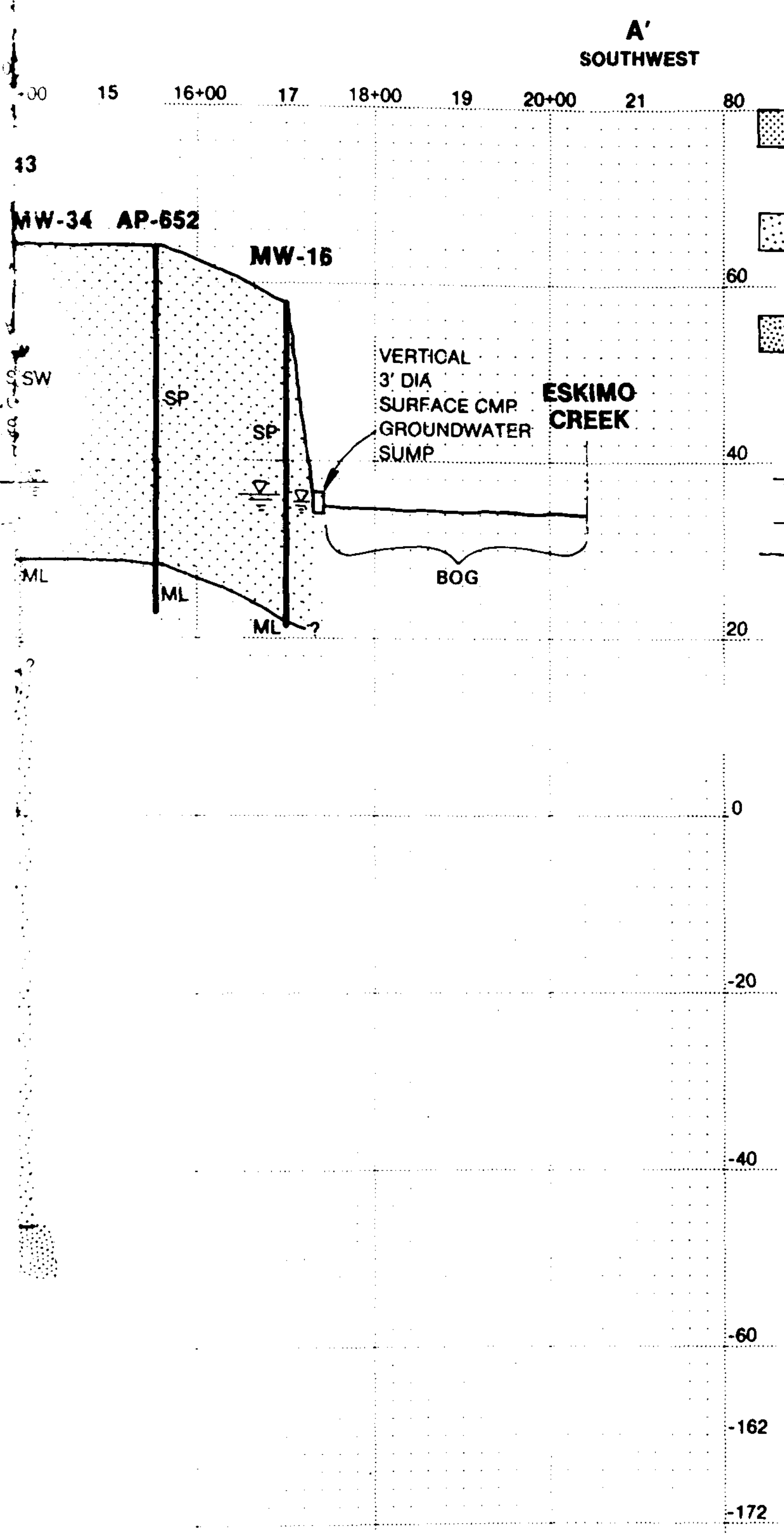
FIGURE 4-4

LOCATION OF HYDROGEOLOGIC CROSS-SECTIONS

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL


A
NORTHWEST
80 0+00 1 2+00 3 4+00 5 6+00 7 8+00 9 10+00 11 12+00 13 14+00 15 16+00 17
MW-24
GROUND SURFACE
MW-39
MW-31
MW-41
KS-5
MW-38
MW-43
MW-34
AP-652
MW-16
SW
SW
SW
SW
SP
SM
SP
SP
SHALLOW AQUIFER
SW
SP
SP
ML
SP
ML
ML
ML
ML
ML
UPPER AQUITARD
SP/SM
GW
GW
SP
INTERMEDIATE AQUIFER
SP/SM
GM
ML
ML
CL
LOWER AQUITARD
SP
DEEP AQUIFER
ELEVATION
60
40
20
0
-20
-40
-60
-162
-172
K24173.A0



LEGEND

⬚ **SHALLOW AQUIFER** — AQUIFER MATERIALS GENERALLY CONSIST OF BEDDED AND MASSIVE UNITS OF SAND AND SILTY SAND. SAND UNITS ARE WELL GRADED WITH FINE AND MEDIUM SIZES PREDOMINANT. LOW PERCENTAGES OF SILT AND GRAVELS MAY ALSO BE PRESENT.

▩ **UPPER AQUITARD** — CONSISTING PRIMARILY OF GRAVELLY SANDY SILT AND SANDY SILT. CHARACTERIZED BY LOWER PERMEABILITY AND INCREASED DENSITY.

░ **INTERMEDIATE AQUIFER** — AQUIFER MATERIALS CONSIST PRIMARILY OF SANDY GRAVELS, GRAVELLY SANDS AND SILTY SANDS.

▒ **LOWER AQUITARD** — CONSISTING PRIMARILY OF SANDY SILT, GRAVELLY CLAY AND CLAY.

BOREHOLE DEPTH INTERVAL

MONITORING WELL SCREEN DEPTH INTERVAL

▽ GROUNDWATER ELEVATION ON 6/14/88

▼ GROUNDWATER ELEVATION ON 4/2/65

— OBSERVED CONTACT BETWEEN DIFFERENT GEOLOGIC UNITS

NOTES

1. THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTION (PROFILE) WERE GENERALIZED FROM AND INTERPOLATED BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL (ROCK) CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THE BORING LOCATIONS. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS

2. WELL KS-5 SHOWN IN APPROXIMATE LOCATION

Group symbol	Typical names
GW	Well-graded gravels, gravel-sand mixtures, little or no fines
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
GM d/u	Silty gravels, gravel-sand-silt mixtures
SW	Well-graded sands, gravelly sands, little or no fines
SP	Poorly graded sands, gravelly sands, little or no fines
SM d/u	Silty sands, sand-silt mixtures
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays

FIGURE 4-5

HYDROGEOLOGIC CROSS-SECTION A-A'
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

east across the site and includes the Eskimo Creek seep. Section B-B' (Figure 4-6) runs from the north to southwest, in the general direction of regional groundwater flow.

Geology of the site consists of alternating sequences of permeable glacial outwash materials and relatively impermeable tills. The outwash deposits contain a surficial unconfined aquifer and numerous locally-confined aquifers at depth. Glacial tills and finer-grained sediments act as semiconfining or confining layers.

4.1.3.1.1 Shallow Aquifer

The surficial geologic unit is composed of 20 to 40 feet of moderately well sorted outwash sands and silty sands. Some coarser gravel zones are found locally. This unit is extensive throughout the King Salmon area forming terraces that have been partially reworked by wind. Within the site boundary, the unit is laterally consistent as it has been encountered in each boring.

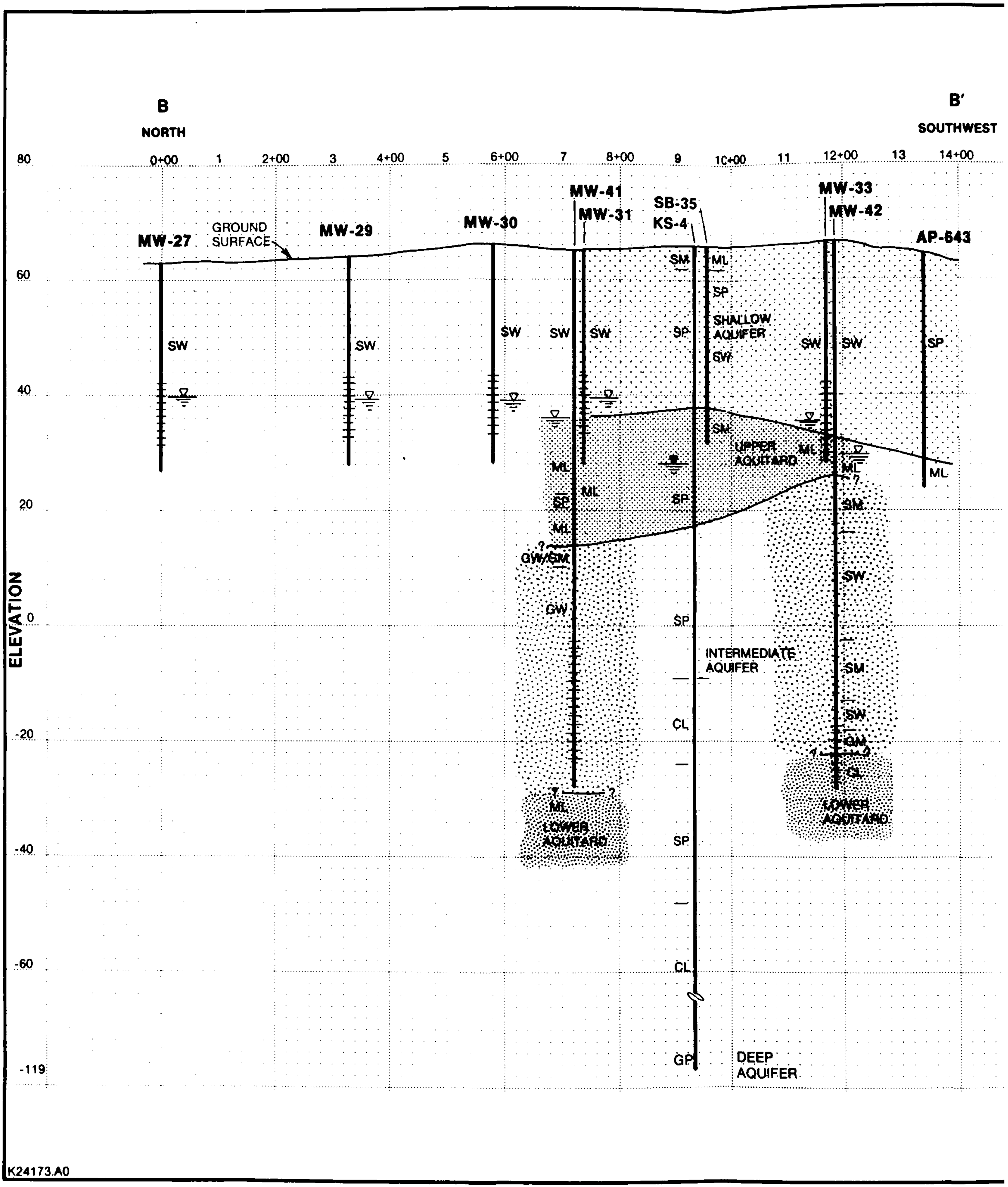
Grain size analyses for shallow aquifer soil samples collected by the U.S. Corps of Engineers are presented in Appendix D-4. Grain size curves indicate the shallow aquifer ranges from clean well-sorted sands (SP) to silty sands (SM).

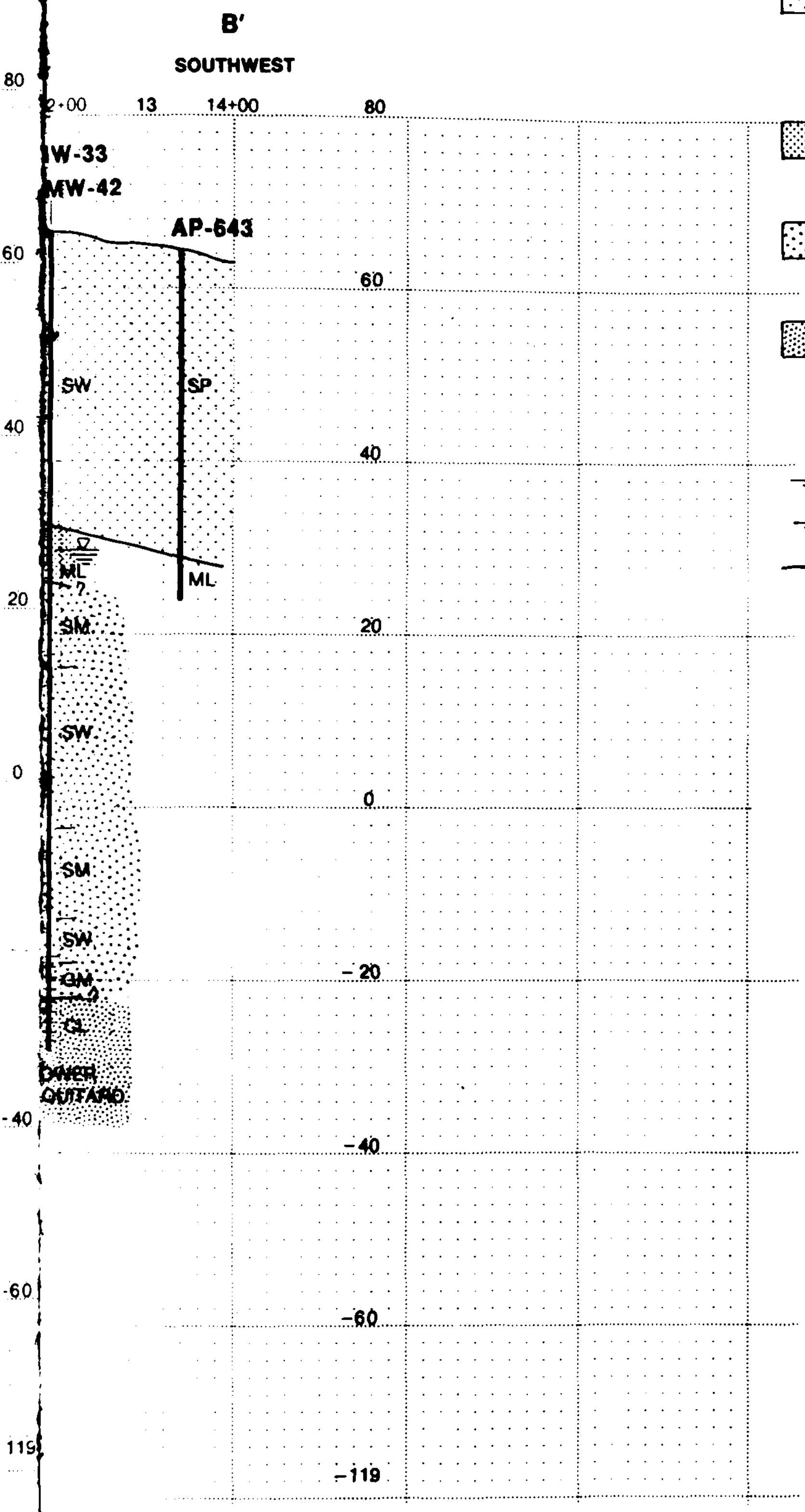
The shallow unconfined aquifer within this unit is found at depths from 21 to 31 feet below ground surface at the site. The aquifer is separated from lower aquifers by an underlying glacial till and has a saturated thickness ranging from 0 to greater than 9 feet beneath the site.

4.1.3.1.2 Upper Aquitard

Underlying the surficial sands is a till deposit consisting of gravelly sandy silt and sandy silt. The contact between the two deposits is distinct (Figures 4-5 and 4-6). The till deposit acts as an aquitard between the upper unconfined aquifer and the intermediate confined aquifer.

Three borings completed during the Stage 1 investigation penetrated through this aquitard into the underlying intermediate aquifer. The thickness of the till ranged from 7 to 22 feet in these borings. Local water well drilling logs indicate the aquitard is laterally extensive throughout the area (station and barrel bluffs). The thickness of the unit may vary greatly. Several base wells and numerous residential water wells have been identified (Figure 4-7). Associated well logs, where available, are in Appendix C-5.


B
NORTH
B′
SOUTHWEST
0+00
1
2+00
3
4+00
5
6+00
7
8+00
9
10+00
11
12+00
13
14+00
80
60
40
20
0
-20
-40
-60
-119
ELEVATION
MW-27
GROUND SURFACE
MW-29
MW-30
MW-41
MW-31
SB-35
KS-4
MW-33
MW-42
AP-643
SW
SM
ML
SP
SHALLOW AQUIFER
UPPER AQUITARD
GW/GM
GW
INTERMEDIATE AQUIFER
CL
GM
LOWER AQUITARD
GP
DEEP AQUIFER
?
K24173.A0



LEGEND

⬚ **SHALLOW AQUIFER** — AQUIFER MATERIALS GENERALLY CONSIST OF BEDDED AND MASSIVE UNITS OF SAND AND SILTY SAND. SAND UNITS ARE WELL GRADED WITH FINE AND MEDIUM SIZES PREDOMINANT. LOW PERCENTAGES OF SILT AND GRAVELS MAY ALSO BE PRESENT.

▨ **UPPER AQUITARD** — CONSISTING PRIMARILY OF GRAVELLY SANDY SILT AND SANDY SILT. CHARACTERIZED BY LOWER PERMEABILITY AND INCREASED DENSITY.

⬚ **INTERMEDIATE AQUIFER** — AQUIFER MATERIALS CONSIST PRIMARILY OF SANDY GRAVELS, GRAVELLY SANDS AND SILTY SANDS.

▨ **LOWER AQUITARD** — CONSISTING PRIMARILY OF SANDY SILT, GRAVELLY CLAY AND CLAY.

BOREHOLE DEPTH INTERVAL

MONITORING WELL SCREEN DEPTH INTERVAL

▽ GROUNDWATER ELEVATION ON 6/14/88

▼ GROUNDWATER ELEVATION ON 4/2/65

— OBSERVED CONTACT BETWEEN DIFFERENT GEOLOGIC UNITS

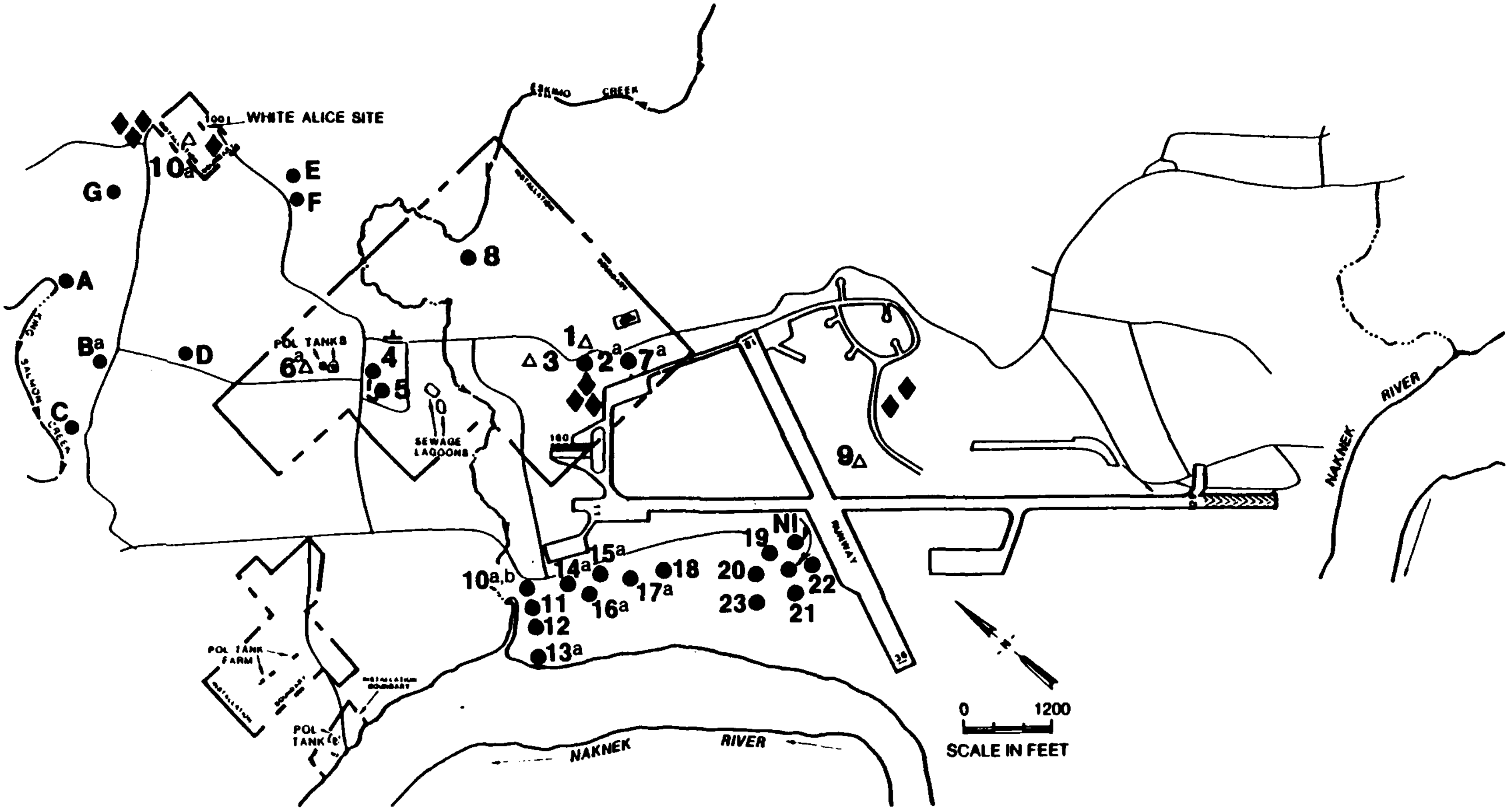
NOTE:
THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTION (PROFILE) WERE GENERALIZED FROM AND INTERPOLATED BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL (ROCK) CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THE BORING LOCATIONS. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

Group symbol	Typical names
GW	Well-graded gravels, gravel-sand mixtures, little or no fines
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
GM d/u	Silty gravels, gravel-sand-silt mixtures
SW	Well-graded sands, gravelly sands, little or no fines
SP	Poorly graded sands, gravelly sands, little or no fines
SM d/u	Silty sands, sand-silt mixtures
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays

FIGURE 4-6

HYDROGEOLOGIC CROSS-SECTION B-B'
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL



NOTE: CONFIRMED WELLS ARE SHOWN. NUMEROUS OTHER WELLS MAY BE PRESENT IN THE STUDY AREA.

SOURCES: ① US GEOLOGICAL SURVEY WATER RESOURCES DIVISION, FILE DATA, UNDATED ② FEULNER, 1963 ③ INSTALLATION DOCUMENTS

NOTE:

WELL IDENTIFICATIONS ARE BASED ON INTERPRETATION OF EXISTING MAPS IDENTIFICATIONS MAY NOT BE ACCURATE

LEGEND

●	DOMESTIC OR PUBLIC SUPPLY WELL
△	INACTIVE DOMESTIC OR PUBLIC SUPPLY WELL
◆	LEACHING OR DRY WELL
NI	NOT IDENTIFIED
a	GEOLOGIC AND WELL CONSTRUCTION LOG NOT AVAILABLE
b	DUPLICATE IDENTIFICATION

K24173.A0

SOURCE: ES *Engineering Science*

FIGURE 4-7

BASE WELLS AND SELECTED RESIDENTIAL WELLS

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

Several of the shallow borings [CH2M HILL and U.S. Army Corps of Engineers (USCOE)] penetrated into the upper aquitard. The stratigraphic contact between shallow aquifer and underlying till was interpreted based on descriptions of grain size, density (split-spoon blow counts), and moisture content. These data points were used to construct the structure contour map of the till surface (Figure 4-8). The accuracy of any one point may be ±2 feet. However, the data set clearly indicates a high area or thickening of the till beneath the site. The upper contact of the till is at a higher elevation than the shallow groundwater table measured in June 1988. Soil boring SB-35, shown in Figure 4-8, encountered till in the unsaturated zone.

4.1.3.1.3 Intermediate Aquifer

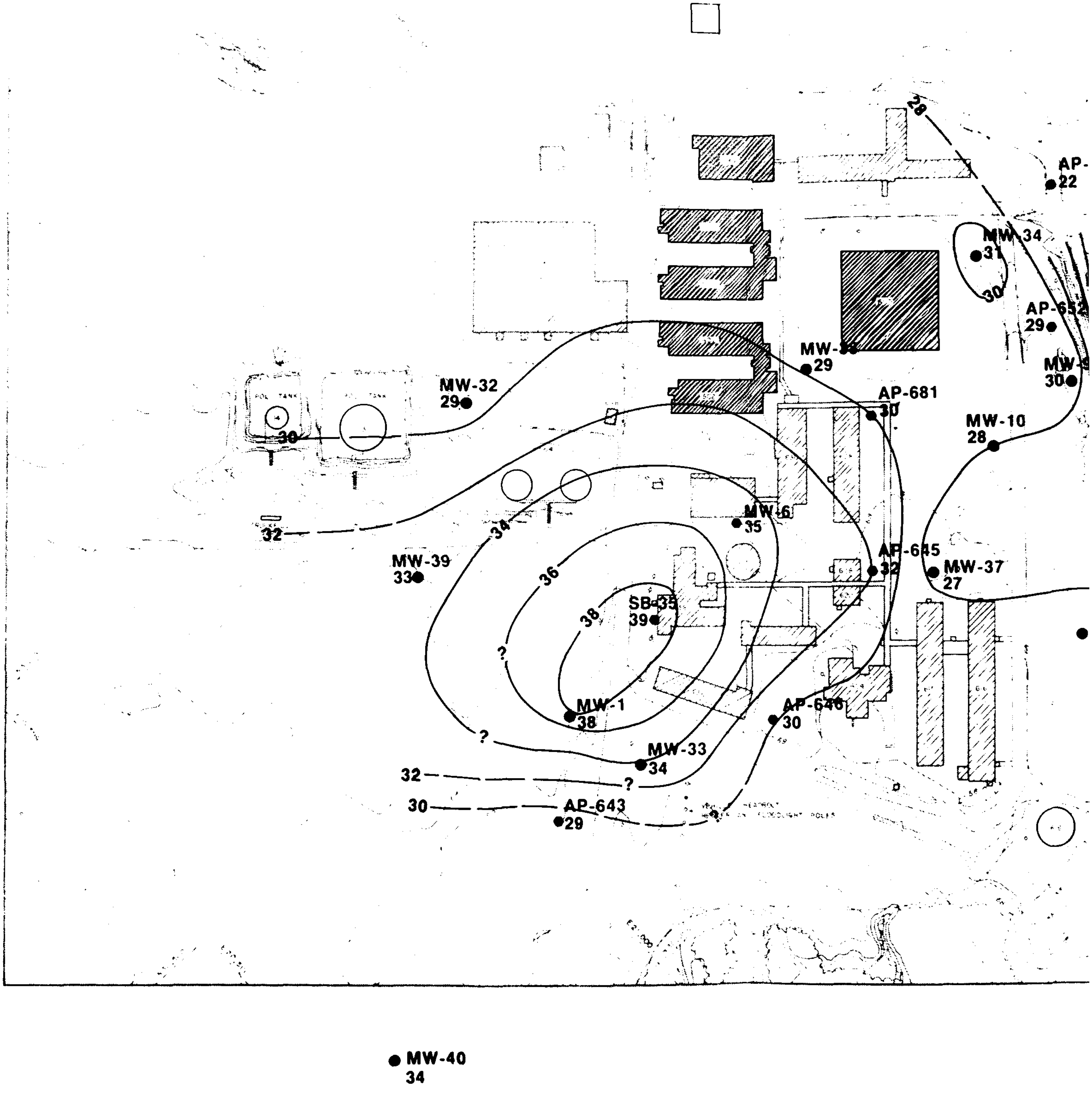
The intermediate confined aquifer is characterized primarily by interbedded sequences of silty sands, sandy gravels, and silty sandy gravels. Gravels are predominantly subrounded to subangular in shape with maximum observed size of 2 inches. The three borings that penetrated this unit during the Stage 1 investigation (MW-41, 42, and 43) indicate a depth to the top of the aquifer ranging from 43 to 48 feet below ground surface and a thickness ranging from 41 to 62 feet. The three borings yielded significant water during drilling throughout this zone.

The intermediate aquifer is generally used for residential water supplies. Nearby wells shown in Figure 4-7 and presented in Appendix C-6 are screened in sandy gravel materials found beneath the upper aquitard. These wells generally produce adequate residential supplies (10 to 20 gpm). This zone could include several small confined aquifers, each contained in a limited extent outwash deposit.

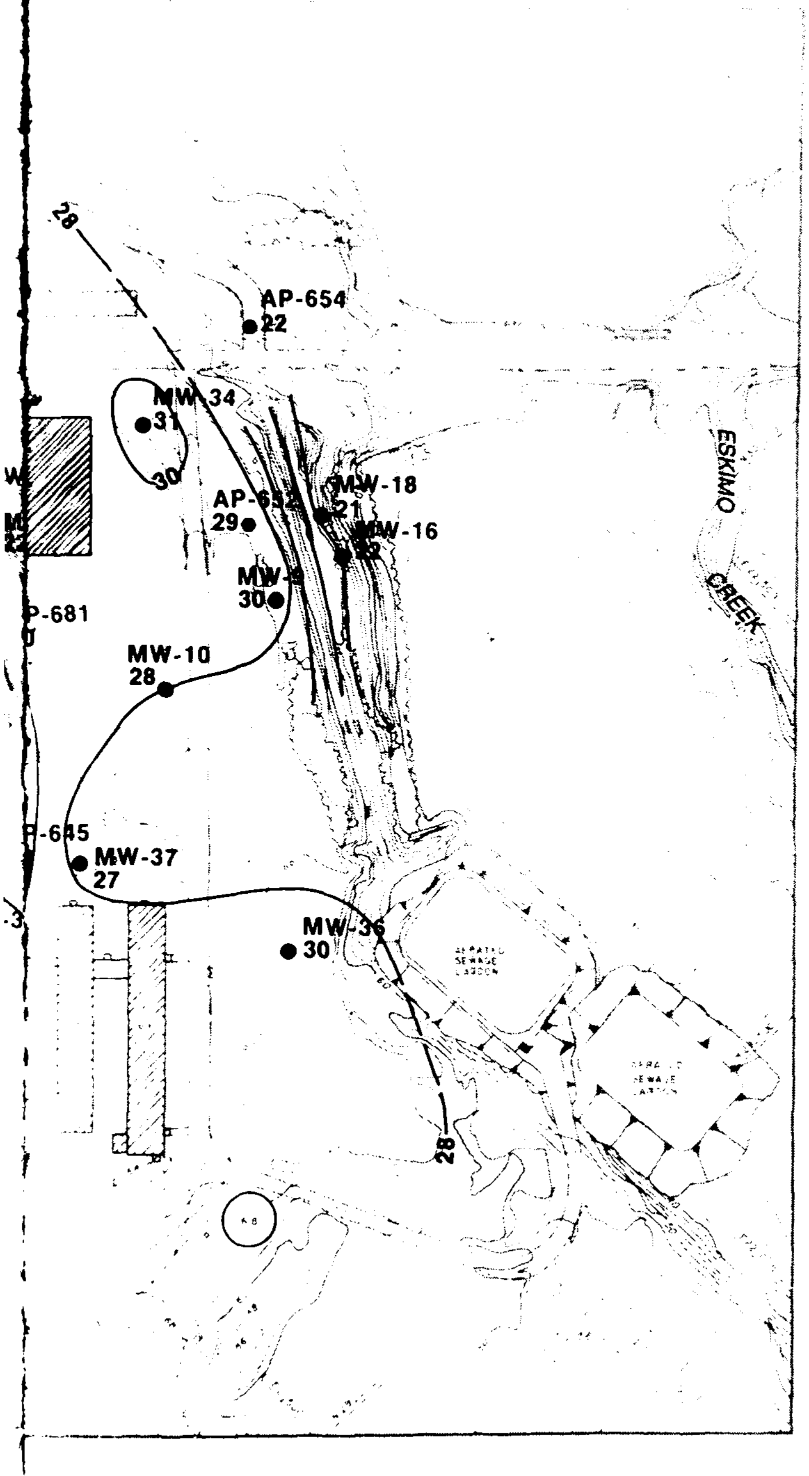
The lateral extent of the intermediate aquifer is unknown. Glacial deposits are very heterogeneous, and it is difficult, therefore, to correlate the intermediate zone at the Eskimo Creek seep site to nearby areas (such as the Barrel Bluffs).

4.1.3.1.4 Lower Aquitard(s)

A second fine-grained deposit was encountered beneath the intermediate aquifer in the three new deep borings at depths ranging from 88 to 110 feet. The geologic logs for two base wells that penetrated this unit, KS-4 and KS-5, indicate a thickness of about 90 to 115 feet. The uppermost portion of the unit is generally characterized by silty sand, sandy/gravelly clay, and clay. A lower moisture content was observed in drill cuttings. Significant quantities of water were observed in boring MW-42 after penetrating several feet into the lower aquitard. The drilling subcontractor indicated


28
AP-
22
MW-34
31
30
AP-652
29
MW-
30
MW-32
29
POL TANK
30
MW-38
29
AP-681
30
MW-10
28
32
34
MW-6
35
MW-39
33
36
AP-645
32
MW-37
27
SB-35
39
38
?
MW-1
38
AP-646
30
?
MW-33
34
32
?
30
AP-643
29
MW-40
34

K24173 A0



LEGEND

- ● US CORPS OF ENGINEERS, (USCOE) SOIL BORING LOCATION, IDENTIFICATION AND TOP OF AQUITARD ELEVATION
- ● NEW MONITOR WELL LOCATION, IDENTIFICATION AND TOP OF UPPER AQUITARD ELEVATION

30 ——— ELEVATION CONTOUR. CONTOUR INTERVAL IS 2 FEET UNLESS NOTED.

NOTE:
SHALLOW AQUIFER-GLACIAL TILL CONTACT ELEVATIONS INTERPRETED FROM BORING LOGS TO REPRESENT SURFACE OF UPPER AQUITARD.

FIGURE 4-8

UPPER AQUITARD STRUCTURE CONTOUR MAP

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

B

that a similar water bearing, fractured clay formation was present at several other water well locations in the area. Whether or not these fractures allow communication between the intermediate aquifer and deeper aquifers is unknown.

4.1.3.1.5 Deep Aquifer

Geologic logs from King Salmon AFS production wells KS-4 and KS-5 show the presence of a deep aquifer at a depth ranging from 205 to 225 feet. The aquifer materials consist primarily of sand and sandy gravels.

4.1.3.2 Groundwater Flow

4.1.3.2.1 Shallow Unconfined Aquifer

Groundwater levels in the shallow unconfined aquifer have been recorded in existing wells on six occasions. Water elevation data is presented in Table 4-2. Data from October 1987 and June 1988 were used to interpret and construct the groundwater elevation maps presented as Figures 4-9 and 4-10. These dates were used because they reflect opposite seasons and are the most complete data sets.

Groundwater flow for October 1987 (Figure 4-9) is generally to the south towards the Naknek River and southeast along Eskimo Creek. This flow pattern is somewhat different than previous presentations (CH2M HILL Presurvey Report, 1986) because previous contour maps were based on well elevations from USCOE well logs that were incorrect. These elevations may have been estimated from contour maps.

This aquifer system is extremely anisotropic and heterogeneous because of glacial till silts located within the relatively clean sands. Consequently, the direction of groundwater flow is not interpreted to be parallel to the hydraulic gradient in this area. Flowlines on the groundwater flow maps reflect the effects of the till barrier.

The groundwater flow map presented for the June 1988 data (Figure 4-10) includes the newly installed well data and represents the most detailed interpretation to date. The water level contours indicate the regional groundwater flow direction is from north to south across the site with a major component towards Eskimo Creek to the southeast. Eskimo Creek and the underlying glacial till ridge affect the regional flow to the south. The Eskimo Creek flood plain is 30 to 35 feet lower in elevation than the station. This area is a local discharge zone for the unconfined aquifer. As the groundwater approaches the bluff, flow lines swing to the southeast to reflect this discharge.

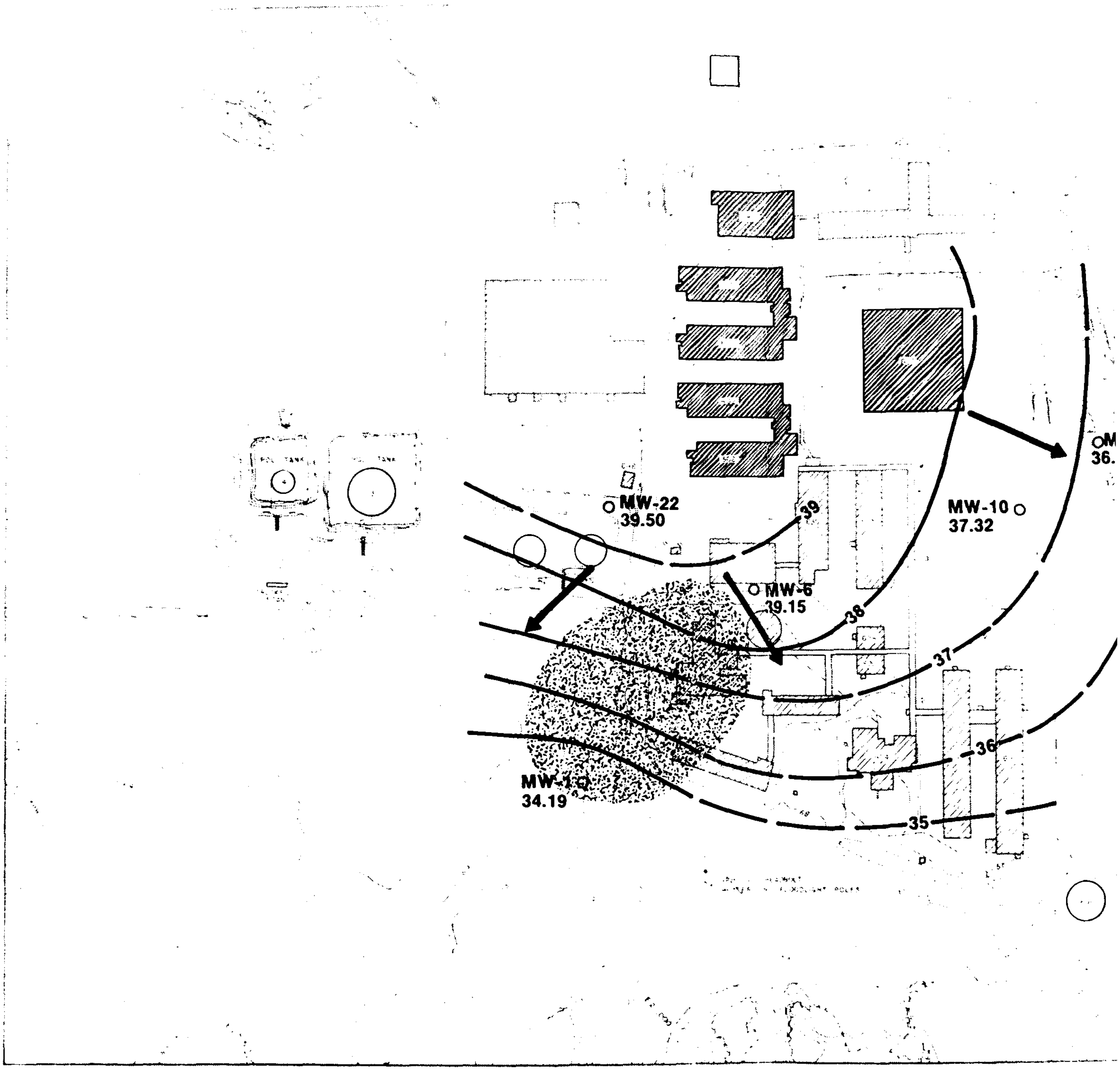
Table 4-2
WATER LEVEL DATA FOR KING SALMON AFS

Well No.	Well Elevation TOC (feet)	1983		October 1985		April 1987		October 1987		May 1988		June 1988	
		Water Depth (BTOC)	Water Elevation TOC (feet)	Water Depth (BTOC)	Water Elevation (feet)	Water Depth (BTOC)	Water Elevation (feet)	Water Depth (BTOC)	Water Elevation (feet)	Water Depth (BTOC)	Water Elevation (feet)	Water Depth (BTOC)	Water Elevation (feet)
MW-1	64.74	27.2	37.54	27.02	37.72	27.03	37.71	30.55	34.19	28.34	36.4	27.99	36.75
MW-6	66.34	26.9	39.44	27.16	39.18	27.8	38.54	27.19	39.15	27.9	38.44	29.833	36.507
MW-9	66.02	28.1	37.92	29.41	36.61	28.75	37.27	29.06	36.96	29.26	36.76	29.39	36.63
MW-10	68.7	29.0	39.7	31.78	36.92	30.91	37.79	31.38	37.32	31.65	37.05	31.74	36.96
MW-16	59.14	21.4	37.74	23.07	36.07	22.5	36.64	23.05	36.09	22.83	36.31	22.94	36.2
MW-18	59.43					22.49	36.94	22.71	36.72	22.9	36.53	22.95	36.48
MW-21	60.41	23.3	37.11	24.47	35.94	23.8	36.61	24.18	36.23	24.12	36.29	24.32	36.09
MW-22	64.3	24.4	39.9	25.3	39.00	24.48	39.82	24.8	39.5	25.42	38.88001	24.875	39.425
MW-23	69.1									33.11	35.99	33.42	35.68
MW-24	60.66									21.77	38.89	21.48	39.18
MW-25	62.05									22.82	39.23	22.54	39.51
MW-26	66.92									27.48	39.44	27.29	39.63
MW-27	64.9									25.58	39.32	25.22	39.68
MW-28	66.68									27.96	38.72	27.79	38.89
MW-29	65.9									26.9	39.0	26.71	39.19
MW-30	68.28									29.36	38.92	29.19	39.09
MW-31	67.08									27.84	39.24	27.82	39.26
MW-32	64.81									25.64	39.35	25.26	39.55
MW-33	68.57									32.59	35.98	32.78	35.79
MW-34	67.55									30.11	37.44	30.07	37.48
MW-36	68.49											32.03	36.46
MW-37	68.93											31.96	36.97
MW-38	59.06											30.84	38.22
MW-39	63.73											24.13	39.6
MW-40	65.79											29.03	36.76
MW-41	65.94											29.73	36.21
MW-42	68.54											38.56	39.98
MW-43	67.25											34.08	33.17
LF-1	65.7							27.12	38.58	27.38	38.32	27.1	38.6
LF-2	63.24							24.42	38.82	24.80	38.44		
LF-3	60.75							22.35	38.40				

TOC--Top of well casing.

BTOC--Below top of casing.

Vertical Datum--King Salmon Air Force Station Site Datum.



K24173.A0

A

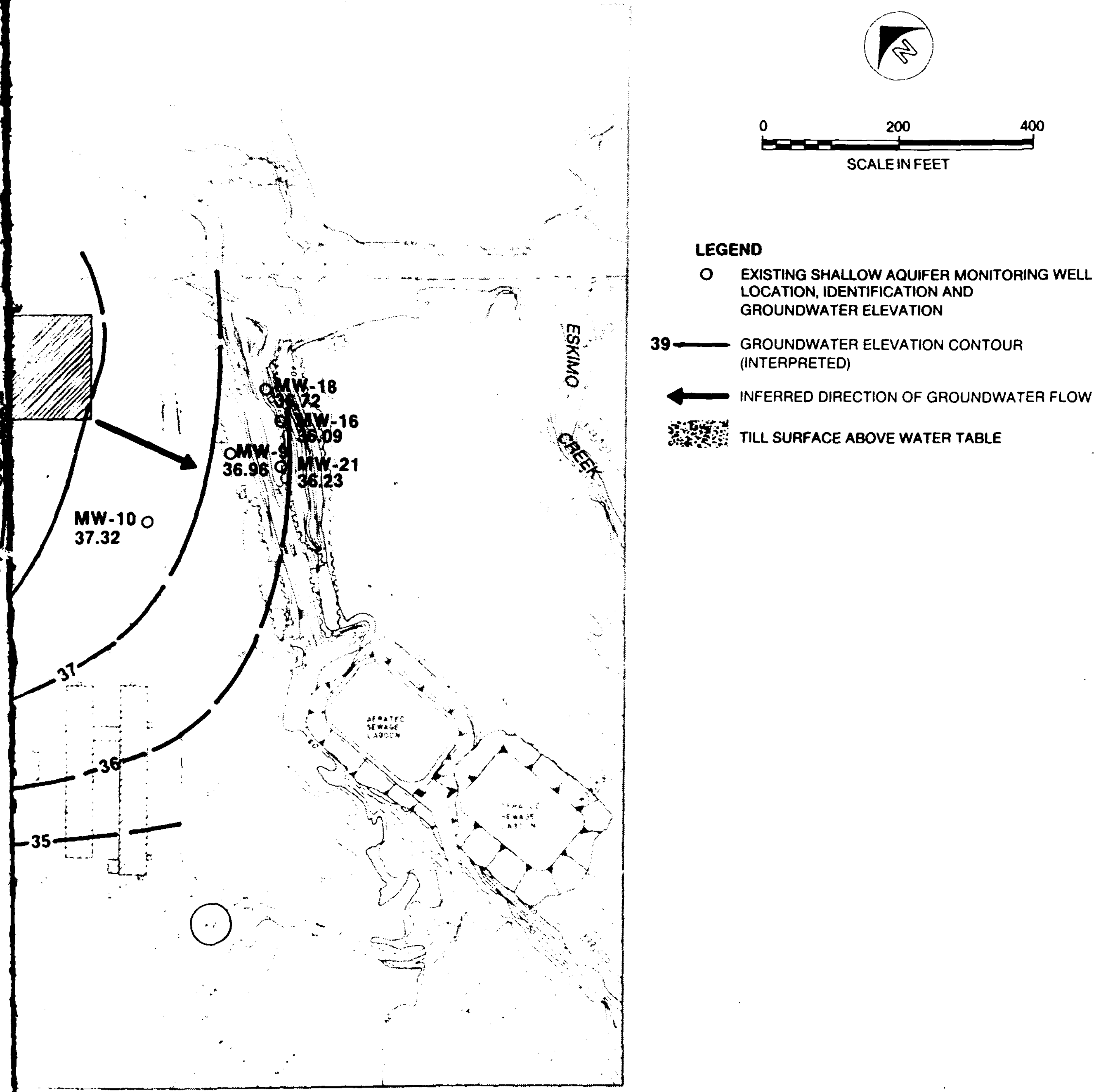
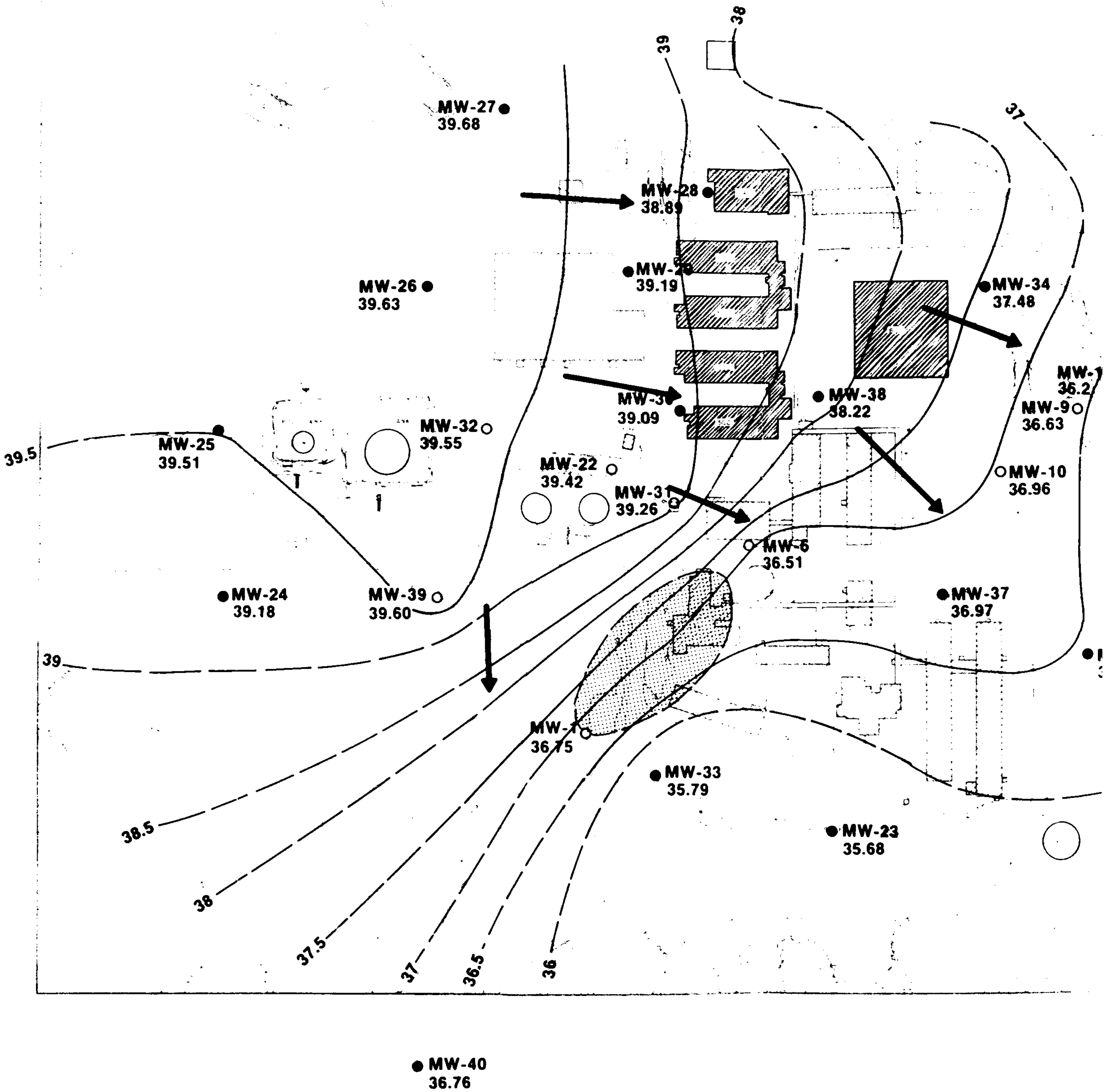


FIGURE 4-9

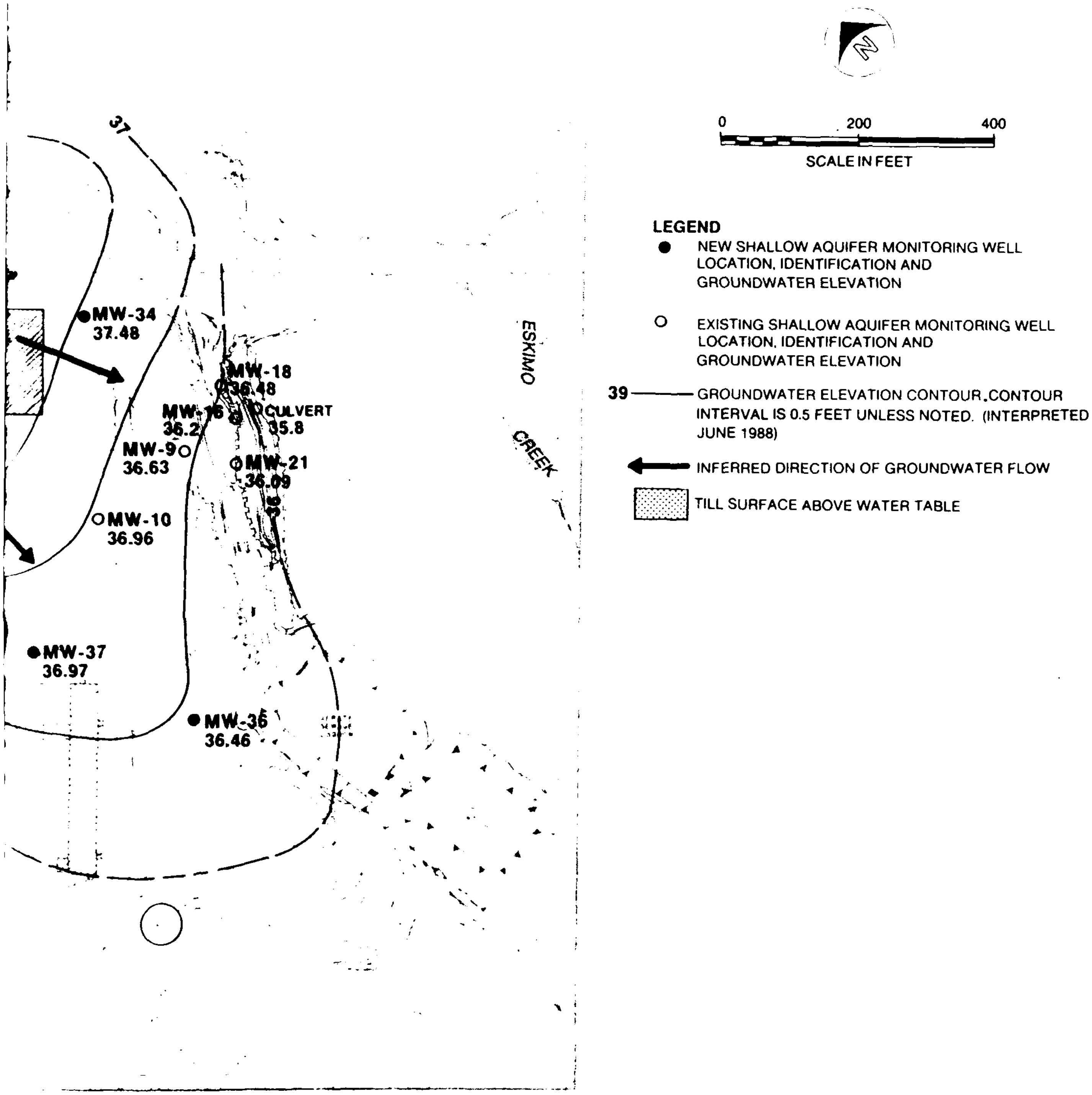
SHALLOW AQUIFER GROUNDWATER ELEVATION CONTOURS

OCTOBER, 1987
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL


38
39
37
MW-27
39.68
MW-28
38.89
MW-26
39.63
MW-29
39.19
MW-34
37.48
MW-1
36.2
MW-30
39.09
MW-38
38.22
MW-9
36.63
MW-32
39.55
39.5
MW-25
39.51
MW-22
39.42
MW-10
36.96
MW-31
39.26
MW-6
36.51
MW-24
39.18
MW-39
39.60
MW-37
36.97
39
MW-1
36.75
MW-33
35.79
MW-23
35.68
38.5
38
37.5
37
36.5
36
MW-40
36.76

K24173 A0



LEGEND

● NEW SHALLOW AQUIFER MONITORING WELL LOCATION, IDENTIFICATION AND GROUNDWATER ELEVATION

○ EXISTING SHALLOW AQUIFER MONITORING WELL LOCATION, IDENTIFICATION AND GROUNDWATER ELEVATION

39 ——— GROUNDWATER ELEVATION CONTOUR, CONTOUR INTERVAL IS 0.5 FEET UNLESS NOTED. (INTERPRETED JUNE 1988)

⬅ INFERRED DIRECTION OF GROUNDWATER FLOW

▨ TILL SURFACE ABOVE WATER TABLE

FIGURE 4-10

SHALLOW AQUIFER
GROUNDWATER
ELEVATION CONTOURS
JUNE 14, 1988
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

The shaded area near the center of the site indicates where the upper aquitard surface is higher in elevation than the groundwater level. This is represented by a steepening of the potentiometric contours where finer grained materials impede groundwater flow. Due to the heterogeneous, anisotropic conditions, groundwater flow directions in this area would be expected to swing to the east and/or west around the till feature (not perpendicular to the equipotential lines). As water levels drop seasonally, the till would be expected to have a greater effect on the direction of groundwater flow as a larger area of the aquifer becomes unsaturated.

The aquifer gradient through areas not affected by the till is about $3.5x10^{-3}$. Through the till area, the gradient steepens to $1x10^{-2}$.

The hydraulic conductivity of the unconfined aquifer was estimated from single well "slug" tests performed on each newly installed shallow well. Parameter values are summarized in Table 4-3. Raw data and plots are presented in Appendix D-1.

Slug and bail tests were attempted in each new well using a solid rod to displace a slug of water. A pressure transducer and data logger were used to record water level and time data. Field data were analyzed with the method presented by Bouwer and Rice (1976), which is applied to unconfined aquifers to determine the hydraulic conductivity principally in the horizontal direction.

Several difficulties were encountered in conducting the tests that resulted from the monitoring well construction and high conductivity of the aquifer. The wells were screened above the saturated interface to allow accumulation of free product. This only left a few feet of water in the wells into which to place a "slug" or withdraw a "bail." Consequently, when the slug or bail was applied, the system often recovered in a very short period of time. This problem was partially compensated for by use of a data logger that could record readings in increments of seconds. However, several wells still responded too quickly (e.g., tenths of seconds) to produce usable results.

Another difficulty arose because the wells were screened above the saturated interface. When a slug was applied, water immediately flowed through the screen into the unsaturated sandpack. On the slug cycle, this took about 1.5 seconds. The slug then decayed through the volume of the borehole. This boundary problem was addressed by using a corrected radius (Bouwer and Rice, 1976) that included the sandpack. On the bail tests, water from the sandpack appeared to drain back into the casing over a much longer period

Table 4-3
SHALLOW AQUIFER PARAMETERS AND HYDRAULIC CONDUCTIVITY ESTIMATE KING SALMON AFS, KING SLAMON, ALASKA

Well ID	Casing Radius rc' (ft)	Borehole Radius rw (ft)	Length of Sandpack L (ft)	Saturated Thickness H (ft)	Ratio L/rw	C Dimensionless Parameter[b]	ln (Re/rw)	Time Lag[a] To (second)	Estimated Hydraulic Conductivity Bouwer and Rice (ft/day)
MW-23	0.268	0.416	4.53	4.53	10.9	1.3	1.72	123.0	10
MW-24	0.268	0.416	9.74	9.74	23.4	1.7	2.37	8.0	94
MW-25	0.268	0.416	8.68	8.68	20.9	1.5	2.30	20.0	41
MW-28	0.268	0.416	9.27	9.27	22.3	1.5	2.37	13.0	61
MW-29	0.268	0.416	8.81	8.81	21.2	1.5	2.32	11.5	71
MW-32	0.268	0.416	10.0	10.0	24.0	1.8	2.38	10.75	69
MW-34	0.268	0.416	7.93	7.93	19.1	1.4	2.24	77.0	11
MW-36	0.268	0.416	6.17	6.17	14.8	1.3	2.02	36.0	28
MW-38	0.268	0.416	8.96	8.96	21.5	1.5	2.34	10.5	77

---

[a] Time lag from plots in Appendix D.

[b] Used in Bouwer and Rice model to calculate ln (Re/Rw).

Required Equations:

Bouwer and Rice (1976): $K = \frac{rc' \ln (Re/rw)}{2 L T_o}$ $\ln (Re/rw) = \left(\frac{1.1}{\ln (H/rw)} + \frac{C-1}{L/rw}\right)$

Casing radius corrected for sandpack: $rc' = [rc + n(rw^2 - rc^2)]^{\frac{1}{2}}$

Where:
re = Effective casing radius
rc = Radius of casing
rc'= Corrected casing radius
n = Porosity of sandpack
rw = Borehole radius
L = Length of sandpack
To = Lag time
Re = Effective zone of influence (Bouwer and Rice)
H = Saturated thickness

CVR193/020

of time (tens of seconds). This interference essentially masked the effects in the aquifer and the bail tests could not be analyzed.

Hydraulic conductivity estimates for nine slug tests ranged from 10 to 94 feet per day. These values are representative of clean fine sands and slightly silty sands. The wells that responded too quickly to produce adequate data may have higher conductivities.

Estimates of the groundwater flow velocity were calculated using a modified form of Darcy's law shown below:

$$V = \frac{Ki}{n_e}$$

where:

V = average linear velocity
K = hydraulic conductivity
i = hydraulic gradient
n_e = effective porosity

The hydraulic conductivity of the shallow unconfined aquifer was determined from slug test data and ranged from 10 to 94 feet per day, with an average of 51 feet per day.

The effective porosity was assumed to be 0.30, which correlates to a clean, fine sand.

The gradient based on the June 1988 water table elevation contour map for an area unobstructed by the till mound is 3.5×10^{-3}. This gradient can vary seasonally; additional water level measurements and flow system interpretations are recommended.

Estimates of flow velocities are provided in Table 4-4. The travel time downgradient for a distance of 100 feet is also provided. The total flow in gallons per minute through the aquifer, assuming a saturated thickness of 10 feet by 100 feet, is included.

These estimates include a number of simplifying assumptions and, therefore, should only be considered as general indicators of the groundwater flow conditions. For engineering purposes (e.g., design of groundwater extraction system), additional investigation to define aquifer parameters is required. Further investigation would include multiple well aquifer testing (horizontal and vertical) and seasonal groundwater level measurements for flow system interpretations.

Table 4-4 presents estimates of the underflow and groundwater flow velocities for the unconfined aquifer.

Table 4-4
SHALLOW AQUIFER PARAMETER ESTIMATES

Estimated Thickness, B (ft)	Hydraulic Conductivity (ft/day)	Average Gradient, I (ft/ft)	Underflow, Q[a] (gpm/100 ft)	Average Velocity[b] (ft/day)	Travel Time (days/100 ft)
10	10 to 94 51[c]	3.5×10^{-3}	0.2 to 1.7 0.9	0.12 to 1.1 0.6	91 to 833 167

---

[a] Underflow Q = KIB (100 feet).

[b] Average velocity $\bar{V} = \frac{KI}{\text{porosity approximately 0.30}}$

[c] Average conductivity from nine slug tests.

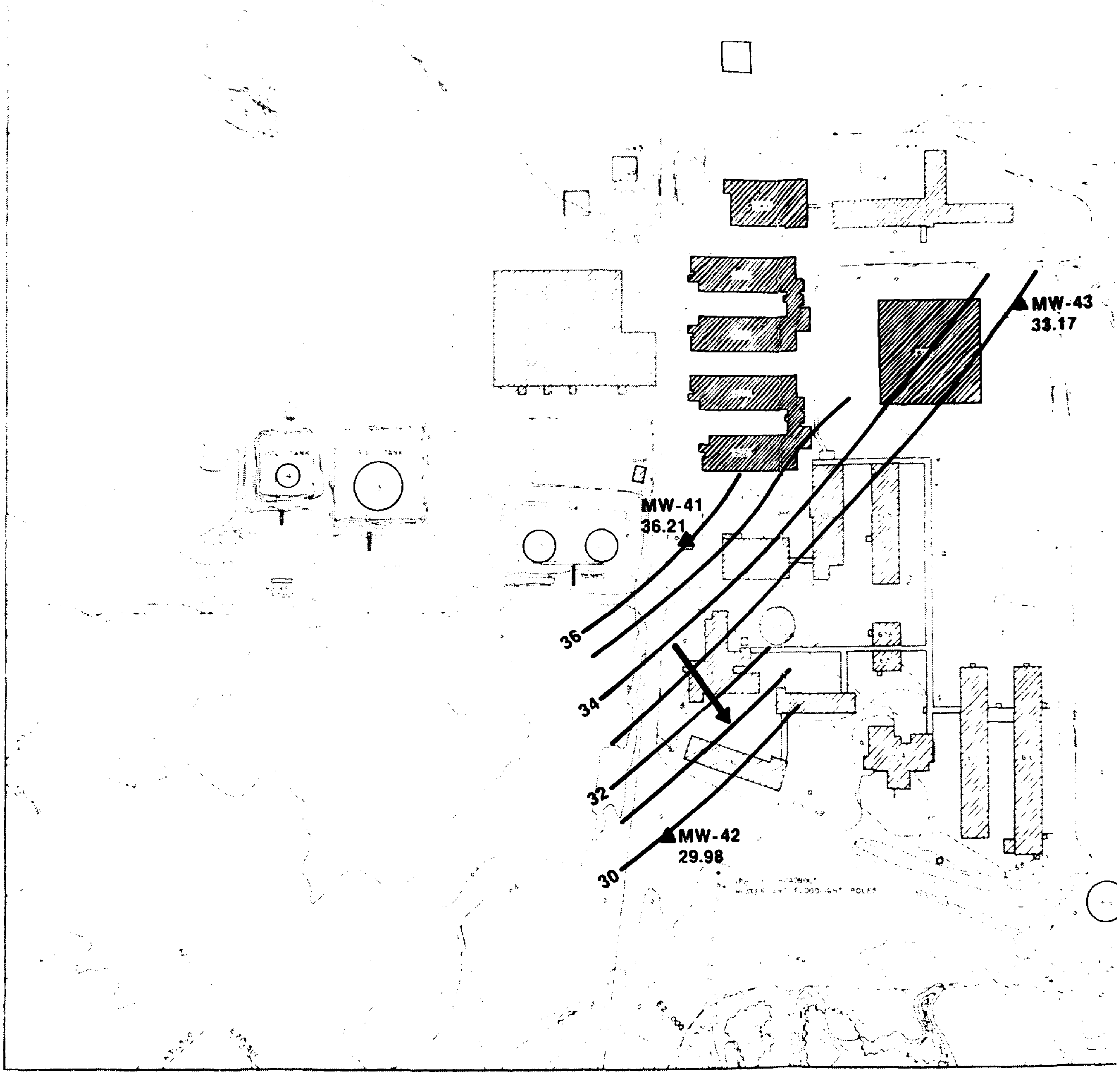
4.1.3.2.2 Intermediate Aquifer

Water levels measured between the shallow aquifer and intermediate aquifer indicate a downward vertical gradient condition of about 7×10^{-2} ft/ft. Thus, the shallow unconfined aquifer is a recharge source to the intermediate aquifer(s) (Table 4-5).

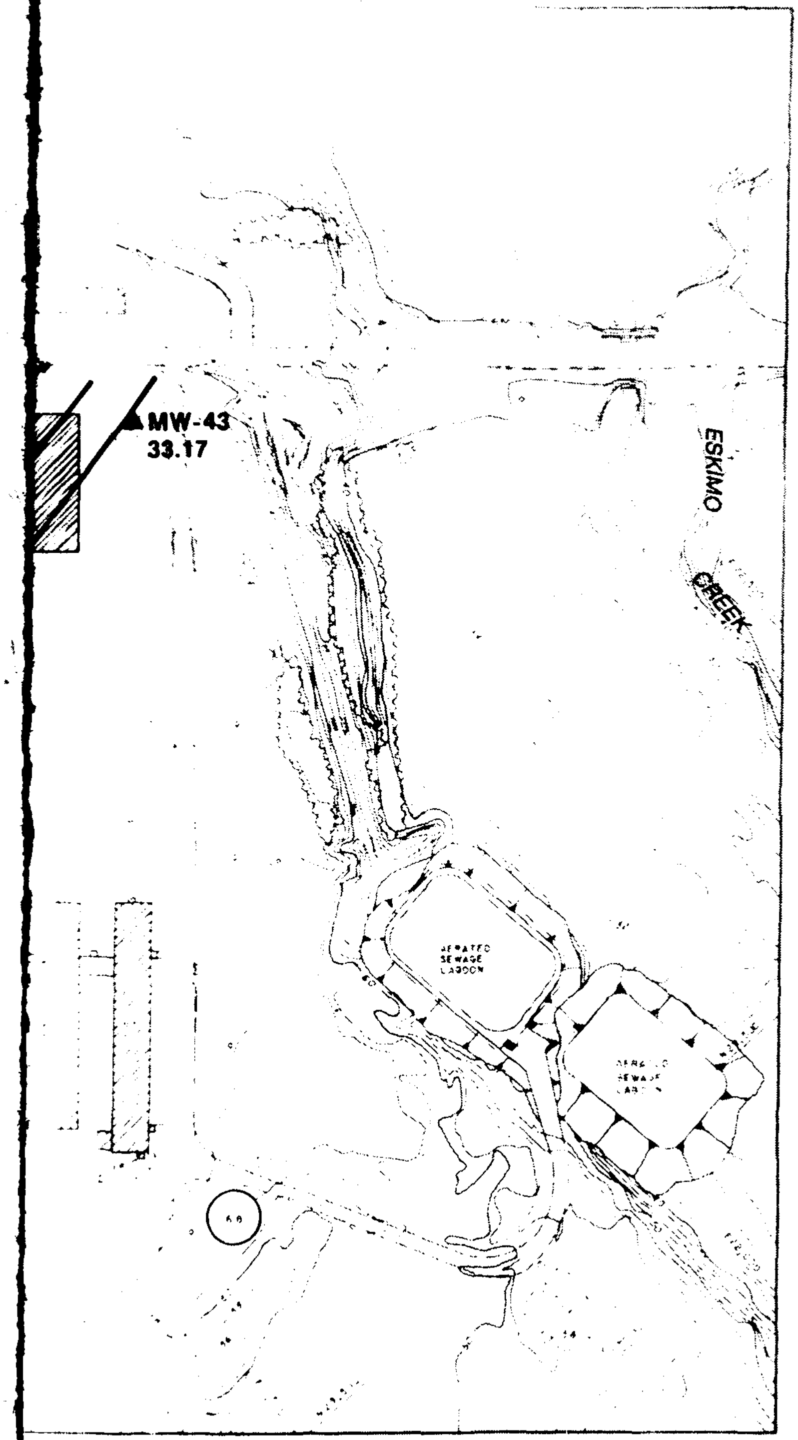
Table 4-5
ESTIMATED VERTICAL GRADIENTS
JUNE 1988
WELL NEST

Shallow Aquifer		Intermediate Aquifer		Vertical Gradient (ft/ft)
Well Identification	Groundwater Elevation	Well Identification	Groundwater Elevation	
MW-31	39.26	MW-41	36.21	0.06
MW-33	35.79	MW-42	29.98	0.1
MW-34	37.48	MW-43	33.17	0.06

The horizontal direction of groundwater flow in the intermediate aquifer was interpreted from water level data from the three newly installed deep wells (Figure 4-11). The flow direction is highly interpretive because only these data points were used and the screened intervals of the wells



K24173.A0



N

0 200 400

SCALE IN FEET

LEGEND

- ▲ NEW INTERMEDIATE AQUIFER MONITORING WELL LOCATION, IDENTIFICATION AND GROUNDWATER ELEVATION
- —35— POTENTIOMETRIC SURFACE CONTOUR LINE AND ELEVATION
- ← INFERRED DIRECTION OF GROUNDWATER FLOW

NOTE:
POTENTIOMETRIC SURFACE CONTOURS ARE BASED ON LIMITED DATA POINTS.

FIGURE 4-11

POTENTIOMETRIC SURFACE CONTOUR MAP OF THE INTERMEDIATE AQUIFER
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

Table 4-6
INTERMEDIATE AQUIFER RECOVERY TEST RESULTS

Well Identification	Aquifer Materials	Discharge Rate, Q, During Pump Test (ft^3/day)	Residual Drawdown Per Log Cycle ΔS (ft)	Aquifer Thickness, B (ft)	Estimated Transmissivity, T (ft^2/day)	Estimated Hydraulic Conductivity (ft/day)
MW-41	Sandy gravels	3,850	0.355	41.0	1,985	48.4
MW-42	Sand	3,850	0.855	47.5	824	17.3
MW-43	Sand and gravel	2,406	0.875	62.5	503	8.1

Theis' Recovery Method: $T = KB = \frac{2.3\ Q}{4\pi\ \Delta S}$

Where:
T = Transmissivity, ft^2/day
K = Hydraulic conductivity, ft/day
B = Aquifer thickness, ft
Q = Discharge rate, ft^3/day
ΔS = Residual drawdown per log cycle

CVR193/045

vary. Also, the lateral continuity of these glacial deposits beneath the site is unknown. The direction of flow appears to be to the south, which roughly correlates with the upper aquifer. The apparent horizontal gradient is about 1x10^{-2} ft/ft.

A single well pumping/recovery test was performed on each intermediate well to provide an estimation of the hydraulic conductivity. The recovery data were analyzed using the This Recovery Method (Kruseman and DeRidder, 1970) and results are summarized in Table 4-6. Raw data and plotted data are presented in Appendix D-2. In each of the analyses, late time recovery sections of the plots were used to minimize the effects of partial penetration.

Table 4-7 presents estimates of aquifer parameters for the intermediate zone. These estimations include the assumptions presented in the shallow aquifer section.

Table 4-7
INTERMEDIATE AQUIFER PARAMETER ESTIMATES

Well No.	Estimated Thickness, B (ft)	Hydraulic Conductivity,[c] K (ft/day)	Average Gradient, I (ft/ft)	Underflow, Q[a] (gpm/100 ft)	Average Velocity[b] (ft/day)	Travel Time (days/100 ft)
41	41.0	48	2×10^{-2}	20.4	3.8	26
42	47.5	17	2×10^{-2}	8.4	1.36	74
43	62.5	8	2×10^{-2}	5.2	0.64	156

---

[a] Underflow Q = KIB (100 feet).

[b] Average velocity = KI/n (assumed porosity n = 0.25).

[c] Hydraulic conductivity from short term recovery tests.

4.1.3.2.3 Deep Aquifer

The water supply wells of the station are shown in Figure 4-7, and well logs are presented in Appendix C-2. A summary of well data is provided in Table 4-8. Well yields range from 7 to 140 gpm.

4.1.4 Subsurface Soil Contamination Investigation

4.1.4.1 Eskimo Creek Seep

Soils contamination data from previous investigations include oil and grease analyses from soil samples in six borings (AH-1 through AH-6) shown in Figure 4-12. The oil and grease

Table 4-8
KING SALMON AFS WELL DATA

Location	Well No. 1 Building 130	Well No. 2 Building 139	Well No. 3 Building 205	Well No. 4 Building 638	Well No. 5 Building 650	Well No. 6 Building 654	Well No. 7 Building 148	Well No. 8 Building 327	Well No. 9 Building 561	Well No. 10 Building 1001
Installation Date	5/49	3/49	na	10/52	10/52	na	na	12/72	1/73	na
Depth (feet)	--	104	--	228	233	137	168	116	224	135
Casing Diameter (inches)	--	--	8	--	8	8	6	6	6	6
GPM (Open Flow)	--	140	--	140	55	--	75	7	10	--
Drawdown (feet)	--	120	--	22.7	9.0	4.0	50.3	9	16	--
Static Water Level[a] (feet below grade)	na	--	na	48	40	--	30	--	34	na
Pump	--	Goulds	--	Goulds	--	--	Goulds	Jacuzzi	Jacuzzi	--
Model	--	Submersible	--	Submersible	--	--	Submersible	Submersible	Submersible	--
Hosepower	--	15	--	15	7.5	--	5	--	--	--
Cycle	--	--	--	--	--	--	--	--	--	--
Phase	--	3	--	3	3	--	3	--	1	--
Amperage	--	40	--	40	23.3	--	15	--	--	--
RPM	--	3,450	--	3,450	3,450	--	3,450	--	--	--
Installation	--	1949	--	1952	1952	--	1957	1972	1972	--
Remarks	Abandoned	Potable	Abandoned	Potable	Potable	Nonpotable	Potable	Potable	Potable	Potable
Condition & Use	--	Standby Fire Protection	--	Main Water Supply	Main Water Supply	Supplies Bldg. 654	Standby Fire Protection	Supplies Bldg. 327	Supplies Bldg. 561	Supplies White Alice Site

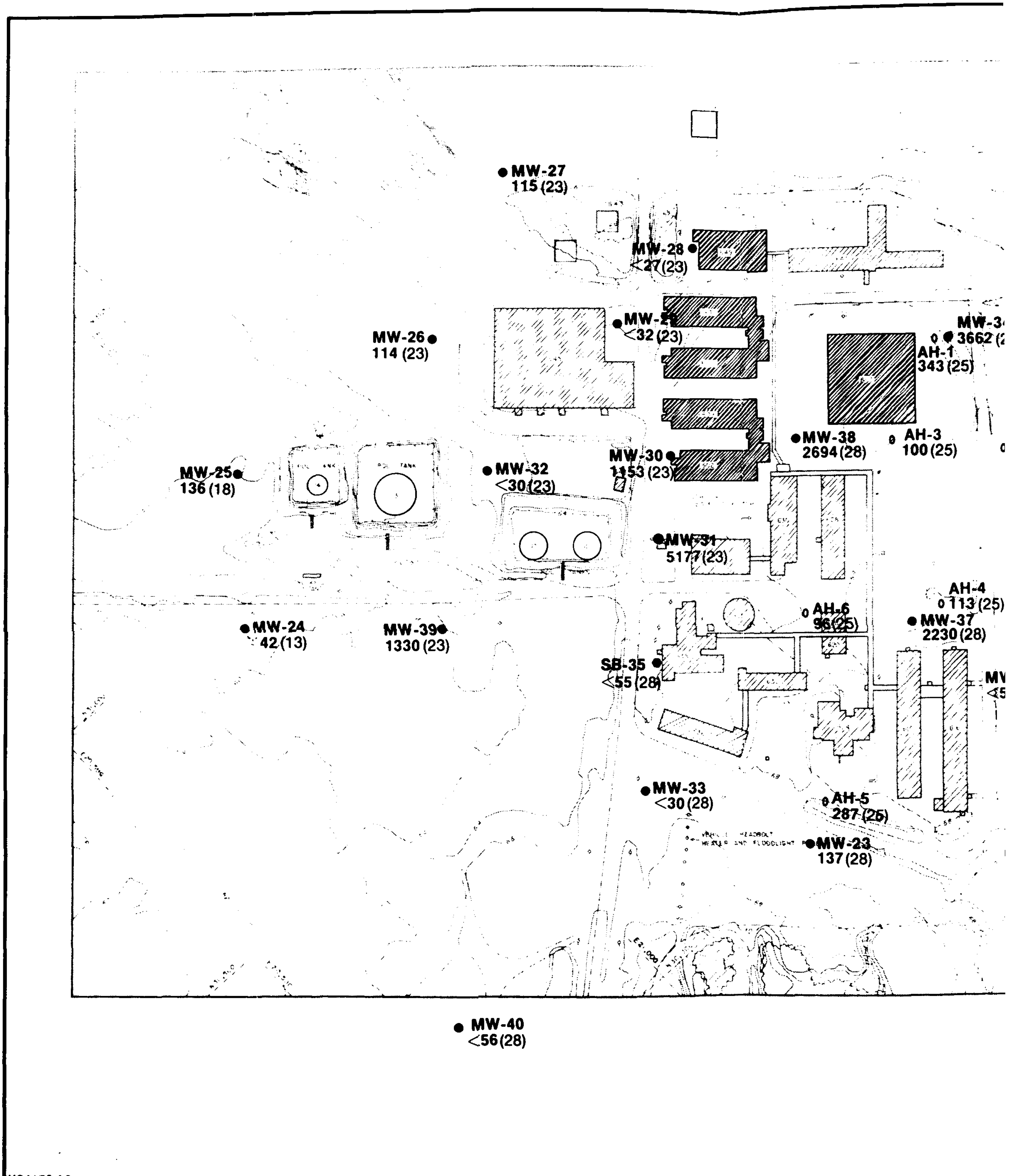
---

[a] Water levels as measured on 10/88.

na = Not available.

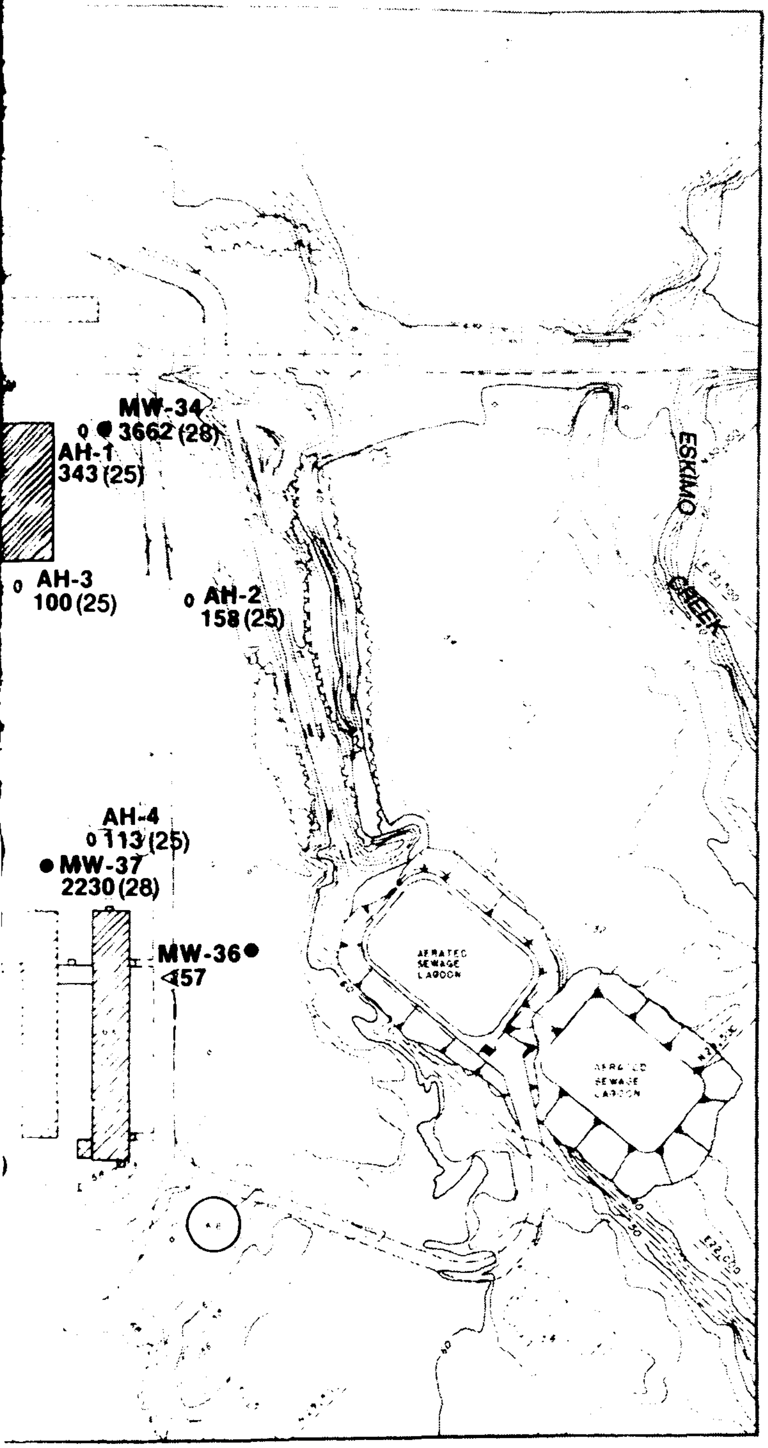
Source: Installation Documents

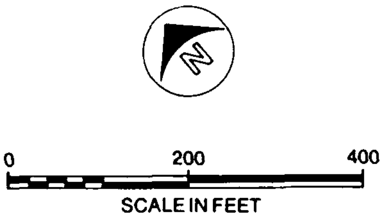
CVR193/023


MW-27
115 (23)
MW-28
<27 (23)
MW-26
114 (23)
MW-29
<32 (23)
MW-3
3662 (2
AH-1
343 (25)
MW-38
2694 (28)
AH-3
100 (25)
MW-25
136 (18)
POL TANK
POL TANK
MW-32
<30 (23)
MW-30
1153 (23)
MW-31
5177 (23)
AH-4
113 (25)
AH-6
96 (25)
MW-37
2230 (28)
MW-24
42 (13)
MW-39
1330 (23)
SB-35
<55 (28)
MW
<5
MW-33
<30 (28)
AH-5
287 (25)
VEHICLE HEADBOLT HEATER AND FLOODLIGHT
MW-23
137 (28)
MW-40
<56 (28)

K24173.A0

A





LEGEND

MW ● TOTAL PETROLEUM HYDROCARBON mg/kg AT VARIOUS DEPTHS (DEPTH IN FEET)
(SOURCE: CH2M HILL DECEMBER 1987 AND JUNE 1988)

AH 0 OIL AND GREASE CONCENTRATION mg/kg at 25' (DEPTH IN FEET)
(SOURCE: CORPS OF ENGINEERS, AUGUST 1978)

FIGURE 4-12

TPH AND OIL/GREASE SOIL CONCENTRATION

AUGUST 1978, DECEMBER 1987 AND JUNE 1988

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

value for the interval 25 feet below ground surface in the unsaturated zone is plotted by each well. The vertical distribution of contamination within each borehole is illustrated in Table 4-9.

One soil sample from each new borehole (MW-23 through MW-40) was selected for total petroleum hydrocarbon analysis. These values are plotted in Figure 4-12 at each well. The soil interval tested in each well was based on the soil sample having the highest volatile organic concentration (soil gas head space) reading with an OVA or HNU. Table 4-10 presents these soil analysis data.

The variation observed in the replicate sample at Boring No. 39 cannot be explained. HNU measurements performed on the discreet and replicate sample at the time of collection correlate reasonably well. Volatile screening values for other intervals are reported on the boring logs in Appendix C-1.

On the basis of available data, hydrocarbon contamination appears to be widespread in the unsaturated zone soils. The oil and grease data suggests contamination has spread vertically in the southern area of the site. The total petroleum hydrocarbons (TPH) data from the newly installed borings indicates contamination is spread laterally across the site at levels well above detection limits shown in Table 4-10.

Soil contamination appears to be highest in the central area of the site at levels above 1,000 mg/kg (dry weight). This correlates with the groundwater and soil gas data identifying a plume that spreads from the POL tanks across the site to the southeast and south towards Eskimo Creek.

As discussed in Section III, cuttings from soil borings exhibiting significant levels of contamination based on visual inspection and/or HNU readings were contained in DOT-approved drums, composited, and then tested for EP Toxicity (metals) and volatile and semivolatile organic compounds. The results of the analyses are presented in Table 4-11.

The drummed cuttings do not meet RCRA criteria for designation as a hazardous waste. The drums are currently in the possession of King Salmon Air Force facility engineers for final disposition.

4.1.5 Water Quality Investigation

Section 3.6 outlines the water quality sampling tasks for this project and procedures used to collect representative groundwater and surface water samples. This section presents the results from this task for each site. Laboratory analytical reports, and QA/QC data are presented in Appendix G.

Table 4-9
OIL AND GREASE ANALYSES
1978 USCOE SOILS INVESTIGATION

Hole No.	Sample No.	Depth (ft BGS)	Grease and Oil mg/kg (dry weight basis)	Water Depth (ft BGS)	Moisture Content %
AH-1	1	5	186.64	30	9.61
	2	10	224.60	30	4.91
	3	15	211.73	30	3.68
	4	20	301.25	30	3.52
	5	25	343.24	30	3.83
	6	30	157.56	30	13.39
AH-2	1	5	157.50	30	6.55
	2	10	104.88	30	4.40
	3	15	62.14	30	5.11
	4	20	50.80	30	6.96
	5	25	158.24	30	5.06
	6	30	198.46	30	28.69
AH-3	1	5	167.63	30	11.03
	2	10	141.84	30	5.29
	3	15	75.17	30	10.42
	4	20	175.68	30	9.14
	5	25	100.65	30	4.78
	6	30	380.02	30	23.52
AH-4	1	5	192.15	30	7.85
	2	10	95.06	30	6.26
	3	15	194.89	30	5.08
	4	20	104.49	30	2.88
	5	25	113.20	30	4.50
	6	30	200.50	30	20.80
AH-5	1	5	271.74	NE	9.28
	2	10	112.60	NE	7.09
	3	15	81.36	NE	4.93
	4	20	83.12	NE	4.31
	5	25	287.23	NE	6.79
	6	30	675.17	NE	10.21
AH-6	1	5	222.78	30	14.45
	2	10	136.36	30	13.09
	3	15	106.67	30	7.01
	4	20	63.49	30	6.66
	5	25	96.15	30	10.46
	6	30	61.95	30	10.99

NOTES: BGS = below ground surface.
NE = not encountered.
The oil and grease tests were conducted in accordance with Standard Methods Section 502D, "Extraction Method for Sludge Samples" which uses the Soxhlet extraction apparatus and 1, 1, 2 trichloro - 1, 2, 2 trifloroethane, freon as the extraction solvent.

CVR193/019

Table 4-10
TOTAL PETROLEUM HYDROCARBONS
ESKIMO CREEK SOIL BORINGS

Boring No.	Sample No.	Depth (feet)	OVA Head Space (ppm)	TPH mg/kg (dry weight)	Water Level (ft BGS)	Moisture (%)	Detection Limit (mg/kg)
23	07	28	NR	137	32	4	66
24	03	13	NR	142	20	8	68
25	01	18	NR	136	21	4	66
26	04	23	NR	114	26	9	70
27	05	23	NR	115	24	9	79
28	05	23	NR	<27	26	6	27
29	05	23	NR	<32	25	23	32
30	05	23	3	1,153	27	12	28
31	05	23	2.6	5,177	26	13	29
32	05	23	0	<30	24	18	30
33	06	28	0	<30	31	16	30
34	06	28	NR	3,662	28	16	82
34 (Rep)	06	28	NR	4,641	28	23	75
35	06	28	0	<55	NE	12	55
36	06	28	0	<57	30	15	57
37	06	28	0	2,231	30	19	229
38	06	28	130	2,694	29	21	166
39	05	23	100	<62	22	16	62
39 (Rep)	05	23	80	1,330	22	19	268
40	06	28	0	<56	27	14	56

Test Methods:
TPH--E418.1
Moisture--ASTM D2216

NOTES:

Detection limits for individual samples are dependent on their moisture content.

Sample depths for TPH analyses were selected on basis of OVA/HNu measurements performed in the field on samples at the time of collection. Samples with the highest observed readings were submitted for TPH analysis.

Sample replicates were taken by splitting the sample vertically into four quarters and collecting the first quarter as the discrete sample and the third as the replicate.

BG = Background.
NE = Water not encountered to a depth of 35 feet.
NR = Not Recorded.

CVR193/018

Table 4-11A
EP TOXICITY (METALS)

ESKIMO CREEK DRUMMED CUTTINGS

Parameter	Method	Detection Limit	Units	DC-MW-30	DC-MW-38	DC-MW-39	DC-MW-41 & MW-31	DC-MW-43	DC-MW89 DUP MW-43
Arsenic	1310	0.5	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Barium	1310	0.5	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cadmium	1310	0.1	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	1310	0.5	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Lead	1310	0.5	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Mercury	1310	0.002	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium	1310	0.1	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	1310	0.5	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Soil Moisture	D2216	-	%	8.86	18.7	16.5	13.8	18.7	16.8

Table 4-11B
VOLATILE ORGANIC COMPOUNDS
(SW8240)

ESKIMO CREEK DRUMMED CUTTINGS

Parameter	Units	DC-MW30	DC-MW38	DC-MW39	DC-MW41 & MW31	DC-MW43	DC-MW89 DUP MW-43
Chloromethane	ug/kg	550U	5200U	3600J	5800U	6200U	6000U
Bromoethane	ug/kg	550U	6200U	6000U	5800U	6200U	6000U
Vinyl chloride	ug/kg	550U	5200U	6000U	5800U	6200U	6000U
Chloroethane	ug/kg	550U	6200U	6000U	5800U	6200U	6000U
Methylene chloride	ug/kg	320	16000	12000	13000	15000	15000
Acetone	ug/kg	550U	8600	6000U	6400	7300	6000U
Carbon disulfide	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
1,1-Dichloroethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
1,1-Dichloroethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Trans-1,2-dichloroethene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Chloroform	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
1,2-Dichloroethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
2-Butanone	ug/kg	550U	6200U	6000U	5800U	3100J	6000U
1,1,1-Trichloroethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Carbon tetrachloride	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Vinyl acetate	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Bromodichloromethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
1,2-Dichloropropane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Cis-1,3-Dichloropropene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Trichloroethene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Dibromochloromethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
1,1,2-Trichloroethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Trans-1,3-dichloropropene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Benzene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
2-Chloroethyl vinyl ether	ug/kg	550U	6200U	6000U	5800U	3100U	6000U
Bromoform	ug/kg	270U	3100U	3000U	2900U	3100U	3000U

U = Indicates the compound was analyzed for, but not detected.
J = Indicates an estimated trace value.
DC = Drum cuttings.

CVR193/033-2

Table 4-11B
(Continued)

Parameter	Units	DC-MW30	DC-MW38	DC-MW39	DC-MW41 & MW31	DC-MW43	DC-MW89 DUP MW-43
4-Methyl-2-pentanone	ug/kg	550U	6200U	6000U	5800U	3100U	6000U
2-Hexanone	ug/kg	550U	6200U	6000U	5800U	3100U	6000U
1,1,2,2-Tetrachloroethane	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Tetrachlorethene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Toluene	ug/kg	330	3100U	1500J	2900U	3100U	3000U
Chlorobenzene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Ethylbenzene	ug/kg	400	3100U	3000U	2900U	3100U	3000U
Styrene	ug/kg	270U	3100U	3000U	2900U	3100U	3000U
Xylenes (o+p)	ug/kg	1800	3100U	3000U	2900U	3100U	3000U
Xylene (p)	ug/kg	1500	3100U	3000U	2900U	3100U	3000U

U = Indicates the compound was analyzed for, but not detected.
J = Indicates an estimated trace value.
DC = *Drum cuttings.*

Table 4-11C
SEMIVOLATILE ORGANICS
(SW8270)
ESKIMO CREEK DRUMMED CUTTINGS

Parameter	Units	DC-MW-30	DC-MW38	DC-MW-39	DC-MW41 & MW31	DC-MW43	DC-MW-89
N-nitroso-dimethylamine	ug/kg	360U	410U	400U	380U	410U	400U
Phenol	ug/kg	360U	410U	400U	380U	410U	400U
Aniline	ug/kg	360U	410U	400U	380U	410U	400U
Bis(2-chloroethyl)ether	ug/kg	360U	410U	400U	380U	410U	400U
2-Chlorophenol	ug/kg	360U	410U	400U	380U	410U	400U
1,3-Dichlorobenzene	ug/kg	360U	410U	400U	380U	410U	400U
1,4-Dichlorobenzene	ug/kg	360U	410U	400U	380U	410U	400U
Benzyl alcohol	ug/kg	360U	410U	400U	380U	410U	400U
1,2-Dichlorobenzene	ug/kg	360U	410U	400U	380U	410U	400U
2-Methylphenol	ug/kg	360U	410U	400U	380U	410U	400U
Bis(2-chloroisopropyl)	ug/kg	360U	410U	400U	380U	410U	400U
4-Methylphenol	ug/kg	360U	410U	400U	380U	410U	400U
N-nitroso-di-n-propylamine	ug/kg	360U	410U	400U	380U	410U	400U
Hexachloroethane	ug/kg	360U	410U	400U	380U	410U	400U
Nitrobenzene	ug/kg	360U	410U	400U	380U	410U	400U
Isophrone	ug/kg	360U	410U	400U	380U	410U	400U
2-Nitrophenol	ug/kg	360U	410U	400U	380U	410U	400U
2,4-Diethylphenol	ug/kg	360U	410U	400U	380U	410U	400U
Benzoic acid	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
Bis(2-chloroethoxy)methane	ug/kg	360U	410U	400U	380U	410U	400U
2,4-Dichlorophenol	ug/kg	360U	410U	400U	380U	410U	400U
1,2,4-trichlorobenzene	ug/kg	360U	410U	400U	380U	410U	400U
Naphthalene	ug/kg	360U	1300	490	380U	410U	400U
4-Chloroaniline	ug/kg	360U	410U	400U	380U	410U	400U
Hexachlorobutadiene	ug/kg	360U	410U	400U	380U	410U	400U
4-Chloro-3-methylphenol	ug/kg	360U	410U	400U	380U	410U	400U
2-Methylnaphthalene	ug/kg	8500	5100	2200	3700	410U	400U
Hexachlorocyclopentadiene	ug/kg	360U	410U	400U	380U	410U	400U

U = Indicates the compound was analyzed for, but not detected.
J = Indicates an estimated trace value.
DC = Drum cuttings.

Table 4-11C
(Continued)

Parameter	Units	DC-MW-30	DC-MW38	DC-MW-39	DC-MW41 & MW31	DC-MW43	DC-MW-89
2,4,6-Trichlorophenol	ug/kg	360U	410U	400U	380U	410U	400U
2,4,5-Trichlorophenol	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
2-Chloronaphthalene	ug/kg	360U	410U	400U	380U	410U	400U
2-Nitroailine	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
Dimethyl phthalate	ug/kg	360U	410U	400U	380U	410U	400U
Acenaphthene	ug/kg	360U	410U	400U	380U	410U	400U
3-nitroaniline	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
Acenaphthene	ug/kg	360U	410U	400U	380U	410U	400U
2,4-Dinitrophenol	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
4-Nitrophenol	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
Dibenzofuran	ug/kg	360U	410U	400U	380U	410U	400U
2,4-Dinitrotoluene	ug/kg	360U	410U	400U	380U	410U	400U
2,6-Dinitrotoluene	ug/kg	360U	410U	400U	380U	410U	400U
Diethyl phthalate	ug/kg	360U	410U	400U	380U	410U	400U
4-Chlorophenyl phenyl ether	ug/kg	360U	410U	400U	380U	410U	400U
Fluorene	ug/kg	630	290J	400U	330J	410U	400U
4-Nitroaniline	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
4,6-Dinitro-2-methylphenol	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
N-nithosodiphenylamine	ug/kg	360U	410U	400U	380U	410U	400U
4-Bromophenyl phenyl ether	ug/kg	360U	410U	400U	380U	410U	400U
Hexachlorobenzene	ug/kg	360U	410U	400U	380U	410U	400U
Pentachlorophenol	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
Phenanthrene	ug/kg	210J	410U	400U	380U	4100U	400U
Anthracene	ug/kg	360U	410U	400U	380U	410U	400U
Di-n-butyl phathalate	ug/kg	360U	410U	400U	380U	410U	400U
Fluoranthene	ug/kg	360U	410U	400U	380U	410U	400U
Benzidine	ug/kg	1800U	2000U	1900U	1900U	2000U	1900U
Pyrene	ug/kg	360U	410U	400U	380U	410U	400U
Butyl benzyl phthalate	ug/kg	360U	410U	400U	1800	870	1200
3,3-dichlorobenzidine	ug/kg	720U	810U	800U	770U	810U	800U

U = Indicates the compound was analyzed for, but not detected.
J = Indicates an estimated trace value.
DC = Drum cuttings.

Table 4-11C
(Continued)

Parameter	Units	DC-MW-30	DC-MW38	DC-MW-39	DC-MW41 & MW31	DC-MW43	DC-MW-89
Benzo(a)anthracene	ug/kg	360U	410U	400U	380U	410U	400U
Bis(2-ethylhexyl)phthalate	ug/kg	360U	410U	1500	380U	1100	950
Chrysene	ug/kg	360U	410U	400U	380U	410U	400U
Di-n-octyl phthalate	ug/kg	360U	410U	400U	380U	210J	400U
Benzo(b)fluoranthene	ug/kg	360U	410U	400U	380U	410U	400U
Benzo(k)fluoranthene	ug/kg	360U	410U	400U	380U	410U	400U
Benzo(a)pyrene	ug/kg	360U	410U	400U	380U	410U	400U
Indeno(1,2,3-cd)pyrene	ug/kg	360U	410U	400U	380U	410U	400U
Dibenz(a,h)anthracene	ug/kg	360U	410U	400U	380U	410U	400U
Benzo(h,h,i)perylene	ug/kg	360U	410U	400U	380U	410U	400U

U=Indicates the compound was analyzed for, but not detected.
J=Indicates an estimated trace value,
DC=drum cuttings.

4.1.5.1 Groundwater Results

4.1.5.1.1 Eskimo Creek Seep

Twenty-seven monitoring wells and two base water wells were sampled for water quality in June 1988. In the shallow unconfined aquifer, 20 newly installed wells and 7 existing USCOE wells were analyzed for total petroleum hydrocarbons (TPH) or total organic carbon (TOC), alkalinity, common anions, lead, and total dissolved solids. (Only sample bottles broken in transit were analyzed for TOCs to try and verify the presence of hydrocarbons.) Eight of these shallow wells were also analyzed for aromatic volatile compounds. Five of the eight wells were selected for aromatic volatile analysis by visual contamination inspection and nearness to deep wells. Three of the wells were selected outside the estimated contaminated zone to try and better define the plume of contamination. Table 4-12 presents results for these analyses.

The extent of TPH contamination is presented in Figure 4-13. The highest value (5,666 ppm) is reported at MW-22 where substantial floating product (>1 foot) has previously been measured (April 1987). Other detected values closely correlate with the soil gas plume (Figure 4-1). The extent of hydrocarbon contamination can be traced from well MW-39 through MW-22 and to the southeast toward the Eskimo Creek seep.

A comparison of the TPH concentrations in the soils (Figure 4-12) to the groundwater (Figure 4-13) indicates detected concentrations in the borehole soils at wells where groundwater contained less than the detection limit of 1 ppm. This suggests significant quantities of petroleum contamination may be sorbed to unsaturated soils. Also, the low aqueous solubilities of heavy petroleum hydrocarbons may limit their detection with the TPH analysis.

Aromatic compound data are plotted with benzene, toluene, and xylene concentrations in Figure 4-14. The extent and relative concentrations of aromatics across the site correlate with the TPH data. The highest values are found in MW-30 with 77 ppb benzene, 130 ppb toluene, and 520 ppb xylene. USCOE wells including MW-22 were not analyzed for aromatics because of uncertainty in their construction (i.e., glued joints).

Each of the shallow and intermediate monitoring wells were measured with an oil/water interface probe to check for light and/or dense nonaqueous phase liquids (NAPLs) on June 12, 1988. NAPLs were not detected in any of the wells. However, these measurements cannot be considered entirely representative due to the relatively short period of time between well development (or redevelopment/purging of USCOE wells) and

Table 4-12

FIELD PARAMETERS, ALKALINITY, COMMON ANIONS, LEAD, TOTAL DISSOLVED SOLIDS, TOTAL PETROLEUM HYDROCARDONS, AND PURGEABLE AROMATICS ESKIMO CREEK SHALLOW AQUIFER

Parameter	Method	Units	Detection Limits	KS-MW-01 6/5/88	KS-MW-06 6/7/88	KS-MW-09 6/6/88	KS-MW-10 6/7/88	KS-MW-16 6/6/88	KS-EBMW 6/6/88
Temperature	FIELD	C	N/A	4.0	4.0	5.0	5.0	5.0	na
pH	FIELD	-	N/A	5.8	6.4	6.8	6.4	6.9	na
Specific Conductivity	FIELD	uMHOS	N/A	150	170	420	295	500	na
Appearance	FIELD	-	N/A	TURBID	TURBID	TURBID	TURBID	TURBID	na
Odor (fuel)	FIELD	-	N/A	NONE	YES	YES	YES	YES	na
Lead	3005/7421	ug/l	5	na	<5	16	110	17	<5
Ortho Phosphate	E365.2	mg/l	0.5	na	0.62	0.84	2.66	0.32	0.01
Alkalinity	A403	mg/l	20	na	128	354	100	415	2.0
Chloride	9252	mg/l	1	na	6.9	6.5	22.7	15.2	<1
Sulfate	9038	mg/l	1	na	8.5	19.4	73.3	50.3	1.0
Fluoride	E340.2	mg/l	0.05	na	<0.05	<0.05	<0.05	0.05	<0.05
Total Diss. Solids	E160.1	mg/l	1	na	193	444	316	536	<1
Nitrate-Nitrite	9200	mg/l	0.05	na	2.26	0.36	10.5	0.22	0.08
TPH	E418.1	mg/l	1	na	23.6	3	4.2	9	3
TOC		mg/l	1	na	na	na	na	na	na
Benzene	SW8020	ug/l	1	na	na	na	na	na	
Toluene	SW8020	ug/l	1	na	na	na	na	na	
Ethyl Benzene	SW8020	ug/l	1	na	na	na	na	na	
Xylene	SW8020	ug/l	1	na	na	na	na	na	
Chlorobenzene	SW8020	ug/l	1	na	na	na	na	na	
1,4-Dichlorobenzene	SW8020	ug/l	1	na	na	na	na	na	
1,3-Dichlorobenzene	SW8020	ug/l	1	na	na	na	na	na	
1,2-Dichlorobenzene	SW8020	ug/l	1	na	na	na	na	na	

na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-12
(Continued)

Parameter	Method	Units	Detection Limits	KS-MW-18 6/6/88	KS-MW-21 6/5/88	KS-W-99 DUP MW-21	KS-EBMW 6/5/88	KS-MW-22 6/8/88	KS-MW-23 6/16/88
Temperature	FIELD	C	N/A	4.0	5.0	na	na	4.0	14
pH	FIELD	-	N/A	5.9	6.3	na	na	6.0	7.4
Specific Conductivity	FIELD	uMHOS	N/A	550	460	na	na	500	380
Appearance	FIELD	-	N/A	TURBID	TURBID	na	na	TURBID	MUDDY
Odor (fuel)	FIELD	-	N/A	YES	YES	na	na	YES	NONE
Lead	3005/7421	ug/l	5	64	85	48	<5	370	na
Ortho Phosphate	E365.2	mg/l	0.5	0.10	2.67	2.22	0.01	1.71	na
Alkalinity	A403	mg/l	20	386	386	391	1.8	394	na
Chloride	9252	mg/l	1	11.6	10.8	11.6	<1	9.9	na
Sulfate	9038	mg/l	1	39.7	27.9	28.2	<1	3.4	na
Fluoride	E340.2	mg/l	0.05	<0.05	0.11	<0.05	<0.05	<0.05	na
Total Diss. Solids	E160.1	mg/l	1	542	558	526	<1	489	na
Nitrate-Nitrite	9200	mg/l	0.05	0.21	0.13	0.11	0.06	0.78	na
TPH	E418.1	mg/l	1	53	3	<.8	5	5666	na
TOC		mg/l	1	na	na	na	na	na	na
Benzene	SW8020	ug/l	1	na	na	na		na	<1
Toluene	SW8020	ug/l	1	na	na	na		na	<1
Ethyl Benzene	SW8020	ug/l	1	na	na	na		na	<1
Xylene	SW8020	ug/l	1	na	na	na		na	<1
Chlorobenzene	SW8020	ug/l	1	na	na	na		na	<1
1,4-Dichlorobenzene	SW8020	ug/l	1	na	na	na		na	<1
1,3-Dichlorobenzene	SW8020	ug/l	1	na	na	na		na	<1
1,2-Dichlorobenzene	SW8020	ug/l	1	na	na	na		na	<1

---

na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-12
(Continued)

Parameter	Method	Units	Detection Limits	KS-MW-24 6/12/88	KS-MW-25 6/10/88	KS-MW-26 6/13/88	KS-MW-27 6/13/88	KS-MW-90 DUP MW-27
Temperature	FIELD	C	N/A	3.5	3	2.5	2	na
pH	FIELD	-	N/A	5.39	6.17	6.25	6.3	na
Specific Conductivity	FIELD	uMHOS	N/A	108	70	200	140	na
Appearance	FIELD	-	N/A	TURBID	TURBID	TURBID	TURBID	na
Odor (fuel)	FIELD	-	N/A	NONE	NONE	NONE	NONE	na
Lead	3005/7421	ug/l	5	28	12	<5	<5	6
Ortho Phosphate	E365.2	mg/l	0.5	0.59	0.38	0.21	0.35	0.26
Alkalinity	A403	mg/l	20	83.8	49.0	141	111	116
Chloride	9252	mg/l	1	3.4	2.0	20.9	5.7	7.5
Sulfate	9038	mg/l	1	9.3	2.8	16.7	4.6	4.5
Fluoride	E340.2	mg/l	0.05	<0.05	0.05	0.06	0.05	0.05
Total Diss. Solids	E160.1	mg/l	1	174	145	253	166	173
Nitrate-Nitrite	9200	mg/l	0.05	1.41	1.97	1.64	0.63	0.63
TPH	E418.1	mg/l	1	<1	<1	<1	<1	<1
TOC		mg/l	1	na	na	na	na	na
Benzene	SW8020	ug/l	1	na	<1	na	na	na
Toluene	SW8020	ug/l	1	na	<1	na	na	na
Ethyl Benzene	SW8020	ug/l	1	na	<1	na	na	na
Xylene	SW8020	ug/l	1	na	<1	na	na	na
Chlorobenzene	SW8020	ug/l	1	na	<1	na	na	na
1,4-Dichlorobenzene	SW8020	ug/l	1	na	<1	na	na	na
1,3-Dichlorobenzene	SW8020	ug/l	1	na	<1	na	na	na
1,2-Dichlorobenzene	SW8020	ug/l	1	na	<1	na	na	na

na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-12
(Continued)

Parameter	Method	Units	Detection Limits	KS-MW-28 6/10/88	KS-MW-29 6/12/88	KS-TBMW 6/9/88	KS-MW-30 6/9/88	KS-EQMW 6/9/88
Temperature	FIELD	C	N/A	3	7.5	na	5	na
pH	FIELD	-	N/A	5.59	6.31	na	6.51	na
Specific Conductivity	FIELD	uMHOS	N/A	230	265	na	425	na
Appearance	FIELD	-	N/A	TURBID	TURBID	na	TURBID	na
Odor (fuel)	FIELD	-	N/A	NONE	NONE	na	YES	na
Lead	3005/7421	ug/l	5	8	21	na	22	<5
Ortho Phosphate	E365.2	mg/l	0.5	0.17	<0.01	na	0.51	0.01
Alkalinity	403	mg/l	20	174	131	na	354	3.6
Chloride	9252	mg/l	1	3.6	10.7	na	6.0	<1
Sulfate	9038	mg/l	1	21.8	18.7	na	8.9	<1
Fluoride	E340.2	mg/l	0.05	0.05	0.05	na	0.07	<0.05
Total Diss. Solids	E160.1	mg/l	1	285	331	na	461	2
Nitrate-Nitrite	9200	mg/l	0.05	2.56	11.4	na	1.0	0.15
TPH	E418.1	mg/l	1	<1	<1	na	34.2	2.6
TOC		mg/l	1	na	na	na	na	na
Benzene	SW8020	ug/l	1	<1	na	<1	77	<1
Toluene	SW8020	ug/l	1	<1	na	<1	130	<1
Ethyl Benzene	SW8020	ug/l	1	<1	na	<1	130	<1
Xylene	SW8020	ug/l	1	<1	na	<1	520	<1
Chlorobenzene	SW8020	ug/l	1	<1	na	<1	<1	<1
1,4-Dichlorobenzene	SW8020	ug/l	1	<1	na	<1	<1	<1
1,3-Dichlorobenzene	SW8020	ug/l	1	<1	na	<1	<1	<1
1,2-Dichlorobenzene	SW8020	ug/l	1	<1	na	<1	<1	<1

na = not analyzed/sampled
MW = Monitoring Well
EB = Equiptment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-12
(Continued)

Parameter	Method	Units	Detection Limits	KS-MW-31 6/9/88	KS-ACMW 6/9/88	KS-MW-32 6/13/88	KS-EQMW 6/13/88
Temperature	FIELD	C	N/A	4	na	4	na
pH	FIELD	-	N/A	6.67	na	6.05	na
Specific Conductivity	FIELD	uMHOS	N/A	185	na	162	na
Appearance	FIELD	-	N/A	TURBID	na	TURBID	na
Odor (fuel)	FIELD	-	N/A	YES	na	NONE	na
Lead	3005/7421	ug/l	5	<5	na	10	<5
Ortho Phosphate	E365.2	mg/l	0.5	0.10	na	0.61	<0.01
Alkalinity	403	mg/l	20	130	na	105	2.5
Chloride	9252	mg/l	1	14.3	na	5.1	<1
Sulfate	9038	mg/l	1	12.8	na	7.2	<1
Fluoride	E340.2	mg/l	0.05	0.06	na	0.05	<0.05
Total Diss. Solids	E160.1	mg/l	1	222	na	206	23
Nitrate-Nitrite	9200	mg/l	0.05	0.46	na	6.29	0.13
TPH	E418.1	mg/l	1	1.0	na	<1	<1
TOC		mg/l	1	na	na	na	na
Benzene	SW8020	ug/l	1	3	<1	na	na
Toluene	SW8020	ug/l	1	14	<1	na	na
Ethyl Benzene	SW8020	ug/l	1	31	<1	na	na
Xylene	SW8020	ug/l	1	170	<1	na	na
Chlorobenzene	SW8020	ug/l	1	<1	<1	na	na
1,4-Dichlorobenzene	SW8020	ug/l	1	<1	<1	na	na
1,3-Dichlorobenzene	SW8020	ug/l	1	<1	<1	na	na
1,2-Dichlorobenzene	SW8020	ug/l	1	<1	<1	na	na

na = not analyzed/sampled
MW = Monitoring Well
EB = Equiptment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-12
(Continued)

Parameter	Method	Units	Detection Limits	KS-MW-33 6/9/88	KS-MW-34 6/10/88	KD-EQMW 6/10/88	KS-ACMW 6/10/88	KS-MW-36 6/14/88
Temperature	FIELD	C	N/A	6.6	5	na	na	3.5
pH	FIELD	-	N/A	6.27	7.08	na	na	6.5
Specific Conductivity	FIELD	uMHOS	N/A	210	475	na	na	180
Appearance	FIELD	-	N/A	TURBID	TURBID	na	na	TURBID
Odor (fuel)	FIELD	-	N/A	NONE	YES	na	na	NONE
Lead	3005/7421	ug/1	5	5	8	<5	na	<5
Ortho Phosphate	E365.2	mg/1	0.5	0.30	0.48	0.01	na	0.32
Alkalinity	403	mg/1	20	131	347	3.0	na	109
Chloride	9252	mg/1	1	5.4	14.1	<1	na	13.2
Sulfate	9038	mg/1	1	16.3	16.4	<1	na	8.4
Fluoride	E340.2	mg/1	0.05	0.05	0.06	0.05	na	0.07
Total Diss. Solids	E160.1	mg/1	1	270	532	12	na	264
Nitrate-Nitrite	9200	mg/1	0.05	3.34	0.22	14	na	8.24
TPH	E418.1	mg/1	1	<1	31.4	<1	na	<1
TOC		mg/1	1	na	na	na	na	na
Benzene	SW8020	ug/1	1	<1	<1	<1	<1	na
Toluene	SW8020	ug/1	1	<1	10	<1	<1	na
Ethyl Benzene	SW8020	ug/1	1	<1	4	<1	<1	na
Xylene	SW8020	ug/1	1	<1	78	<1	<1	na
Chlorobenzene	SW8020	ug/1	1	<1	<1	<1	<1	na
1,4-Dichlorobenzene	SW8020	ug/1	1	<1	<1	<1	<1	na
1,3-Dichlorobenzene	SW8020	ug/1	1	<1	<1	<1	<1	na
1,2-Dichlorobenzene	SW8020	ug/1	1	<1	<1	<1	<1	na

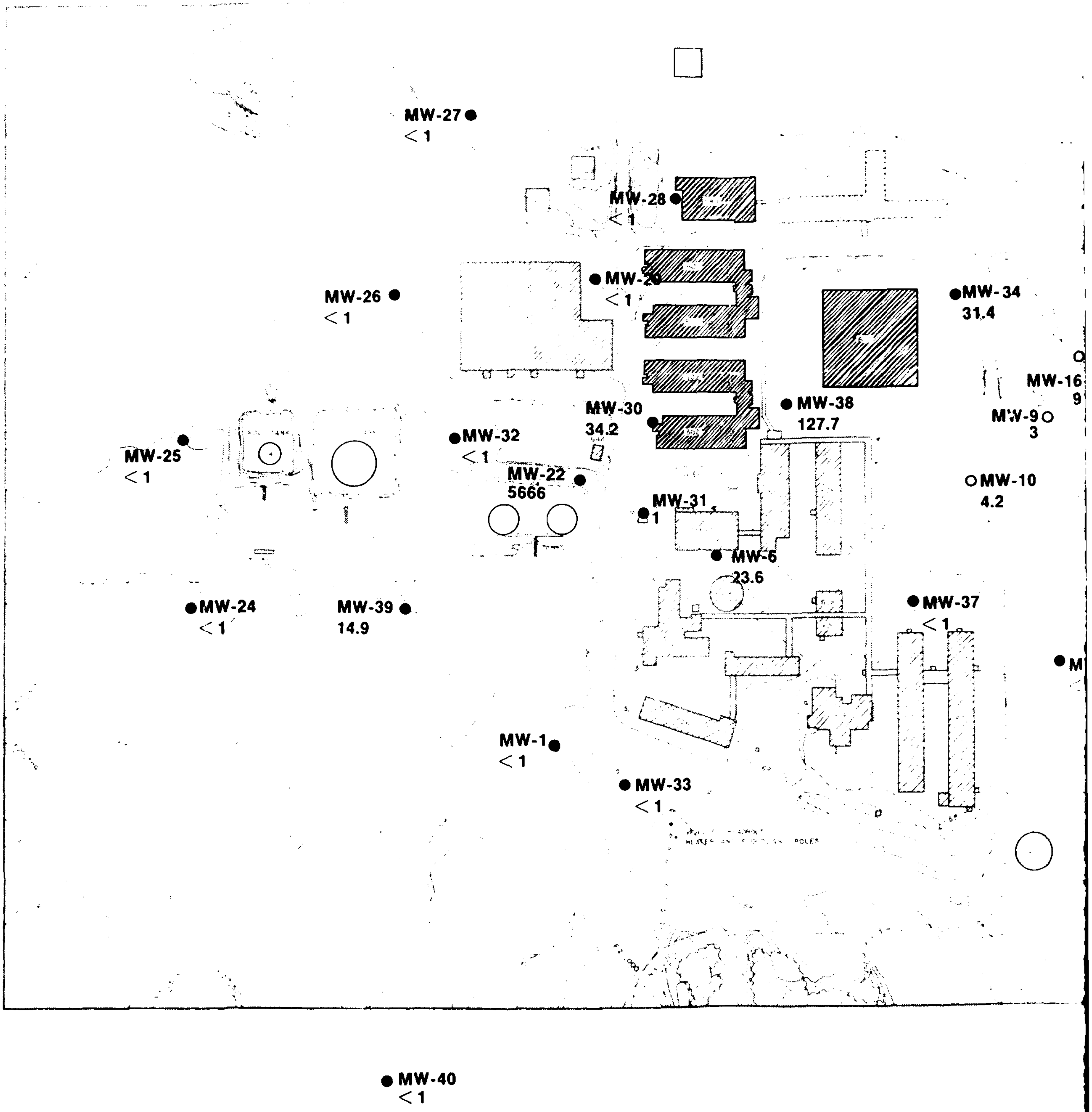
na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
N/A = Not Applicable

Table 4-12
(Continued)

Parameter	Method	Units	Detection Limits	KS-MW-37 6/14/88	KS-MW-38 6/11/88	KS-MW-39 6/11/88	KS-TBMW 6/11/88	KS-MW-40 6/12/88
Temperature	FIELD	C	N/A	4	8	3	na	3
pH	FIELD	-	N/A	6.6	5.88	6.52	na	6.92
Specific Conductivity	FIELD	uMHOS	N/A	245	410	310	na	80
Appearance	FIELD	-	N/A	TURBID	TURBID	TURBID	na	TURBID
Odor (fuel)	FIELD	-	N/A	NONE	YES	YES	na	NONE
Lead	3005/7421	ug/l	5	<5	14	10	na	9
Ortho Phosphate	E365.2	mg/l	0.5	0.16	0.95	0.85	na	0.60
Alkalinity	A403	mg/l	20	98.0	309	264	na	56.0
Chloride	9252	mg/l	1	22.1	6.6	6.0	na	4.6
Sulfate	9038	mg/l	1	55.9	16.1	<1	na	3.1
Fluoride	E340.2	mg/l	0.05	0.07	0.06	0.06	na	0.06
Total Diss. Solids	E160.1	mg/l	1	311	465	409	na	162
Nitrate-Nitrite	9200	mg/l	0.05	6.20	0.22	0.17	na	0.20
TPH	E418.1	mg/l	1	<1	127.7	14.9	na	<1
TOC		mg/l	1	na	na	na	na	na
Benzene	SW8020	ug/l	1	na	6	23	<1	na
Toluene	SW8020	ug/l	1	na	20	7	<1	na
Ethyl Benzene	SW8020	ug/l	1	na	21	29	<1	na
Xylene	SW8020	ug/l	1	na	76	85	<1	na
Chlorobenzene	SW8020	ug/l	1	na	<1	<1	<1	na
1,4-Dichlorobenzene	SW8020	ug/l	1	na	<1	<1	<1	na
1,3-Dichlorobenzene	SW8020	ug/l	1	na	<1	<1	<1	na
1,2-Dichlorobenzene	SW8020	ug/l	1	na	<1	<1	<1	na

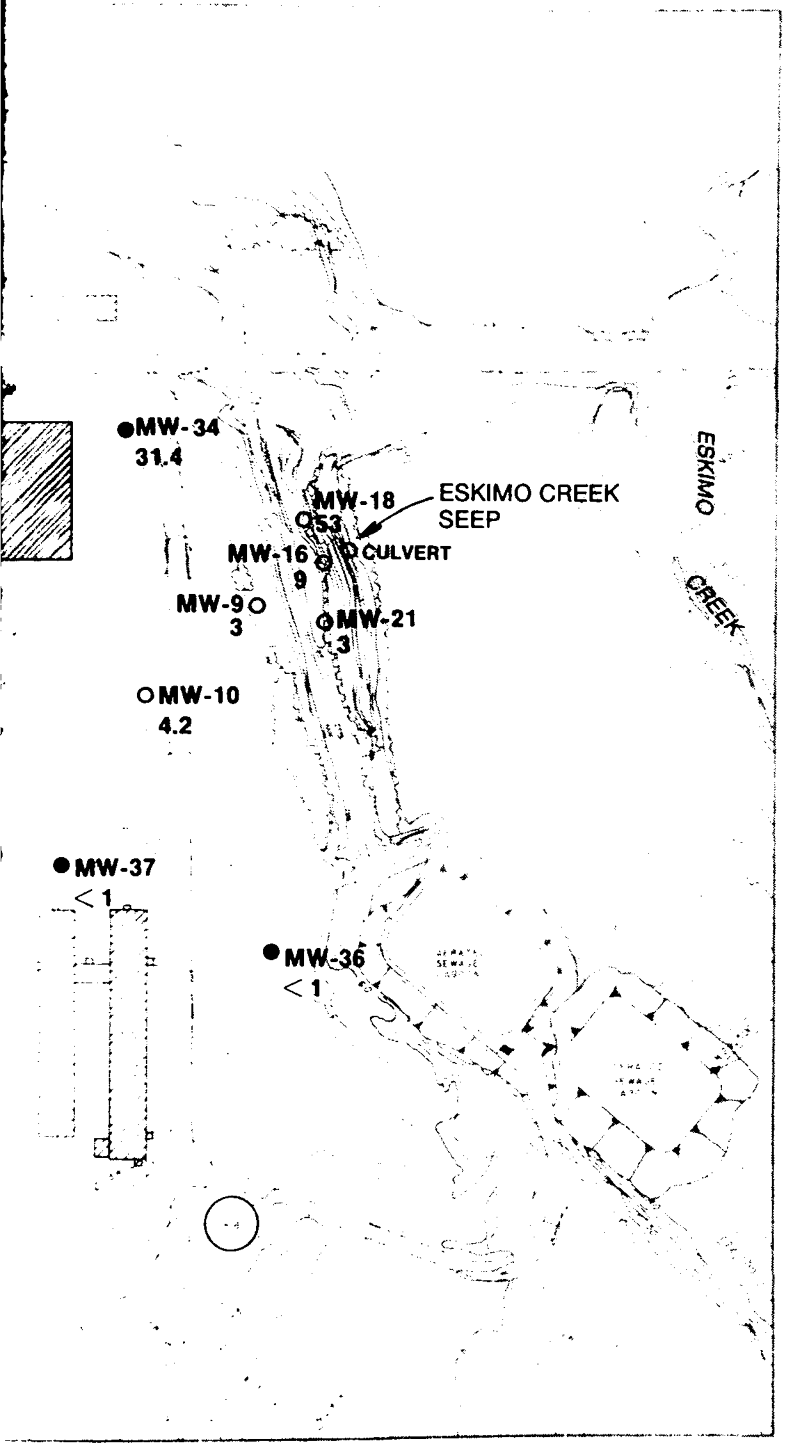
---

na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable


MW-27
< 1
MW-28
< 1
MW-26
< 1
MW-29
< 1
MW-34
31.4
MW-16
9
MW-38
127.7
MW-30
34.2
MW-9
3
MW-25
< 1
MW-32
< 1
MW-22
5666
MW-10
4.2
MW-31
1
MW-6
23.6
MW-37
< 1
MW-24
< 1
MW-39
14.9
M
MW-1
< 1
MW-33
< 1
MW-40
< 1

24173.A0

A



LEGEND

MW ● NEW SHALLOW AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION

30 TOTAL PETROLEUM HYDROCARBON (ppm)

FIGURE 4-13

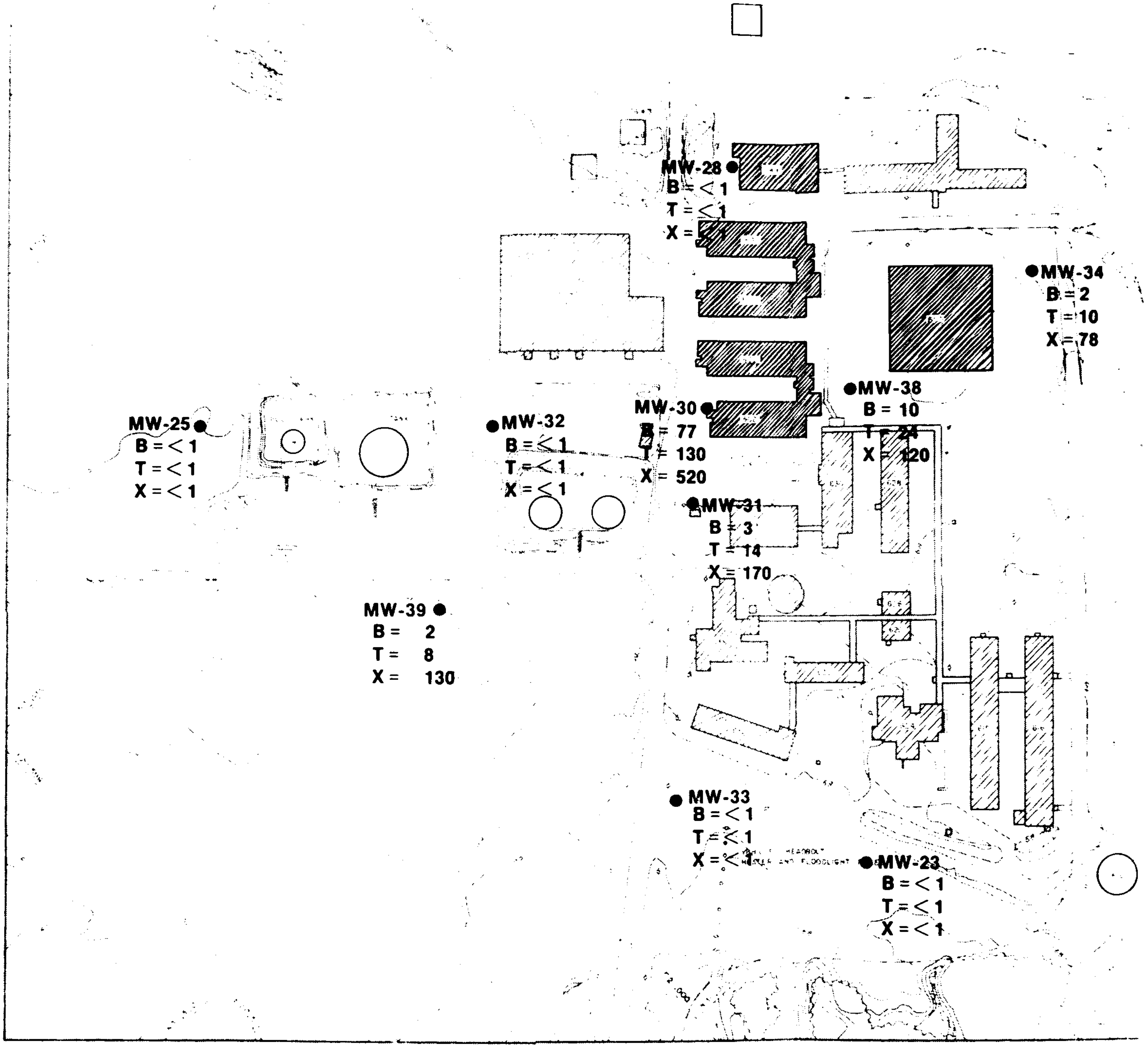
SHALLOW GROUNDWATER CONTAMINATION, TOTAL PETROLEUM HYDROCARBON

JUNE 1988

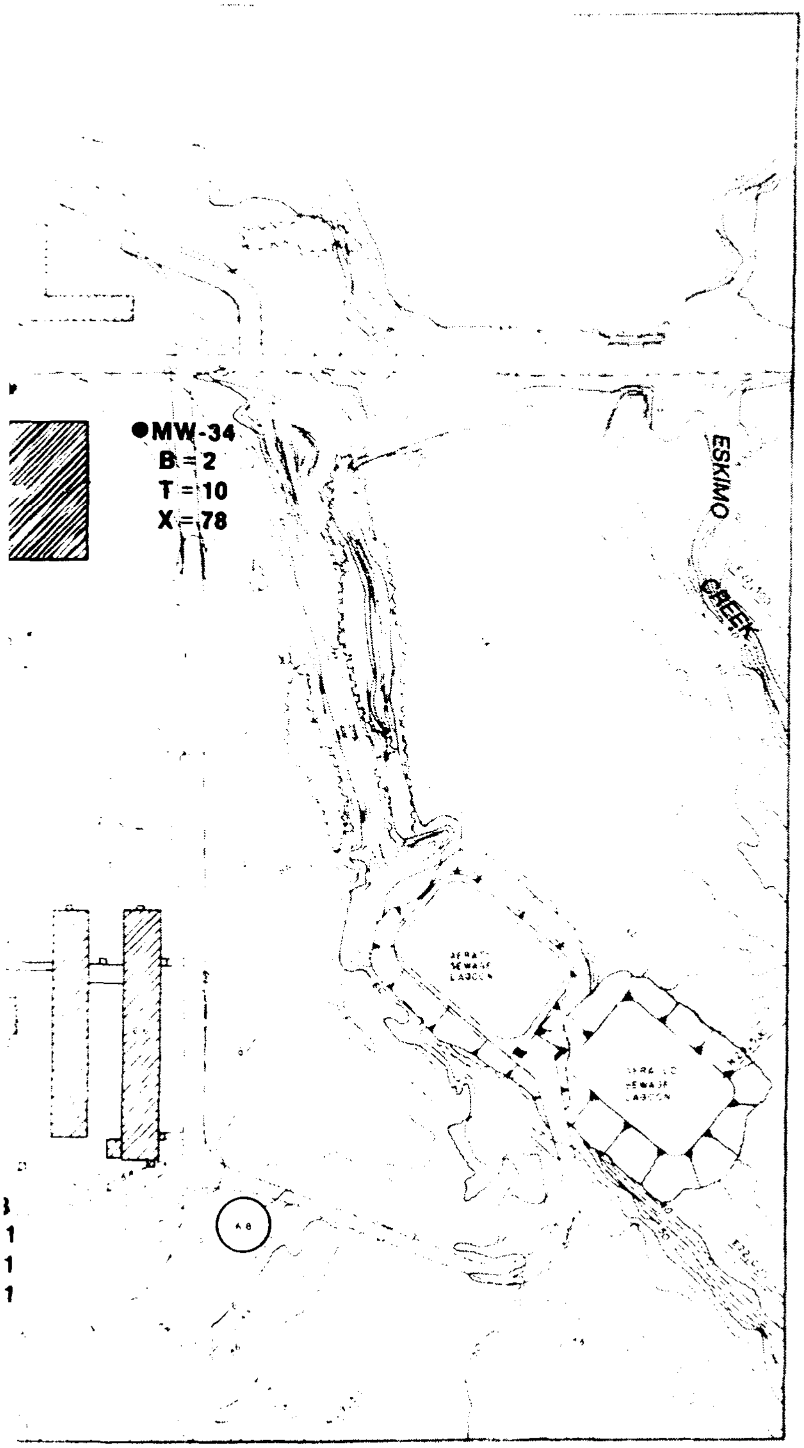
KING SALMON AIR FORCE STATION

KING SALMON, ALASKA

CH2M HILL


MW-28
B = < 1
T = < 1
X = < 1
MW-34
B = 2
T = 10
X = 78
MW-38
B = 10
T = 24
X = 120
MW-30
B = 77
T = 130
X = 520
MW-25
B = < 1
T = < 1
X = < 1
MW-32
B = < 1
T = < 1
X = < 1
MW-31
B = 3
T = 14
X = 170
MW-39
B = 2
T = 8
X = 130
MW-33
B = < 1
T = < 1
X = < 1
MW-23
B = < 1
T = < 1
X = < 1

K24173.A0



LEGEND

MW ● NEW SHALLOW AQUIFER MONITORING WELL LOCATION AND IDENTIFICATION

● **MW**
B = BENZENE (ppb)
T = TOLUENE (ppb)
X = XYLENE (ppb)

FIGURE 4-14

SHALLOW GROUNDWATER CONTAMINATION-AROMATICS

JUNE 1988
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

conducting the measurements. These measurements should be repeated several weeks after the wells have been disturbed to allow the wells to recover to static conditions. As an example, MW-22 has contained significant NAPLs. However, the well was constructed with the top of the screen slightly below the water table (USCOE, 1978) and accumulation of product will require a drop in the regional water levels to expose the screen.

Inorganic analyses indicate high levels of lead (maximum of 370 ppb in MW-22) correlate with the high organic contamination. Monitoring wells with nondetects for the TPH and aromatics generally contain less than or near detection limit levels of 5 ppb lead.

A cross section showing hydrogeologic conditions at the Eskimo Creek seep is presented in Figure 4-5. Groundwater flow from beneath the station discharges into the Eskimo Creek flood plain. Contaminated groundwater may discharge far into the flood plain through the sand deposits. Floating product would be expected to discharge near the contact between the cliff and flood plain.

Intermediate Aquifer

Groundwater from the three intermediate wells (MW-41, 42, and 43) did not have any detectable aromatics (Table 4-13). MW-41 is reported at less than the detection limit of 1 ppm for TPH. MW-42 and MW-43 contained 1.7 and 7.2 ppm of TOC, respectively, which are relatively low values. Background sample analyses should be obtained for comparisons.

Inorganic analyses for the intermediate wells did not indicate the aquifer was contaminated. However, the pH for well MW-43 was elevated (10.1); a condition that often results from grout contamination. Future groundwater analyses will indicate if there is a problem with grout in this well.

Deep Aquifer

Base wells KS-4 and KS-5 were sampled and analyzed for aromatic organics and TPHs. Aromatic values were all below the detection limit of 1 ppm. Both wells, however, contained detectable levels of TPH (KS-4 at 27 ppm and KS-5 at 6.5 ppm) (Table 4-14).

As discussed in Section III, the develcpment water was tested for purgeable aromatics (SW8020) and lead (SW7421). The results of the analyses are presented in Table 4-15. The analyses indicated that the contamination was below the MCLs, and subsequently the water was disposed of through the base oil/water separator and treatment facilities.

Table 4-13
FIELD PARAMETERS, ALKALINITY, COMMON ANIONS, LEAD, TOTAL DISSOLVED SOLIDS, TOTAL PETROLEUM HYDROCARDONS, AND PURGEABLE AROMATICS
ESKIMO CREEK INTERMEDIATE AQUIFER

Parameter	Method	Units	Detection Limits	KS-MW-41 6/17/88	KS-EBMW 6/17/88	KS-MW-97 DUP MW-41	KS-MW-42 6/16/88	KS-MW-43 6/16/88	KS-TBMW 6/16/88
Temperature	FIELD	C	N/A	4	na	na	4.5	5	na
pH	FIELD	-	N/A	7.25	na	na	8.05	10.1	na
Specific Conductivity	FIELD	uMHOS	N/A	345	na	na	215	210	na
Appearance	FIELD	-	N/A	TURBID	na	na	TURBID	TURBID	na
Odor (fuel)	FIELD	-	N/A	NONE	na	na	NONE	NONE	na
Lead	3005/7421	ug/l	5	7	<5	8	6	<5	na
Ortho Phosphate	E365.2	mg/l	0.5	0.07	<0.01	na	0.51	0.04	na
Alkalinity	A403	mg/l	20	223	1.8	240	157	241	na
Chloride	9252	mg/l	1	8.3	<1	8.3	8.7	11.1	na
Sulfate	9038	mg/l	1	22.3	1.2	22.3	13.5	79.7	na
Fluoride	E340.2	mg/l	0.05	0.11	0.05	0.10	0.09	0.09	na
Total Diss. Solids	E160.1	mg/l	1	299	<1	282	229	378	na
Nitrate-Nitrite	9200	mg/l	0.05	0.25	0.16	na	0.16	0.47	na
TPH	E418.1	mg/l	1	<1	<1	na	na	na	na
TOC		mg/l	1	na	na	na	1.7	7.2	na
Benzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
Toluene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
Ethyl Benzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
Xylene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
Chlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
1,3-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1

---

na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-14
FIELD PARAMETERS, ALKALINITY, COMMON ANIONS, LEAD, TOTAL DISSOLVED SOLIDS, TOTAL PETROLEUM HYDROCARDONS, AND PURGEABLE AROMATICS
ESKIMO CREEK DEEP AQUIFER

Parameter	Method	Units	Detection Limits	KS-MW-KS4 6/8/88	KS-MW-KS5 6/8/88	KS-MW-KS6 DUP MW-KS5	KS-ACMW 6/8/88
Temperature	FIELD	C	N/A				na
pH	FIELD	-	N/A				na
Specific Conductivity	FIELD	uMHOS	N/A				na
Appearance	FIELD	-	N/A				na
Odor (fuel)	FIELD	-	N/A				na
Lead	3005/7421	ug/l	5	<5	<5	<5	na
Ortho Phosphate	E365.2	mg/l	0.5	0.67	0.71	0.70	na
Alkalinity	A403	mg/l	20	130	147	147	na
Chloride	9252	mg/l	1	13.0	10.1	10.6	na
Sulfate	9038	mg/l	1	3.9	2.0	1.8	na
Fluoride	E340.2	mg/l	0.05	0.24	0.23	0.23	na
Total Diss. Solids	E160.1	mg/l	1	177	210	194	na
Nitrate-Nitrite	9200	mg/l	0.05	0.23	0.24	0.18	na
TPH	E418.1	mg/l	1	27.1	6.4	6.0	na
TOC		mg/l	1	na	na	na	na
Benzene	SW8020	ug/l	1	<1	<1	<1	<1
Toluene	SW8020	ug/l	1	<1	<1	<1	<1
Ethyl Benzene	SW8020	ug/l	1	<1	<1	<1	<1
Xylene	SW8020	ug/l	1	<1	<1	<1	<1
Chlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1
1,4-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1
1,3-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1
1,2-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1

---

na = not analyzed/sampled
MW = Monitoring Well
EB = Equipment Blank
TB = Trip Blank
AC = Ambient Conditions Blank
N/A = Not Applicable

Table 4-15
PURGEABLE AROMATICS AND LEAD
SW8020 AND SW7421
ESKIMO CREEK DEVELOPMENT WATER

Parameter	Units	Detection Limit	KS-DW 6/8/88	6/17/88
Benzene	ug/l	1	<1	<1
Toluene	ug/l	1	<1	2
Ethyl Benzene	ug/l	1	<1	5
Xylene	ug/l	1	<1	20
Chlorobenzene	ug/l	1	<1	<1
1,4-Dichlorobenzene	ug/l	1	<1	<1
1,3-Dichlorobenzene	ug/l	1	<1	<1
1,2-Dichlorobenzene	ug/l	1	<1	<1
Lead	ug/l	5	<5	<5

4.1.5.1.2 Naknek River Seep

A water sample was collected at the Naknek River seep from a small pool that was excavated in the river bank to intercept the seepage face. Analytical results are presented in the following section on surface water.

4.1.5.1.3 North Barrel Bluff

Groundwaters were not collected at the North Barrel Bluff. Results for surface water samples are provided in the following section.

4.1.5.1.4 South Barrel Bluff

A residential well located along the South Barrel Bluff (see Well B Figure 4-7) was sampled for the following water quality parameters:

- Halogenated volatile organics
- Aromatic volatile organics
- Organochlorine pesticides and PCBs
- Semivolatile organics
- Metals

Results are reported in Tables 4-15A to 4-15D. There were no detected constituents in these analyses. This well was sampled after information gained from the geophysical survey indicated the well may have been drilled through a landfill area (i.e., drums and other metallic debris) into the intermediate aquifer zone.

Table 4-15A
PURGEABLE HALOCARBONS AND AROMATICS
E601 AND SW8020
SOUTH BARREL BLUFF GROUND WATER

Parameters	Units	Detection Limit	KS-MW-SA 6/8/88	KS-MW-SAD Duplicate 6/8/88	ACMW-SA 6/8/88
Chloromethane	ug/l	1	<1	<1	<1
Bromomethane Vinyl	ug/l	1	<1	<1	<1
Chloride Methylene	ug/l	1	<1	<1	<1
Chloride	ug/l	1	<1	<1	<1
1,1-Dichloroethene	ug/l	5	<5	<5	<5
1,1-Dichloroethane	ug/l	1	<1	<1	<1
trans-1,2-Dichloroethene	ug/l	1	<1	<1	<1
Chloroform	ug/l	1	<1	<1	<1
1,2-Dichloroethane	ug/l	1	<1	<1	<5
1,1,1-Trichloroethane	ug/l	1	<1	<1	<1
Carbon Tetrachloride	ug/l	1	<1	<1	<1
Bromodichloromethane	ug/l	1	<1	<1	<1
1,2-Dichloropropane	ug/l	1	<1	<1	<1
cis-1,3-Dichlorpropene	ug/l	1	<1	<1	<1
Trichloroethene	ug/l	1	<1	<1	<1
Dibromochloromethane	ug/l	1	<1	<1	<1
1,1,2-Trichloroethane	ug/l	1	<1	<1	<1
trans-1,3-Dichloropropene	ug/l	1	<1	<1	<1
Bromoform	ug/l	1	<1	<1	<1
1,1,2,2-Tetrachloroethane	ug/l	1	<1	<1	<1
Tetrachloroethene	ug/l	1	<1	<1	<1
Chlorobenzene	ug/l	1	<1	<1	<1
1,3-Dichlorobenzene	ug/l	1	<1	<1	<1
1,2-Dichlorobenzene	ug/l	1	<1	<1	<1
1,4-Dichlorobenzene	ug/l	1	<1	<1	<1
Benzene	ug/l	1	<1	<1	na
Toluene	ug/l	1	<1	<1	na
Ethyl Benzene	ug/l	1	<1	<1	na
Chlorobenzene	ug/l	1	<1	<1	na
1,4-Dichlorobenzene	ug/l	1	<1	<1	na
1,3-Dichlorobenzene	ug/l	1	<1	<1	na
1,2-Dichlorobenzene	ug/l	1	<1	<1	na

AC-Ambient Conditions Blank

TABLE 4-15B
ORGANOCHLORINE PESTICIDES AND PCBs
E608
SOUTH BARREL BLUFF GROUND WATER

Parameters	Units	Detection Limit	KS-MW-SA 6/8/88	KS-MW-SAD Duplicate 6/8/88
a-BHC	ug/l	0.05	<0.05	<0.05
b-BHC	ug/l	0.05	<0.05	<0.05
g-BHC	ug/l	0.05	<0.05	<0.05
d-BHC	ug/l	0.05	<0.05	<0.05
Heptachlor	ug/l	0.02	<0.02	<0.02
Aldrin	ug/l	0.05	<0.05	<0.05
Heptachlor Epoxide	ug/l	0.05	<0.05	<0.05
Endosulfan I	ug/l	0.05	<0.05	<0.05
Dieldrin	ug/l	0.02	<0.02	<0.02
4,4-DDE	ug/l	0.1	<0.1	<0.1
Endrin	ug/l	0.06	<0.06	<0.06
Endosulfan II	ug/l	0.1	<0.1	<0.1
4,4-DDD	ug/l	0.1	<0.1	<0.1
Endrin Aldehyde	ug/l	0.1	<0.1	<0.1
Endosulfan Sulfate	ug/l	0.1	<0.1	<0.1
4,4-DDT	ug/l	0.1	<0.1	<0.1
methxychlor	ug/l	0.1	<0.1	<0.1
Chlordane	ug/l	0.2	<0.2	<0.2
Toxaphene	ug/l	1	<1	<1
PCB-1221	ug/l	2	<2	<2
PCB-1232	ug/l	2	<2	<2
PCB-1242	ug/l	0.8	<0.8	<0.8
PCB-1016	ug/l	0.8	<0.8	<0.8
PCB-1248	ug/l	0.5	<0.5	<0.5
PCB-1254	ug/l	1	<1	<1
PCB-1260	ug/l	1	<1	<1

Table 4-15C
METALS SCREEN
E200.7
SOUTH BARREL BLUFF GROUND WATER

Parameters	Detection	KS-MW-SA 6/8/88	KS-MW-SAD Duplicate 6/8/88
Aluminum	200	<200	<200
Antimony	300	<300	<300
Arsenic	300	<300	<300
Barium	100	<100	<100
Beryllium	5	<5	<5
Cadmium	10	<10	<10
Calcium	1000	19100	18500
Chromium	30	<30	<30
Cobalt	40	<40	<40
Copper	30	<30	<30
Iron	100	150	120
Lead	200	<200	<200
Magnesium	1000	7300	7100
Manganese	15	173	167
Molybdenum	40	<40	<40
Nickel	40	<40	<40
Potassium	1000	3800	3300
Selenium	400	<400	<400
Silver	30	<30	<30
Sodium	1000	8100	7900
Thallium	500	<500	<500
Vanadium	40	<40	<40
Zinc	20	<20	<20
Boron	30	<30	<30
Silica	43	35000	35000

Note: All values in ug/l

CVR193/036

Table 4-15D
EXTRACTABLE PRIORITY POLLUTANTS
EPA625
SOUTH BARREL BLUFF GROUND WATER
STANDARDS, CRITERIA
AND ACTION LEVELS

Parameters	Units	KS-MW-SA 6/8/88	KS-MW-SAD Duplicate 6/8/88
n-nitroso-dimethylamine	ug/l	10U	10U
phenol	ug/l	10U	10U
aniline	ug/l	10U	10U
bis(2-chloroethyl) ether	ug/l	10U	10U
2-chlorophenol	ug/l	10U	10U
1,3-dichlorobenzene	ug/l	10U	10U
1,4-dichlorobenzene	ug/l	10U	10U
benzyl alcohol	ug/l	10U	10U
1,2-dichlorobenzene	ug/l	10U	10U
2-methylphenol	ug/l	10U	10U
bis(2-chloroisopropyl) ether	ug/l	10U	10U
4-methylphenol	ug/l	10U	10U
n-nitroso-di-n-propylamine	ug/l	10U	10U
hexachloroethane	ug/l	10U	10U
nitrobenzene	ug/l	10U	10U
isophrone	ug/l	10U	10U
2-nitrophenol	ug/l	10U	10U
2,4-diethylphenol	ug/l	10U	10U
benzoic acid	ug/l	50U	50U
bis(2-chloroethoxy) methane	ug/l	10U	10U
2,4-dichlorophenol	ug/l	10U	10U
1,2,4-trichlorobenzene	ug/l	10U	10U
naphtalene	ug/l	10U	10U
4-chloroaniline	ug/l	10U	10U
hexachlorobutadiere	ug/l	10U	10U
4-chloro-3-methylphenol	ug/l	10U	10U
2-methylnaphthalene	ug/l	10U	10U
hexachlorocyclopentadiene	ug/l	10U	10U
2,4,6-trichlorophenol	ug/l	10U	10U
2,4,5-trichlorophenol	ug/l	50U	50U
2-chloronaphthalene	ug/l	10U	10U
2-nitroaniline	ug/l	50U	50U
dimethyl phthalate	ug/l	10U	10U
acenaphthylene	ug/l	10U	10U
3-nitroaniline	ug/l	50U	50U
acenaphthene	ug/l	10U	10U
2,4-dinitrophenol	ug/l	50U	50U
4-nitrophenol	ug/l	50U	50U
dibenzofuran	ug/l	10U	10U
2,4-dinitrotoluene	ug/l	10U	10U
2,6-dinitrotoluene	ug/l	10U	10U
diethyl phthalate	ug/l	10U	10U

U=Indicates constituent tested for, but not detected.

J=Indicates an estimated trace value.

Table 4-15D
(Continued)

Parameters	Units	KS-MW-SA 6/8/88	KS-MW-SAD Duplicate 6/8/88
4-chlorophenyl phenyl ether	ug/l	10U	10U
fluorene	ug/l	10U	10U
4-nitroaniline	ug/l	50U	50U
4,6-dinitro-2-methylphenol	ug/l	50U	50U
n-nithosodiphenylamine	ug/l	10U	10U
4-bromophenyl phenyl ether	ug/l	10U	10U
hexachlorobenzene	ug/l	10U	10U
pentachlorophenol	ug/l	50U	50U
phenanthrene	ug/l	10U	10U
anthracene	ug/l	10U	6J
di-n-butyl phathalate	ug/l	10U	10U
fluoranthene	ug/l	10U	10U
benzidine	ug/l	50U	50U
pyrene	ug/l	10U	10U
butyl benzyl phthalate	ug/l	10U	10U
3,3-dichlorobenzidine	ug/l	20U	20U
benzo(a)anthracene	ug/l	10U	10U
bis(2-ethylhexyl)phthalate	ug/l	10U	5J
chrysene	ug/l	10U	10U
di-n-octyl phthalate	ug/l	10U	10U
benzo(b)fluoranthene	ug/l	10U	10U
benzo(k)fluoranthene	ug/l	10U	10U
benzo(a)pyrene	ug/l	10U	10U
indeno(1,2,3-cd)pyrene	ug/l	10U	10U
dibenz(a,h)anthracene	ug/l	10U	10U
benzo(g,h,i)perylene	ug/l	10U	10U

U=Indicates constituent tested for, but not detected.
J=Indicates an estimated trace value.

4.1.5.2 Surface Water Results

Surface water samples were collected in the vicinity of the Eskimo Creek seep and the North and South Barrel Bluffs. A sample was also collected at the Naknek River seep. Sample locations were selected at points located upstream and downstream of each disturbance to provide an indication on whether these areas are contributing hazardous constituents to the surface waters. Surface waters and sediment sampling locations are shown in Figure 4-15. Surface water samples were analyzed for aromatic volatiles, purgeable halocarbons, extractable priority pollutants, organochlorine pesticides and PCBs, TDS, alkalinity, common anions, and field parameters.

The results of these analyses are presented in Tables 4-16A through 4-16E.

A detail summary for each investigation area is provided in the following subsections.

4.1.5.2.1 Eskimo Creek Seep

Laboratory analysis of water samples from Eskimo Creek collected at locations upstream and downstream of the Eskimo Creek seep reported no concentrations above method detection limit for aromatic, purgeable, and halocarbon compounds. Concentrations of inorganic constituents did not vary significantly between the downstream and upstream locations.

4.1.5.2.2 Naknek River Seep

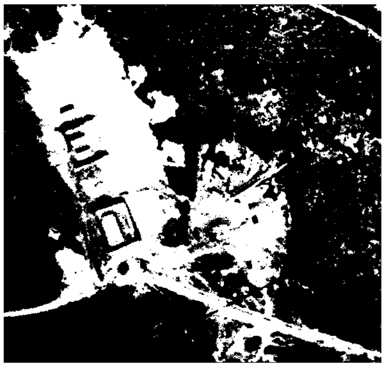
Xylene and trans 1,2-dichloroethene were detected at concentrations of 14 ug/l and 85 mg/l in the Naknek River seep sample. Inorganic constituent concentrations were also significantly higher than were observed at other water sample locations.

While collecting the surface water sample, an oily sheen and discoloration were observed.

4.1.5.2.3 North Barrel Bluff

Organic constituent concentrations for surface water samples collected from the King Salmon Creek flood plain in the vicinity of the North Barrel Bluff were reported at less than method detection limits.

Inorganic constituent concentrations do not indicate specific trends. Potassium was detected at the North Barrel, but was not observed at the South Barrel Bluff. Overall, inorganic constituent concentrations were generally in the same range when comparing concentrations between the North and South Barrel Bluff.




SALMON
SW
STREAM
GE
SW02-0
N
0
800
1600
SCALE IN FEET
SW02-03
SAMPLE
COLLECTED
UPSTREAM
SEDIMEN

6

Table 4-16A

FIELD PARAMETERS, ALKALINITY, COMMON ANIONS, TOTAL DISSOLVED SOLIDS AND PURGEABLE AROMATICS
ESKIMO CREEK, NORTH AND SOUTH BARREL BLUFF AND NAKNEK RIVER SEEP

				Eskimo Creek		South Barrel Bluff		
Parameter	Method	Units	Detection Limit	KS-SW01-01 10/28/87	KS-SW01-02 10/28/87	KS-SW02-01 10/28/87	KS-SW02-02 10/28/87	KS-SW02-03 11/01/87
Temperature	FIELD	°C	N/A	0.5	0.5	1.2	1.2	2.0
pH	FIELD	-	N/A	6.96	6.63	6.64	6.42	7.14
Specific Conductivity	FIELD	uMHOS	N/A	80	80	80	82	42
Appearance	FIELD	-	N/A	CLEAR	CLEAR	SL COLOR	SL COLOR	CLEAR
Odor	FIELD	-	N/A	NO	NO	NO	NO	NO
Ortho Phosphate	E365.2	mg/l	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Alkalinity	A403	mg/l	20	28.6	34.2	49.7	34.2	15.3
Chloride	9252	mg/l	1	5.38	5.35	3.82	3.98	3.81
Sulfate	9038	mg/l	1	1.67	1.63	1.43	1.63	1.85
Fluoride	E340.2	mg/l	0.05	<0.5	<0.5	<0.5	<0.5	<0.5
Total Diss. Solids	E160.1	mg/l	1	55	171	111	77	78
Nitrate-Nitrite	9200	mg/l	0.05	0.17	<0.1	<0.1	0.12	0.49
Benzene	SW8020	ug/l	1	<1	<1	<1	<1	<1
Toluene	SW8020	ug/l	1	<1	<1	<1	<1	<1
Ethyl Benzene	SW8020	ug/l	1	<1	<1	<1	<1	<1
Xylene	SW8020	ug/l	1	<1	<1	<1	<1	<1
Chlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1
1,3-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1

---

na = Not Available
N/A = Not Applicable
KSPB = Ambient Conditions Blank

Table 4-16A
(Continued)

Parameter	Method	Units	Detection Limit	North Barrel Bluff KS-SW03-01 10/31/87	KS-SW03-02 10/31/87	KS-SW03-03 10/31/87	KS-SW03-04 DUP SW03-02 10/31/87	Naknek River Seep KS-SW04-01 10/31/87	KSFB 10/28/87
Temperature	FIELD	C	N/A	3.5	2.0	2.5	na	3.5	na
pH	FIELD	-	N/A	6.30	6.34	6.37	na	6.14	na
Specific Conductivity	FIELD	uMHOS	N/A	52	85	88	na	200	na
Appearance	FIELD	-	N/A	SL COLOR	na	SL COLOR	na	OILY	na
Odor	FIELD	-	N/A	NO	na	na	na	YES	na
Ortho Phosphate	E365.2	mg/l	0.5	<0.5	<0.5	<0.5	<0.5		
Alkalinity	A403	mg/l	20	34	46.1	34.4	47.2	130	na
Chloride	9252	mg/l	1	4.27	4.91	3.82	5.08	4.07	na
Sulfate	9038	mg/l	1	4.18	4.69	2.45	4.71	3.5	na
Fluoride	E340.2	mg/l	0.05	<0.5	<0.5	<0.5	<0.5	<0.5	na
Total Diss. Solids	E160.1	mg/l	1	112	170	53	526	243	na
Nitrate-Nitrite	9200	mg/l	0.05	0.1	1.46	<0.1	1.24	<0.1	na
Benzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
Toluene	SW8020	ug/l	1	<1	<1	<1	<1	3	<1
Ethyl Benzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
Xylene	SW8020	ug/l	1	<1	<1	<1	<1	14	<1
Chlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
1,3-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	SW8020	ug/l	1	<1	<1	<1	<1	<1	<1

na = Not Available
N/A = Not Applicable
KSFB = Ambient Conditions Blank

Table 4-16B
PURGEABLE HALOCARBONS
E601
ESKIMO CREEK, NORTH AND SOUTH BARREL BLUFF, AND NAKNEK RIVER SEEP

Parameters	Units	Detection Limit	Eskimo Creek KS-SW01 -01 10/28/87	Eskimo Creek KS-SW01 -02 10/28/87	South Barrel Bluff KS-SW02 -01 10/28/87	South Barrel Bluff KS-SW02 -02 10/28/87	South Barrel Bluff KS-SW02 -03 11/01/87
Chloromethane	ug/l	1	<1	<1	<1	<1	<1
Bromomethane Vinyl	ug/l	1	<1	<1	<1	<1	<1
Dichloridifluormethane	ug/l	1	<2	<2	<2	<2	<2
Vinyl Chloride	ug/l						
Chloroethane	ug/l	5	<1	<1	<1	<1	<1
Methylene Chloride	ug/l	1	<1	<1	<1	<1	<1
Trichlorofluoromethane	ug/l	1	<1	<1	<1	<1	<1
1,1-Dichloroethene	ug/l	1	<1	<1	<1	<1	<1
1,1-Dichloroethane	ug/l	1	<1	<1	<1	<1	<1
trans-1,2-Dichloroethene	ug/l	1	<1	<1	<1	<1	<1
Chloroform	ug/l	1	<1	<1	<1	<1	<1
1,2-Dichloroethane	ug/l	1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	ug/l	1	<1	<1	<1	<1	<1
Carbon Tetrachloride	ug/l	1	<1	<1	<1	<1	<1
Bromodichloromethane	ug/l	1	<1	<1	<1	<1	<1
1,2-Dichloropropane	ug/l	1	<1	<1	<1	<1	<1
cis-1,3-Dichlorpropene	ug/l	1	<1	<1	<1	<1	<1
Trichloroethene	ug/l	1	<1	<1	<1	<1	<1
Dibromochloromethane	ug/l	1	<3	<3	<3	<3	<3
1,1,2-Trichloroethane	ug/l	1					
trans-1,3-Dichloropropene	ug/l	1					
Bromoform	ug/l	1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethan	ug/l	1	<2	<2	<2	<2	<2
Tetrachloroethene	ug/l	1					
Chlorobenzene	ug/l	1	<1	<1	<1	<1	<1
1,3-Dichlorobenzene	ug/l	1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	ug/l	1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	ug/l	1	<1	<1	<1	<1	<1

KSFB-Ambient Conditions Blank

Table 4-16B
(Continued)

Parameters	Units	Detection Limit	North Barrel Bluff KS-SW03 -01 10/31/87	North Barrel Bluff KS-SW03 -02 10/31/87	North Barrel Bluff KS-SW03 -03 10/31/87	KS-SW03-04 DUP SW03-02 10/31/87	Naknek River Seep KS-SW04 -01 10/31/87	KSFB 10/28/87
Chloromethane	ug/l	1	<1	<1	<1	<1	<1	<1
Bromomethane Vinyl	ug/l	1	<1	<1	<1	<1	<1	<1
Dichloridifluormethane	ug/l	1	<2	<2	<2	<2	<2	<2
Vinyl Chloride	ug/l							
Chloroethane	ug/l	5	<1	<1	<1	<1	<1	<1
Methylene Chloride	ug/l	1	<1	<1	<1	<1	<1	<1
Trichlorofluoromethane	ug/l	1	<1	<1	<1	<1	<1	<1
1,1-Dichloroethene	ug/l	1	<1	<1	<1	<1	<1	<1
1,1-Dichloroethane	ug/l	1	<1	<1	<1	<1	<1	<1
trans-1,2-Dichloroethene	ug/l	1	<1	<1	<1	<1	85	<1
Chloroform	ug/l	1	<1	<1	<1	<1	<1	<1
1,2-Dichloroethane	ug/l	1	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	ug/l	1	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	ug/l	1	<1	<1	<1	<1	<1	<1
Bromodichloromethane	ug/l	1	<1	<1	<1	<1	<1	<1
1,2-Dichloropropane	ug/l	1	<1	<1	<1	<1	<1	<1
cis-1,3-Dichlorpropene	ug/l	1	<1	<1	<1	<1	<1	<1
Trichloroethene	ug/l	1	<1	<1	<1	<1	ND	<1
Dibromochloromethane	ug/l	1	<3	<3	<3	<3	<3	<3
1,1,2-Trichloroethane	ug/l	1						
trans-1,3-Dichloropropene	ug/l	1						
Bromoform	ug/l	1	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethan	ug/l	1	<2	<2	<2	<2	<2	<2
Tetrachloroethene	ug/l	1						
Chlorobenzene	ug/l	1	<1	<1	<1	<1	<1	<1
1,3-Dichlorobenzene	ug/l	1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	ug/l	1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	ug/l	1	<1	<1	<1	<1	<1	<1

KSFB-Ambient Conditions Blank
ND-None Detected

CVR193/039-2

Table 4-16C
EXTRACTABLE PRIORITY POLLUTANTS
E625
NORTH AND SOUTH BARREL BLUFF SURFACE WATER

Parameters	Units	South Barrel Bluff			North Barrel Bluff			
		KS-SW02-01 10/28/87	KS-SW02-02 10/28/87	KS-SW02-03 10/28/87	KS-SW03-01 10/31/87	KS-SW03-02 10/31/87	KS-SW03-03 10/31/87	DUP SW03-02 10/31/87
n-nitroso-dimethylamine	ug/l	10U	10U	10U	10U	10U	10U	10U
phenol	ug/l	10U	10U	10U	10U	10U	10U	10U
aniline	ug/l	10U	10U	10U	10U	10U	10U	10U
bis(2-chloroethyl) ether	ug/l	10U	10U	10U	10U	10U	10U	10U
2-chlorophenol	ug/l	10U	10U	10U	10U	10U	10U	10U
1,3-dichlorobenzene	ug/l	10U	10U	10U	10U	10U	10U	10U
1,4-dichlorobenzene	ug/l	10U	10U	10U	10U	10U	10U	10U
benzyl alcohol	ug/l	10U	10U	10U	10U	10U	10U	10U
1,2-dichlorobenzene	ug/l	10U	10U	10U	10U	10U	10U	10U
2-methylphenol	ug/l	10U	10U	10U	10U	10U	10U	10U
bis(2-chloroisopropyl) ether	ug/l	10U	10U	10U	10U	10U	10U	10U
4-methylphenol	ug/l	10U	10U	10U	10U	10U	10U	10U
n-nitroso-di-n-propylamine	ug/l	10U	10U	10U	10U	10U	10U	10U
hexachloroethane	ug/l	10U	10U	10U	10U	10U	10U	10U
nitrobenzene	ug/l	10U	10U	10U	10U	10U	10U	10U
isophrone	ug/l	10U	10U	10U	10U	10U	10U	10U
2-nitrophenol	ug/l	10U	10U	10U	10U	10U	10U	10U
2,4-diethylphenol	ug/l	10U	10U	10U	10U	10U	10U	10U
benzoic acid	ug/l	50U	50U	50U	50U	50U	50U	50U
bis(2-chloroethoxy) methane	ug/l	10U	10U	10U	10U	10U	10U	10U
2,4-dichlorophenol	ug/l	10U	10U	10U	10U	10U	10U	10U
1,2,4-trichlorobenzene	ug/l	10U	10U	10U	10U	10U	10U	10U
naphtalene	ug/l	10U	10U	10U	10U	10U	10U	10U
4-chloroaniline	ug/l	10U	10U	10U	10U	10U	10U	10U
hexachlorobutadiene	ug/l	10U	10U	10U	10U	10U	10U	10U
4-chloro-3-methylphenol	ug/l	10U	10U	10U	10U	10U	10U	10U
2-methylnaphthalene	ug/l	10U	10U	10U	10U	10U	10U	10U
hexachlorocyclopentadiene	ug/l	10U	10U	10U	10U	10U	10U	10U
2,4,6-trichlorophenol	ug/l	10U	10U	10U	10U	10U	10U	10U

Table 4-16C
(Continued)

Parameters	Units	South Barrel Bluff KS-SW02-01 10/28/87	KS-SW02-02 10/28/87	KS-SW02-03 10/28/87	North Barrel Bluff KS-SW03-01 10/31/87	KS-SW03-02 10/31/87	KS-SW03-03 10/31/87	DUP SW03-02 10/31/87
2,4,5-trichlorophenol	ug/l	50U	50U	50U	50U	50U	50U	50U
2-chloronaphthalene	ug/l	10U	10U	10U	10U	10U	10U	10U
2-nitroaniline	ug/l	50U	50U	50U	50U	50U	50U	50U
dimethyl phthalate	ug/l	10U	10U	10U	10U	10U	10U	10U
acenaphthylene	ug/l	10U	10U	10U	10U	10U	10U	10U
3-nitroaniline	ug/l	50U	50U	50U	50U	50U	50U	50U
acenaphthene	ug/l	10U	10U	10U	10U	10U	10U	10U
2,4-dinitrophenol	ug/l	50U	50U	50U	50U	50U	50U	50U
4-nitrophenol	ug/l	50U	50U	50U	50U	50U	50U	50U
dibenzofuran	ug/l	10U	10U	10U	10U	10U	10U	10U
2,4-dinitrotoluene	ug/l	10U	10U	10U	10U	10U	10U	10U
2,6-dinitrotoluene	ug/l	10U	10U	10U	10U	10U	10U	10U
diethyl phthalate	ug/l	10U	10U	10U	10U	10U	10U	10U
4-chlorophenyl phenyl ether	ug/l	10U	10U	10U	10U	10U	10U	10U
fluorene	ug/l	10U	10U	10U	10U	10U	10U	10U
4-nitroaniline	ug/l	50U	50U	50U	50U	50U	50U	50U
4,6-dinitro-2-methylphenol	ug/l	50U	50U	50U	50U	50U	50U	50U
n-nithosodiphenylamine	ug/l	10U	10U	10U	10U	10U	10U	10U
4-bromophenyl phenyl ether	ug/l	10U	10U	10U	10U	10U	10U	10U
hexachlorobenzene	ug/l	10U	10U	10U	10U	10U	10U	10U
pentachlorophenol	ug/l	50U	50U	50U	50U	50U	50U	50U
phenanthrene	ug/l	10U	10U	10U	10U	10U	10U	10U
anthracene	ug/l	10U	10U	10U	10U	10U	10U	10U
di-n-butyl phathalate	ug/l	10U	10U	10U	10U	10U	10U	10U
fluoranthene	ug/l	10U	10U	10U	10U	10U	10U	10U
benzidine	ug/l	50U	50U	50U	50U	50U	50U	50U
pyrene	ug/l	10U	10U	10U	10U	10U	10U	10U
butyl benzyl phthalate	ug/l	10U	10U	10U	10U	10U	10U	10U
3,3-dichlorobenzidine	ug/l	20U	20U	20U	20U	20U	20U	20U
benzo(a)anthracene	ug/l	10U	10U	10U	10U	10U	10U	10U
bis(2-ethylhexyl)phthalate	ug/l	10U	10U	10U	10U	10U	10U	10U
chrysene	ug/l	10U	10U	10U	10U	10U	10U	10U

Table 4-16C
(Continued)

Parameters	Units	South Barrel Bluff KS-SW02-01 10/28/87	KS-SW02-02 10/28/87	KS-SW02-03 10/28/87	North Barrel Bluff KS-SW03-01 10/31/87	KS-SW03-02 10/31/87	KS-SW03-03 10/31/87	DUP SW03-02 10/31/87
di-n-octyl phthalate	ug/l	10U	10U	10U	10U	10U	10U	10U
benzo(b)fluoranthene	ug/l	10U	10U	10U	10U	10U	10U	10U
benzo(k)fluoranthene	ug/l	10U	10U	10U	10U	10U	10U	10U
benzo(a)pyrene	ug/l	10U	10U	10U	10U	10U	10U	10U
indeno(1,2,3-cd)pyrene	ug/l	10U	10U	10U	10U	10U	10U	10U
dibenz(a,h)anthracene	ug/l	10U	10U	10U	10U	10U	10U	10U
benzo(g,h,i)perylene	ug/l	10U	10U	10U	10U	10U	10U	10U

Table 4-16D
ORGANOCHLORINE PESTICIDES AND PCBs
(E608)
NORTH AND SOUTH BARREL BLUFF SURFACE WATER

Parameters	Units	Detection Limit	South Barrel Bluff KS-SW02-01 10/28/87	South Barrel Bluff KS-SW02-01 10/28/87	South Barrel Bluff KS-SW02-03 10/28/87	North Barrel Bluff KS-SW03-01 10/31/87	North Barrel Bluff KS-SW03-02 10/31/87	North Barrel Bluff KS-SW03-03 10/31/87	KS-SW03-04 DUP-SW03-02 10/31/87
a-BHC	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
b-BHC	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
g-BHC	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
d-BHC	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Heptachlor	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aldrin	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Heptachlor Epoxide	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Endosulfan I	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dieldrin	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
4,4-DDE	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Endrin	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Endosulfan II	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
4,4-DDD	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Endrin Aldehyde	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Endosulfan Sulfate	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
4,4-DDT	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
methxychlor	ug/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlordane	ug/l	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
Toxaphene	ug/l	<1	<1	<1	<1	<1	<1	<1	<1
PCB-1221	ug/l	<2	<2	<2	<2	<2	<2	<2	<2
PCB-1232	ug/l	<2	<2	<2	<2	<2	<2	<2	<2
PCB-1242	ug/l	<1	<1	<1	<1	<1	<1	<1	<1
PCB-1016	ug/l	<1	<1	<1	<1	<1	<1	<1	<1
PCB-1248	ug/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
PCB-1254	ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
PCB-1260	ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

---

[a] SDWA MCL February 1988.

Table 4-16E
METALS SCREEN
ESKIMO CREEK, NORTH AND SOUTH BARREL BLUFF, AND NAKNEK RIVER SEEP

				Eskimo Creek		South Barrel Bluff			North Barrel Bluff				Naknek River Seep
Parameters	Method	Units	Detection Limit	KS-SW01 -01 10/28/87	KS-SW01 -02 10/28/87	KS-SW02 -01 10/28/87	KS-SW02 -02 10/28/87	KS-SW02 -03 11/01/87	KS-SW03 -01 10/31/87	KS-SW03 -02 10/31/87	KS-SW03 -03 10/31/87	KS-SW03-04 DUP SW03-02 10/31/87	KS-SW04 -01 10/31/87
Aluminum	E200.7	ug/l	100	<100	120	<100	<100	<100	<100	<100	<100	100	270
Arsenic	E206.2	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Barium	E200.7	ug/l	10	<10	<10	<10	<10	<10	<10	10	<10	<10	30
Beryllium	E200.7	ug/l	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Cadmium	E213.2	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Calcium	E200.7	ug/l	50	6400	6200	7600	7400	4400	6100	12100	6100	11100	39300
Chromium	E200.7	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cobalt	E200.7	ug/l	40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Copper	E200.7	ug/l	30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Iron	E200.7	ug/l	40	530	880	490	380	120	280	190	160	200	23300
Lead	E239.2	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Magnesium	E200.7	ug/l	200	2600	2600	2500	2500	1080	2400	3900	2400	3600	5600
Manganese	E200.7	ug/l	10	70	70	50	50	80	110	<10	<10	13	6000
Mercury		ug/l	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	E200.7	ug/l	15	<15	<15	15	<15	<15	<15	<15	<15	<15	<15
Potassium	E200.7	mg/l	1	<1.0	<1.0	<1.0	<1.0	<1.0	1.5	3	1.8	3	2.2
Selenium	E270.2	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Silver	E272.2	ug/l	5	<5	<5	<5	<5	8	<5	<5	<5	<5	<5
Sodium	E200.7	mg/l	0.9	7.8	7.4	6	5.8	<5	6.7	7.6	6.8	7.9	10
Thallium	E279.2	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Vanadium	E200.7	ug/l	40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Zinc	E200.7	ug/l	10	30	70	14	15	30	25	34	30	34	24
Antimony	E204.2	ug/l	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Silicon	E200.7	ug/l	300	7200	7100	9300	9500	10400	10200	13100	12000	11100	8800
Molybdenum	E200.7	ug/l	40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Boron	E200.7	ug/l	30	70	60	150	70	<30	110	60	120	160	130

---

[a] SDWA MCLs.

[b] RCRA MCL.

[c] CWA Ambient Water Quality Criteria for Protection of Aquatic Life Freshwater Acute/Chronic.

While collecting the surface water samples, an oily discoloration in the sediments was observed at sample location SW03-1.

4.1.5.2.4 South Barrel Bluff

One organochlorine pesticide/PCB compound, chlordane, was reported at 0.2 ug/l. This detection was observed in the King Salmon Creek surface water sample collected at the upstream location.

Concentrations of calcium, iron, magnesium, and boron show an increased trend between the upstream and downstream locations. This may indicate that a source for these constituents exists between the two sample locations.

While collecting the surface water samples at the South Barrel Bluff, water (leachate) seepage from the toe of the bluff appeared to have an oily sheen and a discernible odor (landfill gas).

4.1.6 Sediment Investigation

This section presents the results of the sediment investigation. Sampling procedures are discussed in Section 3.8, Environmental Sampling. Laboratory analytical reports and QA/QC data are presented in Appendix G, Analytical Data.

4.1.6.1 Eskimo Creek Seep

No sediment samples were collected at the Eskimo Creek seep site.

4.1.6.2 Naknek River Seep

No sediment samples were collected at the Naknek River seep site.

4.1.6.3 North Barrel Bluff

Sediment samples were collected at the same locations as the surface water samples along the toe of the North Barrel Bluff in the flood plain of King Salmon Creek. Samples were initially collected in the fall of 1987. These samples were analyzed for 1) organochlorine pesticides and PCBs, 2) semivolatile organic compounds, and 3) volatile organic compounds. The results of the analyses are shown in Tables 4-17A through 4-17C.

Methylene chloride and acetone were detected in SE05-01 at low concentrations. These constituents are widely used in analytical laboratories and may be the source for the concentrations measured in the sample analysis. Moisture content of the sediment samples was not determined, and the concentrations could not be converted to a dry weight basis.

Sampling and analysis for volatile organic compounds were repeated in the spring of 1988. The results of the repeat analyses are shown in Table 4-17D. No constituents were detected.

4.2 SIGNIFICANCE OF FINDINGS

Contaminant concentrations and migrations are discussed below. The significance of the findings may be viewed in terms of the potential exposure pathways (Figure 4-16) and the risk assessment (Section 4.3).

4.2.1 Eskimo Creek Seep

The approximate extent of groundwater contamination at the Eskimo Creek seep has been characterized by the combination of soil gas sampling, groundwater flow interpretations, and water quality sampling. A summary of these data is presented in Figure 4-17. The gross regional groundwater flow direction in the shallow unconfined aquifer is from north to south across the site. The flow pattern is locally controlled by 1) discharge to Eskimo Creek along the east and southeast and 2) the till surface topography south of the POL tanks. Groundwater flow is impeded by the elevated surface till diverting much of the flow, to the southwest toward MW-40 and to the south toward MW-37. A lowering of the water table due to seasonal fluctuations would increase the size and consequently the effect of this till barrier. Groundwater may be diverted further to the east around the till mound to discharge into Eskimo Creek under low water table conditions.

The elevated surface till may be more extensive than current data indicate, and thus have a greater effect on groundwater flow. Local groundwater flow directions will be altered significantly in areas where this till surface or possibly other till mounds intersect the water table.

Hydrocarbon groundwater contamination in MW-22 at POL tanks 11 and 12 (TPH of 5,666 ppm measured in groundwater) moves downgradient and is apparently split into two plumes by the till barrier. The southwest plume is identified by several soil gas points and well MW-39 (TPH of 14.9 ppm). The extent of this plume is defined on the south by nondetect soil gas points and well MW-33 (TPH less than 1 ppm). The downgradient and west edges of the plume are not fully defined, with distant wells MW-24 and MW-40 showing less than detection limit (1 ppm) of TPH.

The major groundwater plume (east) spreads from the POL tanks across the site to the east and southeast towards Eskimo

Table 4-17A
VOLATILE ORGANICS
SW8240
NORTH BARREL BLUFF SEDIMENT - 1987

Parameter	Units	KS-SE05-01 11/02/87	KS-SE05-02 DUP SE05-04 11/02/87	KS-SE05-03 11/02/87	KS-SE05-04 11/02/87
Chloromethane	ug/kg	10U	10U	10U	10U
Bromoethane	ug/kg	10U	10U	10U	10U
Vinyl chloride	ug/kg	10U	10U	10U	10U
Chloroethane	ug/kg	10U	10U	10U	10U
Methylene chloride	ug/kg	8	12	8	12
Acetone	ug/kg	20	89	12	65
Carbon disulfide	ug/kg	5U	5U	5U	5U
1,1-Dichloroethene	ug/kg	5U	5U	5U	5U
1,1-Dichloroethane	ug/kg	5U	5U	5U	5U
Trans-1,2-dichloroethene	ug/kg	5U	5U	5U	5U
Chloroform	ug/kg	5U	5U	5U	5U
1,2-Dichloroethane	ug/kg	5U	5U	5U	5U
2-Butanone	ug/kg	10U	10U	10U	10U
1,1,1-Trichloroethane	ug/kg	5U	5U	5U	5U
Carbon tetrachloride	ug/kg	5U	5U	5U	5U
Vinyl acetate	ug/kg	10U	10U	10U	10U
Bromodichloromethane	ug/kg	5U	5U	5U	5U
1,2-Dichloropropane	ug/kg	5U	5U	5U	5U
Cis-1,3-dichloropropene	ug/kg	5U	5U	5U	5U
Trichloroethene	ug/kg	5U	5U	5U	5U
Dibromochloromethane	ug/kg	3J	5U	5U	5U
1,1,2-Trichloroethane	ug/kg	6	5U	5U	5U
Trans-1,3-dichloropropene	ug/kg	5U	5U	5U	5U
Benzene	ug/kg	5U	5U	5U	5U
2-Chloroethyl vinyl ether	ug/kg	10U	10U	10U	10U
Bromoform	ug/kg	5U	5U	5U	5U
4-Methyl-2-pentanone	ug/kg	20	10U	10U	10U
2-Hexanone	ug/kg	10U	10U	10U	10U
1,1,2,2-Tetrachloroethane	ug/kg	11	5U	5U	5U
Tetrachloroethene	ug/kg	5U	5U	5U	5U
Toluene	ug/kg	5U	3J	5U	5U
Chlorobenzene	ug/kg	5U	5U	5U	5U
Ethylbenzene	ug/kg	5U	5U	5U	5U
Styrene	ug/kg	5U	5U	5U	5U
Xylenes (o+p)	ug/kg	5U	5U	5U	5U
Xylene (p)	ug/kg	5U	5U	5U	5U

TB-Trip Blank

Values in this table based on dry weight.

U=Indicates constituent tested for, but not detected.

J=Indicates an estimated trace value.

Table 4-17B
SEMI-VOLATILE ORGANIC COMPOUNDS
SW8270
NORTH BARREL BLUFF SEDIMENT

Parameter	Units	KS-SE05-01 11/02/87	KS-SE05-02 DUP SE05-04 11/02/87	KS-SE05-03 11/02/87	KS-SE05-04 11/02/87
n-nitroso-dimethylamine	ug/kg	330U	330U	330U	330U
phenol	ug/kg	330U	330U	330U	330U
aniline	ug/kg	330U	330U	330U	330U
bis(2-chloroethyl) ether	ug/kg	330U	330U	330U	330U
2-chlorophenol	ug/kg	330U	330U	330U	330U
1,3-dichlorobenzene	ug/kg	330U	330U	330U	330U
1,4-dichlorobenzene	ug/kg	330U	330U	330U	330U
benzyl alcohol	ug/kg	330U	330U	330U	330U
1,2-dichlorobenzene	ug/kg	330U	330U	330U	330U
2-methylphenol	ug/kg	330U	330U	330U	330U
bis(2-chloroisopropyl)	ug/kg	330U	330U	330U	330U
4-methylphenol	ug/kg	330U	330U	330U	330U
n-nitroso-di-n-propylamine	ug/kg	330U	330U	330U	330U
hexachloroethane	ug/kg	330U	330U	330U	330U
nitrobenzene	ug/kg	330U	330U	330U	330U
isophrone	ug/kg	330U	330U	330U	330U
2-nitrophenol	ug/kg	330U	330U	330U	330U
2,4-diethylphenol	ug/kg	330U	330U	330U	330U
benzoic acid	ug/kg	1600U	1600U	1600U	1600U
bis(2-chloroethoxy) methane	ug/kg	330U	330U	330U	330U
2,4-dichlorophenol	ug/kg	330U	330U	330U	330U
1,2,4-trichlorobenzene	ug/kg	330U	330U	330U	330U
naphtalene	ug/kg	330U	330U	330U	330U
4-chloroaniline	ug/kg	330U	330U	330U	330U

Values in this table are based on wet weight.

U=Indicates constituent tested for, but not detected.

J=Indicates an estimated trace value.

Table 4-17B
(Continued)

Parameter	Units	KS-SE05-01 11/02/87	KS-SE05-02 DUP SE05-04 11/02/87	KS-SE05-03 11/02/87	KS-SE05-04 11/02/87
hexachlorobutadiene	ug/kg	330U	330U	330U	330U
4-chloro-3-methylphenol	ug/kg	330U	330U	330U	330U
2-methylnaphthalene	ug/kg	330U	330U	330U	330U
hexachlorocyclopentadiene	ug/kg	330U	330U	330U	330U
2,4,6-trichlorophenol	ug/kg	330U	330U	330U	330U
2,4,5-trichlorophenol	ug/kg	1600U	1600U	1600U	1600U
2-chloronaphthalene	ug/kg	330U	330U	330U	330U
2-nitroaniline	ug/kg	1600U	1600U	1600U	1600U
dimethyl phthalate	ug/kg	330U	330U	330U	330U
acenaphthene	ug/kg	330U	330U	330U	330U
3-nitroaniline	ug/kg	1600U	1600U	1600U	1600U
acenaphthene	ug/kg	330U	330U	330U	330U
2,4-dinitrophenol	ug/kg	1600U	1600U	1600U	1600U
4-nitrophenol	ug/kg	1600U	1600U	1600U	1600U
dibenzofuran	ug/kg	330U	330U	330U	330U
2,4-dinitrotoluene	ug/kg	330U	330U	330U	330U
2,6-dinitrotoluene	ug/kg	330U	330U	330U	330U
diethyl phthalate	ug/kg	330U	330U	330U	330U
4-chlorophenyl phenyl ether	ug/kg	330U	330U	330U	330U
fluorene	ug/kg	330U	330U	330U	330U
4-nitroaniline	ug/kg	1600U	1600U	1600U	1600U
4,6-dinitro-2-methylphenol	ug/kg	1600U	1600U	1600U	1600U
n-nithosodiphenylamine	ug/kg	330U	330U	330U	330U
4-bromophenyl phenyl ether	ug/kg	330U	330U	330U	330U
hexachlorobenzene	ug/kg	330U	330U	330U	330U
pentachlorophenol	ug/kg	1600U	1600U	1600U	1600U
phenanthrene	ug/kg	330U	330U	330U	330U
anthracene	ug/kg	330U	330U	330U	330U
di-n-butyl phathalate	ug/kg	330U	330U	330U	330U

Values in this table are based on wet weight.
U=Indicates constituent tested for, but not detected.
J=Indicates an estimated trace value.

Table 4-17B
(Continued)

Parameter	Units	KS-SE05-01 11/02/87	KS-SE05-02 DUP SE05-04 11/02/87	KS-SE05-03 11/02/87	KS-SE05-04 11/02/87
fluoranthene	ug/kg	330U	330U	330U	330U
benzidine	ug/kg	1600U	1600U	1600U	1600U
pyrene	ug/kg	330U	330U	330U	330U
butyl benzyl phthalate	ug/kg	330U	330U	330U	330U
3,3-dichlorobenzidine	ug/kg	660U	660U	660U	660U
benzo(a)anthracene	ug/kg	330U	330U	330U	330U
bis(2-ethylhexyl)phthalate	ug/kg	330U	330U	330U	330U
chrysene	ug/kg	330U	330U	330U	330U
di-n-octyl phthalate	ug/kg	330U	330U	330U	330U
benzo(b)fluoranthene	ug/kg	330U	330U	330U	330U
benzo(k)fluoranthene	ug/kg	330U	330U	330U	330U
benzo(a)pyrene	ug/kg	330U	330U	330U	330U
indeno(1,2,3-cd)pyrene	ug/kg	330U	330U	330U	330U
dibenz(a,h)anthracene	ug/kg	330U	330U	330U	330U
benzo(g,h,i)perylene	ug/kg	330U	330U	330U	330U

Values in this table are based on wet weight.
U=Indicates constituent tested for, but not detected.
J=Indicates an estimated trace value.

Table 4-17C
ORGANOCHLORINE PESTICIDES AND PCBs
E608
NORTH BARREL BLUFF SEDIMENT

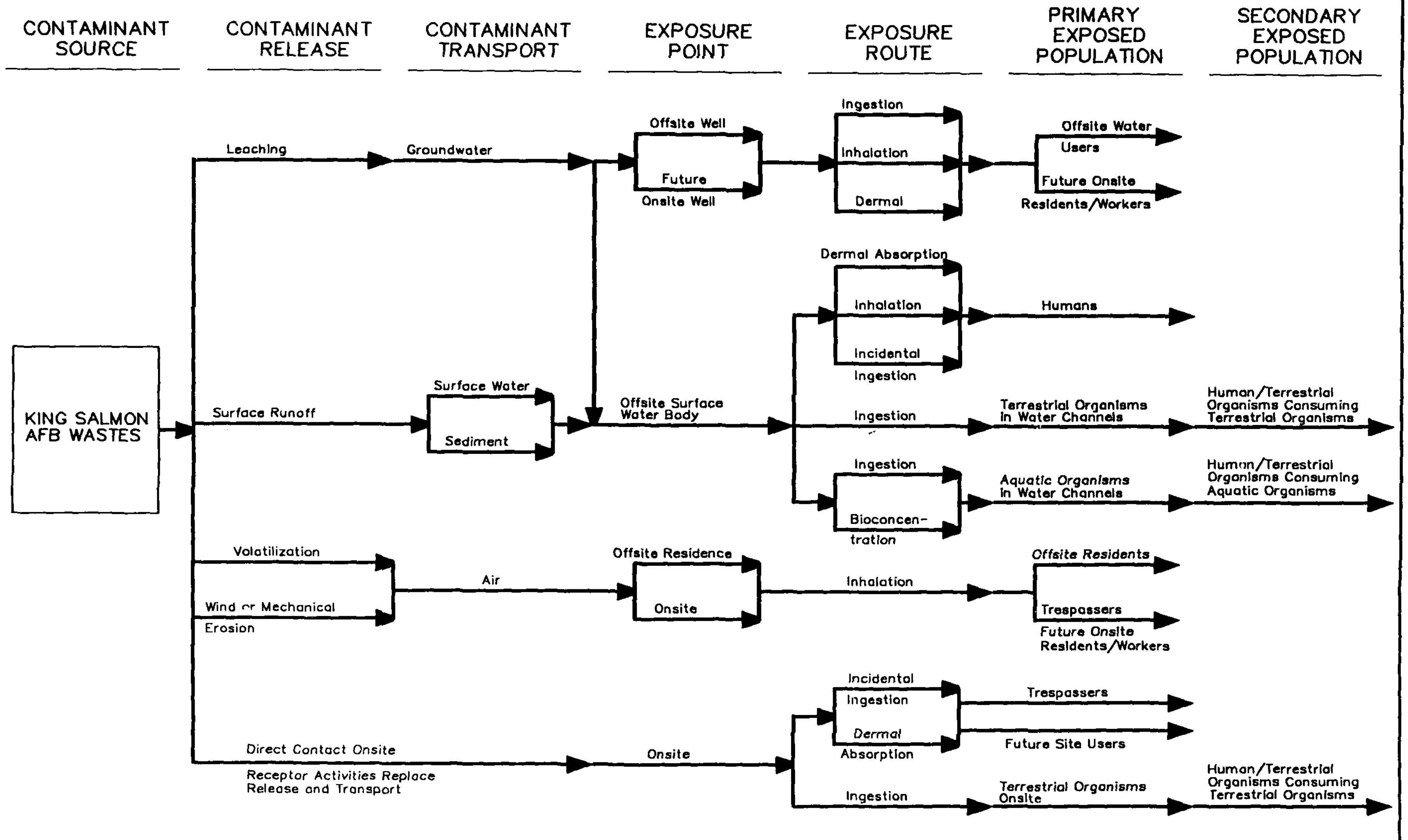
Parameter	Units	Detection Limit	KS-SE05-01 11/02/87	KS-SE05-02 11/02/87	KS-SE05-03 11/02/87	KS-SE05-04 11/02/87
a-BHC	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
b-BHC	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
g-BHC	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
d-BHC	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Heptachlor	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Aldrin	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Heptachlor Epoxide	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Endosulfan I	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Dieldrin	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
4,4-DDE	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Endrin	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Endosulfan II	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
4,4-DDD	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Endrin Aldehyde	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Endosulfan Sulfate	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
4,4-DDT	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
methxychlor	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Chlordane	mg/kg	<0.004	<0.004	<0.004	<0.004	<0.004
Toxaphene	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04
PCB-1221	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04
PCB-1232	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04
PCB-1242	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04
PCB-1016	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04
PCB-1248	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04
PCB-1254	mg/kg	<0.02	<0.02	<0.02	<0.02	<0.02
PCB-1260	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
PCB-1221	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01

Table 4-17D
VOLATILE ORGANICS
SW8240
NORTH BARREL BLUFF SEDIMENT - 1988

Parameter	Units	KS-SE05-01 06/15/88	KS-SE05-02 06/15/88	KS-SE05-03 06/15/88	KS-SE05-04 DUP SE05-02 06/15/88	KS-TBSE 06/15/88
Chloromethane	ug/kg	16U	20U	14U	24U	10U
Bromoethane	ug/kg	16U	20U	14U	24U	10U
Vinyl chloride	ug/kg	16U	20U	14U	24U	10U
Chloroethane	ug/kg	16U	20U	14U	24U	10U
Methylene chloride	ug/kg	20	27	19	44	3J
Acetone	ug/kg	40	32	96	26	10J
Carbon disulfide	ug/kg	8U	10U	7U	12U	5U
1,1-Dichloroethene	ug/kg	8U	10U	7U	12U	5U
1,1-Dichloroethane	ug/kg	8U	10U	7U	12U	5U
Trans-1,2-dichloroethene	ug/kg	8U	10U	7U	12U	5U
Chloroform	ug/kg	8U	10U	7U	12U	5U
1,2-Dichloroethane	ug/kg	8U	10U	7U	12U	5U
2-Butanone	ug/kg	16U	20U	20	24U	10U
1,1,1-Trichloroethane	ug/kg	8U	10U	7U	12U	5U
Carbon tetrachloride	ug/kg	8U	10U	7U	12U	5U
Vinyl acetate	ug/kg	16U	20U	14U	24U	10U
Bromodichloromethane	ug/kg	8U	10U	7U	12U	5U
1,2-Dichloropropane	ug/kg	8U	10U	7U	12U	5U
Cis-1,3-dichloropropene	ug/kg	8U	10U	7U	12U	5U
Trichloroethene	ug/kg	8U	10U	7U	12U	5U
Dibromochloromethane	ug/kg	8U	10U	7U	12U	5U
1,1,2-Trichloroethane	ug/kg	8U	10U	7U	12U	5U
Trans-1,3-dichloroproper	ug/kg	8U	10U	7U	12U	5U
Benzene	ug/kg	8U	10U	7U	12U	5U
2-Chloroethyl vinyl eth	ug/kg	16U	20U	14U	24U	10U
Bromoform	ug/kg	8U	10U	7U	12U	5U
4-Methyl-2-pentanone	ug/kg	16U	20U	14U	24U	10U
2-Hexanone	ug/kg	16U	20U	14U	24U	10U
1,1,2,2-Tetrachloroethane	ug/kg	8U	10U	8U	12U	5U
Tetrachloroethene	ug/kg	8U	10U	7U	12U	5U
Toluene	ug/kg	8U	10U	4J	12U	5U
Chlorobenzene	ug/kg	8U	10U	7U	12U	5U
Ethylbenzene	ug/kg	8U	10U	7U	12U	5U
Styrene	ug/kg	8U	10U	7U	12U	5U
Xylenes (o+m)	ug/kg	8U	10U	7U	12U	5U
Xylene (p)	ug/kg	8U	10U	7U	12U	5U

TB-Trip Blank
Values in this table based on dry weight.
U=Indicates constituent tested for, but not detected.
J=Indicates an estimated trace value.

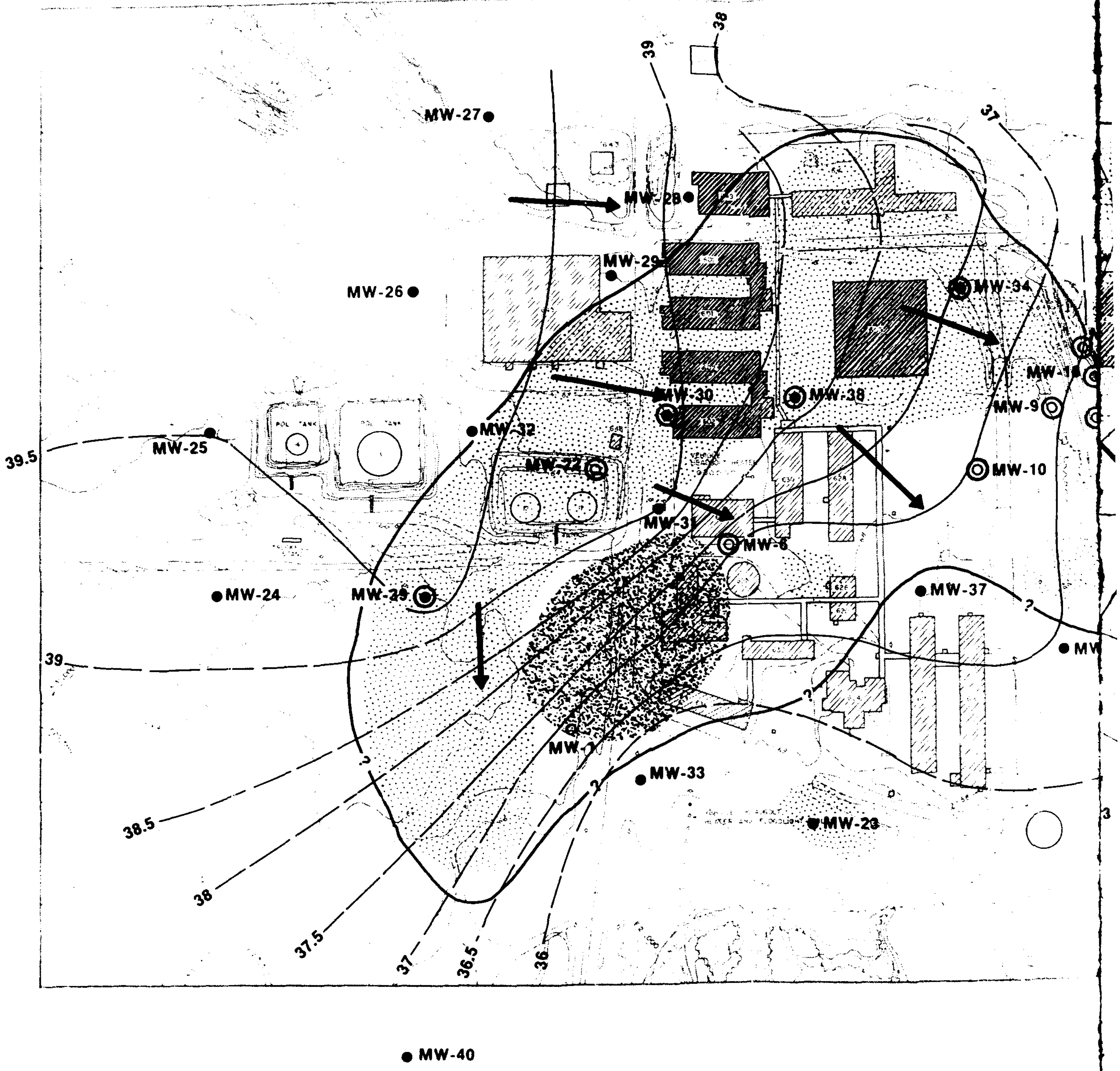
CVR193/042-4



K24173.A0
J: \INDUST\K24173\FIG7-3.DWG

FIGURE 4-16

POTENTIAL EXPOSURE PATHWAYS
RISK ASSESSMENT
KING SALMON AIR FORCE STATION
KING SALMON, ALASKA


MW-27
MW-28
MW-29
MW-26
MW-34
MW-19
MW-9
MW-10
MW-30
MW-38
MW-32
MW-25
MW-22
MW-31
MW-6
MW-24
MW-35
MW-37
MW-1
MW-33
MW-23
MW-40
MW
POL TANK
39.5
39
38.5
38
37.5
37
36.5
36
?

73 A0

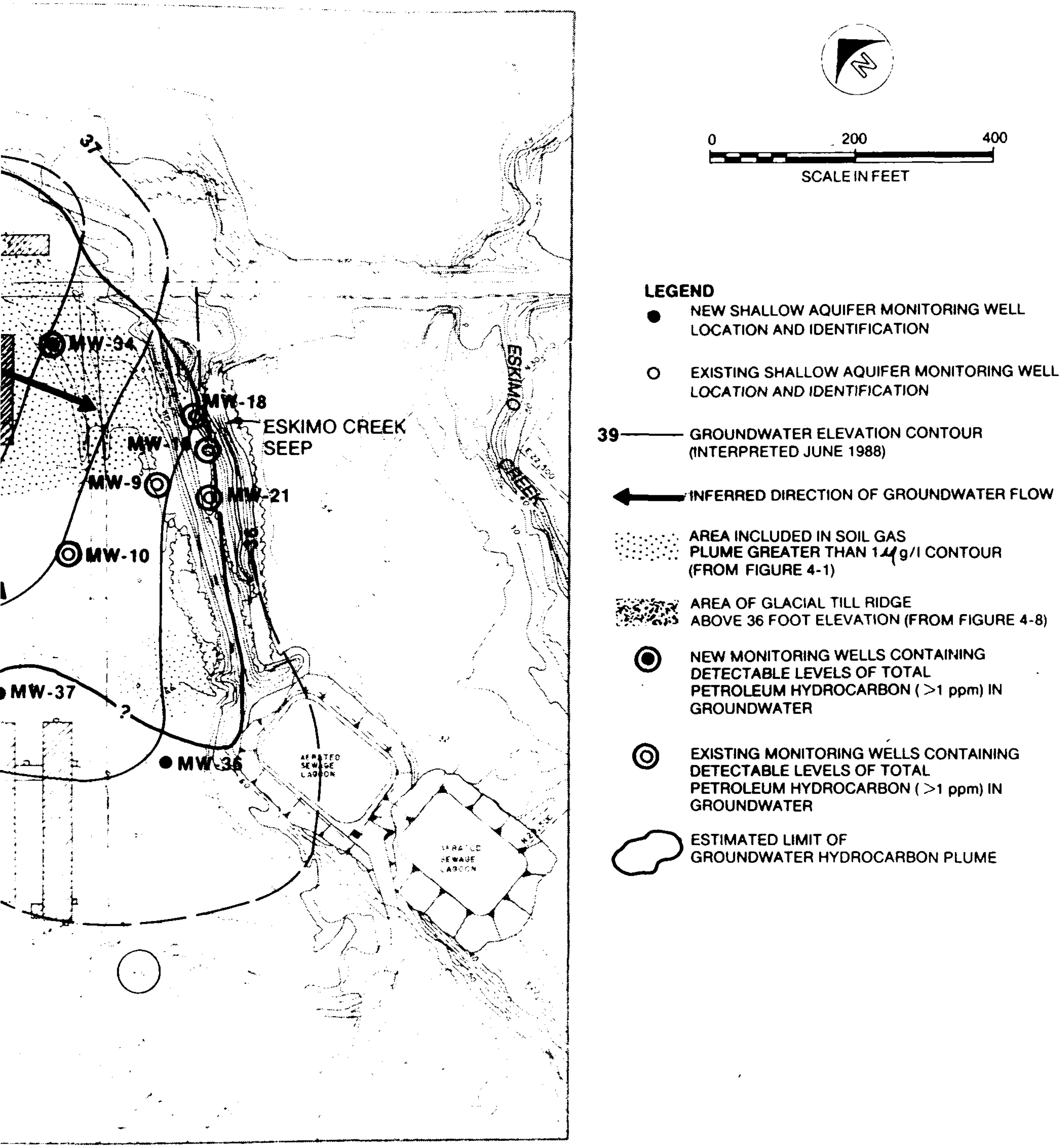


FIGURE 4-17

GROUNDWATER PLUME INTERPRETATION

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

Creek. The interpretations of groundwater flow suggest that contaminated groundwater moves to the east around the till, and then southeast towards MW-6 and MW-10. This scenario, however, does not provide a definite source for the Eskimo Creek seep. A second, currently unrecognized, source may exist hydraulically upgradient of the seep that could also account for the large soil gas plume in the northeast portion of the site. Further analysis of groundwater flow patterns (i.e., seasonal fluctuations) additional monitoring wells and water quality sampling would be necessary to further delineate the source of the Eskimo Creek seep contamination.

Hydrocarbon contamination (TPH and aromatics) in the unsaturated soils is highest in areas correlating with the groundwater plume. However, soils contamination (TPH) at lower levels (less than 200 ppm) does appear to be much more extensive than the plume. Past site practices of road oiling for dust control probably spread hydrocarbon contamination across the site. Other potential sources include underground utility corridors and unreported underground tank locations, drum storage areas, and general cleaning/degreasing of equipment in open areas. These localized areas outside of the primary contaminant plume should be considered as potential future sources for continuing releases to shallow groundwater.

Visual evidence of petroleum contamination was observed discharging with shallow groundwater into the wetland area west of Eskimo Creek. The wetland serves as a migration pathway into the creek. However, for the analyses that were performed on the samples of the creek water no constituents were detected.

The nature of soil and groundwater contamination does not appear to consist of the more volatile hydrocarbons. However, the individual constituents could not be identified on the basis of the analyses completed.

Three intermediate wells were constructed next to (nested) shallow wells to investigate the hydraulic relationships between aquifers and to determine if shallow groundwater contamination has migrated vertically beneath the site. A strong downward vertical gradient was found between the unconfined and intermediate aquifers. However, analytical results did not indicate contamination in any of the three intermediate wells. Because the upper aquifer is a recharge source for the intermediate aquifer, this conclusion should be verified with more extensive sampling.

The direction of groundwater flow in the intermediate zone is apparently to the south. Verification of this interpretation will require additional water level measurements.

The station's two deep wells produce water from a confined system that is screened at depths greater than 200 feet below ground surface. This zone is about 120 feet below the intermediate aquifer, where it is screened by the new wells. The relationship between these two systems is not well defined. Vertical gradients between the two systems cannot be evaluated because the base wells are actively pumped.

Water quality analyses for the base wells indicate hydrocarbon contamination (TPH of 27.1 and 6.4 ppm) in the wells. The individual constituents and their associated risk to human health are unknown.

Because the nested intermediate wells do not appear to be contaminated, a highly likely migration pathway to the deep aquifer is communication along the well bore annulus of the deep wells. This interpretation should be confirmed with more extensive sampling. If the station wells are acting as a source for deep aquifer contamination, the nature and extent of that contamination should be evaluated, and the wells should be abandoned to prevent further contamination.

4.2.2 Naknek Seep

The soil gas analysis and water sample collected at the Naknek seep verify the presence of hydrocarbon contamination at this location. The data are insufficient to allow further interpretation of the nature, extent, or exact source of contamination. However, the proximity of the contamination to the reported location of an abandoned fuel storage tank and the presence of an existing tank suggest the contamination may be localized in this area.

4.2.3 North Barrel Bluff

Geophysical survey data collected at the North Barrel Bluff indicate that the drums extend approximately 50 to 100 feet from the bluff along the lines surveyed. The vertical extent of the drums could not be determined with geophysical techniques, but visual observations indicate that the vertical extent may span a depth equal to the entire bluff face. Additional areas where metallic debris were buried in trenches were identified. Several more of these small "dumps" could exist within the large disturbed area bordering the bluff.

Sediment samples collected in 1987 at the toe of the bluff contained trace concentrations of organic and inorganic constituents. A resampling of these points did not verify these results.

Analysis of surface water samples from the bog at the face of the bluff and from King Salmon Creek did not indicate the presence of constituents above method detection limits.

Many of the drums appeared to be intact and are expected to contain residual fluids. These fluids represent future sources for releases to soil, surface and groundwater. The unsaturated soils beneath the drum and debris area could contain liquids that have already leaked from the drums.

The surface water and sediment samples were not adequate to provide an indication of whether releases are occurring along the bluff. Soil borings into the sediments beneath the drums are required to obtain samples that would be adequate to characterize potentially contaminated soils. Because of uncertainty about the types of waste deposited in this "landfill," the samples should be analyzed for a wide range of constituents.

The greatest potential for adverse affects to human health and the environment results from physical exposure to decomposing materials contained within the bluff area. The uncontrolled areas of buried drums and other debris types pose a potential threat through both physical contact and airborne chemical exposure.

4.2.4 South Barrel Bluff

Geophysical survey data collected along the South Barrel Bluff identified the presence of buried drums and other metallic debris along the bluff face, similar to that observed at the North Barrel Bluff. The large area west of the bluff was determined not to be a landfill. However, an area of smaller extent along the bluff that includes two residential homes does appear to be the site of a landfill. Other small areas within the disturbed areas along the bluff were also identified as "disposal areas."

Visual observations along the toe of the bluff indicated the presence of discolored liquids (i.e., leachate) discharging into the creek. However, for the analysis performed on the surface water samples from King Salmon Creek, no constituents were detected.

The surface water sampling program performed during the Stage I effort was not adequate to provide an indication of whether releases are occurring along the bluff. This sampling represents a limited effort of three sampling locations spaced along the length of the debris area. Additionally, this effort represents a one-time sampling event that does not address the issue of continuing releases and seasonal effects on contaminant transport.

Soil borings into the sediments beneath the drums are required to obtain samples adequate to allow characterization of potential contamination. Because of the uncertainty about the types of waste deposited in this "landfill," samples should be analyzed for a wide range of constituents (priority pollutants).

Analysis of drinking water from a residential well located within the landfill area did not indicate hazardous constituents for the parameters tested. Other residential wells in the area were not sampled. The potential must be considered high for contamination in these wells through borehole leakage (contaminant migration along annulus of well).

4.3 RISK ASSESSMENT FOR HEALTH, WELFARE, AND THE ENVIRONMENT

A qualitative risk assessment was conducted for this report. The limited information available characterizing King Salmon AFS wastes made any quantitative estimation of potential risk unfeasible. More complete data (e.g., priority pollutant scan information) will be needed for contaminated site media before a quantitative risk analysis can be conducted. The following sections address the contaminants that have been identified to date. Background data for local water, soil, and sediment are needed to properly assess the potential risks King Salmon AFS wastes contribute to ambient conditions. Also, more complete knowledge of King Salmon AFS wastes (TPH constituents, TOC constituents, etc.) will be needed to adequately address the human health and environmental risks that may be associated with each operable unit. References to potential human or environmental risks presented in this assessment could change significantly as more contaminant data become available.

4.3.1 Waste Characterization

Discussions in the following sections are based on current knowledge of King Salmon AFS contamination. It should be noted that this knowledge is limited. Background data for local water, soil, and sediment are needed to properly assess the potential risks King Salmon AFS wastes contribute to ambient conditions. Also, more complete analyses of TPHs, TOCs, and suspected priority pollutants will be needed to more fully characterize King Salmon AFS contamination.

4.3.1.1 Identifiable Contaminants

The four areas at the King Salmon AFS were tested for over 146 inorganic, volatile organic, semivolatile organic, and pesticide contaminants. Of these, 39 potential contaminants of concern (or contaminant types, i.e. THP, TOC) have been identified (Table 4-18). These contaminants are considered in this report because their concentrations (or detection

Table 4-18
POTENTIAL CHEMICALS OF CONCERN DETECTED AT KING SALMON AFS

	Soil and Sediment	Groundwater	Surface Water
Inorganics			
Cadmium[a]			
Copper[a]			
Fluoride		+	
Lead		+	
Mercury[a]			
Nitrate-Nitrite		+	+
Manganese		+	+
Barium			+
Zinc			+
Nickel			+
Silver			+
Boron			+
Organics			
Benzene		+	
bis(2-ethylhexyl)phthalate	+		
2-Butanone	+		
Butyl benzyl phthalate	+		
Ethylbenzene	+	+	
Fluorene	+		
2 Methylnapthalene	+		
Napthalene	+		
Toluene	+	+	+
trans-1,2-Dichloroethene			+
Trichloroethene			+
Xylenes	+	+	+
THP	+	+	
TOC		+	
Chloromethane	+		
Methylene chloride	+		
Acetone	+		
Phenanthrene	+		
Di-n-octyl phthalate	+		
Chloroform			+
Pesticides			
Chlordane			+
Dieldrin[a]			
Endosulfan[a]			
Endrin[a]			
Heptachlor[a]			
Methoxychlor[a]			
Toxaphene[a]			

---

[a] Chemical not detected but the analytical detection limit was greater than ambient water quality criteria for aquatic toxicity or drinking water.

limits) exceed federal or state criteria for the protection of human health and the environment, they are consistently present in various site media (groundwater, surface water, soils, sediments), or they are potentially toxic to humans and the environment (carcinogenic, noncarcinogenic, bioaccumulation potential).

4.3.1.2 Toxicity of Site Contaminants

Toxicity profiles outlining the health hazards associated with select King Salmon AFS contaminants are presented in Table 4-19. High concentrations of total petroleum hydrocarbons (TPH) and total organic carbon (TOC) have also been identified in the shallow wells and soils at the site. Although no toxicity data have been identified for these classes of compounds, they could be composed of chemicals that adversely affect human health and/or the environment. Critical toxicity values for protection of public health (as recommended by EPA) are summarized in Table 4-19A. Eleven of these chemicals are classified by EPA as carcinogens.

4.3.1.3 Waste Mobility

The physical and chemical properties of the contaminants detected at King Salmon AFS that may influence their environmental fate, transport, or toxicity are summarized in Table 4-20. Many of the contaminants detected have moderate-to-high mobility in soils and groundwater. Many of the contaminants are also highly volatile. The TPHs detected at the site showed low mobility in soils and groundwater (based on the extent of the plume identified) and exhibited low volatility when measured in the field.

4.3.2 Human Health/Environmental Criteria Comparison

4.3.2.1 Eskimo Creek Seep

4.3.2.1.1 Shallow Groundwater

The sampling results for the shallow groundwater wells at Eskimo Creek are summarized in Table 4-21. Table 4-21 also presents a comparison of shallow well water quality data to criteria for drinking water and the protection of aquatic organisms. The aquatic organism criteria comparison is valid because contaminants from this shallow aquifer could enter Eskimo Creek. This stream supports fish and wildlife populations. The following paragraphs concern the Eskimo Creek shallow well contaminants (lead, total dissolved solids, benzene, and xylene), which have maximum concentrations that exceed federal or Alaska water quality criteria.

Table 4-19

PROFILES OF SELECTED CHEMICALS, KING SALMON AFS

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Acetone	Generally regarded as having low toxicity and, therefore, has not been studied extensively. May produce narcosis, CNS depression, nausea, vomiting, gastric hemorrhage, atoxia, coughing, and bronchial irritation.	Prolonged inhalation of high concentrations may produce irritation of the respiratory tract, coughing, headache, drowsiness, loss of coordination, inflammatory bronchitis, conjunctivitis, paryngitis, gastroduodenitis, renal tubular necrosis, and hyperglycemia.	Not applicable.	Possible mutagenicity, can potentiate carbon tetrachloride hepatotoxicity.
Barium	Ingestion of barium salts can cause prolonged muscular stimulation; gastroenteritis; hypokalemia; and cardiovascular effects such as ventricular fibrillation and extra systoles.	Prolonged occupational inhalation has resulted in baritosis--a benign, reversible pneumonitis.	Not applicable.	Toxicity of compounds depends on solubility.
Benzene	Acute exposures (inhalation) to high levels of benzene may lead to depression of the central nervous system, unconsciousness, and death or may cause fatal cardiac arrhythmias.	Major toxic effect is hematopoietic toxicity (affects formation of blood); chronic exposure of workers to low levels has been associated with blood disorders, such as leukemia and aplastic anemia (depression of all three cell types of the blood in absence of functioning marrow).	Sufficient evidence that is human and animal carcinogen; strong correlation between exposure to benzene by inhalation and leukemia.	Chromosomal aberrations in bone marrow and blood have been reported in experimental animals and some workers.
Bis(2-ethylhexyl)phthalate	Low acute toxicity in experimental animals, accidental acute exposure in man resulted in mild gastric disturbance and catharsis.	Chronic exposure at relatively high concentration have retarded growth and resulted in increased liver and kidney weight in experimental animals.	No evidence for carcinogenicity in man. However, is a potential animal carcinogen. Oral administration to rats and mice resulted in increased heptacellular carcinomas or neoplastic nodules.	Some evidence in animals of teratogenic and fetotoxic effects. Poorly absorbed through skin; rapidly metabolized.
Boron	No information reported.			
2-Butanone	The compounds is of relatively low toxicity, but at high doses affects the nervous system and causes irritation of the eyes, nose, and skin. The oral LD_{50} value for the rat was 27_{50} mg/kg. Exposures to high concentrations may retard fetal development and cause some teratogenic effects.		Has not been adequately tested for carcinogenicity.	Although 2-Butanone is not strongly neurotoxic on its own, it apparently strongly potentiates the neurotoxicity of n-hexane and n-hexanone.

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

CVR193/029-1

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Butyl benzyl phthalate	No information reported.	No information reported.	No information reported.	
Cadmium	For acute exposures by ingestion, symptoms of cadmium toxicity include nausea, vomiting, diarrhea, muscular cramps, salivation, spasms, drop in blood pressure, vertigo, loss of consciousness, and collapse. Acute renal failure, liver damage, and death may occur. Exposure by inhalation can cause irritation, coughing, labored respiration, vomiting, acute chemical pneumonitis, and pulmonary edema.	Respiratory and renal toxicity are major effects in workers. Chronic oral exposures can produce kidney damage; cadmium accumulates in kidney, and nephropathy results after critical concentration in kidney is reached, probably about 200 ug/g. Inhalation can cause chronic obstructive pulmonary disease, including bronchitis, progressive fibrosis, and emphysema. Chronic exposure affects calcium metabolism and can cause loss of calcium from bone, bone pain, osteomalacia, and osteoporosis. Chronic exposure may be associated with hypertension. Cadmium can product testicular atrophy, sterility, and teratogenic effects in experimental animals.	Increased risk of prostate cancer and perhaps respiratory tract cancer in workers exposed by inhalation. No evidence of carcinogenicity from chronic oral exposure.	A nonessential element.
Chlordane	In clinical cases of humans exposed to chlordane, central nervous system (CNS) effects (irritability, salivation, convulsions, depression, and death) and blood dyscrasias (e.g., aplastic anemia and leukemia) were observed; routes of exposure included oral, inhalational, and dermal. Neuroblastoma has been associated with exposure to chlordane and heptachlor, as well as an increase in cerebrovascular disease. In animals, CNS disturbances and kidney and liver effects were seen.	Major target organ is liver. Animal studies indicate toxicity to liver, kidney, heart, lung, and increased mortality. Decreased fertility in mice and toxicity to nursing rat pups have been reported.	An increased incidence of hepatocellular carcinoma (liver tumors) has been observed in mice fed diets containing analytical grade chlordane.	
Chloroform	Anesthetic depresses CHS. Fatalities in humans may be rapid, resulting from cardiac arrest (apparently sensitization to epinephrine) or delayed with kidney and liver damage; respiratory depression, coma, liver and kidney damage are among the symptoms of exposure to chloroform. In laboratory animals, acute toxicity depends on species, strain, sex, and age; liver damage may be cuased of death in rats and mice after acute exposure.	Kidney damage (renal tubular necrosis) can occur in mice; and kidney and liver damage in rats, rabbits, dogs, and guinea pigs exposed by inhalation.	Carcinogenic in mice (hepatomas, hepatocellular caricinomas), male rats (malignant kidney tumors), and demale rats (thyroid tumors).	Tetotoxic in rats and rabbits.
Chloromethane	No information reported.			

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Copper	Exposure (inhalation) to copper dusts result in symptoms similar to metal fume fever. Exposure to metal fumes results in upper respiratory tract irritation, metallic or sweet taste, neurea, metal fume fever, and skin and hair discoloration. Exposure to dusts and mists of copper salt result in congestion of nasal mucous membranes, sometimes of pharnyx, and occasional ulceration with perforation of nasal septum. Acute copper sulfate poisoning in humans (oral) sometimes fatal; includes vomiting, diarrhea, hypotension, coma, and jaundice.	Hemolytic anemia after chronic exposure in some dialysis patients. Sensitive individuals with disorders of metabolism--Wilson's disease and Menke's disease.	Not Applicable	Essential nutrient. Organoleptic threshold in water between 1 to 5 mg/l.
Dieldrin	High order of acute toxicity. The oral LD50 for the rat is approximately 50 mg/kg, and the rat dermal LD50 is about 100 mg/kg.	Chronic toxic effects include liver toxicity and CNS abnormalities. Dieldrin is teratogenic and toxic to the reproductive system. Reproductive effects include decreased fertility and increased fetal deaths. Teratogenic effects include cleft palate, webbed foot, and skeletal anomalies.	Considered a B2 level carcinogen by CAG. A B2 carcinogen is one considered to have sufficient evidence of carcinogenicity in animals, but inadequate data in humans.	Suggestive evidence of mutagenicity available.
Di-n-octyl-phthalate	No information reported.			
Endosulfan	Endosulfan acts on the central nervous system, lungs, and skin. Acute exposure has caused death in humans.	No information reported.	No carcinogenic, mutagenic, or teratogenic potential has been reported.	There is a general absence of toxic reports concerning Endosulfan.
Endrin	Endrin acts on the central nervous system and liver. Symptoms of acute exposure include convulsions, vomiting, abdominal pain, nausea, dizziness, and headache. Acute exposure has caused death in humans.	No information reported.	Potential indicated for oncogenicity and teratogenicity in animals.	EPA filed a rebuttable presumption notice for endrin in 1987 on the basis of oncogenicity, teratogenicity, and reductions in endangered and nontarget species.
Ethylbenzene	Ethylbenzene is irritating to eyes, mucous membranes, and skin. It can cause headaches and narcosis.			

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Fluoride	Fluoride intoxication from inhalation can produce brochospasm, laryngospasm, polmonary edema, irrepairable damage to lungs, and death. Fluoride intoxication through ingestion can cause nausea, vomiting, cramps, diarrhea, convulsions, and coma.	Chronic fluoride exposure can cause nose bleeds, sinus trouble, and irritation of the skin, eyes, mucus membranes, and lungs. Mottling of dental enamel and skeletal fluorosis are other chronic exposure affects.	No carcinogenic potential reported.	The magnitude of toxic effects from fluoride exposure depends on the irritating properties of the compound exposed to.
Heptachlor	Acutely toxic doses can cause tremors, convulsions, abnormal behavior, respiratory collapse, and hyperirritability. Acute exposure by various routes can cause development of hepatic vein thrombi, can affect the CNS, and cause death. The oral LD50 for the rat is 40 mg/kg.	Chronic exposures induce liver changes, affect hepatic microsomal enzyme activity, and cause increased mortality in offspring.	Considered a B2 level carcinogen by CAG. A B2 carcinogen is one considered to have sufficient evidence of carcinogenicity in animals, but inadequate data in humans.	
Lead	Acute inorganic lead intoxication in humans is characterized by encephalopathy, abdominal pain, hemolysis, liver damage, renal tubular necrosis, seizures, coma, and respiratory arrest.	Chronic low levels of exposure to lead can affect the hematopoietic system, the nervous system, and the cardiovascular system. Lead inhibits several key enzymes involved in heme biosynthesis. One characteristic effect of chronic lead intoxication is anemia, by reduced hemoglobin production and shortened erythrocyte survival. In humans, lead exposure has resulted in nervous system injury including reduced hand-eye coordination, reaction time, visual motor performance, and nerve conduction velocity. The developing child appears especially sensitive to lead-induced nervous system injury. Lead can also affect the immune system and produce gingival lead lines. Epidemiological studies have indicated that chronic lead exposure may be associated with increased blood pressure in humans. Exposure to lead is associated with sterility, abortion, neonatal mortality, and morbidity. Organolead compounds are neurotoxic.	Lead salts have some evidence of carcinogenicity in animals.	Children are especially sensitive to low level effects.

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Manganese	Acute inhalation exposures to very high concentrations can cause manganese pneumonitis.	Chronic manganese poisoning results from inhalation fo high concentrations of manganese dust. Chronic manganese poisoning is characterized by psychiatric symptoms, such as irritability, difficulty in walking, speech distrubances, and compulsive behavior and by encephalopathy and progressive deterioration of the central nervous system. Chronic effects of manganese poisoning are similar to Parkinson's disease. Liver changes are also frequently seen. Individuals with an iron deficiency may be more susceptible to chronic poisoning.		Manganese is an essential nutrient. Manganese concentrations in water a 50 ug/l may exhibit undesirable taste and discloration.
Mercury	Inhalation of mercury vapor can cause bronchitis and nervous system effects. Oral exposure can result in abdominal cramps, gastrointestinal effects, ulceration, shock, circulatory collapse, and renal failure.	Occupational exposure to inorganic mercury can produce effects on nervous system, including tremors, erethism, muscular weakness, personality changes, gingivitis, and colored eye reflex. In children, pink disease has been reported after ingestion of mercurous compounds. Exposure to organic mercury can cause sensory and visual disturbances, tingling, paresthesiae, numbness, tunnel vision leading to blindness, weakness in extremities and progressive ataxia, tremor, cerebral atrophy, and degeneration of nerves; visual, peripheral neuropathy, and death.		Mercury crosses placenta. Toxicity depends on chemical form. Metallic, organic, and inorganic compounds can be biotransformed.
Methoxychlor	No human effects reported. In animals, intoxication symptoms include trembling, convulsions, kidney, and liver damage.	No information reported.	Not applicable.	Methoxychlor is an insecticide of low mammal toxicity used for home and garden, domestic animal, and commercial agricultural pest control.

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Methylene Chloride	Methylene chloride acts as a mild narcotic irritating to eyes and upper respiratory passages. At low levels, it may cause elevated carboxyhemoglobin, preventing transfer of oxygen to tissues.	Causes liver and kidney damage, and may substantially increase carboxyhemoglobin levels; preventing the transfer of oxygen to tissues.	The National Toxicological Program (NTP) classifies methylene chloride as having clear evidence of carcinogenicity in female rats and in male and female mice. The International Agency for Research on Cancer (IARC) considers it a Level 3 carcinogen; however, this IARC study was released prior to the time the NTP study was made available. A Level 3 carcinogen is one that has inadequate evidence available to prove its carcinogenicity.	
2-Methylnaphthalene	No information reported.	No information reported.	No information reported.	
Naphthalene	Inhalation or ingestion of dust or vapor can cause intravascular hemolysis, nausea, vomiting, jaundice, hematuria, hemoglobinuria, and acute renal shutdown.	Chronic effects include skin and eye irritation.	Not applicable.	
Nickel	Signs of acute nickel toxicity may include headaches, nausea, vomiting, chest pain, cough, hyperpnea, cyanosis, gastrointestinal and central nervous system effects, weakness, fever, pneumonia, respiratory failure, cerebral edema, and death. Acute exposures to nickel containing dust may result in chemical pneumonitis.	Rhinitis, nasal sinusitis, and nasal mucosal injury are among the effects reported among workers chronically exposed to various nickel compounds. Allergic contact dermatitis and other dermatological effects are the most frequent effects of dermal exposure to nickel and nickel-containing compounds.	There is extensive epidemological evidence indicating excess cancer of the lung and nasal cavity for workers exposed to certain nickel compounds. Nickel compounds implicated as having carcinogenic potential include insoluble dusts of nickel subsulfide and nickel oxides, vapor of nickel carbonyl and soluble aerosols of nickel sulfate, nickel carbonyl.	May or may not be an essential element.
Nitrate	Acute toxicity can result when nitrates are reduced to nitrites. Nitrites oxidize hemoglobin, inhibiting ability to carry oxygen in the blood. Anoxia and death may ensue.	No information reported.	Nitrate exposure can lead to the formation of nitrosamines that are known human carcinogens.	

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

CVR193/029-6

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Phenthrene	No information reported.			
Silver	Argyria (local or generalized impregnation of tissue causes discoloration of skin and eye) may affect eyes and respiratory tract. Gastrointestinal irritation may occur with oral exposure.	Kidney and lung damage and possibly arteriosclerosis have been reported for industrial or medical exposures.		
Toluene	Humans exposed by inhalation experimentally or occupationally or by intentional abuse may exhibit excitation, then CNS depression and necrosis; neurotoxic effects include nausea, fatigue, and incoordination at low levels and confusion, ataxia, and weakness at higher levels; in rats, irritation of mucous membranes and incoordination have been observed, as well as pulmonary irritation with subchronic exposure.	CNS effects have been reported in workers, such as disturbances in memory and thinking, psychomotor skills, visual accuracy, sensorimotor speed, and performance tests; indications of cerebral and cerebellar dysfunction include tremors, ataxia, and equilibrium disorders, bizarre behavior and emotional lobility may occur. In cases of abuse, changes in liver and kidney function have been observed. In rats, a decrease in hematocrit has been reported.	Embryotoxicity and possible teratogenicity in mice have been reported in an abstract; in rats, skeletal retardation of offspring has been described.	
Toxaphene	Acute toxic effects include nausea, confusion, tremors, convulsions, and unconsciousness.	Chronic effects include skin and eye irritation.	Toxaphene is an animal-positive carcinogen.	Toxaphene is currently the most heavily used insecticide in the USA.
Trans-1,2-Dichloroethene	Has anesthetic properties. Exposure at high vapors causes nausea, vomiting, weakness, tremor, and cramps in humans.	Animals exposes to prolonged inhalation results in loss of appetite, decreased body weight, and pathological changes in liver, kidney, and lungs. May interact with drugs and the metabolizing monooxygenase system.	Not Applicable	Very little information available on exposure to trans-1,2-dichloroethene.

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

Table 4-19
(continued)

Chemical	Acute Toxicity Summary[a]	Chronic Toxicity Summary[a]	Cancer Potential	Other
Trichloroethylene	Exposure to TCE can cause depression of the central nervous system, including dizziness, headaches, incoordination similar to that induced by alcohol, nausea, vomiting, and unconsciousness.	Long-term inhalation exposure can affect liver and kidneys in animals. In humans, changes in liver enzymes have been associated with TCE exposure.	Exposure of mice (orally and by inhalation) and rats have produced increases in liver or lung or kidney tumors.	"Degreasers flush" has been described in TCE-exposed workers who consume alcohol.
Xylene	Acute exposures to inhaled xylene can depress the central nervous system and irritate mucous membranes.	Changes in behavioral tests, manual coordination, balance, and electroencephalographic patterns have been reported in humans exposed to xylenes; development of tolerance against some of these effects has been described. Effects on liver of rats have been reported.		
Zinc	Acute adverse effects of zinc include acute metal fume fever by the inhalation of fumes. Fever, nausea, vomiting, stomach cramps, and diarrhea result from acute ingestions. Zinc from 675 to 2,280 ppm acts as an emetric. Inorganic zinc compounds relatively nontoxic (aside from irritant action). Acute oral toxicity in laboratory animal range from 250 mg/kg (LD_{10} in guines pig, ZnF_2) to 1,190 mg/kg as rat oral LD_{50} for zinc nitrate hexahydrate.	Low oral toxicity. Prolonged ingestion of zinc at 40 mg/l resulted in irritability, muscular stiffness and pain, loss of appetite, and nausea. High levels of zinc in diet may retard growth and produce defective mineralization of bone.		Essential nutrient. Taste threshold 15 ppm; 40 ppm soluble zinc salts impart a metallic taste.

Sources:
Casarett and Doull's Toxicology, 3rd edition, ed. C. D. Klassen, M. O. Amdur, and J. Doull, Macmillan Publishing Co., New York 1986.
IARC Monographs, Vol. 3, 20, 23, International Agency for Research on Cancer, Lyon, France, 1973, 1979, 1980.
Drinking Water and Health, Vol. 1, National Academy of Sciences, 1977.
Handbook of Toxic and Hazardous Chemicals, M. Sittig, Noyes Publications, Park Ridge, New Jersey, 1981.
EPA Health Advisories for inorganics, organics, and pesticides, March, 1987.
Experimental and Clinical Neurotoxicology, ed. P. S. Spencer and H. H. Schaumburg, Williams and Wilkins, Baltimore, 1980.
Pesticides Studied in Man, W. J. Hayes, Williams and Wilkins, Baltimore, 1982.
29 CFR 1910:50412-50499, December 10, 1985; OSHA, Occupational Exposure to Formaldehyde.
40 CFR 141:25720-25734, July 8, 1987, EPA, Drinking Water.

CVR193/029

---

[a] Health effect or target organ may be based on animal studies and does not imply that the results of exposure to humans will be the same.

CVR193/029-d

Table 4-19A
CRITICAL TOXICITY VALUES^{a}
(September 26, 1988)

Chemicals of Concern	Noncarcinogen Factors					Cancer Potency Factors		
	Critical Intake Values for Ingestion (mg/kg/day)	Critical Intake Values for Inhalation (mg/kg/day)	1-Day Child Health Advisory (mg/l)	10-Day Child Health Advisory (mg/l)	Long-Term Child/Adult Health Advisory (mg/l)	HEA/CAG^{b} Ingestion Slope Factors $(mg/kg/day)^{-1}$	HEA/CAG^{b} Inhalation Slope Factors $(mg/kg/day)^{-1}$	EPA Carcinogenic Classification^{c}
Acetone	0.1^{d}	--	--	--	--	--	--	--
Barium	0.05^{e}	0.0001^{e}	--	--	--	--	--	--
Benzene	--	--	0.235	0.235	--	0.029	0.029	A
Bis(2-ethylhexyl)phthalate	0.02^{d}	--	--	--	--	0.014	--	B2
2-Butanone	0.05^{d}	--	--	--	--	--	--	--
Cadmium	0.0005^{d}	--	--	--	--	--	6.1	B1
Chlordane	0.00005	--	0.06	0.06	0.05	1.3	1.3	B2
Chloroform	0.01^{d}	--	--	--	--	0.0061	0.081	B2
Dieldrin	0.00005^{d}	--	--	--	--	16	16	B2
Endosulfan	0.00005^{d}	--	--	--	--	--	--	--
Endrin	0.0003	--	0.025	0.005	0.16	--	--	--
Ethylbenzene	0.1^{d}	--	32	3.2	1.0/3.4	--	--	D
Heptachlor	0.0005^{d}	--	0.01	0.01	0.005/0.017	4.5	4.5	B2
Lead	0.0014^{e}	0.00043^{e}	--	--	--	--	--	--
Mercury	0.002^{d}	--	--	--	--	--	--	D
Methoxychlor	--	--	6.4	2.0	0.5	--	--	--
Methylene chloride	0.06^{d}	--	13.3	1.5	0.5/1.75	0.0075	0.014	B2
Naphthalene	0.4^{e}	--	--	--	--	--	--	--
Selenium	0.003^{e}	0.001^{e}	--	--	--	--	--	--
Silver	0.003^{d}	--	--	--	--	--	--	--
Toluene	0.3^{e}	1.0^{e}	--	--	--	--	--	D
Toxaphene	--	--	--	--	--	1.1	1.1	B2
Trichloroethene	--	--	--	--	--	0.011	0.0000017	B2
Xylenes	2.0^{d}	0.4^{e}	--	--	--	--	--	D
Zinc	0.21^{e}	--	--	--	--	--	--	--

---

[a] Source: Superfund Public Health Evaluation Manual: December 1986 (list revised July 1988) as amended by IRIS data base as of September 26, 1988.

[b] The cancer potency factors presented are either from Health Effects Assessments (HEA) or evaluations by the Carcinogen Assessment Group (CAG). All values presented were prepared by the USEPA.

[c] U.S. EPA Carcinogen Assessment Group (CAG) Classification.

Group A	Human carcinogen--Sufficient evidence from epidemiological studies.
Group B1	Probable human carcinogen--At least limited evidence of carcinogenicity to humans.
Group B2	Probable human carcinogen--Combination of sufficient evidence in animals and inadequate data in humans.
Group C	Possible human carcinogen--Limited evidence of carcinogenicity in animals in the absence of human data.
Group D	Not classified--Inadequate animal evidence of carcinogenicity.
Group E	No evidence of carcinogenicity for humans--at least two adequate animal tests show no evidence of carcinogenicity.

[d] Source: RfD = verified Agency-wide value.

[e] Source: HEA = Health Effects Assessment.

CVR109/021

Table 4-20
PHYSICAL AND CHEMICAL PROPERTIES FOR ORGANIC CONTAMINANTS DETECTED AT KING SALMON AFS

Chemical Name	CAS No.	Mole Weight (g/mole)	Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m^3/mol)	Koc (ml/g)	Log Kow	Fish BCF (1/kg)
Acetone	67-64-1	58	1.00E+06	2.70E+02	2.06E-05	2.2	-0.24	
Barium	7440-39-3	137			NA			
Benzene	71-43-2	78	1.75E+03	9.52E+01	5.59E-03	83	2.12	5.2
Bis(2-ethylhexyl)phthalate	117-81-7	391	0.4			123,027		
2-Butanone	78-93-3	72	353,000		1.34	3.89		
Butylbenzyl phthalate	85-68-7		2.9E+00					663
Cadmium	7740-43-9	112		0.00E+00	NA			81
Chlordane			5.60E		9.63E-06	140,000	3.32	14,000
Chloroform	67-66-3	119	8.20E+03	1.51E+02	2.87E-03	31	1.97	3.75
Copper	7440-50-8	64		0.00E+00	NA			200
Dieldrin	60-57-1	381	1.95E-01	1.78E-07	4.58E-07	1,700	3.50	4,760
Endosulfan	115-29-7	407						
Endosulfan I and II								1,000
Endrin								13,000
Ethylbenzene	100-41-4	106	1.52E+02	7.00E+00	6.43E-03	1,100	3.15	37.5
Flourene	86-73-7	166	1.69E+00	7.10E-04	6.42E-05	7,300	4.20	1,300
Heptachlor	76-44-8	374	1.80E-01	3.00E-04	8.19E-04	12,000	4.40	15,700
Lead	7439-92-1	207		0.00E+00	NA			49
Manganese	7439-96-5	55			NA			
Mercury (alkyl)	7439-97-6				NA			3,750
Mercury (inorganic)	7439-97-6	201		2.00E-03	NA			5,500
Methoxychlor			1.75E+03		5.59E-03	83	2.12	1,000
Methylene Chloride	75-09-2	85	2.00E+04	3.62E+02	2.03E-03	8.8	1.30	5
2-methylnapthalene								40-300
Naphthalene	91-20-3	128	3.17E+01		4.82E-04	962	3.30	40-300
Nickel	7440-02-0	59		0.00E+00	NA			47
Phenanthrene	85-01-8	178	1.00E+00	6.80E-04	1.59E-04	14,000	4.46	2,630
Silver	7440-22-4	108		0.00E+00	NA			3,080
Toluene	108-88-3	92	5.35E+02	2.81E+01	6.37E-03	300	2.73	10.7
Toxaphene			5.00E-01		4.36E-01	964	3.3	13,100
Trans 1,2-dichloroethene	540-59-0	97	6.00E+02	3,2E4+02	4.2E-02	59	0.48	1.6
Trichloroethene	79-01-6	131	1.10E+03	5.79E+01	9.10E-03	126	2.38	10.6
Xylenes	1330-20-7	106	1.98E+02	1.00E+01	7.04E-03	240	3.26	
Zinc	7440-66-6	65		0.00E+00	NA			47

Note: NA = Information not available.

Source: Water-Related Environmental Fate of 129 Priority Pollutants. EPA 440/4-79-029a. 1979. Vershueren, 1983. Superfund Public Health Evaluation Manual, EPA 54D/1-86-060 Oct. 1986.

CVR109/022

Table 4-21
GROUNDWATER CONTAMINANT COMPARISONS TO WATER QUALITY CRITERIA (ESKIMO CREEK SEEP, SHALLOW AQUIFER)

Surface Water Contaminants[a]	Number of Wells Sampled vs. Contaminant Detections	Maximum Detected Concentration (ug/l)	Mean[b] Detected Concentration (ug/l)	Federal Drinking Water Criteria (ug/l)	Alaska[c] Drinking Water Criteria (ug/l)	Aquatic[d] Acute Toxicity (ug/l)	Aquatic[d] Chronic Toxicity (ug/l)
Lead	23/19	370	37	50[e]	50	82[f]	3.2[f]
Fluoride	23/20	110	50.3		2,400		
Total Dissolved Solids	23/23	558,000	336,000	250,000[g]	500,000		
Nitrate-Nitrite	23/23	11,400	2,630	10,000[g]	10,000		
Total Petroleum Hydrocarbons	23/12	5,670,000					
Total Organic Carbons	2/2	7,200	4,450				
Benzene	8/4	77	11.6	5[h]		5,300[i]	
Toluene	8/4	130	21.8	2,000[j]		17,000[i]	
Ethyl benzene	8/4	130	25.1	680[j]		32,000[i]	
Xylene	8/4	520	107	440[j]			

---

[a] Chlorobenzene, 1,4-dichlorobenzene, 1,3-dichlorobenzene, and 1,2-dichlorobenzene were also analysed. Their concentrations were below detection (detection limit = 1.0 ug/l).

[b] Arithmethic mean of detected concentrations.

[c] State of Alaska Drinking Water Regulations, Department of Environmental Conservation (1982).

[d] Federal Clean Water Act: Ambient Water Quality Criteria for the Protection of Aquatic Life (EPA, 1986).

[e] RCRA MCL for drinking water (May, 1988).

[f] Hardness dependent criterion (100 mg/l used).

[g] USEPA Water Quality Criteria for Drinking Water (1986).

[h] SDWA MCL for drinking water (May, 1988).

[i] Lowest observed effect level (LOEL).

[j] Proposed SDWA MCL for drinking water (May, 1988).

CVR193/027

The maximum level of lead identified (370 ppb) exceeds drinking water (50 ppb), aquatic organism acute (82 ppb), and aquatic organism chronic toxicity (3.2 ppb) criteria. The mean level of lead (37 ppb) meets drinking water and acute aquatic organism toxicity criteria. However, this average lead level exceeds the chronic toxicity criterion for the protection of aquatic organisms.

The maximum total dissolved solids (TDS) level (558,000 ppb) exceeds the federal (250,000 ppb) and Alaska (500,000 ppb) criteria for drinking water. The mean concentration (336,000 ppb) meets the Alaska drinking water criterion but still exceeds the federal criterion. Because this is a shallow aquifer that is close to the coast, these TDS levels are more likely due to the influence of the ocean, rather than King Salmon AFS operations. There are no total dissolved solids criteria for the protection of aquatic organisms.

The maximum (77 ppb) and mean (11.6 ppb) levels of benzene in the shallow wells exceed the federal drinking water criterion (5 ppb). These levels do not exceed the acute toxicity criterion for the protection of aquatic organisms (5,300 ppb). There is no chronic toxicity criterion for benzene for the protection of aquatic organisms.

The maximum level of xylene (520 ppb) exceeds the federal drinking water criterion (440 ppb). The mean level of xylene (107 ppb) meets the federal drinking water criterion. There are no acute or chronic xylene criteria for the protection of aquatic organisms.

4.3.2.1.2 Intermediate Groundwater

The intermediate depth wells were tested for the same contaminants as the shallow wells (see Table 4-21). Of these contaminants, only the maximum (378,000 ppb) and mean (302,000 ppb) TDS levels exceeded the federal drinking water quality criterion (250,000 ppb). These total dissolved solids levels meet the Alaska drinking water criterion. As with the shallow aquifer, the TDS levels in the intermediate depth wells are more likely due to the influence of the ocean, rather than King Salmon AFS operations.

None of the contaminants measured in the intermediate depth wells exceeded the acute or chronic criteria for the protection of aquatic organisms.

4.3.2.1.3 Deep Groundwater

The King Salmon AFS wells were analyzed for selected inorganics, PCBs, and pesticides. The inorganic concentrations identified meet federal and Alaska drinking water quality criteria. No PCBs or pesticides were detected in the King

Salmon Airport well samples. High levels of TPHs (27,100 ppb and 6,400 ppb) were detected in King Salmon Airport wells drawing water from this deep aquifer. The source of these constituents is uncertain and could be from lubricating fluids contained within the well pumps or from other potential sources, such as leakage along the well bore from the overlying contaminated shallow aquifer.

4.3.2.1.4 Surface Water

The surface water data collected for Eskimo Creek are summarized in Table 4-22. Of the contaminants analyzed, only zinc exceeded the federal water quality criterion for the protection of aquatic organisms from chronic toxicity. Cadmium, copper, and mercury were analyzed at detection limits greater than the criteria for protection of aquatic organisms. Therefore, they could be present at levels that are hazardous to aquatic organisms.

4.3.2.1.5 Soils

Soil data collected for the Eskimo Creek seep site are summarized in Table 4-23. There are no federal or Alaska criteria for contaminated soil or sediment.

4.3.2.2 Naknek River Seep

The inorganic contaminants detected at this site met federal and Alaska criteria for drinking water and acute aquatic organism toxicity. Several of the inorganic constituents analyzed were below detection limits; however, the detection limits exceeded the criteria for chronic aquatic organism toxicity. These inorganics included cadmium (detection limit = 5 ppb; chronic criteria = 1.1 ppb), lead (5 ppb; 3.2 ppb), mercury (0.5 ppb; 0.012), and antimony (5 ppb; 1.6 ppb). Copper was also below detection (30 ppb) but the detection limit exceeds both the acute (18 ppb) and chronic (12 ppb) criteria for the protection of aquatic organisms.

All the organic contaminants detected in the Naknek River met federal and Alaska drinking water criteria. None of the detected organic contaminants exceeded acute or chronic water quality criteria for the protection of aquatic organisms.

4.3.2.3 North Barrel Bluff

4.3.2.3.1 Surface Water

Samples from King Salmon Creek were analyzed for selected inorganic, organic, PCB, and pesticide contaminants. All the organics tested were below detection limits and the

Table 4-22

SURFACE WATER CONTAMINANT COMPARISONS TO WATER QUALITY CRITERIA

(ESKIMO CREEK)

Surface Water Contaminants[a]	Number of Wells Sampled vs. Contaminant Detections	Maximum Detected Concentration (ug/l)	Mean[b] Detected Concentration (ug/l)	Federal Drinking Water Criteria (ug/l)	Alaska[c] Drinking Water Criteria (ug/l)	Aquatic[d] Acute Toxicity (ug/l)	Aquatic[d] Chronic Toxicity (ug/l)
Lead	2/2	70	50			320[e]	47[e]
Chloride	2/2	5,380	5,360		250,000		
Sulfate	2/2	1,670	1,650		250,000		
Fluoride	2/0	<500	<500		2,400		
Total Dissolved Solids	2/2	171,000	113,000	250,000[e]	500,000		
Nitrate-Nitrite	2/1	170	110	10,000[e]	10,000		

---

[a] Benzene, toluene, xylene, ethylbenzene, chlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene and priority pollutant metals were also analyzed. Organic concentrations were below detection (detection limit = 1.0 ug/l). Metals levels were also below their respective detection levels, which did not exceed federal or state action levels for human health or the environment (see Table 4-16E).

[b] Arithmetic mean of detected concentrations.

[c] State of Alaska Drinking Water Regulations, Department of Environmental Conservation (1982).

[d] Federal Clean Water Act: Ambient Water Quality for the Protection of Aquatic Life (EPA, 1986).

[e] USEPA Water Quality Criteria for Drinking Water (1986).

[f] Hardness dependent criterion (100 mg/l used).

CVR193/026

Table 4-23
ESKIMO CREEK SOILS DATA

Contaminant	Maximum Concentration (ug/kg)
Toluene	1,500
Ethylbenzene	400
Xylene (o and m)	1,800
Xylene (p)	1,500
Chloromethane	3,600
2-butanone	3,100
2-methylnaphthalene	8,500
Fluorene	630
Phenanthrene	210
Naphthalene	1,300
Bis(2-ethylhexyl)phthalate	1,500
Butyl benzyl phthalate	1,800
Di-n-octyl phthalate	210
Methylene chloride	16,000
Acetone	8,600

CVR193/025

detection limits used did not conflict with drinking water or aquatic organism water quality criteria.

All the pesticides and PCBs analyzed were below detection limits. However, the detection limits used for heptachlor, Endosulfan I, dieldrin, endrin, methoxychlor, chlordane, and toxaphene were greater than the chronic criteria for the protection of aquatic organisms. In addition, the maximum toxaphene detect (1 ppb) exceeded the acute (0.73 ppb) aquatic organism toxicity criterion.

The inorganic contaminants analyzed met federal and Alaska drinking water criteria. However, as with the Naknek River seep, the detection limits for cadmium, copper, lead, mercury, and antimony exceeded the chronic toxicity criteria for aquatic organisms. Also, the copper detection limit used exceeded the acute toxicity criterion for aquatic organisms. Therefore, these constituents could be present at hazardous levels.

4.3.2.3.2 Sediments

Selected organic analyses were conducted on eight sediment samples from King Salmon Creek. Two organic contaminants were detected in the samples. Toluene (3 and 4 ppb) and 2-butanone (20 ppb) were detected in only one of the four samples collected. There are no federal or Alaska human health or environmental criteria for exposure to contaminated sediments.

4.3.2.4 South Barrel Bluff

4.3.2.4.1 Surface Water

None of the organic contaminants analyzed were above their detection limits and the detection limits do not conflict with federal or Alaska water quality criteria for drinking water or the protection of aquatic organisms.

The inorganic contaminants analyzed met federal and Alaska drinking water criteria. As with the Naknek River seep, the detection limits for cadmium, copper, lead, mercury, and antimony exceeded the chronic toxicity criteria for aquatic organisms. The copper detection limit also exceeded the acute toxicity criterion for aquatic organisms.

All the pesticides and PCBs analyzed were below detection limits. However, the detection limits used for heptachlor, Endosulfan I, dieldrin, endrin, methoxychlor, chlordane, and toxaphene were greater than their chronic criteria for the protection of aquatic organisms.

4.3.2.4.2 Groundwater

No organics, pesticides or PCBs were detected in the groundwater well tested at this site. There were no conflicts between the detection limits used at this operable unit and federal or Alaska water quality criteria.

All the inorganic contaminants analyzed for the well at this operable unit were below detection limits. However, the detection limits for arsenic (300 ppb), lead (200 ppb), and selenium (400 ppb) greatly exceed the federal criteria for drinking water (50 ppb, 50 ppb, and 10 ppb, respectively). Therefore, these contaminants could be present at hazardous levels.

4.3.3 Human Receptors/Human Health Effects

This section identifies the potential human receptors (base personnel, local residents, etc.) that could be adversely affected by site contaminants. It also addresses the potential for human exposure to site contaminants. The presence of contaminated media and the potential for human exposure to those media suggest that the potential exists for adverse human health effects. A summary of the potential human exposure pathways considered for King Salmon AFS is presented in Figure 4-16.

4.3.3.1 Eskimo Creek

4.3.3.1.1 Shallow Groundwater

The shallow groundwater aquifer at King Salmon AFS is not known to be used as a water source (private, municipal, industrial) for the base or surrounding areas. The principal pathways for exposure to the organic and inorganic contaminants identified in the shallow groundwater would be dermal contact or incidental ingestion of water in locations downstream from the seep where it enters Eskimo Creek. The potential also exists for the consumption of potentially contaminated fish (resident trout or salmon).

The section of Eskimo Creek associated with the shallow groundwater is not known to be used for drinking water. Therefore, a drinking water exposure pathway is not considered an immediate hazard for Eskimo Creek.

Potential receptors for shallow groundwater contamination could include King Salmon AFS personnel, local residents or visitors who fish, hunt, boat, or hike downstream from where the shallow groundwater seep enters Eskimo Creek.

4.3.3.1.2 Intermediate Groundwater

No contamination (except total dissolved solids) has been identified in this groundwater source. It is not believed that the TDS levels in the intermediate depth groundwater is associated with King Salmon Airport operations. Based on the information available, the intermediate groundwater aquifer is not believed to represent a substantial immediate human exposure pathway. This aquifer is not currently used as a potable water source. However, a more thorough chemical analysis of this aquifer is needed to confirm that it does not represent a potential human health hazard.

4.3.3.1.3 Deep Groundwater

The deep groundwater aquifer at King Salmon Airport is used as the primary water source for the base. This aquifer is also believed to be the primary water source for the King Salmon community. Therefore, potential receptors for any contaminants in this aquifer would include King Salmon Airport personnel, local residents, and visitors who use the water for drinking, cooking, or bathing.

No contaminants in excess of federal or Alaska drinking water standards have been identified for this deep aquifer. However, total petroleum hydrocarbons (TPHs) have been detected. TPHs may be due to oil in the well pumps or other sources outside the well bore. It is possible that the TPHs contain toxic components.

4.3.1.1.4 Surface Water

Potential human receptors for surface water contamination in Eskimo Creek could include base personnel, local residents, or area visitors. Exposure pathways for Eskimo Creek could include dermal contact and incidental water ingestion while using the area for fishing, hunting, boating, or hiking. The possibility also exists for the consumption of potentially contaminated fish. The section of Eskimo Creek associated with this operable unit is not known to be used for drinking water. Therefore, a complete drinking water exposure pathway has not been identified for Eskimo Creek.

4.3.3.1.5 Soils

Potential receptors for soil contamination on the Eskimo Creek Operable Unit would primarily include base personnel working in the area. Exposure to the soil contaminants identified could occur through dermal contact, incidental soil ingestion, or contaminated dust inhalation.

4.3.3.2 Naknek River Seep

4.3.3.2.1 Surface Water

Potential receptors for surface water contamination at the Naknek River seep could include base personnel, local residents, and area visitors. However, because of the rugged and remote nature of the area near the seep, it is unlikely that significant human exposure to contaminants would occur. The Naknek River seep is adjacent to a tidal mud flat. The water in this area is not a potential potable water source because it is saline. Further, the area is not popular for hiking, clamming, fishing, crabbing, or hunting. Therefore, significant human exposure through ingestion (water, sediment, potentially contaminated fish, etc.) or dermal contact is not considered likely.

4.3.3.3 North Barrel Bluff

4.3.3.3.1 Surface Water

Potential receptors for surface water contamination at North Barrel Bluff could include base personnel, local residents, or area visitors. The organic, inorganic, pesticide, and PCB data for surface water meet federal and state criteria for drinking water. Based on current information, the principal human exposure pathway of concern for surface water is by consumption of potentially contaminated fish.

4.3.3.3.2 Sediments

Potential receptors for sediment contamination on the North Barrel Bluff could include base personnel, local residents, or area visitors. Exposure to the toluene and 2-butanone in the sediments at this site could occur through dermal contact or incidental ingestion while using this section of King Salmon Creek (or downstream areas) for fishing, hunting, boating, or hiking. Unfiltered King Salmon Creek water used as a drinking water source could also represent a potential human exposure pathway to contaminated sediments. Further, the potential exists for consumption of potentially contaminated fish.

4.3.3.3.3 Barrel Contents

The exact contents of exposed or buried barrels at this area are not known. However, potentially hazardous materials are believed to be contained in many of the barrels. If the barrels leak, these hazardous materials may pose potential human health risks for base personnel, local residents, and area visitors.

4.3.3.4 South Barrel Bluff

4.3.3.4.1 Surface Water

Potential receptors for surface water contamination on the South Barrel Bluff could include base personnel, local residents, and area visitors. Potential exposure to surface water contaminants could occur through water use for drinking or through dermal contact and incidental ingestion while fishing, hunting, boating, or hiking.

The data available for this site indicate that no inorganic, organic, pesticide, or PCB contaminants were detected at levels exceeding state or federal drinking water quality criteria. Chlordane, a carcinogen, was detected (0.2 μg/l) but there are not drinking water criteria for it. Based on current information, the principal exposure pathway of concern for surface water is the potential consumption of potentially contaminated fish.

4.3.3.4.2 Groundwater

The well tested at this site is used by local residents as their potable water source. Receptors for contamination in this well would include the residents and their guests. Human exposure to potential well contaminants could occur through drinking, bathing, cooking, and other domestic water uses.

The data available for this well indicate compliance with drinking water criteria for organics, pesticides, and PCB. The inorganic results for lead, arsenic, and selenium are suspect because their detection limits exceed the drinking water quality criteria for these contaminants. Therefore, it is possible that these three contaminants pose a current health threat for the people using the well.

4.3.3.4.3 Barrel Contents

The exact content of exposed or buried barrels at this area unit are unknown. However, potentially hazardous materials are believed to be contained in many of the barrels. If the barrels leak, these hazardous materials pose potential human health risks for base personnel, local residents, and area visitors.

4.3.4 Carcinogenic Risks

This section of the report identifies the carcinogenic contaminants detected to date at each operable unit. The presence of media contaminated with carcinogens and the potential for human exposure to the contaminated media suggests a potential carcinogenic risk exists. Expanded media analyses (e.g., priority pollutant scans) and additional chemical characterizations of TPHs and TOCs could reveal the presence of additional carcinogens at the King Salmon AFS operable units. Cancer potency factors for chemicals of concern were listed in Table 4-19A.

4.3.4.1 Eskimo Creek Seep

Carcinogens have been detected in the shallow groundwater (benzene, a known human carcinogen) and soils (methylene chloride and bis (2-ethylhexyl) phthalate, probable human carcinogens) at this operable unit. The potential human exposure pathways for these contaminated media include incidental ingestion (soil, groundwater), dermal contact (soil, groundwater), and dust inhalation (soil). The primary receptors are base personnel (soil, groundwater), local residents (groundwater), and area visitors (groundwater).

4.3.4.2 Naknek River Seep

Trichloroethene (a probable human carcinogen) has been detected in the Naknek River seep. The potential for substantial human exposure to contamination in this rugged remote area is not considered likely.

4.3.2.3 North Barrel Bluff

No carcinogens have been verified at this operable unit to date. However, it is possible that several pesticides that are carcinogenic (Endosulfan, dieldrin, methoxychlor, chlordane, and toxaphene) are present. Sampling at reduced detection limits will allow their presence to be confirmed or discounted.

4.3.4.4 South Barrel Bluff

No carcinogens have been verified for this operable unit. However, it is possible that arsenic (a known human carcinogen) is present at levels exceeding the drinking water criterion in the well sampled at this site. The data show arsenic to be below detection but the detection limit was above drinking water quality criteria. The receptors of this potential contaminant include the residents using the well and their guests. More extensive sampling is needed here to verify the presence or absence of arsenic in the well.

Similarly, several pesticides that are carcinogenic (Endosulfan, dieldrin, methoxychlor, chlordane, and toxaphene) could be present in local surface waters and sediments. Human exposure to these contaminants could occur while hiking, hunting, or fishing in the area. Analysis with reduced detection limits is needed to verify their presence or absence.

4.3.5 Threat to the Environment

This section presents information concerning the potential for adverse contaminant effects on fish and wildlife resources.

4.3.5.1 Eskimo Creek Seep

Shallow groundwater lead contamination poses a potential environmental threat in areas downstream from where the seep enters Eskimo Creek. The maximum lead concentrations detected in the shallow groundwater samples exceed the acute and chronic criteria for the protection of aquatic organisms. The average lead concentration exceeds the chronic aquatic organism toxicity criteria. Lead also has a moderate bioconcentration factor and represents a potential threat to predators (resident trout, eagles, bears, waterfowl) that eat potentially contaminated prey (insects, fish, etc.).

Several organic contaminants have been detected in the soils at this operable unit. Those present in surface soils could pose a threat to fish and wildlife through surface runoff entering Eskimo Creek, incidental soil ingestion during feeding or preening, and dermal contact. Three of these contaminants (xylene, naphthalene, bis (2-ethylhexyl) phthalate have moderate-to-high bioconcentration factors and could present a threat to the top predators (resident trout, eagles, bears, waterfowl) that eat contaminated prey.

4.3.5.2 Naknek River Seep

No immediate environmental threat has been identified to date at this operable unit. However, the detection limits for cadmium, lead, copper, mercury, and antimony were greater than the chronic aquatic organism toxicity criteria. The detection limit for copper also exceeded the acute toxicity criteria for aquatic organisms. Therefore, even though these contaminant concentrations were below detection, they could be present at chronically toxic levels. Further, all these contaminants have moderate-to-high bioconcentration factors and could represent a threat to predators (resident trout, eagles, bears, waterfowl) that eat potentially contaminated prey.

4.3.5.3 North Barrel Bluff

The maximum concentration detected for toxaphene at this operable unit (1 ppb) exceeds the acute toxicity criteria for aquatic organisms. Therefore, localized toxaphene concentrations may currently present an immediate environmental threat to aquatic organisms.

The detection limits for cadmium, lead, copper, mercury, and antimony were greater than the chronic aquatic organism toxicity criteria, and the detection limit for copper was higher than the acute toxicity criterion for aquatic organisms at this operable unit. Therefore, even though these inorganic contaminant concentrations were below detection, they could be present at toxic levels. Furthermore, all these contaminants have moderate-to-high bioconcentration factors and could represent a threat to predators (resident trout, eagles, bears, waterfowl) that eat potentially contaminated prey.

Similarly, the detection limits for heptachlor, Endosulfan I, dieldrin, methoxychlor, chlordane, and toxaphene were higher than the chronic water quality criteria for the protection of aquatic organisms. Therefore, even though these pesticide concentrations were below detection, they could be present at toxic levels. These contaminants have high bioconcentration factors and could represent a threat to predators (resident trout, eagles, bears, waterfowl) that eat potentially contaminated prey.

4.3.5.4 South Barrel Bluff

Based on current information, no immediate environmental threat is apparent at this operable unit. However, the detection limits for cadmium, lead, copper, mercury, and antimony were greater than the chronic aquatic organism toxicity criteria. The detection limit for copper also exceeded the acute toxicity criterion for aquatic organisms. Therefore, even though these contaminant concentrations were below detection, they could be present at toxic levels. Furthermore, all these contaminants have moderate-to-high bioconcentration factors and could represent a threat to predators (resident trout, eagles, bears, waterfowl) that eat potentially contaminated prey.

Similarly, the detection limits for heptachlor, Endosulfan I, dieldrin, methoxychlor, chlordane, and toxaphene were greater than the chronic water quality criteria for the protection of aquatic organisms. Therefore, even though these pesticide concentrations were below detection, they could be present at toxic levels. All these contaminants have high bioconcentration factors and could represent a threat to predators (resident trout, eagles, bears, waterfowl) that eat potentially contaminated prey.

4.3.6 Finding of No Significant Impact

Given the current limited data base for site contaminants, it is not possible to conclude that the contamination present at the four operable units identified has no significant impact.

The pesticide detection limits should be lowered so it can be determined if their levels comply with water quality criteria for the protection of aquatic organisms or human health.

Deep wells should be resampled with reduced arsenic, selenium, and lead detection limits to determine if water from this well poses a human health threat.

King Salmon Creek sediments should be sampled and analyzed for inorganics, organics, and pesticides to determine if they may pose human or environmental threats.

Detection limits for all carcinogens, particularly volatile organics, should be at least low enough to be equivalent to a 10^{-6} excess cancer risk.

4.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

As presented earlier in this document, the Stage 1 field investigation is for identified contamination at all four sites at King Salmon AFS. A preliminary assessment of Applicable or Relevant and Appropriate Requirements (ARARs) was conducted to identify any existing conditions which violate federal or state ARARs. The results of this assessment were also used in the development of remedial alternatives (Section V), and recommendations (Section VI).

The concept of ARARs was developed as part of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) program for site cleanups. Under CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA), remedial actions on CERCLA sites must comply with all federal and state ARARs unless one of six conditions are met (waivers).

The Installation Restoration Program (IRP) is the Department of Defense's (DOD) response to the requirements of CERCLA. All federal agencies must comply with the procedural and substantive requirements of the Superfund program. The IRP objective is derived from the overall objective of the National Contingency Plan (NCP).

4.4.1 Definitions

ARARs are federal and duly promulgated state environmental and public health laws, requirements, and regulations. In evaluating potential ARARs for a site, a determination is made as to whether a requirement is applicable, relevant, or neither.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements promulgated under federal or state law that specifically address the hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the site.

For a requirement to be applicable, the remedial action or the circumstance at the site must satisfy all of the jurisdictional prerequisites of that requirement. For example, the minimum technology requirement for hazardous waste landfills under RCRA would apply only if a new hazardous waste landfill (or an expansion of an existing hazardous waste landfill) were to be built on the site.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements promulgated under federal or state law that, although not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the site, address problems or situations sufficiently similar to those encountered, that their use is well suited to the site. In some circumstances, a requirement may be relevant but not appropriate to the specific situation.

The relevance and appropriateness of a requirement can be judged by comparing factors such as the characteristics of the remedial action, the hazardous substances in question, and the physical characteristics of the site with those characteristics addressed by the requirement. For example, RCRA hazardous waste management requirements would not be applicable to wastes that could not be strictly classified as hazardous wastes. However, if those wastes are similar to hazardous wastes, the RCRA requirements could be relevant and appropriate to their management.

ARARs are divided into three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include those requirements that regulate the release to the environment of materials possessing certain chemical or physical characteristics or materials containing specific chemical compounds. These requirements generally set health or risk-based concentration limits or discharge limitations for specific hazardous substances. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the two requirements is generally used.

Location-specific ARARs are those requirements that relate to the geographical or physical position of the site, rather that the nature of contamination or the proposed remedial actions. These requirements may limit the type of remedial actions that can be implemented, or may impose additional constraints on the cleanup action. Flood plain restrictions and protection of endangered species are among the potential location-specific ARARs.

Action-specific ARARs are requirements that define acceptable treatment and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities related to management of hazardous substances or pollutants. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Since there are usually several alternative actions for any remedial site, very different requirements may be ARARs. The action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how or to what level cleanup will be achieved.

State standards and requirements must satisfy five criteria in order to be considered ARARs. The requirements must:

1. Be promulgated standards

2. Be more stringent than federal requirements

3. Be identified by the state in a timely manner

4. Not result in a statewide prohibition on land disposal

5. Be consistently applied statewide.

Under CERCLA, it is EPA's policy that state ARARs will be achieved to the greatest extent practicable.

4.4.2 Location-Specific ARARs

There are a number of location-specific ARARs that may affect the remedial actions at the King Salmon AFS. Many of these requirements will be verified during the Stage II efforts. Table 4-24 lists the potential location-specific ARARs, along with their prerequisites and comments. The most significant of the potential requirements are the flood plain requirements under RCRA and the Executive Order 11988 Protection of Floodplains, the wetlands requirements under Executive Order 11990 Protection of Wetlands, and the Fish and Wildlife Coordination Act.

Under RCRA, any of the four sites at King Salmon AFS that are located in a 100-year flood plain, and can be classified as hazardous waste disposal sites, will have to be closed in a manner that prevents washout of wastes during a 24-hour, 25-year flood event. Remedial actions at any of the sites that are located in a flood plain (100-year or otherwise) will be subject to the Executive Order 11988, Protection of Floodplains. This order requires that actions in flood plains avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values.

If any remedial actions affect the wetlands located on King Salmon AFS (the bog), those actions will have to comply with the Executive Order 11990, Protection of Wetlands, which requires action to minimize the destruction, loss, or degradation of wetlands. No dredged or fill materials may be disposed in a wetland without a Clean Water Act 404 Permit from the Army Corps of Engineers.

The Fish and Wildlife Coordination Act requires that the U.S. Department of Fish and Wildlife be consulted regarding any action that modifies a stream or river, or other water of the United States. The intent of this regulation is to protect fish and wildlife that may be adversely affected by changes in the quality or quantity of water in a river, stream, or other water body. This requirement could affect the remedial actions for the Naknek River seep, and the Eskimo Creek seep.

4.4.3 Chemical-Specific ARARs

The potential chemical-specific ARARs for the King Salmon AFS include the Safe Drinking Water Act Maximum Contaminant Levels (MCLs), the RCRA Maximum Concentration Limits (RCRA MCLs), and the Clean Water Act Ambient Water Quality Criteria (AWQC). Evaluation of these potential ARARs cannot be completed with the currently available water quality data. Potential chemical-specific federal and state applicable or relevant and appropriate requirements (ARARs) for particular contaminants identified to date at King Salmon AFS are given in Table 4-24A.

Some of the detection levels for inorganic constituents were above the corresponding MCL or AWQC. This will require confirmation sampling and priority pollutant metals analysis at lower detection levels to verify compliance, or identify noncompliance with ARARs. In addition to the inorganic parameters, there is a need for more specific data on petroleum hydrocarbons. Total petroleum hydrocarbons (TPH), the parameter used in this preliminary investigation, is useful as an indicator of potential contamination by POLs. ARARs evaluations, however, require quantification of the individual components of the waste. Confirmation sampling and analysis for volatile organics, base/neutral and acids extractable, and polynuclear aromatic hydrocarbons (PAHs) will clarify the nature of the TPH contamination.

Table 4-24
POTENTIAL LOCATION-SPECIFIC ARARs

	Location	Requirement	Prerequisite(s)	Citation
1.	Within 61 meters (200 feet) of a fault displaced in Holocene time	New treatment, storage, or disposal of hazardous waste prohibited	RCRA hazardous waste; treatment, storage, or disposal	40 CFR 264.18(a)
2.	Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout	RCRA hazardous waste; treatment, storage, or disposal	40 CFR 264.18(b)
3.	Within floodplain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values	Action that will occur in a floodplain, i.e., lowlands, and relatively flat areas adjoining inland and coastal waters and other flood prone areas	Executive Order 11988, Protection of Floodplains, (40 CFR 6, Appendix A)
4.	Within salt dome formation, underground mine, or cave	Placement of noncontainerized or bulk liquid hazardous waste prohibited	RCRA hazardous waste; placement	40 CFR 264.18(c)
5.	Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Action to recover and preserve artifacts	Alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data	National Archaeological and Historical Preservation Act (16 U.S.C. Section 469); 36 CFR Part 65
6.	Historic project owned or controlled by federal agency	Action to preserve historic properties; planning of action to minimize harm to National Historic Landmarks	Property included in or eligible for the National Register of Historic Places	National Historic Preservation Act Section 106 (16 USC 470 et seq.); 36 CFR Part 800
7.	Critical habitat upon which endangered species or threatened species depends	Action to conserve endangered species or threatened species, including consultation with the Department of the Interior	Determination of endangered species or threatened species	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR Part 200, 50 CFR Part 402
8.	Wetland	Action to minimize the destruction, loss, or degradation of wetlands	Wetland as defined by Executive Order 11990 Section 7	Executive Order 11990, Protection of Wetlands, (40 CFR 6, Appendix A)
		Action to prohibit discharge of dredged or fill material into wetland without permit		Clean Water Act Section 404; 40 CFR Parts 230, 231
9.	Wilderness area	Area must be administered in such a manner as will leave it unimpaired as wilderness and to preserve its wilderness character	Federally owned area designated as wilderness area	Wilderness Act (16 USC 1131 et seq.); 50 CFR 35.1 et seq.

Table 4-24 (Continued)

	Location	Requirement	Prerequisite(s)	Citation
10.	Wildlife refuge	Only actions allowed under the provisions of 16 USC Section 668 dd(c) may be undertaken in areas that are part of the National Wildlife Refuge System	Area designated as part of National Wildlife Refuge System	16 USC 668 dd et seq.; 50 CFR Part 27
11.	Area affecting stream or river	Action to protect fish or wildlife	Diversion, channeling, or other *activity that modifies a stream* or river and affects fish or wildlife	Fish and Wildlife Coordination Act (16 U.S.CC. 661 et seq.); 40 CFR 6.302
12.	Within area affecting national wild, scenic, or recreational river	Avoid taking or assisting in action that *will* have *direct* adverse effect on scenic river	Activities that affect or may *affect any of the rivers* specified in Section 1276(a)	Scenic Rivers Act (16 U.S.C. 1271 et seq. Section 7(a)); 40 CFR 6.302(e)
13.	Within coastal zone	Conduct activities in manner consistent *with approved State management* programs	Activities affecting the coastal *zone* including lands thereunder and adjacent shorelands	Coastal Zone Management Act (16 U.S.C. Section 1451 et seq.)
14.	Oceans or waters of the United States	Action to dispose of dredge and fill material into ocean waters *is prohibited without a permit*	Oceans and waters of the United States	Clean Water Act Section 404 40 CFR 125 Subpart M; Marine Protection Resources and Sanctuary Act Section 103

CVR193/063

Table 4-24A
POTENTIAL CHEMICAL-SPECIFIC FEDERAL ARARs
KING SALMON AFS, ALASKA

Constituent	Primary SDWA (EPA) Maximum Contaminant Levels (MCL)	CWA Ambient Water Quality Criteria for Protection of Freshwater Aquatic Life	
		Acute	Chronic[a]
Benzene	5 ug/l	5.3 mg/l	--
Dieldrin	--	2.5 ug/l	1.9 ng/l
Endosulfan	--	220 ng/l	56 ng/l
Ethylbenzene	--	32 mg/l	--
Heptachlor	--	520 ng/l	3.8 ng/l
Methyl ethyl ketone (2-Butanone)	--	--	--
Toluene	--	17.5 mg/l	--
Trichloroethylene	5 ug/l	45 mg/l	21 mg/l
Xylene(s)	--	--	--

---

[a] Federal Ambient Water Quality Criteria, more stringent than an SDWA MCL, may be found relevant and appropriate when there are environmental factors that are being considered at a site, such as protection of aquatic organisms.

Sources: U.S. EPA, Superfund Public Health Evaluation Manual, EPA 540/1-86/060 (OSWER Directove 9285.4-1) October 1986 and U.S. EPA, Quality Criteria for Water 1986, EPA 440/5-86-001, May 1986 (51 Federal Register 43665).

CVR109/023

The contamination in the seeps at the Naknek River and Eskimo Creek may violate AWQC. Resampling of the seeps and analysis for inorganics and organics as discussed above will resolve this issue.

Groundwater contamination, as evidenced by the results of the TPH and benzene-toluene-xylene (BTX) analyses, needs to be evaluated in more detail, as discussed for surface seep samples. The potential ARARs for groundwater include the MCLs, which are applicable to groundwater that could potentially be a source of public drinking water, and the RCRA MCLs, which are standards for groundwater at RCRA hazardous waste treatment, storage or disposal (TSD) sites. The RCRA MCLs are a subset of the drinking water MCLs, and include primarily inorganic constituents.

4.4.4 Action-Specific ARARs

The action-specific ARARs cannot be evaluated effectively until the wastes at the sites are more thoroughly delineated and classified. Action-specific requirements are derived primarily from RCRA, and therefore, are applicable to hazardous wastes. Some nonhazardous wastes may be sufficiently similar to hazardous wastes to cause the RCRA requirements to be relevant and appropriate to a site or situation.

Although the King Salmon AFS is not strictly classified as a licensed RCRA TSD facility, it would be held to the RCRA operating requirements if hazardous wastes were disposed on the station. Disposal is defined by RCRA to include unintentional spills or leaks. Therefore, if any of the material that is being detected at the Naknek River seep, or the Eskimo Creek seep was derived from hazardous waste, RCRA cleanup standards would be applicable to the contaminated groundwater and soil. An investigation into the source(s) of the contamination at the Naknek River seep and the Eskimo Creek seep will be necessary to determine whether the RCRA standards are applicable.

If the results of the confirmation sampling and analysis indicate that the contaminants in either seep are sufficiently similar to characteristic or listed hazardous wastes, the RCRA standards could be considered relevant and appropriate to the remedial actions at the site.

The North Barrel Bluff and the South Barrel Bluff were the sites of disposal of a large number of drums and other debris. It is reported that, while the majority of the drums were empty, some contained liquid wastes. The ARARs for the bluffs are dependent on the contents of the drums, and the presence or absence of contaminants in the groundwater, soil and surface water surrounding and underlying the sites. These sites have not been fully characterized by the preliminary investigation. Additional sampling and analysis is being recommended for these sites, as described in Section VI, Recommendations.

The disposal of liquid or solid hazardous wastes is strictly regulated by RCRA. If any of the drums disposed of at the bluffs contained hazardous wastes, the site would be classified as an unpermitted hazardous waste disposal facility, and would be subject to RCRA closure standards. If the site has resulted in groundwater contamination, it would be subject to RCRA groundwater standards (if the drums contained hazardous waste) or MCLs (if the contamination exceeded the MCLs and the groundwater is a potential source of public drinking water).

The determination of whether the sites contain hazardous wastes could be made by sampling some of the drums to determine what wastes remain at the site. In addition, an investigation of the sources of the drums at the sites, and the operations or processes that generated the wastes would help to determine the appropriate classification. As described for the seep sites, wastes that are very similar to hazardous wastes may cause the hazardous waste disposal and management requirements to be relevant and appropriate to the remedial actions at the bluff sites.

CVR109/020

V. REMEDIAL ALTERNATIVES

The selection of site remedial alternatives usually involves several steps. Initially, general classes or categories of response actions are considered. As more detailed information about the site and the contaminants becomes available, the selection process advances to the consideration of different technologies, and then to identification and evaluation of processes. Each step involves more detailed analyses and is more tailored to the site and the wastes to be managed.

As discussed in Section 4.4, Applicable or Relevant and Appropriate Requirements, more site investigation work will be required to delineate the nature and extent of contamination at King Salmon AFS. The additional characterization will allow determination of which action-specific ARARs may be applicable or relevant to the site, and will influence the selection of remedial alternatives.

5.1 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

General response actions are generic classes of potential remedial actions that can be considered for a given situation. Each of the general response actions can be seen as meeting one or more of the objectives of the overall remedial measure. Within each of the general response actions, there may be several alternative technologies that may be evaluated. Table 5-1 identifies seven general response actions that may be considered for the sites at the King Salmon AFS. A number of alternative remedial technologies are identified for the response actions that will be discussed in more detail in the next section.

These general response actions will be evaluated for each of the four sites at King Salmon AFS during Stage 2 of the IRP. Alternative technologies that are considered unproven, or that incorporate a high degree of risk, were not included in the table. The technologies presented are primarily conventional technologies, which will be evaluated in more detail after collection of the confirmation sampling data.

The first of the general response actions identified in Table 5-1 is No Action. Under the CERCLA process the No-Action alternative is carried through the entire selection process. The No-Action alternative serves as a basis for comparison of the remaining alternatives. It represents the existing situation, and is evaluated for risk and comparison with ARARs, along with the other alternatives.

Institutional Controls serve to prevent public access to the site or the contaminants, but it does not attempt to remove or modify the contamination. This alternative is typically

TABLE 5-

IDENTIFICATION OF GENERAL

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	DESCRIPTION
NO ACTION	NONE	NO ACTION; REMEDIAL RES
INSTITUTIONAL CONTROLS	ACCESS AND USE RESTRICTIONS	EXAMPLES INCLUDE LEGA FENCES TO REGULATE SIT
	ALTERNATIVE DRINKING WATER SOURCE	ALTERNATIVE WATER SOUR WATER SYSTEM, ETC.
	RELOCATION OF RESIDENTS	RESIDENTS ARE RELOCAT RESIDENCE) BASIS.
CONTAINMENT	CAPPING	IMPERMEABLE COVER MA INFILTRATION AND PREVE
	VERTICAL BARRIERS	WALLS THAT ARE LESS PE MAY BE USED TO ENCIRCL
	SURFACE CONTROLS	SURFACE SEALING, GRAD TO REDUCE SITE RUNON/
	SEDIMENT CONTROL BARRIERS	A PHYSICAL BARRIER, FIL REMOVAL.
	DUST AND VAPOR SUPPRESSION	TARPS, SOIL COVERS,
REMOVAL	DRUM & DEBRIS REMOVAL	DRUMS AND/OR DEBRIS A EQUIPMENT.
	EXCAVATION	CONTAMINATED SOIL, SED
	GROUNDWATER COLLECTION	GROUNDWATER AND LEAC
	ENHANCED OIL RECOVERY (EOR)	CONTAMINANTS THAT AR

BLE 5-1

NERAL RESPONSE ACTIONS

TION

REMEDIAL RESPONSES INITIATED AT SITE ARE ABANDONED; NO MONITORING.

NCLUDE LEGAL RESTRICTIONS ON DEEDS TO REGULATE LAND USE; PERMITS TO REGULATE GROUNDWATER USE;
REGULATE SITE ACCESS.

E WATER SOURCES MIGHT INCLUDE CISTERNS, ABOVEGROUND TANKS, DEEPER OR UPGRADIENT WELLS, MUNICIPAL
TEM, ETC.

ARE RELOCATED ON EITHER A TEMPORARY (APARTMENT OR MOTEL) OR A PERMANENT (PURCHASE OF
BASIS.

LE COVER MATERIALS ARE PLACED OVER CONTAMINATED SOILS AND LANDFILLS TO REDUCE OR ELIMINATE
N AND PREVENT EROSION.

T ARE LESS PERMEABLE THAN THE IN SITU SOIL ARE PLACED UPGRADIENT OF WASTE, OR DOWNGRADIENT OF WASTE, OR
ED TO ENCIRCLE WASTES.

ALING, GRADING, SOIL STABILIZATION, REVEGETATION, AND DIVERSION/COLLECTON PROCESSES ARE IMPLEMENTED
SITE RUNON/RUNOFF, SURFACE WATER INFILTRATION AND EROSION, AND TO STABILIZE SURFACE SOILS.

BARRIER, FILTER SCREEN, OR CAP IS CONSTRUCTED TO MINIMIZE THE SPREAD OF CONTAMINANTS DURING SEDIMENT

L COVERS, SPRAYS, OILS, ETC. ARE APPLIED TO SUPPRESS DUST AND NON-POINT-SOURCE VAPOR.

/OR DEBRIS ARE REMOVED BY VARIOUS MECHANICAL MEANS, E.G., CRANES AND OTHER STANDARD CONSTRUCTION

TED SOIL, SEDIMENT, SLUDGES AND OTHER SOLIDS ARE REMOVED WITH STANDARD CONSTRUCTION EQUIPMENT.

ER AND LEACHATE ARE COLLECTED IN WELLS OR DRAINS AND PUMPED SO THEY CAN BE TREATED AND DISPOSED.

NTS THAT ARE PHYSICALLY OR CHEMICALLY BOUND TO SOILS ARE FLUSHED OR PUMPED FROM THE SOILS.

IDENTIFICATION OF GENERAL

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	DESCRIPTION
TREATMENT	SOLIDS TREATMENT	SOILS, SEDIMENTS, SLU CONSTITUENTS OR CONV
	SOLIDIFICATION, FIXATION, STABILIZATION	STABILIZATION AND FIX FORM. SOLIDIFICATION
	SOLIDS DEWATERING	SOLID/LIQUID SEPARAT SLUDGE PRIOR TO DIS
	PHYSICAL TREATMENT	HAZARDOUS LIQUIDS AR EQUALIZATION, CONCEN
	CHEMICAL TREATMENT	HAZARDOUS LIQUIDS A COMPOUNDS TO A MOR
	BIOLOGICAL TREATMENT	A CULTURE OF MICROO
	IN SITU TREATMENT	PHYSICAL, CHEMICAL, A GROUNDWATER IN PLA
	THERMAL TREATMENT	WASTE MATERIAL IS EX INNOCUOUS OR LESS HA
	AIR EMISSIONS CONTROL & TREATMENT	VAPOR PHASE IMPURIT WASH OPERATIONS TO
DISPOSAL	RESOURCE RECOVERY	COMBUSTIBLE MATERIAL
	TEMPORARY STORAGE	HAZARDOUS MATERIAL
	LAND APPLICATION	LIQUID AND SOLID WAST DEGRADED, TRANSFORM
	WASTEWATER DISCHARGE	AQUEOUS STREAMS AR
	EVAPORATION PONDS	SURFACE IMPOUNDMENT EVAPORATES.
	LANDFILL	SOLID WASTES ARE PE
MONITORING	MONITORING	SHORT-AND/OR LONG

ERAL RESPONSE ACTIONS (CONT.)

TION

MENTS, SLUDGES, AND OTHER SOLIDS ARE PHYSICALLY OR CHEMICALLY TREATED TO REMOVE THE HAZARDOUS
TS OR CONVERT THE CONSTITUENTS TO NONHAZARDOUS SUBSTANCES.

ON AND FIXATION PROCESSES MAINTAIN HAZARDOUS CONSTITUENTS IN THEIR LEAST TOXIC AND/OR LEAST SOLUBLE
IFICATION PRODUCES A MONOLITHIC BLOCK OF TREATED WASTE WITH HIGH STRUCTURAL INTEGRITY.

D SEPARATION CLARIFIES LIQUID STREAMS, RECOVERS SOLIDS AND LIQUIDS, OR REMOVES EXCESS LIQUID FROM
OR TO DISPOSAL.

S LIQUIDS ARE TREATED TO CONVERT THE HAZARDOUS CONSTITUENTS TO A MORE EASILY HANDLED FORM THROUGH
ON, CONCENTRATION, AND/OR PHASE CHANGE.

S LIQUIDS ARE ALTERED BY CHEMICAL REACTIONS TO DETOXIFY HAZARDOUS COMPOUNDS OR TO CONVERT THE
S TO A MORE EASILY TREATED FORM.

OF MICROORGANISMS METABOLIZES BIODEGRADABLE ORGANIC COMPOUNDS.

CHEMICAL, AND BIOLOGICAL PROCESSES ARE EMPLOYED TO TREAT CONTAMINATED SOIL, SOLID WASTES OR
TER IN PLACE.

ERIAL IS EXPOSED TO HIGH TEMPERATURES TO TRANSFORM THE HAZARDOUS COMPOUNDS INTO
OR LESS HARMFUL SUBSTANCES.

SE IMPURITIES ARE REMOVED FROM GAS STREAMS THROUGH PROCESSES RANGING FROM ONCE-THROUGH
ATIONS TO MULTIPLE-STEP RECYCLE SYSTEMS.

E MATERIALS CAN BE CONVERTED TO ENERGY

S MATERIAL IS TEMPORARILY STORED IN SURFACE IMPOUNDMENTS, WASTE PILES, OR CONTAINERS/TANKS.

SOLID WASTES THAT ARE PRIMARILY ORGANIC ARE INCORPORATED INTO THE UPPER SOIL HORIZON SO THEY CAN BE
TRANSFORMED, OR IMMOBILIZED.

TREAMS ARE DISCHARGED TO A POTW, SURFACE WATER, OR SHALLOW OR DEEP WELLS.

POUNDMENTS ARE USED TO CONTAIN TREATED OR UNTREATED WASTEWATER OR GROUNDWATER UNTIL IT
S.

ES ARE PERMANENTLY DISPOSED OF IN A LANDFILL. LANDFILLS CANNOT ACCEPT LIQUID WASTES.

/OR LONG-TERM MONITORING IS IMPLEMENTED TO RECORD SITE CONDITIONS AND CONTAMINATION LEVELS.

selected when contamination is widespread and difficult or impossible to remove.

Containment actions serve to isolate the contamination and prevent it from migrating offsite or into currently uncontaminated areas or media. Containment is often selected when the volume of waste is too large to permit removal and treatment, or when there is no practicable treatment for the waste. Containment options require ongoing monitoring to ensure the effectiveness of the containment system.

Removal actions involve the excavation, extraction, or physical removal of wastes and contaminated media for treatment or disposal. Groundwater extraction and treatment systems are considered removal actions. Removal actions may result in clean closure of a site, with no requirements for ongoing monitoring or maintenance.

Treatment actions may involve some sort of removal process, or may be in-situ operations. The goal of treatment actions is to reduce the toxicity, mobility, or volume of wastes requiring final disposal. Treatment processes may generate a residue or waste stream, which would also require treatment and disposal. The type of treatment selected is dependent on the characteristics and volume of the waste to be treated.

Disposal actions may occur onsite or offsite, and may involve treated or untreated wastes and contaminated materials. Some disposal actions may also fall into other general response action categories. For example, landfilling is both a containment action and a disposal action.

5.2 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Table 5-2 is a screening table for remedial technologies. For each of the general response actions discussed in Section 5.1, a number of remedial technologies were identified. In this table, each of the technologies are further defined by a group of potential process options. A brief description is included for each of the process options. Other process options currently considered experimental or unproven, or that incorporate a high degree of risk, have not been included in the table.

During Stage 2 of the IRP, data from the confirmation sampling will be used to evaluate the general response actions and remedial technologies. Process options will then be evaluated in order to identify alternative remedial measures for each of the four sites. The remedial technologies and process options will be evaluated on the bases of feasibility, implementability, effectiveness, permanence, and cost.

TABLE 5-2

REMEDIAL TECHNOLOGY SCREENING

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
No Action	None	None	No action
Institutional Controls	Access and Use Restrictions	Deed Restrictions	Deed restrictions issued for property within potentially contaminated areas to restrict property use.
		Fences	Security fences installed around potentially contaminated areas to limit access.
		Permits	Regulations promulgated to require a permit for drilling into aquifers.
	Alternative Drinking Water Source	Cisterns or Tanks	Drinking water dispensed to users from a centralized point.
		Bottled Water	Drinking water obtained from a commercial vendor.
		Deeper or Upgradient Wells	Wells installed deep or upgradient if these areas are isolated from contamination.
		Relocation of Intake	Relocate intake in an uncontaminated area.
		Municipal Water Supply	Establish additional water sources.
	Relocation of Residents	Temporary	Move residents to a motel or apartment. Pay for most additional out-of-pocket expenses for a finite period of time.
		Permanent	Move residents to a new residence. Pay for out-of-pocket moving costs, temporary housing and meals, utility connections, mortgage purchase, and closing costs.
Containment	Capping	Native Soil	Uncontaminated native soil placed over contaminated areas. Soil should minimize infiltration of precipitation.
		Clay Cap	Compacted clay placed over contaminated areas. Clay should be covered by at least a foot of silty sand or sandy soil to maintain the integrity of the clay cap.
		Synthetic Mer[illegible]anes	Synthetic membrane placed over prepared soil or geotextile surface that is over a contaminated area. The membrane is seamed by a variety of methods. The membrane must be compatible with the wastes present.
		Sprayed Asphalt	Sprayed asphalt is placed over contaminated areas and covered with soil or opaque reflective paint to protect the asphalt from ultraviolet light and to retard oxidation.
		Asphaltic Concrete	Asphalt for paving grades or special blends mixed with well graded, crushed aggregate, placed over contaminated areas.
		Concrete Cap	Concrete placed over prepared contaminated area. Fill settlement must be evaluated in considering a concrete cap design.
		Multilayered Cap	Cap may be composed of natural soils, soil admixtures, clay, synthetic membranes, spray-on asphalts, asphaltic concrete, or portland cement concrete and placed over contaminated areas. If properly designed, will meet RCRA requirements.
		Chemical Sealants/Stabilizers	Water-dispersible emulsions and/or resins placed over contaminated areas to form a crust that reduces water and wind or dust erosion. Most are nontoxic to plants and animals. Temporary cover only.

J: \INDUST\K24173\5-2-1

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Containment *(continued)*	Vertical Barriers	Soil-Bentonite Slurry Wall	Trench around contaminated area excavated and filled with a bentonite slurry. Trench backfilled with a soil-bentonite mix.
		Cement-Bentonite Slurry Wall	Trench around contaminated area excavated and filled with a cement bentonite water slurry. Cement sets up and forms the wall.
		Grout Curtains	*Grout pressure-injected along contamination* boundaries in a regular overlapping pattern of drilled holes.
		Sheet Piling	Steel sheet piling driven along contamination boundaries.
	Surface Controls	*Surface Sealing*	Cover materials and seal techniques implemented to stabilize waste deposits and to prevent surface water infiltration, control erosion, and isolate and contain the wastes. Similar to capping.
		Grading	Reshaping of topography to manage surface water, infiltration and runoff to control erosion.
		Soil Stabilization	Chemical stabilizers sprayed on bare soils or mulches to coat, penetrate, and bind together the particles. Chemical stabilizers include latex emulsions, plastic films, oil-in-water emulsions, and resin-in-water emulsions.
		Revegetation	A systematic revegetation plan includes selection of a suitable plant species, seedbed preparation, seeding/planting, mulching and/or chemical stabilization, *fertilization*, and *maintenance*.
		Diversion and Collection Systems	Diversion and collection structures installed upslope or at perimeter of the site to control drainage of stormwater runoff. System can also be implemented to collect contaminated surface water for remediation.
	Sediment Control Barriers	Curtain Barriers	A watertight curtain barrier consists of a thin, *impervious membrane* which contains sediments within a certain area to be dredged. A pervious barrier consists of a thin, woven or unwoven, plastic filter fabric which filters out coarse sediment particles.
		Cofferdams	*Cofferdams installed to isolate an area of* contaminated sediments. Depending upon water depth, differential head to be maintained, soil strength, depth of excavation, etc., a gravel or sand berm, a cellular cofferdam, or a sheet pile bulkhead is installed.

J: *indust**k24173*\5-2-2

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Containment *(continued)*	Sediment Control Barriers *(continued)*	Capping Barriers	A permeable cap is installed without dewatering when goal is to prevent the spread of contaminated sediments. An impervious cap is installed after dewatering so remediation can be done in a controlled environment.
		Sandbags	Sandbags are used to divert small flows so that sediment can be excavated.
	Dust and Vapor Suppression	Water	Water sprayed over area of concern to prevent dust generation.
		Organic Agents/Polymers/Foams	Organic agents/polymers/foams sprayed over area of concern to prevent dust/vapor generation.
		Membranes/Tarps	Membranes or tarps are spread over area of concern to prevent dust/vapor generation.
Removal	Drum and Debris Removal	Hydraulic Excavator	Used for large excavation and trenching jobs, pulling down structures, grubbing, and loading debris with attachments; used to shear tanks and piping and to remove drums.
		Forklifts and Attachments	Used for moving drums on pallets.
		Cranes and Attachments	Used with wrecking balls for demolition of wall or concrete pads, clamshells for lifting or ripping, wires or platforms for lifting, and hoppers, buckets, and other devices for carrying.
		Handtools	Used for light demolition and moving debris.
		Backhoes and Attachments	Used for excavation, trenching, pulling down structures, and loading material.
		Bulldozers and Graders	Used for leveling work areas, moving piles of material, or pushing over trees and structures.
		Cutting Devices	Used to cut steel--rebar, beams, drums, tanks, siding, etc.
		Explosives	Used to make big things very small, very rapidly. Fires may result.
	Excavation	Solids	Excavation of contaminated solids can use ordinary construction equipment (backhoes, bulldozers, and front-end loaders).
		Semi-Solids	Excavation of contaminated semi-solids requires working on mats or floating equipment. A toothless bucket is recommended over draglines or clamshells. Transportation and disposal methods must consider the water associated with the semi-solids.
		Sediments	Excavation of contaminated sediments requires floating equipment or operaton of equipment on the bank. Hydraulic dredges, barge-mounted pumps, vacuum trucks, and pneumatic dredges are used for excavation. Generally bulk liquid removal will also be required.
	Groundwater Collection	Wells	groundwater and leachate.
		Drains	Underground gravel-filled trenches generally equipped with tile or perforated pipe installed to collect contaminated groundwater and leachate.
	Enhanced Oil Recovery (EOR)	Thermal EOR	Many reservoir volumes of hot water, steam, or air are injected into a heavy oil reservoir to reduce the viscosity of the oil thus inducing flow. For clean up of low levels of oil.

j:\indust\k24173\5-2-3

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Treatment	Solids Treatment	Neutralization	Acid added to an alkaline waste or base added to an acidic waste to adjust the pH.
		Oxidation	Oxidizing agents added to waste for oxidation of organic contaminants to less toxic oxidation states.
		Chemical Reduction	Reduction agents added to wastes to stabilize metals by converting them to a less soluble, more stable form.
		Other Chemical Modifications	Contaminated solids are treated with appropriate reagents under suitable conditions to convert the contaminants into less toxic forms.
		Water Leaching	Water infiltrates contaminated solid, leaching out water-soluble contamination.
		Solvent Leaching	Solvent infiltrates contaminated solid, leaching out contaminants that are soluble in the selected solvent.
		Solvent Evaporation	Contaminated sludge or soil heated in equipment which allows mixing. Organics volatilized from solids into the gas stream.
	Solidification, Fixation, Stabilization	Sorption	An inert, nondegradable, nonreactive sorbent added to liquid or sludge to soak up moisture and produce a soil-like material.
		Pozzolanic Agents	Lime and fine-grained siliceous material added to aqueous waste to produce a concrete-like solid.
		Encapsulation	Material is encapsulated by either coating the individual particles or enclosing entire mass in a jacket of inert material. Applicable for extremely dangerous or radioactive wastes.
	Solids Dewatering	Sedimentation	Suspended solids removed from liquid by gravity in a tank or lagoon. Sedimentation often preceded by chemical precipitation and/or by coagulation and flocculation.
		Gravity Thickening	Water removed from sludge by gravity in thickening tanks. Chemicals can aid in sludge dewatering.
		Centrifuges	Sludge dewatered by centrifugal force. Centrifuges are used when space is limited or where sludge incineration/disposal is required.
		Screens, Hydraulic Classifiers, and Scalpers	Coarse and/or gross solids removed from raw wastewater by a screening surface in a classifier.
		Belt Filter Presses	Sludge dewatered by an endless filter belt that runs over a drive and guide roller at each end. A press belt runs in the same direction and speed above the filter belt.
		Filter Presses	Sludge passed into press under pressure, water passes through filter cloth while solids form a cake on the filter cloth surface.
		Vacuum Filtration	A partially submerged cylindrical drum rotates in a vat or pan of conditioned sludge. A vacuum is pulled inside the drum, solids collect on outside and are continuously scraped off.
		Dewatering and Drying Beds	Sludge placed on sand layered over gravel. Water in the sludge evaporates and drains.
		Sludge Dryers	Contaminated sludge or soil heated in equipment which allows mixing. Aqueous liquids evaporated from solids into the gas stream.
	Physical Treatment	Flow and Strength Equalization	Equalization basin regulates flow through a treatment facility. Mechanical mixing equalizes concentration.
		Coagulation/Flocculation	Suspended particle aggregation that results from chemical additions to the wastewater. Once particles have aggregated into large particles, they can be removed be sedimentation, flotation, or filtration.

J:\INDUST\K24173\5-2-5

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Treatment *(continued)*	Physical Treatment *(continued)*	Oil-Water Separation	Oil separated from water by gravity. Treatment may be required for dissolved and emulsified oil prior to simple physical separation.
		Flotation	Gas bubbles released into wastewater attach to suspended solids, free and emulsified oils, and grease; float to the top and are skimmed off.
		Media Filtration	Fine solid particles removed from liquid stream by a filter medium. Common media are sand, diatomite, coal, natural or synthetic fabric, and wire cloth.
		Adsorption	Contaminated liquid or gas stream passed over adsorbant that removes contaminants.
		Membrane Processes	Barrier membrane preferentially passes some components of a fluid mixture or solution.
		Air Stripping	Large volumes of air forced through liquid in a packed column or by diffused aeration to promote transfer of volatile contaminants to air.
		Steam Stripping	Similar to air stripping; steam pumped into stripping column; heat promotes transfer of volatile contaminants from liquid to air.
		Evaporation	Wastewater heated to its boiling point then condensed; a brine stream remains that contains virtually all the dissolved solids.
		Distillation	Organic liquid wastes are boiled to release volatile compounds into a vapor phase. The vapor phase is condensed, treated and/or disposed.
		Liquid-Liquid Extraction	Two immiscible liquids brought together by forced mixing or countercurrent flow to promote the transfer of a solute from one liquid to the other. Applicable for removal of organics from aqueous solutions or water soluble compounds from organic solutions.
	Chemical Treatment	Neutralization	Acid added to an alkaline waste or base added to an acidic waste to adjust the pH.
		Precipitation	Chemical equilibria of waste altered to reduce the solubility of heavy metals through the addition of a substance that reacts with the metals or changes the pH or through a change in temperature.
		Ion Exchange	Contaminated water passed through a bed of resin material where exchange of ions occurs between the bed and the water.
		Oxidation	Oxidizing agents added to wastes for oxidation of cyanide, heavy metals, unsaturated organics, sulfides, sulfites, phenolics, pesticides, aldehydes, and aromatic hydrocarbons to less toxic oxidation states.
		Chemical Reduction	Reduction agents added to wastes for reduction of hexavalent chromium, mercury, dissolved lead, and silver to less soluble, more stable forms.
		Greensand	Applied to water streams to remove manganese and iron through oxidation and filtration. Oxidizing agents are chlorine and potassium permanganate. Oxidized iron and manganese are filtered by coal and the oxidants are filtered by the greensand.

J:\INDUST\K24173\5-2-6

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Treatment *(continued)*	Biological Treatment	Aerobic Processes	Organic wastes oxidized through the use of a mixed culture of organisms in aerobic conditions.
		Anaerobic Processes	Organic compounds oxidized through the use of a mixed culture of organisms in anaerobic conditions.
		Facultative Processes	Organic compounds removed from wastewaters through the use of a mixed culture of organisms in both aerobic and anaerobic conditions.
		Land Treatment	Organic liquid and sludge waste applied to open land. Biodegradable organics oxidize and crops consume nutrients and minerals (heavy metals).
	In Situ Treatment	Neutralization	Substances applied or injected into a contaminated site to adjust the pH of the waste. Innovative process option for contaminated soils or buried wastes.
		Bioreclamation	Microbiological degradation, detoxification, and mineralization of hazardous substances is enhanced with respect to electron acceptors, nutrient levels, moisture content, pH, and temperature.
		Thermal Evaporation	Electrodes placed over surface of contaminated site, or in vertical or horizontal bore-holes drilled through contaminated zone. *Electromagnetic energy in radio frequency band is applied to electrodes to cause rapid heating of the soil by molecular excitation.*
		Steam Stripping	VOC removal from soil by application of steam. Injection wells force steam through contaminated subsurface. Steam carrying stripped volatiles are collected at surface through extraction wells.
		Permeable Treatment Beds	Trench excavated, filled with appropriate material, and capped to intercept contaminated groundwater plume. Depending upon bed material, plume can be neutralized, metals and organics can be removed, and nutrients can be added. Conceptual process option.
		Vitrification	Graphite electrodes placed in a square array. Electric current passes through electrodes creating high temperatures that melt the soil or waste solids into a block of glasslike material. *Experimental process option.*
		Soil Vapor Extraction	Large volumes of air pulled through the soil to strip volatile contaminants from the soil in a manner similar to air stripping.

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Treatment *(continued)*	In Situ Treatment *(continued)*	Soil Flushing	Contaminated soil is flushed with an appropriate flushing solution and the elutriate is collected in a series of shallow well points or subsurface drains.
		Other In Situ Treatment	Other treatments include immobilization, polymerization, and photolysis. Generally experimental process options.
	Thermal Treatment	Incineration	Hazardous materials thermally destroyed in a controlled, oxygen-sufficient environment. Generally, products include carbon dioxide, water, and ash. Many types of incinerators with varying capabilities exist.
		Co-Disposal Process	Waste materials mixed with pulverized coal, natural gas, wood chips, etc., or other wastes and used as a supplemental fuel source to produce steam for a conventional power cycle.
		Pyrolysis	Hazardous materials thermally destroyed in an oxygen-deficient environment.
		Gaseous Incineration	Gaseous waste oxidized at high temperatures generated from supplemental fuel.
		Wet Air Oxidation	Waste mixed with air and fed to a reactor where destruction takes place at high temperatures (up to 600°) and pressures (up to 200 atm).
	Air Emission Controls and Treatment	Condensation	Vapor components existing at or near a gas stream's saturation point are removed when the stream is cooled below the dew point.
		Particulate Removal	Particles removed from a gas stream by gravity settling, inertial forces, filtration, electrostatic attraction, and particle conditioning.
		Adsorption	Gas stream constituents removed by their contact and adherence to the surface of a solid. Organic vapors, water vapors, hydrogen sulfide, ammonia, carbon dioxide, and sulfur dioxide can be removed, depending upon the solid used.
		Absorption	Gas stream constituents removed by dissolving them in a selective liquid solvent. Contaminants generally removed include sulfur dioxide, hydrogen sulfide, hydrogen chloride, chlorine, ammonia, oxides of nitrogen, and light hydrocarbons.
		Catalytic Conversion	Gas stream constituents converted to less toxic compounds or to compounds that can be more easily removed by another process. This chemical reaction is generally referred to as catalytic conversion.
		Thermal Destruction	Gas stream is subjected to high temperatures in an oxygen-sufficient environment. Combustible materials are oxidized.
Disposal	Resource Recovery	Energy Recovery	Energy is recovered from thermal treatment, or wastes are converted for use as fuel.
	Temporary Storage	Surface Impoundments	Surface impoundments are used to store or treat liquid and sludge-type waste. Also known as ponds, lagoons, liquid trenches, evaporation ponds, treatment ponds, aeration pits, and stabilization basins.
		Waste Piles	Waste piles are used for temporary storage of solid wastes.
		Containers/Tanks	Containers are used to temporarily store and transport wastes. Tanks are used to temporarily store liquid wastes prior to treatment or disposal.

REMEDIAL TECHNOLOGY SCREENING (CONT.)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION
Disposal *(continued)*	Land Application		Liquid and solid wastes that are primarily organic are incorporated into the upper soil horizon so they can be degraded, transformed, or immobilized.
	Wastewater Discharge	POTW	Aqueous streams are discharged to a POTW for treatment.
		Surface Waters	Aqueous streams are discharged to surface receiving streams.
		Reinjection	Treated groundwater or surface water is reinjected into onsite wells.
		Deep Well Injection	Aqueous wastes are injected into Class I wells. Recent guidance may further regulate this practice.
		Evaporation Ponds	Surface impoundments are used to contain treated or untreated wastewater or groundwater until it evaporates.
	Landfill	RCRA Landfill	Solid hazardous wastes are permanently disposed of in a RCRA-permitted landfill. RCRA landfills cannot accept liquid hazardous waste.
		Non-RCRA Landfill	Solid nonhazardous wastes are permanently disposed of in a non-RCRA landfill. Landfills cannot accept liquid wastes.
Monitoring	Monitoring		Short-and/or long-term monitoring is implemented to record site conditions and contamination levels.

J: \INDUST\K24173\5-2-9

Selection of process options is one of the last steps in the development of a remedial measure. The selection must incorporate detailed information on the characterization and quantity of waste involved, the treatment standards or other restrictions identified by the ARARs analysis, and site specific details such as space availability, climate, etc.

5.3 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Remedial alternatives are developed following the evaluation of general response actions, remedial technologies, and process options. Typically, several alternatives are developed for each site that represent a range of cleanup levels.

The data obtained during Stage 1 of the IRP primarily served to identify areas of contamination and to indicate the types of contaminants present. The confirmation sampling and analysis to be done during Stage 2 will attempt to delineate the sources of the contamination at each site, and to identify the constituents of the wastes. This information is essential to the identification of ARARs, and to the evaluation of appropriate treatment technologies. Therefore, the development of remedial alternatives will be done as part of Stage 2.

The following discussion outlines a range of general remedial alternatives for each site. The purpose of developing general alternatives at this time is to aid in the identification of additional data requirements to be satisfied during Stage 2. For example, if a removal action is considered, it is important to be able to estimate the total volume of material to be removed. This would involve determination of the extent of contamination, which could be done during Stage 2.

The general alternatives described in this section do not reflect site-specific data or conditions. The alternatives were derived from experience at similar sites, and incorporate general response actions and remedial technologies from Tables 5-1 and 5-2.

5.3.1 North Barrel Bluff and South Barrel Bluff

The following general remedial alternatives were developed for the North Barrel Bluff and the South Barrel Bluff. The similarities of the two sites makes the development of separate alternatives impractical at this time. After additional sampling and analysis during Stage 2, sufficient data will be available to allow screening of general response actions, remedial technologies, and process options for each site. The alternatives are ordered by increasing level of protection, which usually corresponds to increasing level of cost and complexity.

5.3.1.1 No Action Alternative

The No-Action alternative is carried through the evaluation and screening process as a basis for comparison of other alternatives. At the North and South Barrel Bluff sites, no action would allow any existing contamination of the groundwater or surface water to continue. The wastes that may be contained in the drums would remain at the sites. In the future, the drums can be expected to fail due to exposure to the weather. Wastes could be expected to leak from the drums and contaminate surrounding and underlying soils. Groundwater or surface water contamination could also result.

Current levels of human and environmental exposure to the wastes at the sites would be expected to continue. Future increases or decreases in habitation or use of the area would change the exposure and risk levels.

5.3.1.2 Institutional Controls

Institutional controls for the North and South Barrel Bluff sites would include restriction of access to the area, and possibly a moratorium on groundwater use (in the event that the groundwater is determined to be contaminated). As discussed for the No-Action alternative, this would not result in the removal of any waste, and would not prevent migration of the wastes from the site. Institutional controls would result in some decrease in the level of human exposure and risk. No change would occur in environmental exposure or risk.

5.3.1.3 Containment

The goal of a containment action is to prevent migration of wastes or waste components from the site. Containment of the wastes and contaminated media at the North and South Barrel Bluff sites would include one or more of the following: capping, surface water controls, and groundwater barriers. The type of cap to be installed, and the treatment or disposal requirements for wastes, drums, and contaminated soils would be dependent on the classification and characterization of the wastes. If the wastes at the sites are hazardous wastes, RCRA capping, waste management, and disposal requirements would be applicable.

Capping of the site would prevent direct contact between humans or wildlife and the site wastes. Capping of a site containing a large number of barrels is exceedingly difficult due to the potential for subsidence and cap failure. It would probably be necessary to remove or crush a number of drums to achieve a surface contour that would sustain capping. Treatment or disposal of the wastes and drums removed from the site would be a separate concern.

Surface water control would be a requirement of the capping program, in order to prevent damage to the cap during storm events. Any contaminated surface soils not covered by the cap would have to be isolated. The surface runoff from these areas would require containment and possible treatment. The surface water control system would be designed to minimize the quantity of storm water requiring containment and treatment by directing offsite storm water around the site, and thereby preventing run-on.

Containment of contaminated groundwater, if necessary, would require extensive site work. Containment of the shallow aquifer could be accomplished by construction of a slurry wall or grout curtain. In order to be effective, the wall or curtain would have to be keyed into an impermeable strata below the shallow aquifer. Local site conditions may make this option impossible.

In the event that contaminated soil is excavated during the construction of the wall or curtain, treatment, or disposal of the soil would be necessary. The appropriate level of treatment would be defined by the classification and characterization of the wastes. Containment of groundwater does not remove contaminants from offsite groundwater. Some risk to offsite users of the shallow groundwater would remain.

5.3.1.4 Removal of Wastes

Removal alternatives offer the benefit of reduced risk and exposure level following the remedial action. During the action, however, the risk to site workers is usually higher than the risk during construction of containment alternatives.

Removal of the wastes from the North and South Barrel Bluffs would be complicated by the condition of the drums. Some of the drums are reported to contain liquid wastes. The source and identity of these wastes is not known. A number of the drums have probably corroded or have been ruptured by the disposal method. These drums would be hard to handle and would present an unknown risk to site workers. Drums containing liquid or solid waste would have to be sampled, and would probably require overpacking to secure the contents. Treatment or disposal of these wastes could trigger RCRA hazardous waste management requirements.

The soil surrounding and underlying the sites is probably contaminated to some depth by the former contents of the drums. Total removal of the contamination would require excavation of the contaminated soil, followed by treatment or disposal.

During implementation of the removal alternative, provisions would have to be made to collect, contain, and treat any storm water runoff that contacts the area of the contamination. As discussed under the containment alternative, the storm water control system would be designed to prevent run-on, and thus minimize the quantity of storm water requiring treatment and disposal.

Groundwater removal is most often accomplished using extraction wells. If the groundwater surrounding or underlying the sites is contaminated, extraction of the contaminated plume, followed by treatment and disposal, would be included in the removal alternative. The level of treatment and the method of disposal would be determined on the basis of evaluations of the waste constituents and concentrations in the groundwater, and the available disposal methods.

In the event that a removal alternative results in the complete removal of all wastes, contaminated soils, and contaminated groundwater, the site would be considered to have undergone clean closure. No further monitoring or maintenance of the site would be required.

Variations in a removal action include the quantities of waste removed, or the level of cleanup, and the treatment or disposal alternatives incorporated in the alternative. Removal with offsite disposal may be appropriate for some wastes. Disposal can range from landfilling at a municipal landfill, to landfilling at a licensed RCRA landfill, to disposal in a licensed RCRA incinerator. The selection of disposal technique will depend on the type and quantity of the waste. Some wastes may be amenable to treatment prior to disposal. If the wastes can be rendered nonhazardous by the treatment, lower cost disposal options may be considered.

5.3.2 Naknek River Seep and Eskimo Creek Seep

The following general remedial alternatives were developed for the Naknek River seep and the Eskimo Creek seep. The similarities of the two sites makes the development of separate alternatives impractical at this time. After additional sampling and analysis during Stage 2, sufficient data will be available to allow screening of general response actions, remedial technologies, and process options for each site. The alternatives are ordered by increasing level of protection, which usually corresponds to increasing level of cost and complexity.

5.3.2.1 No Action Alternative

The No-Action alternative is carried through the evaluation and screening process as a basis for comparison of other alternatives. At the Naknek River seep and the Eskimo Creek seep, no action would allow contamination of the groundwater and surface water to continue. There would be no impact on the sources of the seeps, and current levels of human and environmental exposure to the contaminants at the sites would continue. Future increases or decreases in habitation or use of the area would change the exposure and risk levels.

5.3.2.2 Institutional Controls

Institutional controls for the Naknek River seep and the Eskimo Creek seep would include restriction of access to the area, and a possible moratorium on use of the Naknek River and Eskimo Creek for fishing and recreational use in the area immediately downstream of the seep areas. As discussed for the No-Action alternative, this would not result in the removal or containment of the source of the contamination, and would not prevent continued release of the contaminants to the Naknek River and Eskimo Creek. Institutional controls would result in some decrease in the level of human exposure and risk. No change would occur in environmental exposure or risk.

5.3.2.3 Containment

Containment of the wastes and contaminated media at the Naknek River seep and Eskimo Creek seep would include one or more of the following: groundwater barriers, some capping, and surface water controls to protect the capped area.

In order to contain the contaminants being released at the seeps, the source of each of the seeps would have to be determined. It is suspected that the seeps resulted from the leaking or spilling of POL over a period of time. The sources of the seeps could be extensive areas of contaminated soil in contact with the shallow groundwater. Containment of a large area would require slurry wall construction to isolate the contaminated soil and groundwater, and capping to prevent infiltration of precipitation and surface runoff, which would add to the volume of contaminated groundwater.

Containment of the seep areas themselves would be difficult due to the presence of flowing water. Excavation of some of the contaminated soil could be required, followed by construction of a channel to prevent contact of the river or creek with the contamination.

Surface water controls would be necessary in the area of the cap to protect the cap from storm water damage. The surface water controls would be designed to minimize the quantity of water flowing over the cap by diverting water around the cap and preventing run-on. If the contaminants at the sites are classified as hazardous wastes, the cap and the surface water control system would have to comply with RCRA requirements.

Capping and containment of the sites would prevent direct contact of humans or wildlife with the site contaminants. Ongoing monitoring and maintenance of the sites would be required, since the contamination would remain onsite.

5.3.2.4 Removal

Removal alternatives offer the benefit of reduced risk and exposure level following the remedial action. During the action, however, the risk to site workers is usually higher than the risk during construction of containment alternatives.

Removal of the wastes from the Naknek River seep and Eskimo Creek seep would be complicated by the nature of the suspected sources of the seeps. However, compared to the problems associated with containment of the contaminants at the seep site, a removal alternative would probably be preferred.

Assuming that the current sources of the seeps are large areas of contaminated soil in contact with shallow groundwater, two types of removal alternatives are possible. The first alternative would be to remove the entire source of contamination. This would involve excavation and removal of the soil in the area of contamination. Since much of the soil is below the water table, a significant quantity of dewatering would be required during excavation. The contaminated groundwater, as well as the excavated soil, would have to be contained for treatment or disposal.

Obviously, for all but the smallest areas of contamination, this alternative would be difficult and costly to implement.

Another alternative would involve the removal of the contaminated groundwater without excavation of the soils. Extraction wells could be constructed surrounding the area of contamination. By withdrawing groundwater in the contaminated zone, contaminants could be prevented from entering the river or creek.

The contaminants in the soil would be leached into the groundwater over a period of time. The construction of groundwater barriers upgradient of the contaminated area would limit the quantity of groundwater to be treated, but would extend the duration of treatment. Enhanced leaching of the contaminants from the soil could be accomplished by flushing the soil with water, which would be collected in the extraction wells. Soil vapor extraction could also be used to remove volatile organic contaminants from the soil.

All of these removal alternatives would require long-term operation, monitoring, and maintenance. Human and environmental exposure and risk would be reduced but not eliminated at the site. It would be difficult to project the length of treatment time required to remove the source of the contaminants, or the lowest attainable concentrations in the soil or groundwater.

CVR193/062 (pc)

VI. RECOMMENDATIONS

6.1 DIRECTION AND APPROACH FOR FUTURE WORK

6.1.1 Eskimo Creek Seep

Additional investigative efforts at the Eskimo Creek seep should be directed towards the following:

- Expanding the analyses performed on groundwater samples to define the constituents that contribute to the TPH results, especially for the base drinking water wells. Risk and ARARs analyses should be refined based on the new data.
- Attempting to identify the source of the Eskimo Creek seep and other groundwater contamination.
- Defining the vertical and lateral extent of the hydrocarbon plume moving to the west away from the POL tanks.

Recommendations for addressing these concerns include the following tasks:

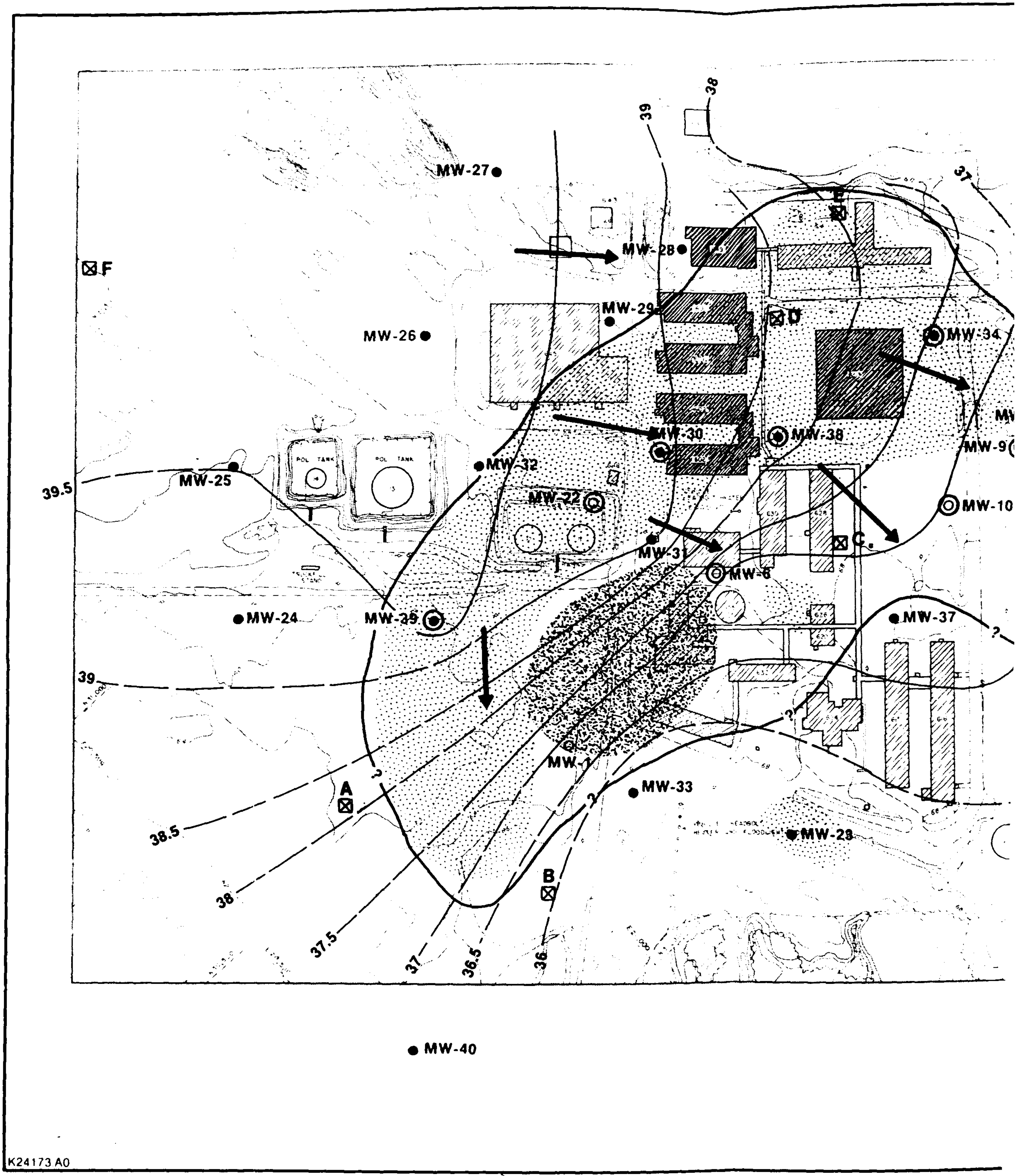
- Review historical site-specific practices including facility operations, tank locations and storage records, drum storage or disposal records, and contents. Task includes additional focused records search, aerial photography analyses, interviews, and field reconnaissance.
- Expand the analyses of base drinking water from KS-4 and KS-5 to identify and quantify individual constituents from TPH results (priority pollutants).
- Consider deep well rehabilitation or abandonment if the contamination is found to be the result of interaquifer communication along the well bore hole.
- Collect additional samples and expand analyses of groundwater from shallow monitoring wells should be performed to characterize the individual constituents. Samples from wells MW-39, MW-32, MW-30, MW-38, MW-34, and MW-9 would provide a distribution between the POL tanks and Eskimo Creek seep that would indicate a "worst case" for potential risk analyses. Analytical results would also provide a basis for determining a "target" list of

constituents for additional groundwater, surface water and sediment samples.

- Sample and analyze Eskimo Creek soils between the seep and Eskimo Creek for a target list of potential contaminants. Sample locations and depths should be adequate (10 locations) to characterize this potential groundwater discharge area.
- Expand sampling and sample analyses of Eskimo Creek surface water to provide a broader data base and allow a comprehensive assessment of the human and environmental risks this area presents.
- Include sampling of background conditions for each media (soil, surface water, and groundwater) to provide input for risk analyses.
- Perform seasonal water level measurements and groundwater flow system interpretations on a quarterly basis to provide a refinement of the current hydrologic model. Lowering of water levels could have a major affect on groundwater flow directions in the area of the till mound.
- Install three to five additional groundwater monitoring wells at locations shown in Figure 6-1. Rationale for each well is provided in Table 6-1. Sample all wells for target list of constituents. Wells should be resampled after 3 to 6 months for verification of analyses and investigation of seasonal effects.
- Develop each well adequately to provide representative groundwater samples. A single well slug/bail or recovery test should be performed to provide an estimate of aquifer parameters.
- Due to the difficult sampling conditions, update the sampling and analysis plan based on actual site sampling experience to provide quality assurance in future field techniques.
- Conduct a shallow aquifer pumping test to provide a more accurate estimate of aquifer parameters if remediation includes a pump-and-treat scenario. This test could be conducted during a predesign stage of remedial activities.

6.1.2 Naknek Seep

Hydrocarbon contamination was detected at the Naknek seep. In addition, two adjacent areas with potential hydrocarbon



MW-27
MW-28
MW-29
MW-26
MW-34
MW-30
MW-38
MW-9
MW-32
MW-25
MW-22
MW-10
MW-31
MW-6
MW-24
MW-35
MW-37
MW-1
MW-33
MW-23
MW-40
A
B
C
D
E
F
POL TANK
POL TANK
39.5
39
38.5
38
37.5
37
36.5
36
?
K24173 A0

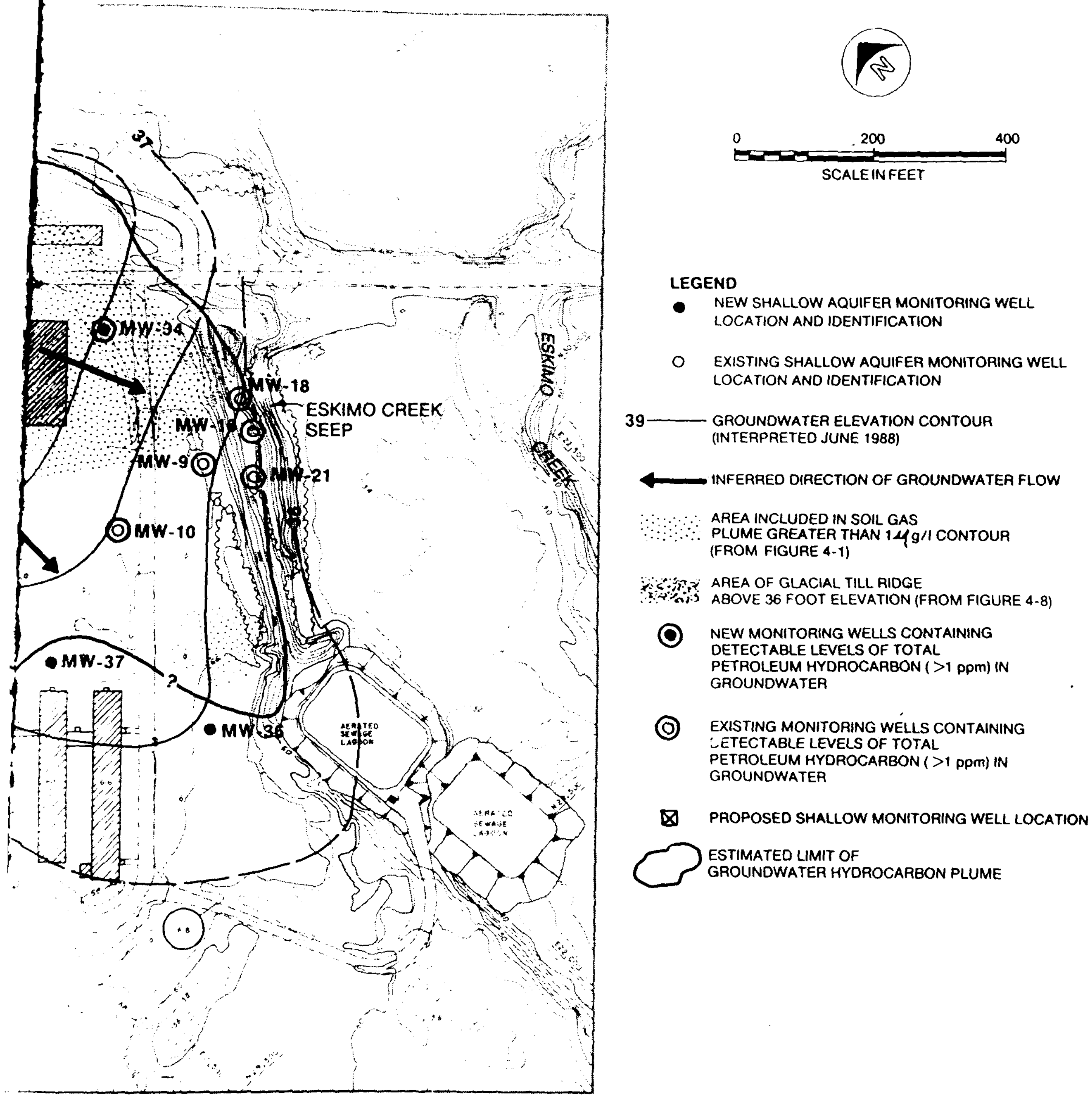


FIGURE 6-1

PROPOSED MONITORING WELL LOCATIONS

KING SALMON AIR FORCE STATION
KING SALMON, ALASKA

CH2M HILL

Table 6-1
RATIONALE FOR ADDITIONAL SHALLOW MONITORING WELLS

Well Number	Rationale
A	Extent of west plume--groundwater quality Water level data Till surface elevation
B	Extent of west plume--groundwater quality Water level data Till surface elevation
C	Extent of major plume Water level data Till surface elevation at critical area to determine flow path from POL tanks towards Eskimo Creek seep
D	Water quality upgradient of Eskimo Creek seep and within soil gas plume Water level data Till surface elevation
E	Water quality data upgradient of Eskimo Creek seep and along discharge route to Eskimo Creek Water level data Till surface elevation
F	Background water quality Upgradient water level data

lw/CVR193/056

were identified. One area includes buried and partially buried drums 1,500 feet northwest of the Naknek seep. The other area includes a POL seep near the large POL tanks, located 1,500 feet north of the Eskimo Seep.

The detection of aromatic and halogenated volatile organic constituents at the site suggests a potential for adverse public health and environmental effects. Additional investigations recommended to evaluate this potential at the three sites are outlined below:

- Review historical site-specific practices including facility operations, tank locations and storage records, drum storage or disposal records, and contents. Task includes additional focused records search, aerial photography analyses, interviews, and field reconnaissance.
- Perform additional soil gas survey work to assist in delineating the lateral extent of the hydrocarbon plume(s) and to aid in placement of shallow monitoring wells.
- Perform additional reconnaissance geophysical surveys to delineate the extent of drums or buried tanks.
- Drill three to five shallow soil borings at each site (depending on soil gas results) with vertical sampling of soils for chemical analysis.
- Install three to five shallow monitoring wells (in soil borings) to allow hydraulic and chemical analyses of the shallow aquifer.
- Develop each well adequately to provide representative groundwater samples. A single well slug/ bail or recovery test should be performed to provide an estimate of aquifer parameters.
- Complete two groundwater measurement and sampling events at a 3-month interval to characterize the flow system and confirm the presence of hazardous constituents.
- Collect and sample seepage fluids along Naknek River for chemical analyses. Background water quality should be established by a sample upstream of the seep.
- Analyze soil and water samples for an expanded constituent list (Priority Pollutants) to identify and quantify potential constituents. Data quality objectives, including detection limits, need to be adequate to determine if concentrations comply with water quality criteria for the protection of

aquatic organisms. Background water quality must be established for correlation with risk analyses data.

6.1.3 North Barrel Bluff

The North Barrel Bluff poses a potential human health and environmental hazard resulting from physical and chemical exposures. Installation of a locking gate and perimeter fence is recommended to reduce this potential and to establish a buffer zone. Further investigations are recommended to better evaluate human health and environmental consequences associated with this debris area. These investigations should include:

- Review historical site-specific practices including facility operations, tank locations and storage records, drum storage or disposal records, and contents. Task includes additional focused records search, aerial photography analyses, interviews, and field reconnaissance.

- Collect soil samples from the area beneath the toe of the bluff. Ten shallow borings should be completed 10 to 15 feet into the soils along the bluff to indicate whether leakage of residual fluids from drums has entered into the soils. Piezometer casing should be installed in the boreholes to provide sampling points for water quality and water level measurements.

- Install six shallow aquifer monitoring wells along the bluff and adjacent to the drums (based on boundaries established in the geophysical survey) to obtain samples for soils and groundwater characterization. Four of the wells should be located within the landfill and two placed as background (upgradient water quality and hydraulic data). The wells should be sampled for the priority pollutants as well as any other target constituents identified in the historical review. Groundwater sampling results should be verified with a second round of sampling the following quarter. Water levels should be monitored seasonally for 1 year (four quarters) to determine shallow aquifer conditions.

- Investigate the intermediate aquifer for direction of groundwater flow and presence of contaminants if groundwater contamination is found in the shallow aquifer. This would initially include three intermediate wells; two would be located within the landfill and one as a background. Sampling should follow the same schedule as the shallow wells.

- Develop each well adequately to provide representative groundwater samples. A single well slug/bail or recovery test should be performed to provide an estimate of aquifer parameters.

- Include sampling of background conditions for each media (surface water, soils, and groundwater) to provide correlation with risk analyses data.

- Conduct four shallow soil borings near the White Alice building. Samples should be analyzed for priority pollutants.

- Use additional reconnaissance geophysical profiling to identify small "dump" areas that are apparently common within the disturbed ground along the top of the bluffs. Any future remedial actions that include a delineation of the extent of the drums along the bluff will require extensive geophysical surveys to fill in the existing reconnaissance grid.

- Conduct backhoe explorations at small "dump" areas identified in the previous (and any future) geophysical surveys to provide soil samples for chemical analyses. Analyses should be a target list (subset of priority pollutants) that reflects the type of debris found in the excavation.

6.1.4 South Barrel Bluff

Drum and other debris types present at the South Barrel Bluff present similar human health and environmental hazards to those present at North Barrel Bluff. The South Barrel Bluff presents an additional problem because of its proximity to residential housing. In two instances, housing has been located near to or on top of fill material placed over the debris area. Installation of a locking gate and fence that encompasses the known perimeter of the debris area, which is not presently inhabited, is recommended to assist in reducing the potential for human and wildlife contact with the deteriorating drums and debris.

To adequately evaluate the potential hazards to human health and the environment associated with this area, the following are suggested:

- Review historical site-specific practices, including facility operations, tank locations and storage records, drum storage or disposal records, and contents. Task includes additional focused records search, aerial photography analyses, interviews, and field reconnaissance.

- Collect soil and leachate samples from beneath the toe of the bluff. Ten shallow auger borings 10 to 15 feet into the soil horizon may provide an indication whether residual liquids that have leaked from deteriorating drums have entered into bluff soils or into King Salmon Creek. Piezometer casing should be installed in the boreholes to provide sampling points for water quality and water level measurements.

- Install five shallow aquifer monitoring wells along the bluff adjacent to the drums and within the landfill to obtain samples for soils and groundwater characterization. Groundwater analyses for the shallow wells and piezometers should include priority pollutant analyses. Sampling results should be verified with a second sampling round the following quarter. Water levels should be monitored quarterly for 1 year to determine shallow aquifer conditions.

- If groundwater contamination is found in the shallow aquifer, investigate the intermediate aquifer for direction of groundwater flow and presence of contaminants. This would initially include three intermediate wells; two would be located within the landfill and one as a background. Sampling should follow the same schedule as the shallow wells.

- Include sampling of background conditions for each media (surface water, soils, and groundwater) to provide correlation with risks analyses data.

- Develop each well adequately to provide representative groundwater samples. A single well slug/ bail or recovery test should be performed to provide an estimate of aquifer parameters.

- Use additional reconnaissance geophysical profiling to identify small "dump" areas that are apparently common within the disturbed ground along the bluffs. Any future remedial actions to be conducted at the South Barrel Bluff will require a detailed delineation of the lateral extent of buried debris. This determination can be made by completing additional geophysical surveys along the bluff.

- Conduct backhoe explorations at small "dump" areas identified in previous geophysical surveys to provide soil samples for chemical analysis.

- o Include residential wells in the area into a periodic, extended groundwater monitoring schedule and/or remove them as drinking water supplies. Wells located within landfill boundaries (two identified) should be removed and alternate water supplies secured. Potential health risks for residents along the bluff should be evaluated and future use of the area controlled. Land use controls may include removal of the two houses located on the landfill.

6.2 CATEGORIZATION OF SITES

At the conclusion of the Stage 1 process, the Department of Defense IRP divides sites into three categories. Category 1 includes sites where no further IRP action is required. In order for a site to be included in Category 1, the data gathered during Stage 1 must be sufficient to conclude that no significant threat to human health or the environment exists at the site. This may be appropriate for sites that are fully characterized and are in attainment with environmental standards. Sites at which access to contaminants is very limited and natural biological processes are expected to degrade the contaminants without producing a threat to human health or the environment are also included in Category 1.

Category 2 includes sites requiring additional IRP effort, such as additional sampling and analysis to complete characterization of contaminants. Sites at which risk assessments have not been completed belong in Category 2, as well as sites for which an evaluation of remedial alternatives is incomplete.

Category 3 includes sites for which the feasibility study is complete and for which a remedial alternative has been recommended.

All four of the King Salmon AFS sites included in this report--the North Barrel Bluff, the South Barrel Bluff, the Naknek River seep, and the Eskimo Creek seep--have been determined to be classified in Category 2.

6.3 METHODOLOGY FOR ABANDONMENT OF TEST AND WATER WELLS

6.3.1 Introduction

Wells that are no longer in use or are in a state of physical deterioration need to be carefully sealed to:

- Prevent contamination of the groundwater source by contaminants entering the well from the ground surface
- Eliminate physical hazards
- Conserve aquifer yield
- Maintain confined head conditions
- Minimize the potential for contaminated groundwater from one aquifer to enter another aquifer

The abandonment procedure should restore as far as possible the hydrogeologic conditions that existed prior to the installation of the well.

Well abandonment procedures are specific to the type of well being abandoned. There are four known well types at King Salmon AFS currently being used for the Eskimo Creek seep groundwater investigation. Prior to the abandonment of any wells, written approval of the abandonment procedure should be obtained from the Director of the Alaska Department of Environmental Conservation. The four known well types at King Salmon AFS are:

- Cased wells under unconfined conditions (MW-1, 6, 9, 10, 16, 18, 21, and 22)
- Cased wells under confined conditions (KS-4 and KS-5)
- Gravel/sand filter pack wells under unconfined conditions (MW-23 through MW-40)
- Gravel/sand filter pack wells under confined conditions (MW-41 through MW-43)

Abandonment procedures specific to each well type are discussed in the following subsections.

6.3.2 Cased Wells Under Unconfined Conditions

The geologic log for USCOE wells MW-1, MW-9, MW-10, MW-16, MW-18, MW-21, and MW-22 did not indicate the placement of a sand or gravel pack around the well casing. The well casing consists of 1-1/2-inch diameter PVC with glued, coupled joints. This type of construction is generally not strong enough to allow extraction of the well casing. Additionally, these wells have been constructed in areas where groundwater contamination is known to exist. The abandonment procedure may consist of the following.

1. The well is measured to record the static water level in the well and the total depth. The measured depth is compared with the construction depth to ascertain whether there are obstructions that may interfere with placement of sealing materials. Obstructions are removed. The volume of the well casing should be calculated to assure that sufficient sealing material is emplaced.

2. The well casing should be pressure grouted throughout the perforated section. The sealing materials should include cement grout, concrete, puddling clay or bentonite. Sealing materials placed below the static water level in the well shall be placed from the bottom up by methods that avoid segregation or dilution of material. When a tremie pipe is used to place the sealing material, the discharge end of the tremie pipe should be submerged in the grout to avoid breaking the seal while filling the annular space. The remainder of the well casing shall be filled in a similar manner.

3. The protective casing and guard post should be extracted and the exposed portion of PVC casing cut off at ground level.

4. A cement or concrete patch should be constructed over the surface exposure of the well.

6.3.3 Cased Wells Under Confined Conditions

Geologic logs for base production wells KS-4 and KS-5 indicate that these wells are cased wells that may have been constructed with a telescope well screen. The abandonment procedure for this well type consists of the following steps.

1. The well is measured to record the static water level in the well and the total depth. The measured depth is compared with the construction depth to ascertain whether there are obstructions that may interfere with placement of sealing materials. Obstructions are removed.

2. If the well construction method included the placement of a telescoped well screen, removal of the well screen is recommended. This is performed using a method called sand locking. A pipe of smaller diameter, generally one-half the diameter of the well screen, is lowered inside of the well screen. 'Angular sand particles are then placed in the annular space between the pulling pipe and the well screen. The sand particles form the sand joint that serves as a structural connection between the pulling pipe and the well screen.

3. Removal of the well casing is also recommended. This can be accomplished by pulling up the well casing using a cable tool drilling rig, vibration hammers, or hydraulic jacks. If the well construction method includes leaving the casing drive shoe in place, a casing cutter may be used to separate the drive shoe from the casing to facilitate removal of the well casing.

   If the well casing cannot be removed, the casing should be perforated from the bottom to within 5 feet of the land surface. Perforations should be at least four equidistant cuts per row, with one row per foot of well casing. Each cut should be a minimum of 1-1/2 inches long. The perforations are necessary to allow contact of the sealing material with the walls of the borehole.

4. As the well casing is being withdrawn, sealing materials such as cement grout, neat cement, or bentonite are placed concurrently into the borehole using a dump bailer or tremie pipe. The sealing material is placed from the bottom up to avoid segregation or dilution of these materials. When a tremie pipe is used, it is submerged at the discharge end to avoid breaking the seal while filling the annular space.

6.3.4 <u>Gravel/Sand Filter Pack Wells Under Unconfined Conditions</u>

These wells have been constructed using 2-inch-diameter flush-threaded PVC well casing. The construction also includes a 2- to 5-foot bottom sump with a fitted end cap. This type of installation is not compatible with a concurrent casing extraction, seal material emplacement procedure.

Abandonment procedures are the same as those presented for casing wells under unconfined conditions, Section 6.3.2.

6.3.5 <u>Gravel/Sand Filter Pack Wells Under Confined Conditions</u>

These well types have been constructed using 4-inch-diameter, flush-threaded PVC well casing. The construction also includes a 1- to 6-foot bottom sump with fitted end cap. This well installation type cannot be extracted while concurrently placing sealing materials.

The abandonment procedure should consist of the following steps.

1. The static water level and total depth should be measured. The measured depth is compared with the construction depth to ascertain whether or not there are obstructions that may interfere with placement of sealing

material. Obstructions are removed. The volume of the well casing should be calculated to assure that sufficient sealing material is emplaced.

2. A cement grout or concrete plug should be placed in the confining stratum overlying the confined zone to minimize subsurface leakage from the confined zone. The remainder of the well should be filled with cement grout, concrete, or bentonite.

3. The protective casing and guard posts should be extracted, and the exposed portion of PVC casing cut off at ground level.

4. A cement or concrete patch should be constructed over the surface exposure of the well.

Records of the abandonment procedure are kept to provide future reference and to demonstrate to federal or state agencies that the abandonment was properly performed. Information to be recorded should include:

- The depth of each layer of all sealing materials
- The quantity of sealing materials used
- Physical changes made to the well casing (e.g., perforations)

CVR193/051

REFERENCES

11th Weather Squadron, Elmendorf AFB, AK. 1942-82.

Alaska Department of Community and Regional Affairs. "King Salmon Community Map." 1982.

Alaska Department of Education, personal communication. September 1987.

American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 16th Edition, 1985.

Benson, R.C., and others. Geophysical Techniques for Sensing Buried Wastes and Waste Migration. USEPA-EMSL. 1982.

Bouwer, H. and Rice, R.C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells," Water Resources Research, 12 (1976):423-28.

Code of Federal Regulations, Guidelines Establishing Test Procedures for the Analysis of Pollutants. 40 CFR 136.

CH2M HILL, Phase II--Task 1, Presurvey Report, Shemya Air Force Base and King Salmon Air Force Station, June 1986.

Dumond, Don E. "Archaeology on the Alaska Peninsula: The Naknek Region, 1960-1975. University of Oregon. 1981.

Engineering Science, 57 Executive Park South, NE, Suite 590, Atlanta, Georgia 30329. September 1985.

Engineering Science, Installation Restoration Program Phase I: Records Search, Alaskan Air Command Southern Region (King Salmon AFS, Cape Newhaven AFS, Cape Romanzof AFS, Cold Bay AFS, Sparrejohn AFS, and Tatalina AFS), September 1985.

Kruseman, G.P. and DeRidder, N.A., Analysis and Evaluation of Pumping Test Data, 3rd Edition 1983, ILRI, The Netherlands.

Patrick, James H., and P.E. Black. "Potential Evapotranspiration and Climate in Alaska by Thornthwaite's Classification." Pacific Northwest Forest and Range Experiment Station, Department of Agriculture, Juneau, Alaska. Forest Service Research Paper PNW 71. 1968.

USAFOEHL, King Salmon AFS, Alaska, Installation Restoration Program Proposed Order 5 (later adjusted to Proposed Order 6), Scope of Work, July 6, 1987.

U.S. Air Force Director of Public Affairs. Personal communication. September 22, 1987.

U.S. Census Bureau. Personal communication. September 1987.

U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, 1979, Revised March 1983.

U.S. Environmental Protection Agency, SW 846, Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition, 1986.

jy/CVOR193/064.WP