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Paraho Environmental Data

Part I. Process Characterization

Part II. Air Quality

Part III. Water Quality

Published June 1980

Prepared for

U.S. Department of Energy
Assistant Secretary for Environment
Office of Environment

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Prepared by
R. N. Heistand — R. A. Atwood — K. L. Richardson
Paraho Development Corporation

Prepared for
U.S. Department of Energy
Assistant Secretary for Environment
Office of Environment
Washington, D.C. 20858

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PARAHO ENVIRONMENTAL DATA

Part I

Process Characterization

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April, 1980

PREFACE

During the period of 1973-1978, Development Engineering, Inc. (DEI), a subsidiary of Paraho Development Corporation, conducted an extensive demonstration of the Paraho technology for surface oil shale retorting at Anvil Points, Colorado. Approximately 100,000 barrels of crude shale oil were ultimately produced on behalf of the U.S. Navy, and subsequently refined into several military fuels. Since the potential environmental, health, and safety impacts of oil shale retorting are of concern and must also be ascertained, a considerable amount of environmentally-related research was also conducted as part of this effort by DEI and by other investigators under the auspices primarily of the Department of Energy (DOE) and the Environmental Protection Agency (EPA). This body of data represents the most comprehensive environmental data base relating to surface retorting that is currently available. In order to make this information available to other government agencies, the industry, and the public in a useful form, the DOE Office of Environment has undertaken to compile, assemble and publish this environmental data.

The compilation has been prepared by DEI, under contract to DOE, with the assistance of nearly 50 technical experts from government, industry, and universities. For convenience, the data base has been subdivided into eight categories as follows: I. Process Characterization, II. Air Quality, III. Water Quality, IV. Ecology, V. Land Disturbance, VI. Health Effects, VII. Occupational Health and Safety, and VIII. End Use. Each of these sections have been examined by a panel of experts and by a governmental interagency group including individuals from DOE, EPA, USGS, and other agencies as appropriate. This report includes the process characterization, air quality, and water quality categories. Others will be issued as they are completed.

This report was prepared under Contract Number EP-78-C-02-4708.A000 for the Department of Energy. Sponsorship of the effort to produce this report does not imply approval of any of the details of this report by the Department of Energy.

The authors of this report would like to acknowledge the assistance of the Process Characterization Panel for their helpful comments and criticisms on the format, details, and conclusions made in this report. This Process Characterization Panel consisted of the following persons:

Jon Fruchter, BNW

Dick Poulson, DOE

Dale Spall, LASL

PROCESS CHARACTERIZATION

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1-1
	1.1 Paraho Anvil Points Operation	1-1
	1.2 Paraho Technology	1-1
	1.3 The Paraho Process	1-2
	1.4 Characterization Background	1-4
	1.5 General Information	1-5
2.0	SOLIDS	2-1
	2.1 General	2-1
	2.2 Organic Data	2-1
	2.3 Major Elements	2-2
	2.4 Minor Elements	2-3
3.0	LIQUIDS	3-1
	3.1 General	3-1
	3.2 Product Oil	3-1
	3.3 Process Water	3-2
4.0	GASES	4-1
	4.1 General	4-1
	4.2 Product Gas	4-1
	4.3 Thermal Oxidizer	4-2
	4.4 Miscellaneous Stacks	4-3
5.0	QUALITY ASSURANCE	5-1

LIST OF FIGURES

		Page
1.1	The Paraho Retort, an Isometric Diagram	1-10
1.2	Paraho Direct Heated Mode	1-11
1.3	Paraho Operations Schematic	1-12
1.4	Anvil Points Operations Schematic	1-13
1.5	Retort Samples	1-14
2.1	Raw Shale Sampling System	2-5
4.1	Recycle Gas - Hydrogen Sulfide and Ammonia	4-4

LIST OF TABLES

		Page
2.1	Solids - Fischer Assay Data	2-6
2.2	Solids - Organic Elemental Data	2-7
2.3	Solids - Organic Species	2-8
2.4	Solids - Major Elements	2-9
2.5	Solids - Trace Elements	2-10
3.1	Crude Shale Oil - Major Elements	3-5
3.2	Crude Shale Oil - Trace Elements	3-6
3.3	Product Water - Bulk Properties	3-7
3.4	Product Water - Major Species/Gross Salinity	3-8
3.5	Product Water - Trace Elements	3-9
3.6	Product Water - Organic Analysis	3-10
3.7	Product Water - Miscellaneous Data	3-11
3.8	Recycle Gas Line Drain	3-12
3.9	Recycle Gas Condensates	3-13
3.10	Evaporation Pond - Gross Salinity	3-14
3.11	Evaporation Pond - Organics	3-15
3.12	Evaporation Pond - Trace Elements	3-16
3.13	Evaporation Pond - Miscellaneous Parameters	3-19
4.1	Product Gas - GC Data	4-5
4.2	Product Gas - Trace Organics	4-6
4.3	Product Gas - Sulfur and Nitrogen Gases	4-8
4.4	Product Gas - Toxic Elemental Analysis	4-9
4.5	Product Gas - General Elemental Analyses	4-10
4.6	Product Gas - Particulates	4-12
4.7	Thermal Oxidizer - GC Data	4-13
4.8	Thermal Oxidizer - Sulfur and Nitrogen Gases	4-14
4.9	Thermal Oxidizer - Trace Elements	4-15
4.10	Thermal Oxidizer - General Elemental Analysis	4-16
4.11	Thermal Oxidizer - Particulate Loading	4-18
4.12	Thermal Oxidizer - Particulates, Elemental Analyses	4-19
4.13	Heater and Boiler Stack Effluents	4-20
5.1	Enrichment Ratios	5-2
5.2	Mass Balances	5-4

1.0 INTRODUCTION

1.1 Paraho Anvil Points Operation

From 1973 to 1976, the Paraho Oil Shale Demonstration, a 3-year, $10 million research program, privately sponsored by 17 participants, was carried out to demonstrate the operability of the Paraho technology in retorting oil shale. Retorting operations were carried out in Direct Heated, Indirect Heated, and Combination Modes. Because of the research nature of that earlier program, there was practically no environmental monitoring of the Paraho operations. The environmental monitoring carried out during that time was performed to obtain some qualitative information or to define valid sampling, preparation, and analytical procedures useful in assessing oil shale retorting operations.

During 1977-1978 both Paraho retorts, the 2-1/2 ft I.D. pilot plant and the larger 8-1/2 ft I.D. semi-works retorts, were operated in the Direct Heated Mode to produce 100,000 barrels of crude shale oil for testing by the U. S. Navy. It was during these operations, especially during 1977, that most of the process characterization environmental data were obtained.

1.2 Paraho Technology

The main portion of the Paraho technology is the Paraho retort. An isometric drawing of a Paraho retort is presented in Figure 1.1. The retort consists of a refractory-lined, mild steel cylindrical shell. The only moving parts are: rotary seals, top and bottom to prevent the escape of gases; a rotating shale spreader at the top to assure even distribution of raw shale across the bed; and the grate mechanism at the bottom to assure the even flow of shale throughout the retort. Other parts of the retort are the off-gas collector and the air-gas distributor. The off-gas collector separates the off-gas, containing the oil mist, from the incoming shale. The air-gas distributors provide even distribution of the air-gas mixture across the shale bed. The dilution gas and the multiple level of air-gas distributors control the maximum bed temperatures so that sufficient heat is introduced to assure

complete retorting without excessive, heat-wasting carbonate decomposition reactions.

As shown in Figure 1.2, the functional zones within the Paraho retort are:

- Mist Formation Zone. As the gas stream is cooled by the descending shale, oil vapors condense into a stable fog entrained by the now cooled gas.
- Retorting Zone. The preheated shale from the mist formation zone is heated further by gaseous products of combustion from below. The organic matter (kerogen) in the shale decomposes to evolve oil vapors and gas and to leave a carbonaceous residue in the retorted shale particles.
- Combustion Zone. This zone extends in the region of the top and middle distributors which inject and distribute an oxygen containing gas mixture over the cross-section of the shale bed. The carbonaceous residue of the retorted shale along with some of the gas serve as the fuel in this combustion zone.
- Retorted Shale Cooling Zone. This zone has the principal function of recovering some of the sensible heat in the retorted shale. This conserved heat reduces overall process heat requirements and preheats recycle gas entering the combustion zone.

1.3 The Paraho Process

A diagram of the Direct Heated Mode is shown in Figure 1.2. The heat needed for retorting is supplied internally by the combustion of the organic carbon remaining on the retorted shale after the oil and gas have been removed. No external fuel is needed, the raw shale feed provides all of the fuel needs. The energy efficiency is enhanced by using the shale carbon residue as fuel. In addition to the liquid oil product, a fuel gas is produced

which can be used to produce steam and generate electricity. The principal change between the Direct Heated Mode and the Indirect Heated Mode is the replacement of the air blower (shown in Figure 1.2) with external heaters. The heat needed for retorting is supplied by these heaters. An external fuel source is needed. The heated recycle gas serves as the heat carrying medium to heat the shale to retorting temperature. Since no combustion occurs within the retort in the Indirect Heated Mode, the organic carbon remaining on the retorted shale is not utilized. The product gas has a high heating value as it is not diluted with by-products of combustion. The Combination Mode is a combination of the Direct Heated and Indirect Heated Modes.

The Paraho retort provides gas-to-solids contact and the counter-current flow of the gas and solids make it a heat exchanger. The shale flows downward by gravity as a continuous moving bed and the gas flows upward. The shale is progressively heated by ascending hot gases. The shale is preheated and retorted before it reaches the top gas/air distributor. The shale continues downward over the distributors and begins to cool as it moves below the middle distributor. It continues to cool until it moves past the distributors built into the top of the grate. The shale then flows through the moving grate and is discharged by a pressure seal at the bottom of the retort.

In the Direct Heated Mode, the cool recycle gas enters the bottom of the retort through distributors built into the grate. The gas, as it ascends through the shale bed, is heated by the descending retorted shale which, in turn, is cooled. The additional process heat requirements are generated by injecting air into the distributors. This air utilizes the carbon in the retorted shale and burns some of the gas. The air is diluted by recycle gas to moderate the otherwise high local temperatures in the combustion zone and to distribute the heat evenly across the bed.

All of the gases pass through the combustion zone and are heated. These gases transport enough heat to retort the shale in the zone just above the top distributor. They also sweep the oil vapors out of the retorting zone and are cooled rapidly by the incoming raw shale. The vapors condense into an oil mist near the top of the retort. The mist and gases leave the retort through off-gas collectors and are piped to oil-gas separators. The separators remove the mist from the gas and send the oil to storage.

1.4 Characterization Background

Essentially all of the monitoring studies compiled in this report involved Semi-Works Direct Heated Mode operations. Many of the process streams and effluents from the smaller Pilot retort were too small to provide valid samples. Even some of the process streams and effluents from the larger Paraho Semi-Works retort were too small and variable to provide adequate, valid, and reliable samples. This is particularly true for process water samples.

A general schematic of the Paraho Anvil Points operation is pictured in Figure 1.3. A more detailed schematic is pictured in Figure 1.4. Not pictured are the fugitive dust and gas emissions which can occur from the various parts of the overall operations. These are compiled and discussed in Volume II, Air Quality. Raw shale is blasted in the room and pillar mine, located in the Mahogany Zone at 8,000 ft. elevation. The mined shale is hauled down a 5.5 mile road using 50-ton haul trucks. The shale is hauled to stockpiles or the crushing-screening operations at the 6,000 ft. elevation. At these operations, the mine-run shale is crushed and screened to a nominal + 1/2", - 2-1/2" (plus one-half inch to minus two-and-one-half inch) size for retort feed. Two streams of fines material (- 1/2", or minus one-half inch) are discarded at the crushing-screening operations. The properly sized shale is conveyed to the storage bins. Before being conveyed to the top of the retorting structure, the shale passes across a polishing screen. Here any remaining fines are discarded and any dust adhering to the raw shale is removed. This dust, removed by the polishing screen along with any generated at transfer points along the covered conveyor system, is transported to the raw shale bag house and eventually discarded as raw shale dust. The retorted shale exits from the bottom of the retort at 300-400°F and is transported by a second covered conveyor system to the retorted shale disposal area. Any dust, generated by the retorted shale passing through double rotating seals at the bottom of the retort and at the transfer points along the covered conveyor system, is transported to the retorted shale bag house and eventually discarded as retorted shale dust. The gases flowing countercurrent to the shale flow within the Paraho retorts exit through off-gas collectors located in the top of the retort. This off-gas carries the product oil as a mist to the oil-gas separators where wet oil is removed. A portion of the oil-free gas is returned as recycle gas to the

retort; the balance of the gas, the product gas, is piped to a thermal oxidizer where it is combusted to prevent hydrocarbon emissions. The composition of product gas and recycle gas is the same. Waste water is periodically drained from the recycle gas blower and lines. The wet oil is sent to run-down tanks (not shown in Figure 1.3) where it is gauged and sampled for laboratory analysis. From the run-down tanks, the wet oil is piped to an oil-water separation tank. Here, dry shale oil is separated from product water by decantation.

All of the effluents shown in Figure 1.5 have been sampled and analyzed along with the raw shale feed. Since most of these effluents are common streams for both the Pilot and Semi-Works retorts, it is difficult to assess the characterization of these streams and relate it to a specific retorting operation. However, in order to assess the effect of retorting on the fate of various elements, several researchers performed balances around the Semi-Works retort. A schematic of the samples is shown in Figure 1.3. Obtaining a representative sample of product water was a problem since the total production rate (even from the larger Semi-Works) was only 8-10 gal/hr. Samples of product water were usually obtained in the laboratory by performing a separation on a composite sample of wet product oil.

1.5 General Information

The data compiled in this volume has been arranged into four categories. These categories are:

- Solids
- Liquids
- Gases
- Quality Assurance

Included in the raw shale category are the following: raw shale feed, crushed and screened for feedstock to the Paraho retorts; raw shale fines, the - 1/2" (minus one-half inch) material rejected from the crushing and polishing screen operations; raw shale dust, collected from the raw shale dust baghouse. Any fugitive dust emission data are not compiled in this volume. Included in the retorted shale category are the material conveyed to the disposal area and the retorted shale dust collected from the retorted shale dust baghouse. Liquids

include crude shale oil and process water. Crude shale oil samples include wet oil from the run-down tanks and the dry oil from the oil-water separation tanks. Since the water is removed in the laboratory before performing chemical analyses, the data from the two oil samples are presented together. Process water includes the following: product water drained from the crude shale oil; process water, condensed and drained from the recycle gas blower and lines; evaporation pond, a collection of waters from the industrial sewer system, leachate from the retorted shale, and surface runoff from the retorting, shale disposal and oil storage areas. Included in the gases are the recycle, or product, gas and the stack gas from the thermal oxidizer. Not compiled in this volume are the fugitive gas emission data.

Since the scope of this data compilation is the Paraho process characterization data relating to environmental aspects, not all the characterization data have been compiled. For example, the physical properties of the crude shale oil (gravity, viscosity, and pour point) have not been compiled. In the case of the solid samples, the ash, moisture, and carbonates (mineral CO_2) have not been compliled, but the oil yield data (Fischer Assay) are included. Since most oil shale retorting operations are ranked on the basis of oil production, these data (though not necessarily an environmental aspect) have been included in this compilation.

This compilation represents all of the data received or obtained by the Paraho Laboratory by December 1979. Although the data base, provided by this volume, is essentially a complete representation of the Paraho operations at Anvil Points, there are a number of liquid and solid samples which had been collected for which data have not been received.

In order to keep this report (especially the tables and figures) as concise as possible, abbreviations are used. Since these abbreviations refer to technical terms, government agencies, and corporate names, a list of these abbreviations is included in this section (see pg 1-9). Common symbols of the chemical elements have not been considered as abbreviations.

The bibliography included in this section is a listing of the data base reports received by Development Engineering, Inc. (DEI) by December, 1979.

The entire data base dealing with the environmental, health and safety aspects of the recently-completed Paraho operations at Anvil Points is incomplete. However, it is believed that most of the data pertaining to process characterization has been received by DEI and has been presented in this report.

PROCESS CHARACTERIZATION

PARAHO OPERATIONS

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LIST OF ABBREVIATIONS

AA	-	Atomic Absorption Spectroscopy
BNW	-	Battelle Pacific Northwest Laboratories
C.O.D.	-	Chemical Oxygen Demand
CSM	-	Colorado School of Mines
CTE	-	Commercial Testing and Equipment, Inc.
CVAA	-	Cold Vapor Atomic Absorption
DEI	-	Development Engineering, Inc.
FAA	-	Conventional Flame Atomic Absorption
FES	-	Flame Emission Spectroscopy
FID	-	Flame Ionization Detector
g	-	Gram
g/l	-	Grams per Liter
Gal/Hr	-	Gallons per Hour
G.C.	-	Gas Chromatography
GE	-	General Electric
G.E. Tempo	-	General Electric TEMPO
GFAA	-	Graphite Furnace Atomic Absorption
GPT	-	Gallons per Ton
Grav.	-	Gravimetric
GSRI	-	Gulf South Research Institute
Gulf	-	Gulf Energy and Mineral Company
ID	-	Inside Diameter
INAA	-	Instrumental Neutron Activation Analyses
ISE	-	Ion Selective Electrode
Leco	-	Leco Sulfur Analyzer
ug/l	-	Micrograms per Liter
mg/l	-	Milligrams per Liter
ug/m^3	-	Microgram per Cubic Meter
mg/m^3	-	Milligram per Cubic Meter
MS	-	Mass Spectroscopy
MW	-	Molecular Weight
ND	-	Not Determined
NRL	-	Natural Resources Laboratory, Inc.
PAR	-	Paraho Development Corporation
PES DC	-	Coupled Plasma Emission Spectroscopy
ppm	-	Parts per Million
Precip.	-	Precipitation
RCAA	-	Radiochemical Neutron Activation Analysis
RMT	-	Rocky Mountain Technology, Inc.
SSMS	-	Spark Source Mass Spectroscopy
TC	-	Thermal Conductivity Detector
Titr.	-	Titration
TRW	-	TRW Environmental Engineering Division
TSS	-	Total Suspended Solids
WCC	-	Woodward-Clyde Consultants
XRF	-	X-ray Fluorescence

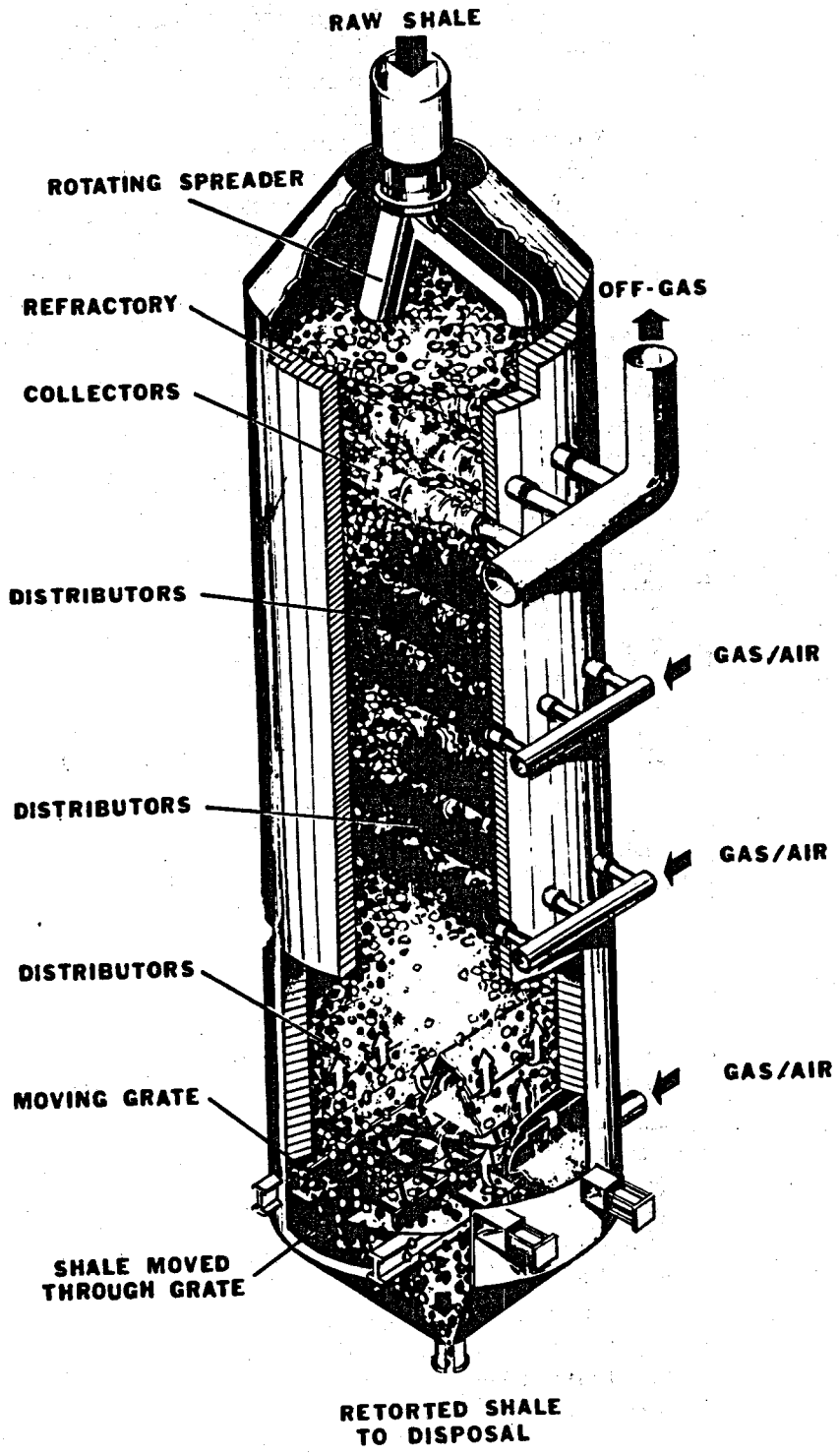


FIGURE 1.1

PARAHO RETORT

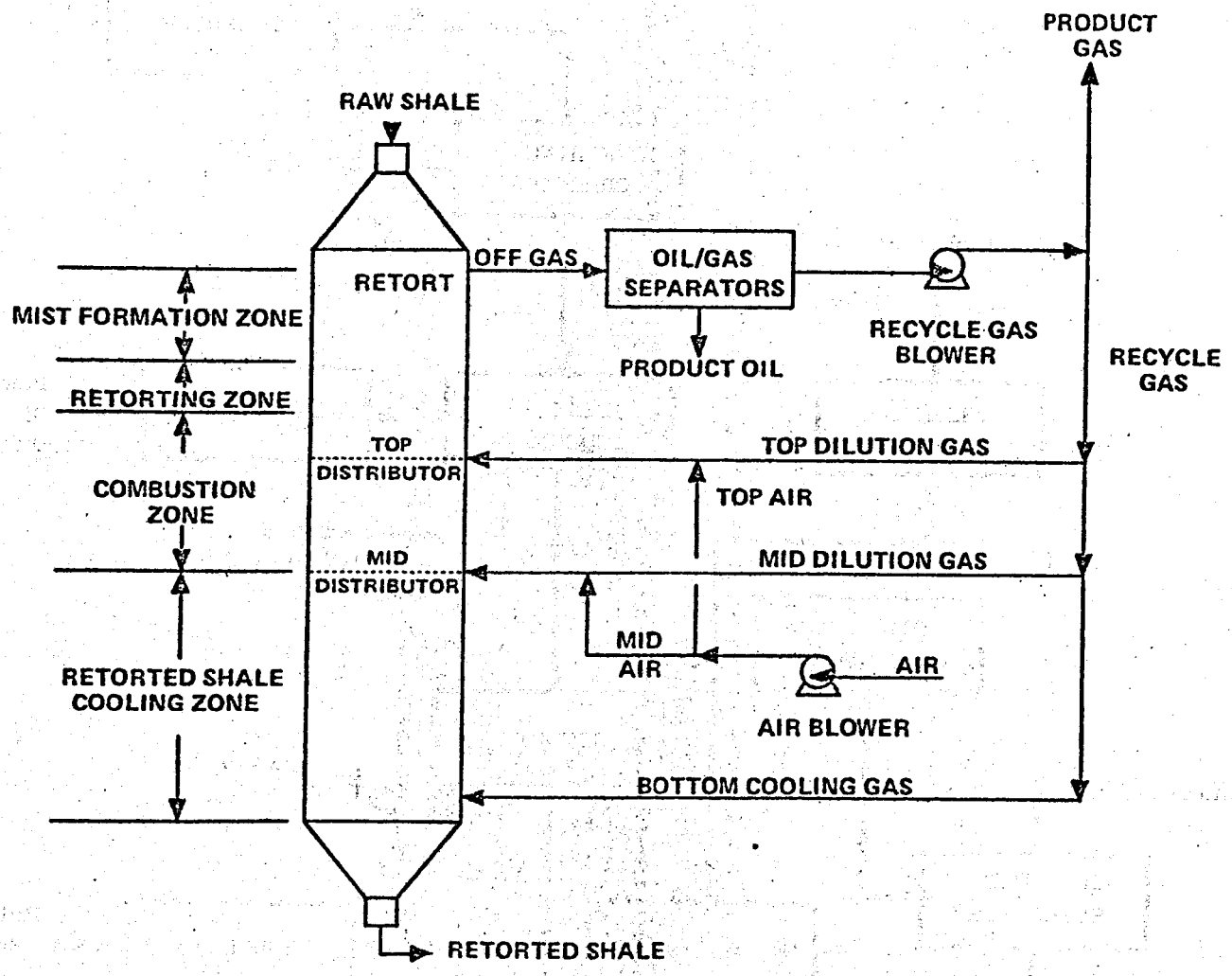


FIGURE 1.2

PARAHO
DIRECT HEATED
MODE

FIGURE 1.3

PARAHO SCHEMATIC

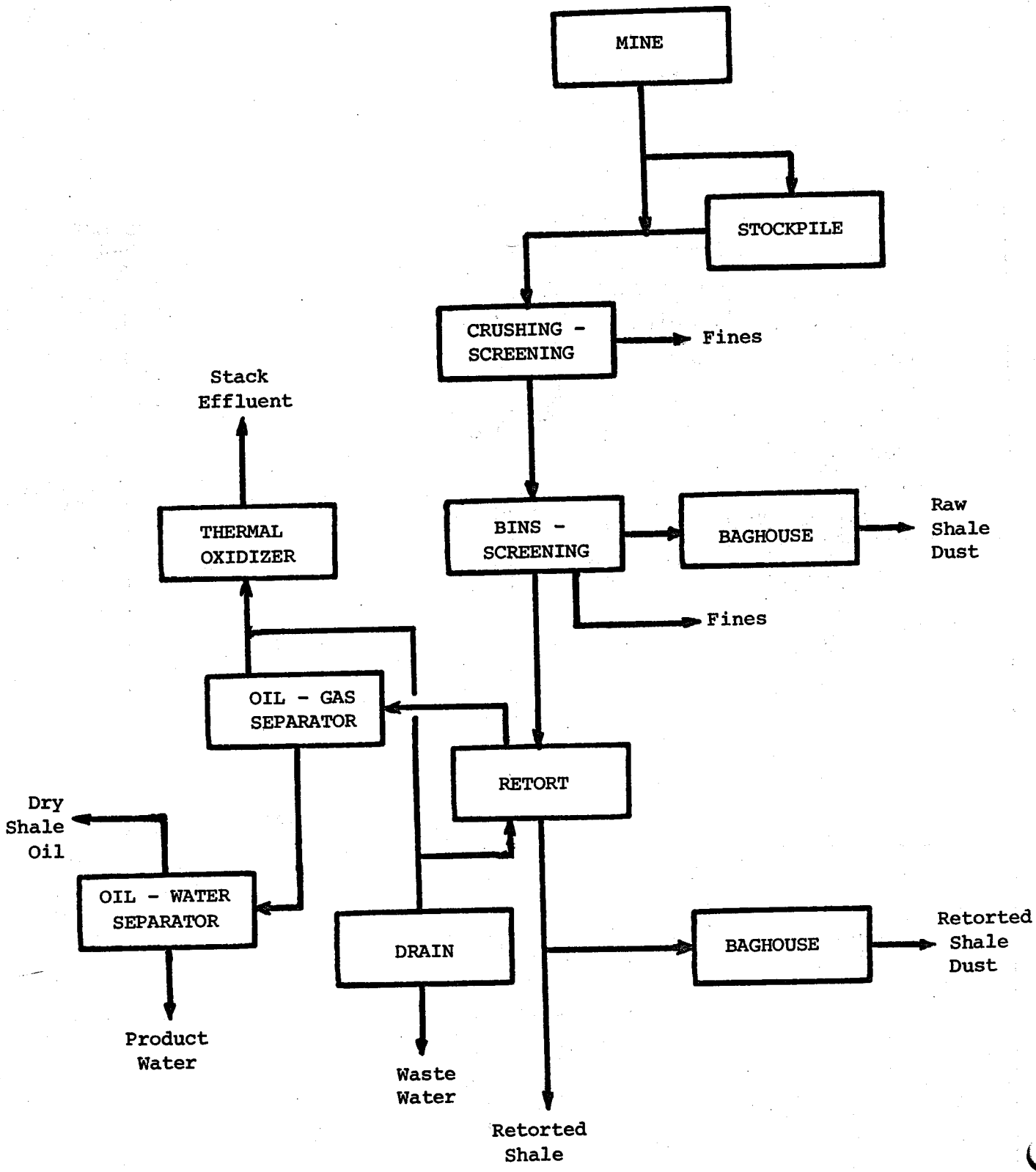


FIGURE 1.4

ANVIL POINTS OPERATIONS

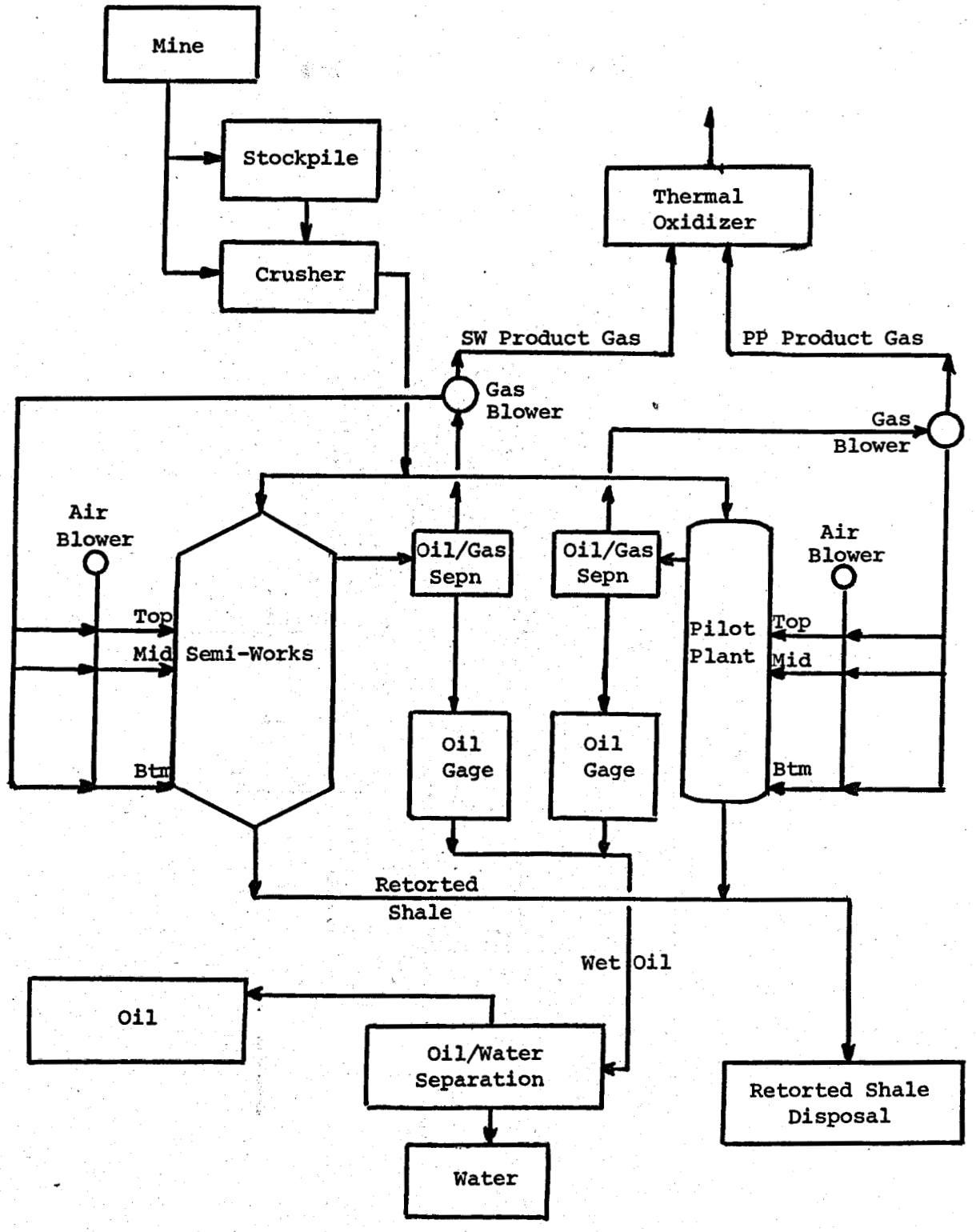
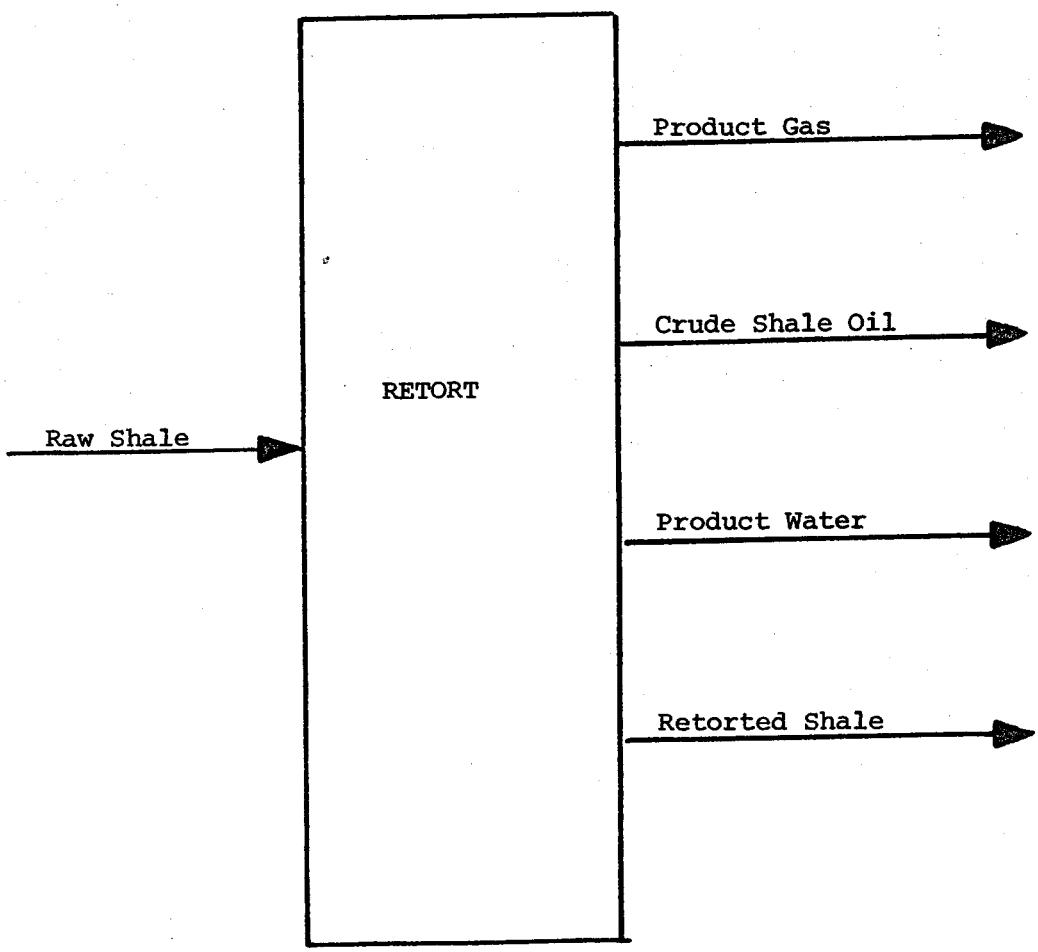


FIGURE 1.5

Retort Samples



2.0 SOLIDS

2.1 General

Well-designed sampling systems to obtain representative samples of raw shale feed and retorted shale were an integral part of the Paraho operations. Although designed to obtain valid and representative samples for the calculation of yields and material balances, they also provided samples for researchers examining the environmental aspects. A schematic of the raw shale sampling system is pictured in Figure 2.1. It consists of an automated, mechanically-operated flop gate, a crusher, a four-stage splitter, a second crusher, and a second four-stage splitter. The mechanical flop gate is set to divert 40-60 samples of raw shale feed per 24-hour operation into the sampling system. Each sample weighs about 50 pounds. The first crusher reduces the top size to - 3/4" (minus three-quarters inch); the second crusher, to - 1/4" (minus one-quarter inch). The retorted shale sampling system is similar. No systems are available for sampling fines and dust; data from these materials were obtained from grab samples taken from the appropriate streams.

Data on solid samples are grouped by analysis rather than by type of solid to permit comparisons between raw and retorted shale and between particle sizes. Tables are compiled to show organic data (Fischer Assay and the organic elements, C,H,N,S), major elemental constituents, and trace element constituents. Specific studies such as organic speciation and method assessment are compiled in separate tables.

2.2 Organic Data

Listed in Tables 2.1 and 2.2 are the organic data obtained from samples of raw shale feed and retorted shale. Because of the large data base provided by the Paraho Laboratory while monitoring the operations, these data are presented as monthly means. The large data base obtained by Colorado School of Mines (CSM) (Wildeman and Hoeffner) in a 30-day, nested-sample, statistical experiment is also presented as a mean. Overall, the data listed in Tables 2.1 and 2.2 show profound differences when comparing raw shale samples

with retorted shale samples. The CSM study showed that no individual sample can be considered representative of the shale grade (oil GPT) for a month's operation. A breakdown of the variance of the CSM data shows:

24-hour level	69%
8-hour level	0%
1-hour level	31%
analysis level	0%

These results show that analytical variance did not contribute significantly to the variance in the 30-day mean. Most of the variance was caused by differences in the 24-hour composite samples.

Determination of organic species in solids has not been assessed to any large extent. There are several studies in this area underway; no results have been published at this time. This information, particularly in dusts and retorted shale, is needed for a complete assessment of any adverse impacts on the environment or health-related aspects. Early studies in the Paraho Laboratory showed benzene extractables in the Direct Heated Mode Paraho retorted shale were $\leq$ 0.2 wt%. Some detailed examinations of this residual organic were carried out in early 1976. Results are listed in Table 2.3.

2.3 Major Elements

Major elements, generally those having concentrations greater than 0.1 wt%, are listed in Table 2.4. There appears to be significant interlaboratory differences in these data, especially since they represent means rather than individual analyses. Silicon represent total silicon; about half of this total exists as clays and complex silicates. For the most part, the data show a retorted to raw ratio of 1.2. This indicates that the elements were not volatilized during retorting. This ratio was also obtained at Battelle Pacific Northwest Laboratories (BNW) for various analytical procedures (Fruchter et al, 1979):

INAA	1.20 $\pm$ 0.02	(14 analyses)
XRF	1.21 $\pm$ 0.05	(4 analyses)
PES	1.18 $\pm$ 0.04	(8 analyses)
FAA	1.21 $\pm$ 0.05	(7 analyses)

In Table 2.4, thirty sets of data are presented as error weighted averages of various instrumental results (INAA, RCAA, XRF, PES, FAA, GFAA, and CVAA). Only two sets of data were rejected from these weighted averages: Ca, raw, by FAA; K, retorted, by PES. The ratio of the major element concentrations in retorted shale fines to raw shale averaged 1.27; the ratio of major elements of raw shale fines and dust samples to the raw shale feed averages is 1.00. Data in Table 2.4 indicate that the concentrations in fines and dust samples are the same as those found in the bulk samples.

2.4 Minor Elements

Minor elements, having concentrations expressed in ppm (less than 2,000 ppm), are compiled in Table 2.5. The data in Table 2.5 were obtained in the same fashion as those for major elements listed in Table 2.4. The general comments made regarding the major elements hold true for the minor elements. Although there is good agreement for trace elements, for the most part there is still significant interlaboratory differences. The day-to-day results used to obtain CSM means were quite consistent; relative standard deviations for these means were generally less than 10%. Mean relative standard deviation for the day-to-day results was about 8%. A breakdown of the variance for the retorted shale trace element data show a marked difference from that listed in Section 2.2 for the Fischer Assay oil data. The mean percent of variance for the trace element results is:

24-hour level	10%
8-hour level	19%
1-hour level	33%
analysis level	38%

These data show that, for the most part, any 24-hour sample would be representative of the 30-day mean. Most of the variance lies in the analytical precision. More precise methods are needed for trace element analysis of raw and retorted oil shale samples. Only one set of data was rejected from the weighted means in Table 2.5: Sr, retorted, by INAA. As in the case of the major elements, the mean concentration ratio (retorted:raw) is about 1.2. Only mercury is volatilized; its ratio is only 0.4. Arsenic is twice as high in the retorted shale dust (110 ppm) as in the retorted shale bulk sample (60 ppm).

Data in Table 2.5 show that the concentrations of trace elements in the fines and dust samples are approximately the same as those found in the bulk samples.

FIGURE 2.1

Raw Shale Sampling System

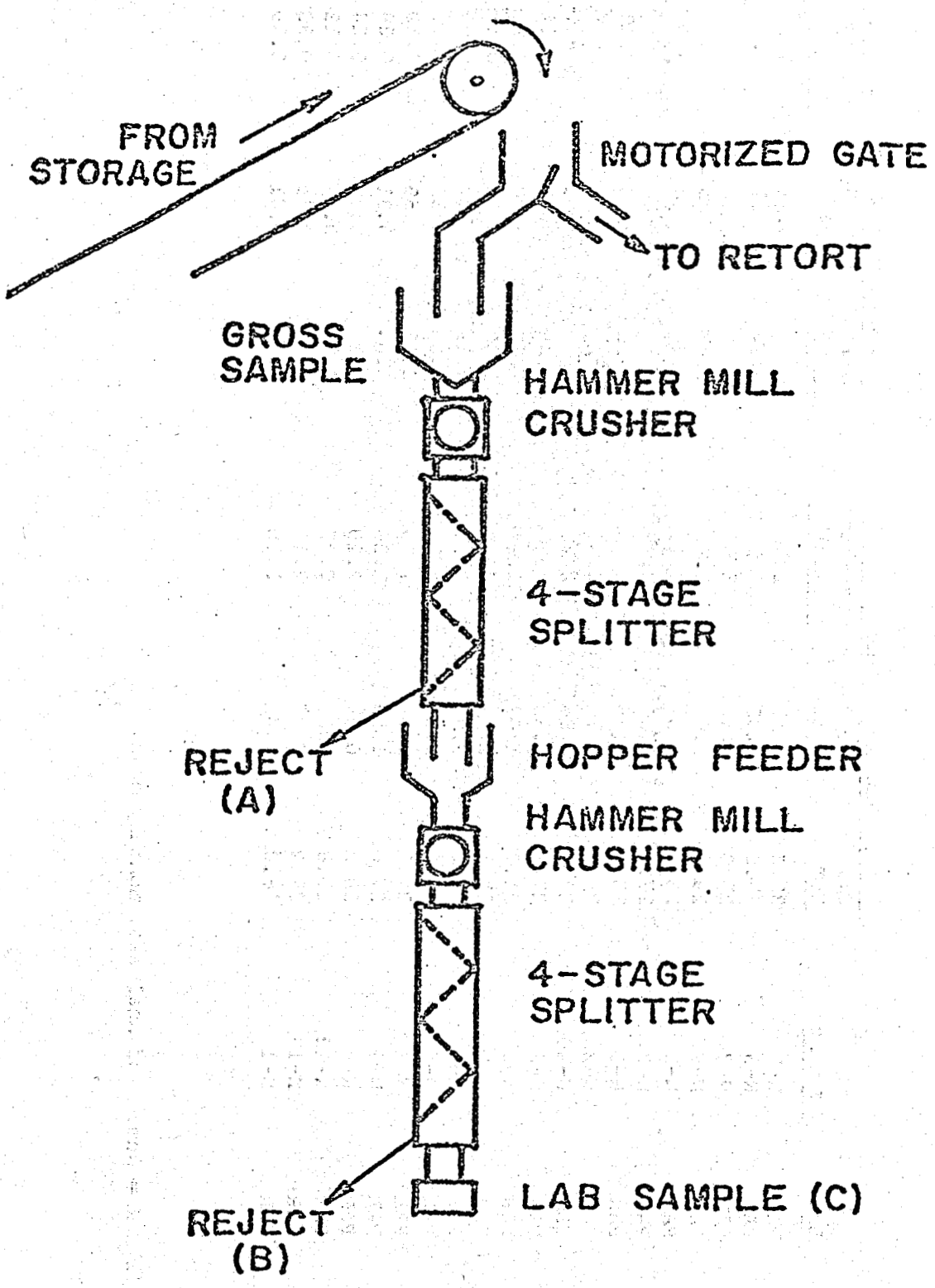


TABLE 2.1

SOLIDS

Fischer Assay Data

			Raw Shale Feed			Retorted Shale Bulk		
Date	Lab	Comments	Oil (GPT	H_2O (Wt%)	Gas + Loss (Wt%)	Oil (GPT)	H_2O (Wt%)	Gas + Loss (Wt%)
1-77	PAR	N-2 (1)	22.0	2.17	2.06	0.22	0.21	0.23
2-77	PAR	N-3	27.0	2.03	2.05	0.22	0.21	0.18
3-77	PAR	N-2	27.0	2.32	1.95	-	-	-
4-77	PAR	N-2	29.0	1.64	1.90	0.42	0.83	0.08
5-77	PAR	N-2	26.5	1.81	2.12	0.49	0.24	0.69
6-77	PAR	N-2	27.3	1.69	2.29	-	-	-
7-77	PAR	N-2	33.0	1.95	2.59	0.33	0.10	0.00
8-77	PAR	N-2	28.7	0.70	2.68	-	-	-
8-23/9-20	CSM	N-40	27.0	1.84	2.20	-	-	-
9-77	PAR	N-2	28.8	1.33	2.23	0.35	0.23	0.44
10-77	PAR	N-2	26.3	1.07	1.94	0.37	0.28	0.06
11-77	PAR	N-2	27.1	1.02	2.32	0.42	0.66	0.07
12-77	PAR	N-2	27.6	0.99	2.12	0.19	0.25	0.09
2-78	PAR	N-4	28.6	2.26	2.26	0.00	0.33	0.00
4-78	PAR	N-7	27.2	1.36	1.99	0.31	0.59	0.10
5-78	PAR	N-4	27.0	1.09	2.26	0.04	0.31	0.29
6-78	PAR	N-9	28.2	0.94	2.29	0.10	0.48	0.24
7-78	PAR	N-12	27.8	0.89	2.32	0.29	0.64	0.12
8-78	PAR	N-13	27.2	0.86	2.19	0.16	0.39	0.33
9-78	PAR	N-1	26.8	1.41	2.10	0.13	0.41	0.09

Note: (1) N = Number of analyses, monthly mean.

TABLE 2.2

SOLIDS

Organic Elemental Data

Wt%

Date	Lab	Comments	Raw Shale Feed						Retorted Shale Bulk					
			Org. C	Min. CO_2	C	H	N	S	Org. C	Min. CO_2	C	H	N	S
1-77	PAR	N-2 (1)	11.00	18.26	15.98	1.69	0.47	0.85	1.69	16.20	6.11	0.18	0.20	0.94
2-77	PAR	N-3	11.95	18.11	16.89	1.80	0.55	0.78	2.02	16.79	6.60	0.19	0.24	0.74
3-77	PAR	N-2	12.08	17.32	16.80	1.80	0.52	0.71	2.34	15.97	6.70	0.19	0.23	0.73
4-77	PAR	N-2	12.88	17.52	17.66	1.86	0.53	0.81	2.55	17.13	7.25	0.20	0.25	0.78
5-77	PAR	N-2	11.76	17.79	16.61	1.68	0.51	0.73	2.26	16.45	6.75	0.17	0.21	0.63
6-77	PAR	N-2	11.49	17.75	16.33	1.72	0.49	0.84	2.64	16.41	7.12	0.20	0.23	0.85
7-77	PAR	N-2	14.60	17.57	19.39	2.03	0.51	0.75	3.12	17.03	7.76	0.19	0.24	0.80
8-77	PAR	N-2	12.68	17.50	17.45	1.83	0.54	0.79	2.76	18.32	7.76	0.19	0.24	0.30
9-77	PAR	N-2	12.83	17.35	17.56	1.91	0.54	0.80	1.98	15.33	6.16	0.18	0.21	0.82
10-77	PAR	N-2	11.79	17.70	16.62	1.77	0.52	0.75	2.29	14.99	6.38	0.17	0.15	0.79
11-77	PAR	N-2	12.09	17.47	16.85	1.77	0.60	0.78	2.38	16.21	6.80	0.21	0.22	0.88
12-77	PAR	N-2	12.32	16.68	16.87	1.80	0.53	0.77	2.08	17.29	6.63	0.19	0.24	0.92
2-78	PAR	N-4	12.51	17.04	17.16	1.82	0.55	0.73	2.43	15.59	6.68	0.17	0.20	0.87
4-78	PAR	N-7	10.67	18.05	15.59	1.59	0.46	0.72	2.37	14.99	6.46	0.18	0.20	0.84
5-78	PAR	N-4	12.02	17.80	16.87	1.78	0.52	0.73	2.16	16.07	6.54	0.18	0.22	0.74
6-78	PAR	N-9	11.77	17.54	16.55	1.73	0.49	0.74	2.37	15.68	6.65	0.19	0.26	0.82
7-78	PAR	N-12	11.69	17.57	16.48	1.76	0.52	0.73	2.19	16.14	6.59	0.19	0.23	0.80
8-78	PAR	N-13	11.86	17.36	16.59	1.76	0.52	0.79	2.03	15.56	6.27	0.18	0.22	0.76

(1) N = number of analyses, monthly mean.

Note: Method of analysis: Min. CO_2 - Coulometer; CHN - Perkin Elmer Model 240 Elemental Analyzer; S - Leco Sulfur Analyzer.

TABLE 2.3

Solids - Organic Species

Benzene Solubles, Retorted Shale 0.03 wt%

Benzene Solubles, Water Extract 0.00 wt%

PAH Fraction of

Benzene Solubles, Retorted Shale

Compound	Concentration (Retorted Shale Basis)	
Benzo(a)pyrene	2 ppb, 2 ppb	3-12-76
	2 ppb	3-75
Coronene	(qualitatively identified)	
1,2-Benzanthracene	(qualitatively identified)	
Pyrene	(qualitatively identified)	
Fluoranthene	(qualitatively identified)	

TABLE 2.4

SOLIDS

Major Elements (Wt%)

Element	Lab	Raw Shale Feed	Raw Shale Fines	Raw Shale Dust	Retorted Shale Bulk	Retorted Shale Dust
Al	WCC				1.27	
	BNW[a]	3.79		3.80[e]	4.70	4.52[e]
	BNW[c]	3.73			4.60	
Ca	WCC				11.5	
	BNW[a]	10.9		11.1	13.4	13.4
	CSM[b]	12.5	12.7/12.1/12.9[d]	11.2	12.0	15.9
	BNW[c]	10.4			13.4	
Fe	WCC				2.03	
	BNW[a]	2.04		2.03	2.45	2.40
	CSM[b]	2.13	2.26/2.19/2.30	2.07	2.31	2.66
	BNW[c]	2.14			2.56	
K	WCC				0.60	
	BNW[a]	1.56		1.48	1.82	1.66
	CSM[b]		2.99/2.74/2.88	2.41	1.85	2.93
	BNW[c]	1.67				
Mg	WCC				4.22	
	BNW[a]	3.58		3.36	4.21	4.30
	BNW[c]	3.64			4.47	
Na	WCC				1.48	
	BNW[a]	1.68		2.23	2.24	2.60
	BNW[c]	1.77			2.36	
Si	WCC				16.1	
	BNW[a]	14.4		14.1	17.7	17.2
	BNW[c]	15.4			18.0	
Ti	BNW[a]	0.19		0.20	0.22	0.23
	BNW[c]	0.17			0.22	

(a) BNW data based on samples taken 8-23-77, 8-24-77, 8-25-77, 8-26-77 as weighted means of various instrumental methods (INAA, RCAA, XRF, PES, FAA, GFAA, and CVAA).

(b) CSM data based on means from samples taken 8-17-77, 8-23-77, 8-24-77, 8-27-77, 9-7-77, 9-15-77, 9-20-77 and obtained using XRF.

(c) BNW data based on samples taken 11-15-77, 11-16-77, 11-17-77 as weighted means of various instrumental methods (INAA, RCAA, XRF, PES, FAA, GFAA, and CVAA).

(d) Fines data from Crusher Conveyer #1, Crusher Conveyor #2, and Polishing Screen.

(e) BNW dust data from sample taken 8-24-77.

TABLE 2.5

SOLIDS

Trace Elements (ppm)

Element	Lab	Raw Shale Feed	Raw Shale Fines A[a]	Raw Shale Fines B[b]	Raw Shale Fines C[c]	Raw Shale Dust	Retorted Shale Bulk	Retorted Shale Dust
As	BNW[d]	43				46[g]	59	106[g]
	CSM[e]		46	45	45	50	60	115
	BNW[f]	44					64	
B	BNW[d]	104				104	120	105
	CSM	140					190	
	BNW[f]	83					96	
Ba	BNW[d]	526				510	625	563
	CSM		486	490	530	546	586	508
	BNW[f]	523					737	
Br	BNW[d]	0.6				< 1	0.8	< 1
	CSM		< 1	< 1	< 1	1		< 2
	BNW[f]	< 1					< 1	
Cd	BNW[d]	0.6					0.9	
	CSM		< 1	< 1	< 1	< 1		2.1
Ce	BNW[d]	43					52	
Co	BNW[d]	9				7.7	10	14.3
	BNW[f]	8					11	
Cr	BNW[d]	37					41	39
	BNW[f]	36					37	
Cs	BNW[d]	3.8					4.7	
Cu	BNW[d]	41				44	53	70
	CSM		35	34	35	30	42	63
	BNW[f]	39					57	
Dy	BNW[d]	2.4					2.4	
Eu	BNW[d]	0.66				0.58	0.71	0.69
	BNW[f]	0.65					0.82	
F	CSM	1340					1900	
Ga	BNW[d]	8.9				10.0	11.5	13.0
	CSM		7.3	6.8	7.4	6.8	7.8	7.6
	BNW[f]	8.0					11.7	
Hf	BNW[d]	1.8					2.1	
	BNW[f]	1.8					2.1	
Hg	BNW[d]	0.09					0.03	
	BNW[f]	0.10					0.02	
Ho	BNW[d]	0.7					0.9	
La	BNW[d]	19				16	24	24
Lu	BNW[d]	0.3				0.3	0.4	0.4
Mn	BNW[d]	324				344	416	419
	CSM		339	318	336	300	332	417
	BNW[f]	347					411	
Mo	BNW[d]	22				29	33	53
	CSM	29	20	20	20	27	33,43	48
	BNW[f]						33	
Nb	BNW[d]	8.7				8.0	10.3	8.0
	CSM		5.8	5.7	5.8	6.0	7.0	7.5
	BNW[f]	5.7					7.0	
Ni	BNW[d]	26				28	34	46
	CSM		35	35	36	37	35	49
	BNW[f]	25					35	
Pb	BNW[d]	26				30	34	42
	CSM		25	24	24	26	32	41
	BNW[f]	23					33	
Rb	BNW[d]	70				65	85	91
	CSM		83	82	83	81	97	106
	BNW[f]	73					87	
Sb	BNW[d]	2.1				1.9	2.8	3.5
	BNW[f]	2.1					2.9	
Sc	BNW[d]	5.9				5.4	7.1	6.5
	BNW[f]	5.8					7.0	
Se	BNW[d]	2.2				2.7	2.9	3.8
	CSM		1.5	1.6	1.5	1.5	1.6	1.6
	BNW[f]	2.5					3.3	

TABLE 2.5 (Cont'd)

Element	Lab	Raw Shale					Retorted Shale	
		Feed	Fines A[a]	Fines B[b]	Fines C[c]	Dust	Bulk	Dust
Sm	BNW[d]	3.3					4.1	
	BNW[f]	3.1					3.6	
Sn	CSM		< 2	< 2	< 2	< 2		< 2
Sr	BNW[d]	701				710	832	783
	CSM		718	740	779	757	935	954
	BNW[f]	733					877	
Ta	BNW[d]	0.6					0.7	
Tb	BNW[d]	0.4					0.4	
Th	BNW[d]	6.3				5.5	7.0	6.6
	BNW[f]	6.4					7.5	
U	BNW[d]	4.5				4.2	5.2	5.0
V	BNW[d]	89					114	143
	BNW[f]	77					102	
Y	BNW[d]	14				12	16	15
	CSM		11	11	11	11	14	12
	BNW[f]	12					15	
Yb	BNW[d]	1.3					1.6	
Zn	BNW[d]	67				80	85	103
	CSM		67	65	68	76	79	102
	BNW[f]	65					88	
Zr	BNW[d]	53				63	70	69
	CSM		72	55	56	62	68	66
	BNW[f]	63					71	

(a) Crusher Conveyor #1

(b) Crusher Conveyor #2

(c) Polishing Screen

(d) BNW data based on samples taken 8-23-77, 8-24-77, 8-25-77, 8-26-77 as weighted means of various instrumental methods (INAA, RCAA, XRF, PES, FAA, GFAA, and CVAA).

(e) CSM data based on means from samples taken 8-17-77, 8-23-77, 8-24-77, 8-27-77, 9-7-77, 9-15-77, 9-20-77 and obtained using XRF.

(f) BNW data based on samples taken 11-15-77, 11-16-77, 11-17-77 as weighted means of various instrumental methods (INAA, RCAA, XRF, PES, FAA, GFAA, and CVAA).

(g) Dust data from sample 8-24-77.

3.0 LIQUIDS

3.1 General

The most important liquid sampled at the Paraho Anvil Points operation, from the engineering, economic, and environmental aspect, is the crude shale oil. Co-produced with this crude shale oil is the product water (at about 3-5 wt%). None of the liquid streams were large enough with sufficiently constant flow or composition to permit valid on-stream monitoring as had been carried out for the raw and retorted shale.

In particular, obtaining a sample of process water was a problem. There are several sources of process water in the Paraho process which are available to the researcher. These include: product water separated from the crude shale oil; the evaporation pond, chiefly seepage from the retorted shale disposal and effluent from the industrial sewer system; and condensate drainage from the recycle gas blowers and lines.

3.2 Product Oil

Product oil composition was monitored routinely by the Paraho Laboratory in the determination of product yields and material balances. Listed in Table 3.1 are the results of this monitoring along with spot analyses by other researchers. The composition of the product oil was quite uniform. Typical concentrations are:

Total Carbon	84.73 Wt%
Total Hydrogen	11.38 Wt%
Total Nitrogen	1.99 Wt%
Total Sulfur	0.63 Wt%

The unaccounted portion, 1.27 wt%, is probably oxygen since other elements found in the crude shale oil exist only in trace amounts.

Although several studies are being carried out, there is very little data available concerning trace elements in crude shale oil at the present time. Results from a single researcher (Fruchter et al, 1979) are listed in Table 3.2.

These results are error weighted means using several instrumental procedures such as INAA, XRF, PES and FAA. Concentrations of any given element are quite uniform.

No data concerning the organic compounds in crude shale oil are available. No studies directed towards obtaining this information have been carried out with the Paraho retorting operations. Data have been obtained in conjunction with the refining operations; these will be presented in Part 8, End Use.

3.3 Process Water

Process water samples compiled in this report include the product water (co-produced with the product oil), the water condensed and drained from the recycle gas blower and lines, and the evaporation pond water. Extensive data obtained in these process waters are presented in Tables 3.3-3.13.

Product water is co-produced with the crude product oil. In an effort to produce dry shale oil for storage during 1977-1978, the product water was separated by decantation in large 1000-barrel tanks. Dry oil was pumped off the top of these tanks every few days. Water bottoms (the product water) were drained as needed into the industrial sewer system. Thus, the normal product water sample represents a broad composite in time rather than water actually produced at the time of sampling.

Bulk properties of the product water, obtained by Paraho to improve material and elemental balance closures, are listed in Table 3.3. Although there were some variations in these data, the results can be summarized as follows:

Organic Carbon	3.8 Wt%
Mineral Carbon	0.9 Wt%
Total Nitrogen	3.0 Wt%
Total Sulfur	4.1 Wt%

The solution is electrically neutral. Data listed in Table 3.3 show the nitrogen as ammonia. The organic carbon represents low molecular weight, water-soluble components of crude shale oil. The data in Table 3.3 indicate that the sulfur

does not exist as sulfide. The nature of the sulfur species in these water samples is unknown at this time. Data in Table 3.4 would indicate that a large fraction of the total sulfur exists as sulfate.

Other analyses of product water are presented in Tables 3.4-3.7. Major species contributing to gross salinity (should discharge occur) are listed in Table 3.4. The data are quite variable. Data on thirteen trace elements are presented in Table 3.5. Silver, lead, and mercury are, for the most part, below their limits of detection. Mercury, detected by flameless AA, appears to be present at the 5 ppb (5 ug/l) level. One must view the data from organic analyses presented in Table 3.6 with caution. As mentioned at the start of this section, the research studies carried out using the Paraho technology did not produce a process water stream; rather a wet oil (3-5 wt% water) was produced. The organic data shown in Table 3.6 represent, to a large degree, a measure of the time of contact between the product oil and water and the separation achieved in storage tanks and in the laboratory. Miscellaneous data are presented in Table 3.7. These data indicate that the variability found in alkalinity (3.49 $\pm$ 1.24 mg/l) is not reflected in pH (8.76 $\pm$ 0.23 pH). Note that the overall pH values are nearly neutral (8.40 to 9.16).

The samples obtained from gas line drains and by condensation represent, to a degree, the type of water which may be produced during product gas clean-up in a commercial operation. Data obtained from these samples are presented in Tables 3.8 and 3.9. Although these data obtained from the gas line drains and condensates are similar to the data obtained from oil storage tanks, there are several significant differences noted between these two process water samples. Most of the metal ions are lower in the water samples obtained from the gas - even volatile metal such as arsenic is lower. Surprisingly, some of the organic parameters, such as COD and phenol, are higher in this gas condensate water found in product water - even though the product water was co-produced with, and then separated from, the product oil. Although COD and phenol are higher in the samples drained from gas lines, the organic carbon is lower in the process water obtained from the gas line.

The lined evaporation pond, installed by Paraho in early 1974, was designed to prevent discharge into natural waters by intercepting the industrial

sewer water; seepage from the shale disposal area; and surface runoff from the retorting, oil storage, and shale disposal areas. The concentrations of parameters measured in this evaporation pond were quite variable due to the variety of input and the influence of weather (precipitation, drought, freezing, etc.). Nevertheless, the evaporation pond was monitored routinely. Many researchers and laboratories participated in this effort leading to the data presented in Tables 3.10-3.13. Even though the data are influenced by several factors and the results are difficult to interpret, this monitoring effort is justified because the samples represent a composite of waste water produced from the research operations.

In an effort to evaluate data obtained from the evaporation pond, the following table was set up comparing evaporation pond data to natural water data. The natural water parameters were monitored in the stream east of the retorting area. These data are presented more fully in Part 3, Water Quality. Data are presumed similar when higher concentration is less than three times the lower concentration.

	Pond > Natural	Same	Pond < Natural
Major Elements	Cl	Ca,Mg,K,Na SO_4,TDS	Al,Fe
Organics	COD,Org C Phenols	Oil & Grease	
Trace Elements	As,Se	Ba,B,Cu,Cd, CN,F,Pb,Hg, Ag,Zn	
Other	Tot N,$PO_4^{\equiv}$ $S^{\equiv}$	Alk,pH,Si	

These data show that, for the most part, there is no significant difference between the evaporation pond from the Paraho operations and the natural streams in the Anvil Points region. Organics, generally, are higher in the evaporation pond. Only two toxic materials, arsenic and selenium, are higher in the evaporation pond; aresenic levels in the pond range from < 0.1 to 8 ppm and selenium from < 1 to 90 ppb.

TABLE 3.1

CRUDE SHALE OIL

Major Elements

Wt%

Date	Lab	Comments	C	H	N	S
1-77	PAR	N-2 (1)	84.77	11.50	1.71	0.58
2-77	PAR	N-3	84.55	11.34	2.13	0.61
3-77	PAR	N-2	84.41	11.35	1.99	0.61
4-77	PAR	N-2	85.14	11.51	1.92	0.54
5-77	PAR	N-2	84.34	11.33	1.92	0.70
6-77	PAR	N-2	84.97	11.44	2.08	0.74
7-77	PAR	N-1	84.94	11.48	2.01	0.63
8-77	PAR	N-2	85.29	11.46	1.87	0.66
9-77	PAR	N-2	85.18	11.47	2.02	0.58
10-77	PAR	N-2	85.08	11.45	2.05	0.59
11-77	PAR	N-2	84.91	11.33	2.02	0.62
12-77	PAR	N-2	84.61	11.36	1.98	0.65
2-78	PAR	N-4	84.75	11.24	1.82	0.65
4-78	PAR	N-7	84.75	11.36	2.14	0.58
5-78	PAR	N-4	84.02	11.29	1.64	0.58
6-78	PAR	N-9	84.45	11.37	1.88	0.68
7-78	PAR	N-12	84.44	11.29	2.05	0.62
8-78	PAR	N-13	84.62	11.29	1.99	0.62
9-78	PAR	N-1	84.57	11.28	2.06	0.66

(1) N = number of analyses, monthly mean

Note: Method of Analysis: CHN - Perkin Elmer 240 Elemental Analyzer;
S - Leco Sulfur Analyzer.

TABLE 3.2

PRODUCT OIL

Trace Elements
ppm

	8/23	8/24	8/25	8/26	11/15	11/16	11/17
Al	11	16	22	10	7	3	18
As	27	31	30	29	35	36	37
Ba					< 2	< 3	< 3
Ca	42		48			34	
Co	1.1	0.9	1.4	1.0	1.4	1.3	1.2
Cr	< 0.03	< 0.05		< 0.03	< 0.1	< 0.2	< 0.1
Cu	0.7	0.4	0.7	0.5	0.4	0.4	0.4
Fe	50	49	59	53	70	59	57
Hg		0.3					
K							< 100
Mg	12	25	53	18	< 7	6	18
Mn	0.2	0.2	0.4	0.2	0.1	0.4	0.2
Mo		< 2					
Na	3	4	7	6	3	1	4
Ni		0.5	0.2	0.2	0.4	0.4	0.4
Pb	< 0.3	< 0.3	< 0.4	< 0.3	< 0.3	< 0.3	
Rb	< 0.1	< 0.1	< 0.2	< 0.1	< 0.1	< 0.5	< 0.6
Sb	0.04	0.03		0.04	0.05	0.05	< 0.03
Se	0.8	0.9		1.0	1.0	0.6	0.8
Si	55					44	
Sr	< 1	< 1	< 1	< 1	< 1	< 1	
Th	0.01	0.01		< 0.01	< 0.01	0.02	< 0.01
Ti			2.6				
U				< 0.03	< 0.07	< 0.09	< 0.08
V	0.2	0.3	0.3	0.2	0.2	0.2	0.3
Zn	0.5	0.4	0.6	0.3	0.3	0.3	0.3

Source: BNW, error weighted means from various instrumental methods.

TABLE 3.3

PRODUCT WATER

BULK PROPERTIES (%)

Date	Source	C	H	N	S	Min CO_2	H_2S	NH_3	N[1]	Comments
5-77	PAR	5.10	10.00	3.73	3.50	2.96			2	Instrument[2]
6-77		4.28	10.57	2.92	4.27	3.41			2	Instrument[2]
7-77		4.07	10.18	3.07	5.14	2.07			1	Instrument[2]
8-24-77	BNW	2.42	10.53	2.23					1	Instrument[2]
					3.90					INAA
8-25-77					5.1					
8-26-77					4.8					
8-77	PAR	2.99	10.52	2.13	3.47	2.78			3	Instrument[2]
9-77		4.52	10.53	3.00	2.74	4.10			3	Instrument[2]
9-77	CSM				3.14				1	Precip.
						2.23				Titr.
10-77	PAR	4.65	9.87	2.93	3.84	4.53			3	Instrument[2]
11-15-77	BNW				4.8				1	INAA
11-16-77					4.6					
11-17-77					2.2					
11-77	PAR	4.27	10.17	2.80	4.43	4.50			3	Instrument[2]
12-77		2.42	10.60	2.57	4.46	3.89	< 0.01	3.22	2	Instrument[2]
1-4-78		3.58	10.15	2.43	4.44	4.44	< 0.01	2.57	1	Instrument[2]
2-78		5.48	10.83	2.96	3.88	3.48	< 10 ppm	3.54	1	Inst[2], H_2S Color
4-78		3.98	10.62	1.66	3.93	0.82			4	Instrument[2]
5-78		7.35	9.97	3.84	5.70	4.65			3	Instrument[2]
6-78	CSM[3]				3.08				3	Precip.
						2.22			3	Titr.
6-78	CSM[3]				2.78				4	Precip.
						4.35			4	Titr.
6-78	PAR	5.88	9.12	6.12	6.37	6.80			10	Instrument[2]
7-78	CSM[3]				2.74				4	Precip.
						2.50			4	Titr.
7-78	CSM[3]				2.94				4	Precip.
						3.97			3	Titr.
7-78	PAR	4.82	10.21	3.89	4.33	2.24			12	Instrument[2]
8-78		6.10	10.04	4.40	4.37	2.99			13	Instrument[2]
9-78		8.06	6.66	5.64	6.49	1.00				Instrument[2]

Notes:
(1) Number of analyses - mean reported.
(2) Paraho - CHN - P.E. 240 Elemental Analyzer, S - Leco Sulfur, Min. CO_2 - CO_2 Coulometer, H_2S Titrimeter, NH_3 Colorimeter.
(3) CSM - sample taken after 8 hours in holding tank, during 9-77.

TABLE 3.4

PRODUCT WATER

MAJOR SPECIES/GROSS SALINITY (ppm)

Date	Source	Al	Cl	Ca	Fe	Mg	K	Na	$SO_4^{=}$	Si	Total Dissolved Solids	Comments
8-24-77	DNW	< 100		< 100	< 100	< 100	< 100	< 100		< 100		INAA
		< 0.4	36	38.4	3	460	38	106/115				INAA
					1.5		17	111		44		AA
										37		PES
8-25-77	DNW	0.26	65	2000	1.8	220	< 20	104/103				INAA
				35.9		258	8	112		25		AA
										22		PES
					2.6							XRF
8-26-77	DNW	0.7		64	4.2	960	65	39.6				INAA
										23		PES
										24		AA
1-4-78	PAR	< 1		23.8	4.5	400	3.2	215		48		AA
									15000		119.4	Precip.
6-1-78	PAR	< 1		0.30	8.4	680	18.6	340		16		AA)Four Analyses
			81									Titr.)on one Sample
									3300		140.1	Precip.
11-15-77	DNW	< 1		43	1.9	870	< 30	335				INAA
										34		PES
										35		AA
11-16-77	DNW	< 2	71	42	1.9	790	< 30	316				INAA
										20		PES
										28		AA
11-17-77	DNW	0.4	1.6	41	< 7	320	< 10	73				INAA
										36		PES
					5.4			70		41		AA
					2.1							XRF
9-78	CE-TEMPO			30.3	3.0	1190	67.5	521				AA
									8500			Turbidimetric
12-13-78	GSRI	0.8	1	18	28	16	17	4		12		

Note: (1) CSM - Sample taken after 8 hours in rundown tank *

* During 9-77

TABLE 3.5

PRODUCT WATER

TRACE ELEMENTS (ppm)

Date	Source	As	Ba	B	Cd	Cu	CN	F	Pb	Hg	Mo	Se	Ag	Zn	Comments
6/1/77	PAR	9	< 0.5	30	0.30	0.18	8.8	3.8	< 1		3	< 1	< 0.2	1.02	AA;CN, Color
8-24-77	BNW	5.5				< 1		2.6				9.5		0.44	INAA
		4.9				0.7			< 0.4	< 0.4	0.14	8.8		0.36	XRF
		6.9		43							0.15	11		0.15	PES
						0.66				0.0023				0.42	AA
8-25-77	BNW	4.7				0.8		1.4				4.0		0.39	INAA
		3.8				0.8			< 0.2	< 0.3	0.11	3.4		0.39	XRF
		3.1		2.1							0.30	1.5		0.24	PES
						0.91				0.0058				0.21	AA
8-26-77	BNW	5.0	0.8			0.50		10				4.0		1.26	INAA
		3.9				0.53			< 0.2	< 0.3	0.10	3.4		0.87	XRF
		4.3		13							0.07	3.8		1.08	PES
														1.02	AA
9-9-77	GE-TEMPO	22.2	0.4			2.6		43	0.4			7.9		1.5	AA
11-15-77	BNW	18.2	< 3			7.3		36				6.6		0.73	INAA
		15.1				5.5			< 0.3	< 0.5	0.52	6.8		0.80	XRF
		18.0		43							0.50			1.01	PES
						7.5				0.0056				0.87	AA
11-16-77	BNW	15.2	3			11.8		33		< 0.008		5.4		7.0	INAA
		10.8				7.7			< 0.3	< 0.5		6.5		6.7	XRF
		13.0		36							0.43	8.3		7.5	PES
						10.4				0.0063				8.5	AA
11-17-77	BNW	6.5	< 3			< 0.3		16						0.07	INAA
		4.9				0.5			< 0.3	< 0.4	< 0.10	4.1		< 0.2	XRF
		5.6		16							0.007	4.2		0.12	PES
												3.9		0.06	AA
12-13-77	GSRI	6	0.3	0.2	< 0.2			0.8	0.3		0.3	0.2	< 0.2	0.5	
1-4-78	PAR	9	< 0.5	40	0.13	2.5	1.6	0.1	3.5		0.7		0.4	0.62	AA;CN, Color

TABLE 3.6

PRODUCT WATER

ORGANIC ANALYSIS

Date	Source	Chemical Oxygen Demand	Organic Carbon %	Phenol ppm	N (1)	Comments
5-77	PAR		4.29 (2)		2	
6-77	PAR		3.35		2	
7-77	PAR		3.51		1	
8-77	PAR		2.23		3	
9-77	PAR		3.40		3	
10-77	PAR		3.41		3	
11-77	PAR		3.04		3	
12-77	PAR		1.36		2	
1-4-78	PAR	7.62			1	Titr.
			2.37			
				8.0		Color
2-78	PAR		4.53		1	
4-78	PAR		3.76		4	
5-78	PAR		6.08		3	
6-1-78	PAR	7.53			1	Titr.
			4.20			
				0.12		Color
6-78	PAR		4.03		10	
7-78	PAR		4.21		12	
8-78	PAR		5.28		13	
8-78	BNW		3.89		1	
9-78	PAR		7.79		1	

Note: (1) N - number of analyses - mean reported.

(2) Calculated by difference; (total carbon) - (12/44 x Min CO_2).

TABLE 3.7

PRODUCT WATER

MISCELLANEOUS DATA

Date	Source	Alkalinity as $CaCO_3$	pH
9-77	CSM (4)		8.88
9-77	CSM		8.80
11-15-77	BNW		8.5
11-16-77	BNW		8.55
11-17-77	BNW		8.60
1-4-78	PAR (1)	2.95 (2)	8.5 (3)
6-1-78	PAR	1.99	8.4
6-78	CSM (4)	3.60	9.16
6-78	CSM	3.60	9.15
6-78	CSM	3.30	8.78
6-78	CSM	3.81	8.75
6-78	CSM	3.09	8.97
6-78	CSM	2.84	9.07
6-78	CSM	2.64	8.63
6-78	CSM	7.80	8.68
7-78	CSM (4)	3.52	8.86
7-78	CSM	3.53	8.63
7-78	CSM	3.65	8.64
7-78	CSM	3.53	8.54
7-78	CSM	2.97	8.60
7-78	CSM	3.08	8.80
7-78	CSM		8.60
7-78	CSM		8.68
8-78	BNW		8.6

Note: (1) PAR 1-4-78 phosphate < 1 ppm, total suspended solids 168 ppm
PAR 6-1-78 phosphate < 0.1 ppm

(2) Alk. by titration, wt%.

(3) pH meter.

(4) CSM - sample taken after 8 hours in holding tank during 9-77.

TABLE 3.8

Recycle Gas Line Drain

(ppm)

Analyses	GE-TEMPO 9-9-77	GSRI 12-13-77	PAR 1-4-78	PAR 6-1-78
Aluminum		0.2	< 1	< 1
Arsenic	10.3	0.9	≤ 2	< 2
Barium	< 0.1	0.1	< 0.5	< 0.5
Boron		< 0.02	< 20	< 20
Cadmium		< 0.01	≤ 0.01	< 0.05
Calcium	13.7	4	2.8	21
Chromium	< 0.03	0.02	0.01	0.00
Copper	0.2	0.9	0.09	< 0.05
Iron	1.5	2	2.2	0.9
Lead	0.2	0.04	< 0.5	< 1
Magnesium	29.5	1	20	30
Mercury		4.8 ppb	< 5	< 7
Molybdenum		0.04	≤ 0.2	2
Potassium	2.4		0.82	2.1
Selenium	1.8	0.1	2	< 1
Silver		< 0.01	0.7	1.0
Sodium	27.6		11	60
Silicon		3	< 2	7
Zinc	0.1	0.6	0.02	0.03
Alkalinity as $CaCO_3$			19400	25000
Carbonates			13410	2514
Carbon, Total			7400	6970
Carbon, Organic			3740	6280
Chemical Oxygen Demand			1600	1850
Chloride		0.5	750	32
Cyanide			60.0	5.3
Fluoride	1.6	≃ 0.07	0.96	< 0.04
Hydrogen, Total			106900	
Nitrogen, Total			4900	5910
Nitrogen, Ammonia			5960	6985
Nitrogen, Nitrate			< 0.02	< 0.1
pH	8.9		8.9	9.0
Phenol			19.2	67
Phosphate, Total			< 1	< 0.1
Total Suspended Solids			9	< 0.02
Total Dissolved Solids*			3.3	11.9/9.3
Sulfur, Sulfate	1540		1400	460
Sulfur, Sulfide			< 1	< 0.01
Sulfur, Total			≤ 500	2570

* Values reported are for TDS after vacuum evaporation at ambient temperature and after evaporation at 180°C, respectively.

TABLE 3.9

Recycle Gas Condensates

(ppm)

Date	Source	Sampled from	Alkalinity as $CaCO_3$	Nitrogen Ammonia	Sulfur Total	pH	Mercury
12-13-77	GSRI	Recycle Cond.					0.05 mg/g
9-77	CSM	Recycle Cond.				8.70	
6-78	CSM	Recycle Cond.	85500	25100		8.56	
7-78	CSM	Recycle Cond.	86500	23500	200	8.76	
9-77	CSM	Blower Cond.				8.95	
6-78	CSM	Blower Cond.	204000	21000		9.20	
7-78	CSM	Blower Cond.	516500	7400	100	8.94	

TABLE 3.10

EVAPORATION POND

Gross Salinity

Date	Lab	TDS Method	TDS g/l	Al Method	Al mg/l	Cl (Total) Method	Cl (Total) mg/l	Ca Method	Ca mg/l	Fe Method	Fe mg/l	Mg Method	Mg mg/l	K Method	K mg/l	Na Method	Na mg/l	Sulfate Method	Sulfate mg/l
7/22/74	RMT	Grav.	0.9	AA	1.3			AA	33	AA	0.29	AA	33	FES	9	FES	150	Titr.	600
7/29/74	RMT	Grav.	1.5	AA	0.7	Titr.	61	AA	96	AA	0.07	AA	96	FES	41	FES	238	Titr.	1000
8/5/74	RMT	Grav.	1.5	AA	0.8	Titr.	70	AA	102	AA	0.09	AA	102	FES	35	FES	343	Titr.	1030
8/13/74	RMT	Grav.	1.5	AA	0.6	Titr.	46	AA	72	AA	0.10	AA	72	FES	24	FES	239	Titr.	770
10/74	RMT	Grav.	1.9	AA	0.3	Titr.	142	AA	60	AA	0.10	AA	104	FES	33	FES	289	Titr.	900
4/75	RMT	Grav.	1.0	AA	2.5	Titr.	170	AA	70	AA	0.40	AA	43	FES	27	FES	239	Titr.	280
7/75	RMT	Grav.	1.2	AA	0.7	Titr.	181	AA	80	AA	0.90	AA	51	FES	21	FES	258	Titr.	590
10/75	RMT	Grav.	1.4	AA	0.3	Titr.	227	AA	74	AA	0.20	AA	74	FES	18	FES	29	Titr.	680
3/76	TRW			SSMS	0.8	SSMS	2	SSMS	> 10	SSMS	5.0	SSMS	> 10	SSMS	> 10	SSMS	> 10		
	GE							AA	47	AA	< 0.05	AA	80.9	AA	20.9	AA	303	Turb.	110
10/77	PAR	Grav.	2.4	AA	0.10	Titr.	335	AA	92	AA	0.25	AA	77	AA	22	AA	310	Grav.	680
	NRL	Grav.	3.2	AA	< 0.5	ISE	2000	AA	88	AA	< 0.09	AA	66	FES	21	FES	310	Grav.	600
	CTE	Grav.	1.6	AA	≤ 0.1	ISE	120	AA	123	AA	0.53	AA	75	FES	23	FES	320	Grav.	249
11/77	PAR	Grav.	2.4	AA	0.30	Titr.	400	AA	100	AA	0.14	AA	78	AA	11	AA	280	Grav.	570
	NRL	Grav.	2.7	AA	< 0.05	ISE	250	AA	90	AA	0.15	AA	77	FES	24	FES	330	Grav.	770
	CTE	Grav.	1.2	AA	≤ 0.13	ISE	250	AA	100	AA	0.14	AA	77	FES	9	FES	286	Grav.	572
	BNW			INAA	< 0.8	INAA	223	PES	70	INAA	< 5	INAA	70	INAA	< 30	INAA	357		
								AA	198	XRF	< 1	PES	101	AA	24	AA	366		
										AA	2.1	AA	84						
12/77	PAR	Grav.	2.4	AA	0.17	Titr.	1100	AA	96	AA	0.24	AA	80	AA	23	AA	235	Grav.	610
	NRL	Grav.	2.7	AA	< 0.5	ISE	270	AA	93	AA	0.30	AA	75	FES	24	FES	320	Grav.	600
	CTE	Grav.	4.1	AA	≤ 0.13	ISE	660	AA	3	AA	≤ 0.02	AA	3	FES	24	FES	1016	Grav.	481
	GSRI			SSMS	0.2	SSMS	> 10	SSMS	> 10	SSMS	0.40	SSMS	> 10	SSMS	> 10	SSMS	≥ 4		
1/78	PAR	Grav.	0.6	AA	0.62	Titr.	260	AA	84	AA	1.24	AA	53	AA	6	AA	206	Grav.	410
2/78	PAR	Grav.	0.5	AA	< 0.2	Titr.	67	AA	24	AA	0.10	AA	22	AA	6	AA	81	Grav.	290
	NRL	Grav.	0.5	AA	< 1.0	ISE	50	AA	25	AA	< 0.1	AA	22	FES	3	FES	79	Grav.	180
	CTE	Grav.	0.5	AA	≤ 0.1	ISE	160	AA	23	AA	0.09	AA	21	FES	7	FES	81	Grav.	150
3/78	PAR	Grav.	1.6	AA	16	Titr.	140	AA	38	AA	0.70	AA	50	AA	6	AA	325	Grav.	520
	CTE	Grav.	1.4	AA	≤ 0.2	ISE	280	AA	52	AA	≤ 0.06	AA	66	FES	12	FES	57	Grav.	590
4/78	PAR	Grav.	2.1	AA	14	Titr.	228	AA	38	AA	0.50	AA	65	AA	6	AA	475	Grav.	750
	NRL	Grav.	2.8	AA	< 0.5	ISE	180	AA	67	AA	0.20	AA	65	FES	15	FES	160	Grav.	890
	CTE	Grav.	2.1	AA	≤ 0.3	ISE	417	AA	72	AA	0.10	AA	67	FES	18	FES	403	Grav.	790

TABLE 3.11

EVAPORATION POND

Organics

Date	Lab	Parameter			
		COD, mg/l	Oil & Grease, mg/l	Org. C, g/l	Phenols, µg/l
7/22/74	RMT	229	19		40
7/29/74	RMT	114	11		40
8/5/74	RMT	35	11		< 10
8/13/74	RMT	53	15		< 10
10/74	RMT	< 5	2		< 10
4/75	RMT	70	< 2		< 10
7/75	RMT	168	< 2		< 10
10/75	RMT	136	< 2		20
10/77	PAR	2070		1.7	420
	NRL	320		0.5	19
	CTE	1510		0.5	350
11/77	PAR	2210		1.5	410
	NRL	420		0.4	750
	CTE	1360		0.5	790
12/77	PAR	2000		0.13	490
	NRL	280		0.04	620
	CTE	1440		0.05	930
1/78	PAR	609		0.6	30
2/78	PAR	24		0.2	22
	NRL	20		0.03	25
	CTE	107		0.05	23
3/78	PAR	775		0.2	56
	CTE	719		0.06	35
4/78	PAR	748		0.2	193
	NRL	120		0.2	180
	CTE	565		0.2	264

TABLE 3.12

EVAPORATION POND

TRACE ELEMENTS

Date	Lab	As Method	As mg/l	Ba Method	Ba mg/l	B Method	B mg/l	Cd Method	Cd ug/l	Cu Method	Cu ug/l
7/22/74	RMT							AA	< 2	AA	10
7/29/74	RMT							AA	6	AA	< 10
8/5/74	RMT							AA	6	AA	10
8/13/74	RMT							AA	< 2	AA	20
10/74	RMT							AA	< 2	AA	90
4/75	RMT	H.G.	0.04			Color	0.2	AA	< 2	AA	20
7/75	RMT					Color	0.2	AA	< 2	AA	< 10
10/75	RMT	H.G.	0.04			Color	0.4	AA	< 2	AA	≤ 10
3/76	TRW	SSMS	1.0	SSMS	2.0	SSMS	5.0			SSMS	200
	GE	AA	< 1	AA	< 0.1					AA	< 10
10/77	PAR	AA	< 2	AA	0.31	AA	4	AA	60	AA	20
	NRL	AA	0.83	AA	< 0.5	AA	1.0	AA	15	AA	12
	CTE	AA	0.17	AA	0.4	AA	≤ 25	AA	18	AA	40
11/77	PAR	AA	< 2	AA	0.28	AA	2	AA	< 30	AA	10
	NRL	AA	0.8	AA	< 0.5	AA	2.0	AA	< 10	AA	5
	CTE	AA	1.2	AA	0.5	AA	≤ 11	AA	4	AA	40
	BNW	INAA	1.6	INAA	< 1	PES	0.76			INAA	< 2000
		XRF	1.2	PES	0.19					XRF	< 500
		PES	1.7							AA	< 20
12/77	PAR	AA	< 2	AA	0.30	AA	2	AA	< 30	AA	20
	NRL	AA	0.88	AA	0.5	AA	1.8	AA	< 10	AA	6
	CTE	AA	1.1	AA	0.10	AA	≤ 11	AA	≤ 3	AA	≤ 20
	GSRI	SSMS	2	SSMS	0.2	SSMS	0.3	SSMS	5	SSMS	20
1/78	PAR	AA	< 2	AA	0.05	AA	2	AA	< 30	AA	40
2/78	PAR	AA	< 2	AA	< 0.5	AA	0.2	AA	< 50	AA	10
	NRL	AA	0.05	AA	< 0.5	AA	0.2	AA	< 10	AA	6
	CTE	AA	≤ 0.04	AA	≤ 0.1	AA	0.16	AA	≤ 5	AA	≤ 20
3/78	PAR	AA	11	AA	2	AA	2	AA	< 70	AA	< 90
	CTE	AA	≤ 0.15	AA	≤ 0.12	AA	≤ 0.12	AA	≤ 3	AA	≤ 20
4/78	PAR	AA	8	AA	2	AA	2	AA	< 20	AA	< 90
	NRL	AA	0.31	AA	< 0.5	AA	< 0.5	AA	< 1	AA	2
	CTE	AA	0.27	AA	≤ 0.2	AA	≤ 0.2	AA	≤ 3	AA	20

TABLE 3.12 (Cont'd)

Date	Lab	Cyanide Method	Cyanide µg/l	F Method	F mg/l	Pb Method	Pb µg/l	Hg Method	Hg µg/l
7/22/74	RMT	Color	< 0.2	Color	1.3	AA	110	AA	4
7/29/74	RMT	Color	2.8	Color	2.4	AA	30	AA	5
8/5/74	RMT	Color	< 0.2	Color	2.3	AA	14	AA	2
8/13/74	RMT	Color	0.3	Color	2.2	AA	< 2	AA	< 1
10/74	RMT	Color	< 0.2	Color	2.8	AA	< 10	AA	6
4/75	RMT	Color	7	Color	4.5	AA	< 10	AA	< 0.2
7/75	RMT	Color	< 0.2	Color	1.7	AA	< 10	AA	< 0.2
10/75	RMT	Color	< 0.2	Color	2.5	AA	< 10	AA	14
3/76	TRW			SSMS	7	SSMS	200	SSMS	< 10
	GE			ISE	2	AA	< 100		
10/77	PAR	Color	11	ISE	4.9	AA	200	AA	< 5000
	NRL	Color	< 10000	ISE	2.5	AA	600	AA	10
	CTE	Color	25	ISE	2.0	AA	≤ 40	AA	3
11/77	PAR	Color	22	ISE	4.6	AA	200	AA	< 5000
	NRL	Color	< 10000	ISE	2.3	AA	55	AA	1.5
	CTE	Color	30	ISE	2.2	AA	≤ 40	AA	0.6
	BNW			AA	2.5	XRF	< 200	XRF	< 300
12/77	PAR	Color	23	ISE	2.4	AA	200	AA	< 5000
	NRL	Color	< 10000	ISE	2.2	AA	55	AA	1.4
	CTE	Color	≤ 10	ISE	1.4	AA	≤ 40	AA	0.15
	GSRI			SSMS	1	SSMS	20	AA	< 0.4
1/78	PAR	Color	3	ISE	0.8	AA	100	AA	< 5000
2/78	PAR	Color	360	ISE	1.2	AA	50	AA	< 7500
	NRL	Color	< 10000	ISE	0.7	AA	< 5	AA	0.2
	CTE	Color	≤ 10	ISE	0.6	AA	≤ 60	AA	≤ 2
3/78	PAR	Color	12700	ISE	1.3	AA	< 1000	AA	< 7000
	CTE	Color	≤ 10	ISE	1.3	AA	≤ 60	AA	≤ 0.2
4/78	PAR	Color	93000	ISE	1.5	AA	< 1000	AA	< 7000
	NRL	Color	< 50	ISE	1.4	AA	< 5	AA	0.2
	CTE	Color	41	ISE	1.6	AA	≤ 50	AA	0.2

TABLE 3.12 (Cont'd)

Date	Lab	Mo Method	Mo µg/l	Se Method	Se µg/l	Ag Method	Ag µg/l	Zn Method	Zn µg/l
7/22/74	RMT							AA	10
7/29/74	RMT							AA	10
8/5/74	RMT							AA	10
8/3/74	RMT							AA	10
10/74	RMT							AA	60
4/75	RMT	AA	< 200					AA	50
7/75	RMT	AA	< 200					AA	< 10
10/75	RMT	AA	< 200					AA	20
3/76	TRW	SSMS	100	SSMS	100			SSMS	400
10/77	PAR	AA	< 100	AA	< 100	AA	< 50	AA	20
	NRL	AA	< 20	H.G.	62	AA	30	AA	200
	CTE	AA	70	H.G.	2.7	AA	10	AA	20
11/77	PAR	AA	< 100	AA	< 100	AA	< 50	AA	30
	NRL	AA	< 20	H.G.	65	AA	2	AA	27
	CTE	AA	≤ 340	H.G.	10	AA	≤ 10	AA	30
	BNW	XRF	< 80	XRF	< 70			XRF	< 20
		PES	130	PES	< 200			PES	24
12/77	PAR	AA	< 100	AA	< 100	AA	< 50	AA	20
	NRL	AA	< 40	H.G.	66	AA	< 10	AA	23
	CTE	AA	≤ 340	H.G.	12	AA	10	AA	10
	GSRI	SSMS	70	SSMS	90	SSMS	< 2	SSMS	80
1/78	PAR	AA	< 100	AA	< 100	AA	< 50	AA	10
2/78	PAR	AA	50	AA	< 50	AA	< 10	AA	20
	NRL	AA	28	H.G.	6	AA	< 10	AA	22
	CTE	AA	≤ 600	H.G.	≤ 0.5	AA	≤ 20	AA	≤ 20
3/78	PAR	AA	< 500	AA	< 500	AA	< 60	AA	20
	CTE	AA	≤ 300	H.G.	≤ 0.6	AA	≤ 60	AA	8
4/78	PAR	AA	< 500	AA	< 500	AA	< 60	AA	20
	NRL	AA	50	H.G.	33	AA	< 1	AA	17
	CTE	AA	≤ 200	H.G.	0.02	AA	≤ 4	AA	20

TABLE 3.13

EVAPORATION POND

Miscellaneous Parameters

Date	Lab	Alkalinity, $CaCO_3$		pH		N, Total		PO_4 as P		Sulfide as S		Si	
		Method	mg/l	Method	Anal.	Method	mg/l	Method	mg/l	Method	mg/l	Method	mg/l
7/22/74	RMT	Titr.	163	Meter	7.7	Titr.	1.7	Color	0.08	Color	< 1	AA	4
7/29/74	RMT	Titr.	143	Meter	7.3	Titr.	2.0	Color	0.15	Color	< 1	AA	6
8/5/74	RMT	Titr.	179	Meter	8.1	Titr.	2.0	Color	0.13	Color	< 1	AA	2
8/13/74	RMT	Titr.	97	Meter	7.7	Titr.	0.8	Color	0.09	Color	< 1	AA	1.6
10/74	RMT	Titr.	189	Meter	7.3	Titr.	< 0.1	Color	0.05			AA	0.1
4/75	RMT	Titr.	104	Meter	7.7	Titr.	16.8	Color	0.20			AA	5.0
7/75	RMT	Titr.	115	Meter	7.4	Titr.	8.4	Color	< 0.01			AA	3.7
10/75	RMT	Titr.	165	Meter	7.7	Titr.	20.5	Color	< 0.01			AA	5.1
3/76	TRW											SSMS	> 10
	GE			Meter	7.9								
10/77	PAR	Titr.	806	Meter	8.4	Color	200	Color	< 1	Titr.	31	AA	6.4
	NRL			Meter	8.5	Color	280	Color	< 0.05	Titr.	18	AA	4.9
	CTE	Titr.	820	Meter	8.1	Color	60	Color	0.03	Titr.	6	AA	0.5
11/77	PAR	Titr.	850	Meter	8.2	Color	200	Color	< 1	Titr.	40	AA	6.3
	NRL			Meter	8.0	Color	280	Color	< 0.05	Titr.	34	AA	7.5
	CTE	Titr.	876	Meter	7.2	Color	260	Color	0.02	Titr.	51	AA	6.9
	BNW											PES	7.0
												AA	11
12/77	PAR	Titr.	840	Meter	7.9	Color	< 200	Color	< 1	Titr.	50	AA	6.4
	NRL			Meter	8.3	Color	280	Color	0.1	Titr.	79	AA	7.9
	CTE	Titr.	2855	Meter	11.4	Color	255	Color	0.07	Titr.	13	AA	3.1
	GSRI											SSMS	4
1/78	PAR	Titr.	240	Meter	7.9	Color	< 100	Color	< 1	Titr.	0.1	AA	2.4
2/78	PAR	Titr.	88	Meter	7.9	Color	< 100	Color	0.02	Titr.	0.4	AA	1.5
	NRL			Meter	7.9	Color	15	Color	< 0.05	Titr.	0.6	AA	1.4
	CTE	Titr.	111	Meter	8.3	Color	19	Color	0.06	Titr.	1.7	AA	1.4
3/78	PAR	Titr.	277	Meter	8.0	Color	114	Color	1.63	Titr.	0.8	AA	1.6
	CTE	Titr.	282	Meter	7.6	Color	56	Color	0.13	Titr.	4.6	AA	3.4
4/78	PAR	Titr.	444	Meter	8.4	Color	88	Color	0.54	Titr.	3.5	AA	3.6
	NRL			Meter	8.0	Color	75	Color	0.20	Titr.	16	AA	5.9
	CTE	Titr.	437	Meter	7.8	Color	100	Color	0.05	Titr.	10.2	AA	4.7

TABLE 3.13 (Cont'd)

Date	Lab	TSS Method	TSS mg/l	Cr Method	Cr mg/l	NH_3 as N Method	NH_3 as N mg/l	Nitrates as N Method	Nitrates as N mg/l	Total Sulfur Method	Total Sulfur mg/l
7/22/74	RMT	Grav.	7								
7/29/74	RMT	Grav.	14								
8/5/74	RMT	Grav.	8								
8/13/74	RMT	Grav.	19								
10/74	RMT	Grav.	27								
4/75	RMT	Grav.	48								
7/75	RMT	Grav.	18								
10/75	RMT	Grav.	27								
3/76	TRW			SSMS	0.3					SSMS	> 10
	GE			AA	< 0.03						
10/77	PAR	Grav.	73	AA	0.1	Color	190	Color	< 0.02	LECO	400
	NRL	Grav.	160	AA	0.1	Color	180	Color	< 0.05		
	CTE	Grav.	252	AA	0.1	Color	176	Color	4.2		
11/77	PAR	Grav.	47	AA	< 0.01	Color	169	Color	< 0.02	LECO	300
	NRL	Grav.	240	AA	0.8	Color	115	Color	< 0.05		
	CTE	Grav.	40	AA	0.07	Color	209	Color	≤ 1		
	BNW			XRF	< 0.2					INAA	140
12/77	PAR	Grav.	32	AA	0.01	Color	192	Color	< 0.02	LECO	400
	NRL	Grav.	44	AA	0.8	Color	150	Color	< 0.05		
	CTE	Grav.	592	AA	0.01	Color	213	Color	≤ 0.1		
	GSRI			SSMS	0.01					SSMS	> 10
1/78	PAR	Grav.	7	AA	0.03	Color	122	Color	< 0.02	LECO	< 300
2/78	PAR	Grav.	18	AA	< 0.05	Color	29	Color	< 0.02	LECO	< 300
	NRL	Grav.	36	AA	< 0.1	Color	8	Color	0.5		
	CTE	Grav.	53	AA	0.03	Color	12	Color	3.7		
3/78	PAR	Grav.	7	AA	< 0.1	Color	46	Color	< 0.02	LECO	340
	CTE	Grav.	44	AA	≤ 0.02	Color	44	Color	1.4		
4/78	PAR	Grav.	26	AA	< 0.1	Color	79	Color	< 0.02	LECO	240
	NRL	Grav.	24	AA	< 0.01	Color	68	Color	< 0.05		
	CTE	Grav.	35	AA	≤ 0.02	Color	86	Color	10.4		

4.0 GASES

4.1 General

Since this compilation deals with the characterization of process streams, data regarding fugitive gas emissions and ambient air quality are not included. Thus, data collected in the mine, haul road, crushing and screening, oil storage, and retorted shale disposal areas will not be included in this volume. There are no process gas streams in these areas.

There are three process gas streams associated with the Paraho operations. The most important gas stream is the product, or recycle, gas. This is the gas which, in a commercial operation, would serve as fuel for the production of steam or electricity, or would be pipelined for off-site use. This is the gas which could be lost by fugitive emission. Another process gas stream is the effluent from the thermal oxidizer where, during the recent Paraho research operations, the excess, or product, gas was combusted to reduce hydrocarbon emissions. This stream represents, to a degree, the gaseous by-products of product gas combustion which could occur in a commercial oil shale retorting operation. Finally, the stack emissions of the process heaters and boilers have been monitored and the results are included in this compilation.

4.2 Product Gas

Product gas composition was monitored routinely by the Paraho Laboratory in the determination of product yields and material balances. Listed in Table 4.1 are the data obtained by GC (hydrogen, nitrogen, oxygen, carbon monoxide, carbon dioxide, and gaseous hydrocarbons). Composition is typical gases from retorting; interlaboratory agreement is good. Trace organics found in the product gas are listed in Table 4.2. The sum of these concentrations agree quite well with the C_5+ data shown in Table 4.1.

Listed in Table 4.3 is a compilation of the sulfur and nitrogen (other than N_2) gaseous components. Very little oxides of sulfur or nitrogen (or any sulfur or nitrogen gases except H_2S and NH_3) were detected. Ammonia

concentrations appear to be increasing (from 0.2 vol% to 0.7 vol%) during the period of monitoring (1975-1978) while hydrogen sulfide remained constant (0.3 $\pm$ 0.1 vol%). This observation is pictured in Figure 4.1

A summary of the elemental analyses of recycle gas is presented in Tables 4.4 and 4.5. Traces of the volatile elements, arsenic and mercury, have been detected (As, 120-150 $\mu g/m^3$; Hg, 45-75 $\mu g/m^3$). Some speciation data for arsenic is listed in Table 4.5. Most of the arsenic exists as the oxide (As_2O_3). It appears that gold amalgamation is needed to collect mercury. Concentrations of 28 other elements were below the limits of detection.

Product gas particulate data is listed in Table 4.6. Particulate levels are low: first, the off-gas leaving the top of the retort is essentially free of particulates; second, the electrostatic precipitator, used to remove the oil mist, removes solid particulates from the gas stream.

4.3 Thermal Oxidizer

Thermal oxidizer effluent composition is presented in Tables 4.7 and 4.8. Since this is not a closely controlled process, the gaseous composition varies. Large amounts of excess air are present in the effluent; oxygen varies from 7 to 14 vol%. Carbon dioxide also varied widely -- from 2 to 10 vol%. For the most part, combustion was complete; carbon monoxide and methane were not detected using thermal conductivity. Using more sensitive flame ionization, carbon monoxide is about 400 ppm and methane is about 30 ppm. Sulfur and nitrogen gas composition in the thermal oxidizer is shown in Table 4.8. Again, these data show efficient combustion; little or no ammonia or hydrogen sulfide is in the thermal oxidizer effluent. Sulfur dioxide varies from about 10 ppm to 300 ppm; median value is about 200 ppm. The 1200 ppm and < 1 ppm values are outliers. Oxides of nitrogen vary from 100 to 500 ppm; these are split about evenly between nitrous oxide (NO) and nitric oxide (NO_2).

Results from sampling thermal oxidizer gas and analysis for trace toxic elements are listed in Table 4.9. Of all the trace toxic elemental analyses,

only arsenic and mercury were found in the product gas and thermal oxidizer effluent. Practically all the arsenic existed as the oxide (As_2O_3). Some arsine but no methyl-substituted arsines were detected. In the thermal oxidizer effluent, total arsenic varied from 12 to 55 $\mu g/m^3$ and mercury from 5 to 12 $\mu g/m^3$. The mercury was determined by flameless AA. Analyses were made for about 20 additional elements (other than those in Tables 4.7, 4.8 and 4.9) in thermal oxidizer effluent (see Table 4.10). All of the results were below the limits of detection.

Particulates from the thermal oxidizer were monitored over a 3-year period by five researchers (see Table 4.11). Results vary widely: mean $\pm$ 1.0 S.D. = 94 $\pm$ 88 mg/m^3. The variation is caused by the problem of measuring the very low concentrations isokinetically. Insufficient samples are obtained using standard stack monitoring equipment. A high volume probe, used 11/17/77, produced a single value of 70 mg/m^3. Since the particulate concentrations were low, it was difficult to obtain a sample for chemical analysis. Results of chemical analyses of a single sample of thermal oxidizer particulates are listed in Table 4.12. For the most part, these concentrations are similar to those found in raw and retorted shale (see Tables 2.4 and 2.5). The concentrations of arsenic, selenium, antimony, and mercury are significantly higher in the thermal oxidizer particulates.

4.4 Miscellaneous Stacks

All stacks at the Paraho Anvil Points operation have been monitored. In Table 4.13 the results of monitoring the heater and boiler stacks are listed. External heaters were used to heat the recycle gas while performing research on the Indirect Heated and Combination Mode of retort operations. Boilers were used to supply steam for heating. The high SO_2 (394 ppm) found in the Semi-Works heater stack during March, 1976 indicated tube failure and loss of recycle gas into the heater. The other data in Table 4.13 are typical stack effluents using low-sulfur fuel oil as the fuel.

FIGURE 4.1

Hydrogen Sulfide and Ammonia

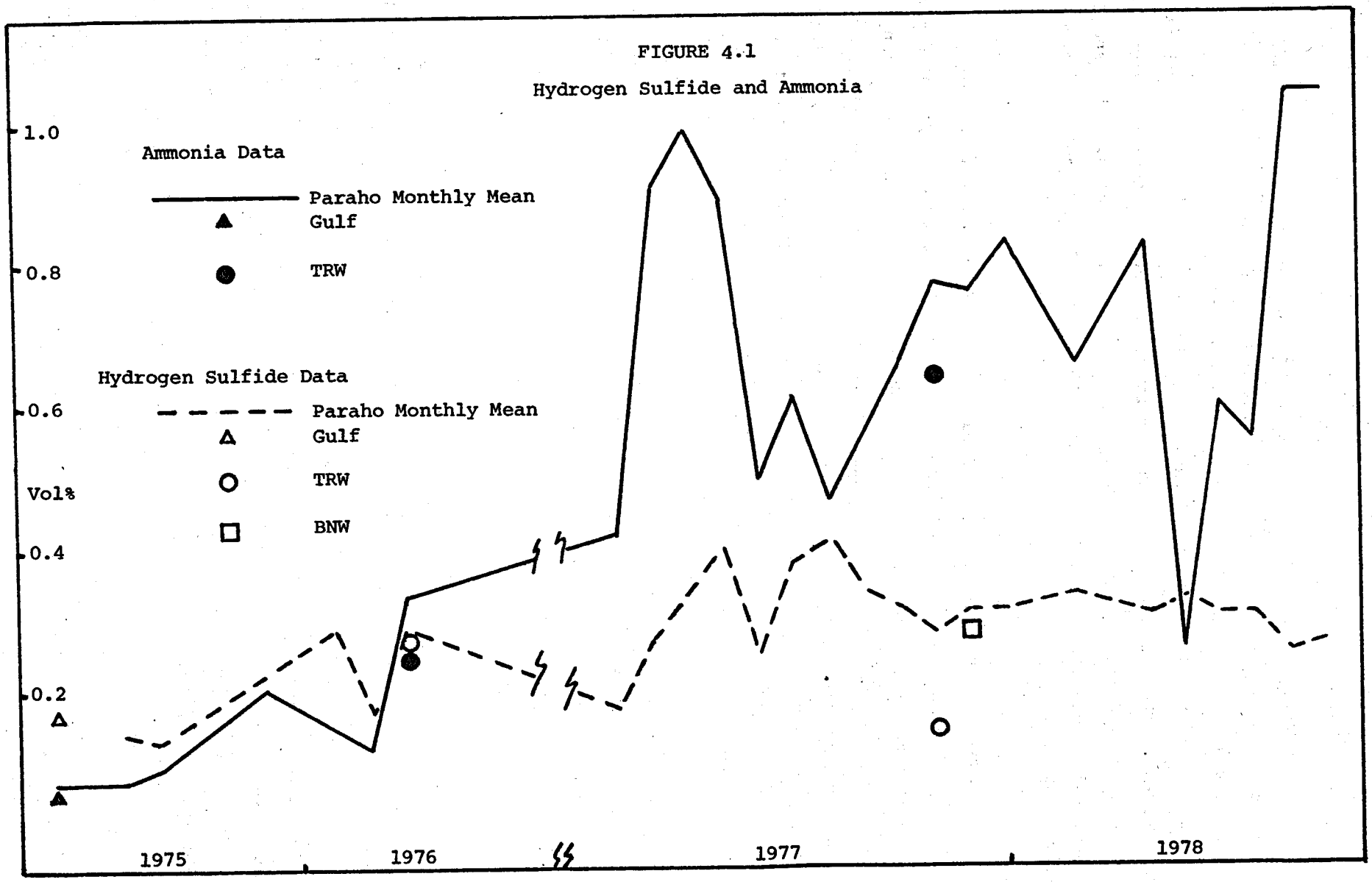


TABLE 4.1

PRODUCT GAS

G.C. DATA

(Vol%)

Date	Lab	Comments	H_2	N_2 + Ar	O_2	CO	CH_4	CO_2	C_2H_4	C_2H_6	C_3H_6	C_3H_8	C4's	C5+'s
1-77	PAR(2)	N-2(1)	3.9	63.6	0.19	2.6	1.8	23.7	0.55	0.42	0.29	0.20	0.66	0.37
2-77	PAR	N-3	2.5	66.1	0.21	2.7	2.3	21.5	0.55	0.47	0.39	0.28	0.71	0.55
3-77	PAR	N-2	4.4	64.4	0.03	2.4	2.1	21.9	0.35	0.50	0.51	0.39	0.67	0.52
4-77	PAR	N-2	4.3	64.7	0.63	2.4	2.4	20.0	0.67	0.73	0.59	0.51	0.52	0.42
5-77	PAR	N-2	4.1	65.2	0.79	2.2	2.2	21.4	0.63	0.66	0.40	0.30	0.58	0.55
6-77	PAR	N-2	4.4	63.9	0.03	2.9	2.4	21.8	0.79	0.67	0.31	0.23	0.62	0.49
7-77	PAR	N-2	5.6	62.1	-	2.3	2.6	22.3	0.99	0.72	0.51	0.28	0.61	0.63
8-77	PAR	N-2	5.3	63.4	0.24	2.4	2.3	22.1	0.66	0.56	0.43	0.27	0.52	0.45
9-77	PAR	N-2	4.6	61.2	-	2.7	2.3	24.2	0.66	0.61	0.49	0.35	0.81	0.47
10-77	PAR	N-2	4.3	62.0	-	2.5	2.2	23.8	0.62	0.65	0.52	0.38	0.62	0.94
10-77	TRW(3)	N-8	-	-	0.78	2.2	1.7	24.0	-	0.31	-	0.13	0.14(5)	0.05(6)
11-77	PAR	N-2	4.5	62.2	0.16	2.5	1.8	24.9	0.57	0.51	0.35	0.26	0.41	0.47
11-77	BNW(4)	N-2	-	-	-	1.9	-	-	-	-	-	-	-	-
12-77	PAR	N-2	4.7	64.0	0.08	2.3	2.2	21.9	0.65	0.61	0.43	0.30	0.63	0.62
2-78	PAR	N-4	4.8	61.7	-	2.5	2.0	24.5	0.72	0.54	0.35	0.22	0.36	0.56
4-78	PAR	N-7	4.7	62.2	0.10	2.7	2.2	24.5	0.57	0.48	0.26	0.16	0.09	0.68
5-78	PAR	N-3	5.0	61.3	0.04	2.7	2.2	24.5	0.66	0.57	0.37	0.20	0.18	0.88
6-78	PAR	N-9	5.9	62.6	0.09	2.7	2.4	21.8	0.69	0.61	0.37	0.21	0.26	0.83
7-78	PAR	N-12	5.2	62.9	0.07	2.6	2.3	22.1	0.64	0.58	0.66	0.35	0.57	0.72
8-78	PAR	N-14	4.8	64.0	0.10	2.4	2.0	21.7	0.63	0.50	0.49	0.29	0.47	0.78

Note:
(1) N - number of analyses, monthly means.
(2) GC with TC.
(3) GC with FID.
(4) Estimate.
(5) n-Butane.
(6) n-Pentane, n-Hexane.

TABLE 4 • 2

Product Gas Trace Organics, 1977

Peak No.	Assignment	MS Reference	MW	Relative Retention Time	Concentration mg/m^3, dry basis 9/10/77	9/12/77	10/18/77	10/19/77
1	Low MW hydrocarbons	-	-	-	-	-	-	-
2	1-Pentene	21-6	70	2.0	389	340	543	230
3	Hexane	48-3	86	2.2	443	362	712	291
4	Hexene	42-8	84	2.5	473	424	815	321
5	Thia-4-(methylthio)-3-cyclo-pentene-2-one	365-7	146	2.7	159	174	257	198
6	Branched C_7H_{14} hydrocarbon		98	3.2	131	126	341	120
7	n-Heptane	88-4	100	3.8	384	362	791	292
8	1-Heptene	78-9	98	4.3	344	346	788	323
9	Branched C_8H_{16} hydrocarbon		112	5.7	149	152	367	128
10	$C_7H_{12}O$ unsaturated ketone or alcohol		112	7.2	9	12	31	8
11	n-Octane	146-12	114	7.6	206	215	572	200
12	Benzene	33-9	78	7.8	244	221	380	169
13	Branched C_8H_{16} hydrocarbon		112	8.4	27	38	64	60
14	1-Octene	134-8	112	8.7	197	214	566	193
15	$C_7H_{12}O$ branched ketone or alcohol		112	9.8	12	20	56	21
16	Thiophene		84	10.1	31	36	83	41
17	C_8H_{14} hydrocarbon		110	10.8	41	40	73	31
18	1,2,4-trimethylcyclohexane	207-4	126	11.5	84	105	209	96
19	Branched C_9H_{18} hydrocarbon		126	11.9	39	48	101	42
20	$C_8H_{14}O$ alcohol or ether		126	12.8	25	29	66	26
21	n-Nonane	223-1	128	13.6	156	197	401	176
22	Toluene	64-7	92	14.0	211	224	509	206
23	(E)-6-methyl-3,5-heptadiene-2-one	197-2	124	14.3	37	41	95	42
24	1-Nonene	206-5	126	14.7	87	86	252	93
25	Branched $C_{10}H_{22}$ hydrocarbon		142	15.0	34	46	101	35
26	Branched $C_8H_{14}O$		126	15.7	64	79	168	70
27	$C_{10}H_{18}$ unsaturated hydrocarbon		138	16.1	18	17	44	20
28	C_9H_{16} unsaturated hydrocarbon		124	16.9	21	23	38	20
29	$C_9H_{16}O$ alcohol or ketone		140	17.9	22	24	34	18
30	$C_{10}H_{20}$ alkane		140	18.9	12	22	34	19
31	n-Decane	320-9	142	19.2	115	164	299	172
32	o-Xylene	113-4	106	19.6	23	29	62	27
33	m-Xylene	113-5	106	19.8	31	25	61	26
34	Branched $C_9H_{16}O$ or $C_{10}H_{20}$		140	19.9	31	25	61	26
35	1-Decene	306-6	140	20.3	171	197	554	239
36	p-Xylene	113-6	106	22.1	22	23	61	21
37	2,3,4,5-tetramethyl-1,4-hexadiene	292-8	138	22.2	21	26	61	30
38	Cyclooctatetraene or styrene	105-11	104	23.4	11	16	32	13
39	$C_{10}H_{16}$ terpene	105-5	136	24.0	8	14	22	13
40	n-Undecane	439-7	156	24.4	55	84	134	117
41	Isopropylbenzene or methyl-ethyl-benzene	178-11 179-3,4,5	120	24.8	8	14	23	12
42	1-Undecene	419-6	154	25.3	42	93	119	109
43	Methyl-ethyl-benzene or trimethylbenzene	p. 178,179	120	25.8	8	12	17	10
44	Branched $C_{11}H_{20}$ hydrocarbon		152	26.1	6	9	12	12

TABLE 4.2 (Cont'd)

Peak No.	Assignment	MS-Reference	MW	Relative Retention Time	Concentration mg/m^3, dry basis			
					9/10/77	9/12/77	10/18/77	10/19/77
45	6-Methyl-6-ethylfulvene	178-9	120	26.4	11	21	29	19
46	Trimethylbenzene	178-12, 179-1,2	120	27.1	14	18	32	20
47	Diethylbenzene or sec-butylbenzene	p. 262,263	134	28.7	15	19	13	11
48	n-Dodecane	589-6	170	29.0	16	59	72	123
49	sec-butyl or methyl-propyl-benzene	p. 262,263	134	29.3	23	30	39	31
50	Branched $C_{10}H_{20}$ hydrocarbon		140	29.4	23	28	39	31
51	t-butylbenzene	261-12	134	31.8	7	9	7	10
52	Naphthalene	220-1	128	37.5	8	11	7	16
53	C_4H_9 substituted benzene		134	38.4	7	8	3	12

Lab-Ref: TRW-8
Analysis Method: G.C./M.S.
Sample Type: Effluent

TABLE 4.3

PRODUCT GAS

Sulfur and Nitrogen Gases

Lab	Date	Hydrogen Sulfide Vol%	Hydrogen Sulfide N	Ammonia Vol%	Ammonia N
Par[a]	May, 1975	-	-	0.07	1
Gulf[b]	May, 1975	0.17	2	0.06	2
PAR	July, 1975	0.14	2	0.07	1
PAR	Aug., 1975	0.13	3	0.09	1
PAR	Oct., 1975	0.01	1	0.10	2
PAR	Nov., 1975	0.22	17	0.20	5
PAR	Jan., 1976	0.29	4	-	-
PAR	Feb., 1976	0.16	1	0.12	1
PAR	Mar., 1976	0.28	3	0.33	3
TRW[c]	Mar., 1976	0.26	1	0.23	2
PAR	Jan., 1977	0.18	4	0.42	4
PAR	Feb., 1977	0.27	4	0.91	4
PAR	Mar., 1977	0.34	3	0.99	3
PAR	Apr., 1977	0.40	2	0.89	2
PAR	May, 1977	0.25	2	0.47	2
PAR	June, 1977	0.38	3	0.61	3
PAR	July, 1977	0.41	3	0.46	3
PAR	Aug., 1977	0.34	4	0.42	4
PAR	Sept., 1977	0.31	3	0.66	3
PAR	Oct., 1977	0.28	3	0.77	3
TRW[d]	Oct., 1977	0.13	4	0.63	4
PAR	Nov., 1977	0.31	3	0.76	3
BNW[e]	Nov., 1977	0.26	2	-	-
PAR	Dec., 1977	0.31	2	0.83	2
PAR	Feb., 1978	0.33	4	0.66	4
PAR	Apr., 1978	0.30	7	0.83	7
PAR	May, 1978	0.32	3	0.23	3
PAR	June, 1978	0.30	10	0.60	10
PAR	July, 1978	0.30	12	0.55	12
PAR	Aug., 1978	0.24	13	1.04	13
PAR	Sept., 1978	0.26	1	1.04	1

a H_2S by titration, NH_3 by colorimetry.

b NO_x = 1-2 ppm; SO_2, COS, CS_2 not detected.

c Instrumental.

d Instrumental; SO_2 = 16.6 ppm; NO_x = 168.2 ppm: COS, CS_2 not detected.

e H_2S by titration, NH_3 by colorimetry.

TABLE 4.4

Product Gas, Toxic Elemental Analysis

Parameter	Date	Data	Lab-Ref	Methods: Sampling	Methods: Analyses	Comments
As	11/16/77	155 $\mu g/m^3$	BNW-7	Impingers Ag	PES	As_2O_3 = 149 $\mu g/m^3$ Organic As < 12 $\mu g/m^3$ AsH_3 = 1.8 $\mu g/m^3$ Methyl Arsine = 2.8 $\mu g/m^3$ Di-methyl Arsine = 1.0 $\mu g/m^3$ Other Organic Arsine = 0.5 $\mu g/m^3$
	11/17/77	120 $\mu g/m^3$	BNW-7	Impingers Ag	PES	As_2O_3 = 112 $\mu g/m^3$ Organic As = < 12 $\mu g/m^3$ AsH_3 = 2 $\mu g/m^3$ Methyl Arsine = 3 $\mu g/m^3$ Di-methyl Arsine = 1.7 $\mu g/m^3$ Other Organic Arsine = 0.5 $\mu g/m^3$ Particulate As = 1.2 $\mu g/m^3$
	7/27/78	< 4 $\mu g/m^3$	PAR-9	Impingers	AA	
AsH_3	3/10/76	ND	TRW-4	Selective Absorption		
	3/11/76	ND	TRW-4	Selective Absorption		
	10/14/77	0.17 $\mu g/m^3$	TRW-8	Impingers	GC/MS	
	10/14/77	0.25 $\mu g/m^3$	TRW-8	Impingers	GC/MS	
	10/14/77	0.35 $\mu g/m^3$	TRW-8	Impingers	GC/MS	
	10/14/77	0.46 $\mu g/m^3$	TRW-8	Impingers	GC/MS	
B	8/24/77	< 30 $\mu g/m^3$	BNW-7		PES	
Cu	8/23/77	< 30 $\mu g/m^3$	BNW-7		XRF	
	8/24/77	< 5 $\mu g/m^3$	BNW-7		XRF	
	8/25/77	< 40 $\mu g/m^3$	BNW-7		XRF	
	8/26/77	< 40 $\mu g/m^3$	BNW-7		XRF	
	11/15/77	< 40 $\mu g/m^3$	BNW-7		XRF	
	11/15/77	< 40 $\mu g/m^3$	BNW-7		XRF	
	11/16/77	< 100 $\mu g/m^3$	BNW-7		XRF	
	11/17/77	< 30 $\mu g/m^3$	BNW-7		XRF	
Hg	8/24/77	< 20 $\mu g/m^3$	BNW-7	Impingers	AA	
	10/15/77	0.304 $\mu g/m^3$	TRW-8	Selective Absorption	AA	
	10/15/77	0.113 $\mu g/m^3$	TRW-8	Selective Absorption	AA	
	10/15/77	0.155 $\mu g/m^3$	TRW-8	Selective Absorption	AA	
	10/15/77	0.235 $\mu g/m^3$	TRW-8	Selective Absorption	AA	
	10/15/77	1.298 $\mu g/m^3$	TRW-8	Selective Absorption	AA	
	11/15/77	45 ± 5 $\mu g/m^3$	BNW-7	Gold Amalgamation	AA	Flameless
	11/16/77	75 ± 15 $\mu g/m^3$	BNW-7	Gold Amalgamation	AA	Flameless
	7/28/78	< 30 $\mu g/m^3$	PAR-9	Impingers	AA	
Pb	8/23/77	< 100 $\mu g/m^3$	BNW-7		XRF	
	8/24/77	< 70 $\mu g/m^3$	BNW-7		XRF	
	8/25/77	< 200 $\mu g/m^3$	BNW-7		XRF	
	8/26/77	< 200 $\mu g/m^3$	BNW-7		XRF	
	11/15/77	< 100 $\mu g/m^3$	BNW-7		XRF	
	11/16/77	< 300 $\mu g/m^3$	BNW-7		XRF	
	11/17/77	< 100 $\mu g/m^3$	BNW-7		XRF	
	7/28/78	< 4 $\mu g/m^3$	PAR-9	Impingers	AA	
Se	7/28/78	< 2 $\mu g/m^3$	PAR-9	Impingers	AA	
Zn	8/23/77	< 300 $\mu g/m^3$	BNW-7		INAA	
	8/23/77	< 200 $\mu g/m^3$	BNW-7		XRF	
	8/24/77	< 5 $\mu g/m^3$	BNW-7		XRF	
	8/25/77	< 200 $\mu g/m^3$	BNW-7		INAA	
	8/25/77	< 100 $\mu g/m^3$	BNW-7		XRF	
	8/26/77	< 100 $\mu g/m^3$	BNW-7		INAA	
	8/26/77	< 200 $\mu g/m^3$	BNW-7		XRF	
	11/15/77	< 20 $\mu g/m^3$	BNW-7		XRF	
	11/17/77	< 30 $\mu g/m^3$	BNW-7		XRF	

TABLE 4.5

Product Gas, General Elemental Analysis

Element	Date	Data (μg/m³)	Analytical Method
Ba	8/23/77	< 3000	INAA
	8/24/77	< 3000	INAA
	8/25/77	< 4000	INAA
	8/26/77	< 4000	INAA
	11/15/77	< 900	INAA
	11/16/77	< 700	INAA
	11/17/77	< 800	INAA
Ca	8/24/77	< 400	XRF
Co	8/23/77	< 7	INAA
	8/23/77	< 60	XRF
	8/24/77	< 30	INAA
	8/24/77	< 10	XRF
	8/25/77	< 10	INAA
	8/25/77	< 50	XRF
	8/26/77	< 10	INAA
	11/15/77	< 5	INAA
	11/16/77	< 2	INAA
	11/17/77	< 3	INAA
	11/17/77	< 60	XRF
Cr	8/23/77	< 7	INAA
	8/23/77	< 100	XRF
	8/24/77	< 7	INAA
	8/24/77	< 30	XRF
	8/25/77	< 10	INAA
	8/25/77	< 20	XRF
	8/26/77	< 10	INAA
	11/15/77	< 50	INAA
	11/16/77	< 20	INAA
	11/17/77	< 60	INAA
	11/17/77	< 100	XRF
Fe	8/23/77	< 100	XRF
	8/24/77	< 20	XRF
	8/25/77	< 500	XRF
	8/26/77	< 6000	INAA
	11/15/77	< 4000	INAA
	11/16/77	< 2000	INAA
Ga	8/23/77	< 30	XRF
	8/24/77	< 5	XRF
	8/25/77	< 2000	XRF
	8/26/77	< 40	XRF
	11/15/77	< 20	XRF
	11/16/77	< 80	XRF
	11/17/77	< 20	XRF
K	8/23/77	< 2000	XRF
	8/24/77	< 500	XRF
	8/25/77	< 2000	XRF
	8/26/77	< 3000	XRF
	11/15/77	< 2000	INAA
	11/17/77	< 800	INAA
	11/17/77	< 500	XRF
La	8/23/77	< 5	INAA
	8/24/77	< 5	INAA
	8/25/77	< 7	INAA
	8/26/77	< 7	INAA
	11/15/77	< 6	INAA
	11/16/77	< 0.4	INAA
	11/17/77	< 3	INAA
Mg	8/24/77	< 90	PES
Mn	8/23/77	< 100	XRF
	8/24/77	< 20	XRF
	8/25/77	< 50	XRF
	8/26/77	< 100	XRF
	11/15/77	< 100	XRF
	11/17/77	< 100	XRF
Na	11/15/77	< 1000	INAA
	11/16/77	< 60	INAA

TABLE 4.5 (Cont'd)

Element	Date	Data (μg/m³)	Analytical Method
Ni	8/23/77	< 60	XRF
	8/24/77	< 5	XRF
	8/25/77	< 50	XRF
	11/15/77	< 1	XRF
	11/16/77	< 200	XRF
	11/17/77	< 100	XRF
Rb	8/23/77	< 200	INAA
	8/23/77	< 50	XRF
	8/24/77	< 10	XRF
	8/25/77	< 200	INAA
	8/25/77	< 80	XRF
	8/26/77	< 200	INAA
	8/26/77	< 100	XRF
	11/15/77	< 100	INAA
	11/15/77	< 40	XRF
	11/16/77	< 10	INAA
	11/17/77	< 100	INAA
	11/17/77	< 40	XRF
Sb	8/23/77	< 20	INAA
	8/24/77	< 20	INAA
	8/25/77	< 20	INAA
	8/26/77	< 20	INAA
	11/15/77	< 9	INAA
	11/16/77	< 5	INAA
	11/17/77	< 3	INAA
Sc	8/23/77	< 1	INAA
	8/24/77	< 0.7	INAA
	8/25/77	< 1	INAA
	8/26/77	< 1	INAA
	11/15/77	< 0.3	INAA
	11/16/77	< 0.2	INAA
	11/17/77	< 0.3	INAA
Si	8/24/77	< 600	PES
Sm	8/26/77	< 800	XRF
Sr	8/23/77	< 600	XRF
	8/24/77	< 600	XRF
	8/25/77	< 400	XRF
	11/15/77	< 200	XRF
	11/16/77	< 800	XRF
	11/17/77	< 300	XRF
Th	8/23/77	< 200	INAA
	8/24/77	< 200	INAA
	8/25/77	< 200	INAA
	8/26/77	< 200	INAA
	11/15/77	< 3	INAA
	11/16/77	< 2	INAA
	11/17/77	< 2	INAA
U	8/23/77	< 40	INAA
	8/24/77	< 40	INAA
	8/25/77	< 50	INAA
	8/26/77	< 50	INAA
	11/15/77	< 20	INAA
	11/16/77	< 2	INAA
	11/17/77	< 2	INAA
V	8/23/77	< 300	XRF
	8/24/77	< 40	XRF
	8/25/77	< 400	XRF
	8/26/77	< 400	XRF
	11/15/77	< 100	XRF
	11/17/77	< 100	XRF
Y	11/16/77	< 100	XRF
Zr	11/16/77	< 200	XRF

Lab-Ref: BNW-7
Sample Type: Effluent

TABLE 4.6

Product Gas Particulates

Date	mg/m^3	Sample Size (m^3)
8/24/77	2.4	0.60
11/15/77	2.5	0.18
11/16/77	4.2	0.06
11/17/77	1.5	0.12

Note: Not an isokinetic sample.

Lab Ref: BNW-7
Sampling Method: 0.45 nucleopore filter.

TABLE 4.7

Thermal Oxidizer, Gas Chromatography Data

Vol.%

Date	Lab-Ref	O_2	CO_2	CO	CH_4	Detector	Comments
12/30/74	PAR-1	9.8	6.2	< 0.05	< 0.05	T.C.	
3/5/75	PAR-1	7.6	8.6	0.46	< 0.05	T.C.	
3/5/75	PAR-1	7.2	9.6	0.18	< 0.05	T.C.	
3/12/75	PAR-1	7.7	8.9	< 0.05	< 0.05	T.C.	
5/9/75	PAR-1	8.6	8.8	< 0.05	< 0.05	T.C.	
5/8/75	GULF-1	7.7	8.1	< 0.05	< 0.05	T.C.	
5/14/75	GULF-1	7.9	7.9	< 0.05	< 0.05	T.C.	
8/5-6/75	LFE-2	7-16	6-10	0-1.3			
8/22/75	PAR-1	8.0	11.3	< 0.05	< 0.05	T.C.	
8/26/75	PAR-1	11.0	7.9	< 0.05	< 0.05	T.C.	
11/11/75	PAR-1	11.4	7.6	< 0.05	< 0.05	T.C.	
11/13/75	PAR-1	11.6	7.8	< 0.05	< 0.05	T.C.	
11/18/75	PAR-1	11.5	8.0	< 0.05	< 0.05	T.C.	
11/20/75	PAR-1	11.7	7.0	< 0.05	< 0.05	T.C.	
11/25/75	PAR-1	9.8	8.6	< 0.05	< 0.05	T.C.	
9/3/77	TRW-8	12.36	6.03	0.04	35 ppm	F.I.D.	$C_2 - C_6$ < 1 ppm
10/4/77	PAR-9	9.9	6.3	< 0.05	< 0.05	T.C.	
10/10/77	PAR-9	8.6	5.8	< 0.05	< 0.05	T.C.	
10/17/77	PAR-9	8.4	9.0	< 0.05	< 0.05	T.C.	
10/17/77	TRW-8	12.36	9.88	0.04	28 ppm	F.I.D.	$C_2 - C_6$ 1-2 ppm
10/26/77	PAR-9	7.7	7.0	< 0.05	< 0.05		
11/77	BNW-7			0.18			Estimate, Potentiometric
11/77	BNW-7			0.14			Estimate, Potentiometric
11/77	PAR-9	12.8	7.6	< 0.05	< 0.05	T.C.	
11/77	PAR-9	9.0	6.9	< 0.05	< 0.05	T.C.	
11/77	PAR-9	8.9	8.0	< 0.05	< 0.05	T.C.	
11/77	PAR-9	14.3	1.5	< 0.05	< 0.05	T.C.	
11/77	PAR-9	13.6	10.2	< 0.05	< 0.05	T.C.	
12/77	PAR-9	12.0	4.5	< 0.05	< 0.05	T.C.	
12/77	PAR-9	9.7	1.8	< 0.05	< 0.05	T.C.	
2/78	PAR-9	11.1	7.9	< 0.05	< 0.05	T.C.	
2/78	PAR-9	14.0	6.3	< 0.05	< 0.05	T.C.	
4/78	PAR-9	14.0	6.9	< 0.05	< 0.05	T.C.	
4/78	PAR-9	9.7	7.8	< 0.05	< 0.05	T.C.	
5/78	PAR-9	9.3	10.0	< 0.05	< 0.05	T.C.	
5/78	PAR-9	12.3	5.2	< 0.05	< 0.05	T.C.	
5/78	PAR-9	13.6	7.1	< 0.05	< 0.05	T.C.	
6/78	PAR-9	13.3	7.1	< 0.05	< 0.05	T.C.	
6/78	PAR-9	13.6	5.4	< 0.05	< 0.05	T.C.	
6/78	PAR-9	10.0	9.8	< 0.05	< 0.05	T.C.	

TABLE 4.8

Thermal Oxidizer, Sulfur and Nitrogen Gases

Analysis in PPM

Date	Lab-Ref	SO_2	Method	H_2S	Method	NO_x	Method	NH_3	Method	Comments
3/5/75	PAR-1	140	1							
3/6/75	PAR-1	20	1							
3/12/75	PAR-1	120	1							
3/12/75	PAR-1	80	1							
5/6/75	PAR-1	100	1			160	1			
5/6/75	PAR-1	140	1							
5/8/75	GULF-1	380				220				
5/9/75	PAR-1	180	1							
5/9/75	PAR-1	220	1							
5/14/75	GULF-1	150				220				
5/29/75	PAR-1	190	1							
7/2/75	PAR-1	260	1			170	1			
7/30/75	PAR-1	50	1			220	1			
8/5-6/75	LFE-2					106-160				
8/22/75	PAR-1	100	1			420	1			
8/26/75	PAR-1	170	1			300	1			
10/21/75	PAR-1	70	1			300	1			
11/5/75	PAR-1	30	1			360	1			
11/11/75	PAR-1	30	1			160	1			
11/13/75	PAR-1	130	1			230	1			
11/18/75	PAR-1	210	1			220	1			
11/20/75	PAR-1	100	1			280	1			
11/25/75	PAR-1	260	1			260	1			
11/25/75	PAR-1	190	1							
11/26/75	PAR-1	330	1							
12/13/75	PAR-1	1200	1							
10/4/77	PAR-9	15	1	< 10	2	320	1	< 5	1	
10/10/77	PAR-9	6	1	< 10	2	310	1	< 5	1	
10/17/77	PAR-9	119	1	< 10	2	50	1	< 5	1	
10/17/77	TRW-8	27	3			280	3			
10/21/77	TRW-8	5.1	3	24.9	3					SO_3 = 13.1 ppm
10/21/77	TRW-8	17.0	3							
10/26/77	PAR-9	71	1	< 10	2	150	1	< 5	1	
11/2/77	PAR-9	60	1	< 10	2	180	1	< 5	1	
11/12/77	PAR-9	22	1	< 10	2	202	1	< 5	1	
11/15/77	PAR-9	3	1	< 10	2	23	1	< 5	1	
11/15/77	BNW-7	276	4	< 0.4						Mercaptans < 0.4
11/15/77	BNW-7	256	4							
11/22/77	PAR-9	99	1	< 10	2	178	1	< 5	1	
12/6/77	PAR-9	40	1	< 10	2	140	1	< 5	1	
12/27/77	PAR-9	44	1	< 10	2	260	1	< 5	1	
4/4/78	PAR-9					127	3			NO = 88 ppm, NO_2 = 44 ppm
4/17/78	PAR-9	19	1	< 10	2	226	1	< 5	1	
4/21/78	PAR-9					230	3			NO = 134 ppm, NO_2 = 73 ppm
4/24/78	PAR-9			48	3	154	3			NO = 49 ppm, NO_2 = 106 ppm
4/25/78	PAR-9			41	3	194	3			NO = 104 ppm, NO_2 = 112 ppm
5/2/78	PAR-9	< 1	1	< 10	1	354	1	< 5	1	
5/10/78	PAR-9	< 1	1	< 10	1	317	1	< 5	1	
5/22/78	PAR-9	< 1	1	< 10	1	338	1	< 5	1	
5/1/78	PAR-9			53	3	493	3			NO = 263 ppm, NO_2 = 205 ppm
5/2/78	PAR-9			75	3	494	3			NO = 269 ppm, NO_2 = 193 ppm
5/3/78	PAR-9			60	3	317	3			NO = 198 ppm, NO_2 = 157 ppm
6/1/78	PAR-9	< 1	1	< 10	1	105	1	< 5	1	
6/5/78	PAR-9	< 1	1	< 10	1	261	1	< 5	1	
6/12/78	PAR-9	< 1	1	< 10	1	341	1	< 5	1	

1 = Colorimetry
2 = Titration
3 = Single Parameter Instrument
4 = Potentiometric

TABLE 4.9

Thermal Oxidizer Gases, Trace Elements

Parameter	Date	Data	Analytical Methods	Comments
As, $\mu g/m^3$	11/16/77	12.3	PES	As_2O_3 12 Organic As ND AsH_3 0.3 Methyl Arsine ND Di-methyl Arsine ND Other Organic Arsine ND
	11/17/77	55	PES	As_2O_3 36 Organic As ND AsH_3 ND Methyl Arsine ND Di-methyl Arsine ND Other Organic Arsine ND Particulate As 19
Cu, $\mu g/m^3$	8/24/77	< 20	XRF	
	8/25/77	< 20	XRF	
	11/17/77	< 20	XRF	
F, $\mu g/m^3$	11/16/77	< 10	XRF	
Hg, $\mu g/m^3$	8/24/77	9	AA	
	8/25/77	6.7	AA	
	8/26/77	4.5	AA	Hg^{++} as $HgCl_2$ ND as CH_3HgCl Hg ND as $(CH_3)_2$ Hg Hg ND
	11/15/77	7.2	AA	
	11/16/77	12	AA	
	11/16/77	9.4	AA	Hg^{++} as $HgCl_2$ < 0.1 as CH_3HgCl Hg < 0.4 as $(CH_3)_2$ Hg Hg < 0.4
Pb, $\mu g/m^3$	8/24/77	< 50	XRF	
	8/25/77	< 50	XRF	
	8/26/77	< 50	XRF	
	11/16/77	< 50	XRF	
	11/17/77	< 50	XRF	
Zn, $\mu g/m^3$	8/24/77	< 100	INAA	
	8/24/77	< 100	XRF	
	8/25/77	< 100	INAA	
	8/25/77	< 50	XRF	
	8/26/77	< 100	INAA	
	8/26/77	< 60	XRF	
	11/16/77	< 10	XRF	
	11/16/77	< 30	XRF	

Lab-Ref: BNW-7
Sample Type: Effluent

TABLE 4.10

Thermal Oxidizer Gas, General Elemental Analyses

Parameter	Date	Data ($\mu g/m^3$)	Analytical Method
Ba	8/24/77	< 1000	INAA
	8/25/77	< 1000	INAA
	8/26/77	< 2000	INAA
	11/15/77	< 800	INAA
	11/16/77	< 800	INAA
	11/17/77	< 1000	INAA
Ca	8/25/77	< 2000	XRF
	8/26/77	< 20	XRF
Co	8/24/77	< 3	INAA
	8/24/77	< 30	XRF
	8/25/77	< 3	INAA
	8/26/77	< 7	INAA
	11/15/77	< 3	INAA
	11/16/77	< 4	INAA
	11/16/77	< 40	XRF
	11/17/77	< 3	INAA
Cr	8/24/77	< 3	INAA
	8/24/77	< 50	XRF
	8/25/77	< 3	INAA
	8/26/77	< 7	INAA
	8/26/77	< 40	XRF
	11/15/77	< 30	INAA
	11/16/77	< 100	INAA
	11/16/77	< 40	XRF
	11/17/77	< 100	INAA
	11/17/77	< 100	XRF
Fe	8/24/77	< 2000	INAA
	8/25/77	< 30	XRF
	8/26/77	< 20	XRF
	11/15/77	< 2000	INAA
	11/16/77	< 20	XRF
	11/17/77	< 500	XRF
Ga	8/24/77	< 10	XRF
	8/25/77	< 10	XRF
	8/26/77	< 6	XRF
	11/17/77	< 20	XRF
K	8/24/77	< 2000	XRF
	8/25/77	< 2000	XRF
	8/26/77	< 600	XRF
	11/15/77	< 600	XRF
	11/16/77	< 1000	XRF
	11/17/77	< 100	XRF
La	8/24/77	< 2	INAA
	8/25/77	< 2	INAA
	8/26/77	< 5	INAA
	11/15/77	< 0.5	INAA
	11/16/77	< 1	INAA
	11/17/77	< 2	INAA
Mn	8/24/77	< 50	XRF
	8/25/77	< 30	XRF
	8/26/77	< 20	XRF
	11/16/77	< 100	XRF
Na	11/15/77	< 200	INAA
Ni	8/24/77	< 20	XRF
	8/25/77	< 20	XRF
	8/26/77	< 20	XRF
	11/16/77	< 60	XRF
	11/17/77	< 70	XRF
Rb	8/24/77	< 60	INAA
	8/24/77	< 20	XRF
	8/25/77	< 60	INAA
	8/25/77	< 20	XRF
	8/26/77	< 20	XRF
	11/15/77	< 60	INAA
	11/16/77	< 60	INAA
	11/16/77	< 30	XRF
	11/17/77	< 100	INAA
	11/17/77	< 20	XRF

TABLE 4.10 (Cont'd)

Parameter	Date	Data ($\mu g/m^3$)	Analytical Method
Sb	8/24/77	< 6	INAA
	8/25/77	< 6	INAA
	8/26/77	< 10	INAA
	11/15/77	< 7	INAA
	11/16/77	< 6	INAA
	11/17/77	< 4	INAA
Sc	8/24/77	< 0.3	INAA
	8/25/77	< 0.3	INAA
	8/26/77	< 0.7	INAA
	11/15/77	< 0.2	INAA
	11/16/77	< 0.2	INAA
	11/17/77	< 0.5	INAA
Sr	8/24/77	< 200	XRF
	8/25/77	< 200	XRF
	8/26/77	< 60	XRF
	11/16/77	< 200	XRF
	11/17/77	< 200	XRF
Th	8/24/77	< 60	INAA
	8/25/77	< 60	INAA
	8/26/77	< 100	INAA
	11/15/77	< 2	INAA
	11/16/77	< 2	INAA
	11/17/77	< 2	INAA
Ti	8/24/77	< 200	XRF
	8/26/77	< 60	XRF
U	8/24/77	< 20	INAA
	8/25/77	< 20	INAA
	8/26/77	< 40	INAA
	11/15/77	< 2	INAA
	11/16/77	< 3	INAA
	11/17/77	< 3	INAA
V	8/24/77	< 100	XRF
	8/25/77	< 100	XRF
	11/16/77	< 100	XRF
	11/17/77	< 70	XRF
Y	8/26/77	< 50	XRF

Lab-Ref: BNW-7
Sample Type: Effluent

TABLE 4.11

Thermal Oxidizer, General Particulate Data

Date	Lab-Ref	Loading, mg/m^3	Sample Size
5/75	Gulf-1	175	
5/75	Gulf-1	6	
10/11/75	RMT-1	270	
8/24/77	BNW-7	< 0.8	0.2 m^3 Sample
9/3/77	TRW-8	23	
9/3/77	TRW-8	19	
11/15/77	BNW-7	120	0.2 m^3 Sample
11/16/77	BNW-7	160	0.2 m^3 Sample
11/17/77	BNW-7	70	7 m^3 Sample
2/9/78	PAR-9	100	0.3 m^3 Sample

Sample Type: Effluent

TABLE 4.12

PARAHO SEMI-WORKS RETORT - DIRECT MODE

Elemental Analysis of Thermal Oxidizer Dust
by Instrumental Neutron Activation Analysis
(all values ug/g unless noted)

Element	Dust Collected 11-16-77	Retorted Shale (8-24-77)	Ratio Dust/Retorted
Al (%)	2.92 ± 0.08	4.83 ± 0.10	0.60
As	520 ± 10	59 ± 1	8.81
Ba	430 ± 50	600 ± 10	0.72
Br	2.8 ± 0.31	0.80 ± 0.20	3.50
Ca (%)	10.6 ± 0.9	13.3 ± 0.2	0.80
Ce	51.0 ± 0.7	52 ± 2	0.98
Cs	2.8 ± 0.2	4.7 ± 0.2	0.60
Fe (%)	1.91 ± 0.02	2.40 ± 0.03	0.80
Hg	4.2 ± 0.1	0.030 ± 0.003	140
K (%)	1.4 ± 0.3	1.86 ± 0.03	0.75
La	26.0 ± 0.5	24.7 ± 0.3	1.05
Lu	0.29 ± 0.02	0.35 ± 0.03	0.83
Mn	380 ± 40	396 ± 14	0.96
Na (%)	1.35 ± 0.01	2.19 ± 0.03	0.62
Nd	27 ± 3	22 ± 1	1.23
Rb	86 ± 6	88 ± 2	0.98
Sb	5.0 ± 0.3	2.6 ± 0.2	1.92
Se	41.0 ± 0.8	2.3 ± 0.1	17.8
Sr	730 ± 20	880 ± 10	0.83
Ta	0.70 ± 0.06	0.65 ± 0.02	1.08
Tb	0.48 ± 0.05	0.42 ± 0.04	1.14
Th	8.9 ± 0.4	7.6 ± 0.1	1.17
Ti (%)	0.21 ± 0.05	0.24 ± 0.01	0.88
U	7.0 ± 1.0	5.1 ± 0.1	1.37
V	140 ± 10	130 ± 6	1.08
Yb	1.4 ± 0.2	1.6 ± 0.1	0.88
Zn	120 ± 3	82 ± 3	1.46

TABLE 4.13

Heater and Boiler Stack Effluents

Date	Stack	Comment	O_2 Vol%	CO_2 Vol%	CO Vol%	HC Vol%	SO_2 ppm	NO_x ppm
Mar., 1975	Boiler N	(3)[a]	9.2	5.1	0.0	0.2	< 1	91
Mar., 1975	Boiler S	(3)	10.5	3.5	0.0	0.2	1	61
Mar., 1975	Boiler G	(2)	8.4	6.0	0.0	0.3	< 1	
Jun., 1975	PP Heater	(4)	9.6	7.0	0.0	0.0		
Oct., 1975	Boiler N	(1)	12.3	5.5	0.0	0.0	3	94
Oct., 1975	Boiler S	(1)					< 1	128
Jan., 1976	SW Heater	(7)	3.1	13.0	< 0.1	0.0	1	
Feb., 1976	SW Heater	(4)	4.6	11.0	0.1	0.1	< 1	
Mar., 1976	SW Heater	(5)	5.2	10.8	0.0	< 0.1	< 1	
Apr., 1976	SW Heater	(5)	4.0	11.4	0.3	0.4	394	

a Figures in brackets are number of samples; data are monthly means.

SO_2 determined by color (West-Gaeke).

NO_x determined by color (Saltzman).

All other components determined by GC using thermal conductivity.

5.0 QUALITY ASSURANCE DATA

Since the Paraho oil shale retorting operations were quite stable during 1977, an opportunity was available to study elemental distribution around the retorting process. Samples were obtained as shown in Figure 1.3 and analyzed for various elements. Two types of studies were carried out - enrichment ratios (the ratio of elemental concentrations between the retorted and raw shale) were calculated; mass balances of the elements (the sum of the products divided by the amount in the raw shale feed) were calculated. Both the enrichment ratios and the mass balances serve as a quality assurance program.

Listed in Table 5.1 are the enrichment ratios determined by two researchers. The overall mean enrichment ratio is 1.24. Since the mass of retorted shale is about 82% that of the raw shale, the theoretical enrichment ratio would be 1.22. Only mercury, with a value of 0.67, is significantly lower indicating losses probably through volatilization. The 30-day nested mean values for calcium and zinc (0.98 and 0.95) appear to be erroneously low; the error-weighted averages for these elements are: Ca, 1.23; Zn, 1.26.

Mass balance calculated results are listed for 31 elements in Table 5.2. A value of 1.00 denotes a perfect mass balance. The mass balances listed in Table 5.2 range from 0.84 to 1.18. The overall mean balance is 1.029. The data used in these calculations are valid.

TABLE 5.1

Retorted:Raw Enrichment Ratios

Element	30-Day Nested Mean[a]	Error Weighted Averages[b]
Al		1.24 ± 0.024
As	1.36	1.29 ± 0.03
B	1.36	1.14 ± 0.03
Ba	1.22	1.19 ± 0.03
Br		1.40 ± 0.45
Ca	0.98	1.23 ± 0.04
Cd		1.43 ± 0.09
Ce		1.20 ± 0.04
Co		1.23 ± 0.03
Cr		1.21 ± 0.03
Cs		1.22 ± 0.09
Cu	1.20	1.37 ± 0.08
Dy		1.45 ± 0.26
Eu		1.22 ± 0.05
F	1.42	
Fe	1.08	1.17 ± 0.02
Ga	1.11	1.38 ± 0.19
Hf		1.21 ± 0.04
Hg		.67 ± 0.09
Ho		1.31 ± 0.22
K		1.17 ± 0.02
La		1.20 ± 0.02
Lu		1.25 ± 0.17
Mg		1.14 ± 0.02
Mn	1.06	1.24 ± 0.07
Mo	1.43	1.33 ± 0.15
Na		1.28 ± 0.02
Nb	1.23	1.15 ± 0.21
Nd		1.09 ± 0.12
Ni	1.09	1.20 ± 0.06
Pb	1.33	1.37 ± 0.13
Rb	1.21	1.19 ± 0.04
S		1.18 ± 0.15
Sb		1.26 ± 0.09
Sc		1.19 ± 0.04
Se	1.07	1.16 ± 0.08
Si		1.20 ± 0.02
Sm		1.19 ± 0.03
Sr	1.21	1.26 ± 0.02
Ta		1.18 ± 0.06

TABLE 5.1 (Cont'd)

Element	30-Day Nested Mean[a]	Error Weighted Averages[b]
Tb		1.14 ± 0.14
Th		1.19 ± 0.03
Ti		1.33 ± 0.15
U		1.08 ± 0.05
V		1.38 ± 0.07
Y	1.14	1.17 ± 0.11
Yb		1.28 ± 0.15
Zn	0.95	1.26 ± 0.05
Zr	1.21	1.10 ± 0.06

(a) Mean from samples taken 8-17-77, 8-23-77, 8-24-77, 8-27-77, 9-7-77, 9-15-77, 9-20-77 using XRF by CSM.

(b) Averages using BNW multitechniques (INAA, RCAA, XRF, PES, FAA, CVAA) on samples taken 8-24-77.

TABLE 5.2

Elemental Mass Balances

Element	Mass Balance[1]
Al	1.07
As	1.18
B	0.95
Ba	0.98
C	1.01
Ca	1.10
Co	1.04
Cr	1.08
Cu	1.17
Fe	0.97
H	1.18
Hg	0.84
K	0.96
Mg	0.96
Mn	0.95
Mo	1.17
N	0.87
Na	1.08
Ni	0.96
Pb	1.08
Rb	0.98
S	1.07
Sb	1.03
Se	1.02
Si	1.01
Sr	1.05
Th	1.01
Ti	1.11
U	0.94
V	1.02
Zn	1.07

(1) Amounts of elements in retorting products divided by amounts of elements in raw shale feed (BNW multitechnique approach).

PARAHO ENVIRONMENTAL DATA

Part II

Air Quality

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TABLE OF CONTENTS

	Page
INTRODUCTION	
Table of Contents	1.1-
List of Illustrations	1.2
Introduction	1.5
List of Abbreviations	1.7
Bibliography	1.9
MINE	2.1-
Discussion	2.1
Figures	2.2
Tables	2.5
MINE ADIT AND HAUL ROAD	3.1-
Discussion	3.1
Figures	3.4
Tables	3.6
CRUSHING	4.1-
Discussion	4.1
Figures	4.5
Tables	4.8
RETORTING	5.1-
Discussion	5.1
Figures	5.7
Tables	5.10
SHALE DISPOSAL	6.1-
Discussion	6.1
Figure	6.4
Tables	6.5
MISCELLANEOUS	7.1-
Discussion	7.1
Tables	7.3

LIST OF ILLUSTRATIONS

		Page
Figures		
2.1	Anvil Points Mine	2.2
2.2	Mine Particulates, Size Distribution	2.7
3.1	Mine Adit Particulates, Size Distribution	3.4
3.2	Haul Road Particulates, Size Distribution	3.5
4.1	Crushing Area	4.5
4.2	Crushing Particulates, Size Distribution	4.6
5.1	Retort Area	5.7
5.2	Paraho Direct Mode Schematic	5.8
5.3	Retort and Oil Transfer Particulates, Size Distribution	5.9
6.1	Shale Disposal Particulates, Size Distribution	6.4
Tables		
Mine		
2-1	Total Suspended Particulates	2.8
2-2	Respirable Dust	2.9
2-3	Particulates, Particle Size	2.10
2-4	Particulates, Proximate Analysis	2.11
2-5	Particulates, Toxic Elements	2.12
2-6	Particulates, General Elemental	2.13
2-7	Gases, General Analyses	2.15
2-8	Gases, Volatile Organics	2.16
2-9	Gases, Toxic Volatile Metals	2.17
Mine Adits and Haul Road		
3-1	Total Suspended Particulates	3.6
3-2	Respirable Dust	3.9
3-3	Particulates, Particle Size	3.10
3-4	Particulates, Toxic Elements	3.11
3-5	Particulates, Other Elemental Analyses	3.12
3-6	General Gas Data	3.13
3-7	Volatile Organics	3.14

LIST OF ILLUSTRATIONS (Cont'd)

		Page
Tables (Cont'd)		
Crushing		
4-1	Total Suspended Particulates	4.8
4-2	Respirable Dust	4.10
4-3	Particle Size	4.11
4-4	Particulates, Proximate Analysis	4.12
4-5	Particulates, Toxic Elements	4.13
4-6	Particulates, Toxic Elements, Analysis by Particle Size	4.14
4-7	Particulates, Other Elemental	4.15
4-8	Particulates, Elemental Analysis by Particle Size	4.18
4-9	Particulates, Chemical Analysis by Particle Size, Hi-Vol Sample	4.19
4-10	Particulates, Elemental Analysis by Impactor Stages	4.21
4-11	Mineral Analysis	4.22
4-12	Gas Data	4.23
4-13	Gas Elemental Analysis	4.24
Retort		
5-1	Product Gas Particulates	5.10
5-2	Thermal Oxidizer, General Particulate Data	5.11
Retort and Oil Transfer		
5-3	Total Suspended Particulates	5.12
5-4	Respirable Dust	5.13
5-5	Particle Size	5.14
5-6	Thermal Oxidizer Particulates, Elemental Analysis	5.15
5-7	Retort and Oil Transfer Particulates, Proximate Analysis	5.16
5-8	Retort and Oil Transfer Particulates, Toxic Elements	5.17
5-9	Retort and Oil Transfer Particulates, Other Elemental Analysis	5.18
5-10	Retort and Oil Transfer Particulates, Chemical Analysis by Particle Size	5.19
5-11	Product Gas Analysis, Paraho Data	5.22
5-12	Product Gas Composition	5.23

LIST OF ILLUSTRATIONS (Cont'd)

		Page
Tables (Cont'd)		
Retort and Oil Transfer (Cont'd)		
5-13	Product Gas Trace Organics, 1977	5.24
5-14	Thermal Oxidizer, Gas Chromatography Data	5.26
5-15	Thermal Oxidizer, Sulfur and Nitrogen Gases	5.27
5-16	Retort and Oil Transfer, General Gas Analysis	5.28
5-17	Retort and Oil Transfer, Volatile Organics	5.30
5-18	Product Gas, Toxic Elemental Analysis	5.32
5-19	Product Gas, General Elemental Analysis	5.33
5-20	Thermal Oxidizer Gases, Toxic Elements	5.35
5-21	Thermal Oxidizer Gases, General Elemental Analysis	5.36
5-22	Retort and Oil Transfer, Toxic Metals	5.38
Shale Disposal		
6-1	Total Suspended Solids	6.5
6-2	Respirable Dust	6.7
6-3	Particle Size	6.8
6-4	Saturated n-Hydrocarbons	6.9
6-5	Particulates, Proximate Analysis	6.10
6-6	Particulates, Toxic Elements	6.11
6-7	Particulates, Toxic Elements by Particle Size	6.12
6-8	Particulates, General Elemental Analyses	6.13
6-9	Particulates, Chemical Analysis by Particle Size	6.15
6-10	Baghouse Fines, Elemental Analysis by Particle Size	6.18
6-11	Particulates, Mineral Analysis	6.19
6-12	Gases	6.20
6-13	Gases, Volatile Metals	6.21
Miscellaneous		
7-1	Average Elemental Analysis of Background Particulates	7.3
7-2	Particulate Chemical Analysis of Background Particulates by Particle Size	7.4
7-3	Gas Data	7.5

1.0 INTRODUCTION

1.1 General

Data concerning the air quality of the Paraho operations at the DoE Anvil Points Oil Shale Research Facility have been obtained by various researchers. These data have been obtained during the Paraho oil shale demonstration (1974-1976) and the ONR-DoE sponsored research (1977-1978) directed towards the production of 100,000 barrels. The air quality data are compiled, categorized, and reduced in this report. All data received by the researchers are included; for the purpose of this report none have been edited or eliminated. This report is a data summary. It is not meant to imply worker exposure data since, in many cases, both the Paraho research operations and the air quality monitoring represent starts on a learning curve.

This air quality report is arranged in seven sections - 1.0, INTRODUCTION; 2.0, MINE; 3.0, MINE ADIT AND HAUL ROAD; 4.0, CRUSHING; 5.0, RETORT; 6.0, SHALE DISPOSAL; 7.0, MISCELLANEOUS. Air quality data and discussions are grouped into Sections 2-7 which parallel the Paraho operations at Anvil Points.

Whenever possible, samples are identified as ambient or background, fugitive emissions, effluents or point sources, and process streams. The only process stream sample included in this report is the recycle, or product, gas associated with the retorting operation. Recycle gas has been included to aid in assessing the data presented as background, fugitive emission, and point source. Much of the data is presented as fugitive emissions. However, because of extreme variability in wind characteristics and terrain and the close proximity of most of the crushing, retorting, and shale disposal operations, it is not possible to quantify emission factors from the data presented.

The air quality data presented in this report fall into two broad areas - particulates and gases. Information regarding particulates has been grouped accordingly:

- Loading or TSP
- Particle size distribution
- Chemical characterization
  - Organic elements
  - Toxic elements
  - General elemental
- Specific samples

Information regarding gases has been grouped accordingly:

- General
- Inorganic speciation
- Trace organics
- General elemental

Due to limitations of the normal Paraho operations and restrictions in the researcher's scopes of work, not all the above information has been obtained for all the portions of the Paraho operations or sections of this report. Not only are more data and information required, but the following comment made by one of the researchers should be kept in mind:

> "The data obtained must be considered unique to the Paraho oil shale demonstration, and cannot be compared to those from a full scale Paraho operation".

Even though the data compiled in this report are not complete and do not represent worker exposure data, these data represent first generation information which can serve as an important base and a guide for future research efforts.

1.2 Abbreviations and Bibliography

In order to keep this report (especially the tables and figures) as concise as possible, abbreviations are used. Since these abbreviations refer to technical terms, government agencies, and corporate names, a list of these abbreviations is included in this section (see pg 1-3). Common symbols of the chemical elements have not been considered as abbreviations.

The bibliography included in this section is a listing of the data base reports received by Development Engineering, Inc. (DEI) by April, 1979. The entire data base dealing with the environmental, health and safety aspects of the recently-completed Paraho operations at Anvil Points is incomplete. However, it is believed that all of the data pertaining to air quality has been received by DEI and has been presented in this report.

LIST OF ABBREVIATIONS

AA	Atomic Absorption
And. Impac.	Andersen Impactor
AV	AeroVironment, Inc.
Blwr.	Blower
BNW	Battelle Pacific Northwest Laboratory
Btm.	Bottom
Cas. Impac.	Cascade Impactor
Color	Colorimetry
Conc.	Concentration
CTE	Commercial Testing and Engineering
D	Downwind
DEI	Development Engineering, Inc.
Det. Tube	Detector Tube
Dist.	Distributor
DoE	Department of Energy
ESP	Electrostatic Precipitator
FES	Flame Emission Spectrophotometry
F.I.D.	Flame Ionization Detector
g	Grams
G.C.	Gas Chromatograph
HC	Hydrocarbons
Hi-Vol	High Volume Sampler
HR	Haul Road
I.D.	Inside Diameter
INAA	Instrumental Neutron Activation Analysis
ISE	Ion Sensing Electrode
LASL	Los Alamos Scientific Laboratory
LFE	LFE Environmental Labs
m^3	Cubic Meters
mg	Milligrams
Mid.	Middle
Mmad	Mass Median Aerodynamic Diameter
MS	Mass Spectrophotometer

LIST OF ABBREVIATIONS (Cont'd)

MW	Molecular Weight
μ	50% Cutoff in Microns
ug	Micrograms
N	Number of Samples
ND	None Detected
ng	Nanograms
ONR	Office of Naval Research
PAH	Polycyclic Aromatic Hydrocarbons
PAR	Paraho
% P	Percent Passing
Pers. Samp.	Personal Sampler
PES	Plasma Emission Spectroscopy
PP	Pilot Plant
Prim.	Primary
Rm.	Room
R.S.D.	Relative Standard Deviation
S.D.	Standard Deviation
Sec.	Secondary
Seq. Samp.	Sequential Sampler
SSMS	Spark Source Mass Spectrophotometer
SW	Semi-Works
σg	Geometric Standard Deviation
T.C.	Thermal Conductivity Detector
Tert.	Tertiary
THC	Total Hydrocarbons
TO	Thermal Oxidizer
TRW	TRW Environmental Engineering Division
TSP	Total Suspended Particulates
U	Upwind
Vol%	Volume Percent
WF	Working Face
Wt%	Weight Percent
XRF	X-Ray Fluorescence

CHARACTERIZATION DATA

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2.0 MINE

2.1 General Background

The mine at Anvil Points is a room-and-pillar mine. Access is by adits. As such, the mine would be representative of a modular or commercial oil shale operation. However, the mining operations (drilling, charging, blasting, scaling, roofbolting, mucking, and loading) were not typical of the larger-scale operations. During the recently-completed Paraho operations, the mining operations were done sequentially rather than simultaneously. Thus, sampling, depending on when it was carried out, may not be representative of the overall mining operation.

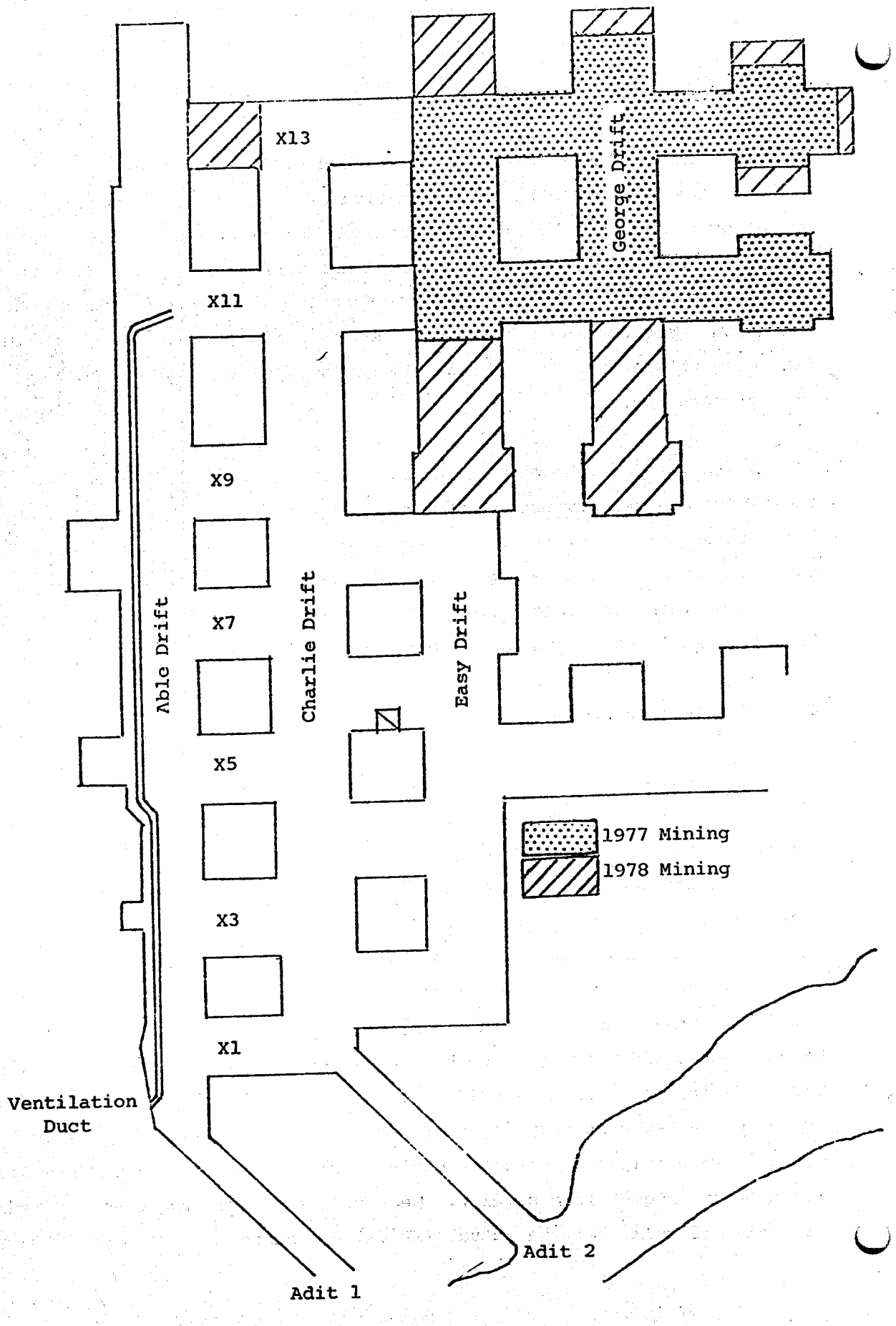
A schematic of the Anvil Points mine is pictured in Figure 2.1. Shown in the figure are the advances made during 1977 and 1978 operations, location of the ventilation air ducts, the adits, the drifts (designated by capital letters), and the cross-cuts (designated by Arabic numerals). In this section there are nine tables detailing the concentration and composition of gases and particulates. All mine samples are considered to be fugitive.

2.2 Mine Particulates

The loading or TSP of mine particulates are presented in Table 2-1. These data were obtained using personal samplers, Andersen impactors, high-volume samplers, and cascade impactors. Sampling times ranged from 0.5 to 1.0 hours and volume sampled ranged from 0.04 to 0.85 m^3. Total suspended particulates averaged 8.3 mg/m^3 with a standard deviation of 5.9 mg/m^3. Although the TSP value for the working face appears higher than the other TSP values for various locations, the values are not significantly different; working face (WF), TSP = 11.3 mg/m^3; near the work area (E-11, C-13, E-13) TSP = 8.7 mg/m^3; midway between adits and working face (A-7, C-7, General) TSP = 5.7 mg/m^3. The variation in the overall mean TSP value is caused by changes in time (mine activity) rather than sampling procedure. Five times over a five-month period TSP data were collected simultaneously using two different methods - cascade impactor and high-volume sampler. Mean differences in these six paired data are only 0.5 mg/m^3 yet the actual TSP values ranged from 3.6 to 15.6 mg/m^3.

FIGURE 2.1

Anvil Points Mine



Some direct measurements of respirable dusts were made using personal samplers. These were not made concurrently with TSP sampling. Respirable dust data in Table 2-2 show a mean of 5.7 mg/m^3 and a standard deviation of 6.4 mg/m^3.

Size distribution data are presented in Table 2-3 and Figure 2-2. The average mass median aerodynamic diameter (Mmad) throughout the mine is 3.2 μ. The high geometric standard deviation ($\sigma g > 10$) indicates improperly sized equipment.

As expected, the composition of total mine dust approximates normal raw shale feed used in the Paraho retorting operations (see Table 2-4). Sulfur is somewhat higher in the dust.

Toxic elements (As, B, Cd, Cu, F, Hg, Mo, Pb, Se, and Zn) were determined using x-ray fluorescence (XRF) and spark source mass spectroscopy (SSMS). These data, shown in Table 2-5, have been grouped with similar data from Paraho operations (see Tables 3-4, 4-5, and 5-8) in the following table:

Statistical Evaluation

	Outliers	ND	N	$\bar{X}$ (ppm)	S.D. (ppm)	R.S.D.,%
As	0	2	13	45	32	100
B	0	0	4	57	57	57
Cd	0	5	11	2.2	1.8	85
Cu	1	1	12	70	38	55
F	1	1	6	1116	548	49
Hg	1	4	8	0.4	0.4	100
Mo	0	0	4	28	13	47
Pb	1	1	12	49	26	53
Se	1	1	10	9	11	125
Zn	0	0	12	122	58	47

Although these data showing toxic elements concentration are widely scattered (relative standard deviations range from 47 to 125 percent of mean values), less than 7% of the data base can be classified as outliers (greater than four times the standard deviation from the mean). In Table 2-5, the 334 ppm Cu and the 281 ppm Pb are outliers. The other results in Table 2-5, when compared with other toxic element concentration in raw shale dust, appear to be valid.

Concentrations of most of the other elements were determined in the total suspended particulates in the mine using XRF and SSMS (see Table 2-6). These data have been grouped with similar data from the Paraho operations (see Tables 3-5, 4-7, and 5-9) and compared in the following tables. The first table lists the major (conc. > 0.1%) elements.

Statistical Evaluation

	Outlier	ND	N	$\bar{X}$, %	S.D., %	R.S.D., %
Al	0	0	3	3.0	1.7	56
Ca	0	0	4	8.1	4.2	52
Fe	0	0	9	2.1	0.2	11
K	0	0	2	1.5	-	-
Mg	0	0	3	3.2	0.8	24
Na	0	0	4	1.9	0.7	37
Si	0	0	4	11.4	4.4	39
Ti	1	2	6	0.20	0.03	16

The second table lists the minor (conc. < 1000 ppm) elements. No statistical evaluations were made unless N ≥ 3; in those cases where no evaluation was made, both S.D. and R.S.D. are marked with a dash (-). Statistical evaluations could be performed on 34 elements. There were only 3 outliers. Variations for both major and minor elements are high; the R.S.D. for the major elements ranges from 11 to 56%; for the minor elements, the R.S.D. ranges from 16 to 127%. For the mine particulates, the 11 ppm Ag appears to be high. The other data in Table 2-6, when compared with other raw shale dust data, appear to be valid.

2.3 Mine Gases

General gas data, obtained in the Anvil Points mine during the 1975-1978 Paraho operations, are listed in Table 2-7. The mine atmosphere resembles normal air. Oxygen is 21.0 ± 0.16 Vol.%; carbon dioxide is 350 ± 100 ppm. About half the carbon monoxide readings were below limits of detection; the other CO readings averaged 7 ± 5 ppm. For the most part, during normal working hours, the Anvil Points mine is free of sulfur and nitrogen gases. No hydrogen sulfide, mercaptans, ammonia, cyanide or nitrates were found. Practically all

Statistical Evaluation

	Outliers	ND	N	$\bar{X}$,ppm	SD,ppm	RSD,%
Ag	1	5	7	0.4	-	-
Au	0	2	2	-	-	-
Ba	0	0	2	510	-	-
Be	0	1	2	0.1	-	-
Bi	0	1	2	1	-	-
Br	0	2	5	5	4	87
Ce	0	0	2	40	18	44
Cs	0	0	2	7	6	81
Cl	0	0	2	51	-	-
Co	0	1	6	27	34	127
Cr	0	4	11	39	25	64
Dy	0	0	2	1	-	-
Er	0	0	2	1	-	-
Eu	0	0	4	0.7	0.3	48
Ga	0	0	4	20	9	45
Ge	0	0	2	1	-	-
Gd	0	0	2	1	-	-
Hf	0	1	2	1	-	-
Ho	0	0	2	1	-	-
I	0	0	2	3	-	-
Ir	0	2	2	-	-	-
La	1	0	5	25	12	47
Li	0	1	2	7	-	-
Lu	0	1	4	0.23	0.06	28
Mn	0	0	8	320	122	38
Nb	0	0	4	11	6	52
Nd	0	0	2	9	-	-
Ni	0	4	10	23	10	43
Os	0	2	2	-	-	-
P	0	0	0	-	-	-
Pd	0	2	2	-	-	-
Pr	0	0	2	4	-	-
Pt	0	2	2	-	-	-
Rb	0	0	6	66	26	39
Sb	0	0	4	4	2	43
Sc	0	0	4	4	2	38
Sm	0	0	3	8	7	82
Sn	0	0	2	1	-	-
Sr	0	0	6	632	100	16
Ta	0	2	2	-	-	-
Tb	0	0	2	1	-	-
Te	0	2	2	-	-	-
Th	0	0	4	7	4	52
Tl	0	1	2	1	-	-
Tm	0	1	2	0.1	-	-
U	0	0	4	9	4	46
V	0	0	5	202	177	87
W	0	1	2	1	-	-
Y	0	0	4	19	14	75
Yb	0	1	2	1	-	-
Zr	0	0	4	68	42	62

sulfur dioxide data were below the limits of detection. One sample showed 0.4 ppm SO_2. Low levels of oxides of nitrogen were found. Nitrous oxide (N_2O) averaged 3.4 $\pm$ 1.6 ppm; nitric oxide (NO_2) averaged 0.3 ppm. Only one sample of oxides of nitrogen (NO_x) was above the detection limits. That value, 5 ppm NO_x, confirmed the low N_2O and NO_2 data.

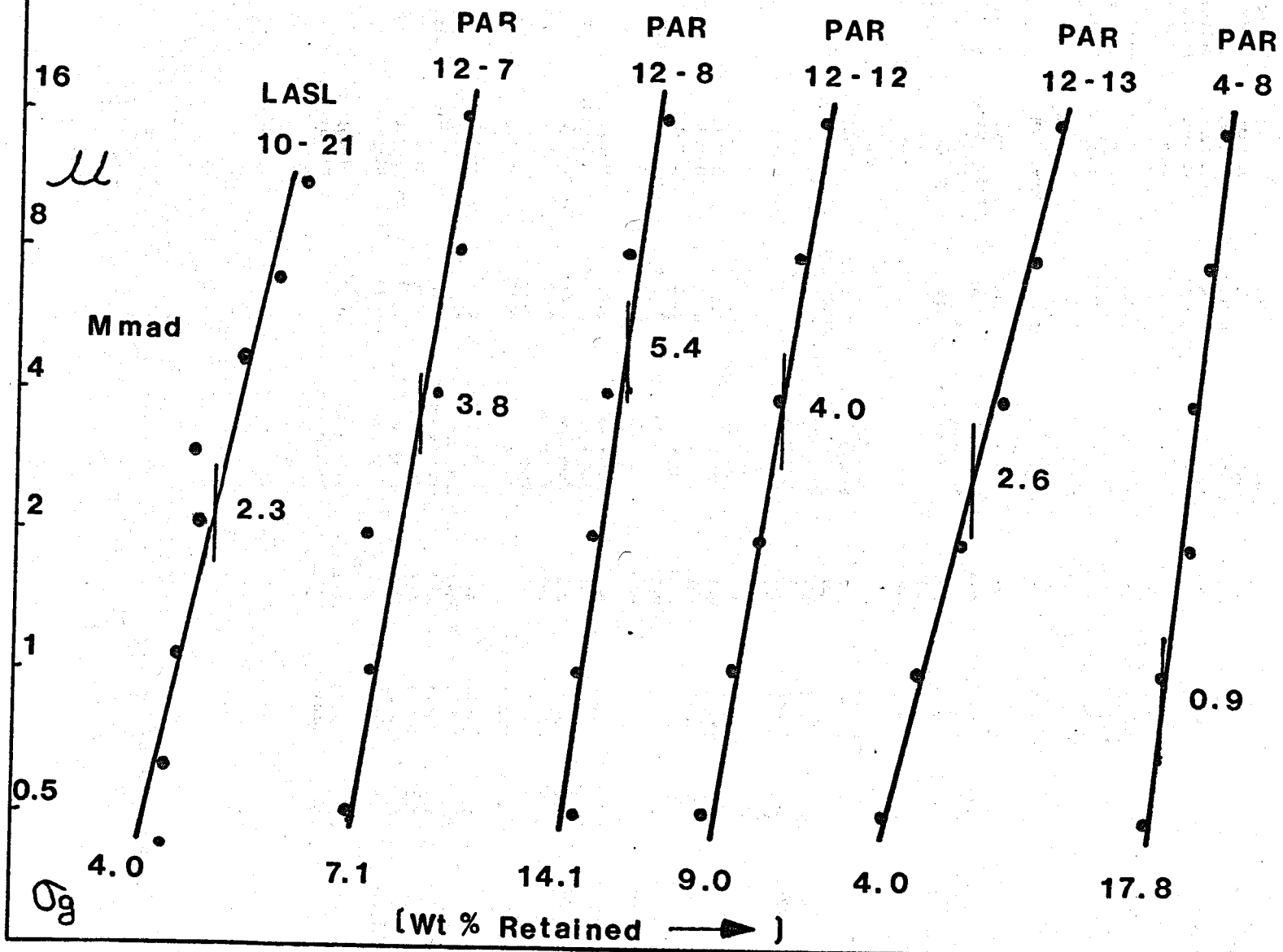
Data gathered for volatile organics in mine gases is presented in Table 2-8. No mercaptans, phenols, methane, formaldehyde, or coal tar volatiles were detected. Total hydrocarbons (HC) ranged from none detected to 12.5 ppm; mean HC level (from those detected) was 9 $\pm$ 4 ppm.

The air in the mine was also analyzed for some volatile metals. As shown in Table 2-9, no arsenic, mercury, selenium, or lead was detected.

Detector tubes were frequently used in gas sampling at the mine and other locations discussed in this report. The use of detector tubes further illustrates the preliminary nature of these monitoring operations. Although quantitative figures are placed on these results, the detector tube data should be viewed as semi-quantitative at best.

Figure 2.2

Mine Particulates, Size Distribution



AIR QUALITY

PARAHO OPERATIONS

TABLE 2-1

Mine, Total Suspended Particulates

Date	Data mg/m3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Methods	Comments
8/6-7/75	5.0	LFE-2	WF	Fugitive	0.0015	Pers. Samp.	Loader Operator
8/6-7/75	3.7	LFE-2	WF	Fugitive	0.0011	Pers. Samp.	Loader Operator
7/18/77	20.8	LASL-6	WF	Fugitive	0.0029	Pers. Samp.	Drill Operator
7/18/77	31.9	LASL-6	WF	Fugitive	0.0045	Pers. Samp.	Drill Operator
7/18/77	6.6	LASL-6	WF	Fugitive	0.0019	Pers. Samp.	Loader Operator
7/18/77	3.8	LASL-6	General	Fugitive	0.0004	Pers. Samp.	LASL Personnel
7/18/77	10.0	LASL-6	WF	Fugitive	0.0021	Pers. Samp.	Drill Operator
7/18/77	7.0	LASL-6	WF	Fugitive	0.0015	Pers. Samp.	Loader Operator
7/18/77	6.5	LASL-6	WF	Fugitive	0.0011	Pers. Samp.	Drill Operator
7/18/77	14.6	LASL-6	General	Fugitive	0.0012	Pers. Samp.	LASL Personnel
10/18/77	6.7	LASL-6	WF	Fugitive	0.0003	Pers. Samp.	
10/19/77	19.2	LASL-6	WF	Fugitive	0.0012	Pers. Samp.	
10/19/77	7.4	LASL-6	WF	Fugitive	0.0063	And. Impac.	While Drilling
10/21/77	5.79	LASL-6	E-13	Fugitive	0.0041	And. Impac.	Size Distribution
12/7/77	4.0	PAR-9	A-7	Fugitive	0.25	Hi-Vol	
12/7/77	3.6*	PAR-9	A-7	Fugitive	0.16	Hi-Vol	
12/7/77	4.6*	PAR-9	A-7	Fugitive	0.0024	Cas. Impac.	Size Distribution
12/7/77	3.3	PAR-9	A-7	Fugitive	0.16	Hi-Vol	
12/7/77	4.0	PAR-9	A-7	Fugitive	0.21	Hi-Vol	
12/8/77	8.2*	PAR-9	C-7	Fugitive	0.38	Hi-Vol	
12/8/77	9.4*	PAR-9	C-7	Fugitive	0.0042	Cas. Impac.	Size Distribution
12/8/77	5.4	PAR-9	C-7	Fugitive	0.30	Hi-Vol	
12/8/77	6.3	PAR-9	C-7	Fugitive	0.28	Hi-Vol	
12/8/77	6.2	PAR-9	C-7	Fugitive	0.27	Hi-Vol	
12/8/77	7.8	PAR-9	C-7	Fugitive	0.35	Hi-Vol	
12/12/77	17.3	PAR-9	E-11	Fugitive	0.66	Hi-Vol	
12/12/77	8.3	PAR-9	E-11	Fugitive	0.38	Hi-Vol	
12/12/77	9.1*	PAR-9	E-11	Fugitive	0.25	Hi-Vol	
12/12/77	9.2*	PAR-9	E-11	Fugitive	0.0026	Cas. Impac.	Size Distribution
12/12/77	6.4	PAR-9	E-11	Fugitive	0.30	Hi-Vol	
12/13/77	15.6*	PAR-9	C-13	Fugitive	0.76	Hi-Vol	
12/13/77	15.4*	PAR-9	C-13	Fugitive	0.0032	Cas. Impac.	Size Distribution
12/13/77	10.6	PAR-9	C-13	Fugitive	0.51	Hi-Vol	
12/13/77	11.6	PAR-9	C-13	Fugitive	0.18	Hi-Vol	
12/13/77	4.7	PAR-9	C-13	Fugitive	0.46	Hi-Vol	
12/13/77	9.3	PAR-9	C-13	Fugitive	0.47	Hi-Vol	
4/18/78	5.1	PAR-9	A-7	Fugitive	0.21	Hi-Vol	
4/18/78	4.4*	PAR-9	A-7	Fugitive	0.20	Hi-Vol	
4/18/78	4.7*	PAR-9	A-7	Fugitive	0.0026	Cas. Impac.	Size Distribution
4/18/78	2.3	PAR-9	A-7	Fugitive	0.15	Hi-Vol	
5/3/78	4.2	PAR-9	C-13	Fugitive	0.27	Hi-Vol	
5/3/78	5.7	PAR-9	C-13	Fugitive	0.29	Hi-Vol	
5/3/78	5.8	PAR-9	C-13	Fugitive	0.30	Hi-Vol	
5/3/78	0.8	PAR-9	C-13	Fugitive	0.48	Hi-Vol	

* Sampled Concurrently

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-2

Mine, Respirable Dust

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Methods	Comments
8/6-7/75	3.0	LFE-2	WF	Fugitive	0.00090	Pers. Samp.	Loader Operator
10/18/77	0.0	LASL-6	WF	Fugitive	0.00000	Pers. Samp.	
10/18/77	0.3	LASL-6	E-13	Fugitive	0.00012	Pers. Samp.	
10/19/77	12.6	LASL-6	WF	Fugitive	0.0005	Pers. Samp.	
10/19/77	3.7	LASL-6	WF	Fugitive	0.00022	Pers. Samp.	
10/19/77	14.6	LASL-6	WF	Fugitive	0.0007	Pers. Samp.	

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-3

Mine Particulates, Particle Size

Lab-Ref	Date		Analysis								Location	Sampling Method	Quantity	Mmad	∇g
		(μ)	12	7	4.8	3.4	2.2	1.2	0.66	0.44					
LASL-6	10/21/77	% P	98.4	82.5	63.5	39.7	39.7	33.4	25.4	25.4	E-13	And. Impac.	5.79 mg	2.3	4.0
		(μ)	16	8	4	2	1	0.5							
PAR-9	12/7/77	% P	70.6	70.6	58.8	23.5	23.5	17.7			A-7	Cas. Impac.	2.4 mg	3.8	7.1
PAR-9	12/8/77		64.3	46.4	39.3	32.2	28.6	28.6			C-7	Cas. Impac.	2.8 mg	5.4	14.1
PAR-9	12/12/77		70.0	60.0	50.0	40.0	30.0	15.0			E-11	Cas. Impac.	2.0 mg	4.0	9.0
PAR-9	12/13/77		92.9	82.1	64.3	42.9	21.4	7.1			C-13	Cas. Impac.	8.0 mg	2.6	4.0
PAR-9	4/18/78		83.3	75.0	70.8	66.6	50.0	46.7			A-7	Cas. Impac.	2.6 mg	0.9	17.8

μ = 50% cut-off in microns
% P = % Passing
Mmad = mean mass aerodynamic diameter
∇g = particle size deviation
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-4

Mine Particulates, Proximate Analysis

	Particulate Sample Wt%	Raw Shale Wt%	Analytical Method
Mineral CO_2	14.65	17.54	Coulometric
Mineral C	4.00	4.79	Coulometric
Total C	13.06	16.65	Elemental Analyzer
Total Organic C	9.06	11.86	Difference
H	1.38	1.75	Elemental Analyzer
N	0.48	0.52	Elemental Analyzer
S	1.34 > 1*	0.74	Sulfur Analyzer SSMS
Ash	70.95	66.67	Gravimetric

Date: 4/18/78
Lab-Ref: PAR-9
Location: A-7
Sample Type: Fugitive Dust
Sampling Method: Hi-Vol

* This Analysis CTE-9, all other analyses by PAR-9.

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-5

Mine Particulates, Toxic Elements

Parameter	Date	Data (ppm)	Lab-Ref	Location	Sample Type	Methods: Sampling	Methods: Analytical
As	8/6-7/75	< 55	LFE-2	WF	Fugitive	Pers. Samp.	XRF
	4/18/78	24	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
B	4/18/78	49	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
Cd	8/6-7/75	ND	LFE-2	WF	Fugitive	Pers. Samp.	XRF
	4/18/78	2	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
Cu	8/6-7/75	334	LFE-2	WF	Fugitive	Pers. Samp.	XRF
	4/18/78	> 1000	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
F	4/18/78	~ 820	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
Hg	8/6-7/75	< 72	LFE-2	WF	Fugitive	Pers. Samp.	XRF
Mo	4/18/78	13	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
Pb	8/6-7/75	281	LFE-2	WF	Fugitive	Pers. Samp.	XRF
	4/18/78	53	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
Se	4/18/78	11	CTE-9	A-7	Fugitive	Hi-Vol	SSMS
Zn	8/6-7/75	269	LFE-2	WF	Fugitive	Pers. Samp.	XRF
	4/18/78	100	CTE-9	A-7	Fugitive	Hi-Vol	SSMS

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-6

Mine Particulates, General Elemental

Parameter	Date	Data (ppm)	Lab-Ref	Location	Methods: Sampling	Methods: Analysis
Ag	8/6-7/75	< 360	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	11	CTE-9	A-7	Hi-Vol	SSMS
Al	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Au	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Ba	4/18/78	420	CTE-9	A-7	Hi-Vol	SSMS
Be	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Bi	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Br	4/18/78	10	CTE-9	A-7	Hi-Vol	SSMS
Ca	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Ce	4/18/78	27	CTE-9	A-7	Hi-Vol	SSMS
Cs	4/18/78	3	CTE-9	A-7	Hi-Vol	SSMS
Cl	4/18/78	52	CTE-9	A-7	Hi-Vol	SSMS
Co	8/6-7/75	≤ 205	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	18	CTE-9	A-7	Hi-Vol	SSMS
Cr	8/6-7/75	< 225	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	11	CTE-9	A-7	Hi-Vol	SSMS
Dy	4/18/78	0.6	CTE-9	A-7	Hi-Vol	SSMS
Er	4/18/78	0.3	CTE-9	A-7	Hi-Vol	SSMS
Eu	4/18/78	0.3	CTE-9	A-7	Hi-Vol	SSMS
Fe	8/6-7/75	17000	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Ga	4/18/78	15	CTE-9	A-7	Hi-Vol	SSMS
Ge	4/18/78	1	CTE-9	A-7	Hi-Vol	SSMS
Gd	4/18/78	0.5	CTE-9	A-7	Hi-Vol	SSMS
Hf	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Ho	4/18/78	0.4	CTE-9	A-7	Hi-Vol	SSMS
I	4/18/78	5	CTE-9	A-7	Hi-Vol	SSMS
Ir	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
K	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
La	4/18/78	24	CTE-9	A-7	Hi-Vol	SSMS
Li	4/18/78	7	CTE-9	A-7	Hi-Vol	SSMS
Lu	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Mg	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Mn	8/6-7/75	550	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	390	CTE-9	A-7	Hi-Vol	SSMS
Na	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Nb	4/18/78	6	CTE-9	A-7	Hi-Vol	SSMS
Nd	4/18/78	5	CTE-9	A-7	Hi-Vol	SSMS
Ni	8/6-7/75	< 115	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	12	CTE-9	A-7	Hi-Vol	SSMS
Os	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
P	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Pd	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Pr	4/18/78	3	CTE-9	A-7	Hi-Vol	SSMS
Pt	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Rb	4/18/78	25	CTE-9	A-7	Hi-Vol	SSMS
Re	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Rh	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Ru	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
S	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Sb	4/18/78	4	CTE-9	A-7	Hi-Vol	SSMS
Sc	4/18/78	2	CTE-9	A-7	Hi-Vol	SSMS
Si	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS

Sample Type: Fugitive

TABLE 2-6 (Cont'd)

Parameter	Date	Data (ppm)	Lab-Ref	Location	Methods Sampling	Methods Analysis
Sm	4/18/78	2	CTE-9	A-7	Hi-Vol	SSMS
Sn	4/18/78	1	CTE-9	A-7	Hi-Vol	SSMS
Sr	8/6-7/75	575	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	470	CTE-9	A-7	Hi-Vol	SSMS
Ta	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Tb	4/18/78	0.2	CTE-9	A-7	Hi-Vol	SSMS
Te	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Th	4/18/78	2	CTE-9	A-7	Hi-Vol	SSMS
Ti	8/6-7/75	1700	LFE-2	WF	Pers. Samp.	XRF
	4/18/78	> 1000	CTE-9	A-7	Hi-Vol	SSMS
Ti	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Tm	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
U	4/18/78	9	CTE-9	A-7	Hi-Vol	SSMS
V	4/18/78	39	CTE-9	A-7	Hi-Vol	SSMS
W	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Y	4/18/78	10	CTE-9	A-7	Hi-Vol	SSMS
Yb	4/18/78	ND	CTE-9	A-7	Hi-Vol	SSMS
Zr	4/18/78	30	CTE-9	A-7	Hi-Vol	SSMS

Sample Type: Fugitive

TABLE 2-7

Mine Gases, General Analyses

Parameter	Date	Data	Lab-Ref	Location	Quantity	Methods: Sampling	Methods: Analysis
O_2 (%)	7/18/77	20.8	LASL-6	General			O_2 Meter
	12/21/77	21.0	PAR-9	C-7		Gas Bomb	G.C. with T.C.
	4/18/78	21.1	PAR-9	A-7		Gas Bomb	G.C. with T.C.
CO (ppm)	8/6-7/75	< 5	LFE-2	WF			Det. Tube
	7/18/77	< 10	LASL-6	E			Det. Tube
	7/18/77	10-20	LASL-6	WF			Det. Tube
	10/18/77	10	LASL-6	E-13			Det. Tube
	10/18/77	10	LASL-6	E-13			Det. Tube
	10/18/77	3	LASL-6	A-7			CO Meter
	10/18/77	3	LASL-6	A-7			CO Meter
	10/19/77	2	LASL-6	A-7			CO Meter
	12/21/77	< 0.05	PAR-9	C-7		Gas Bomb	G.C. with T.C.
	4/18/78	< 0.05	PAR-9	A-7		Gas Bomb	G.C. with T.C.
CO_2 (ppm)	10/18/77	500	LASL-6	E-13			Det. Tube
	10/19/77	300	LASL-6	WF			Det. Tube
	12/21/77	300	PAR-9	C-7		Gas Bomb	G.C. with T.C.
	1/17/78	250	PAR-9	C-9			Det. Tube
	4/18/78	400	PAR-9	A-7		Gas Bomb	G.C. with T.C.
SO_2, (ppm)	8/6-7/75	0.4	LFE-2	WF			Det. Tube
	7/18/77	ND	LASL-6	WF			Det. Tube
	10/18/77	ND	LASL-6	E-13	100 ml		Det. Tube
	10/19/77	ND	LASL-6	WF			Det. Tube
	12/21/77	< 0.1	PAR-9	C-7		Bubbler	Color
	1/17/78	< 10	PAR-9	C-9			Det. Tube
	4/18/78	< 0.1	PAR-9	C-7			Det. Tube
H_2S (ppm)	10/18/77	ND	LASL-6	E-13	200 ml		Det. Tube
	10/19/77	ND	LASL-6	WF	100 ml		Det. Tube
H_2SO_4 (mg/m^3)	8/6-7/75	0.27	LFE-2	WF			
NH_3 (ppm)	10/18/77	ND	LASL-6	E-13	100 ml		Det. Tube
	10/19/77	ND	LASL-6	WF	100 ml		Det. Tube
HCN (ppm)	7/18/77	ND	LASL-6	WF			
HNO_3 (ppm)	7/18/77	ND	LASL-6	WF			Det. Tube
	10/18/77	ND	LASL-6	E-13	100 ml		Det. Tube
NO_2 (ppm)	8/6-7/75	1.6	LFE-2	WF	0.003 m^3	Absorber	
	8/6-7/75	4.6	LFE-2	WF			Det. Tube
	7/18/77	< 2	LASL-6	WF			Det. Tube
	10/18/77	4	LASL-6	E-13	100 ml		Det. Tube
	10/19/77	ND	LASL-6	WF	100 ml		Det. Tube
NO_2 (ppm)	8/6-7/75	0.3	LFE-2	WF	0.003 m^3	Absorber	
	8/6-7/75	0.4	LFE-2	General			Det. Tube
	7/18/77	< 1	LASL-6	WF			Det. Tube
NO_x (ppm)	8/6-7/75	5	LFE-2	WF			Det. Tube
	10/18/77	< 25	LASL-6	E-13	100 ml		Det. Tube
	12/21/77	< 1	PAR-9	C-7		Bubbler	Color
	1/17/77	< 2	PAR-9	C-9			Det. Tube
	4/18/78	< 5	PAR-9	C-7			Det. Tube

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-8

Mine Gases, Volatile Organics

Parameter	Date	Data	Lab-Ref	Location	Methods: Sampling	Methods: Analysis
CH_4 (ppm)	12/21/77	< 500	PAR-9	C-7	Gas Bomb	G.C. with T.C.
	4/18/78	< 500	PAR-9	A-7	Gas Bomb	G.C. with T.C.
Coal Tar Volatiles (mg/m^3)	8/6-7/75	< 0.03	LFE-2	WF	Filter	
Formaldehyde (ppm)	8/6-7/75	< 2	LFE-2	WF	Absorber	
	10/18/77	< 2	LASL-6	E-13		Det. Tube
	10/19/77	ND	LASL-6	WF		Det. Tube
Total Hydrocarbon (ppm)	7/18/77	12.5	LASL-6	WF		Gas Meter
	7/18/77	< 10	LASL-6	WF		Gas Meter
	7/18/77	< 10	LASL-6	A-7		Gas Meter
	7/21/77	< 25	LASL-6	General		Gas Meter
	10/18/77	16	LASL-6	WF		THC Analyzer
	10/18/77	10	LASL-6	WF		THC Analyzer
	10/18/77	3	LASL-6	A-7		THC Analyzer
	10/18/77	4	LASL-6	A-7		THC Analyzer
	10/19/77	8	LASL-6	C-11		THC Analyzer
	10/19/77	9	LASL-6	E-11		THC Analyzer
	10/19/77	11	LASL-6	WF		THC Analyzer
	1/17/78	< 5	PAR-9	C-7		Det. Tube
Mercaptans (ppm)	4/18/78	< 1	PAR-9	C-7		Color
Phenols (ppm)	4/18/78	< 3	PAR-9	C-7		Color

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 2-9

Mine Gases, Toxic Volatile Metals

Parameter	Date	Data, $\mu g/m^3$	Location	Methods: Sampling	Methods: Analysis	Comments
As	12/21/77	< 4	C-7	Seq. Samp.	AA	
	1/17/78	< 0.1 ppm	C-9		Det. Tube	Arsine
	4/18/78	< 4	C-7	Seq. Samp.	AA	
Hg	12/21/77	< 30	C-7	Seq. Samp.	AA	
	1/17/78	< 0.1 ppm	C-9		Det. Tube	Hg Vapor
	4/18/78	< 30	C-7	Seq. Samp.	AA	
Se	12/21/77	< 2	C-7	Seq. Samp.	AA	
	4/18/78	< 2	C-7	Seq. Samp.	AA	
Pb	12/21/77	< 2	C-7	Seq. Samp.	AA	
	4/18/78	< 2	C-7	Seq. Samp.	AA	

Lab-Ref: PAR-9

Sample Type: Fugitive

3.0 MINE ADITS AND HAUL ROAD

3.1 General Background

Studies were centered on the two mine adits and the 5.5 mile haul road because access to the mine for environmental monitoring was limited due to various safety rules and regulations. Even though shale may not be mined from an adit mine and a fleet of haul trucks may not be used in larger modular and commercial operation, these data are useful. Since the adits serve as exhausts for mine ventilation and the area adjacent to the haul road has been proposed as a modular site, data from the adits and haul road are useful in assessing mine activities and providing future background information.

In this section there are seven tables in which the concentration and composition of gases and particulates at the mine adits and haul road are presented. All adit data are listed as fugitive emissions. Classification of the haul road data depends on sampling site being located in an upwind or downwind position.

3.2 Particulates, Mine Adit and Haul Road

In Table 3-1, the TSP values are listed for the adits (68 samples), haul road upwind (15 samples), and haul road downwind (57 samples). These data were obtained using high volume samplers, cascade impactors, and personal samplers. Compiled results from these three sites are: adits, 5.7 $\pm$ 5.6 mg/m^3; haul road downwind, 2.3 $\pm$ 3.7 mg/m^3; haul road upwind, 0.7 $\pm$ 0.6 mg/m^3. The haul road data were obtained during those times when the 50-ton haul trucks passed the sampling site. The background or upwind data compiled into this mean and standard deviation were obtained during normal working hours and could be influenced by truck traffic on the winding haul road. Additional haul road background data, obtained from a 3-meter platform during weekends, indicated TSP value: mean, 0.014 mg/m^3 (N = 30); high, 0.060 mg/m^3. The adits, Adit #1 and Adit #2, serve as parallel exhausts for the mine ventilation system. For the most part, the results shown in Table 3-1 demonstrate this: variation is primarily day-to-day, results between adits are quite similar.

Only a few respirable dust samples were also taken for limited times at the mine adits and on the haul road. Results of these analyses are presented in Table 3-2. The haul road data was gathered during a period of vehicular traffic.

Size distribution of particulates from the mine adits and haul road (downwind) are presented in Table 3-3 and Figure 3-1. Mean Mmad values are: 4.6 μ, adit; and 3.4 μ, haul road. The high σg values indicate questionable data. Size distribution for adit particulates is fairly uniform. Size distribution for the haul road, demonstrating the variability in wind condition and terrain, varied from $< 0.5\ \mu$ to $> 10\ \mu$. More than half the samples analyzed produced results in these extremes. These data were not plotted in Figure 3-1. The mean Mmad value for the haul road from Figure 3-1 is $2.5 \pm 2.0\ \mu$.

Limited studies were made for elemental composition of mine adit and haul road particulates. Analyses for toxic elements are shown in Table 3-4. Data from the adit particulates do not differ from normal raw shale particulates (discussed in Section 2.2). Both fluorine and selenium are significantly higher in the haul road particulates. These outliers may be errors in sampling and analysis or may indicate that the haul road material does differ from normal raw shale particulates. Other elemental analyses of mine adit and haul road particulates are presented in Table 3-5. Again, the data from the adits do not differ from normal raw shale particulates, while the concentrations of several elements do show significant differences between haul road particulates and normal raw shale. Sulfur is low and magnesium and silicon are higher. Apparently, the haul road particulates originate from sources other than raw shale.

3.3 Gases, Mine Adit and Haul Road

No studies of gases were made along the haul road during the Paraho operations. Gas monitoring was directed towards the two adits which serve both as the mine access and the principal ventilation exhaust (see Figure 2-1). Much of the data, presented in Tables 3-6 and 3-7, were obtained before and after blasting.

Carbon monoxide levels show a temporary increase after blasting (see Table 3-6). The level before blasting was about 15 ppm, but increased to a mean of 40 ppm (high of 100 ppm) after a blast. Nitrous oxide and nitric oxide exhibited small increases after blasting; NO_2 increased from < 10 ppm to as high as 20 ppm; NO_2 increased from < 1 ppm to 1 ppm. Neither increase is statistically significant. A small amount of ammonia was detected after the blast (3-6 ppm NH_3). No other sulfur and nitrogen gases (H_2S, SO_2, HNO_3, HCN, NO_x) were detected. The limits of detection for NO_x was 25 ppm so that the 20 ppm NO and 1 ppm NO_2 cannot be considered invalid on the basis of no detectable NO_x.

Total hydrocarbon levels also increased temporarily after blasting (see Table 3-7). Total hydrocarbons increased from 4 ppm to a mean of 72 ppm (highest level detected was 120 ppm). Formaldehyde, hexane, and toluene remained below the limits of detection.

Figure 3.1

Mine Adit Particulates, Size Distribution

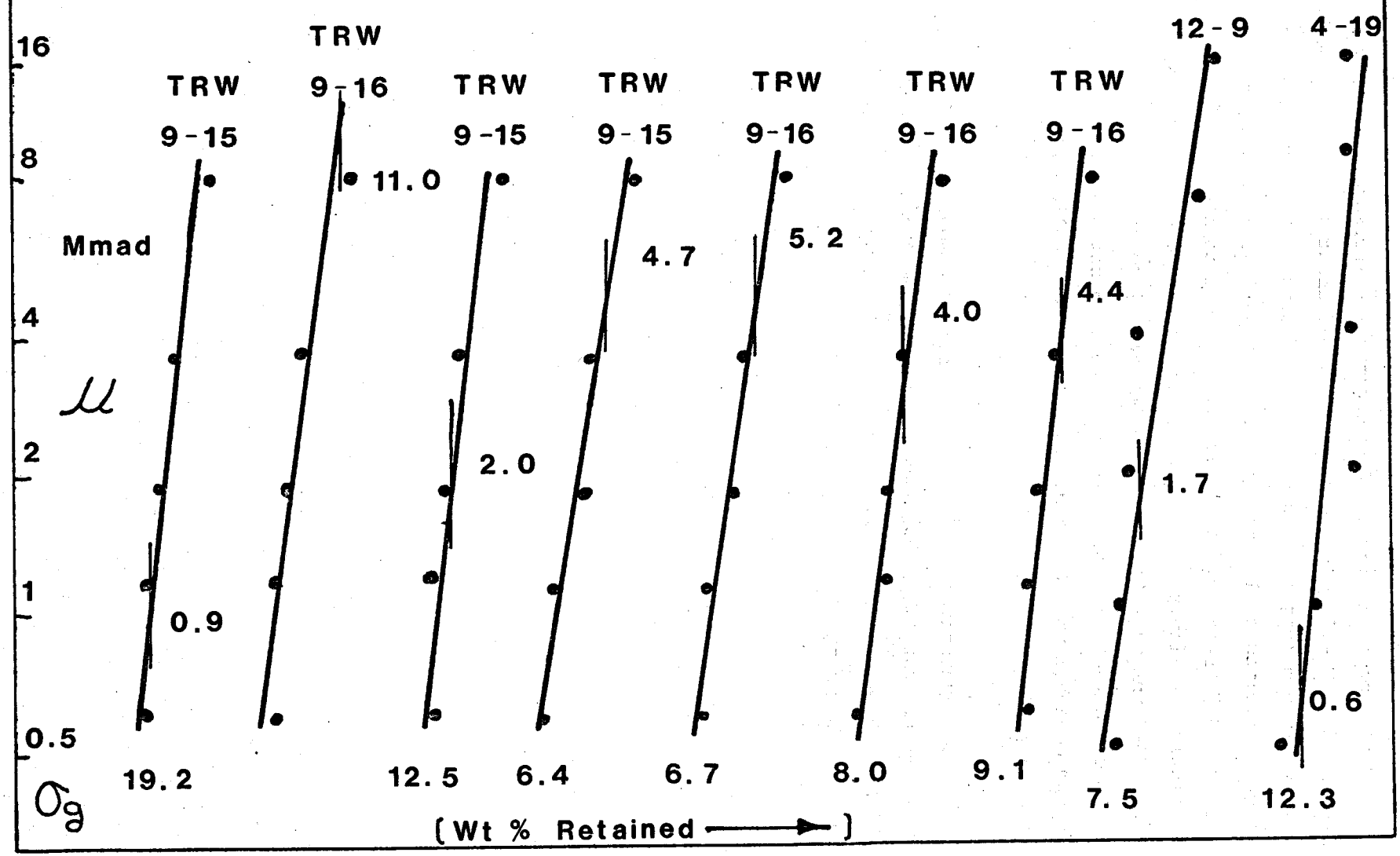
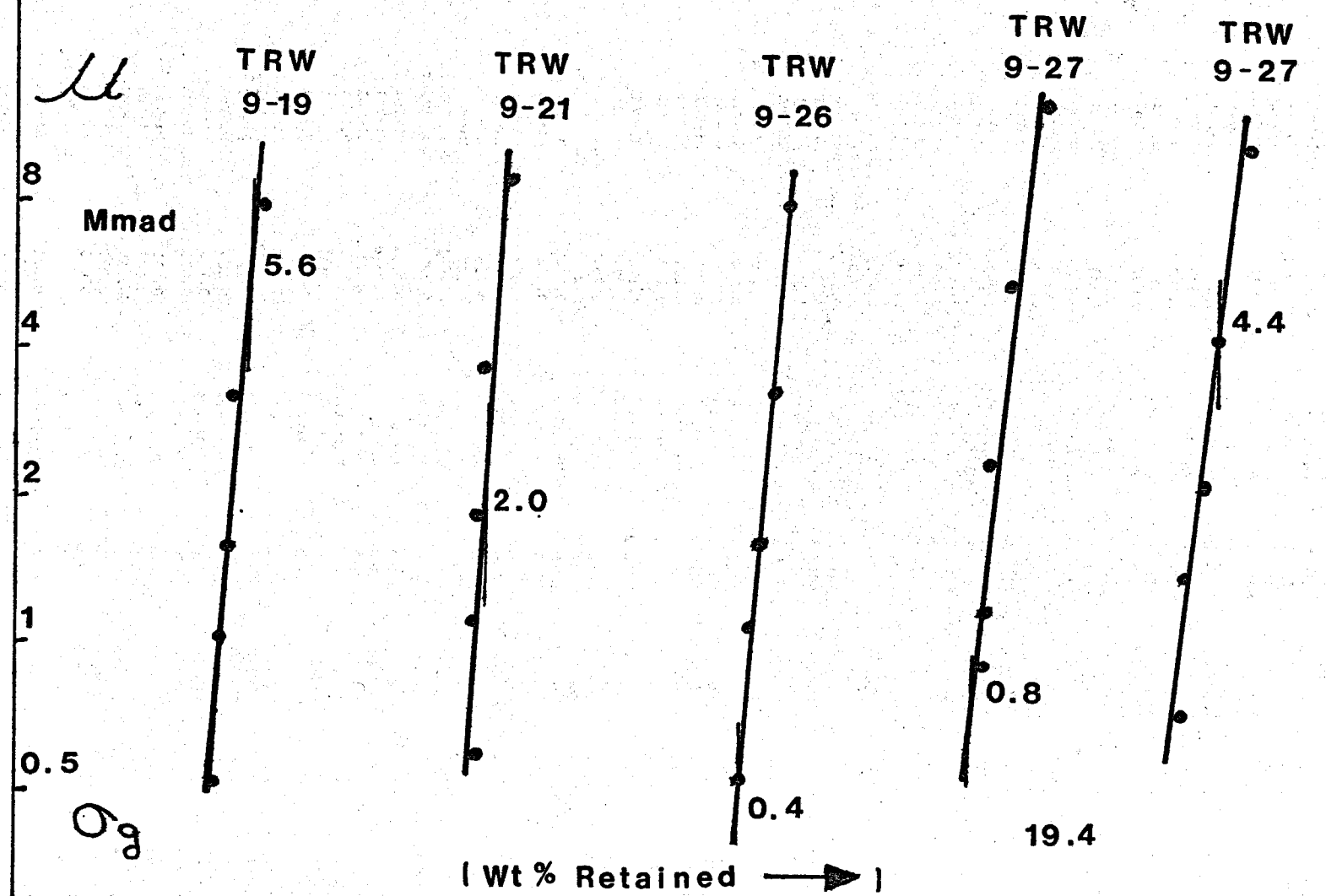


Figure 3.2

Haul Road Particulates, Size Distribution



AIR QUALITY

PARAHO OPERATIONS

TABLE 3-1

Mine Adit and Haul Road, Total Suspended Particulates

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method	Comments
9/7/77	4.26	TRW-10	Adit 1	Fugitive	0.240	Hi-Vol	
9/7/77	4.31	TRW-10	Adit 1	Fugitive	0.258	Hi-Vol	
9/7/77	5.44	TRW-10	Adit 2	Fugitive	0.261	Hi-Vol	
9/7/77	2.34	TRW-10	Adit 2	Fugitive	0.112	Hi-Vol	
9/14/77	10.34	TRW-10	Adit 1	Fugitive	0.313	Hi-Vol	
9/14/77	18.01	TRW-10	Adit 1	Fugitive	0.892	Hi-Vol	
9/14/77	5.11	TRW-10	Adit 1	Fugitive	0.278	Hi-Vol	
9/14/77	8.43	TRW-10	Adit 1	Fugitive	0.458	Hi-Vol	
9/14/77	11.38	TRW-10	Adit 1	Fugitive	0.628	Hi-Vol	
9/14/77	10.67	TRW-10	Adit 2	Fugitive	0.190	Hi-Vol	
9/14/77	6.03	TRW-10	Adit 2	Fugitive	0.263	Hi-Vol	
9/14/77	1.75	TRW-10	Adit 2	Fugitive	0.091	Hi-Vol	
9/14/77	1.70	TRW-10	Adit 2	Fugitive	0.096	Hi-Vol	
9/14/77	2.91	TRW-10	Adit 2	Fugitive	0.164	Hi-Vol	
9/15/77	3.70	TRW-10	Adit 1	Fugitive	0.202	Hi-Vol	
9/15/77	3.45	TRW-10	Adit 1	Fugitive	0.181	Hi-Vol	
9/15/77	2.90	TRW-10	Adit 1	Fugitive	0.082	Hi-Vol	
9/15/77	4.80	TRW-10	Adit 1	Fugitive	0.275	Hi-Vol	
9/15/77	10.73	TRW-10	Adit 1	Fugitive	0.386	Hi-Vol	
9/15/77	2.22	TRW-10	Adit 2	Fugitive	0.145	Hi-Vol	
9/15/77	3.19	TRW-10	Adit 2	Fugitive	0.163	Hi-Vol	
9/15/77	1.19	TRW-10	Adit 2	Fugitive	0.039	Hi-Vol	
9/15/77	1.61	TRW-10	Adit 2	Fugitive	0.103	Hi-Vol	
9/15/77	4.32	TRW-10	Adit 2	Fugitive	0.238	Hi-Vol	
9/15/77	6.26	TRW-10	Adit	Fugitive	0.2499	Cas. Impac.	Size Distribution
9/15/77	2.66	TRW-10	Adit	Fugitive	0.0713	Cas. Impac.	Size Distribution
9/15/77	4.27	TRW-10	Adit	Fugitive	0.1658	Cas. Impac.	Size Distribution
9/16/77	6.22	TRW-10	Adit 1	Fugitive	0.333	Hi-Vol	
9/16/77	7.64	TRW-10	Adit 1	Fugitive	0.390	Hi-Vol	
9/16/77	6.44	TRW-10	Adit 1	Fugitive	0.333	Hi-Vol	
9/16/77	7.08	TRW-10	Adit 1	Fugitive	0.287	Hi-Vol	
9/16/77	6.07	TRW-10	Adit 1	Fugitive	0.314	Hi-Vol	
9/16/77	1.16	TRW-10	Adit 2	Fugitive	0.068	Hi-Vol	
9/16/77	1.82	TRW-10	Adit 2	Fugitive	0.100	Hi-Vol	
9/16/77	1.83	TRW-10	Adit 2	Fugitive	0.104	Hi-Vol	
9/16/77	1.93	TRW-10	Adit 2	Fugitive	0.102	Hi-Vol	
9/16/77	2.15	TRW-10	Adit 2	Fugitive	0.116	Hi-Vol	
9/16/77	6.88	TRW-10	Adit	Fugitive	0.2725	Cas. Impac.	Size Distribution
9/16/77	4.87	TRW-10	Adit	Fugitive	0.2025	Cas. Impac.	Size Distribution
9/16/77	11.03	TRW-10	Adit	Fugitive	0.235	Cas. Impac.	Size Distribution
9/19/77	15.60	TRW-10	HR-D	Fugitive	0.176	Hi-Vol	
9/19/77	1.15	TRW-10	HR-D	Fugitive	0.136	Hi-Vol	
9/19/77	0.99	TRW-10	HR-D	Fugitive	0.073	Hi-Vol	
9/19/77	1.00	TRW-10	HR-D	Fugitive	0.125	Hi-Vol	
9/19/77	1.80	TRW-10	HR-D	Fugitive	0.215	Hi-Vol	
9/19/77	1.83	TRW-10	HR-D	Fugitive	0.107	Hi-Vol	
9/19/77	2.55	TRW-10	HR-D	Fugitive	0.1881	Cas. Impac.	Size Distribution
9/19/77	4.98	TRW-10	HR-D	Fugitive	0.3292	Cas. Impac.	Size Distribution
9/19/77	0.63	TRW-10	HR-U	Ambient	0.0584	Hi-Vol	
9/19/77	0.64	TRW-10	HR-U	Ambient	0.0678	Hi-Vol	
9/20/77	2.07	TRW-10	HR-D	Fugitive	0.124	Hi-Vol	
9/20/77	2.06	TRW-10	HR-D	Fugitive	0.110	Hi-Vol	
9/20/77	0.90	TRW-10	HR-D	Fugitive	0.051	Hi-Vol	
9/20/77	3.29	TRW-10	HR-D	Fugitive	0.049	Hi-Vol	
9/20/77	1.10	TRW-10	HR-D	Fugitive	0.0983	Hi-Vol	
9/20/77	1.05	TRW-10	HR-D	Fugitive	0.0883	Hi-Vol	
9/20/77	1.29	TRW-10	HR-D	Fugitive	0.113	Hi-Vol	
9/20/77	1.04	TRW-10	HR-D	Fugitive	0.080	Hi-Vol	
9/20/77	1.55	TRW-10	HR-D	Fugitive	0.136	Hi-Vol	
9/20/77	0.22	TRW-10	HR-D	Fugitive	0.020	Hi-Vol	
9/20/77	1.05	TRW-10	HR-D	Fugitive	0.091	Hi-Vol	
9/20/77	0.54	TRW-10	HR-D	Fugitive	0.047	Hi-Vol	
9/20/77	1.21	TRW-10	HR-D	Fugitive	0.135	Hi-Vol	
9/20/77	1.88	TRW-10	HR-D	Fugitive	0.071	Hi-Vol	
9/20/77	0.95	TRW-10	HR-D	Fugitive	0.056	Hi-Vol	
9/20/77	2.00	TRW-10	HR-D	Fugitive		Cas. Impac.	Size Distribution
9/21/77	0.33	TRW-10	HR-D	Fugitive	0.021	Hi-Vol	
9/21/77	0.03	TRW-10	HR-D	Fugitive	0.0024	Hi-Vol	
9/21/77	2.41	TRW-10	HR-D	Fugitive	0.159	Hi-Vol	
9/21/77	2.87	TRW-10	HR-D	Fugitive	0.215	Hi-Vol	
9/21/77	0.92	TRW-10	HR-D	Fugitive	0.127	Hi-Vol	
9/21/77	1.24	TRW-10	HR-D	Fugitive	0.135	Hi-Vol	

TABLE 3-1 (Cont'd)

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method	Comments
9/21/77	1.39	TRW-10	HR-D	Fugitive	0.104	Hi-Vol	
9/21/77	1.55	TRW-10	HR-D	Fugitive	0.111	Hi-Vol	
9/21/77	1.04	TRW-10	HR-D	Fugitive	0.078	Hi-Vol	
9/21/77	1.34	TRW-10	HR-D	Fugitive	0.084	Hi-Vol	
9/21/77	0.90	TRW-10	HR-D	Fugitive	0.093	Hi-Vol	
9/21/77	1.94	TRW-10	HR-D	Fugitive	0.232	Hi-Vol	
9/21/77	1.43	TRW-10	HR-D	Fugitive	0.189	Hi-Vol	
9/21/77	2.18	TRW-10	HR-D	Fugitive	0.152	Hi-Vol	
9/21/77	1.86	TRW-10	HR-D	Fugitive	0.137	Hi-Vol	
9/21/77	1.63	TRW-10	HR-D	Fugitive	0.126	Hi-Vol	
9/21/77	1.13	TRW-10	HR-D	Fugitive	0.046	Hi-Vol	
9/21/77	1.05	TRW-10	HR-D	Fugitive	0.043	Hi-Vol	
9/21/77	0.72	TRW-10	HR-D	Fugitive	0.031	Hi-Vol	
9/21/77	1.27	TRW-10	HR-D	Fugitive	0.095	Hi-Vol	
9/21/77	1.70	TRW-10	HR-D	Fugitive	0.132	Hi-Vol	
9/21/77	1.99	TRW-10	HR-D	Fugitive	0.0845	Cas. Impac.	Size Distribution
9/21/77	1.41	TRW-10	HR-D	Fugitive	0.0877	Cas. Impac.	Size Distribution
9/21/77	0.12	TRW-10	HR-U	Ambient	0.013	Hi-Vol	
9/21/77	0.45	TRW-10	HR-U	Ambient	0.028	Hi-Vol	
9/21/77	0.10	TRW-10	HR-U	Ambient	0.016	Hi-Vol	
9/21/77	0.27	TRW-10	HR-U	Ambient	0.034	Hi-Vol	
9/21/77	0.21	TRW-10	HR-U	Ambient	0.027	Hi-Vol	
9/21/77	0.22	TRW-10	HR-U	Ambient	0.017	Hi-Vol	
9/21/77	0.73	TRW-10	HR-U	Ambient	0.049	Hi-Vol	
9/22/77	4.05	TRW-10	HR-D	Fugitive	0.335	Hi-Vol	
9/22/77	3.28	TRW-10	HR-D	Fugitive	0.274	Hi-Vol	
9/22/77	0.13	TRW-10	HR-D	Fugitive	0.0081	Hi-Vol	
9/22/77	0.31	TRW-10	HR-D	Fugitive	0.017	Hi-Vol	
9/22/77	2.32	TRW-10	HR-D	Fugitive	0.145	Hi-Vol	
9/22/77	2.63	TRW-10	HR-D	Fugitive	0.156	Hi-Vol	
9/22/77	0.58	TRW-10	HR-D	Fugitive	0.034	Hi-Vol	
9/22/77	2.67	TRW-10	HR-D	Fugitive	0.157	Hi-Vol	
9/22/77	3.52	TRW-10	HR-D	Fugitive	0.149	Hi-Vol	
9/22/77	5.15	TRW-10	HR-D	Fugitive	0.188	Hi-Vol	
9/22/77	2.55	TRW-10	HR-D	Fugitive	0.110	Hi-Vol	
9/22/77	2.73	TRW-10	HR-D	Fugitive	0.249	Hi-Vol	
9/22/77	4.97	TRW-10	HR-D	Fugitive	0.374	Hi-Vol	
9/22/77	2.35	TRW-10	HR-D	Fugitive	0.169	Hi-Vol	
9/22/77	2.19	TRW-10	HR-D	Fugitive	0.148	Hi-Vol	
9/22/77	2.28	TRW-10	HR-D	Fugitive	0.155	Hi-Vol	
9/22/77	1.13	TRW-10	HR-D	Fugitive	0.051	Hi-Vol	
9/22/77	2.51	TRW-10	HR-D	Fugitive	0.068	Hi-Vol	
9/22/77	3.01	TRW-10	HR-D	Fugitive	0.147	Hi-Vol	
9/22/77	2.28	TRW-10	HR-D	Fugitive	0.152	Hi-Vol	
9/22/77	1.59	TRW-10	HR-D	Fugitive	0.866	Cas. Impac.	Size Distribution
9/22/77	0.34	TRW-10	HR-D	Fugitive	0.0086	Cas. Impac.	Size Distribution
9/22/77	0.84	TRW-10	HR-D	Fugitive	0.0255	Cas. Impac.	Size Distribution
9/22/77	1.77	TRW-10	HR-U	Ambient	0.063	Hi-Vol	
9/22/77	0.96	TRW-10	HR-U	Ambient	0.066	Hi-Vol	
9/22/77	0.48	TRW-10	HR-U	Ambient	0.021	Hi-Vol	
9/22/77	0.51	TRW-10	HR-U	Ambient	0.022	Hi-Vol	
9/22/77	0.39	TRW-10	HR-U	Ambient	0.032	Hi-Vol	
9/22/77	0.77	TRW-10	HR-U	Ambient	0.066	Hi-Vol	
9/22/77	1.69	TRW-10	HR-U	Ambient	0.0764	Hi-Vol	
9/22/77	0.81	TRW-10	HR-U	Ambient	0.038	Hi-Vol	
9/22/77	1.82	TRW-10	HR-U	Ambient	0.076	Hi-Vol	
9/23-24/77	0.21	TRW-10	Adit 1	Fugitive	0.135	Hi-Vol	
9/23-24/77	0.30	TRW-10	Adit 2	Fugitive	0.171	Hi-Vol	
9/23-24/77	0.34	TRW-10	Adit 2	Fugitive	0.281	Hi-Vol	
9/24-27/77	1.43	TRW-10	Adit 1	Fugitive	3.574	Hi-Vol	
9/24-27/77	1.87	TRW-10	Adit 1	Fugitive	3.590	Hi-Vol	
9/24-27/77	1.48	TRW-10	Adit 2	Fugitive	1.908	Hi-Vol	
9/26/77	2.84	TRW-10	HR-D	Fugitive	0.0896	Cas. Impac.	Size Distribution
9/26/77	1.83	TRW-10	HR-D	Fugitive	0.0484	Cas. Impac.	Size Distribution
9/26/77	3.04	TRW-10	HR-D	Fugitive	0.2026	Cas. Impac.	Size Distribution
9/26/77	25.90	TRW-10	HR-D	Fugitive	0.7538	Cas. Impac.	Size Distribution
9/26/77	3.88	TRW-10	HR-D	Fugitive	0.1326	Cas. Impac.	Size Distribution
9/27/77	4.24	TRW-10	Adit	Fugitive	0.1508	Cas. Impac.	Size Distribution
9/27/77	8.19	TRW-10	Adit	Fugitive	0.1237	Cas. Impac.	Size Distribution
9/27/77	1.52	TRW-10	Adit 1	Fugitive	0.125	Hi-Vol	
9/27/77	2.20	TRW-10	Adit 1	Fugitive	0.078	Hi-Vol	
9/27/77	10.13	TRW-10	Adit 1	Fugitive	0.245	Hi-Vol	
9/27/77	2.37	TRW-10	Adit 1	Fugitive	0.015	Hi-Vol	
9/27/77	14.62	TRW-10	Adit 1	Fugitive	0.044	Hi-Vol	
9/27/77	13.30	TRW-10	Adit 2	Fugitive	1.908	Hi-Vol	
9/27/77	1.66	TRW-10	Adit 2	Fugitive	0.142	Hi-Vol	
9/27/77	14.24	TRW-10	Adit 2	Fugitive	0.174	Hi-Vol	
9/27/77	36.90	TRW-10	Adit 2	Fugitive	1.325	Hi-Vol	

TABLE 3-1 (Cont'd)

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method	Comments
10/21/77	1.90	LASL-6	Adit 2	Fugitive	0.0002	Pers. Sampler	
10/21/77	9.67	LASL-6	Adit 1	Fugitive	0.0013	Pers. Sampler	After Blast
12/9/77	10.46*	PAR-9	Adit 2	Fugitive	0.57	Hi-Vol	
12/9/77	10.23*	PAR-9	Adit 2	Fugitive	0.0033	Cas. Impac.	
12/9/77	3.87	PAR-9	Adit 2	Fugitive	0.23	Hi-Vol	
12/9/77	7.77	PAR-9	Adit 2	Fugitive	0.39	Hi-Vol	
12/9/77	5.20	PAR-9	Adit 2	Fugitive	0.25	Hi-Vol	
12/9/77	8.53	PAR-9	Adit 2	Fugitive	0.31	Hi-Vol	
12/77-3/78	0.014	AV-5	HR	Ambient	24 Hr. ea.	Hi-Vol	Mean of 30,High=0.060
4/19/78	2.28	PAR-9	Adit 2	Fugitive	0.10	Hi-Vol	
4/19/78	0.93*	PAR-9	Adit 2	Fugitive	0.04	Hi-Vol	
4/19/78	0.86*	PAR-9	Adit 2	Fugitive	0.0005	Cas. Impac.	

* Sampled Concurrently

AIR QUALITY

PARAHO OPERATIONS

TABLE 3-2

Mine Adit and Haul Road, Respirable Dust

Date	Data (mg/m^3)	Location	Comments
7/19/77	12.60	Haul Road	
10/21/77	3.05	Adit 2	
10/21/77	3.42	Adit 1	After Blast

Lab-Ref: LASL-6
Sampling Method: Personal Sampler
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 3-6

Mine Adit and Haul Road Particulates, Particle Size

Lab-Ref	Date		Analysis						Location	Sampling Method	Mmad	σ g
		μ	9.0	3.8	1.9	1.2	0.6					
TRW-10	9/15/77	% P	82.7	62.9	56.7	53.2	48.0		Adit	Cas. Impac.	0.9	19.2
TRW-10	9/16/77		57.4	30.6	22.8	19.0	15.6		Adit	Cas. Impac.	11.0	-
TRW-10	9/15/77		77.0	52.2	43.9	38.7	34.0		Adit	Cas. Impac.	2.0	12.5
		μ	8.8	3.7	1.8	1.2	0.6					
TRW-10	9/15/77	% P	64.5	41.1	34.1	29.8	25.6		Adit	Cas. Impac.	4.7	6.4
TRW-10	9/16/77		65.3	42.8	34.1	29.8	29.2		Adit	Cas. Impac.	5.2	6.7
TRW-10	9/16/77		67.0	45.9	38.4	34.3	30.7		Adit	Cas. Impac.	4.0	8.0
TRW-10	9/16/77		65.3	42.8	34.1	29.8	29.0		Adit	Cas. Impac.	4.4	9.1
		μ	16	8	4	2	1	0.5				
PAR-9	12/9/77	% P	91.3	82.6	47.8	43.5	39.1	34.8	Adit 2	Cas. Impac.	1.7	7.5
PAR-9	4/19/78		80.0	80.0	80.0	80.0	60.0	40.0	Adit 2	Cas. Impac.	0.6	12.3
		μ	8.1	3.4	1.7	1.1	0.6					
TRW-10	9/19/77	% P	71.6	62.6	58.4	56.1	52.8		Haul Road	Cas. Impac.	< 0.5	
		μ	7.6	3.2	1.6	1.0	0.5					
TRW-10	9/19/77	% P	58.8	48.5	45.2	41.5	38.8		Haul Road	Cas. Impac.	5.6	
TRW-10	9/22/77		89.0	84.7	84.7	84.7	80.4		Haul Road	Cas. Impac.	< 0.5	
		μ	8.6	3.6	1.8	1.1	0.6					
TRW-10	9/20/77	% P	84.5	83.7	78.4	77.5	71.8		Haul Road	Cas. Impac.	< 0.5	
		μ	8.8	3.7	1.8	1.2	0.6					
TRW-10	9/21/77	% P	62.1	47.7	46.8	45.5	45.3		Haul Road	Cas. Impac.	2.0	
TRW-10	9/21/77		98.3	95.3	95.3	95.3	95.3		Haul Road	Cas. Impac.	< 0.5	
TRW-10	9/22/77		78.6	71.2	70.4	70.4	70.4		Haul Road	Cas. Impac.	< 0.5	
TRW-10	9/22/77		36.1	7.0	0	0	0		Haul Road	Cas. Impac.	> 10	
		μ	7.9	3.3	1.7	1.1	0.5					
TRW-10	9/26/77	% P	78.9	69.7	63.8	59.6	56.5		Haul Road	Cas. Impac.	0.4	
TRW-10	9/26/77		44.8	26.2	16.1	5.8	0		Haul Road	Cas. Impac.	> 10	
		μ	8.3	3.5	1.7	1.1	0.6					
TRW-10	9/26/77	% P	83.4	75.5	71.1	65.7	62.3		Haul Road	Cas. Impac.	< 0.5	
TRW-10	9/26/77		9.9	9.5	9.1	8.6	8.5		Haul Road	Cas. Impac.		
TRW-10	9/26/77		87.1	80.2	76.0	74.0	71.5		Haul Road	Cas. Impac.	< 0.5	
		μ	13.0	5.5	2.8	1.8	0.9					
TRW-10	9/27/77	% P	84.9	66.9	59.6	53.9	52.0		Haul Road	Cas. Impac.	0.8	19.4
		μ	10.7	4.4	2.2	1.4	0.7					
TRW-10	9/27/77	% P	65.3	49.9	42.1	34.7	28.9		Haul Road	Cas. Impac.	4.4	

Sample Type: Fugitive

μ = 50% stage cut-off in microns
% P = Percent passing

Mmad = Mean mass aerodynamic diameter
σ g = Particle size deviation

TABLE 3-4

Mine Adit and Haul Road Particulates, Toxic Elements

Element	Mine Adit ppm	Haul Road ppm
As	7.8	16.3
Cd	2	2
Cu	145	133
F	1925	10800
Hg	0.1	0.9
Pb	68	96
Se	4.4	397.7
Zn	150	200

Date: 9/77, composited from several samples.

Lab-Ref: TRW-10

Methods:

Sampling: Hi-Vol
Analysis: AA, F by ISE

AIR QUALITY

PARAHO OPERATIONS

TABLE 3-5

Mine Adit and Haul Road Particulates, Other Elemental Analyses

Element	Mine Adit	Haul Road
Al, wt%	1.28	2.71
Ca, wt%	7.50	8.23
Cr, ppm	13	29
Fe, wt%	1.33	2.29
Mg, wt%	2.77	5.06
Mn, ppm	315	503
Na, wt%	3.22	2.03
Ni, ppm	19	43
S, wt%	13.45	2.95
Si, wt%	8.3	29.9
V, ppm	43	57

Date: 9/77, composited from several samples.
Lab-Ref: TRW-10
Methods:
Sampling: Hi-Vol
Analysis: AA, Na by FES, Si by Colorimetry

AIR QUALITY

PARAHO OPERATIONS

TABLE 3-6

Mine Adit and Haul Road, General Gas Data

Parameter	Date	Data	Location	Analytical Method
CO, ppm	7/18/77	< 5	Adit 1	Det. Tube
	7/18/77	10-20	Adit 1	Det. Tube
	7/21/77	33	Adit 1	CO Meter
	10/21/77	100*	Adit 1	CO Meter
	10/21/77	80*	Adit 1	CO Meter
	10/21/77	60*	Adit 1	CO Meter
	10/21/77	25*	Adit 1	CO Meter
	10/21/77	10*	Adit 1	CO Meter
	10/21/77	10*	Adit 1	CO Meter
	10/21/77	5-25*	Adit 1	CO Meter
	10/21/77	25-70*	Adit 1	CO Meter
	10/21/77	10-15*	Adit 1	CO Meter
	10/21/77	2.5	Adit 2	CO Meter
	10/21/77	ND	Adit 2	CO Meter
	10/21/77	25*	Adit 2	CO Meter
	10/21/77	70*	Adit 2	CO Meter
CO_2, Vol%	7/21/77	< .25*	Adit 1	Det. Tube
	7/21/77	< .25*	Adit 1	Det. Tube
	7/21/77	~ .12*	Adit 1	Det. Tube
H_2S, ppm	10/21/77	ND*	Adit 1	Det. Tube
SO_2, ppm	7/18/77	ND	Adit 1	Det. Tube
NH_3, ppm	10/21/77	3-5*	Adit 1	Det. Tube
	10/21/77	6*	Adit 1	Det. Tube
	10/21/77	ND*	Adit 1	Det. Tube
HNO_3, ppm	7/18/77	ND	Adit 1	Det. Tube
	10/21/77	ND*	Adit 1	Det. Tube
	10/21/77	ND*	Adit 1	Det. Tube
HCN, ppm	7/18/77	ND	Adit 1	Det. Tube
	10/21/77	ND*	Adit 1	Det. Tube
NO_2, ppm	7/18/77	< 10	Adit 1	Det. Tube
	10/21/77	20*	Adit 1	Det. Tube
	10/21/77	< 5*	Adit 1	Det. Tube
NO_2, ppm	7/18/77	< 1	Adit 1	Det. Tube
	10/21/77	1*	Adit 1	Det. Tube
	10/21/77	1*	Adit 1	Det. Tube
NO_x, ppm	10/21/77	ND*	Adit 2	Det. Tube
	10/21/77	ND	Adit 2	Det. Tube
	10/21/77	ND*	Adit 2	Det. Tube
	10/21/77	< 25*	Adit 1	Det. Tube
	10/21/77	< 25*	Adit 1	Det. Tube

* After Blast
Lab-Ref: LASL-6
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 3-7

Mine Adit and Haul Road, Volatile Organics

Parameter	Date	Data	Location	Analytical Method
Total HC, ppm	10/18/77	4	Adit 1*	Det. Tube
	10/21/77	80	Adit 1*	THC Analyzer
	10/21/77	90	Adit 1*	THC Analyzer
	10/21/77	90	Adit 1*	THC Analyzer
	10/21/77	120	Adit 1*	THC Analyzer
	10/21/77	90	Adit 1*	THC Analyzer
	10/21/77	20	Adit 1*	THC Analyzer
	10/21/77	40	Adit 1*	THC Analyzer
	10/21/77	40-80	Adit 1*	THC Analyzer
	10/21/77	60	Adit 2*	THC Analyzer
HCHO, ppm	10/21/77	ND	Adit 1*	Det. Tube
Hexane, ppm	10/21/77	ND	Adit 1*	Det. Tube
	10/21/77	ND	Adit 1*	Det. Tube
Toluene, ppm	7/18/77	ND	Adit 1	Det. Tube

* After Blast

Lab-Ref: LASL-6
Sample Type: Fugitive

4.0 CRUSHING

4.1 General Background

The crushing operations carried out at Anvil Points during 1977-1978 consisted of a temporary arrangement of three mobile crushers provided by ONR for the Paraho operations. These crushers were modified and positioned to crush mine-run shale into feed for the retorting operations. A diagram of the crushing operation is shown in Figure 4.1. Although not drawn precisely to scale, the approximate scale is 1 inch: 20 feet. The overall crushing operation consisted of the following: mine-run shale stockpile, front-end loader, primary jaw crusher, secondary jaw crusher, tertiary jaw crusher, sized screens, fines reject conveyors, crushed product conveyor, crushed product stockpile, storage bins, polishing screens, final conveyor to the retort structure.

The crushing operations, located outdoors, were situated on steep terrain to take advantage of the drop in the terrain in minimizing material handling costs. The crushers, although providing adequate retort feed, presented some problems. First, they were somewhat small. Large rocks caused frequent stoppages. To overcome this problem, the mine operations used heavier charges to blast the rock into smaller fragments. Although this obviated the oversize rock problem, it created additional gases and dusts in the mining operations and produced more fines in the mine-run material. In addition to the increased fines from the modified mining operations, the crushers, not designed for oil shale, produced more fines than normal. Because of the temporary arrangement, the crushers were not outfitted with permanent, efficient dust control. Because of these problems, the TSP levels were higher than would be normally anticipated. The nature of these crushing operations resulted in frequent, short-term shutdowns. Overall on-stream factors were about 60%. Thus, the relatively close proximity of the crushing components, the uneven terrain, the resulting variations in wind conditions, the unusually large amounts of fines, and the uncertainty of stable, continuous operations presented formidable problems to researchers attempting to determine fugitive emissions which can be projected to larger modular and commercial operations.

Nevertheless, extensive monitoring was carried out in the Paraho crushing operations. Results have been compiled into 13 tables and are discussed is Sections 4.2 and 4.3.

4.2 Crushing Particulates

The loading, or TSP, of crushing particulates are presented in Table 3-1. Data were collected using equipment mentioned in Section 2.2, Mining Particulates. Sampling times averaged about one hour; the amount of dust sample obtained varied greatly, 0.0003 - 8.64 grams, depending upon the sampling site and equipment used. The overall mean TSP value was 26.3 mg/m^3. However, this value needs additional consideration. It appears that all values from the mine-run stockpile represent ambient rather than fugitive emissions; both the TSP and the Mmad are small (2.4 mg/m^3 and < 0.5 μ). Screening room values show excessive variations (4.6 to 1178.7 mg/m^3). When the mine-run stockpile and the screening room data are not included, the mean fugitive TSP value for the Paraho crushing operations was 24.0 $\pm$ 29.3 mg/m^3. The variations in the fugitive crushing TSP is a result of the problems discussed in Section 4.1 and, to some extent, of particle size distribution data which will be presented later. Ambient TSP levels in the crushing area were 2.2 mg/m^3.

It appears that some of the variation in sampling the screening room is caused by locating the samplers too near direct dust fall. For some samples, an Mmad as high as 20 μ had been observed. The 1178.7 mg/m^3 TSP is a statistical outlier. For the other samples obtained in the screening room (N = 9), the TSP was 110.1 $\pm$ 48.8 mg/m^3.

Respirable crusher dusts are presented in Table 4-2. Respirable dust levels for the Paraho crushing operation were 7.3 $\pm$ 6.5 mg/m^3. Again, the respirable dust monitoring was carried out for short periods of time independent of the TSP monitoring.

Size distribution data for crushing particulates is presented in Table 4-3 and Figure 4-2. Samples obtained by TRW during September, 1977, were too large (188-402 mg). Errors caused by excessive particle bounce produced low Mmad values (all < 0.5 u). These data were not plotted in Figure 4-2. Much of the Paraho data in Figure 4-2 include high σg values indicating again improperly

sized equipment. When all the data in Figure 4-2 are considered, the average Mmad is 8.4 μ. However, this average contains several samples having unusually low and unusually high values (< 0.5 and ~ 20 μ Mmad). Eliminating these unusual values, the mean Mmad for the Paraho crushing operation was 5.0 μ.

Samples taken in the vicinity of the fines reject streams produced unusual results. During January, 1978, samples taken at the belts showed Mmad values of about 20 μ; during May of 1978, a sample taken between the two belts had a Mmad of < 0.5 μ. TSP values for the three samples were 27, 46, and 17 mg/m^3. It appears that the samples taken during January were too close to the dust fall and were contaminated with large particulates. The unusual results, the high TSP (17 mg/m^3) and small Mmad (< 0.5 μ), obtained between the two fines belts cannot be readily explained. High σg values indicate incorrect TSP data.

Chemical analyses of crushing particulates are presented in Table 4-4 through Table 4-11. In Table 4-4, the general analysis of the crusher particulates is similar to normal raw shale feed (see Table 2-4). The paired data, obtained by two researchers nearly two years apart, show remarkable agreement. Trace toxic elements are presented in Table 4-5. Based on the statistical evaluations made in Section 2.2, the 11.5 ppm Hg is erroneously high. Average Hg value is 0.3 ppm or less. All other data in Table 4-5 appear to be valid. Arsenic varies widely (4 to 84 ppm) and averages 43 $\pm$ 29 ppm. After screening the crushing particulates into various particle size fractions, the concentrations of some of the toxic elements in the various fractions are compared in Table 4-6. Concentrations of As, B, Cu, Mo, P, Se, and Zn do not appear to change with various particle size fractions. None are significantly different from the unscreened material. General elemental analyses are presented in Table 4-7 and 4-8. Based upon the statistical evaluation made in Section 2.2, all the data obtained for the various crushing particulate composition appear to be valid. There does not appear to be any significant differences between these data and the raw shale dusts obtained at various sites of the Paraho operations. Finally, in Tables 4-9 and 4-10, concentrations of various elements have been measured in various screened samples. Like the toxic elements in Table 4-6, there is no significant change in concentration among various particle size fractions.

The approximate mineral composition of the inorganic portion of the crushing particulates is presented in Table 4-11. Sample source was the raw shale baghouse effluent. Analysis was carried out using X-ray diffraction (XRD). These XRD data, though somewhat qualitative, show that carbonates account for nearly 60% of the minerals and that quartz accounts for less than 20% of the total particulates sampled.

4.3 Crushing Gases

The limited studies performed on gas monitoring in the area of the Paraho crushing operations show that the air in that region was typical of a normal atmosphere and that no gaseous pollutants were released (see Table 4-12). Oxygen level is about 21.3 Vol.% and CO_2 is about 0.04 Vol.%. No carbon monoxide, methane (total hydrocarbons), oxides of nitrogen, sulfur dioxide, mercaptans, or phenols were detected. As shown in Table 4-13, no volatile gaseous elements (As, Hg, Se, Pb) were detected.

CRUSHING AREA

Figure 4.1

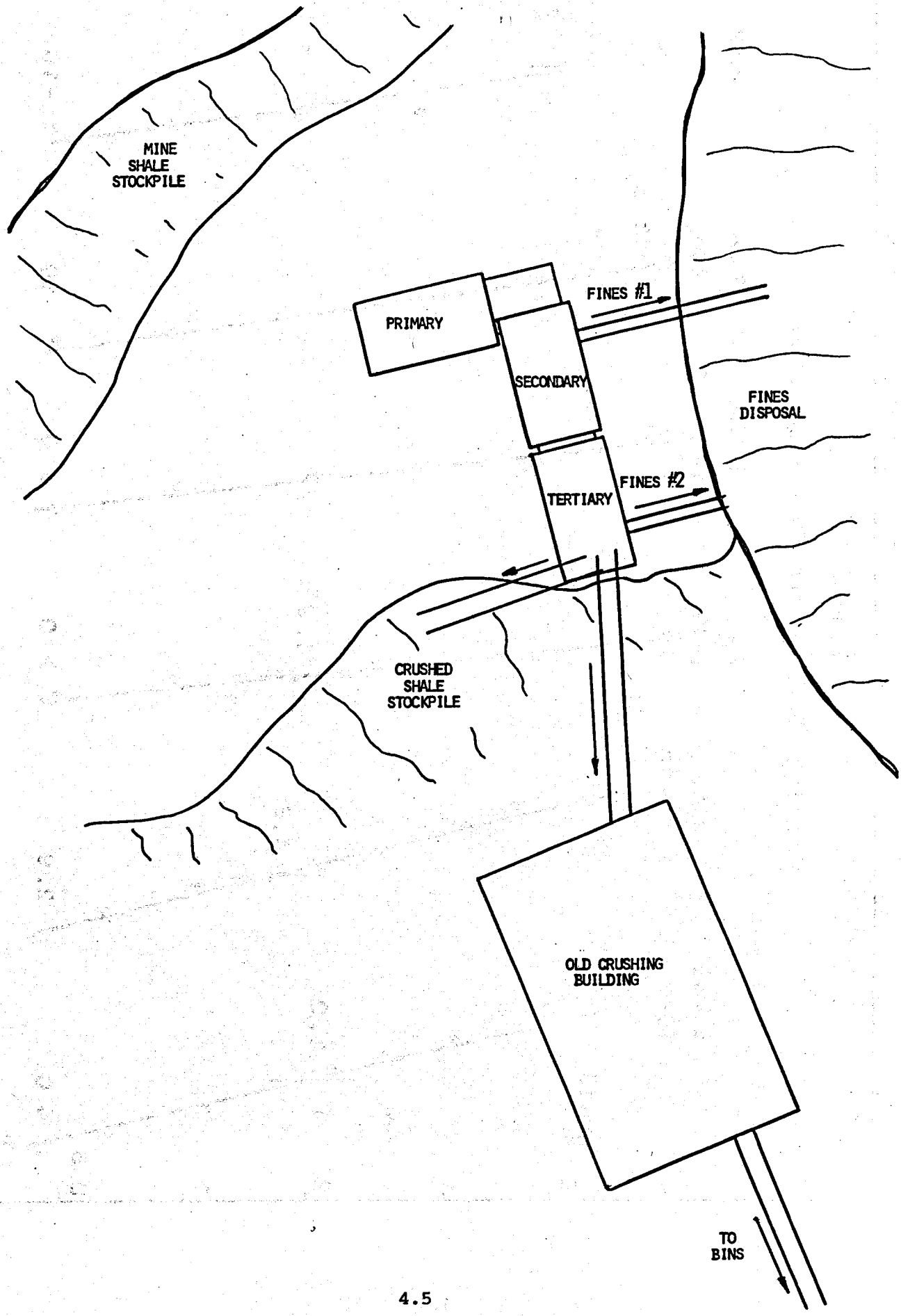


Figure 4.2

Crushing, Particulates, Size Distribution

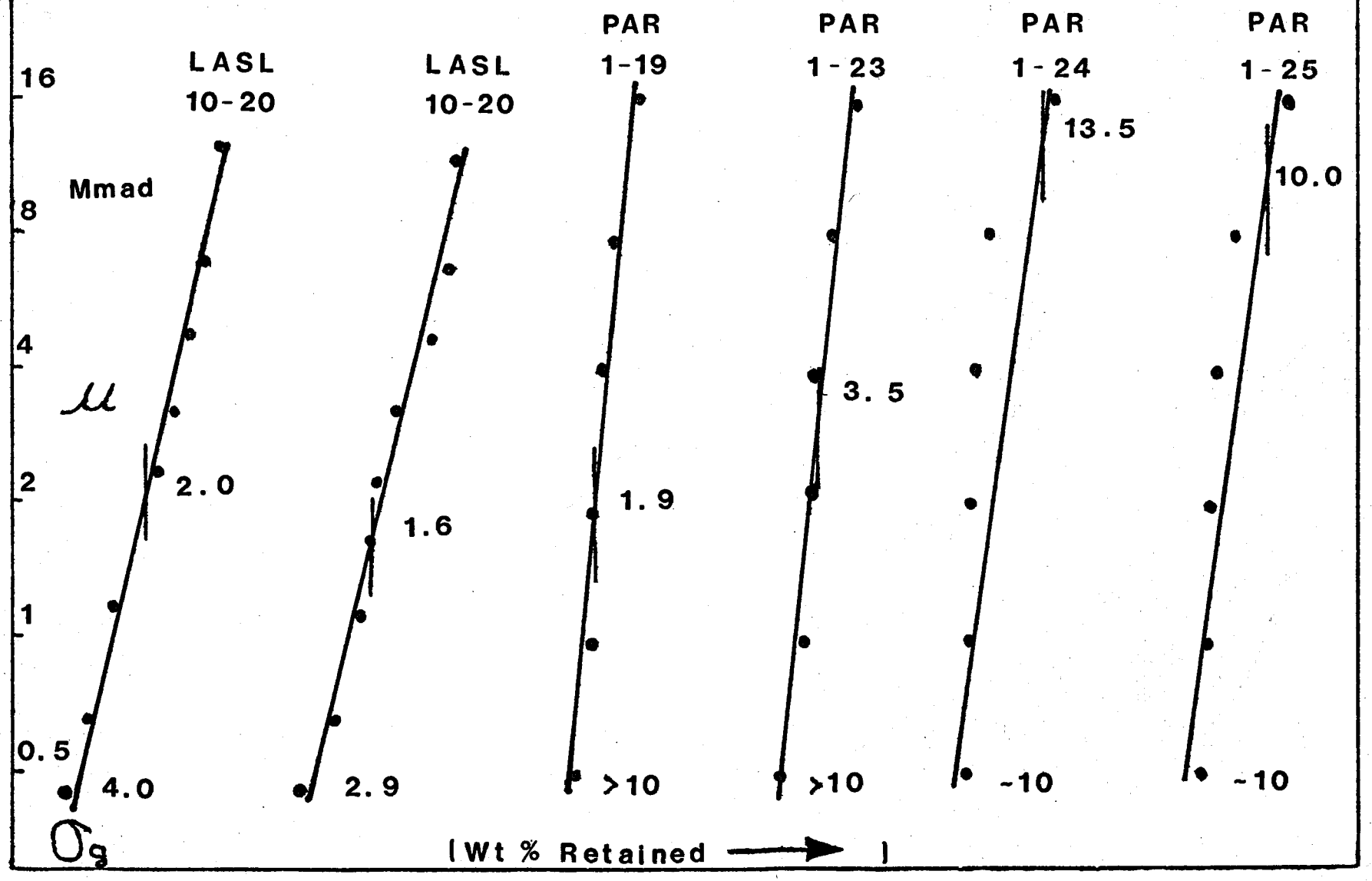
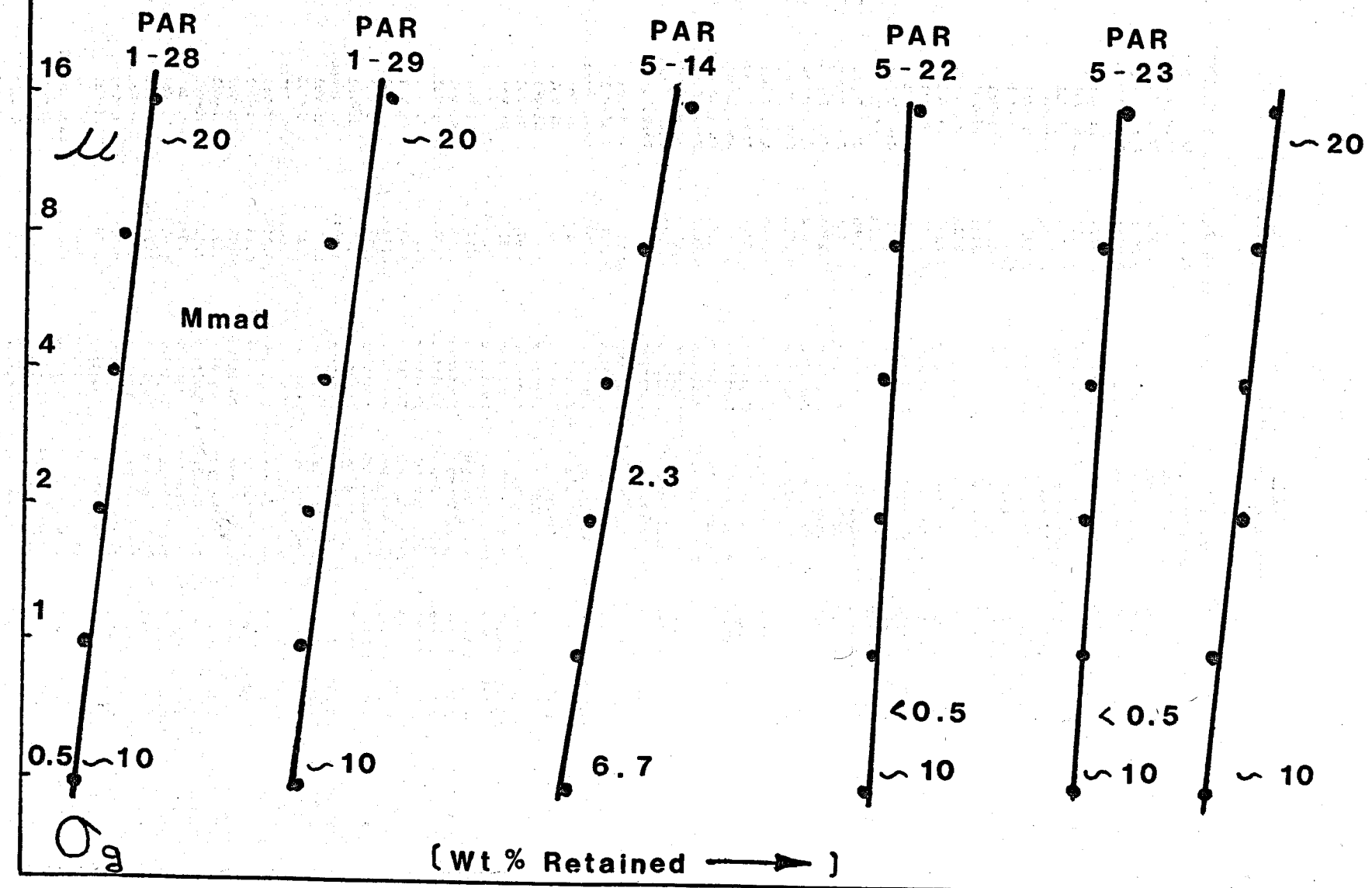


Figure 4.2 (cont'd.)

Crushing Particulates, Size Distribution



AIR QUALITY

PARAHO OPERATIONS

TABLE 4-1

Crushing and Screening, Total Suspended Particulates

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method	Comments
7/18/77	2.3	LASL-6	Prim. Crusher	Fugitive	0.0003	Pers. Samp.	
7/18/77	ND	LASL-6	Tert. Crusher	Fugitive	-	Pers. Samp.	
7/19/77	9.05	LASL-6	Tert. Crusher	Fugitive	0.0043	Pers. Samp.	
7/19/77	1178.7	LASL-6	Screening Rm.	Fugitive	0.3654	Pers. Samp.	
7/19/77	35.8	LASL-6	Screening Rm.	Fugitive	0.0053	Pers. Samp.	
9/4/77	4.14	TRW-10	Crusher	Fugitive	1.8476	Hi-Vol	
9/8/77	2.97	TRW-10	Crusher	Fugitive	0.2412	Hi-Vol	
9/8/77	6.66	TRW-10	Crusher	Fugitive	0.4180	Hi-Vol	
9/8/77	0.99	TRW-10	Crusher	Ambient	0.2070	Hi-Vol	
9/9/77	1.27	TRW-10	Crusher	Fugitive	0.1733	Hi-Vol	
9/9/77	6.59	TRW-10	Crusher	Fugitive	0.2563	Hi-Vol	
9/9/77	7.96	TRW-10	Crusher	Fugitive	0.1823	Hi-Vol	
9/9/77	5.60	TRW-10	Crusher	Fugitive	0.2484	Hi-Vol	
9/9/77	1.02	TRW-10	Crusher	Ambient	0.2229	Hi-Vol	
9/9/77	2.63	TRW-10	Crusher	Ambient	0.1432	Hi-Vol	
9/10/77	5.28	TRW-10	Crusher	Fugitive	0.3540	Hi-Vol	
9/10/77	3.48	TRW-10	Crusher	Fugitive	0.3270	Hi-Vol	
9/24/77	3.49	TRW-10	Crusher	Fugitive	0.2235	Cas. Impac.	Size Distribution
9/24/77	1.17	TRW-10	Crusher	Ambient	0.0850	Hi-Vol	
9/25/77	6.69	TRW-10	Crusher	Fugitive	0.1880	Cas. Impac.	Size Distribution
9/25/77	17.59	TRW-10	Crusher	Fugitive	0.3466	Cas. Impac.	Size Distribution
9/25/77	13.45	TRW-10	Crusher	Fugitive	0.2704	Cas. Impac.	Size Distribution
9/25/77	24.52	TRW-10	Crusher	Fugitive	0.4022	Cas. Impac.	Size Distribution
9/26/77	9.97	TRW-10	Crusher	Fugitive	0.2850	Cas. Impac.	Size Distribution
10/20/77	11.53	LASL-6	Sec. Crusher	Fugitive	0.0098	And. Impac.	
10/20/77	36.22	LASL-6	Tert. Crusher	Fugitive	0.0308	And. Impac.	
10/20/77	10.60	LASL-6	Prim. Crusher	Fugitive	0.0149	And. Impac.	Size Distribution
10/20/77	8.25	LASL-6	Storage Bin	Fugitive	0.0047	And. Impac.	Size Distribution
10/20/77	33.6	LASL-6	Prim. Crusher	Fugitive	0.0026	Pers. Samp.	
10/20/77	4.7	LASL-6	Sec. Crusher	Fugitive	0.0003	Pers. Samp.	
10/20/77	47.2	LASL-6	Tert. Crusher	Fugitive	0.0033	Pers. Samp.	
10/21/77	42.18	LASL-6	Storage Bin	Fugitive	0.0031	Pers. Samp.	
1/18/78	1.38	PAR-9	Stockpile	Fugitive	0.06	Hi-Vol	
1/18/78	4.21*	PAR-9	Stockpile	Fugitive	0.12	Hi-Vol	
1/18/78	4.51*	PAR-9	Stockpile	Fugitive	0.0015	Cas. Impac.	Size Distribution
1/18/78	1.60	PAR-9	Stockpile	Fugitive	0.02	Hi-Vol	
1/18/78	1.04	PAR-9	Stockpile	Fugitive	0.05	Hi-Vol	
1/18/78	2.84	PAR-9	Stockpile	Fugitive	0.12	Hi-Vol	
1/19/78	98.40	PAR-9	Prim. Crusher	Fugitive	3.97	Hi-Vol	
1/19/78	27.82*	PAR-9	Prim. Crusher	Fugitive	0.63	Hi-Vol	
1/19/78	28.52*	PAR-9	Prim. Crusher	Fugitive	0.0066	Cas. Impac.	Size Distribution
1/19/78	0.94	PAR-9	Prim. Crusher	Fugitive	0.14	Hi-Vol	
1/19/78	28.17	PAR-9	Prim. Crusher	Fugitive	1.15	Hi-Vol	
1/19/78	98.12	PAR-9	Prim. Crusher	Fugitive	4.76	Hi-Vol	
1/19/78	3.56	PAR-9	Prim. Crusher	Fugitive	0.17	Hi-Vol	
1/19/78	86.26	PAR-9	Prim. Crusher	Fugitive	3.69	Hi-Vol	
1/23/78	5.36	PAR-9	Screening Rm.	Fugitive	0.29	Hi-Vol	
1/23/78	5.00	PAR-9	Screening Rm.	Fugitive	0.30	Hi-Vol	
1/23/78	4.56*	PAR-9	Screening Rm.	Fugitive	0.23	Hi-Vol	
1/23/78	4.56*	PAR-9	Screening Rm.	Fugitive	0.0023	Cas. Impac.	Size Distribution
1/24/78	15.58	PAR-9	Sec. Crusher	Fugitive	0.67	Hi-Vol	
1/24/78	8.90*	PAR-9	Sec. Crusher	Fugitive	0.25	Hi-Vol	
1/24/78	8.97*	PAR-9	Sec. Crusher	Fugitive	0.0024	Cas. Impac.	Size Distribution
1/24/78	0.77	PAR-9	Sec. Crusher	Fugitive	0.04	Hi-Vol	
1/24/78	2.92	PAR-9	Sec. Crusher	Fugitive	0.16	Hi-Vol	
1/24/78	0.19	PAR-9	Sec. Crusher	Fugitive	0.01	Hi-Vol	
1/25/78	69.12	PAR-9	Tert. Crusher	Fugitive	3.23	Hi-Vol	
1/25/78	113.8*	PAR-9	Tert. Crusher	Fugitive	2.72	Hi-Vol	
1/25/78	113.9*	PAR-9	Tert. Crusher	Fugitive	0.0345	Cas. Impac.	Size Distribution
1/25/78	123.4	PAR-9	Tert. Crusher	Fugitive	5.81	Hi-Vol	
1/25/78	61.55	PAR-9	Tert. Crusher	Fugitive	1.33	Hi-Vol	
1/25/78	14.78	PAR-9	Tert. Crusher	Fugitive	0.70	Hi-Vol	
1/25/78	0.78	PAR-9	Tert. Crusher	Fugitive	0.06	Hi-Vol	
1/28/78	21.71	PAR-9	Fines Belt #1	Fugitive	0.78	Hi-Vol	
1/28/78	6.41	PAR-9	Fines Belt #1	Fugitive	0.43	Hi-Vol	
1/28/78	22.40*	PAR-9	Fines Belt #1	Fugitive	0.0036	Cas. Impac.	Size Distribution
1/28/78	19.41*	PAR-9	Fines Belt #1	Fugitive	1.00	Hi-Vol	
1/28/78	33.64	PAR-9	Fines Belt #1	Fugitive	1.31	Hi-Vol	
1/28/78	32.15	PAR-9	Fines Belt #1	Fugitive	1.28	Hi-Vol	
1/28/78	53.08	PAR-9	Fines Belt #1	Fugitive	2.21	Hi-Vol	

* Collected Concurrently

TABLE 4-1 (Cont'd)

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method	Comments
1/29/78	17.93*	PAR-9	Fines Belt #2	Fugitive	0.0118	Cas. Impac.	Size Distribution
1/29/78	32.93*	PAR-9	Fines Belt #2	Fugitive	0.97	Hi-Vol	
1/29/78	66.99	PAR-9	Fines Belt #2	Fugitive	4.48	Hi-Vol	
1/29/78	78.34	PAR-9	Fines Belt #2	Fugitive	3.25	Hi-Vol	
1/29/78	43.65	PAR-9	Fines Belt #2	Fugitive	0.21	Hi-Vol	
5/12/78	1.77	PAR-9	Stockpile	Fugitive	0.12	Hi-Vol	
5/12/78	2.53*	PAR-9	Stockpile	Fugitive	0.17	Hi-Vol	
5/12/78	2.53*	PAR-9	Stockpile	Fugitive	0.0016	Cas. Impac.	Size Distribution
5/12/78	2.26	PAR-9	Stockpile	Fugitive	0.17	Hi-Vol	
5/14/78	8.41	PAR-9	Prim.-Sec. Crusher	Fugitive	0.56	Hi-Vol	
5/14/78	8.24*	PAR-9	Prim.-Sec. Crusher	Fugitive	0.57	Hi-Vol	
5/14/78	8.25*	PAR-9	Prim.-Sec. Crusher	Fugitive	0.0050	Cas. Impac.	Size Distribution
5/14/78	14.32	PAR-9	Prim.-Sec. Crusher	Fugitive	1.00	Hi-Vol	
5/22/78	13.11	PAR-9	Sec.-Tert. Crusher	Fugitive	0.92	Hi-Vol	
5/22/78	16.92*	PAR-9	Sec.-Tert. Crusher	Fugitive	1.04	Hi-Vol	
5/22/78	17.17*	PAR-9	Sec.-Tert. Crusher	Fugitive	0.0099	Cas. Impac.	Size Distribution
5/22/78	12.79	PAR-9	Sec.-Tert. Crusher	Fugitive	0.91	Hi-Vol	
5/23/78	27.47	PAR-9	Fines Belt #1-#2	Fugitive	1.59	Hi-Vol	
5/23/78	13.36*	PAR-9	Fines Belt #1-#2	Fugitive	0.82	Hi-Vol	
5/23/78	14.48*	PAR-9	Fines Belt #1-#2	Fugitive	0.0090	Cas. Impac.	Size Distribution
5/31/78	145.8	PAR-9	Screening Rm.	Fugitive	8.64	Hi-Vol	
5/31/78	103.5*	PAR-9	Screening Rm.	Fugitive	6.42	Hi-Vol	
5/31/78	103.8*	PAR-9	Screening Rm.	Fugitive	0.0667	Cas. Impac.	Size Distribution
5/31/78	161.6	PAR-9	Screening Rm.	Fugitive	9.1	Hi-Vol	

* Collected Concurrently

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-2

Crushing and Screening, Respirable Dust

Date	Data mg/m^3	Location	Quantity, g
7/19/77	2.0	Prim. Crusher	0.0002
7/19/77	20.0	Sec. Crusher	0.0032
7/19/77	11.0	Tert. Crusher	0.0020
10/20/77	6.48	Prim. Crusher	0.0004
10/20/77	0.67	Sec. Crusher	0.00004
10/20/77	5.55	Tert. Crusher	0.0004
10/21/77	5.24	Storage Bin	0.0003

Lab-Ref: LASL-6
Sample Type: Fugitive
Sampling Method: Personal Sampler

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-3

Crushing and Screening, Particle Size

Lab-Ref	Date		Analysis								Location	Sampling Method	Mmad	σ_g
		μ	8.50	3.54	1.79	1.13	0.59							
TRW-10	9/25/77	% P	79.6	73.7	71.1	69.1	66.9				Crusher	Cas. Impac.		
		μ	8.86	3.69	1.86	1.18	0.61							
TRW-10	9/24/77	% P	84.1	84.1	80.6	75.5	70.8				Crusher	Cas. Impac.		
TRW-10	9/25/77		73.9	72.6	68.5	59.7	53.9				Crusher	Cas. Impac.		
TRW-10	9/25/77		78.1	71.8	67.2	61.5	55.9				Crusher	Cas. Impac.		
TRW-10	9/25/77		75.5	68.8	64.4	59.4	55.2				Crusher	Cas. Impac.		
TRW-10	9/26/77		87.6	83.9	80.1	76.8	73.3				Crusher	Cas. Impac.		
		μ	12	7	4.8	3.4	2.2	1.2	0.66	0.44				
LASL-6	10/20/77	% P	91.4	82.8	75.2	64.7	54.2	35.2	20.9	9.5	Prim. Crusher	And. Impac.	2.0	4.0
LASL-6	10/20/77		93.5	93.5	82.9	68.0	57.3	44.6	31.9	10.7	Storage Bin	And. Impac.	1.6	2.9
		μ	16	8	4	2	1	0.5						
PAR-9	1/19/78	% P	77.3	63.6	56.1	51.5	47.0	37.9			Prim. Crusher	Cas. Impac.	1.9	> 10
PAR-9	1/23/78		68.4	57.9	47.4	47.4	42.1	31.6			Screening Rm.	Cas. Impac.	3.5	> 10
PAR-9	1/24/78		58.3	41.7	37.5	33.3	33.3	29.2			Sec. Crusher	Cas. Impac.	13.5	~ 10
PAR-9	1/25/78		62.7	34.0	24.7	22.2	19.0	18.3			Tert. Crusher	Cas. Impac.	10.0	~ 10
PAR-9	1/28/78		45.1	31.4	27.4	21.6	13.6	9.8			Fines Belt #1	Cas. Impac.	~ 20	~ 10
PAR-9	1/29/78		52.3	22.1	19.8	11.6	5.8	5.8			Fines Belt #2	Cas. Impac.	~ 20	~ 10
PAR-9	5/12/78		92.9	85.7	78.6	71.4	71.4	64.3			Stockpile	Cas. Impac.		
PAR-9	5/14/78		92.9	71.4	50.0	42.9	35.7	28.6			Prim-Sec Crusher	Cas. Impac.	2.3	6.7
PAR-9	5/22/78		93.3	82.7	77.3	74.7	72.0	70.7			Sec-Tert Crusher	Cas. Impac.	< 0.5	~ 10
PAR-9	5/23/78		84.1	72.5	66.7	65.2	62.3	59.4			Fines Belt #1-#2	Cas. Impac.	< 0.5	~ 10
PAR-9	5/31/78		44.2	34.2	28.9	28.0	10.4	9.4			Screening Rm.	Cas. Impac.	~ 20	~ 10

Sample Type: Fugitive

μ = 50% stage cut-off (in microns).
% P = Percent passing.
Mmad = Mean mass aerodynamic diameter.
σ_g = Particle size deviation.

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-4

Crushing and Screening, Particulates Proximate Analysis

Parameter	Date	Data, Wt%	Lab-Ref	Analytical Methods
Mineral CO_2, Wt%	6/5/78	16.65	PAR-9	Coulometry
Mineral C, Wt%	3/15-16/76	4.67	TRW-4	
	6/5/78	4.54	PAR-9	Coulometry
Total C	3/15-16/76	14.25	TRW-4	
	6/5/78	14.47	PAR-9	Elemental Analyzer
Organic C	3/15-16/76	9.58	TRW-4	
	6/5/78	9.93	PAR-9	Difference
H	3/15-16/76	1.51	TRW-4	
	6/5/78	1.52	PAR-9	Elemental Analyzer
N	3/15-16/76	0.43	TRW-4	
	6/5/78	0.44	PAR-9	Elemental Analyzer
S (Total)	9/24-26/77	0.024	TRW-10	
	9/24-26/77	0.64	TRW-10	
	6/5/78	> 1	CTE-9	SSMS
	6/5/78	0.74	PAR-9	Sulfur Analyzer
SO_4	3/15-16/76	0.01	TRW-4	
S_x	3/15-16/76	0.04	TRW-4	
Ash	3/15-16/76	70.91	TRW-4	
	6/5/78	69.54	PAR-9	Gravimetric
Benzene Solubles	3/15-16/76	2.05	TRW-4	
% of Polar Compounds that is PAH	3/15-16/76	16		

Sample Type: Fugitive
Collection Method: Hi-Vol
Sampling Location: Crusher

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-5

Crushing and Screening, Particulates, Toxic Elements

Parameter	Date	Data, ppm	Lab-Ref	Location	Analytical Method
As	8/6-7/75	≤ 17	LFE-2	Crusher	XRF
	8/6-7/75	62	LFE-2	Bins	XRF
	8/24/77	48	BNW-7	Raw Shale Baghouse	INAA
	8/24/77	43	BNW-7	Raw Shale Baghouse	XRF
	9/24-26/77	3.8	TRW-10	Crusher	AA
	9/24-26/77	16.6	TRW-10	Screening Room	AA
	6/5/78	84	CTE-9	Crusher	SSMS
B	8/24/77	104	BNW-7	Raw Shale Baghouse	PES
	6/5/78	38	CTE-9	Crusher	SSMS
Cd	8/6-7/75	< 133	LFE-2	Crusher	XRF
	8/6-7/75	< 68	LFE-2	Bins	XRF
	9/24-26/77	ND	TRW-10	Crusher	AA
	9/24-26/77	6	TRW-10	Screening Room	AA
	6/5/78	0.9	CTE-9	Crusher	SSMS
Cu	8/6-7/75	63	LFE-2	Crusher	XRF
	8/6-7/75	56	LFE-2	Bins	XRF
	8/24/77	44	BNW-7	Raw Shale Baghouse	XRF
	9/24-26/77	40	TRW-10	Crusher	AA
	9/24-26-77	53	TRW-10	Screening Room	AA
	6/5/78	54	CTE-9	Crusher	SSMS
F	9/24-26-77	745	TRW-10	Crusher	ISE
	9/24-26-77	975	TRW-10	Screening Room	ISE
	6/5/78	> 1000	CTE-9	Crusher	SSMS
Hg	8/6-7/75	< 72	LFE-2	Crusher	XRF
	8/6-7/75	< 16	LFE-2	Bins	XRF
	9/24-26/77	11.5	TRW-10	Crusher	AA
	9/24-26/77	0.3	TRW-10	Screening Room	AA
Mo	8/24/77	29	BNW-7	Raw Shale Baghouse	XRF
	6/5/78	45	CTE-9	Crusher	SSMS
Pb	8/6-7/75	80	LFE-2	Crusher	XRF
	8/6-7/75	≤ 10	LFE-2	Bins	XRF
	8/24/77	30	BNW-7	Raw Shale Baghouse	XRF
	9/24-26/77	17	TRW-10	Crusher	AA
	9/24-26/77	64	TRW-10	Screening Room	AA
	6/5/78	33	CTE-9	Crusher	SSMS
Se	8/6-7/75	≤ 15	LFE-2	Crusher	XRF
	8/24/77	3.1	BNW-7	Raw Shale Baghouse	INAA
	8/24/77	2.3	BNW-7	Raw Shale Baghouse	XRF
	9/24-26/77	11	TRW-10	Crusher	AA
	9/24-26/77	35.3	TRW-10	Screening Room	AA
	6/5/78	2	CTE-9	Crusher	SSMS
Zn	8/6-7/75	138	LFE-2	Crusher	XRF
	8/6-7/75	79	LFE-2	Bins	XRF
	8/24/77	80	BNW-7	Raw Shale Baghouse	XRF
	9/24-26/77	161	TRW-10	Crusher	AA
	9/24-26/77	165	TRW-10	Screening Room	AA
	6/5/78	120	CTE-9	Crusher	SSMS

Sample Type: Fugitive, raw shale baghouse is effluent
Collection Method: Hi-Vol for TRW and CTE, bulk for LFE and BNW

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-6

Crushing and Screening, Particulates, Toxic Elements

Analysis by Particle Size

ppm

Element	Unscreened			< 325 Mesh		200-325 Mesh		140-200 Mesh		> 140 Mesh
	INAA	XRF	PES	INAA	XRF	INAA	XRF	INAA	XRF	INAA
As	48	43		51	42	44	41	50	43	59
B			104							
Cu		44			35		42		47	
Mo		29			30		30		36	
Pb		30			36		29		33	
Se	3.1	2.3			2.4		2.1		2.8	
Zn		80			77		74		83	

Date: 8/24/77
Lab-Ref: BNW-7
Sample Type: Effluent
Location: Raw Shale Baghouse

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-7

Crushing and Screening, Particulates, Other Elemental

Parameter	Date	Data	Lab-Ref	Location	Sample Type	Methods Sampling	Methods Analysis
Ag, ppm	8/6-7/75	< 133	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	< 72	LFE-2	Bins	Fugitive	Bulk	XRF
	6/5/78	0.4	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Al, %	8/24/77	3.75	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	9/24-26/77	1.12	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	4.17	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Au, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ba, ppm	8/24/77	480	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	8/24/77	540	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	> 1000	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Be, ppm	6/15/78	0.7	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Bi, ppm	6/15/78	0.7	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Br, ppm	8/24/77	< 0.7	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	8/24/77	< 1	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	2	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ca, %	8/24/77	11.6	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	8/24/77	11.4	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	9/24-26/77	2.87	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	6.25	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ce, ppm	6/5/78	120	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Cl, ppm	6/5/78	40	CTE-9	Crusher	Fugitive	Hi-Vol	XRF
Co, ppm	8/6-7/75	< 59	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	82	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	7.7	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	3	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Cr, ppm	8/6-7/75	< 133	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	< 72	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	26	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	8/24/77	41	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	9/24-26/77	15	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	54	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	82	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Cs, ppm	6/5/78	6	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Dy, ppm	6/5/78	2	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Er, ppm	6/5/78	0.4	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Eu, ppm	8/24/77	0.58	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Fe, %	8/6-7/75	2.3	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	2.3	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	1.85	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	8/24/77	2.07	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	8/24/77	1.94	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	9/24-26/77	1.92	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	2.28	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ga, ppm	8/24/77	10	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	24	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Gd, ppm	6/5/78	2	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ge, ppm	6/5/78	0.9	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Hf, ppm	6/5/78	1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ho, ppm	6/5/78	1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
I, ppm	6/5/78	0.4	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
I_1, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
K, %	8/24/77	1.54	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	8/24/77	1.42	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
La, ppm	8/24/77	17.7	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	8/24/77	15	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	94	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Li, ppm	6/5/78	≥ 250	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Lu, ppm	8/24/77	0.31	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	0.2	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS

TABLE 4-7 (Cont'd)

Parameter	Date	Data	Lab-Ref	Location	Sample Type	Methods Sampling	Methods Analysis
Mg, %	8/24/77	3.44	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	9/24-26/77	2.14	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	3.92	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Mn, ppm	8/6-7/75	293	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	288	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	340	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	8/24/77	349	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	9/24/77	135	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	6/5/78	≥ 920	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Na, %	8/24/77	1.58	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	8/24/77	1.70	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	9/24-26/77	1.30	TRW-10	Crusher	Fugitive	Hi-Vol	FES
	9/24-26/77	2.88	TRW-10	Screen Room	Fugitive	Hi-Vol	FES
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Nb, ppm	8/24/77	8	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	19	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Nd, ppm	6/5/78	10	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ni, ppm	8/6-7/75	< 28	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	< 19	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	28	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	9/24-26/77	12	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	39	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	30	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Os, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
P, %	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Pd, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Pr, ppm	6/5/78	3	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Pt, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Rb, ppm	8/6-7/75	50	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	65	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	80	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Re, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Rh, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ru, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Sb, ppm	8/24/77	1.9	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	6	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Sc, ppm	8/24/77	5.4	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	5	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Si, %	8/24/77	13.6	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	8/24/77	15.0	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	9/24-26/77	11.91	TRW-10	Crusher	Fugitive	Hi-Vol	Color
	9/24-26/77	5.04	TRW-10	Screen Room	Fugitive	Hi-Vol	Color
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Sm, ppm	6/5/78	15	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Sn, ppm	6/5/78	0.8	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Sr, ppm	8/6-7/75	641	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	753	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	710	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	> 1000	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ta, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Tb, ppm	6/5/78	0.8	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Te, ppm	6/5/78	< 0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Th, ppm	8/24/77	5.5	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	9	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Ti, %	8/6-7/75	< 0.13	LFE-2	Crusher	Fugitive	Bulk	XRF
	8/6-7/75	0.24	LFE-2	Bins	Fugitive	Bulk	XRF
	8/24/77	0.19	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	8/24/77	0.18	BNW-7	Raw Shale Baghouse	Effluent	Bulk	AA
	6/5/78	> 1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Tl, ppm	6/5/78	0.6	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Tm, ppm	6/5/78	0.1	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
U, ppm	8/24/77	4.2	BNW-7	Raw Shale Baghouse	Effluent	Bulk	INAA
	6/5/78	8	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
V, ppm	9/24-26/77	24	TRW-10	Crusher	Fugitive	Hi-Vol	AA
	9/24-26/77	228	TRW-10	Screen Room	Fugitive	Hi-Vol	AA
	6/5/78	270	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS

TABLE 4-7 (Cont'd)

Parameter	Date	Data	Lab-Ref	Location	Sample Type	Methods	
						Sampling	Analysis
W, ppm	6/5/78	2	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Y, ppm	8/24/77	12	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	40	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Yb, ppm	6/5/78	0.9	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS
Zr, ppm	8/24/77	63	BNW-7	Raw Shale Baghouse	Effluent	Bulk	XRF
	6/5/78	130	CTE-9	Crusher	Fugitive	Hi-Vol	SSMS

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-8

Crushing and Screening Particulates, Elemental Analysis by Particle Size

From Bulk Sample

PPM Except as Noted

Element	Method	Bulk	< 325 Mesh	200-325 Mesh	140-200 Mesh	> 140 Mesh
Al	AA	3.75	3.80	3.79	3.59	3.45
Ba	INAA	480	720	550	500	725
	XRF	540	680	540		
Br	INAA	ND	ND	ND	ND	ND
	XRF	ND	ND	ND	ND	
Ca (%)	XRF	11.6	10.9	9.7	9.0	
	AA	11.4	11.2	9.7	9.7	8.8
Co	INAA	7.7	8.5	9.7	9.4	11.5
Cr	INAA	26	40	33	29	58
	XRF	41	28	48	35	
Eu	INAA	0.58	0.67	0.57	0.54	0.61
Fe (%)	INAA	1.85	2.01	1.74	1.57	1.97
	XRF	2.07	1.95	1.81	1.65	
	AA	1.94	2.12	1.97	1.75	1.24
Ga	XRF	10	8	8	9	
K (%)	XRF	1.54	1.54	1.48	1.41	
	AA	1.42	1.41	1.44	1.41	1.36
La	INAA	17.7	19.7	18.4	17.1	20.2
	XRF	15	23	19		
Lu	INAA	0.31	0.28	0.27	0.29	0.34
Mg (%)	AA	3.44	3.36	3.14	3.09	2.99
Mn	XRF	340	320	280	250	
	AA	349	420	378	315	294
Na (%)	INAA	1.58	2.36	2.14	1.92	2.19
	AA	1.70	2.10	2.02	1.98	1.92
Nb	XRF	8	8	9	9	
Ni	XRF	28	29	30	30	
Rb	XRF	65	69	68	76	
Sb	INAA	1.9	2.7	2.3	2.4	3.3
Sc	INAA	5.4	6.1	5.4	4.9	5.7
Si	XRF	13.6	13.5	12.6	13.3	
	AA	15.0	15.6	15.8	14.1	13.7
Sm	INAA		3.2	3.3	3.2	3.9
Sr	XRF	710	760	630	630	
Th	INAA	5.5	5.7	5.7	5.0	6.8
Ti	XRF	0.19	0.19	0.23	0.18	
	AA	0.18	0.20	0.19	0.19	0.22
U	INAA	4.2	4.5	3.9	4	6.4
Y	XRF	12	12	13	14	
Zr	XRF	63	70	66	75	

Date: 8/23-26/77
Lab-Ref: BNW-7
Sample Type: Effluent
Location: Raw Shale Baghouse

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-9

Crushing and Screening Particulates, Chemical Analysis by Particle Size, from Hi-Vol Sample

Particle Size (Microns)	Al $\mu g/m^3$	As ng/m^3	Ca $\mu g/m^3$	Co ng/m^3	Cr ng/m^3	Cs ng/m^3	Fe $\mu g/m^3$	K $\mu g/m^3$
> 2.5	30.0 ± 0.8	70 ± 2	91 ± 9	13.1 ± 0.2	43 ± 1	3.9 ± 0.4	18.0 ± 0.2	13 ± 3
1.5-2.5	8.5 ± 0.3	15.8 ± 0.8	28 ± 4	3.47 ± 0.07	16.4 ± 0.5	1.1 ± 0.1	4.71 ± 0.07	2.6 ± 0.7
1.1-1.5	5.8 ± 0.2	12.0 ± 0.7	13 ± 2	2.42 ± 0.06	11.1 ± 0.4	0.84 ± 0.09	3.74 ± 0.07	2.3 ± 0.6
0.8-1.1	5.6 ± 0.2	11.6 ± 0.6	14 ± 2	2.22 ± 0.05	12.6 ± 0.4	0.85 ± 0.01	3.71 ± 0.06	2.1 ± 0.6
< 0.8	106 ± 3	168 ± 5	280 ± 20	33.5 ± 0.3	142 ± 2	15 ± 1	57.5 ± 0.4	40 ± 11
Σ	156 ± 3	278 ± 6	430 ± 20	54.7 ± 0.2	225 ± 1	22 ± 1	87.7 ± 0.4	60 ± 11

Particle Size (Microns)	La ng/m^3	Mg $\mu g/m^3$	Mn ng/m^3	Na $\mu g/m^3$	Ni ng/m^3	Rb ng/m^3	Sb ng/m^3	Sc ng/m^3
> 2.5	22 ± 2	41 ± 5	350 ± 10	15.2 ± 0.3	47 ± 14	56 ± 10	3.2 ± 0.4	5.63 ± 0.02
1.5-2.5	4.8 ± 0.9	12 ± 3	98 ± 4	3.8 ± 0.1	27 ± 7	14 ± 3	0.86 ± 0.13	1.50 ± 0.01
1.1-1.5	3.8 ± 0.6	10 ± 2	62 ± 3	3.3 ± 0.1	18 ± 6	9.1 ± 2.2	0.60 ± 0.10	1.11 ± 0.01
0.8-1.1	3.5 ± 0.7	7.1 ± 2.2	63 ± 3	3.3 ± 0.1	7 ± 4	11 ± 2	0.66 ± 0.11	1.03 ± 0.01
< 0.8	54 ± 5	93 ± 14	1030 ± 30	59 ± 1	100 ± 30	160 ± 20	8.5 ± 1.0	16.4 ± 0.1
Σ	88 ± 6	160 ± 15	1600 ± 30	85 ± 1	199 ± 30	250 ± 20	13.8 ± 1.0	25.7 ± 0.1

Particle Size (Microns)	Sm ng/m^3	Sr ng/m^3	Th ng/m^3	Ti ng/m^3	V ng/m^3
> 2.5	3.9 ± 0.3	570 ± 50	5.9 ± 0.2	2.2 ± 0.4	74 ± 7
1.5-2.5	0.93 ± 0.10	130 ± 10	1.56 ± 0.05	0.67 ± 0.18	26 ± 3
1.1-1.5	0.66 ± 0.08	150 ± 20	1.07 ± 0.04	0.49 ± 0.14	22 ± 3
0.8-1.1	0.73 ± 0.08	62 ± 9	1.06 ± 0.04	0.37 ± 0.14	14 ± 3
< 0.8	12.7 ± 0.4	1480 ± 130	14.7 ± 0.4	0.52 ± 1.0	322 ± 18
Σ	18.9 ± 0.5	2390 ± 140	24.3 ± 0.4	4.3 ± 1.1	460 ± 20

Date: 8/24/77
Lab-Ref: BNW-7
Sample Type: Fugitive
Sample Location: Crusher

TABLE 4-9 (Cont'd)

Particle Size (Microns)	Al µg/m^3	As ng/m^3	Ca µg/m^3	Ce ng/m^3	Co ng/m^3	Cr ng/m^3	Cs ng/m^3	Eu ng/m^3
> 7.0	32.8 ± 1.1	77 ± 11	95 ± 11	33 ± 1	11.0 ± 0.2	44 ± 1	2.5 ± 0.6	0.59 ± 0.05
3.3-7.0	9.55 ± 0.39	23 ± 4	25 ± 4	14 ± 1	4.7 ± 0.2	19 ± 1	0.94 ± 0.23	0.24 ± 0.03
2.0-3.3	4.07 ± 0.22	13 ± 2	ND	6.5 ± 0.4	2.3 ± 0.1	13.2 ± 0.1	0.38 ± 0.11	0.12 ± 0.03
1.1-2.0	2.93 ± 0.18	12 ± 2	10 ± 2	6.0 ± 0.4	2.0 ± 0.1	21 ± 1	0.51 ± 0.13	0.14 ± 0.03
< 1.1	106 ± 4	254 ± 34	310 ± 30	74 ± 3	20.9 ± 0.6	146 ± 4	4.7 ± 1.2	1.51 ± 0.13
Σ	155 ± 4	384 ± 36	440 ± 30	134 ± 3	41 ± 1	243 ± 4	9.0 ± 1.4	2.6 ± 0.1

Particle Size (Microns)	Fe µg/m^3	Hf ng/m^3	K µg/m^3	La ng/m^3	Mg µg/m^3	Mn ng/m^3	Na µg/m^3	Sm ng/m^3
> 7.0	16.4 ± 0.2	1.3 ± 0.2	15 ± 1	23 ± 3	53 ± 6	326 ± 11	15.1 ± 0.2	3.6 ± 0.3
3.3-7.0	5.5 ± 0.2	0.52 ± 0.09	6.7 ± 0.5	9.7 ± 1.7	14 ± 3	101 ± 5	3.6 ± 0.1	1.2 ± 0.2
2.0-3.3	2.5 ± 0.1	0.13 ± 0.07	1.7 ± 0.4	4.0 ± 1.3	11 ± 3	46 ± 3	1.48 ± 0.07	0.99 ± 0.15
1.1-2.0	2.3 ± 0.1	0.26 ± 0.07	1.5 ± 0.4	4.3 ± 1.5	6.7 ± 2.9	37 ± 3	1.32 ± 0.07	1.7 ± 0.2
< 1.1	31.0 ± 0.6	2.8 ± 0.4	42 ± 3	69 ± 10	124 ± 16	1070 ± 30	52 ± 1	14.7 ± 1.7
Σ	57.7 ± 0.7	5.0 ± 0.5	67 ± 3	110 ± 11	209 ± 18	1580 ± 30	74 ± 1	22.2 ± 1.8

Particle Size (Microns)	Sb ng/m^3	Sc ng/m^3	Se ng/m^3	Ta ng/m^3	Th ng/m^3	Ti µg/m^3	V ng/m^3
> 7.0	3.3 ± 07	4.94 ± 0.03	ND	0.57 ± 0.11	5.6 ± 0.3	2.0 ± 0.4	109 ± 8
3.3-7.0	1.4 ± 0.3	1.68 ± 0.02	ND	0.23 ± 0.07	2.5 ± 0.2	0.46 ± 0.17	39 ± 4
2.0-3.3	0.71 ± 0.25	0.82 ± 0.01	ND	0.17 ± 0.05	1.03 ± 0.08	0.37 ± 0.16	16 ± 3
1.1-2.0	0.56 ± 0.21	0.68 ± 0.01	ND	0.19 ± 0.06	1.09 ± 0.09	0.63 ± 0.16	14 ± 3
< 1.1	8.2 ± 1.8	8.97 ± 0.08	ND	1.1 ± 0.3	9.8 ± 0.6	6.1 ± 1.0	330 ± 23
Σ	14 ± 2	17.1 ± 0.09		2.3 ± 0.3	20 ± 1	9.6 ± 1.1	508 ± 25

Date: 11/15-17/77
Lab-Ref: BNW-7
Sample Type: Fugitive
Sample Location: Crusher

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-10

Crushing and Screening Particulates, Elemental Analysis for Impactor Stages

Element	Quantity of Element on Each Impactor Stage (μgs)								
	0	1	2	3	4	5	6	7	8
Li	1.2	6	10	3	0.6	< 0.2	< 0.2	< 0.2	< 0.3
Be	< 0.03	< 0.03	< 0.05	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03
B	0.1	0.5	1	0.15	0.06	< 0.06	< 0.06	< 0.06	6
Na	60	100	150	60	20	4	8	8	30
Mg	300	600	1000	150	50	15	5	2	30
Al	150	300	500	200	40	12	3	1	20
Si	600	900	1500	450	100	30	10	4	100
P	< 10	< 10	< 15	< 10	< 6	< 6	< 6	< 6	< 10
K	30	100	150	30	8	3	< 4	< 4	< 6
Ca	450	1200	2000	600	100	60	12	5	60
Ti	1.2	2.5	4	12	3	1.2	0.3	< 0.5	1.5
V	1	2.5	4	1	0.2	< 0.2	< 0.2	< 0.5	< 0.3
Cr	1	2	3	1.2	0.8	0.8	0.4	0.2	< 0.3
Mn	10	12	20	6	2	0.8	< 0.2	< 0.06	1.2
Fe	100	150	250	120	20	8	3	1	15
Co	1	0.3	0.5	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.3
Ni	0.6	1.2	2	0.6	0.2	< 0.2	< 0.2	< 0.2	< 0.3
Cu	3	3	5	6	2	0.8	0.4	0.2	3
Zn	1	1	1.5	1.2	0.8	0.6	0.6	0.6	1.5
Ga	< 0.3	< 0.3	< 0.5	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.3
Ge	< 0.3	< 0.3	< 0.5	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.3
Sr	15	30	50	15	3	1	0.3	0.1	15
Zr	0.5	0.6	1.2	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.5
Nb	< 1	< 1	< 1.5	< 1	< 0.6	< 0.6	< 0.6	< 0.6	< 1.5
Mo	0.3	0.6	1	0.5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.5
Ag	< 0.06	< 0.06	< 0.1	< 0.06	< 0.04	0.6	< 0.04	< 0.04	< 0.06
Cd	0.3	0.3	0.5	< 0.3	< 0.2	< 0.2	< 0.02	< 0.2	< 0.3
In	< 0.3	< 0.3	< 0.5	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.3
Sn	< 0.6	< 0.6	< 1	6	< 0.4	< 0.4	< 0.4	< 0.4	< 0.6
Sb	< 1	< 1	< 1.5	< 1	< 0.6	< 0.6	< 0.6	< 0.6	< 1
Ba	8	12	20	10	2	0.8	0.1	0.06	2.5
Ta	< 10	< 10	< 15	< 10	< 6	< 6	< 6	< 6	< 10
W	< 10	< 10	< 15	< 10	< 6	< 6	< 6	< 6	< 10
Tl	< 1	< 1	< 1.5	< 1	< 0.6	< 0.6	< 0.6	< 0.6	< 1
Pb	0.6	1	1.5	1	0.4	0.3	< 0.2	< 0.2	< 0.3
Bi	< 0.3	< 0.3	< 0.5	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.3

Date: 7/22/77
Lab-Ref: LASL-6
Sample Type: Fugitive

TABLE 4-11

Crushing and Screening, Mineral Analysis

Mineral	Estimated Wt%, ± 10%
Dolomite	45
Quartz	25
Calcite	15
Feldspar	10
Analcime	5

Date: 8/77
Lab-Ref: BNW-7
Location: Raw Shale Baghouse
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-12

Crushing and Screening Gas Data

General Area

Parameter	Date	Data	Method: Sampling	Method: Analysis
O_2, Vol.%	12/22/77	21.1	Gas Bomb	G.C. with T.C.
	4/19/78	21.4	Gas Bomb	G.C. with T.C.
CO_2, Vol.%	12/22/77	< 0.05	Gas Bomb	G.C. with T.C.
	1/18/78	0.03		Det. Tube
	4/19/78	0.04	Gas Bomb	G.C. with T.C.
CO, Vol.%	12/22/77	< 0.05	Gas Bomb	G.C. with T.C.
	4/19/78	< 0.05	Gas Bomb	G.C. with T.C.
CH_4, Vol.%	12/22/77	< 0.05	Gas Bomb	G.C. with T.C.
	1/18/78	< 0.005		Det. Tube
	4/19/78	< 0.05	Gas Bomb	G.C. with T.C.
NO_x, ppm	12/22/77	< 1	Sequential Sampler	Colorimetry
	1/18/78	< 2		Det. Tube
	4/19/78	< 1	Sequential Sampler	Colorimetry
SO_2, ppm	12/22/77	< 0.1	Sequential Sampler	Colorimetry
	1/18/78	< 10		Det. Tube
	4/19/78	< 0.1	Sequential Sampler	Colorimetry
Mercaptans, ppm	4/19/78	< 1	Sequential Sampler	Colorimetry
Phenols, ppm	4/19/78	< 1	Sequential Sampler	Colorimetry

Lab-Ref: PAR-9
Sample Location: Crusher
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 4-13

Crushing and Screening, Gas Elemental Analysis

$\mu g/m^3$

Date	As	Hg	Se	Pb
12/21/77	< 4	< 30	< 2	< 2
1/15/78	< 4			
4/78	< 4	< 30	< 2	< 2

Lab-Ref: PAR-9

Sampling Method: Sequential Sampler

Analysis Method: Atomic Absorption

Sample Type: Fugitive

5.0 RETORTING

5.1 General Discussion

The retorting operations contain the Paraho Pilot Plant (2.5 ft. I.D.) and Semi-Works (8.5 ft. I.D.) retorts, control rooms and auxiliary equipment. A plot diagram is shown in Figure 5.1. Though not precisely drawn to scale, 1 inch equals about 15 feet. The auxiliary equipment consists primarily of the air and gas blowers, the oil-gas separation equipment (which includes an electrostatic precipitator, ESP), and the thermal oxidizer (where the excess, or product, gas is combusted with excess air). A simplified flow schematic of the Paraho retort operations is shown in Figure 5.2.

Like the crushing operations, the retort operations presented formidable problems to researchers attempting to obtain fugitive emission data. First, the retort operations are located outdoors so that monitoring for fugitive emissions is subject to the variations in wind speed and directions. The retorting operations are continuous and the on-stream factor is high (> 90%). Thus, there are no problems arising from frequent, unscheduled shutdowns. The main problem in monitoring fugitive emissions in the Paraho retorting operation is that there is so much equipment in relatively small space. Often upwind from one source is downwind from another. It is difficult to position a sampler so that fugitive data can be collected from a specific source without interference from a secondary source or without being so close to the primary source that non-airborne particulates are being collected.

Nevertheless, monitoring for particulates and gases was carried out around the Paraho retorts. These data are compiled in 23 tables and figures and are discussed in Sections 5.2 and 5.3.

5.2 Retorting Particulates

Total particulate loading (mg/m^3) data for the retort area have been obtained in a process stream (Table 5-1, Product Gas) an effluent (Table 5-2, Thermal Oxidizer) and fugitive (Table 5-3, Retort and Oil Transfer).

Since the samples from the flowing recycle gas stream were obtained through a valve under non-isokinetic conditions, the data in Table 5-1 are questionable.

The effluent from the thermal oxidizer was sampled over a 3-year period by five researchers (see Table 5-2). Results vary widely: mean $\pm$ 1.0 S.D. = 94 $\pm$ 88 mg/m^3. The variation is caused by the problem of measuring the very low concentrations isokinetically. Insufficient samples are obtained using standard stack monitoring equipment. A high volume probe, used 11/17/78, produced a single value of 70 mg/m^3.

TSP measured at various locations around the retort shows a large degree of variation (see Table 5-3). The mean $\pm$ 1.0 S.D. = 16.5 $\pm$ 20.4 mg/m^3 for 77 samples; none can be considered to be statistical outliers. Because of the large number of locations that were examined, the data have been arranged below by location in an effort to examine these data more closely.

Location	N	Mean, mg/m^3	S.D., mg/m^3
Semi-Works			
Top Seal	20	22	26
Mid Distributor	10	9	9
Bottom Seal	20	17	18
Bottom	2	8	6
General	4	1	1
Pilot Plant			
Top Seal	6	4	1
Bottom Seal	6	50	13
Gas Blowers	4	2	1
Oil Tanks	4	16	6
Thermal Oxidizer	1	1	-

Data show that the rotating equipment that handle solids produce the highest TSP values. The mean TSP from the seals, top and bottom, from both retorts is 22 mg/m^3. Of the 21 samples showing TSP values greater than 20 mg/m^3, 19 are rotary seal samples. Although the mean TSP for the retort is 16.5 mg/m^3, more than half the samples listed in Table 5-3 show TSP values less than 10 mg/m^3.

The scatter in the retort TSP data appear to be valid. Samples taken concurrently at the rotary seals, distributors, blowers, and oil run-down tanks, as shown in Table 5-3, range from 2.95 to 53.29 mg/m^3 TSP. Yet the mean difference between the nine pairs of concurrent samples is only 0.21 mg/m^3. Clearly, the variance contributed from the analytical measurements is minimal.

Respirable dust was measured around the Semi-Works retort (see Table 5-4). These samples were not taken concurrently with TSP samples. Respirable and total dust should not be compared. Mean respirable dust levels is 3.3 mg/m^3. The respirable dust level at the rotary seals is somewhat higher (5.3 mg/m^3).

Particle size distribution data are presented in Table 5-5 and Figure 5-3. None of the data appear to be unusual. These data show that the Mmad values are faily small. Again, many σg values are quite high (> 10).

Composition of the particulates from the retort area are presented in Tables 5-6 through 5-10.

Elemental analyses of the particulates emitted from the thermal oxidizer are presented in Table 5-6. Because the quantities of this particulate matter were so small, only one sample was obtained and analyzed. Standard deviations in Table 5-6 represent the analytical variance. Only arsenic is significantly higher than the levels found in typical raw shale dusts (see Section 2.2). All other elements listed in Table 5-6 are not significantly different from raw shale dusts.

The proximate analyses of the retort particulates (see Table 5-7) indicate that this material is a mixture of raw and retorted shale. The mineral CO_2 and total CHNS are lower than typical raw shale (see Table 2-4). The organic carbon is significantly lower and the ash is higher than raw shale.

Toxic element concentrations in retort particulates are presented in Table 5-8. None of these elements differ significantly from those found in typical raw shale (see Section 2.2). The other elements are presented in Table 5-9.

None of these concentrations are significantly different than those normally occurring in raw shale dusts. However, much of the SSMS data are listed as "less than" or "greater than". Elemental concentrations by particle size are presented for three samples in Table 5-10. These data show qualitatively that none of the listed elements tend to concentrate in any particular particle size range.

5.3 Retort Gases - Gas Concentrations

Gas concentrations (vol% or ppm) in the retort and oil transfer area have been obtained in various samples: process stream, recycle or product gas (see Figure 5.2), Tables 5-11, 5-12, 5-13; effluent, thermal oxidizer stack (see Figure 5.2), Tables 5-14, 5-15; fugitive, Tables 5-16, 5-17. As pointed out in Section 5.1, because of the close proximity of various equipment in the retort and oil transfer, it is difficult to obtain quantitative and valid data to calculate fugitive emission rates. No ambient data have been obtained in the retort area.

Product gas data, obtained by Development Engineering, Inc. in the Paraho Laboratory, is shown in Table 5-11. Results from 86 samples have been condensed in this table presenting high, low, and mean concentrations for 13 gases over a 4-year period. For the most part, the gas concentrations show no significant changes during this period. Carbon dioxide apparently was reduced by operations from 24-25 vol% in 1975 operations to 18-27 vol% (mean = 22-23 vol%) in the 1977-78 operations. Hydrogen sulfide appears to have increased somewhat from 0.22 vol% (1975) to 0.30 vol% (1977-78). Ammonia increased significantly -- 0.21 vol% (1975) to 0.70 vol% (1977-78). Gas data obtained by other researchers (Table 5-12) agrees quite well with the Paraho data (Table 5-11) when examining hydrocarbons, carbon monoxide, carbon dioxide, and oxygen. Most of the N- and S- gas data also agree. Hydrogen sulfide is about 0.2 vol%; ammonia has increased from 0.2 to 0.7 vol%; sulfur dioxide is about 10-20 ppm; oxides of nitrogen (NO_x) have increased from about 10 ppm to about 100-200 ppm. Trace organics (C_5 to C_{11}) have been measured in recycle gas (see Table 5-13). Results from the sample taken on 10/18/77 are high for all components; results from the other three samples agree fairly well. Although, as a combined group,

these results agree with the "C5+" results in Table 5-11, no quantitative appraisal of individual trace organics can be made at this time.

Thermal oxidizer effluent composition is presented in Tables 5-14 and 5-15. Since this is not a closely controlled process, the gaseous composition varies. Large amounts of excess air are present in the effluent; oxygen varied from 7 to 14 vol%. Carbon dioxide also varied widely -- from 2 to 10 vol%. For the most part, combustion was complete; carbon monoxide and methane were not detected using thermal conductivity. Using more sensitive flame ionization, carbon monoxide is about 400 ppm and methane is about 30 ppm. Sulfur and nitrogen gas composition in the thermal oxidizer is shown in Table 5-15. Again, these data show efficient combustion; little or no ammonia or hydrogen sulfide is in the thermal oxidizer effluent. Sulfur dioxide varies from about 10 ppm to 300 ppm; median value is about 200 ppm. The 1200 ppm and < 1 ppm values are outliers. Oxides of nitrogen vary from 100 to 500 ppm; these are split about evenly between nitrous oxide (NO) and nitric oxide (NO_2).

Gas composition of possible fugitive emissions is presented in Tables 5-16 and 5-17. For the most part, these values appear reasonable; they appear to be a small amount of recycle gas diluted with air. The only possible outlier would be the 1000 ppm hydrocarbon value shown in Table 5-17. Because of the close proximity of the various pieces of equipment and operations, no attempt was made to sort these data. For the most part, all data are below accepted TLV values. The only high values found for most general gases and volatile organics was near the recycle gas blower. Close proximity to the recycle gas blower is not a normal work area.

5.4 Retort Gases - Elemental Composition

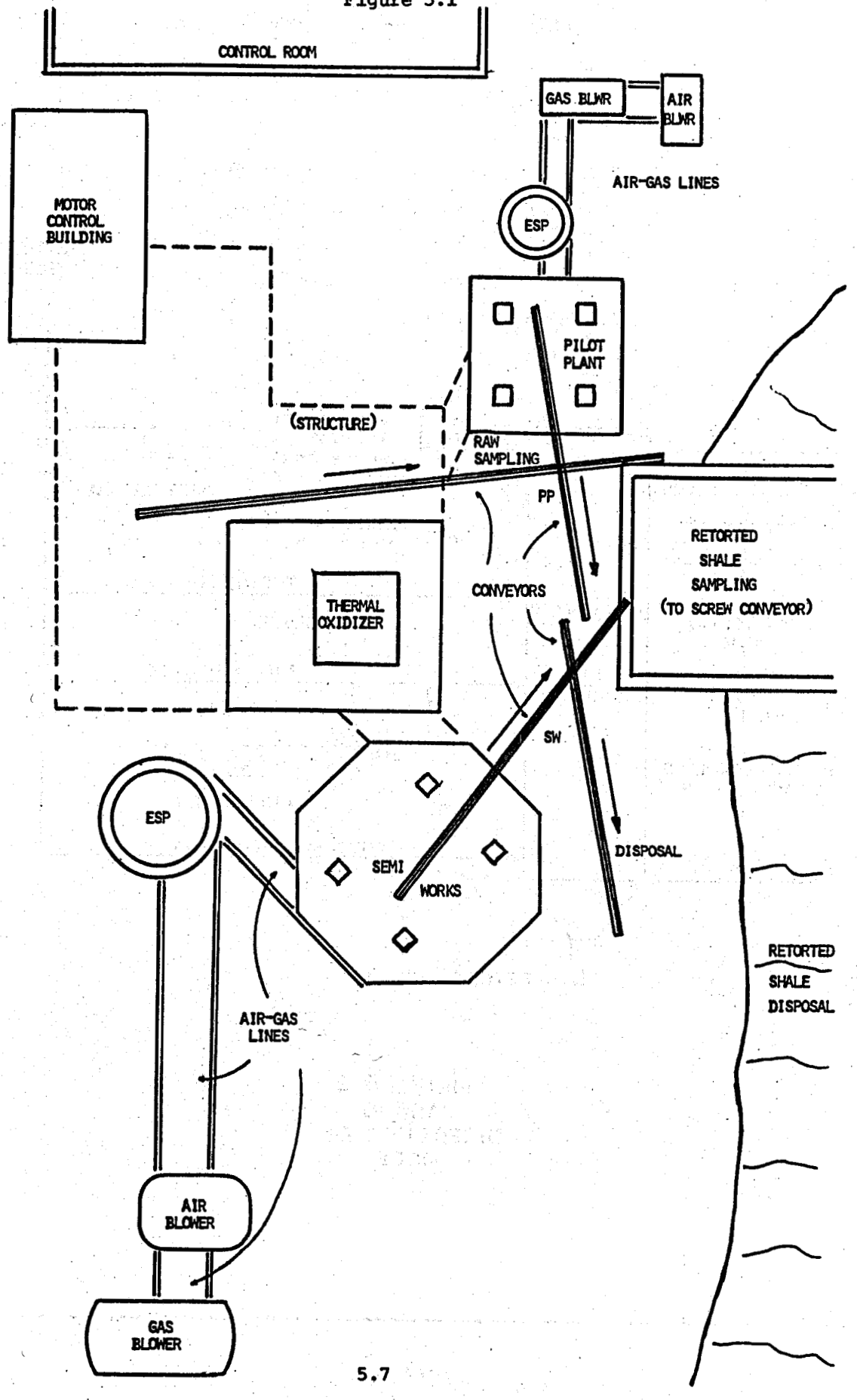
In an effort to obtain elemental material balances around the Paraho retorting process, a large amount of data were collected for the product gas and the thermal oxidizer effluent. Some fugitive data have also been obtained.

Toxic elemental concentrations are presented for the product gas (see Table 5-18), thermal oxidizer effluent (Table 5-20) and fugitive emissions from

the retort and oil transfer area (Table 5-22). Practically all the data are below the limits of detection. It appears that normal atomic absorption (AA) should not be used for these analyses; normal AA produce only "less than" results. Of all the trace toxic elemental analyses, only arsenic and mercury were found in the product gas and thermal oxidizer effluent. About 120 to 150 $\mu g/m^3$ total arsenic was found in recycle gas. Practically all the arsenic in recycle gas existed as the oxide (As_2O_3). Some arsine (2 $\mu g/m^3$) and methyl-substituted arsines (4 $\mu g/m^3$) were detected. There is some question regarding mercury in recycle gas: gold amalgamation followed by flameless AA produced 45-75 $\mu g/m^3$; selective absorption produced 0.1-1.3 $\mu g/m^3$. In the thermal oxidizer effluent, total arsenic varied from 12 to 55 $\mu g/m^3$ and mercury from 5 to 12 $\mu g/m^3$. The arsenic exists exclusively as the oxide or other particulate forms; the mercury was determined by flameless AA. Analyses were made for about 20 additional elements (other than those in Tables 5-18 and 5-20) in product gas and thermal oxidizer effluents (see Tables 5-19 and 5-21). All of the results (more than 230 tests) were below the limits of detection.

RETORT AREA

Figure 5.1



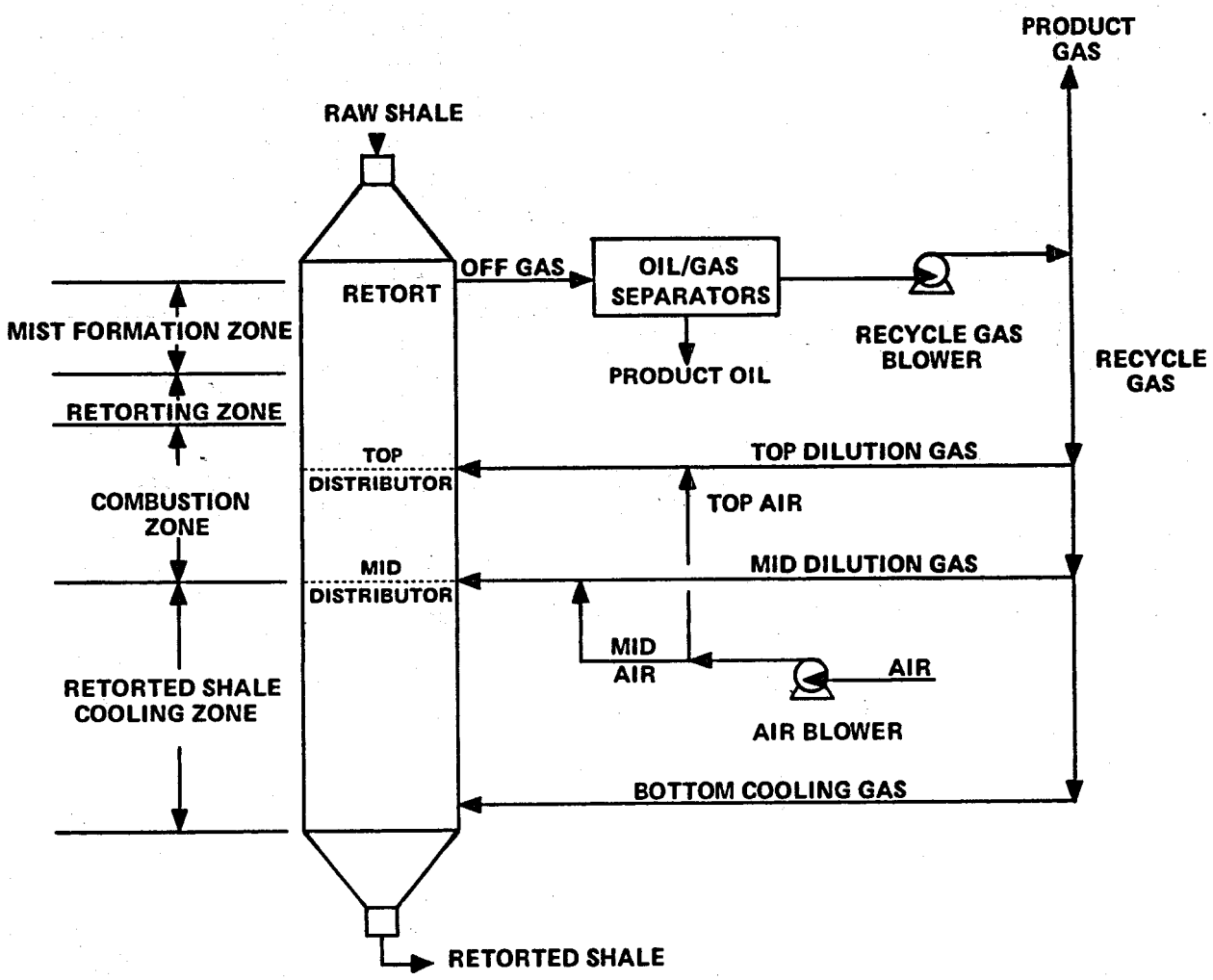
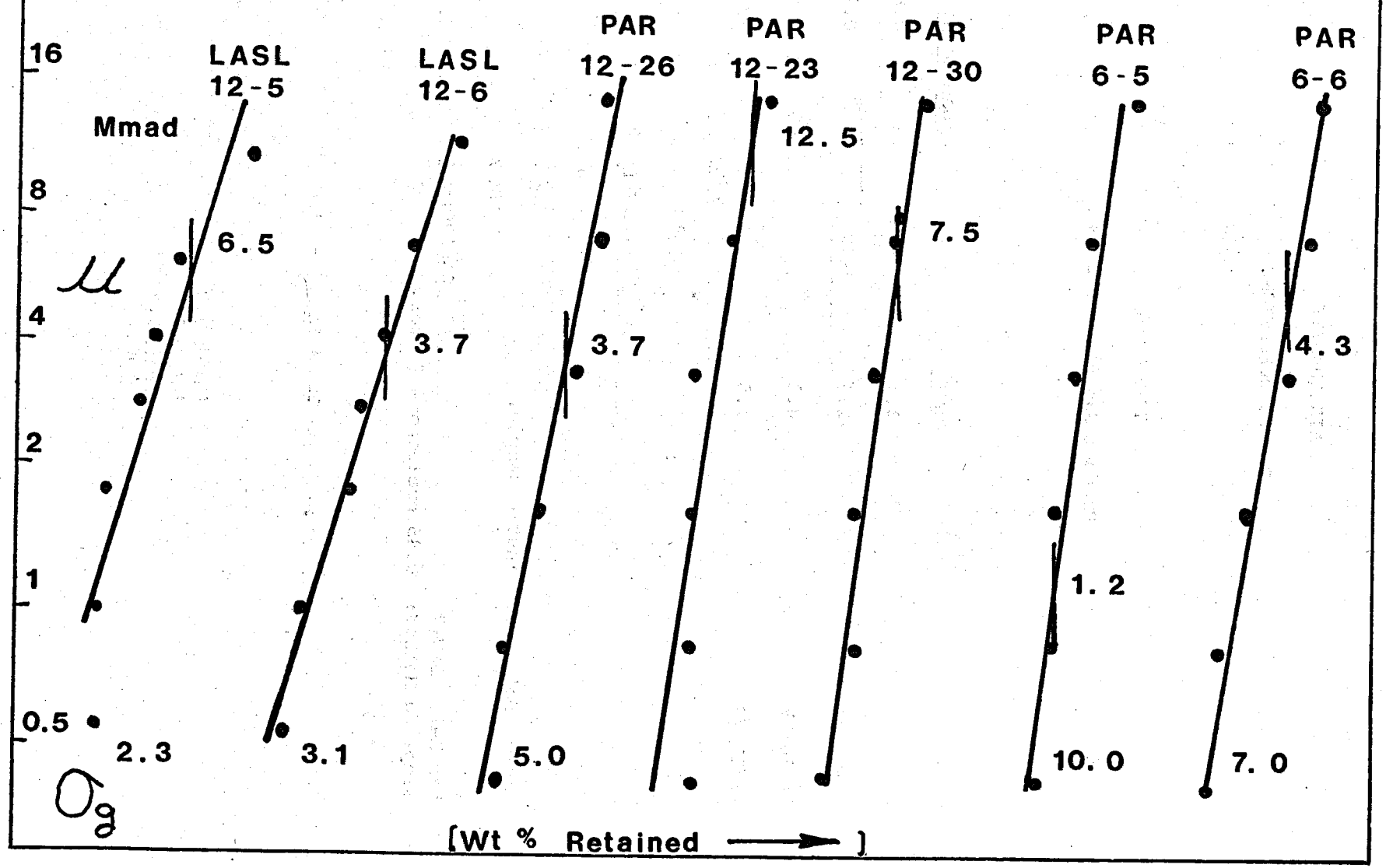


FIGURE 5.2
PARAHO
DIRECT HEATED
MODE

Figure 5.3

Retort Particulates



AIR QUALITY

PARAHO OPERATIONS

TABLE 5-1

Product Gas Particulates

Date	mg/m^3	Sample Size (m^3)
8/24/77	2.4	0.60
11/15/77	2.5	0.18
11/16/77	4.2	0.06
11/17/77	1.5	0.12

Note: Not an isokinetic sample.

Lab Ref: BNW-7
Sampling Method: 0.45 nucleopore filter.

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-2

Thermal Oxidizer, General Particulate Data

Date	Lab-Ref	Loading, mg/m^3	Sample Size
5/75	Gulf-1	175	
5/75	Gulf-1	6	
10/11/75	RMT-1	270	
8/24/77	BNW-7	< 0.8	0.2 m^3 Sample
9/3/77	TRW-8	23	
9/3/77	TRW-8	19	
11/15/77	BNW-7	120	0.2 m^3 Sample
11/16/77	BNW-7	160	0.2 m^3 Sample
11/17/77	BNW-7	70	7 m^3 Sample
2/9/78	PAR-9	100	0.3 m^3 Sample

Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-3

Retort and Oil Transfer, Total Suspended Particulates

Date	Data mg/m^3	Lab-Ref	Location	Quantity, g	Sampling Method	Comments
7/19/77	59.15	LASL-6	SW Btm. Dist.	0.0126	Pers. Sampler	
7/19/77	12.0	LASL-6	SW Btm.	0.0060	Pers. Sampler	
7/19/77	3.9	LASL-6	SW Btm.	0.0080	Pers. Sampler	
7/19/77	13.2	LASL-6	SW Top Seal	0.0037	Pers. Sampler	
12/5/77	2.96	LASL-6	SW Btm. Seal	0.0038	And. Impac.	Size Distribution
12/5/77	29.33	LASL-6	SW Top Seal	0.0135	And. Impac.	Size Distribution
12/5/77	8.42	LASL-6	SW Btm. Seal	0.0006	Pers. Sampler	
12/5/77	63.16	LASL-6	SW Top Seal	0.0048	Pers. Sampler	
12/5/77	ND	LASL-6	SW Btm. Seal		Pers. Sampler	
12/5/77	10	LASL-6	SW Btm. Seal		Pers. Sampler	
12/5/77	3.5	LASL-6	SW Btm. Seal		Pers. Sampler	
12/5/77	42.0	LASL-6	SW Top Seal		Pers. Sampler	
12/5/77	3.28	LASL-6	SW Top Seal	0.0019	And. Impac.	
12/5/77	1.59	LASL-6	SW Btm. Seal	0.0011	And. Impac.	Size Distribution
12/5/77	90.83	LASL-6	SW Top Seal	0.0044	Pers. Sampler	
12/5/77	20.46	LASL-6	SW Btm. Seal	0.0010	Pers. Sampler	
12/6/77	35.34	LASL-6	SW Btm. Seal	0.0250	And. Impac.	
12/6/77	53.87	LASL-6	SW Btm. Seal	0.0027	Pers. Sampler	
12/6/77	51.2	LASL-6	SW Top Seal	0.0026	Pers. Sampler	
12/6/77	58.68	LASL-6	SW Top Seal	0.0415	And. Impac.	Size Distribution
12/6/77	28.57	LASL-6	SW Mid Dist.	0.0009	Pers. Sampler	
12/6/77	20.94	LASL-6	SW Mid Dist.	0.0013	Pers. Sampler	
12/6/77	8.92	LASL-6	SW Mid Dist.	0.0005	Pers. Sampler	
12/6/77	ND	LASL-6	SW Mid Dist.		Pers. Sampler	
12/6/77	7.6	LASL-6	SW Btm. Seal		Pers. Sampler	
12/6/77	0.1	LASL-6	SW General		Pers. Sampler	
12/6/77	0.4	LASL-6	SW 3rd Landing		Pers. Sampler	
12/6/77	2.7	LASL-6	SW 4th Landing		Pers. Sampler	
12/6/77	1.4	LASL-6	SW 5th Landing		Pers. Sampler	
12/6/77	1.3	LASL-6	SW Top Seal		Pers. Sampler	
12/6/77	1.1	LASL-6	TO Top		Pers. Sampler	
12/6/77	29.7	LASL-6	SW Top Seal		Pers. Sampler	
12/22/77	28.19	PAR-9	PP Btm. Seal	1.53	Hi-Vol	
12/22/77	60.18	PAR-9	PP Btm. Seal	3.14	Hi-Vol	
12/22/77	53.29*	PAR-9	PP Btm. Seal	1.78	Hi-Vol	
12/22/77	52.76*	PAR-9	PP Btm. Seal	0.0164	Cas. Impac.	Size Distribution
12/22/77	61.79	PAR-9	PP Btm. Seal	3.51	Hi-Vol	
12/22/77	40.56	PAR-9	PP Btm. Seal	1.46		
12/23/77	9.03	PAR-9	SW Mid Dist.	0.54	Hi-Vol	
12/23/77	0.93	PAR-9	SW Mid Dist.	0.05	Hi-Vol	
12/23/77	4.94	PAR-9	SW Mid Dist.	0.31	Hi-Vol	
12/23/77	11.01	PAR-9	SW Mid Dist.	0.68	Hi-Vol	
12/23/77	3.12*	PAR-9	SW Mid Dist.	0.13	Hi-Vol	
12/23/77	2.97*	PAR-9	SW Mid Dist.	0.0012	Cas. Impac.	Size Distribution
12/24/77	3.15	PAR-9	PP Top Seal	0.19	Hi-Vol	
12/24/77	3.31	PAR-9	PP Top Seal	0.21	Hi-Vol	
12/24/77	4.51	PAR-9	PP Top Seal	0.20	Hi-Vol	
12/24/77	2.78	PAR-9	PP Top Seal	0.19	Hi-Vol	
12/24/77	5.86*	PAR-9	PP Top Seal	0.36	Hi-Vol	
12/24/77	5.74*	PAR-9	PP Top Seal	0.0031	Cas. Impac.	Size Distribution
12/26/77	13.82	PAR-9	SW Top Seal	0.95	Hi-Vol	
12/26/77	2.02	PAR-9	SW Top Seal	0.14	Hi-Vol	
12/26/77	4.80	PAR-9	SW Top Seal	0.32	Hi-Vol	
12/26/77	1.07	PAR-9	SW Top Seal	0.06	Hi-Vol	
12/26/77	7.41*	PAR-9	SW Top Seal	0.42	Hi-Vol	
12/26/77	7.39*	PAR-9	SW Top Seal	0.0041	Cas. Impac.	Size Distribution
12/27/77	6.97*	PAR-9	SW Btm. Seal	0.42	Hi-Vol	
12/27/77	6.81*	PAR-9	SW Btm. Seal	0.0021	Cas. Impac.	Size Distribution
12/27/77	1.95	PAR-9	SW Btm. Seal	0.11	Hi-Vol	
12/27/77	1.22	PAR-9	SW Btm. Seal	0.06	Hi-Vol	
12/27/77	2.07	PAR-9	SW Btm. Seal	0.10	Hi-Vol	
12/30/77	2.95*	PAR-9	Gas Blowers	0.08	Hi-Vol	
12/30/77	3.05*	PAR-9	Gas Blowers	0.0009	Cas. Impac.	Size Distribution
12/30/77	0.20	PAR-9	Gas Blowers	0.01	Hi-Vol	
12/30/77	1.28	PAR-9	Gas Blowers	0.06	Hi-Vol	
6/5/78	15.80	PAR-9	SW Btm. Seal	0.73	Hi-Vol	
6/5/78	29.54*	PAR-9	SW Btm. Seal	1.04	Hi-Vol	
6/5/78	29.10*	PAR-9	SW Btm. Seal	0.0095	Cas. Impac.	Size Distribution
6/5/78	35.16	PAR-9	SW Btm. Seal	1.64	Hi-Vol	
6/6/78	8.21	PAR-9	Oil Tanks	0.41	Hi-Vol	
6/6/78	19.28*	PAR-9	Oil Tanks	1.25	Hi-Vol	
6/6/78	19.34*	PAR-9	Oil Tanks	0.0111	Cas. Impac.	Size Distribution
6/6/78	18.91	PAR-9	Oil Tanks	1.00	Hi-Vol	
6/6/78	2.40	PAR-9	SW Top Seal	0.17	Hi-Vol	
6/6/78	3.16*	PAR-9	SW Top Seal	0.20	Hi-Vol	
6/6/78	3.56*	PAR-9	SW Top Seal	0.0019	Cas. Impac.	Size Distribution
6/6/78	2.55	PAR-9	SW Top Seal	0.18	Hi-Vol	

* Sampled Concurrently

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-4

Retort and Oil Transfer, Respirable Dust

Date	Data mg/m^3	Location	Quantity, g	Sampling Method
7/19/77	4.4	SW Btm.	0.0017	Pers. Sampler
7/19/77	0.54	SW Btm.	0.0002	Pers. Sampler
12/5/77	0.26	SW Btm. Seal	0.00002	Pers. Sampler
12/5/77	15.66	SW Top Seal	0.0009	Pers. Sampler
12/5/77	ND	SW Btm. Seal		Pers. Sampler
12/5/77	2.7	SW Btm. Seal		Pers. Sampler
12/5/77	0.6	SW Btm. Seal		Pers. Sampler
12/5/77	9.2	SW Top Seal		Pers. Sampler
12/5/77	7.02	SW Top Seal	0.0003	Pers. Sampler
12/5/77	0.23	SW Btm. Seal	0.00001	Pers. Sampler
12/6/77	2.60	SW Btm. Seal	0.0001	Pers. Sampler
12/6/77	6.55	SW Top Seal	0.0003	Pers. Sampler
12/6/77	4.21	SW Mid Dist.	0.0011	Pers. Sampler
12/6/77	1.74	SW Mid Dist.	0.0009	Pers. Sampler
12/6/77	ND	SW Mid Dist.		Pers. Sampler
12/6/77	ND	SW Mid Dist.		Pers. Sampler
12/6/77	4.5	SW Btm. Seal		Pers. Sampler
12/6/77	0.3	SW 3rd Landing		Pers. Sampler
12/6/77	1.8	SW 4th Landing		Pers. Sampler
12/6/77	ND	SW 5th Landing		Pers. Sampler
12/6/77	0.9	SW Top Seal		Pers. Sampler
12/6/77	0.9	TO Top		Pers. Sampler
12/6/77	12.9	SW Top Seal		Pers. Sampler

Lab-Ref: LASL-6
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-5

Retort and Oil Transfer, Particle Size

Lab-Ref	Date		Analysis								Location	Sampling Method	Mmad	σ_g
		u	12	7	4.8	3.4	2.2	1.2	0.66	0.44				
LASL-6	12/5/77	% P	86.1	46.3	33.2	24.7	7.9	3.7	1.5	0.2	Bottom Seal (SW)	And. Impac.	6.5	2.3
LASL-6	12/6/77		89.3	69.4	54.5	45.1	36.7	16.7	3.9	1.4	Top Seal (SW)	And. Impac.	3.7	3.1
		u	16	8	4	2	1	0.5						
PAR-9	12/27/77	% P	33.3	24.3	21.2	21.2	18.2	12.1			Bottom Seal (SW)	Cas. Impac.	< 0.5	
PAR-9	12/22/77		43.3	32.8	27.6	23.1	20.9	5.2			Bottom Seal (PP)	Cas. Impac.	< 0.5	
PAR-9	12/26/77		76.5	70.6	58.8	38.2	20.6	17.7			Top Seal (SW)	Cas. Impac.	3.7	5.0
PAR-9	12/24/77		48.0	40.0	36.0	32.0	28.0	20.0			Top Seal (PP)	Cas. Impac.	< 0.5	
PAR-9	12/23/77		60.0	40.0	30.0	30.0	30.0	30.0			Structure	Cas. Impac.	12.5	
PAR-9	12/30/77		62.5	50.0	37.5	25.0	25.0	12.5			Blower (SW)	Cas. Impac.	7.5	
PAR-9	6/5/78		94.8	70.1	64.9	53.8	48.1	42.9			Bottom Seal (SW)	Cas. Impac.	1.2	10
PAR-9	6/6/78		75.0	68.8	56.3	31.3	18.8	12.5			Top Seal (SW)	Cas. Impac.	4.3	7.0
PAR-9	6/6/78		35.0	33.0	28.0	18.0	16.0	12.0			Oil Storage	Cas. Impac.	< 0.5	

u = 50% cut-off in microns.
% P = Percent passing.
Mmad = Mean mass aerodynamic diameter.
σ_g = Particle size deviation.

TABLE 5-6

Thermal Oxidizer Particulates, Elemental Analysis

Element	Concentration
Al, Wt%	2.92 ± 0.08
As, ppm	520 ± 10
Ba, ppm	434 ± 54
Br, ppm	2.76 ± 0.31
Ca, Wt%	10.6 ± 0.9
K, Wt%	1.37 ± 0.27
La, ppm	26.0 ± 0.5
Lu, ppm	0.29 ± 0.02
Mn, ppm	380 ± 40
Na, Wt%	1.35 ± 0.01
Nd, ppm	27 ± 3
Sb, ppm	5.72 ± 0.10
Ti, Wt%	0.21 ± 0.05
U, ppm	7.0 ± 1.0
V, ppm	140 ± 10
Yb, ppm	1.42 ± 0.16

Date: 11/15/77

LAB-Ref: BNW-7

Analytical Method: INAA

Single Sample

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-7

Retort and Oil Transfer Particulates, Proximate Analyses

	Wt.%	Analytical Method
Mineral CO_2	14.94	Coulometric
Mineral C	4.08	Coulometric
Total C	11.65	Elemental Analyzer
Organic C	7.57	Difference
H	1.13	Elemental Analyzer
N	0.36	Elemental Analyzer
S	0.86 > 1*	Sulfur Analyzer SSMS
Ash	75.02	Gravimetric

* This analysis by CTE-9

Date: 6/6/78
Lab-Ref: PAR-9
Location: Retort
Sample Type: Fugitive Dust
Sampling Time: 1 Hour
Sampling Method: Hi-Vol

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-8

Retort and Oil Transfer Particulates, Toxic Elements

Element	Date	Data, ppm	Lab-Ref	Analytical Method
As	8/6-7/75	85	LFE-2	XRF
	6/7/78	150	CT&E-9	SSMS
B	6/7/78	37	CT&E-9	SSMS
Cd	8/6-7/75	< 53	LFE-2	XRF
	6/7/78	1	CT&E-9	SSMS
Cu	8/6-7/75	35	LFE-2	XRF
	6/7/78	80	CT&E-9	SSMS
F	6/7/78	> 1000	CT&E-9	SSMS
Hg	8/6-7/75	< 10	LFE-2	XRF
Mo	6/7/78	25	CT&E-9	SSMS
Pb	8/6-7/75	14	LFE-2	XRF
	6/7/78	36	CT&E-9	SSMS
Se	6/7/78	3	CT&E-9	SSMS
Zn	8/6-7/75	129	LFE-2	XRF
	6/7/78	120	CT&E-9	SSMS

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-9

Retort and Oil Transfer Particulates, Other Elemental Analyses

PPM Except as Noted

Lab-Ref:	LFE-8	CTE-9		LFE-8	CTE-9
Date:	8/6-7/75	6/7/78		8/6-7/75	6/7/78
Element			Element		
Ag	< 53	< 0.1	Nb		12
Al		> 1000	Nd		13
Au		< 0.1	Ni	< 115	30
Ba		> 1000	Os		< 0.1
Be		0.1	P		> 1000
Bi		1	Pd		< 0.1
Br		3	Pr		5
Ca		> 1000	Pt		< 0.1
Ce		52	Rb	75	100
Cs		11	Re		< 0.1
Cl		50	Rh		< 0.1
Co	40	3	Ru		< 0.1
Cr	≤ 40	45	Sb		3
Dy		2	Sc		3
Er		1	Si		> 1000
Eu		1	Sm		7
Fe, Wt%	2.2	> 1	Sn		1
Ga		30	Sr	644	> 1000
Ge		1	Ta		< 0.1
Gd		2	Tb		1
Hf		1	Te		< 0.1
Ho		1	Th		10
I		0.4	Ti	270	> 1000
Ir		< 0.1	Tl		1
K		> 1000	Tm		0.1
La		41	U		14
Li		≥ 250	V		450
Lu		0.2	W		1
Mg		> 1000	Y		13
Mn	218	≥ 910	Yb		1
Na		> 1000	Zr		58

Analytical Methods:
CT&E analyses by SSMS.
LFE analyses by XRF.

Location: Retort

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-10

Retort and Oil Transfer, Particulate Chemical Analysis by Particle Size

Particle Size (Microns)	Al µg/m³	As ng/m³	Ca µg/m³	Co ng/m³	Cr ng/m³	Cs ng/m³	Fe µg/m³	K µg/m³
> 6.8	146 ± 4	260 ± 10	450 ± 40	42.4 ± 0.5	137 ± 3	10 ± 1	62.9 ± 0.5	57 ± 11
4.1-6.8	23.0 ± 0.7	60 ± 1	57 ± 9	9.4 ± 0.2	48 ± 1	1.90 ± 0.25	11.5 ± 0.2	14 ± 3
3.0-4.1	7.9 ± 0.4	26.9 ± 0.9	< 14	3.8 ± 0.1	30.8 ± 0.9	0.88 ± 0.13	4.53 ± 0.12	6.4 ± 1.3
2.0-3.0	4.7 ± 0.3	13.2 ± 0.7	< 13	2.6 ± 0.1	22.7 ± 0.8	0.44 ± 0.08	3.18 ± 0.10	2.9 ± 0.6
< 2.0	42 ± 1	75 ± 3	110 ± 10	15.2 ± 0.3	194 ± 3	4.2 ± 0.6	22.5 ± 0.4	20 ± 4
Σ	224 ± 4	435 ± 11	620 ± 40	73.4 ± 0.6	433 ± 4	17 ± 1	105 ± 1	100 ± 12

Particle Size (Microns)	La ng/m³	Mg µg/m³	Mn ng/m³	Na µg/m³	Sb ng/m³	Sc ng/m³
> 6.8	67 ± 6	180 ± 20	1630 ± 40	70 ± 1	8.4 ± 1.0	19.2 ± 0.1
4.1-6.8	15 ± 1	39 ± 9	290 ± 10	12.6 ± 0.2	2.0 ± 0.3	3.81 ± 0.03
3.0-4.1	7.1 ± 0.7	19 ± 6	77 ± 7	6.4 ± 0.1	1.1 ± 0.2	1.52 ± 0.02
2.0-3.0	3.4 ± 0.5	< 10	52 ± 5	4.0 ± 0.1	0.53 ± 0.15	1.03 ± 0.01
< 2.0	25 ± 2	29 ± 9	440 ± 10	27 ± 1	4.7 ± 0.7	7.11 ± 0.05
Σ	118 ± 6	270 ± 20	2490 ± 40	120 ± 1	16.8 ± 1.3	32.7 ± 0.1

Particle Size (Microns)	Sm ng/m³	Th ng/m³	Ti ng/m³	V ng/m³
> 6.8	14 ± 1	22.9 ± 0.8	8.6 ± 1.4	430 ± 30
4.1-6.8	4.1 ± 0.2	5.6 ± 0.2	1.8 ± 0.5	81 ± 7
3.0-4.1	2.0 ± 0.1	2.29 ± 0.11	0.62 ± 0.37	27 ± 7
2.0-3.0	1.22 ± 0.09	1.42 ± 0.09	0.96 ± 0.37	13 ± 5
< 2.0	7.9 ± 0.5	7.9 ± 0.4	2.6 ± 0.6	151 ± 13
Σ	29 ± 1	40.1 ± 0.9	14.6 ± 1.7	700 ± 30

Date: 8/24/77
Lab-Ref: BNW-7
Sample Type: Fugitive
Sample Location: Retort

TABLE 5-10 (Cont'd)

Particle Size (Microns)	Al µg/m³	As ng/m³	Ca µg/m³	Co ng/m³	Cr ng/m³	Cs ng/m³	Fe µg/m³	K µg/m³
> 6.8	546 ± 8	2420 ± 50	1760 ± 80	351 ± 2	1010 ± 20	91 ± 12	508 ± 2	490 ± 80
4.1-6.8	182 ± 5	655 ± 15	660 ± 50	110 ± 1	336 ± 6	24 ± 3	123 ± 1	120 ± 20
3.0-4.1	59 ± 2	239 ± 4	240 ± 30	40.6 ± 0.5	127 ± 3	8.2 ± 1.1	38.1 ± 0.5	40 ± 6
2.0-3.0	21.9 ± 0.8	113 ± 3	65 ± 12	18.0 ± 0.3	80.8 ± 2.4	3.4 ± 0.5	16.0 ± 0.3	17 ± 3
< 2.0	111 ± 3	356 ± 9	340 ± 30	64.3 ± 0.5	372 ± 6	16 ± 2	74.9 ± 0.6	58 ± 9
Σ	920 ± 10	3780 ± 50	4070 ± 100	584 ± 2	1930 ± 20	143 ± 12	760 ± 2	725 ± 80

Particle Size (Microns)	La ng/m³	Mg µg/m³	Mn ng/m³	Na µg/m³	Ni ng/m³	Rb ng/m³	Sb ng/m³	Sc ng/m³
> 6.8	480 ± 30	760 ± 40	6440 ± 90	486 ± 9	1100 ± 200	1200 ± 200	73 ± 9	158 ± 1
4.1-6.8	133 ± 10	300 ± 40	2290 ± 60	78 ± 1	500 ± 100	340 ± 60	22 ± 3	41.2 ± 0.1
3.0-4.1	50 ± 2	96 ± 19	760 ± 30	24.8 ± 0.4	150 ± 40	110 ± 20	8.0 ± 1.1	13.4 ± 0.1
2.0-3.0	25 ± 2	19 ± 12	320 ± 20	12.9 ± 0.3	130 ± 30	44 ± 10	3.8 ± 0.6	5.89 ± 0.04
< 2.0	70 ± 6	180 ± 20	1360 ± 40	61 ± 1	260 ± 60	200 ± 40	12.1 ± 1.6	23.7 ± 0.1
Σ	758 ± 32	1360 ± 60	1170 ± 120	663 ± 9	2140 ± 240	1890 ± 240	119 ± 10	242 ± 2

Particle Size (Microns)	Sm ng/m³	Sr ng/m³	Th ng/m³	Ti ng/m³	V ng/m³
> 6.8	99 ± 3	22700 ± 3500	166 ± 6	31.8 ± 2.6	1880 ± 50
4.1-6.8	29 ± 1	5900 ± 900	57 ± 2	15.2 ± 2.2	770 ± 40
3.0-4.1	13.1 ± 0.4	1700 ± 300	20.8 ± 0.8	7.1 ± 1.2	290 ± 20
2.0-3.0	6.33 ± 0.23	1600 ± 300	8.79 ± 0.39	3.4 ± 0.8	130 ± 10
< 2.0	15.6 ± 0.7	7000 ± 1100	30.1 ± 1.2	7.1 ± 1.3	440 ± 30
Σ	163 ± 3	38900 ± 3800	283 ± 6	65 ± 4	3510 ± 70

Date: 8/25/77
Lab-Ref: BNW-7
Sample Type: Fugitive
Sample Location: Retort

TABLE 5-10 (Cont'd)

Particle Size (Microns)	Al µg/m³	As ng/m³	Ca µg/m³	Ce ng/m³	Co ng/m³	Cr ng/m³	Cs ng/m³	Eu ng/m³
> 7.0	59.2 ± 2.1	158 ± 9	205 ± 47	64 ± 4	24.2 ± 0.6	76 ± 4	3.8 ± 0.4	1.14 ± 0.12
3.3-7.0	17.0 ± 0.7	60 ± 4	68 ± 9	23 ± 2	9.8 ± 0.3	32 ± 2	1.6 ± 0.2	0.44 ± 0.07
2.0-3.3	8.3 ± 0.4	31 ± 2	80 ± 12	14 ± 1	5.8 ± 0.3	24 ± 2	0.99 ± 0.17	0.21 ± 0.07
1.1-2.0	6.32 ± 0.34	30 ± 2	33 ± 5	14 ± 1	5.2 ± 0.3	23 ± 2	0.70 ± 0.16	0.26 ± 0.06
< 1.1	63.4 ± 2.4	159 ± 11	205 ± 25	109 ± 7	52.6 ± 1.4	280 ± 15	5.8 ± 0.7	1.63 ± 0.24
Σ	154 ± 3	438 ± 15	590 ± 60	224 ± 8	98 ± 2	435 ± 16	12.9 ± 0.9	3.7 ± 0.3

Particle Size (Microns)	Fe µg/m³	Hf ng/m³	K µg/m³	La ng/m³	Mg µg/m³	Mn ng/m³	Na µg/m³	Sm ng/m³
> 7.0	31.9 ± 0.5	2.6 ± 0.4	23 ± 1	40 ± 5	68 ± 24	610 ± 20	32.5 ± 0.7	6.3 ± 0.5
3.3-7.0	10.6 ± 0.3	0.83 ± 0.19	8.7 ± 0.8	18 ± 3	32 ± 6	193 ± 9	8.7 ± 0.3	3.1 ± 0.3
2.0-3.3	6.2 ± 0.2	0.77 ± 0.16	4.5 ± 0.6	9.6 ± 2.4	19 ± 5	98 ± 5	4.3 ± 0.24	1.4 ± 0.2
1.1-2.0	5.5 ± 0.2	0.37 ± 0.13	2.4 ± 0.6	10 ± 4	ND	76 ± 5	3.0 ± 0.2	1.3 ± 0.2
< 1.1	42.3 ± 1.0	1.9 ± 0.6	21 ± 3	51 ± 9	106 ± 15	700 ± 30	33.6 ± 1.0	16.3 ± 1.3
Σ	96.5 ± 1.2	6.5 ± 0.8	60 ± 3	129 ± 12	225 ± 29	1680 ± 40	82 ± 1	28.4 ± 1.5

Particle Size (Microns)	Sb ng/m³	Sc ng/m³	Se ng/m³	Ta ng/m³	Th ng/m³	Ti µg/m³	V ng/m³
> 7.0	4.4 ± 0.5	10.0 ± 0.1	ND	0.97 ± 0.22	9.9 ± 1.1	2.5 ± 0.7	213 ± 14
3.3-7.0	2.5 ± 0.3	3.40 ± 0.05	ND	0.60 ± 0.15	3.9 ± 0.4	1.9 ± 0.4	67 ± 7
2.0-3.3	1.3 ± 0.3	1.96 ± 0.04	ND	0.33 ± 0.14	2.1 ± 0.3	0.81 ± 0.24	34 ± 4
1.1-2.0	1.8 ± 0.3	1.71 ± 0.03	ND	0.29 ± 0.12	2.3 ± 0.3	0.96 ± 0.24	40 ± 5
< 1.1	13 ± 1	11.4 ± 0.2	ND	1.41 ± 0.43	10.8 ± 1.2	4.3 ± 0.9	244 ± 21
Σ	23 ± 1	28.5 ± 0.2		3.6 ± 0.5	29 ± 2	10.5 ± 1.3	598 ± 27

Date: 11/16/77
Lab-Ref: BNW-7
Sample Type: Fugitive
Sample Location: Retort

TABLE 5-11

Product Gas Analysis, Paraho Data

		11/75(5)[1]	1977(31)	1978(51)
H_2	Hi	4.94	5.61	7.47
	Mean	4.72	4.38	5.09
	Lo	4.63	1.79	3.96
N_2	Hi	63.58	68.68	67.89
	Mean	63.03	64.17	63.43
	Lo	62.15	60.35	60.27
O_2	Hi	0.00	1.49	0.19
	Mean	0.00	0.14	0.04
	Lo	0.00	0.00	0.00
CO	Hi	2.73	3.33	3.21
	Mean	2.55	2.46	2.55
	Lo	2.41	2.07	2.17
CH_4	Hi	2.31	2.88	2.68
	Mean	2.27	2.16	2.16
	Lo	2.23	1.70	1.13
CO_2	Hi	25.25	26.59	27.71
	Mean	24.31	22.90	22.73
	Lo	23.88	18.02	18.92
C_2H_4	Hi	0.75	1.08	0.94
	Mean	0.68	0.66	0.65
	Lo	0.62	0.49	0.36
C_2H_6	Hi	0.62	0.82	0.72
	Mean	0.56	0.57	0.55
	Lo	0.52	0.39	0.28
C_3's	Hi	0.77	1.39	1.50
	Mean	0.72	0.71	0.71
	Lo	0.67	0.40	0.31
C_4's	Hi	0.39	0.95	1.09
	Mean	0.36	0.56	0.56
	Lo	0.32	0.47	0.04
C_5+	Hi	0.42	1.03	1.00
	Mean	0.41	0.57	0.57
	Lo	0.40	0.40	0.39
H_2S	Hi		0.55	0.44
	Mean	0.22	0.30	0.29
	Lo		0.26	0.19
NH_3	Hi		1.23	1.21
	Mean	0.21	0.68	0.72
	Lo		0.63	0.50

1 Number in parentheses is test days or samples.

Lab-Ref: PAR-9
Analysis Method: G.C. with T.C., H_2S by potentiometric titration, NH_3 by colorimetry.

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-12

Product Gas Composition

Date	Lab-Ref	Vol.% C_1	C_2	C_3	C_4	C_5	C_6	CO	CO_2	O_2	Analytical Method	Comments
8/5-6/75	LFE-2	2.0	1.2	0.6	0.2			2-3.4	20-40	0.1-1.2		
3/11/76	TRW-4							2.1	24.5	ND	G.C. with F.I.D.	
10/17/77	TRW-8	1.79	0.18	0.10	0.11	0.09	0.02				G.C. with F.I.D.	
10/18/77	TRW-8	1.58	0.37	0.18	0.14	0.09	ND				G.C. with F.I.D.	
10/18/77	TRW-8	1.88	0.40	0.11	0.10	0.11	ND				G.C. with F.I.D.	
10/18/77	TRW-8	1.93	0.41	0.18	0.40	0.10	0.02				G.C. with F.I.D.	
10/19/77	TRW-8	1.49	0.20	0.11	0.08	0.07	0.02				G.C. with F.I.D.	
10/20/77	TRW-8	1.28	0.23	0.10	0.07	0.05	0.02				G.C. with F.I.D.	
10/21/77	TRW-8	1.48	0.30	0.12	0.08	0.07	0.04				G.C. with F.I.D.	
10/21/77	TRW-8	1.73	0.35	0.16	0.11	0.07	0.04				G.C. with F.I.D.	
10/21/77	TRW-8							2.18	24.02	0.78	G.C. with T.C.	
11/15/77	BNW-7							2.14				Estimate
11/16/77	BNW-7							1.60				Estimate

Date	Lab-Ref	Vol.% H_2S	NH_3	ppm SO_2	NO_x	Analytical Method
8/5-6/75	LFE-2	0.75-1.2	0.43-1.0	1	6	
3/9/76	TRW-4			14	9	
3/10/76	TRW-4			4	16	
3/11/76	TRW-4	0.26	0.16			
3/11/76	TRW-4		0.27			
10/15/77	TRW-8	0.12	0.50	16	160	Single Parameter Inst.
10/17/77	TRW-8	0.13	0.71	16	160	Single Parameter Inst.
10/17/77	TRW-8	0.12	0.58	22	235	Single Parameter Inst.
10/19/77	TRW-8	0.13	0.71	14.5	250	Single Parameter Inst.
10/20/77	TRW-8			23	224	Single Parameter Inst.
10/21/77	TRW-8			14	44	Single Parameter Inst.
10/21/77	TRW-8			11	105	Single Parameter Inst.
11/15/77	BNW-7	0.28				Potentiometric
11/16/77	BNW-7	0.24				Potentiometric

TABLE 5-13

Product Gas Trace Organics, 1977

Peak No.	Assignment	MS Reference	MW	Relative Retention Time	Concentration mg/m^3, dry basis 9/10/77	9/12/77	10/18/77	10/19/77
1	Low MW hydrocarbons	-	-	-	-	-	-	-
2	1-Pentene	21-6	70	2.0	388	340	543	230
3	Hexane	48-3	86	2.2	443	362	712	291
4	Hexene	42-8	84	2.5	473	424	815	321
5	Thia-4-(methylthio)-3-cyclo-pentene-2-one	365-7	146	2.7	159	174	257	198
6	Branched C_7H_{14} hydrocarbon		98	3.2	131	126	341	120
7	n-Heptane	88-4	100	3.8	384	362	791	292
8	1-Heptene	78-9	98	4.3	344	346	788	323
9	Branched C_8H_{16} hydrocarbon		112	5.7	149	152	367	128
10	$C_7H_{12}O$ unsaturated ketone or alcohol		112	7.2	9	12	31	8
11	n-Octane	146-12	114	7.6	206	215	572	200
12	Benzene	33-9	78	7.8	244	221	380	169
13	Branched C_8H_{16} hydrocarbon		112	8.4	27	38	64	60
14	1-Octene	134-8	112	8.7	197	214	566	193
15	$C_7H_{12}O$ branched ketone or alcohol		112	9.8	12	20	56	21
16	Thiophene		84	10.1	31	36	83	41
17	C_8H_{14} hydrocarbon		110	10.8	41	40	73	31
18	1,2,4-trimethylcyclohexane	207-4	126	11.5	84	105	209	96
19	Branched C_9H_{18} hydrocarbon		126	11.9	39	48	101	42
20	$C_8H_{14}O$ alcohol or ether		126	12.8	25	29	66	26
21	n-Nonane	223-1	128	13.6	156	197	401	176
22	Toluene	64-7	92	14.0	211	224	509	206
23	(E)-6-methyl-3,5-heptadiene-2-one	197-2	124	14.3	37	41	95	42
24	1-Nonene	206-5	126	14.7	87	86	252	93
25	Branched $C_{10}H_{22}$ hydrocarbon		142	15.0	34	46	101	35
26	Branched $C_8H_{14}O$		126	15.7	64	79	168	70
27	$C_{10}H_{18}$ unsaturated hydrocarbon		138	16.1	18	17	44	20
28	C_9H_{16} unsaturated hydrocarbon		124	16.9	21	23	38	20
29	$C_9H_{16}O$ alcohol or ketone		140	17.9	22	24	34	18
30	$C_{10}H_{20}$ alkane		140	18.9	12	22	34	19
31	n-Decane	320-9	142	19.2	115	164	299	172
32	o-Xylene	113-4	106	19.6	23	29	62	27
33	m-Xylene	113-5	106	19.8	31	25	61	26
34	Branched $C_9H_{16}O$ or $C_{10}H_{20}$		140	19.9	31	25	61	26
35	1-Decene	306-6	140	20.3	171	197	554	239
36	p-Xylene	113-6	106	22.1	22	23	61	21
37	2,3,4,5-tetramethyl-1,4-hexadiene	292-8	138	22.2	21	26	61	30
38	Cyclooctatetraene or styrene	105-11	104	23.4	11	16	32	13
39	$C_{10}H_{16}$ terpene	105-5	136	24.0	8	14	22	13
40	n-Undecane	439-7	156	24.4	55	84	134	117
41	Isopropylbenzene or methyl-ethyl-benzene	178-11 179-3,4,5	120	24.8	8	14	23	12
42	1-Undecene	419-6	154	25.3	42	93	119	109
43	Methyl-ethyl-benzene or trimethylbenzene	p. 178,179	120	25.8	8	12	17	10
44	Branched $C_{11}H_{20}$ hydrocarbon		152	26.1	6	9	12	12

TABLE 5-13 (Cont'd)

Peak No.	Assignment	MS-Reference	MW	Relative Retention Time	Concentration mg/m^3, dry basis 9/10/77	9/12/77	10/18/77	10/19/77
45	6-Methyl-6-ethylfulvene	178-9	120	26.4	11	21	29	19
46	Trimethylbenzene	178-12, 179-1,2	120	27.1	14	18	32	20
47	Diethylbenzene or sec-butylbenzene	p. 262,263	134	28.7	15	19	13	11
48	n-Dodecane	589-6	170	29.0	16	59	72	123
49	sec-butyl or methyl-propyl-benzene	p. 262,263	134	29.3	23	30	39	31
50	Branched $C_{10}H_{20}$ hydrocarbon		140	29.4	23	28	39	31
51	t-butylbenzene	261-12	134	31.8	7	9	7	10
52	Naphthalene	220-1	128	37.5	8	11	7	16
53	C_4H_9 substituted benzene		134	38.4	7	8	3	12

Lab-Ref: TRW-8
Analysis Method: G.C./M.S.
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-14

Thermal Oxidizer, Gas Chromatography Data

Vol.%

Date	Lab-Ref	O_2	CO_2	CO	CH_4	Detector	Comments
12/30/74	PAR-1	9.8	6.2	< 0.05	< 0.05	T.C.	
3/5/75	PAR-1	7.6	8.6	0.46	< 0.05	T.C.	
3/5/75	PAR-1	7.2	9.6	0.18	< 0.05	T.C.	
3/12/75	PAR-1	7.7	8.9	< 0.05	< 0.05	T.C.	
5/9/75	PAR-1	8.6	8.8	< 0.05	< 0.05	T.C.	
5/8/75	GULF-1	7.7	8.1	< 0.05	< 0.05	T.C.	
5/14/75	GULF-1	7.9	7.9	< 0.05	< 0.05	T.C.	
8/5-6/75	LFE-2	7-16	6-10	0-1.3			
8/22/75	PAR-1	8.0	11.3	< 0.05	< 0.05	T.C.	
8/26/75	PAR-1	11.0	7.9	< 0.05	< 0.05	T.C.	
11/11/75	PAR-1	11.4	7.6	< 0.05	< 0.05	T.C.	
11/13/75	PAR-1	11.6	7.8	< 0.05	< 0.05	T.C.	
11/18/75	PAR-1	11.5	8.0	< 0.05	< 0.05	T.C.	
11/20/75	PAR-1	11.7	7.0	< 0.05	< 0.05	T.C.	
11/25/75	PAR-1	9.8	8.6	< 0.05	< 0.05	T.C.	
9/3/77	TRW-8	12.36	6.03	0.04	35 ppm	F.I.D. (HC)	C_2 - C_6 < 1 ppm
10/4/77	PAR-9	9.9	6.3	< 0.05	< 0.05	T.C.	
10/10/77	PAR-9	8.6	5.8	< 0.05	< 0.05	T.C.	
10/17/77	PAR-9	8.4	9.0	< 0.05	< 0.05	T.C.	
10/17/77	TRW-8	12.36	9.88	0.04	28 ppm	F.I.D. (HC)	C_2 - C_6 1-2 ppm
10/26/77	PAR-9	7.7	7.0	< 0.05	< 0.05		
11/77	BNW-7			0.18			Estimate, Potentiometric
11/77	BNW-7			0.14			Estimate, Potentiometric
11/77	PAR-9	12.8	7.6	< 0.05	< 0.05	T.C.	
11/77	PAR-9	9.0	6.9	< 0.05	< 0.05	T.C.	
11/77	PAR-9	8.9	8.0	< 0.05	< 0.05	T.C.	
11/77	PAR-9	14.3	1.5	< 0.05	< 0.05	T.C.	
11/77	PAR-9	13.6	10.2	< 0.05	< 0.05	T.C.	
12/77	PAR-9	12.0	4.5	< 0.05	< 0.05	T.C.	
12/77	PAR-9	9.7	1.8	< 0.05	< 0.05	T.C.	
2/78	PAR-9	11.1	7.9	< 0.05	< 0.05	T.C.	
2/78	PAR-9	14.0	6.3	< 0.05	< 0.05	T.C.	
4/78	PAR-9	14.0	6.9	< 0.05	< 0.05	T.C.	
4/78	PAR-9	9.7	7.8	< 0.05	< 0.05	T.C.	
5/78	PAR-9	9.3	10.0	< 0.05	< 0.05	T.C.	
5/78	PAR-9	12.3	5.2	< 0.05	< 0.05	T.C.	
5/78	PAR-9	13.6	7.1	< 0.05	< 0.05	T.C.	
6/78	PAR-9	13.3	7.1	< 0.05	< 0.05	T.C.	
6/78	PAR-9	13.6	5.4	< 0.05	< 0.05	T.C.	
6/78	PAR-9	10.0	9.8	< 0.05	< 0.05	T.C.	

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-15

Thermal Oxidizer, Sulfur and Nitrogen Gases

Analysis in PPM

Date	Lab-Ref	SO_2	Method	H_2S	Method	NO_x	Method	NH_3	Method	Comments
3/5/75	PAR-1	140	1							
3/6/75	PAR-1	20	1							
3/12/75	PAR-1	120	1							
3/12/75	PAR-1	80	1							
5/6/75	PAR-1	100	1			160	1			
5/6/75	PAR-1	140	1							
5/8/75	GULF-1	380				220				
5/9/75	PAR-1	180	1							
5/9/75	PAR-1	220	1							
5/14/75	GULF-1	150				220				
5/29/75	PAR-1	190	1							
7/2/75	PAR-1	260	1			170	1			
7/30/75	PAR-1	50	1			220	1			
8/5-6/75	LFE-2					106-160				
8/22/75	PAR-1	100	1			420	1			
8/26/75	PAR-1	170	1			300	1			
10/21/75	PAR-1	70	1			300	1			
11/5/75	PAR-1	30	1			360	1			
11/11/75	PAR-1	30	1			160	1			
11/13/75	PAR-1	130	1			230	1			
11/18/75	PAR-1	210	1			220	1			
11/20/75	PAR-1	100	1			280	1			
11/25/75	PAR-1	260	1			260	1			
11/25/75	PAR-1	190	1							
11/26/75	PAR-1	330	1							
12/13/75	PAR-1	1200	1							
10/4/77	PAR-9	15	1	< 10	2	320	1	< 5	1	
10/10/77	PAR-9	6	1	< 10	2	310	1	< 5	1	
10/17/77	PAR-9	119	1	< 10	2	50	1	< 5	1	
10/17/77	TRW-8	27	3			280	3			
10/21/77	TRW-8	5.1	3	24.9	3					SO_3 = 13.1 ppm
10/21/77	TRW-8	17.0	3							
10/26/77	PAR-9	71	1	< 10	2	150	1	< 5	1	
11/2/77	PAR-9	60	1	< 10	2	180	1	< 5	1	
11/12/77	PAR-9	22	1	< 10	2	202	1	< 5	1	
11/15/77	PAR-9	3	1	< 10	2	23	1	< 5	1	
11/15/77	BNW-7	276	4	< 0.4						Mercaptans < 0.4
11/15/77	BNW-7	256	4							
11/22/77	PAR-9	99	1	< 10	2	178	1	< 5	1	
12/6/77	PAR-9	40	1	< 10	2	140	1	< 5	1	
12/27/77	PAR-9	44	1	< 10	2	260	1	< 5	1	
4/4/78	PAR-9					127	3			NO = 88 ppm, NO_2 = 44 ppm
4/17/78	PAR-9	19	1	< 10	2	226	1	< 5	1	
4/21/78	PAR-9					230	3			NO = 134 ppm, NO_2 = 73 ppm
4/24/78	PAR-9			48	3	154	3			NO = 49 ppm, NO_2 = 106 ppm
4/25/78	PAR-9			41	3	194	3			NO = 104 ppm, NO_2 = 112 ppm
5/2/78	PAR-9	< 1	1	< 10	1	354	1	< 5	1	
5/10/78	PAR-9	< 1	1	< 10	1	317	1	< 5	1	
5/22/78	PAR-9	< 1	1	< 10	1	338	1	< 5	1	
5/1/78	PAR-9			53	3	493	3			NO = 263 ppm, NO_2 = 205 ppm
5/2/78	PAR-9			75	3	494	3			NO = 269 ppm, NO_2 = 193 ppm
5/3/78	PAR-9			60	3	317	3			NO = 198 ppm, NO_2 = 157 ppm
6/1/78	PAR-9	< 1	1	< 10	1	105	1	< 5	1	
6/5/78	PAR-9	< 1	1	< 10	1	261	1	< 5	1	
6/12/78	PAR-9	< 1	1	< 10	1	341	1	< 5	1	

1 = Colorimetry
2 = Titration
3 = Single Parameter Instrument
4 = Potentiometric

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-16

Retort and Oil Transfer, General Gas Analysis

Parameter	Date	Data	Location	Lab-Ref	Analytical Method
CO, ppm	7/19/77	ND	SW Top	LASL-6	Det. Tube
	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/19/77	100	Blower	LASL-6	Det. Tube
	7/19/77	> 50	Blower	LASL-6	Det. Tube
	7/19/77	10-20	Blower	LASL-6	Det. Tube
	7/20/77	15-25	Blower	LASL-6	Det. Tube
	7/20/77	70	Blower	LASL-6	Det. Tube
	7/20/77	3-5	SW Middle	LASL-6	Det. Tube
	7/20/77	10	SW Conveyors	LASL-6	Det. Tube
	7/20/77	> 200	T.O.	LASL-6	Det. Tube
	7/22/77	< 10	SW Top	LASL-6	Det. Tube
	7/22/77	150	Blower	LASL-6	Det. Tube
	12/5/77	5	SW Bottom	LASL-6	Det. Tube
	12/5/77	5	SW Top	LASL-6	Det. Tube
	12/6/77	700	Blower	LASL-6	Det. Tube
	12/6/77	500	Blower	LASL-6	Det. Tube
	4/6/78	< 500	SW Bottom	PAR-9	G.C. with T.C.
	5/19/78	< 500	Oil Tanks	PAR-9	G.C. with T.C.
	6/29/78	< 500	SW Bottom	PAR-9	G.C. with T.C.
CO_2, %	12/5/77	0.1	SW Top	LASL-6	Det. Tube
	12/6/77	0.5	Blower	LASL-6	Det. Tube
	1/15/78	< 0.02	SW Bottom	PAR-9	G.C. with T.C.
	1/16/78	0.03	SW Bottom	PAR-9	G.C. with T.C.
	3/8/78	0.02	Oil Tanks	PAR-9	G.C. with T.C.
	4/16/78	0.04	SW Bottom	PAR-9	G.C. with T.C.
	5/19/78	0.02	Oil Tanks	PAR-9	G.C. with T.C.
	6/29/78	0.03	SW Bottom	PAR-9	G.C. with T.C.
H_2S, ppm	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/19/77	10-20	Blower	LASL-6	Det. Tube
	7/20/77	ND	T.O.	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/22/77	< 5	SW Top	LASL-6	Det. Tube
	12/5/77	20	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	10	Blower	LASL-6	Det. Tube
	1/16/78	< 10	SW Bottom	PAR-9	Titration
	3/8/78	< 10	Oil Tanks	PAR-9	Titration
	5/19/78	< 10	Oil Tanks	PAR-9	Titration
NO, ppm	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	ND	Blower	LASL-6	Det. Tube
NO_2, ppm	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/19/77	ND	Blower	LASL-6	Det. Tube
	7/20/77	10-15	T.O.	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	< 0.4	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	ND	Blower	LASL-6	Det. Tube
NO_x, ppm	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	ND	Blower	LASL-6	Det. Tube
	1/15/78	< 5	SW Bottom	PAR-9	Colorimetry
	1/16/78	9	SW Bottom	PAR-9	Colorimetry
	3/8/78	< 5	Oil Tanks	PAR-9	Colorimetry
	4/6/78	< 5	SW Bottom	PAR-9	Colorimetry
	5/19/78	< 5	Oil Tanks	PAR-9	Colorimetry
	6/29/78	< 5	SW Bottom	PAR-9	Colorimetry
NH_3, ppm	7/19/77	ND	Blower	LASL-6	Det. Tube
	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	0.1 ppm	SW Bottom	LASL-6	Det. Tube
	12/6/77	> 30 ppm	Blower	LASL-6	Det. Tube
	12/6/77	40 ppm	Blower	LASL-6	Det. Tube
	1/16/78	< 5 ppm	SW Bottom	PAR-9	Colorimetry
	3/8/78	< 5 ppm	Oil Tanks	PAR-9	Colorimetry
	5/19/78	< 5 ppm	Oil Tanks	PAR-9	Colorimetry
	6/29/78	< 5 ppm	SW Bottom	PAR-9	Colorimetry
O_2, %	1/16/78	20.5	SW Bottom	PAR-9	G.C. with T.C.
	3/8/78	20.6	Oil Tanks	PAR-9	G.C. with T.C.
	4/6/78	21.6	SW Bottom	PAR-9	G.C. with T.C.
	5/19/78	20.6	Oil Tanks	PAR-9	G.C. with T.C.
	6/29/78	21.5	SW Bottom	PAR-9	G.C. with T.C.

TABLE 5-16 (Cont'd)

Parameter	Date	Data	Location	Lab-Ref	Analytical Method
SO_2, ppm	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/19/77	ND	Blower	LASL-6	Det. Tube
	7/20/77	> 35	T.O.	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	< 5	Blower	LASL-6	Det. Tube
	1/15/78	< 1	SW Bottom	PAR-9	Colorimetry
	1/16/78	< 1	SW Bottom	PAR-9	Colorimetry
	3/8/78	< 1	Oil Tanks	PAR-9	Colorimetry
	4/6/78	< 1	SW Bottom	PAR-9	Colorimetry
	5/19/78	< 1	Oil Tanks	PAR-9	Colorimetry
	6/29/78	< 1	SW Bottom	PAR-9	Colorimetry

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-17

Retort and Oil Transfer, Volatile Organics

Parameter	Date	Data	Location	Lab-Ref	Analytical Method
Benzene, ppm	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
CCl_4, ppm	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
Ethyl Ether, %	12/5/77	< 0.04	SW Top	LASL-6	Det. Tube
	12/5/77	< 0.04	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	0.5	SW Blower	LASL-6	Det. Tube
Gasoline, %	12/5/77	< 0.015	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	0.05	SW Blower	LASL-6	Det. Tube
HCHO, ppm	12/5/77	2	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	10-15	SW Blower	LASL-6	Det. Tube
Hexane, ppm	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	100	SW Blower	LASL-6	Det. Tube
	12/6/77	50-100	SW Blower	LASL-6	Det. Tube
HCN, ppm	7/19/77	ND	SW Top	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/19/77	5	SW Blower	LASL-6	Det. Tube
	12/5/77	8	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	15	SW Blower	LASL-6	Det. Tube
HNO_3, ppm	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/22/77	ND	SW Top	LASL-6	Det. Tube
	7/19/77	ND	SW Bottom	LASL-6	Det. Tube
	7/19/77	ND	SW Blower	LASL-6	Det. Tube
	7/21/77	ND	T.O.	LASL-6	Det. Tube
	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	ND	SW Blower	LASL-6	Det. Tube
Hydrocarbons, ppm	7/20/77	500	Blower	LASL-6	Det. Tube
	7/20/77	100	SW Bottom	LASL-6	Det. Tube
	7/20/77	< 25	T.O.	LASL-6	Det. Tube
	7/20/77	< 25	SW Top	LASL-6	Det. Tube
	7/20/77	50	SW Middle	LASL-6	Det. Tube
	7/20/77	100-400	SW Top	LASL-6	Det. Tube
	12/6/77	200-1000	General	LASL-6	Det. Tube
	12/6/77	100-400	SW Top	LASL-6	Det. Tube
	12/6/77	0.2	SW Bottom	LASL-6	Det. Tube
	12/6/77	0.2	SW Middle	LASL-6	Det. Tube
	12/6/77	4.0	SW Top	LASL-6	Det. Tube
	12/6/77	0.6	T.O.	LASL-6	Det. Tube
	12/6/77	170	SW Blower	LASL-6	Det. Tube
	12/6/77	80	SW Blower	LASL-6	Det. Tube
	12/6/77	0.7	SW Bottom	LASL-6	Det. Tube
	12/6/77	9	SW Bottom	LASL-6	Det. Tube
	12/6/77	ND	T.O.	LASL-6	Det. Tube
	12/6/77	3	SW Bottom	LASL-6	Det. Tube
	12/6/77	3	SW Middle	LASL-6	Det. Tube
	12/6/77	4.5	SW Top	LASL-6	Det. Tube
	12/6/77	10-30	SW Top	LASL-6	Det. Tube
	1/15/78	< 5	SW Bottom	PAR-9	Det. Tube
	5/19/78	< 5	SW Bottom	PAR-9	Det. Tube
Mercaptans, ppm	1/17/78	< 1	Oil Tank	PAR-9	Colorimetry
	4/6/78	< 1	Area	PAR-9	Colorimetry
	5/19/78	< 1	Oil Tank	PAR-9	Colorimetry
Methane, %	3/8/78	< 0.05	Oil Tanks	PAR-9	G.C. with T.C.
	5/19/78	< 0.05	Oil Tanks	PAR-9	G.C. with T.C.
	6/29/78	< 0.05	SW Bottom	PAR-9	G.C. with T.C.
Phenols, ppm	1/17/78	< 3	Oil Tank	PAR-9	Colorimetry
	4/6/78	< 3	Area	PAR-9	Colorimetry
	5/19/78	< 3	Oil Tank	PAR-9	Colorimetry

TABLE 5-17 (Cont'd)

Parameter	Date	Data	Location	Lab-Ref	Analytical Method
Styrene, ppm	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Top	LASL-6	Det. Tube
	12/6/77	5	SW Blower	LASL-6	Det. Tube
Toluene, ppm	12/5/77	< 0.5	SW Top	LASL-6	Det. Tube
	12/5/77	ND	SW Bottom	LASL-6	Det. Tube
	12/6/77	ND	SW Blower	LASL-6	Det. Tube
Xylene, ppm	12/5/77	ND	SW Bottom	LASL-6	Det. Tube

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-18

Product Gas, Toxic Elemental Analysis

Parameter	Date	Data	Lab-Ref	Methods: Sampling	Methods: Analyses	Comments
As	11/16/77	155 ug/m^3	BNW-7	Impingers Ag	PES	As_2O_3 = 149 ug/m^3 Organic As < 12 ug/m^3 AsH_3 = 1.8 ug/m^3 Methyl Arsine = 2.8 ug/m^3 Di-methyl Arsine = 1.0 ug/m^3 Other Organic Arsine = 0.5 ug/m^3
	11/17/77	120 ug/m^3	BNW-7	Impingers Ag	PES	As_2O_3 = 112 ug/m^3 Organic As = < 12 ug/m^3 AsH_3 = 2 ug/m^3 Methyl Arsine = 3 ug/m^3 Di-methyl Arsine = 1.7 ug/m^3 Other Organic Arsine = 0.5 ug/m^3 Particulate As = 1.2 ug/m^3
	7/27/78	< 4 ug/m^3	PAR-9	Impingers	AA	
AsH_3	3/10/76	ND	TRW-4	Selective Absorption		
	3/11/76	ND	TRW-4	Selective Absorption		
	10/14/77	0.17 ug/m^3	TRW-8	Impingers	GC/MS	
	10/14/77	0.25 ug/m^3	TRW-8	Impingers	GC/MS	
	10/14/77	0.35 ug/m^3	TRW-8	Impingers	GC/MS	
	10/14/77	0.46 ug/m^3	TRW-8	Impingers	GC/MS	
B	8/24/77	< 30 ug/m^3	BNW-7		PES	
Cu	8/23/77	< 30 ug/m^3	BNW-7		XRF	
	8/24/77	< 5 ug/m^3	BNW-7		XRF	
	8/25/77	< 40 ug/m^3	BNW-7		XRF	
	8/26/77	< 40 ug/m^3	BNW-7		XRF	
	11/15/77	< 40 ug/m^3	BNW-7		XRF	
	11/15/77	< 40 ug/m^3	BNW-7		XRF	
	11/16/77	< 100 ug/m^3	BNW-7		XRF	
	11/17/77	< 30 ug/m^3	BNW-7		XRF	
Hg	8/24/77	< 20 ug/m^3	BNW-7	Impingers	AA	
	10/15/77	0.304 ug/m^3	TRW-8	Selective Absorption	AA	
	10/15/77	0.113 ug/m^3	TRW-8	Selective Absorption	AA	
	10/15/77	0.155 ug/m^3	TRW-8	Selective Absorption	AA	
	10/15/77	0.235 ug/m^3	TRW-8	Selective Absorption	AA	
	10/15/77	1.298 ug/m^3	TRW-8	Selective Absorption	AA	
	11/15/77	45 ± 5 ug/m^3	BNW-7	Gold Amalgamation	AA	Flameless
	11/16/77	75 ± 15 ug/m^3	BNW-7	Gold Amalgamation	AA	Flameless
	7/28/78	< 30 ug/m^3	PAR-9	Impingers	AA	
Pb	8/23/77	< 100 ug/m^3	BNW-7		XRF	
	8/24/77	< 70 ug/m^3	BNW-7		XRF	
	8/25/77	< 200 ug/m^3	BNW-7		XRF	
	8/26/77	< 200 ug/m^3	BNW-7		XRF	
	11/15/77	< 100 ug/m^3	BNW-7		XRF	
	11/16/77	< 300 ug/m^3	BNW-7		XRF	
	11/17/77	< 100 ug/m^3	BNW-7		XRF	
	7/28/78	< 4 ug/m^3	PAR-9	Impingers	AA	
Se	7/28/78	< 2 ug/m^3	PAR-9	Impingers	AA	
Zn	8/23/77	< 300 ug/m^3	BNW-7		INAA	
	8/23/77	< 200 ug/m^3	BNW-7		XRF	
	8/24/77	< 5 ug/m^3	BNW-7		XRF	
	8/25/77	< 200 ug/m^3	BNW-7		INAA	
	8/25/77	< 100 ug/m^3	BNW-7		XRF	
	8/26/77	< 100 ug/m^3	BNW-7		INAA	
	8/26/77	< 200 ug/m^3	BNW-7		XRF	
	11/15/77	< 20 ug/m^3	BNW-7		XRF	
	11/17/77	< 30 ug/m^3	BNW-7		XRF	

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-19

Product Gas, General Elemental Analysis

Element	Date	Data (μg/m³)	Analytical Method
Ba	8/23/77	< 3000	INAA
	8/24/77	< 3000	INAA
	8/25/77	< 4000	INAA
	8/26/77	< 4000	INAA
	11/15/77	< 900	INAA
	11/16/77	< 700	INAA
	11/17/77	< 800	INAA
Ca	8/24/77	< 400	XRF
Co	8/23/77	< 7	INAA
	8/23/77	< 60	XRF
	8/24/77	< 30	INAA
	8/24/77	< 10	XRF
	8/25/77	< 10	INAA
	8/25/77	< 50	XRF
	8/26/77	< 10	INAA
	11/15/77	< 5	INAA
	11/16/77	< 2	INAA
	11/17/77	< 3	INAA
	11/17/77	< 60	XRF
Cr	8/23/77	< 7	INAA
	8/23/77	< 100	XRF
	8/24/77	< 7	INAA
	8/24/77	< 30	XRF
	8/25/77	< 10	INAA
	8/25/77	< 20	XRF
	8/26/77	< 10	INAA
	11/15/77	< 50	INAA
	11/16/77	< 20	INAA
	11/17/77	< 60	INAA
	11/17/77	< 100	XRF
Fe	8/23/77	< 100	XRF
	8/24/77	< 20	XRF
	8/25/77	< 500	XRF
	8/26/77	< 6000	INAA
	11/15/77	< 4000	INAA
	11/16/77	< 2000	INAA
Ga	8/23/77	< 30	XRF
	8/24/77	< 5	XRF
	8/25/77	< 2000	XRF
	8/26/77	< 40	XRF
	11/15/77	< 20	XRF
	11/16/77	< 80	XRF
	11/17/77	< 20	XRF
K	8/23/77	< 2000	XRF
	8/24/77	< 500	XRF
	8/25/77	< 2000	XRF
	8/26/77	< 3000	XRF
	11/15/77	< 2000	INAA
	11/17/77	< 800	INAA
	11/17/77	< 500	XRF
La	8/23/77	< 5	INAA
	8/24/77	< 5	INAA
	8/25/77	< 7	INAA
	8/26/77	< 7	INAA
	11/15/77	< 6	INAA
	11/16/77	< 0.4	INAA
	11/17/77	< 3	INAA
Mg	8/24/77	< 90	PES
Mn	8/23/77	< 100	XRF
	8/24/77	< 20	XRF
	8/25/77	< 50	XRF
	8/26/77	< 100	XRF
	11/15/77	< 100	XRF
	11/17/77	< 100	XRF
Na	11/15/77	< 1000	INAA
	11/16/77	< 60	INAA

TABLE 5-19 (Cont'd)

Element	Date	Data (μg/m³)	Analytical Method
Ni	8/23/77	< 60	XRF
	8/24/77	< 5	XRF
	8/25/77	< 50	XRF
	11/15/77	< 1	XRF
	11/16/77	< 200	XRF
	11/17/77	< 100	XRF
Rb	8/23/77	< 200	INAA
	8/23/77	< 50	XRF
	8/24/77	< 10	XRF
	8/25/77	< 200	INAA
	8/25/77	< 80	XRF
	8/26/77	< 200	INAA
	8/26/77	< 100	XRF
	11/15/77	< 100	INAA
	11/15/77	< 40	XRF
	11/16/77	< 10	INAA
	11/17/77	< 100	INAA
	11/17/77	< 40	XRF
Sb	8/23/77	< 20	INAA
	8/24/77	< 20	INAA
	8/25/77	< 20	INAA
	8/26/77	< 20	INAA
	11/15/77	< 9	INAA
	11/16/77	< 5	INAA
	11/17/77	< 3	INAA
Sc	8/23/77	< 1	INAA
	8/24/77	< 0.7	INAA
	8/25/77	< 1	INAA
	8/26/77	< 1	INAA
	11/15/77	< 0.3	INAA
	11/16/77	< 0.2	INAA
	11/17/77	< 0.3	INAA
Si	8/24/77	< 600	PES
Sm	8/26/77	< 800	XRF
Sr	8/23/77	< 600	XRF
	8/24/77	< 600	XRF
	8/25/77	< 400	XRF
	11/15/77	< 200	XRF
	11/16/77	< 800	XRF
	11/17/77	< 300	XRF
Th	8/23/77	< 200	INAA
	8/24/77	< 200	INAA
	8/25/77	< 200	INAA
	8/26/77	< 200	INAA
	11/15/77	< 3	INAA
	11/16/77	< 2	INAA
	11/17/77	< 2	INAA
U	8/23/77	< 40	INAA
	8/24/77	< 40	INAA
	8/25/77	< 50	INAA
	8/26/77	< 50	INAA
	11/15/77	< 20	INAA
	11/16/77	< 2	INAA
	11/17/77	< 2	INAA
V	8/23/77	< 300	XRF
	8/24/77	< 40	XRF
	8/25/77	< 400	XRF
	8/26/77	< 400	XRF
	11/15/77	< 100	XRF
	11/17/77	< 100	XRF
Y	11/16/77	< 100	XRF
Zr	11/16/77	< 200	XRF

Lab-Ref: BNW-7
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-20

Thermal Oxidizer Gases, Toxic Elements

Parameter	Date	Data	Analytical Methods	Comments
As, $\mu g/m^3$	11/16/77	12.3	PES	As_2O_3 12 Organic As ND AsH_3 0.3 Methyl Arsine ND Di-methyl Arsine ND Other Organic Arsine ND
	11/17/77	55	PES	As_2O_3 36 Organic As ND AsH_3 ND Methyl Arsine ND Di-methyl Arsine ND Other Organic Arsine ND Particulate As 19
Cu, $\mu g/m^3$	8/24/77	< 20	XRF	
	8/25/77	< 20	XRF	
	11/17/77	< 20	XRF	
F, $\mu g/m^3$	11/16/77	< 10	XRF	
Hg, $\mu g/m^3$	8/24/77	9	AA Flameless	
	8/25/77	6.7	AA "	
	8/26/77	4.5	AA "	$HgCl_2$ ND CH_3HgCl ND $(CH_3)_2$ Hg ND
	11/15/77	7.2	AA "	
	11/16/77	12	AA "	
	11/16/77	9.4	AA "	$HgCl_2$ < 0.1 CH_3HgCl <0.4 $(CH_3)_2$ Hg < 0.4
Pb, $\mu g/m^3$	8/24/77	< 50	XRF	
	8/25/77	< 50	XRF	
	8/26/77	< 50	XRF	
	11/16/77	< 50	XRF	
	11/17/77	< 50	XRF	
Zn, $\mu g/m^3$	8/24/77	< 100	INAA	
	8/24/77	< 100	XRF	
	8/25/77	< 100	INAA	
	8/25/77	< 50	XRF	
	8/26/77	< 100	INAA	
	8/26/77	< 60	XRF	
	11/16/77	< 10	XRF	
	11/16/77	< 30	XRF	

Lab-Ref: BNW-7
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-21

Thermal Oxidizer Gas, General Elemental Analyses

Parameter	Date	Data (μg/m³)	Analytical Method
Ba	8/24/77	< 1000	INAA
	8/25/77	< 1000	INAA
	8/26/77	< 2000	INAA
	11/15/77	< 800	INAA
	11/16/77	< 800	INAA
	11/17/77	< 1000	INAA
Ca	8/25/77	< 2000	XRF
	8/26/77	< 20	XRF
Co	8/24/77	< 3	INAA
	8/24/77	< 30	XRF
	8/25/77	< 3	INAA
	8/26/77	< 7	INAA
	11/15/77	< 3	INAA
	11/16/77	< 4	INAA
	11/16/77	< 40	XRF
	11/17/77	< 3	INAA
Cr	8/24/77	< 3	INAA
	8/24/77	< 50	XRF
	8/25/77	< 3	INAA
	8/26/77	< 7	INAA
	8/26/77	< 40	XRF
	11/15/77	< 30	INAA
	11/16/77	< 100	INAA
	11/16/77	< 40	XRF
	11/17/77	< 100	INAA
	11/17/77	< 100	XRF
Fe	8/24/77	< 2000	INAA
	8/25/77	< 30	XRF
	8/26/77	< 20	XRF
	11/15/77	< 2000	INAA
	11/16/77	< 20	XRF
	11/17/77	< 500	XRF
Ga	8/24/77	< 10	XRF
	8/25/77	< 10	XRF
	8/26/77	< 6	XRF
	11/17/77	< 20	XRF
K	8/24/77	< 2000	XRF
	8/25/77	< 2000	XRF
	8/26/77	< 600	XRF
	11/15/77	< 600	XRF
	11/16/77	< 1000	XRF
	11/17/77	< 100	XRF
La	8/24/77	< 2	INAA
	8/25/77	< 2	INAA
	8/26/77	< 5	INAA
	11/15/77	< 0.5	INAA
	11/16/77	< 1	INAA
	11/17/77	< 2	INAA
Mn	8/24/77	< 50	XRF
	8/25/77	< 30	XRF
	8/26/77	< 20	XRF
	11/16/77	< 100	XRF
Na	11/15/77	< 200	INAA
Ni	8/24/77	< 20	XRF
	8/25/77	< 20	XRF
	8/26/77	< 20	XRF
	11/16/77	< 60	XRF
	11/17/77	< 70	XRF
Rb	8/24/77	< 60	INAA
	8/24/77	< 20	XRF
	8/25/77	< 60	INAA
	8/25/77	< 20	XRF
	8/26/77	< 20	XRF
	11/15/77	< 60	INAA
	11/16/77	< 60	INAA
	11/16/77	< 30	XRF
	11/17/77	< 100	INAA
	11/17/77	< 20	XRF

TABLE 5-21 (Cont'd)

Parameter	Date	Data (μg/m³)	Analytical Method
Sb	8/24/77	< 6	INAA
	8/25/77	< 6	INAA
	8/26/77	< 10	INAA
	11/15/77	< 7	INAA
	11/16/77	< 6	INAA
	11/17/77	< 4	INAA
Sc	8/24/77	< 0.3	INAA
	8/25/77	< 0.3	INAA
	8/26/77	< 0.7	INAA
	11/15/77	< 0.2	INAA
	11/16/77	< 0.2	INAA
	11/17/77	< 0.5	INAA
Sr	8/24/77	< 200	XRF
	8/25/77	< 200	XRF
	8/26/77	< 60	XRF
	11/16/77	< 200	XRF
	11/17/77	< 200	XRF
Th	8/24/77	< 60	INAA
	8/25/77	< 60	INAA
	8/26/77	< 100	INAA
	11/15/77	< 2	INAA
	11/16/77	< 2	INAA
	11/17/77	< 2	INAA
Ti	8/24/77	< 200	XRF
	8/26/77	< 60	XRF
U	8/24/77	< 20	INAA
	8/25/77	< 20	INAA
	8/26/77	< 40	INAA
	11/15/77	< 2	INAA
	11/16/77	< 3	INAA
	11/17/77	< 3	INAA
V	8/24/77	< 100	XRF
	8/25/77	< 100	XRF
	11/16/77	< 100	XRF
	11/17/77	< 70	XRF
Y	8/26/77	< 50	XRF

Lab-Ref: BNW-7
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 5-22

Retort and Oil Transfer, Toxic Metals

Element	Date	Location	Data, $\mu g/m^3$	Analytical Method
Arsenic	12/20/77	Retort Area	< 8	AA
	1/15/78	Retort Area	< 0.1 ppm	Det. Tube (Arsine)
	1/15/78	SW Bottom	< 8	AA
	1/17/78	Oil Tank	< 8	AA
	4/6/78	Retort Area	< 8	AA
	5/19/78	Oil Tank	< 8	AA
Lead	12/30/77	Retort Area	< 4	AA
	1/15/78	SW Bottom	< 4	AA
	1/17/78	Oil Tank	< 4	AA
	4/6/78	Retort Area	< 4	AA
	5/19/78	Oil Tank	< 4	AA
Mercury	12/30/77	Retort Area	< 30	AA
	1/15/78	SW Bottom	< 30	AA
	1/17/78	Oil Tank	< 30	AA
	4/6/78	Retort Area	< 30	AA
	5/19/78	Oil Tank	< 30	AA
Selenium	12/30/77	Retort Area	< 2	AA
	1/15/78	SW Bottom	< 2	AA
	1/17/78	Oil Tank	< 2	AA
	4/6/78	Retort Area	< 2	AA
	5/19/78	Oil Tank	< 2	AA

Lab-Ref: PAR-9
Sampling Method: Sequential Sampler for AA Analysis.

6.0 SHALE DISPOSAL

6.1 General

Retorted shale disposal from the Paraho retorts utilized covered conveyors in the retort area (see Fig. 5.1). Samples of this stream are taken mechanically for process control and research studies. Two conveyors are used to transport the retorted shale from the retort area to the shale disposal area. An open (uncovered) conveyor system was used for the bulk of the retorted shale disposal. A water spray (fog) system was used for dust suppression. Dust from the bag-house and excess, ground, retorted shale samples were transported through the screw conveyor. Shale from these systems was placed in the disposal area using mobile equipment (front-end loader for the screw conveyor and a movable stacker loader for the open conveyor).

In this section, there are 13 tables of data describing the particulate and gaseous emissions from the shale disposal area. Since the principal problem associated with retorted shale disposal is dusting or particulate emissions, most of this section (11 tables) deal with particulates -- TSP, respirable dusts, size distribution, and chemical analyses. Two tables are used to describe the gaseous emissions.

6.2 Shale Disposal Particulates - Amount and Size Distribution

TSP data for shale disposal particulates are given in Table 6-1. The data are quite variable. The data show that the mean fugitive TSP level is 12.3 $\pm$ 11.5 mg/m^3. The highest TSP value used in calculating this mean was 48.06 mg/m^3. Two data, 72.13 and 70.89 mg/m^3, obtained 9/27/77, are considered outliers and have not been included in the mean. Included in Table 6-1 are 12 background TSP values. The mean $\pm$ 1.0 S.D. for background TSP is 1.3 $\pm$ 1.6 mg/m^3.

Again, those samples obtained concurrently show that the variation in the TSP values is caused by the sample and not the analytical error. The mean difference between six pair of samples is 0.16 mg/m^3; the difference between the individual high and low values from those samples is 35-53 mg/m^3.

Five samples for respirable dust in the shale disposal area are presented in Table 6-2. The mean respirable dust ($\pm$ 1.0 S.D.) is 4.5 $\pm$ 2.0 mg/m^3.

Size distribution data for the retorted shale disposal is presented in Table 6-3 and Figure 6.1. Several of the samples having Mmad values < 0.5 μ (1 having an Mmad > 10 μ) were not plotted in Figure 6.1. The sample obtained 12/5/77 differs from the others plotted in Figure 6.1; this sample has an Mmad of 6.0 μ and a σ g of 3.5. Most of the other samples have values greater than 10.

6.3 Chemical Characterization of Shale Disposal Particulates

Heavy hydrocarbons (C_{10} - C_{36}) were determined on retorted shale particulates obtained from the conveyors, baghouse, and airborne from the shale disposal area. Data are presented in Table 6-4. Although differences of individual compounds are seen between these samples, the totals are fairly constant (37.7 $\pm$ 14.5 ug/g), or 0.0037 wt%. This agrees with the low values found for benzene extractables.

The proximate analyses of shale disposal particulates are compared with typical retorted shale in Table 6-5. The agreement shows that these particulates are essentially retorted shale.

Trace toxic metal concentrations in shale disposal particulates are presented in Table 6-6. The only apparent outlier is the 14.9 ppm As level found 9/77. The other data show a mean $\pm$ 1.0 S.D. of 186 $\pm$ 79. This mean As level is unusual; the mean As level in raw shale particulates (see Section 2.2) is only 45 ppm. The other trace elements in Table 6-6 (except Hg) show the normal 20% increase over the typical raw shale concentrations. Mercury is not completely retained on the retorted shale. The trace toxic metals concentrations are not dramatically affected by particle size. Data in Table 6-7 show that concentrations remain essentially constant in various size distribution fractions. Some increase in concentration of all but Se is indicated in the smaller size fractions.

Data from general elemental analyses are presented in Table 6-8. Most of the results appear valid. Only the 160 ppm Ce and the 2000 ppm Mn can be classified as statistical outliers. However, many of the data in Table 6-8 are questionable when compared with the compiled raw shale data presented in Section 2.2. For example, the iron in raw shale particulates is 2.1 $\pm$ 0.2 wt% and in the retorted shale particulates is 1.6 $\pm$ 0.1 wt%; nickel in the raw shale is 23 $\pm$ 10 ppm and in four samples of the retorted shale is 188 $\pm$ 48 ppm; antimony in raw shale is 4 $\pm$ 2 ppm, in retorted shale 26 $\pm$ 29 ppm. Since the error can lie in the raw shale data, the cause of the difference is uncertain. Most of the retorted particulate data presented in Table 6-8 do fall within 1.0 to 1.3 times the raw shale particulate data summarized in Section 2.2.

In Tables 6-9 and 6-10, elemental concentrations in retorted shale particulates are presented as a function of particle size fractions. No significant concentration of any of the elements is seen in any of the size fractions.

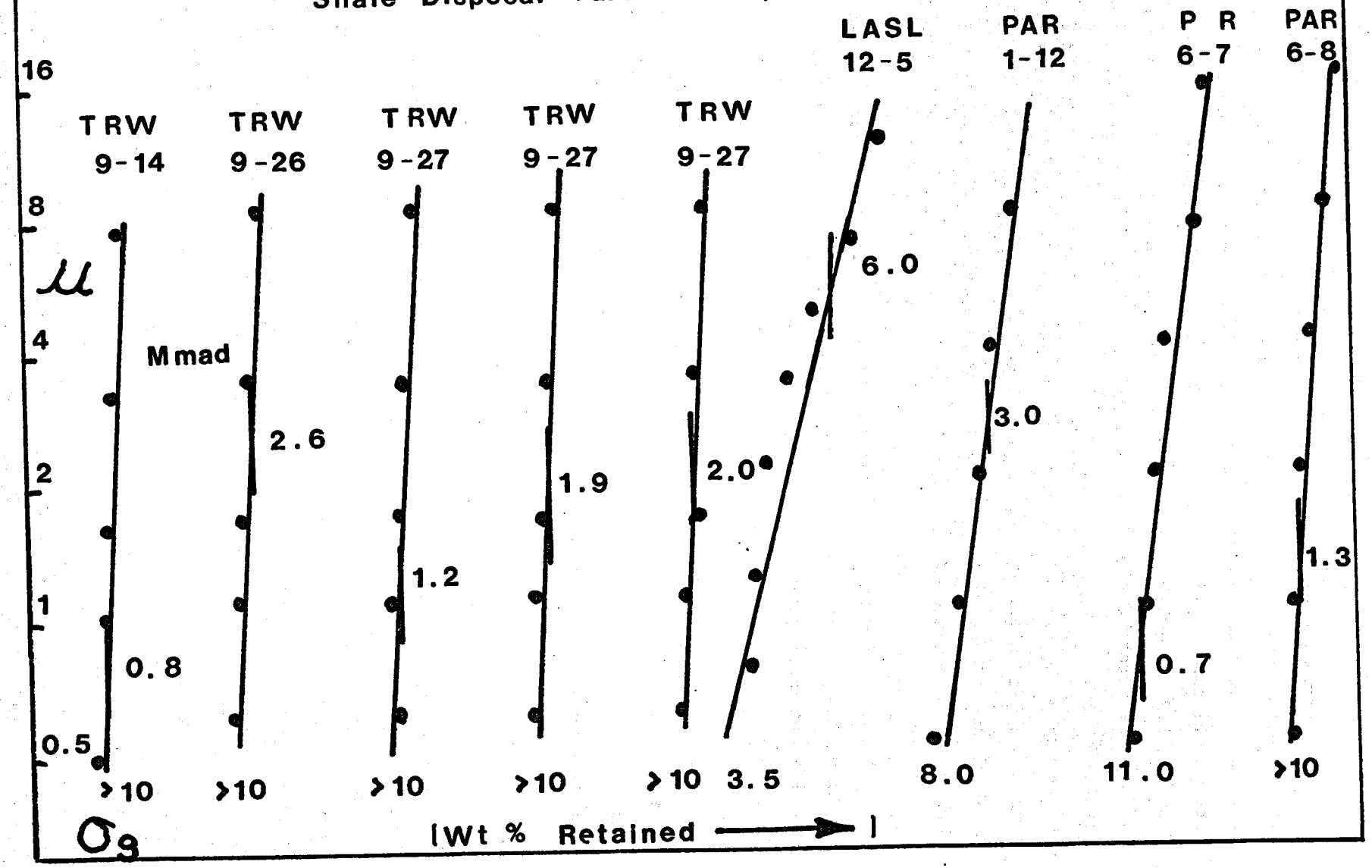
Major mineral components in the retorted shale particulates are presented in Table 6-11. Concentrations are presented as weight percent of the total inorganics. Both the quartz and calcite contents (30 wt% and 25 wt%) are higher than those in retorted shale (9 wt% and 14 wt%).

6.4 Shale Disposal Gases

Analyses of the gases in the shale disposal area are presented in Tables 6-12 and 6-13. For the most part, the data indicate that these samples are essentially pure air. In Table 6-12, oxygen is 21.6 vol%, carbon dioxide is about 100 ppm, carbon monoxide is $\leq$ 10 ppm. No methane or other hydrocarbons, cyanide, phenol, or sulfur and nitrogen compounds were detected. In Table 6-13, no volatile metals (As, Hg, Se, Pb) were detected.

Figure 6.1

Shale Disposal Particulates, Size Distribution



AIR QUALITY

PARAHO OPERATIONS

TABLE 6-1

Shale Disposal, Total Suspended Solids

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method
9/3/77	23.2	TRW-10	General	Fugitive	4.52	Hi-Vol
9/1/77	10.93	TRW-10	General	Fugitive	10.13	Hi-Vol
9/4/77	3.82	TRW-10	General	Fugitive	0.29	Hi-Vol
9/4/77	8.61	TRW-10	General	Fugitive	0.63	Hi-Vol
9/4/77	0.72	TRW-10	General	Ambient	0.17	Hi-Vol
9/5/77	7.35	TRW-10	General	Fugitive	0.52	Hi-Vol
9/5/77	9.58	TRW-10	General	Fugitive	11.90	Hi-Vol
9/5/77	7.04	TRW-10	General	Fugitive	0.33	Hi-Vol
9/5/77	6.85	TRW-10	General	Fugitive	0.48	Hi-Vol
9/5/77	5.16	TRW-10	General	Fugitive	0.26	Hi-Vol
9/5/77	0.49	TRW-10	General	Ambient	0.12	Hi-Vol
9/6/77	8.65	TRW-10	General	Fugitive	0.64	Hi-Vol
9/6/77	12.27	TRW-10	General	Fugitive	1.36	Hi-Vol
9/6/77	2.54	TRW-10	General	Fugitive	0.42	Hi-Vol
9/6/77	6.23	TRW-10	General	Fugitive	0.24	Hi-Vol
9/6/77	7.05	TRW-10	General	Fugitive	17.48	Hi-Vol
9/6/77	1.05	TRW-10	General	Ambient	0.21	Hi-Vol
9/6/77	0.71	TRW-10	General	Ambient	0.13	Hi-Vol
9/6/77	0.92	TRW-10	General	Ambient	0.15	Hi-Vol
9/8/77	2.70	TRW-10	General	Fugitive	0.33	Hi-Vol
9/8/77	2.17	TRW-10	General	Fugitive	0.19	Hi-Vol
9/8/77	7.42	TRW-10	General	Fugitive	0.58	Hi-Vol
9/8/77	5.62	TRW-10	General	Fugitive	0.36	Hi-Vol
9/8/77	6.50	TRW-10	General	Fugitive	0.75	Hi-Vol
9/8/77	5.93	TRW-10	General	Fugitive	0.69	Hi-Vol
9/8/77	5.05	TRW-10	General	Fugitive	12.29	Hi-Vol
9/8/77	0.94	TRW-10	General	Ambient	0.18	Hi-Vol
9/8/77	0.64	TRW-10	General	Ambient	0.11	Hi-Vol
9/8/77	0.81	TRW-10	General	Ambient	0.20	Hi-Vol
9/8/77	0.96	TRW-10	General	Ambient	0.16	Hi-Vol
9/14/77	29.13	TRW-10	General	Fugitive	0.37	Cas. Impac.
9/14/77	23.16	TRW-10	General	Fugitive	0.57	Cas. Impac.
9/14/77	17.08	TRW-10	General	Fugitive	1.02	Cas. Impac.
9/26/77	39.81	TRW-10	General	Fugitive	1.33	Cas. Impac.
9/26/77	16.3	TRW-10	General	Fugitive	0.54	Hi-Vol
9/26/77	2.72	TRW-10	General	Fugitive	0.09	Hi-Vol
9/26/77	12.60	TRW-10	General	Fugitive	0.55	Hi-Vol
9/26/77	1.68	TRW-10	General	Fugitive	0.06	Hi-Vol
9/26/77	2.0	TRW-10	General	Ambient	0.10	Hi-Vol
9/26/77	0.54	TRW-10	General	Ambient	0.04	Cas. Impac.
9/27/77	72.13	TRW-10	General	Fugitive	1.05	Cas. Impac.
9/27/77	43.60	TRW-10	General	Fugitive	0.60	Cas. Impac.
9/27/77	48.06	TRW-10	General	Fugitive	0.84	Cas. Impac.
9/27/77	37.93	TRW-10	General	Fugitive	0.63	Cas. Impac.
9/27/77	70.89	TRW-10	General	Fugitive	0.94	Cas. Impac.
9/27/77	25.88	TRW-10	General	Fugitive	0.35	Hi-Vol
9/27/77	11.71	TRW-10	General	Fugitive	0.52	Hi-Vol
9/27/77	29.32	TRW-10	General	Fugitive	1.32	Hi-Vol
9/27/77	18.53	TRW-10	General	Fugitive	0.66	Hi-Vol
9/27/77	11.09	TRW-10	General	Fugitive	0.41	Hi-Vol
9/27/77	6.10	TRW-10	General	Ambient	0.13	Hi-Vol
12/5/77	13.11	LASL-6	General	Fugitive	0.011	And. Impac.
12/5/77	5.35	LASL-6	General	Fugitive	0.00034	Pers. Sampler
12/5/77	12.06	LASL-6	General	Fugitive	0.0102	And. Impac.
12/5/77	18.63	LASL-6	General	Fugitive	0.00098	Pers. Sampler
12/6/77	7.6	LASL-6	General	Fugitive		Pers. Sampler
12/6/77	8.9	LASL-6	General	Fugitive		Pers. Sampler
12/6/77	6.0	LASL-6	General	Fugitive		Pers. Sampler
12/6/77	2.2	LASL-6	General	Fugitive		Pers. Sampler
1/8/78	1.42	PAR-9	Screw Conveyor	Fugitive	0.07	Hi-Vol
1/8/78	0.86	PAR-9	Screw Conveyor	Fugitive	0.04	Hi-Vol
1/8/78	0.75*	PAR-9	Screw Conveyor	Fugitive	0.04	Hi-Vol
1/8/78	0.83*	PAR-9	Screw Conveyor	Fugitive	0.0005	Cas. Impac.
1/8/78	1.91	PAR-9	Screw Conveyor	Fugitive	0.10	Hi-Vol
1/12/78	3.12	PAR-9	Conveyor	Fugitive	0.15	Hi-Vol
1/12/78	3.69*	PAR-9	Conveyor	Fugitive	0.16	Hi-Vol
1/12/78	3.85*	PAR-9	Conveyor	Fugitive	0.0019	Cas. Impac.
1/12/78	3.95	PAR-9	Conveyor	Fugitive	0.18	Hi-Vol

* Sampled Concurrently

TABLE 6-1 (Cont'd)

Date	Data mg/m^3	Lab-Ref	Location	Sample Type	Quantity, g	Sampling Method
1/22/78	4.70	PAR-9	Middle	Fugitive	0.25	Hi-Vol
1/22/78	4.18	PAR-9	Middle	Fugitive	0.21	Hi-Vol
1/22/78	2.74*	PAR-9	Middle	Fugitive	0.13	Hi-Vol
1/22/78	2.85*	PAR-9	Middle	Fugitive	0.0014	Cas. Impac.
6/7/78	14.36	PAR-9	Middle	Fugitive	1.04	Hi-Vol
6/7/78	13.76*	PAR-9	Middle	Fugitive	0.89	Hi-Vol
6/7/78	13.83*	PAR-9	Middle	Fugitive	0.0073	Cas. Impac.
6/7/78	4.24	PAR-9	Middle	Fugitive	0.29	Hi-Vol
6/7/78	18.33	PAR-9	South	Fugitive	1.26	Hi-Vol
6/7/78	15.82*	PAR-9	South	Fugitive	1.27	Hi-Vol
6/7/78	15.90*	PAR-9	South	Fugitive	0.0108	Cas. Impac.
6/7/78	4.37	PAR-9	South	Fugitive	0.31	Hi-Vol
6/8/78	35.48	PAR-9	North	Fugitive	2.03	Hi-Vol
6/8/78	36.28*	PAR-9	North	Fugitive	1.72	Hi-Vol
6/8/78	35.54*	PAR-9	North	Fugitive	0.0153	Cas. Impac.
6/8/78	20.51	PAR-9	North	Fugitive	1.92	Hi-Vol

* Sampled Concurrently

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-2

Shale Disposal, Respirable Dust

Date	Data, mg/m^3	Quantity, g	Sampling Method
12/5/77	5.15	0.00022	Personal Sampler
12/5/77	7.02	0.00028	Personal Sampler
12/6/77	4.5		Personal Sampler
12/6/77	1.6		Personal Sampler
12/6/77	4.0		Personal Sampler

Lab-Ref: LASL-6
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-3

Retorted Shale Disposal, Particle Size

Lab-Ref	Date		Analysis							Location	Sampling Method	Mmad	σ_g
		µ1	7.6	3.2	1.6	1.0	0.5						
TRW-10	9/14/77	%	62.4	55.8	53.4	50.6	48.2			Shale Disposal	Cas. Impac.	0.8	> 10
		µ1	8.3	3.5	1.7	1.1	0.6						
TRW-10	9/14/77	%	72.1	67.6	65.2	61.3	57.8			Shale Disposal	Cas. Impac.	< 0.5	
	9/14/77		97.4	83.6	80.2	75.8	72.2			Shale Disposal	Cas. Impac.	< 0.5	
	9/26/77		57.6	49.2	45.9	42.9	40.9			Shale Disposal	Cas. Impac.	2.6	> 10
	9/27/77		62.2	55.5	52.3	49.1	46.7			Shale Disposal	Cas. Impac.	1.2	> 10
	9/27/77		58.2	52.0	48.8	45.1	42.7			Shale Disposal	Cas. Impac.	1.9	> 10
		µ1	8.9	3.7	1.9	1.2	0.6						
TRW-10	9/27/77	%	34.8	27.0	23.0	18.3	14.9			Shale Disposal	Cas. Impac.	> 10	
	9/27/77		62.6	57.9	55.3	52.3	50.1			Shale Disposal	Cas. Impac.	0.5	> 10
	9/27/77		59.1	51.9	49.6	46.6	43.1			Shale Disposal	Cas. Impac.	2.0	> 10
		µ1	12	7	4.8	3.4	2.2	1.2	0.66				
LASL-6	12/5/77	%	74.6	58.1	37.7	21.9	8.6	1.6	0.48	Shale Disposal	And. Impac.	6.0	3.5
		µ1	16	8	4	2	1	0.5					
PAR-9	1/12/78	%	83.3	77.8	72.2	66.7	61.1	55.5		Conveyors	Cas. Impac.	< 0.5	
	1/22/78		81.8	63.6	54.5	45.4	36.4	18.2		Screw Conveyor	Cas. Impac.	3.0	8.0
	6/7/78		95.8	85.6	66.9	62.7	55.1	47.5		North	Cas. Impac.	0.7	11.0
	6/7/78		89.7	86.3	82.8	79.3	74.1	74.1		Middle	Cas. Impac.	< 0.5	
	6/8/78		75.0	67.1	58.0	50.0	46.6	43.2		South	Cas. Impac.	1.3	> 10

µ1 = 50% cut-off in microns
% = Percent passing
Mmad = Mean mass aerodynamic diameter
σ_g = Particle size deviation

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-4

Shale Disposal Saturated n- Hydrocarbons

Compound	Concentration in Particulates, µg/g 9/3/77 Conveyor	8/24/77 Baghouse	9/77* Airborne	8/24/77 Baghouse, 0-10 um
$C_{10}H_{22}$	≥ 0.73	0.38	----	0.38
$C_{11}H_{24}$	2.27	1.52	----	----
$C_{12}H_{26}$	5.72	4.42	----	1.70
$C_{13}H_{28}$	7.74	6.58	----	3.02
$C_{14}H_{30}$	2.96	2.76	----	4.09
$C_{15}H_{32}$	1.58	1.45	1.47	2.16
$C_{16}H_{34}$	1.37	1.10	----	2.22
$C_{17}H_{36}$	1.89	1.08	----	3.85
$C_{18}H_{38}$	3.03	1.04	5.28	1.93
$C_{19}H_{40}$	0.95	0.36	1.70	0.66
$C_{20}H_{42}$	0.73	0.25	----	0.45
$C_{21}H_{44}$	0.86	0.28	1.74	0.49
$C_{22}H_{46}$	0.84	0.33	2.28	0.40
$C_{23}H_{48}$	0.79	0.39	2.99	0.60
$C_{24}H_{50}$	0.51	0.29	1.93	0.57
$C_{25}H_{52}$	0.57	0.32	4.14	0.51
$C_{26}H_{54}$	0.45	0.29	2.12	0.54
$C_{27}H_{56}$	0.62	0.45	5.58	1.28
$C_{28}H_{58}$	0.50	0.37	2.17	0.69
$C_{29}H_{60}$	0.83	0.55	7.66	0.98
$C_{30}H_{62}$	0.30	0.24	1.45	0.51
$C_{31}H_{64}$	0.79	0.52	5.67	0.77
$C_{32}H_{66}$	0.32	0.28	2.12	0.32
$C_{33}H_{68}$	0.82	0.36	7.29	0.35
$C_{34}H_{70}$	0.90	0.083	0.26	0.15
$C_{35}H_{72}$	----	----	0.58	0.14
$C_{36}H_{74}$	0.17	0.078	1.52	0.14
Total	38.24 µg/g	25.77 µg/g	57.95 µg/g	28.90 µg/g

* Composite of several Hi-Vol samples.

Lab-Ref: ORNL-12.
Analytical Method: Extraction, concentration, GC with FID.
Sample Type: Airborne sample was fugitive dust, all other samples were effluent.

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-5

Shale Disposal Particulates, Proximate Analysis

	Date	Particulate Sample Wt.%	Retorted Shale* Wt.%	Lab-Ref	Analytical Method
Mineral CO_2	6/7/78	12.66	15.63	PAR-9	Coulometric
Mineral C	6/7/78	3.46	4.27	PAR-9	Coulometric
Total C	6/7/78	6.29	6.48	PAR-9	Elemental Analyzer
Organic C	6/7/78	2.83	2.21	PAR-9	Difference
H	6/7/78	0.21	0.18	PAR-9	Elemental Analyzer
N	6/7/78	0.20	0.23	PAR-9	Elemental Analyzer
S	6/7/78	1.55	0.80	PAR-9	Sulfur Analyzer
	9/77	0.53		TRW-10	Gravimetric
	6/7/78	> 1		CTE-9	SSMS
Ash	6/7/78	84.29	81.44	PAR-9	Gravimetric

* Mean 1978 Value

Sample Type: Fugitive
Sampling Method: Hi-Vol

Note: TRW sulfur value is a mean of several samples.

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-6

Shale Disposal Particulates, Toxic Elements

Analysis in PPM

Element	BNW-7 8/24/77 Baghouse Fines, Bulk INAA	BNW-7 8/24/77 Baghouse Fines, Bulk XRF	BNW-7 8/24/77 Baghouse Fines, Bulk PES	ORNL-12 9/77 Ref. 12 Conveyor	ORNL-12 9/77 Ref. 12 Airborne	ORNL-12 9/77 Ref. 12 Baghouse	ORNL-12 9/77 Ref. 12 Baghouse 0-10 um	TRW-10 9/77 Area Sample	CTE-9 6/7/78 Area Sample
As	108	104		150	300	250	250	14.9	140
B			105	70	50	130	50		11
Cd				ND	ND	ND	ND	5	2
Cu		70		150	150	200	120	71	90
F								1291	MC
Hg								0.2	
Mo		53		30	50	90	70		75
Pb		42		60	60	60	30	55	120
Se		3.8						11.7	3
Zn		103		250	250	300	300	179	180

ORNL and CT&E samples analyzed by SSMS.
TRW analyses were primarily by AA, fluoride by ion sensing electrode.

Sample Type: Baghouse samples are effluent, all others are fugitive.

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-7

Shale Disposal Particulates, Toxic Elements by Particle Size

Analysis in ppm

Element	Method	Unscreened	Mesh Size > 20	20-40	40-70	70-140	140-200	200-325	< 325
AS	INAA	108		50	79	117	117	118	158
	XRF	104	40	45	71	108	107	103	109
B	PES	105							
Cu	XRF	70	39	41	58	72	72	67	69
Mo	XRF	53	17	22	37	60	47	53	52
Pb	XRF	42	19	37	37	48	44	42	37
Se	XRF	3.8	2.8	3.6	3.7	3.4	3.1	2.8	2.9
Zn	XRF	103	73	77	87	110	109	101	115

Date: 8/24/77
Lab-Ref: BNW-7
Sample Location: Retorted Shale Baghouse
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-8

Shale Disposal Particulates, General Elemental Analyses

Parameter	TRW-10 9/77 Area Sample	ORNL-12 9/77 Conveyors	ORNL-12 9/77 Baghouse	ORNL-12 9/77 Baghouse 0-10 um	ORNL-12 9/77 Airborne	CTE-9[b] 6/7/78 Area Sample
Al, %	1.56[d]	11[a]	9.3[a]	10[a]	9[a]	> 0.1
Ag, ppm						0.5
Au, ppm						< 0.1
Ba, ppm		450[b]	400[b]	1500[b]	570[b]	> 1000
Be, ppm						0.2
Bi, ppm						2
Br, ppm						2
Ca, %	10.56[d]	7.2[a]	6.7[a]	8.1[a]	7.6[a]	> 0.1
Ce, ppm		30[b]	20[b]	30[b]	30[b]	160
Cl, ppm						38
Co, ppm		ND[b]	ND[b]	70[b]	ND[b]	2
Cr, ppm	31[d]	60[b]	60[b]	70[b]	65[b]	30
Cs, ppm		7[b]	3[b]	ND[b]	10[b]	32
Dy, ppm						1
Er, ppm						0.5
Eu, ppm						2
Fe, %	1.78[d]	1.7[a]	1.6[a]	1.5[a]	1.5[a]	> 0.1
Ga, ppm		20[b]	20[b]	10[b]	30[b]	30
Gd, ppm						2
Ge, ppm				70[b]		0.1
Hf, ppm						2
Ho, ppm						0.7
I, ppm						0.4
In, ppm		ND[b]	ND[b]	ND[b]	ND[b]	< 0.1
Ir, ppm						< 0.1
K, %		1[c]	1[c]	≤ 1[c]	3[c]	> 0.1
La, ppm		30[b]	10[b]	15[b]	15[b]	120
Li, ppm						> 100
Lu, ppm						0.1
Mg, %	2.87[d]	0.4[a]	0.4[a]	1.7[a]	0.5[a]	> 0.1
Mn, ppm	295[d]	200[b]	300[b]	2000[b]	250[b]	> 280
Na, %	2.30	1[c]	0.5[c]	≥ 1[c]	1[c]	> 0.1
Nb, ppm						35
Nd, ppm						75
Ni, ppm	30[d]	200[b]	150[b]	250[b]	150[b]	28
Os, ppm						< 0.1
P, %		0.08[b]	0.05[b]	0.4[b]	0.08[b]	> 0.1
Pd, ppm						< 0.1
Pr, ppm		10[b]	ND[b]	2[b]	ND[b]	56
Pt, ppm						< 0.1
Rb, ppm		200[b]	200[b]	300[b]	200[b]	230
Re, ppm						< 0.1
Rh, ppm						< 0.1
Ru, ppm						< 0.1
Sb, ppm		70[b]	10[b]		20[b]	5
Sc, ppm						2
Si, %		> 0.1[a]	> 0.1[a]	> 0.1[a]	> 0.1[a]	> 0.1
Sm, ppm						11
Sn, ppm		ND[b]	ND[b]	ND[b]	ND[b]	2
Sr, %		0.12	0.12	0.1	0.12	> 1

TABLE 6-8 (Cont'd)

Parameter	TRW-10 9/77 Area Sample	ORNL-12 9/77 Conveyors	Baghouse	Baghouse 0-10 um	Airborne	CTE-9[b] 6/7/78 Area Sample
Ta, ppm						< 0.1
Tb, ppm						0.5
Te, ppm						< 0.1
Th, ppm						51
Ti, %		0.25[a]	0.2[a]	0.3[a]	0.25[a]	> 0.1
Tl, ppm		0.5[b]	0.5[b]	ND[b]	1[b]	2
Tm, ppm						0.1
U, ppm						42
V, ppm	131[d]	50[b]	70[b]	200[b]	100[b]	51
W, ppm						3
Y, ppm		7[b]	4[b]	25[b]	10[b]	35
Yb, ppm						1
Zr, ppm		10[b]	4[b]	30[b]	10[b]	70

a = Inductively Coupled Plasma

b = Spark Source Mass Spectrometry

c = Estimate

d = Atomic Absorption

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-9

Shale Disposal, Particulate Chemical Analysis by Particle Size

Particle Size (Microns)	Al $\mu g/m^3$	As ng/m^3	Ca $\mu g/m^3$	Co ng/m^3	Cr ng/m^3	Cs ng/m^3	Fe $\mu g/m^3$	K $\mu g/m^3$
> 2.5	22.3 ± 0.7	58 ± 1	76 ± 8	6.0 ± 0.1	31 ± 1	1.2 ± 0.1	10.6 ± 0.1	8.7 ± 0.9
1.5-2.5	9.3 ± 0.3	23.1 ± 0.6	39 ± 5	5.0 ± 0.1	28 ± 1	0.98 ± 0.12	7.17 ± 0.09	3.9 ± 0.4
1.1-1.5	7.8 ± 0.3	17.9 ± 0.6	30 ± 4	4.1 ± 0.1	20 ± 1	0.82 ± 0.11	6.17 ± 0.08	2.7 ± 0.3
0.8-1.1	5.7 ± 0.2	14.4 ± 0.5	< 9	3.7 ± 0.1	20 ± 1	0.66 ± 0.09	5.22 ± 0.08	2.1 ± 0.2
< 0.8	87 ± 4	162 ± 4	240 ± 20	34.8 ± 0.3	147 ± 2	8.5 ± 1.0	54.2 ± 0.4	24 ± 3
Σ	132 ± 4	275 ± 4	390 ± 20	53.6 ± 0.3	246 ± 2	12.2 ± 1.0	83.4 ± 0.4	41 ± 3

Particle Size (Microns)	La ng/m^3	Mg $\mu g/m^3$	Mn ng/m^3	Na $\mu g/m^3$	Ni ng/m^3	Rb ng/m^3	Sb ng/m^3	Sc ng/m^3
> 2.5	15 ± 1	31 ± 5	280 ± 10	12.4 ± 0.2	11 ± 5	23 ± 3	1.5 ± 0.2	2.46 ± 0.01
1.5-2.5	5.9 ± 0.5	19 ± 3	120 ± 10	5.5 ± 0.1	21 ± 6	18 ± 2	1.5 ± 0.2	1.96 ± 0.01
1.1-1.5	4.7 ± 0.4	17 ± 3	90 ± 10	4.2 ± 0.1	15 ± 5	15 ± 2	1.0 ± 0.2	1.63 ± 0.01
0.8-1.1	3.4 ± 0.4	13 ± 3	70 ± 10	3.5 ± 0.1	11 ± 4	12 ± 2	1.0 ± 0.17	1.34 ± 0.01
< 0.8	48 ± 4	94 ± 14	930 ± 30	48 ± 1	90 ± 22	130 ± 15	10.2 ± 1.4	14.4 ± 0.1
Σ	77 ± 4	174 ± 16	1490 ± 40	74 ± 1	148 ± 24	198 ± 16	15.2 ± 1.5	21.8 ± 0.1

Particle Size (Microns)	Sm ng/m^3	Sr ng/m^3	Th ng/m^3	Ti ng/m^3	V ng/m^3
> 2.5	3.8 ± 0.2	270 ± 30	2.8 ± 0.1	1.9 ± 0.4	92 ± 7
1.5-2.5	1.8 ± 0.1	200 ± 30	2.3 ± 0.1	0.75 ± 0.22	38 ± 4
1.1-1.5	1.3 ± 0.1	160 ± 20	1.9 ± 0.1	0.62 ± 0.20	35 ± 4
0.8-1.1	1.3 ± 0.1	150 ± 20	1.6 ± 0.1	0.46 ± 0.18	24 ± 2
< 0.8	14.0 ± 0.7	1430 ± 160	14.8 ± 0.4	5.0 ± 1.0	300 ± 19
Σ	22.2 ± 0.8	2210 ± 170	23.4 ± 0.4	8.7 ± 1.1	490 ± 20

Date: 8/24/77
Lab-Ref: BNW-7
Sample Type: Fugitive

TABLE 6-9 (Cont'd)

Particle Size (Microns)	Al µg/m³	As ng/m³	Ca µg/m³	Co ng/m³	Cr ng/m³	Cs ng/m³	Fe µg/m³	K µg/m³
> 6.8	170 ± 5	420 ± 13	550 ± 60	62 ± 1	177 ± 4	13 ± 1	81.5 ± 0.8	68 ± 13
4.1-6.8	31 ± 1	114 ± 6	94 ± 12	18.0 ± 0.2	58 ± 1	2.8 ± 0.3	18.0 ± 0.2	17 ± 3
3.0-4.1	10.5 ± 0.4	35 ± 1	36 ± 7	7.2 ± 0.2	37 ± 1	1.19 ± 0.15	6.93 ± 0.14	5.1 ± 1.0
2.0-3.0	6.0 ± 0.3	19.2 ± 0.8	25 ± 6	5.31 ± 0.14	58 ± 1	0.81 ± 0.11	4.69 ± 0.12	3.2 ± 0.6
< 2.0	37 ± 1	124 ± 5	110 ± 10	18.3 ± 0.3	189 ± 2	3.7 ± 0.4	20.3 ± 0.2	16 ± 3
Σ	255 ± 5	712 ± 15	820 ± 60	111 ± 1	519 ± 5	22 ± 1	131 ± 1	109 ± 14

Particle Size (Microns)	La ng/m³	Mg µg/m³	Mn ng/m³	Na µg/m³	Sb ng/m³	Sc ng/m³
> 6.8	97 ± 10	250 ± 40	1900 ± 60	76 ± 1	12 ± 1	25.7 ± 0.2
4.1-6.8	36 ± 4	43 ± 9	390 ± 10	15.2 ± 0.3	3.2 ± 0.4	6.15 ± 0.05
3.0-4.1	8.6 ± 0.9	15 ± 6	130 ± 10	5.1 ± 0.1	1.3 ± 0.2	2.34 ± 0.03
2.0-3.0	5.0 ± 0.7	8 ± 7	94 ± 6	4.0 ± 0.1	1.1 ± 0.2	1.56 ± 0.01
< 2.0	34 ± 4	42 ± 9	450 ± 10	22.3 ± 0.4	4.4 ± 0.5	6.34 ± 0.05
Σ	181 ± 12	360 ± 40	2960 ± 90	123 ± 1	22 ± 1	42.1 ± 0.2

Particle Size (Microns)	Sm ng/m³	Th ng/m³	Ti ng/m³	V ng/m³
> 6.8	16 ± 1	26.9 ± 0.7	9.3 ± 2.5	670 ± 50
4.1-6.8	6.6 ± 0.6	7.9 ± 0.2	3.1 ± 0.6	140 ± 10
3.0-4.1	2.0 ± 0.1	2.9 ± 0.1	2.1 ± 0.4	37 ± 6
2.0-3.0	1.24 ± 0.08	1.92 ± 0.01	0.63 ± 0.40	26 ± 6
< 2.0	5.2 ± 0.5	6.6 ± 0.2	3.0 ± 0.5	130 ± 10
Σ	31 ± 1	46.2 ± 0.7	18.1 ± 2.7	1000 ± 50

Date: 8/25/77
Lab-Ref: BNW-7
Sample Type: Fugitive

TABLE 6-9 (Cont'd)

Particle Size (Microns)	Al µg/m³	As ng/m³	Ca %	Ce ng/m³	Co ng/m³	Cr ng/m³	Cs ng/m³	Eu ng/m³
> 7.0	60.6 ± 2.8	125 ± 20	ND	60 ± 3	20.7 ± 0.6	107 ± 4	4.3 ± 1.7	0.96 ± 0.11
3.3-7.0	23.8 ± 1.0	71 ± 12	89 ± 12	35 ± 2	12.1 ± 0.4	69 ± 3	2.7 ± 1.1	0.59 ± 0.09
2.0-3.3	14.1 ± 0.7	46 ± 8	56 ± 9	22 ± 1	7.9 ± 0.3	50 ± 3	2.1 ± 0.8	0.48 ± 0.09
1.1-2.0	13.7 ± 0.7	46 ± 8	51 ± 9	21 ± 1	8.2 ± 0.4	48 ± 3	1.4 ± 0.6	0.38 ± 0.08
< 1.1	138 ± 5	301 ± 48	440 ± 50	152 ± 8	61.3 ± 1.5	378 ± 14	15 ± 6	2.63 ± 0.30
Σ	251 ± 6	589 ± 55	640 ± 50	290 ± 9	110 ± 2	652 ± 15	26 ± 6	5.0 ± 0.4

Particle Size (Microns)	Fe µg/m³	Hf ng/m³	K %	La ng/m³	Mg %	Mn ng/m³	Na µg/m³	Sm ng/m³
> 7.0	27.4 ± 0.6	2.7 ± 0.5	26 ± 2	51 ± 7	86 ± 27	605 ± 35	28.2 ± 1.1	6.3 ± 0.6
3.3-7.0	15.5 ± 0.4	1.4 ± 0.3	13 ± 2	17 ± 5	37 ± 9	260 ± 12	18.4 ± 0.7	4.4 ± 0.5
2.0-3.3	9.3 ± 0.3	0.73 ± 0.26	9.6 ± 1.6	14 ± 4	33 ± 8	169 ± 9	8.32 ± 0.56	3.5 ± 0.4
1.1-2.0	9.5 ± 0.3	0.90 ± 0.24	4.8 ± 1.3	17 ± 4	20 ± 9	150 ± 9	6.90 ± 0.52	3.1 ± 0.4
< 1.1	76.4 ± 1.6	7.3 ± 1.2	61 ± 6	113 ± 17	180 ± 30	1360 ± 50	80 ± 2	17.5 ± 1.7
Σ	138 ± 2	13 ± 1	114 ± 7	212 ± 20	360 ± 40	2540 ± 60	137 ± 3	34.8 ± 2.0

Particle Size (Microns)	Sb ng/m³	Sc ng/m³	Ta ng/m³	Th ng/m³	Ti µg/m³	V ng/m³
> 7.0	5.9 ± 1.3	8.45 ± 0.08	0.98 ± 0.23	9.3 ± 0.9	6.1 ± 1.7	259 ± 31
3.3-7.0	3.4 ± 0.8	4.64 ± 0.06	0.60 ± 0.20	6.2 ± 0.6	2.1 ± 0.5	79 ± 10
2.0-3.3	3.4 ± 0.8	3.06 ± 0.05	0.42 ± 0.17	4.3 ± 0.4	1.9 ± 0.4	51 ± 9
1.1-2.0	2.2 ± 0.6	2.88 ± 0.04	0.55 ± 0.18	4.1 ± 0.4	1.3 ± 0.4	55 ± 7
< 1.1	18.3 ± 3.9	23.3 ± 0.2	6.4 ± 0.9	23 ± 2	8.6 ± 1.8	460 ± 40
Σ	33 ± 4	42.3 ± 0.2	9.0 ± 1.0	47 ± 2	20 ± 3	909 ± 50

Date: 11/16/77
Lab-Ref: BNW-7
Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-10

Baghouse Fines Elemental Analysis by Particle Size

Analysis in ppm, except as noted

		Mesh Size							
Element	Method	Bulk	> 20	20-40	40-70	70-140	140-200	200-325	< 325
Al (%)	AA	4.52	4.37	4.19	4.50	4.46	4.59	4.50	4.23
Ba	INAA	610		650	790	570	640	660	800
	XRF	590			600	560	550		520
	PES	474		495		478		486	501
	AA	580	600	600	600	600	500	600	600
Br	INAA	ND		ND	ND	ND	ND	ND	ND
	XRF	ND	ND	ND	ND	ND	ND	ND	ND
Ca (%)	XRF	13.8	13.8	14.2	13.2	12.5	13.2	13.7	15.2
	AA	12.8	13.1	13.5	12.3	11.5	11.9	12.8	14.0
Co	INAA	14.3		9.8	13.9	17.8	17.0	15.5	20.0
Cr	INAA	36		39		45	36	36	51
	XRF	34	47	50	35	55	57	42	44
	PES	46	65	57		53		46	49
Cs	INAA				42	ND			
Eu	INAA	0.69		0.83	0.66	0.74	0.71	0.79	
Fe (%)	INAA	2.27		2.64	2.72	2.55	2.54	2.40	2.75
	XRF	2.56	3.5	2.96	2.72	2.59	2.82	2.39	2.60
	AA	2.39	3.72	2.65	2.86	2.51	2.59	2.42	2.27
Ga	XRF	13	11.9	12.1	11	12.4	12	10	10
K (%)	XRF	1.66	2.38	2.24	1.98	1.73	1.85	1.60	1.68
	AA	1.65	2.40	2.02	1.95	1.74	1.67	1.60	1.58
La	INAA	21.5		24.02	23.6	23.9	24.0	23.2	31.2
	XRF	26			30	23	22		30
Lu	INAA	0.39		0.45	0.45	0.38	0.41	0.43	0.47
Mg (%)	AA	4.30	4.36	4.41	4.26	4.21	4.15	4.25	4.53
Mn	XRF	400	494	440	380	390	410	400	470
	PES	408	482	428		387		388	416
	AA	450	540	500	500	440	450	460	520
Na (%)	INAA	2.55		1.78	2.14	2.54	2.76	2.74	3.31
	AA	2.65	1.44	1.80	2.17	2.57	2.77	2.48	2.47
Nb	XRF	8	10	9	11	10	9	8	7
Ni	XRF	46	37	30	37	52	47	40	51
Rb	XRF	91	90	90	95	108	90	95	89
Sb	INAA	3.5		2.2	2.8	3.6	3.5	3.7	5.2
Sc	INAA	6.5		8.1	7.4	7.2	6.8	6.9	9.6
Si (%)	XRF	16.5	17.1	16.8	17.2	18.6	17.2	17.3	17.8
	AA	17.8	18.1	17.8	18.4	19.2	19.1	18.5	17.8
Sm	INAA	3.7		4.3		4.2	4.1	4.1	5.4
Sr	XRF	830	770	870	830	800	760	860	870
	PES	735		735		671		753	815
Th	INAA	6.6		6.8	6.9	6.8	6.2	6.6	8.7
	AA								0.99
Ti (%)	XRF	0.26	0.26	0.27	0.26		0.28	0.25	0.25
	PES					0.27			
	AA	0.19	0.21	0.20	0.22	0.21	0.22	0.20	0.19
U	INAA	5.0		4.5	5.2	6.3	5.8	6.0	8.3
V	XRF					108			
	PES	143		114		150		132	132
Y	XRF	15	16	15.5	15	16	12	15	12
Zr	XRF	69	77	66	85	70	67	75	63

Date: 8/24/77
Lab-Ref: BNW-7

TABLE 6-11

Shale Disposal Particulates, Mineral Analysis

	Wt.%
Quartz	30
Calcite	25
Feldspar	20
Dolomite	15
Analcime	15
Illite	5

Date: 8/77
Lab-Ref: BNW-7
Location: Retorted Shale Baghouse
Sample Type: Effluent

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-12

Retorted Shale Disposal Gases

Date	Lab-Ref	Sample Comments	Vol %		ppm			
			O_2[a]	CH_4[a]	CO_2	CO	NO_x[d]	SO_2
7/20/77	LASL-6	Conveyor				10[c]		
7/20/77	LASL-6	General				ND[b]		
7/21/77	LASL-6	General				12[c]		ND[b]
1/17/78	PAR-9	General	22.0	< 0.05	< 200[a]	< 200	< 5	< 1[d]
1/18/78	PAR-9	General			100[b]		< 5	< 1[d]
4/6/78	PAR-9	General	21.2	< 0.05	200[a]	< 200	< 5	< 1[d]

Date	Lab-Ref	Sample Comments	ppm				
			Tot HC[b]	HCN[b]	H_2S[b]	Mercaptans[d]	Phenols[d]
7/20/77	LASL-6	Conveyor	ND				
7/21/77	LASL-6	General		ND	ND		
12/5/77	LASL-6	General	ND				
1/17/78	PAR-9	General	< 10				
4/6/78	PAR-9	General				ND	ND

a = Gas Chromatograph with Thermal Conductivity Detector

b = Detector Tube

c = CO Meter

d = Colorimetry

Sample Type: Fugitive

AIR QUALITY

PARAHO OPERATIONS

TABLE 6-13

Shale Disposal Gases, Volatile Metals

$\mu g/m^3$

Date	As	Hg	Se	Pb	Analysis Comments
12/77	< 4	< 30	< 2	< 4	AAS
1/78		< 0.1 ppm			Vapor, Det. Tubes
4/78	< 4	< 30	< 2	< 4	AAS

Lab-Ref: PAR-9

7.0 MISCELLANEOUS

7.1 General

Some of the air quality data obtained at Anvil Points during Paraho operations does not "fit" any of the operating categories that have been discussed previously (Mining, Mine Adits and Haul Road, Crushing, Retort and Oil Transfer, and Shale Disposal). These data will be discussed, along with the background or ambient data, in this Miscellaneous Section.

7.2 Ambient

Because Paraho operations were essentially continuous during the periods of monitoring and study by most researchers, very little ambient data have been obtained. No ambient gas data were obtained.

Background particulates were obtained just outside the main entrance. Roads and parking lots in this area were paved. Although no TSP or particle size data were obtained, some chemical characterization was carried out (see Tables 7-1 and 7-2). All major constituents (> 1000 ppm) were in the same concentration range as normal raw shale particulates (see Section 2.2). However, most of the trace metals were much higher in concentrations than raw shale particulates. For example, mercury was 115 ppm and fluoride was 6923 ppm (0.69 wt%) in this background particulate sample. Both values are suspect. In Table 7-2, the effects of particle size on concentration was studied. No trends or effects are noted. Neither mercury nor fluorine were determined on this sample so that the unusual results, presented in Table 7-1, cannot be explained.

Ambient TSP data were compiled and discussed in Sections 3, 4, and 6 (Mine Adit and Haul Road, Crushing, and Shale Disposal). Results obtained by upwind sampling can be tabulated as follows:

Location	N	TSP (mg/m^3)
Haul Road	17	0.7
Crusher	13	2.4
Shale Disposal	12	1.3

Overall, the background, or ambient, TSP values would be about 1.2 mg/m^3. This is significantly higher than the ambient TSP values obtained at the Haul Road during weekends when there was no mining or hauling activities. These studies show a mean TSP = 0.014 mg/m^3 with a high of 0.060 mg/m^3 for 30 samples. Apparently, upwind results are not true background or ambient data.

7.3 Miscellaneous

Miscellaneous data are presented in Table 7-3. These data were obtained by sampling the atmospheres of the gas sampling room in the retort control building and the welding shop in the maintenance building. Data obtained in the gas sampling room indicate a possible trace of gas leakage. All levels were well below TLV levels. Data obtained in the welding shop indicated high levels for lead. This condition has been corrected by improved exhaust and ventilation.

AIR QUALITY

PARAHO OPERATIONS

TABLE 7-1

Miscellaneous, Average Elemental Analysis of Background Particulates

PPM Except as Noted

Element		Element	
Al, Wt%	3.05	Mn	272
As	4.5	Na, Wt%	1.56
Ca, Wt%	10.26	Ni	321
Cd	2	Pb	195
Cr	72	S, Wt%	0.45
Cu	231	Se	14.8
F, Wt%	0.69	Si, Wt%	10.48
Fe, Wt%	2.03	V	38
Hg	114.7	Zr	420
Mg, Wt%	3.42		

Date: 9/77
Lab-Ref: TRW-10
Analytical Methods: AA, F by ISE
Sample Type: Ambient

AIR QUALITY

PARAHO OPERATIONS

TABLE 7-2

Miscellaneous - Particulate Chemical Analysis of Background Particulates by Particle Size

Particle Size (Microns)	Al µg/m³	As ng/m³	Ca µg/m³	Ce ng/m³	Co ng/m³	Cr ng/m³	Cs ng/m³	Eu ng/m³
> 7.0	1.00 ± 0.04	1.56 ± 0.33	2.6 ± 0.3	1.28 ± 0.06	0.33 ± 0.02	1.89 ± 0.09	0.11 ± 0.03	0.023 ± 0.004
3.3-7.0	0.447 ± 0.02	0.64 ± 0.14	1.1 ± 0.2	0.57 ± 0.04	0.18 ± 0.01	1.81 ± 0.08	0.05 ± 0.014	0.015 ± 0.003
2.0-3.3	0.242 ± 0.014	0.52 ± 0.13	0.65 ± 0.14	0.036 ± 0.04	0.13 ± 0.01	1.46 ± 0.07	0.032 ± 0.01	ND
1.1-2.0	0.178 ± 0.012	0.43 ± 0.10	0.49 ± 0.12	0.035 ± 0.03	0.12 ± 0.01	1.42 ± 0.08	0.033 ± 0.01	0.014 ± 0.003
< 1.1	1.64 ± 0.07	3.77 ± 0.83	4.3 ± 0.7	2.0 ± 0.1	0.81 ± 0.04	13.7 ± 0.3	0.20 ± 0.05	0.037 ± 0.008
Σ	3.53 ± 0.09	6.92 ± 0.92	9.1 ± 0.8	3.9 ± 0.1	1.54 ± 0.05	20.4 ± 0.3	0.43 ± 0.06	

Particle Size (Microns)	Fe µg/m³	Hf ng/m³	K µg/m³	La ng/m³	Mg µg/m³	Mn ng/m³	Na µg/m³	Sm ng/m³
> 7.0	0.60 ± 0.02	0.068 ± 0.011	0.33 ± 0.06	0.63 ± 0.15	1.18 ± 0.25	9.2 ± 0.4	0.40 ± 0.03	0.13 ± 0.01
3.3-7.0	0.30 ± 0.01	0.022 ± 0.009	0.23 ± 0.04	0.47 ± 0.10	0.59 ± 0.18	4.3 ± 0.2	0.14 ± 0.03	0.060 ± 0.006
2.0-3.3	0.196 ± 0.01	0.028 ± 0.007	0.88 ± 0.023	0.20 ± 0.07	0.75 ± 0.21	2.0 ± 0.2	0.083 ± 0.013	0.050 ± 0.006
1.1-2.0	0.164 ± 0.01	0.018 ± 0.007	0.062 ± 0.021	0.18 ± 0.06	0.35 ± 0.18	2.1 ± 0.2	0.072 ± 0.012	0.039 ± 0.004
< 1.1	1.05 ± 0.04	0.11 ± 0.03	0.57 ± 0.11	0.66 ± 0.22	2.5 ± 0.5	16.2 ± 0.7	0.82 ± 0.06	0.18 ± 0.02
Σ	2.31 ± 0.05	0.25 ± 0.03	1.28 ± 0.14	2.14 ± 0.30	5.4 ± 0.6	33.8 ± 0.9	1.52 ± 0.07	0.46 ± 0.02

Particle Size (Microns)	Sb ng/m³	Sc ng/m³	Ta ng/m³	Th ng/m³	Ti µg/m³	V ng/m³
> 7.0	0.066 ± 0.016	0.182 ± 0.002	0.019 ± 0.007	0.21 ± 0.01	0.079 ± 0.016	3.4 ± 0.3
3.3-7.0	0.046 ± 0.012	0.085 ± 0.001	ND	0.11 ± 0.01	0.034 ± 0.010	0.9 ± 0.2
2.0-3.3	0.030 ± 0.014	0.052 ± 0.001	ND	0.059 ± 0.007	0.035 ± 0.010	1.0 ± 0.2
1.1-2.0	0.057 ± 0.013	0.048 ± 0.001	ND	0.059 ± 0.007	0.037 ± 0.010	1.5 ± 0.2
< 1.1	0.29 ± 0.04	0.264 ± 0.004	0.061 ± 0.019	0.31 ± 0.03	0.096 ± 0.029	7.5 ± 0.7
Σ	0.49 ± 0.05	0.63 ± 0.005		0.75 ± 0.03	0.28 ± 0.04	14.3 ± 0.8

Date: 11/17/77
Lab-Ref: BNW-7
Sample Type: Ambient

AIR QUALITY

PARHO OPERATIONS

TABLE 7-3

Miscellaneous Gas Data

Gas Sampling Room

Analysis	Concentration	Analytical Method
CO_2	400 ppm	Detector Tube
CO	< 1 ppm	Detector Tube
NH_3	2 ppm	Detector Tube
Aromatics	0.30 ppm	Charcoal Tube
Alkanes	0.26 ppm	Charcoal Tube

Welding Shop (Personal Sampler)

Analysis	Concentration (mg/m^3)
Cd	< 0.004
Cr_2O_3	< 0.02
Fe_2O_3	10
Mn	0.6
Ni	0.02
Pb	0.5
ZnO	0.04

Date: 8/6-7/75
Lab-Ref: LFE-2

PARAHO ENVIRONMENTAL DATA

PART III

WATER QUALITY

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WATER QUALITY

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1-1
1.1	The Paraho Anvil Points Operation	1-1
1.2	Water Quality Background	1-1
1.3	Sampling, Preparation, and Analytical Procedures	1-2
1.4	Abbreviations and Bibliography	1-3
2.0	PROCESS WATER	2-1
2.1	Product Water	2-1
2.2	Evaporation Pond	2-3
2.3	Other Process Waters	2-4
3.0	GROUND AND SURFACE WATER	3-1
3.1	General	3-1
3.2	Ground and Surface Water - Amphitheater	3-3
3.3	Surface Water - Anvil Points Region	3-7
4.0	LEACHATE WATER	4-1
4.1	Laboratory Studies	4-2
4.2	Field Studies	4-4

LIST OF TABLES

		Page
1.1	Parameter Classification	1-7
2.1	Product Water - 1975/1976 Data	2-5
2.2	Product Water - Bulk Properties	2-7
2.3	Product Water - Major Inorganics	2-8
2.4	Product Water - Trace Elements	2-9
2.5	Product Water - Organic Analyses	2-10
2.6	Product Water - Miscellaneous Data	2-11
2.7	Evaporation Pond - Major Inorganics	2-12
2.8	Evaporation Pond - Organics	2-13
2.9	Evaporation Pond - Trace Elements	2-14
2.10	Evaporation Pond - Other Parameters	2-17
2.11	Recycle Gas Line Drain	2-19
2.12	Miscellaneous Process Water	2-20
2.13	Mine Dust Control Water	2-21
3.1	Ground and Surface Water - Total Dissolved Solids	3-9
3.2	Ground and Surface Water - Aluminum	3-10
3.3	Ground and Surface Water - Chlorine (Total Cl)	3-11
3.4	Ground and Surface Water - Calcium	3-12
3.5	Ground and Surface Water - Iron	3-13
3.6	Ground and Surface Water - Magnesium	3-14
3.7	Ground and Surface Water - Potassium	3-15
3.8	Ground and Surface Water - Sodium	3-16
3.9	Ground and Surface Water - Sulfate	3-17
3.10	Ground and Surface Water - Chemical Oxygen Demand	3-18
3.11	Ground and Surface Water - Oil and Grease	3-19
3.12	Ground and Surface Water - Organic Carbon	3-20
3.13	Ground and Surface Water - Phenols	3-21
3.14	Ground and Surface Water - Arsenic	3-22
3.15	Ground and Surface Water - Barium	3-23
3.16	Ground and Surface Water - Boron	3-24
3.17	Ground and Surface Water - Cadmium	3-25
3.18	Ground and Surface Water - Copper	3-26
3.19	Ground and Surface Water - Cyanide	3-27
3.20	Ground and Surface Water - Fluorine	3-28
3.21	Ground and Surface Water - Lead	3-29
3.22	Ground and Surface Water - Mercury	3-30
3.23	Ground and Surface Water - Molybdenum	3-31
3.24	Ground and Surface Water - Selenium	3-32
3.25	Ground and Surface Water - Silver	3-33
3.26	Ground and Surface Water - Zinc	3-34
3.27	Ground and Surface Water - Alkalinity as $CaCO_3$	3-35
3.28	Ground and Surface Water - pH	3-36
3.29	Ground and Surface Water - Total Nitrogen	3-37
3.30	Ground and Surface Water - Phosphate as P	3-38
3.31	Ground and Surface Water - Sulfide as S	3-39
3.32	Ground and Surface Water - Silicon	3-40
3.33	Ground and Surface Water - Total Suspended Solids	3-41
3.34	Ground and Surface Water - Miscellaneous Parameters	3-42
3.35	Special Stream Samples	3-43

LIST OF TABLES (Continued)

		Page
4.1	Leachate Studies - Woodward-Clyde Laboratory	4-6
4.2	Leachate - Retorted Shale - CSU - Lower Level Lysimeter	4-7
4.3	Leachate - Retorted Shale - CSU - Upper Level Lysimeter	4-8
4.4	Laboratory Leachates - Utah State University - Colorado and Utah Shales	4-10
4.5	Laboratory Leachates - Utah State University	4-11
4.6	Leachate Data - EPA EP TEST (RCRA)	4-12
4.7	Laboratory Leachates - University of Colorado	4-13
4.8	Field Leachate Studies - Woodward-Clyde Consultants	4-14
4.9	Field Leachate - University of Colorado - Sulfur Species	4-15
4.10	Field Leachate - University of Colorado	4-16
4.11	Field Leachates - Battelle PNL	4-17

LIST OF FIGURES

		Page
1.1	Schematic of Water Sources	1-8
3.1	Anvil Points Streams and Drainages	3-45
3.2	Ground and Surface Monitoring Sites - Amphitheater Drainage	3-46
3.3	Total Dissolved Solids	3-47
3.4	Aluminum	3-48
3.5	Total Chlorine	3-49
3.6	Calcium	3-50
3.7	Iron	3-51
3.8	Magnesium	3-52
3.9	Potassium	3-53
3.10	Sodium	3-54
3.11	Sulfate	3-55
3.12	Chemical Oxygen Demand	3-56
3.13	Boron	3-57
3.14	Cadmium	3-58
3.15	Copper	3-59
3.16	Fluorine	3-60
3.17	Lead	3-61
3.18	Zinc	3-62
3.19	Alkalinity as $CaCO_3$	3-63
3.20	pH	3-64
3.21	Phosphate as P	3-65
3.22	Silicon	3-66
3.23	Total Suspended Solids	3-67
4.1	Leachate - Utah State University	4-33
4.2	Pond No. 1 and Pond No. 2	4-34
4.3	Plot Plan of Lysimeter Study Site	4-35
4.4	Cross Section Showing the Design of the Lysimeters	4-36

1.0 INTRODUCTION

1.1 The Paraho Anvil Points Operation

Water quality studies at the Paraho Anvil Points operations have been made (and in many cases are continuing) in the areas of process water, ground and surface water, and leachate water. A simple schematic of the sources of these water samples is pictured in Figure 1.1. None of the sample sources shown in Figure 1.1 offer a continuous, reliable sample.

During the research studies carried out using the pilot plant and semi-works scale, there was no continuous stream of process water - neither product water from the oil-water separation tank nor waste water drained from the recycle gas blower and lines. The evaporation pond represented water drained from the industrial sewer system and runoff from the shale disposal. Ground and surface water samples were obtained from the Amphitheater drainage in the canyon east of the retorting area (see map, Fig. 3.1). Both the alluvium wells and intermittent stream, used as sampling sites, were dry at times throughout the year. The lysimeters, designed to study plant growth in retorted shale, were watered heavily to promote the plant growth. These field lysimeters provided leachate water only during those times.

The Paraho Anvil Points operations were designed and sized to test the Paraho technology on oil shale retorting and to provide sufficient crude oil for downstream refining and research. The process was not scaled large enough to provide adequate, continuous process streams for valid water quality assessment. Nevertheless, the water quality data obtained and compiled in this report does represent a significant step from laboratory studies towards modular operations and full-scale commercial development.

1.2 Water Quality Background

Because of the long-term previous oil shale retorting research which has been carried out at Anvil Points and because the time frame needed to detect changes resulting in the ground and surface water quality (if any) from those

previous, or the recently-completed Paraho operations, ground and surface water monitoring is continuing. Lysimeter studies are also continuing. Rather than wait several years to compile the water quality data from the Anvil Points operations, it was decided to compile all data available from the start of the Paraho operations in 1974 to the end of CY 1978. As data are available, annual updates of this water quality data compilation will be considered.

At most of the sampling sites, up to 40 parameters were monitored routinely. In order to provide some reasonable arrangement, these parameters have been classified into four general groups: Major Inorganics, Organics, Trace Elements, and Others. A list of the common parameters in the four groups is presented in Table 1.1. These groupings are used throughout this water quality report.

With the exception of research studies carried out from late 1975 until early 1976, the Paraho retorts were operated in the Direct Heated Mode. No detailed log of retorting operations is provided in this report. As pointed out earlier, the time frame needed for these operations to possibly effect groundwater quality is largely unknown. Also, since there was no process water stream available for sampling and analyzing, one cannot compare the composition of a composited water sample with a specific operating period.

1.3 Sampling, Preparation, and Analytical Procedures

Whenever specific information is available, the procedures used in sampling, preparation, and analysis is stated. All water samples described in this report represent grab samples; continuous sampling was not used. This procedure introduces some doubt concerning sample validity or representativeness. For the most part, the water samples were analyzed as received. Stabilization procedures and filtration were not used. To the best of our knowledge, only the Paraho and BNW data represent analyses made on stabilized and filtered samples. For the most part, the analytical procedures used on samples taken after 1976 are known and are included in this report. Whenever possible, specific information is provided in the tabulated data; i.e. colorimetric <u>plus</u> reagent, or titrimetric <u>plus</u> titrant.

1.4 Abbreviations and Bibliography

In order to keep this report (especially the tables and figures) as concise as possible, abbreviations are used. Since these abbreviations refer to technical terms, government agencies, and corporate names, a list of these abbreviations is included in this section (see pg 1-). Common symbols of the chemical elements have not been considered as abbreviations.

The bibliography included in this section is a listing of the data base reports received by Development Engineering, Inc. (DEI) by April, 1979. The entire data base dealing with the environmental, health, and safety aspects of the recently-completed Paraho operations at Anvil Points is incomplete. However, it is believed that all of the data pertaining to water quality has been received by DEI and has been presented in this report.

LIST OF ABBREVIATIONS

AA	Atomic Absorption Spectroscopy
BNW	Battelle Pacific Northwest Laboratories
C	Colorimeter
Cond. (EC_E)	Electrical Conductivity
CSM	Colorado School of Mines
CSU	Colorado State University
CTE	Commercial Testing and Equipment, Inc.
CU	University of Colorado
FES	Flame Emissions Spectroscopy
GC	Gas Chromatography
GE TEMPO	General Electric TEMPO
g	Gram
g/l	Grams per liter
Grav.	Gravimetric
GSRI	Gulf South Research Institute
Gulf	Gulf Energy and Mineral Company
INAA	Instrumental Neutron Activation Analyses
ISE	Ion Selective Electrode
Leco	Leco Sulfur Analyzer
LETC	Laramie Energy Technology Center
meq	Milli-equivalents
mg/ml	Milligram per Milliliter
NRL	Natural Resources Laboratory, Inc.
Par	Paraho Development Corporation
PES	Plasma Emission Spectroscopy
ppm	Parts per Million
ppt	Parts per Thousand
Precip.	Precipitation
RMT	Rocky Mountain Technology, Inc.
S.D.	Standard Deviation
SSMS	Spark Source Mass Spectroscopy
TDS	Total Dissolved Solids
T.	Titration
TRW	TRW Environmental Engineering Division
TSS	Total Suspended Solids
µmhos/cm	Micromhos per Centimeter
USBM	United States Bureau of Mines
USGS	United States Geological Survey
USU	Utah State University
WCC	Woodward-Clyde Consultants
XRF	X-ray Fluorescence (Energy Dispersion)

WATER QUALITY

PARAHO OPERATIONS

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WATER QUALITY

PARAHO OPERATIONS

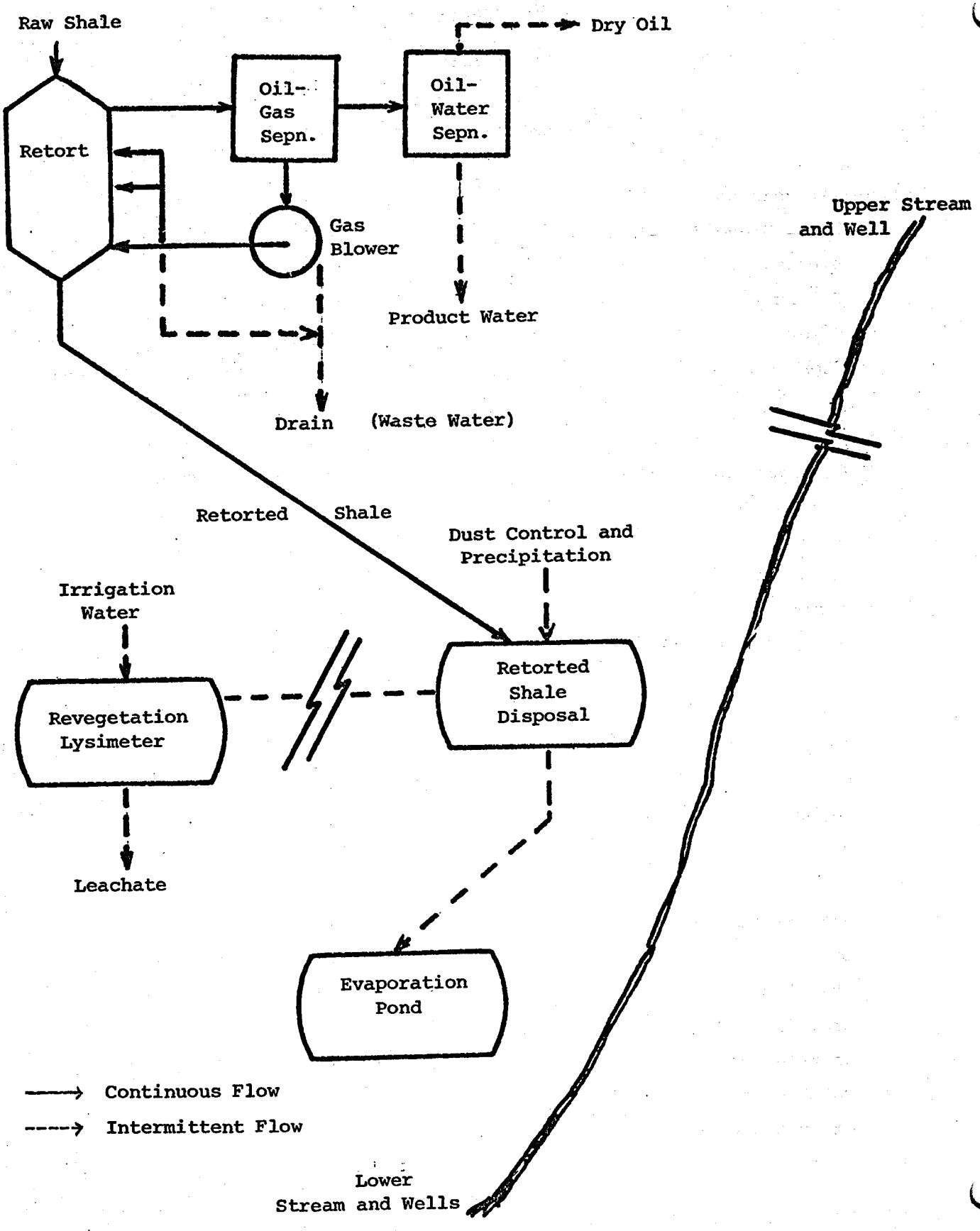
TABLE 1.1

Parameter Classification

Major Inorganics	
Total Dissolved Solids	Magnesium
Aluminum	Potassium
Calcium	Sodium
Chlorine	Sulfate
Iron	
Organics	
Chemical Oxygen Demand	Organic Carbon
Oil and Grease	Phenols
Trace Elements	
Arsenic	Lead
Barium	Mercury
Boron	Molybdenum
Cadmium	Selenium
Copper	Silver
Cyanide	Zinc
Fluoride	
Others	
Alkalinity	Phosphate as P
pH	Total Sulfur as S
Chromium	Sulfide as S
Ammonia as N	Silicon
Nitrates as N	Total Suspended Solids
Total Nitrogen as N	
Other Elements	

FIGURE 1.1

Schematic of Water Sources



2.0 PROCESS WATER

The recently completed research studies using the Paraho Pilot Plant and Semi-Works retorts did not provide any process water stream for sampling and analysis. Total water production during the larger Semi-Works operations was only 1-2 gal/min, with most of it produced as vapor with the product gas. Liquid water, produced with the oil, was only 10-15 gal/hour. Process water, because of the low quantities produced, was not separated, sampled, and analyzed routinely until mid-1977.

As pictured in Figure 1.1, there are several sources of process water in the Paraho process which are available to the ambitious (and somewhat imaginative) researcher. These include: product water separated from the crude shale oil; the evaporation pond, chiefly seepage from the retorted shale disposal and effluent from the industrial sewer system; and miscellaneous - drainage from the recycle gas blowers and lines, product gas condensate (obtained by passing product gas through cooled condensers), and treated drinking water used in the housing and plant areas, and as boiler feed, dust control, and lysimeter watering. Analyses of these process waters - product water, evaporation pond, and others - will be discussed in this section.

2.1 Product Water

Historically, product water, co-produced with the crude product oil, was stored in tankage with the oil during the Paraho Oil Shale Demonstration during 1974-1976. A few samples of various tank bottoms were analyzed to obtain a qualitative idea of the chemical and physical properties. Results are presented in Table 2.1; no information regarding the history, tank condition, analytical procedures, etc. are available. Because none of this information is available, the data in 2.1 are presented only for information.

In an effort to produce dry shale oil for storage during 1977-1978 operations, the product water was separated by decantation in large 1000-barrel tanks. Dry oil was pumped off the top of these tanks every few days. Water bottoms (the product water) were drained as needed into the industrial sewer

system. Thus, the normal product water sample represents a broad composite rather than water actually produced at the time of sampling.

Bulk properties of the product water, obtained by Paraho to improve material and elemental balance closures, are listed in Table 2.2. Although there were some variations in these data, the results can be reported as the following means:

Organic Carbon	3.8 wt%
Mineral Carbon	0.9 wt%
Total Nitrogen	3.0 wt%
Total sulfur	4.1 wt%

Data listed in Table 2.2 show the nitrogen as ammonia. The data in Table 2.2 indicate that the sulfur does not exist as sulfide. The nature of the sulfur species in these water samples is unknown at this time. Data in Table 2.3 indicate that a large fraction of the total sulfur exists as sulfate.

Other analyses of product water are presented in Tables 2.3-2.6. Major species contributing to gross salinity should discharge occur are listed in Table 2.3. The data are quite variable. Most of the major species listed in Table 2.3 show lower concentrations in Paraho product water, co-produced with the crude shale oil, than they do in the natural waters in the Anvil Points area (see Table 3.35). Only magnesium and total chlorine show higher concentrations in the product water. Data on thirteen potential toxins are presented in Table 2.4. Silver, lead, and mercury are, for the most part, below their limits of detection. Mercury, detected by flameless AA, appears to be present at the 5 ppb (5 ug/l) level. Boron, cadmium, copper, cyanide, selenium, and zinc are higher in process water than in natural waters. One must view the data from organic analyses presented in Table 2.5 with caution. As mentioned at the start of this section, the research studies carried out using the Paraho technology did not produce a process water stream; rather a wet oil (2-6 wt% water) was produced. The organic data shown in Table 2.5 represent, to a large degree, a measure of the separation achieved in storage tanks and in the laboratory. As pointed out in Section 1.1, the Paraho operations did not produce a product water stream. These samples were obtained manually from the wet oil. Miscellaneous data are presented in Table 2.6.

These data (mean ± S.D.) indicate that the variability found in alkalinity (3.49 ± 1.24 mg/l) is not reflected in pH (8.76 ± 0.23 pH). Note that the overall pH values are nearly neutral (8.40 to 9.16).

2.2 Evaporation Pond

The lined evaporation pond, installed by Paraho in early 1974, was designed to prevent discharge into natural waters by intercepting the industrial sewer water; seepage from the shale disposal area; and surface runoff from the retorting, oil storage, and shale disposal areas. The concentrations of parameters measured in this evaporation pond were quite variable due to the variety of inputs and the influence of weather (precipitation, evaporation, freezing, etc.). Nevertheless, the evaporation pond was monitored routinely. Many researchers and laboratories participated in this effort leading to the data presented in Tables 2.7-2.10. Even though the data are influenced by several factors and the results are difficult to interpret, this monitoring effort is justified because the samples represent a composite of waste water produced from the research operations.

In an effort to evaluate the mass of data obtained from the evaporation pond, the following table was set up comparing mean evaporation pond data to mean natural water data (see Table 3.35). Data are presumed similar when higher concentration is less than three times the lower concentration.

	Pond > Natural	Same	Pond < Natural
Major Inorganics	Cl	Ca,Mg,K,Na SO_4,TDS	Al,Fe
Organics	COD,Org C Phenols	Oil & Grease	
Trace Elements	As,Se	Ba,B,Cd,Cu,CN F,Pb,Hg,Ag,Zn	Mo
Other	Tot N,$PO_4^{=}$ $S^{=}$	Alk,pH,Si	

These data show that, for the most part, there is no real difference between the evaporation pond from the Paraho operations and the natural streams in the Anvil Points region. Organics, generally, are higher in the

evaporation pond. Only two toxic materials, arsenic and selenium, are higher in the evaporation pond; arsenic levels in the pond range from < 0.1 to 8 ppm and selenium from < 1 to 90 ppb.

2.3 Other Process Waters

Since no process water stream was available for analysis during the Paraho research operations, researchers requiring data to assess water quality sampled several miscellaneous samples. In addition to sampling and analyzing the water bottoms from oil storage tanks (Section 2.1, Product Water), samples of fluid drained from the gas blowers and lines, condensates of the product gas, and water used for dust control in the mine were obtained and analyzed.

The samples obtained from gas line drains and by condensation represent, to a degree, the type of water which may be produced during product gas clean-up in a commercial operation. Data obtained from these samples are presented in Tables 2.11 and 2.12. Although these data obtained from the gas line drains and condensates are similar to the data obtained from oil storage tanks, there are several significant differences noted between these two process water samples. Most of the metal ions are lower in the water samples obtained from the gas - even volatile metals such as aresenic are lower. Surprisingly, some of the organic parameters, such as COD and phenol, are higher in Table 2.11 - even though the product water was co-produced with, and then separated from, the product oil. Although COD and phenol are higher in the samples drained from gas lines, the organic carbon is lower in the process water obtained from the gas line.

Only one laboratory sampled and analyzed the dust control water used in the Anvil Points mine (see Table 2.13). During most of the recent operations this water was obtained from a reservoir located on top of the plateau above the mine. Since this water is used directly for dust control with no treatment, the data in Table 2.13 can be viewed as an indication of the natural water quality at the higher (8000 ft.) level. Since the data in Table 2.13 represent only one sample, no comparisons with the natural surface waters at the lower (6000 ft) level are made.

WATER QUALITY

PARAHO OPERATIONS

TABLE 2.1

PRODUCT WATER

1975-1976 Data

	Product 3/75 RMT	Product 3/75 LETC	Product 8/75 Gulf	Product 8/75 PAR	Product 11/75 PAR	Product 11/75 PAR	Waste Water 11/75 PAR
Major Inorganics							
Total Dissolved Solids, g/l	23.0	17.4	160	137	158	49	7.0
Aluminum	4.6		2.4				
Ammonium, g/l	0.8	4.9	40.8	2.6	10.4	5.0	16.1
Bicarbonate	1.5				31.8	3.2	26.8
Calcium	100	76	18				
Chloride	1550	5300	70000	13300			
Iron	2.2		9	7			
Magnesium	200	58	30				
Potassium	18	35	3				
Sodium	140	290	30				
Sulfate	210	5900	5500				
Sulfide	< 0.5		< 0.5	0.5	2	2	1
Organics							
Biological Oxygen Demand, g/l	> 5.000						
Chemical Oxygen Demand, g/l	132.0	17.0	86.4				
Oil and Grease	900		964				
Organic Carbon, g/l	1.0	3.4	19.3				
Phenols	19		8.7				
Trace Elements							
Arsenic, µg/l			< 5				
Barium			< 3				
Boron	10		1.2				
Cadmium, µg/l	< 5		< 900				
Copper	0.04		9				
Cyanide, µg/l	< 1		< 100				
Fluoride	19		5				
Lead	0.3		3				
Mercury, µg/l	< 60		< 0.1				
Molybdenum	0.4		< 0.2				
Selenium							
Silver			0.6				
Zinc			1.2				
Other							
Alkalinity, g/l	5.9		35.2				
Ash			300	66			
pH	8.6	7.6	8.4	8.0			
Nitrates			2570				
Nitrites			0.3				
Phosphate	33		< 1.5				
Total Suspended Solids	11	700	70				
Total Sulfur							
Total Nitrogen, g/l	6.1	4.6	3.4		33.5	12.5	10.9
Total Carbon, g/l					38.3	23.5	14.8
Antimony			< 0.9				
Chromium			0.3				
Cobalt			0.15				
Lithium			< 2				
Manganese			1.2				
Nickel			0.2				
Silicon	3.5		3				
Strontium			0.6				
Titanium			< 0.2				
Vanadium			< 0.3				
Uranium							

All data in mg/l unless otherwise noted.

TABLE 2.1 (Cont'd)

	Waste Water 11/75 PAR	Cond(Lab) 3/76 PAR	Cond(Lab) 3/76 PAR	Cond(Lab) 3/76 TRW	Product 3/76 TRW	Cond(SW) 3/76 PAR	Cond(SW) 3/76 TRW
Major Inorganics							
Total Dissolved Solids, g/l	67			22.0			0.4
Aluminum				0.2	0.8		
Ammonium, g/l	11.1	34.1	37.6	38.1		6.7	
Bicarbonate	21.5	86.9	83.6	49.2		11.4	8.1
Calcium				60.7	> 10		39.2
Chloride				Trace	2		Trace
Iron				> 10	5		
Magnesium				3	> 10		
Potassium				0.1	> 10		0.2
Sodium				0.2	> 10		0.3
Sulfate				1136			1.7
Sulfide	2	500	400	< 0.1		200	390
Organics							
Biological Oxygen Demand, g/l				12.0			4.9
Chemical Oxygen Demand, g/l				19.4			17.1
Oil and Grease				502			33.3
Organic Carbon, g/l				29.2			9.8
Phenols				46			42
Trace Elements							
Arsenic, µg/l				90	1000		
Barium				0.1	2.0		
Boron				0.06	~ 5		
Cadmium, µg/l							
Copper				0.1	0.2		
Cyanide, µg/l							
Fluoride				0.35	7		0.10
Lead				0.7	0.2		
Mercury, µg/l				< 10	< 10		
Molybdenum				0.3	0.1		
Selenium				0.04	0.1		
Silver							
Zinc				0.2	0.4		
Other							
Alkalinity, g/l							
Ash							
pH							
Nitrates							
Nitrites							
Phosphate				0.58			0.75
Total Suspended Solids							
Total Sulfur				3	> 10		
Total Nitrogen, g/l	20.1	26.5	28.4	31.4		9.7	
Total Carbon, g/l	30.9	25.9	20.6	39.0		10.1	11.4
Antimony							
Chromium				0.07	0.3		
Cobalt				< 0.01	< 0.04		
Lithium				0.02	1.0		
Manganese				0.2	0.3		
Nickel				0.1	0.2		
Silicon				4	> 10		
Strontium				0.1	3.0		
Titanium				0.9	0.3		
Vanadium				< 0.01	0.03		
Uranium				0.03			

All data in mg/l unless otherwise noted.

TABLE 2.2

PRODUCT WATER

BULK PROPERTIES (%)

Date	Source	C	H	N	S	Min CO_2	H_2S	NH_3	N[1]	Comments
5-77	PAR	5.10	10.00	3.73	3.50	2.96			2	Instrument[2]
6-77		4.28	10.57	2.92	4.27	3.41			2	Instrument[2]
7-77		4.07	10.18	3.07	5.14	2.07			1	Instrument[2]
8-24-77	BNW	2.42	10.53	2.23					1	Instrument[2]
					3.90					INAA
8-25-77					5.1					
8-26-77					4.8					
8-77	PAR	2.99	10.52	2.13	3.47	2.78			3	Instrument[2]
9-77		4.52	10.53	3.00	2.74	4.10			3	Instrument[2]
9-77	CSM				3.14				1	Precip.
						2.23				Titr.
10-77	PAR	4.65	9.87	2.93	3.84	4.53			3	Instrument[2]
11-15-77	BNW				4.8				1	INAA
11-16-77					4.6					
11-17-77					2.2					
11-77	PAR	4.27	10.17	2.80	4.43	4.50			3	Instrument[2]
12-77		2.42	10.60	2.57	4.46	3.89	< 0.01	3.22	2	Instrument[2]
1-4-78		3.58	10.15	2.43	4.44	4.44	< 0.01	2.57	1	Instrument[2]
2-78		5.48	10.83	2.96	3.88	3.48	< 10 ppm	3.54	1	Inst[2], H_2S Color
4-78		3.98	10.62	1.66	3.93	0.82			4	Instrument[2]
5-78		7.35	9.97	3.84	5.70	4.65			3	Instrument[2]
6-78	CSM[3]				3.08				3	Precip.
						2.22			3	Titr.
6-78	CSM[3]				2.78				4	Precip.
						4.35			4	Titr.
6-78	PAR	5.88	9.12	6.12	6.37	6.80			10	Instrument[2]
7-78	CSM[3]				2.74				4	Precip.
						2.50			4	Titr.
7-78	CSM[3]				2.94				4	Precip.
						3.97			3	Titr.
7-78	PAR	4.82	10.21	3.89	4.33	2.24			12	Instrument[2]
8-78		6.10	10.04	4.40	4.37	2.99			13	Instrument[2]
9-78		8.06	6.66	5.64	6.49	1.00				Instrument[2]

Notes: (1) Number of analyses - mean reported.
(2) Paraho - CHN - P.E. 240 Elemental Analyzer, S - Leco Sulfur, Min. CO_2 - CO_2 Coulometer, H_2S Titrimeter, NH_3 Colorimeter.
(3) CSM - sample taken after 8 hours in holding tank during 9-77.

TABLE 2.3

PRODUCT WATER

Major Inorganics (ppm)

Date	Source	Al	Cl	Ca	Fe	Mg	K	Na	$SO_4^{=}$	Si	Total Dissolved Solids	Comments
8-24-77	BNW	< 100		< 100	< 100	< 100	< 100	< 100		< 100		INAA
		< 0.4	36	38.4	3	460	38	106/115				INAA
					1.5		17	111		44		AA
										37		PES
8-25-77	BNW	0.26	65	2000	1.8	220	< 20	104/103				INAA
				35.9		258	8	112		25		AA
										22		PES
					2.6							XRF
8-26-77	BNW	0.7		64	4.2	960	65	39.6				INAA
										23		PES
										24		AA
1977 Samples: 1-4-78	PAR	< 1		23.8	4.5	400	3.2	215		48		AA
									15000		119.4	Precip.
6-1-78	PAR	< 1		0.30	8.4	680	18.6	340		16		AA)Four Analyses
			81									Titr.)on one Sample
									3300		148.1	Precip.
6-78	CSM(1)								226/152)			Precip.
									221/136)			Precip.
6-78	CSM(1)								293/246)			Precip.
									299/242)			Precip.
7-78	CSM(1)								202/148)			Precip.
									197/157)			Precip.
7-78	CSM(1)								304/257)			Precip.
									312/272)			Precip.
11-15-77	BNW	< 1		43	1.9	870	< 30	335				INAA
										34		PES
										35		AA
11-16-77	BNW	< 2	71	42	1.9	790	< 30	316				INAA
										20		PES
										28		AA
11-17-77	BNW	0.4	1.6	41	< 7	320	< 10	73				INAA
										36		PES
					5.4			70		41		AA
					2.1							XRF
9-78	GE-TEMPO			30.3	3.0	1190	67.5	521				AA
									8500			Turbidimetric
12-13-78	GSRI	0.8	1	18	28	16	17	4		12		

Note: (1) CSM - Sample taken after 8 hours in rundown tank

TABLE 2.4

PRODUCT WATER

Trace Elements (ppm)

Date	Source	As	Ba	B	Cd	Cu	CN	F	Pb	Hg	Mo	Se	Ag	Zn	Comments
6/1/77	PAR	9	< 0.5	30	0.30	0.18	8.8	3.8	< 1		3	< 1	< 0.2	1.02	AA;CN, Color
8-24-77	BNW	5.5				< 1		2.6				9.5		0.44	INAA
		4.9				0.7			< 0.4	< 0.4	0.14	8.8		0.36	XRF
		6.9		43							0.15	11		0.15	PES
						0.66				0.0023				0.42	AA
8-25-77	BNW	4.7				0.8		1.4				4.0		0.39	INAA
		3.8				0.8			< 0.2	< 0.3	0.11	3.4		0.39	XRF
		3.1		2.1							0.30	1.5		0.24	PES
						0.91				0.0058				0.21	AA
8-26-77	BNW	5.0	0.8			0.50						4.0		1.26	INAA
		3.9				0.53			< 0.2	< 0.3	0.10	3.4		0.87	XRF
		4.3		13							0.07	3.8		1.08	PES
														1.02	AA
9-9-77	GE-TEMPO	22.2	0.4			2.6		43	0.4			7.9		1.5	AA
11-15-77	BNW	18.2	< 3			7.3		36				6.6		0.73	INAA
		15.1				5.5			< 0.3	< 0.5	0.52	6.8		0.80	XRF
		18.0		43							0.50			1.01	PES
						7.5				0.0056				0.87	AA
11-16-77	BNW	15.2	3			11.8		33		< 0.008		5.4		7.0	INAA
		10.8				7.7			< 0.3	< 0.5		6.5		6.7	XRF
		13.0		36							0.43	8.3		7.5	PES
						10.4				0.0063				8.5	AA
11-17-77	BNW	6.5	< 3			< 0.3		16						0.07	INAA
		4.9				0.5			< 0.3	< 0.4	0.10	4.1		< 0.2	XRF
		5.6		16							0.007	4.2		0.12	PES
												3.9		0.06	AA
12-13-77	GSRI	6	0.3	0.2	< 0.2			0.8	0.3		0.3	0.2	< 0.2	0.5	
1-4-78	PAR	9	< 0.5	40	0.13	2.5	1.6	0.1	3.5		0.7		0.4	0.62	AA;CN, Color

Note: All Hg by ISE

TABLE 2.5

PRODUCT WATER

ORGANIC ANALYSIS

Date	Source	Chemical Oxygen Demand	Organic Carbon %	Phenol ppm	N[1]	Comments
5-77	PAR		4.29[2]		2	
6-77	PAR		3.35		2	
7-77	PAR		3.51		1	
8-77	PAR		2.23		3	
9-77	PAR		3.40		3	
10-77	PAR		3.41		3	
11-77	PAR		3.04		3	
12-77	PAR		1.36		2	
1-4-78	PAR	7.62			1	T-dichromate
			2.37			
				8.0		C-aminoanti-pyrene
2-78	PAR		4.53		1	
4-78	PAR		3.76		4	
5-78	PAR		6.08		3	
6-1-78	PAR	7.53			1	T-Dichromate
			4.20			
				0.12		C-aminoanti-pyrene
6-78	PAR		4.03		10	
7-78	PAR		4.21		12	
8-78	PAR		5.28		13	
8-78	BNW		3.89		1	
9-78	PAR		7.79		1	

Note: (1) N - number of analyses - mean reported.

(2) Calculated by difference; (total carbon) - (12/44 x Min CO_2).

TABLE 2.6

PRODUCT WATER

MISCELLANEOUS DATA

Date	Source	Alkalinity as $CaCO_3$	pH
9-77	CSM (4)		8.88
9-77	CSM		8.80
11-15-77	BNW		8.5
11-16-77	BNW		8.55
11-17-77	BNW		8.60
1-4-78	PAR (1)	2.95 (2)	8.5 (3)
6-1-78	PAR	1.99	8.4
6-78	CSM (4)	3.60	9.16
6-78	CSM	3.60	9.15
6-78	CSM	3.30	8.78
6-78	CSM	3.81	8.75
6-78	CSM	3.09	8.97
6-78	CSM	2.84	9.07
6-78	CSM	2.64	8.63
6-78	CSM	7.80	8.68
7-78	CSM (4)	3.52	8.86
7-78	CSM	3.53	8.63
7-78	CSM	3.65	8.64
7-78	CSM	3.53	8.54
7-78	CSM	2.97	8.60
7-78	CSM	3.08	8.80
7-78	CSM		8.60
7-78	CSM		8.68
8-78	BNW		8.6

Note: (1) PAR 1-4-78 phosphate < 1 ppm, total suspended solids 168 ppm
PAR 6-1-78 phosphate < 0.1 ppm

(2) Alk. by titration.

(3) pH meter.

(4) CSM - sample taken after 8 hours in holding tank during 9-77.

WATER QUALITY

PARAHO OPERATIONS

TABLE 2.7

EVAPORATION POND

Major Inorganics

Date	Lab	TDS Method	TDS g/l	Al Method	Al mg/l	Cl (Total) Method	Cl (Total) mg/l	Ca Method	Ca mg/l	Fe Method	Fe mg/l	Mg Method	Mg mg/l	K Method	K mg/l	Na Method	Na mg/l	Sulfate Method	Sulfate mg/l
7/22/74	RMT	Grav.	0.9	AA	1.3			AA	33	AA	0.29	AA	33	FES	9	FES	150	Titr.	600
7/29/74	RMT	Grav.	1.5	AA	0.7	Titr.	61	AA	96	AA	0.07	AA	96	FES	41	FES	238	Titr.	1000
8/5/74	RMT	Grav.	1.5	AA	0.8	Titr.	70	AA	102	AA	0.09	AA	102	FES	35	FES	343	Titr.	1030
8/13/74	RMT	Grav.	1.5	AA	0.6	Titr.	46	AA	72	AA	0.10	AA	72	FES	24	FES	239	Titr.	770
10/74	RMT	Grav.	1.9	AA	0.3	Titr.	142	AA	60	AA	0.10	AA	104	FES	33	FES	289	Titr.	900
4/75	RMT	Grav.	1.0	AA	2.5	Titr.	170	AA	70	AA	0.40	AA	43	FES	27	FES	239	Titr.	280
7/75	RMT	Grav.	1.2	AA	0.7	Titr.	181	AA	80	AA	0.90	AA	51	FES	21	FES	258	Titr.	590
10/75	RMT	Grav.	1.4	AA	0.3	Titr.	227	AA	74	AA	0.20	AA	74	FES	18	FES	29	Titr.	680
3/76	TRW			SSMS	0.8	SSMS	2	SSMS	> 10	SSMS	5.0	SSMS	> 10	SSMS	> 10	SSMS	> 10		
	GE							AA	47	AA	< 0.05	AA	80.9	AA	20.9	AA	303	Turb.	110
10/77	PAR	Grav.	2.4	AA	0.10	Titr.	335	AA	92	AA	0.25	AA	77	AA	22	AA	310	Grav.	680
	NRL	Grav.	3.2	AA	< 0.5	ISE	2000	AA	88	AA	< 0.09	AA	66	FES	21	FES	310	Grav.	600
	CTE	Grav.	1.6	AA	≤ 0.1	ISE	120	AA	123	AA	0.53	AA	75	FES	23	FES	320	Grav.	249
11/77	PAR	Grav.	2.4	AA	0.30	Titr.	400	AA	100	AA	0.14	AA	78	AA	11	AA	280	Grav.	570
	NRL	Grav.	2.7	AA	< 0.05	ISE	250	AA	90	AA	0.15	AA	77	FES	24	FES	330	Grav.	770
	CTE	Grav.	1.2	AA	≤ 0.13	ISE	250	AA	100	AA	0.14	AA	77	FES	9	FES	286	Grav.	572
	BNW			INAA	< 0.8	INAA	223	PES	70	INAA	< 5	INAA	70	INAA	< 30	INAA	357		
								AA	198	XRF	< 1	PES	101	AA	24	AA	366		
										AA	2.1	AA	84						
12/77	PAR	Grav.	2.4	AA	0.17	Titr.	1100	AA	96	AA	0.24	AA	80	AA	23	AA	235	Grav.	610
	NRL	Grav.	2.7	AA	< 0.5	ISE	270	AA	93	AA	0.30	AA	75	FES	24	FES	320	Grav.	600
	CTE	Grav.	4.1	AA	≤ 0.13	ISE	660	AA	3	AA	≤ 0.02	AA	3	FES	24	FES	1016	Grav.	481
	GSRI			SSMS	0.2	SSMS	> 10	SSMS	> 10	SSMS	0.40	SSMS	> 10	SSMS	> 10	SSMS	≥ 4		
1/78	PAR	Grav.	0.6	AA	0.62	Titr.	260	AA	84	AA	1.24	AA	53	AA	6	AA	206	Grav.	410
2/78	PAR	Grav.	0.5	AA	< 0.2	Titr.	67	AA	24	AA	0.10	AA	22	AA	6	AA	81	Grav.	290
	NRL	Grav.	0.5	AA	< 1.0	ISE	50	AA	25	AA	< 0.1	AA	22	FES	3	FES	79	Grav.	180
	CTE	Grav.	0.5	AA	≤ 0.1	ISE	160	AA	23	AA	0.09	AA	21	FES	7	FES	81	Grav.	150
3/78	PAR	Grav.	1.6	AA	16	Titr.	140	AA	38	AA	0.70	AA	50	AA	6	AA	325	Grav.	520
	CTE	Grav.	1.4	AA	≤ 0.2	ISE	280	AA	52	AA	≤ 0.06	AA	66	FES	12	FES	57	Grav.	590
4/78	PAR	Grav.	2.1	AA	14	Titr.	228	AA	38	AA	0.50	AA	65	AA	6	AA	475	Grav.	750
	NRL	Grav.	2.8	AA	< 0.5	ISE	180	AA	67	AA	0.20	AA	65	FES	15	FES	160	Grav.	890
	CTE	Grav.	2.1	AA	≤ 0.3	ISE	417	AA	72	AA	0.10	AA	67	FES	18	FES	403	Grav.	790

WATER QUALITY

PARAHO OPERATIONS

TABLE 2.8

EVAPORATION POND

Organics

Date	Lab	Parameter			
		COD, mg/l	Oil & Grease, mg/l	Org. C, g/l	Phenols, ug/l
7/22/74	RMT	229	19		40
7/29/74	RMT	114	11		40
8/5/74	RMT	35	11		< 10
8/13/74	RMT	53	15		< 10
10/74	RMT	< 5	2		< 10
4/75	RMT	70	< 2		< 10
7/75	RMT	168	< 2		< 10
10/75	RMT	136	< 2		20
10/77	PAR	2070		1.7	420
	NRL	320		0.5	19
	CTE	1510		0.5	350
11/77	PAR	2210		1.5	410
	NRL	420		0.4	750
	CTE	1360		0.5	790
12/77	PAR	2000		0.13	490
	NRL	280		0.04	620
	CTE	1440		0.05	930
1/78	PAR	609		0.6	30
2/78	PAR	24		0.2	22
	NRL	20		0.03	25
	CTE	107		0.05	23
3/78	PAR	775		0.2	56
	CTE	719		0.06	35
4/78	PAR	748		0.2	193
	NRL	120		0.2	180
	CTE	565		0.2	264

Note: COD, T-dichromate; O & G, IR; Org C, instrument or calculated by difference; phenols, C-aminoantipyrene.

WATER QUALITY

PARAHO OPERATIONS

TABLE 2.9

EVAPORATION POND

Trace Elements

Date	Lab	As Method	As mg/l	Ba Method	Ba mg/l	B Method	B mg/l	Cd Method	Cd ug/l	Cu Method	Cu ug/l
7/22/74	RMT							AA	< 2	AA	10
7/29/74	RMT							AA	6	AA	< 10
8/5/74	RMT							AA	6	AA	10
8/13/74	RMT							AA	< 2	AA	20
10/74	RMT							AA	< 2	AA	90
4/75	RMT	H.G.	0.04			Color	0.2	AA	< 2	AA	20
7/75	RMT					Color	0.2	AA	< 2	AA	< 10
10/75	RMT	H.G.	0.04			Color	0.4	AA	< 2	AA	≤ 10
3/76	TRW	SSMS	1.0	SSMS	2.0	SSMS	5.0			SSMS	200
	GE	AA	< 1	AA	< 0.1					AA	< 10
10/77	PAR	AA	< 2	AA	0.31	AA	4	AA	60	AA	20
	NRL	AA	0.83	AA	< 0.5	AA	1.0	AA	15	AA	12
	CTE	AA	0.17	AA	0.4	AA	≤ 25	AA	18	AA	40
11/77	PAR	AA	< 2	AA	0.28	AA	2	AA	< 30	AA	10
	NRL	AA	0.8	AA	< 0.5	AA	2.0	AA	< 10	AA	5
	CTE	AA	1.2	AA	0.5	AA	≤ 11	AA	4	AA	40
	BNW	INAA	1.6	INAA	< 1	PES	0.76			INAA	< 2000
		XRF	1.2	PES	0.19					XRF	< 500
		PES	1.7							AA	< 20
12/77	PAR	AA	< 2	AA	0.30	AA	2	AA	< 30	AA	20
	NRL	AA	0.88	AA	0.5	AA	1.8	AA	< 10	AA	8
	CTE	AA	1.1	AA	0.10	AA	≤ 11	AA	≤ 3	AA	≤ 20
	GSRI	SSMS	2	SSMS	0.2	SSMS	0.3	SSMS	5	SSMS	20
1/78	PAR	AA	< 2	AA	0.05	AA	2	AA	< 30	AA	40
2/78	PAR	AA	< 2	AA	< 0.5	AA	0.2	AA	< 50	AA	10
	NRL	AA	0.05	AA	< 0.5	AA	0.2	AA	< 10	AA	6
	CTE	AA	≤ 0.04	AA	≤ 0.1	AA	0.16	AA	≤ 5	AA	≤ 20
3/78	PAR	AA	11	AA	2	AA	2	AA	< 70	AA	< 90
	CTE	AA	≤ 0.15	AA	≤ 0.12	AA	≤ 0.12	AA	≤ 3	AA	≤ 20
4/78	PAR	AA	8	AA	2	AA	2	AA	< 20	AA	< 90
	NRL	AA	0.31	AA	< 0.5	AA	< 0.5	AA	< 1	AA	2
	CTE	AA	0.27	AA	≤ 0.2	AA	≤ 0.2	AA	≤ 3	AA	20

TABLE 2.9 (Cont'd)

Date	Lab	Cyanide Method	Cyanide ug/l	F Method	F mg/l	Pb Method	Pb ug/l	Hg Method	Hg ug/l
7/22/74	RMT	Color	< 0.2	Color	1.3	AA	110	AA	4
7/29/74	RMT	Color	2.8	Color	2.4	AA	30	AA	5
8/5/74	RMT	Color	< 0.2	Color	2.3	AA	14	AA	2
8/13/74	RMT	Color	0.3	Color	2.2	AA	< 2	AA	< 1
10/74	RMT	Color	< 0.2	Color	2.8	AA	< 10	AA	6
4/75	RMT	Color	7	Color	4.5	AA	< 10	AA	< 0.2
7/75	RMT	Color	< 0.2	Color	1.7	AA	< 10	AA	< 0.2
10/75	RMT	Color	< 0.2	Color	2.5	AA	< 10	AA	14
3/76	TRW			SSMS	7	SSMS	200	SSMS	< 10
	GE			ISE	2	AA	< 100		
10/77	PAR	Color	11	ISE	4.9	AA	200	AA	< 5000
	NRL	Color	< 10000	ISE	2.5	AA	600	AA	10
	CTE	Color	25	ISE	2.0	AA	≤ 40	AA	3
11/77	PAR	Color	22	ISE	4.6	AA	200	AA	< 5000
	NRL	Color	< 10000	ISE	2.3	AA	55	AA	1.5
	CTE	Color	30	ISE	2.2	AA	≤ 40	AA	0.6
	BNW			AA	2.5	XRF	< 200	XRF	< 300
12/77	PAR	Color	23	ISE	2.4	AA	200	AA	< 5000
	NRL	Color	< 10000	ISE	2.2	AA	55	AA	1.4
	CTE	Color	≤ 10	ISE	1.4	AA	≤ 40	AA	0.15
	GSRI			SSMS	1	SSMS	20	AA	< 0.4
1/78	PAR	Color	3	ISE	0.8	AA	100	AA	< 5000
2/78	PAR	Color	360	ISE	1.2	AA	50	AA	< 7500
	NRL	Color	< 10000	ISE	0.7	AA	< 5	AA	0.2
	CTE	Color	≤ 10	ISE	0.6	AA	≤ 60	AA	≤ 2
3/78	PAR	Color	12700	ISE	1.3	AA	< 1000	AA	< 7000
	CTE	Color	≤ 10	ISE	1.3	AA	≤ 60	AA	≤ 0.2
4/78	PAR	Color	93000	ISE	1.5	AA	< 1000	AA	< 7000
	NRL	Color	< 50	ISE	1.4	AA	< 5	AA	0.2
	CTE	Color	41	ISE	1.6	AA	≤ 50	AA	0.2

TABLE 2.9 (Cont'd)

Date	Lab	Mo Method	Mo ug/l	Se Method	Se ug/l	Ag Method	Ag ug/l	Zn Method	Zn ug/l
7/22/74	RMT							AA	10
7/29/74	RMT							AA	10
8/5/74	RMT							AA	10
8/3/74	RMT							AA	10
10/74	RMT							AA	60
4/75	RMT	AA	< 200					AA	50
7/75	RMT	AA	< 200					AA	< 10
10/75	RMT	AA	< 200					AA	20
3/76	TRW	SSMS	100	SSMS	100			SSMS	400
10/77	PAR	AA	< 100	AA	< 100	AA	< 50	AA	20
	NRL	AA	< 20	H.G.	62	AA	30	AA	200
	CTE	AA	70	H.G.	2.7	AA	10	AA	20
11/77	PAR	AA	< 100	AA	< 100	AA	< 50	AA	30
	NRL	AA	< 20	H.G.	65	AA	2	AA	27
	CTE	AA	≤ 340	H.G.	10	AA	≤ 10	AA	30
	BNW	XRF	< 80	XRF	< 70			XRF	< 20
		PES	130	PES	< 200			PES	24
12/77	PAR	AA	< 100	AA	< 100	AA	< 50	AA	20
	NRL	AA	< 40	H.G.	66	AA	< 10	AA	23
	CTE	AA	≤ 340	H.G.	12	AA	10	AA	10
	GSRI	SSMS	70	SSMS	90	SSMS	< 2	SSMS	80
1/78	PAR	AA	< 100	AA	< 100	AA	< 50	AA	10
2/78	PAR	AA	50	AA	< 50	AA	< 10	AA	20
	NRL	AA	28	H.G.	6	AA	< 10	AA	22
	CTE	AA	≤ 600	H.G.	≤ 0.5	AA	≤ 20	AA	≤ 20
3/78	PAR	AA	< 500	AA	< 500	AA	< 60	AA	20
	CTE	AA	≤ 300	H.G.	≤ 0.6	AA	≤ 60	AA	8
4/78	PAR	AA	< 500	AA	< 500	AA	< 60	AA	20
	NRL	AA	50	H.G.	33	AA	< 1	AA	17
	CTE	AA	≤ 200	H.G.	0.02	AA	≤ 4	AA	20

WATER QUALITY

PARAHO OPERATIONS

TABLE 2.10

EVAPORATION POND

Other Parameters

Date	Lab	Alkalinity, $CaCO_3$ Method	Alkalinity, $CaCO_3$ mg/l	pH Method	pH Anal.	N, Total Method	N, Total mg/l	PO_4 as P Method	PO_4 as P mg/l	Sulfide as S Method	Sulfide as S mg/l	Si Method	Si mg/l
7/22/74	RMT	Titr.	163	Meter	7.7	Titr.	1.7	Color	0.08	Color	< 1	AA	4
7/29/74	RMT	Titr.	143	Meter	7.3	Titr.	2.0	Color	0.15	Color	< 1	AA	6
8/5/74	RMT	Titr.	179	Meter	8.1	Titr.	2.0	Color	0.13	Color	< 1	AA	2
8/13/74	RMT	Titr.	97	Meter	7.7	Titr.	0.8	Color	0.09	Color	< 1	AA	1.6
10/74	RMT	Titr.	189	Meter	7.3	Titr.	< 0.1	Color	0.05			AA	0.1
4/75	RMT	Titr.	104	Meter	7.7	Titr.	16.8	Color	0.20			AA	5.0
7/75	RMT	Titr.	115	Meter	7.4	Titr.	8.4	Color	< 0.01			AA	3.7
10/75	RMT	Titr.	165	Meter	7.7	Titr.	20.5	Color	< 0.01			AA	5.1
3/76	TRW											SSMS	> 10
	GE			Meter	7.9								
10/77	PAR	Titr.	806	Meter	8.4	Color	200	Color	< 1	Titr.	31	AA	6.4
	NRL			Meter	8.5	Color	280	Color	< 0.05	Titr.	18	AA	4.9
	CTE	Titr.	820	Meter	8.1	Color	60	Color	0.03	Titr.	6	AA	0.5
11/77	PAR	Titr.	850	Meter	8.2	Color	200	Color	< 1	Titr.	40	AA	6.3
	NRL			Meter	8.0	Color	280	Color	< 0.05	Titr.	34	AA	7.5
	CTE	Titr.	876	Meter	7.2	Color	260	Color	0.02	Titr.	51	AA	6.9
	BNW											PES	7.0
												AA	11
12/77	PAR	Titr.	840	Meter	7.9	Color	< 200	Color	< 1	Titr.	50	AA	6.4
	NRL			Meter	8.3	Color	280	Color	0.1	Titr.	79	AA	7.9
	CTE	Titr.	2855	Meter	11.4	Color	255	Color	0.07	Titr.	13	AA	3.1
	GSRI											SSMS	4
1/78	PAR	Titr.	240	Meter	7.9	Color	< 100	Color	< 1	Titr.	0.1	AA	2.4
2/78	PAR	Titr.	88	Meter	7.9	Color	< 100	Color	0.02	Titr.	0.4	AA	1.5
	NRL			Meter	7.9	Color	15	Color	< 0.05	Titr.	0.6	AA	1.4
	CTE	Titr.	111	Meter	8.3	Color	19	Color	0.06	Titr.	1.7	AA	1.4
3/78	PAR	Titr.	277	Meter	8.0	Color	114	Color	1.63	Titr.	0.8	AA	1.6
	CTE	Titr.	282	Meter	7.6	Color	56	Color	0.13	Titr.	4.6	AA	3.4
4/78	PAR	Titr.	444	Meter	8.4	Color	88	Color	0.54	Titr.	3.5	AA	3.6
	NRL			Meter	8.0	Color	75	Color	0.20	Titr.	16	AA	5.9
	CTE	Titr.	437	Meter	7.8	Color	100	Color	0.05	Titr.	10.2	AA	4.7

TABLE 2.10 (Cont'd)

Date	Lab	TSS Method	TSS mg/l	Cr Method	Cr mg/l	NH_3 as N Method	NH_3 as N	Nitrates as N Method	Nitrates as N	Total Sulfur Method	Total Sulfur mg/l
7/22/74	RMT	Grav.	7								
7/29/74	RMT	Grav.	14								
8/5/74	RMT	Grav.	8								
8/13/74	RMT	Grav.	19								
10/74	RMT	Grav.	27								
4/75	RMT	Grav.	48								
7/75	RMT	Grav.	18								
10/75	RMT	Grav.	27								
3/76	TRW			SSMS	0.3					SSMS	> 10
	GE			AA	< 0.03						
10/77	PAR	Grav.	73	AA	0.1	Color	190	Color	< 0.02	LECO	400
	NRL	Grav.	160	AA	0.1	Color	180	Color	< 0.05		
	CTE	Grav.	252	AA	0.1	Color	176	Color	4.2		
11/77	PAR	Grav.	47	AA	< 0.01	Color	169	Color	< 0.02	LECO	300
	NRL	Grav.	240	AA	0.8	Color	115	Color	< 0.05		
	CTE	Grav.	40	AA	0.07	Color	209	Color	≤ 1		
	BNW			XRF	< 0.2					INAA	140
12/77	PAR	Grav.	32	AA	0.01	Color	192	Color	< 0.02	LECO	400
	NRL	Grav.	44	AA	0.8	Color	150	Color	< 0.05		
	CTE	Grav.	592	AA	0.01	Color	213	Color	≤ 0.1		
	GSRI			SSMS	0.01					SSMS	> 10
1/78	PAR	Grav.	7	AA	0.03	Color	122	Color	< 0.02	LECO	< 300
2/78	PAR	Grav.	18	AA	< 0.05	Color	29	Color	< 0.02	LECO	< 300
	NRL	Grav.	36	AA	< 0.1	Color	8	Color	0.5		
	CTE	Grav.	53	AA	0.03	Color	12	Color	3.7		
3/78	PAR	Grav.	7	AA	< 0.1	Color	46	Color	< 0.02	LECO	340
	CTE	Grav.	44	AA	≤ 0.02	Color	44	Color	1.4		
4/78	PAR	Grav.	26	AA	< 0.1	Color	79	Color	< 0.02	LECO	240
	NRL	Grav.	24	AA	< 0.01	Color	68	Color	< 0.05		
	CTE	Grav.	35	AA	≤ 0.02	Color	86	Color	10.4		

TABLE 2.11

PROCESS WATER (ppm)

Recycle Gas Line Drain

Analyses	GE-TEMPO 9-9-77	GSRI 12-13-77	PAR 1-4-78	PAR 6-1-78
Aluminum		0.2	< 1	< 1
Arsenic	10.3	0.9	≤ 2	< 2
Barium	< 0.1	0.1	< 0.5	< 0.5
Boron		< 0.02	< 20	< 20
Cadmium		< 0.01	≤ 0.01	< 0.05
Calcium	13.7	4	2.8	21
Chromium	< 0.03	0.02	0.01	0.00
Copper	0.2	0.9	0.09	< 0.05
Iron	1.5	2	2.2	0.9
Lead	0.2	0.04	< 0.5	< 1
Magnesium	29.5	1	20	30
Mercury		4.8 ppb	< 5	< 7
Molybdenum		0.04	≤ 0.2	2
Potassium	2.4		0.82	2.1
Selenium	1.8	0.1	2	< 1
Silver		< 0.01	0.7	1.0
Sodium	27.6		11	60
Silicon		3	< 2	7
Zinc	0.1	0.6	0.02	0.03
Alkalinity as $CaCO_3$			19400	25000
Carbonates			13410	2514
Carbon, Total			7400	6970
Carbon, Organic			3740	6280
Chemical Oxygen Demand			1600	1850
Chloride		0.5	750	32
Cyanide			60.0	5.3
Fluoride	1.6	≃ 0.07	0.96	< 0.04
Hydrogen, Total			106900	
Nitrogen, Total			4900	5910
Nitrogen, Ammonia			5960	6985
Nitrogen, Nitrate			< 0.02	< 0.1
pH	8.9		8.9	9.0
Phenol			19.2	67
Phosphate, Total			< 1	< 0.1
Total Suspended Solids			9	< 0.02
Total Dissolved Solids*			3.3	11.9/9.3
Sulfur, Sulfate	1540		1400	460
Sulfur, Sulfide			< 1	< 0.01
Sulfur, Total			≤ 500	2570

* Values reported are for TDS after vacuum evaporation at ambient temperature and after evaporation at 180°C, respectively.

TABLE 2.12

PROCESS WATER

MISCELLANEOUS SITES

(ppm)

Date	Source	Sampled from	Alkalinity as $CaCO_3$	Nitrogen Ammonia	Sulfur Total	pH	Mercury
12-13-77	GSRI	Recycle Cond.					0.05 mg/g
9-77	CSM	Recycle Cond.				8.70	
6-78	CSM	Recycle Cond.	85500	25100		8.56	
7-78	CSM	Recycle Cond.	86500	23500	200	8.76	
9-77	CSM	Blower Cond.				8.95	
6-78	CSM	Blower Cond.	204000	21000		9.20	
7-78	CSM	Blower Cond.	516500	7400	100	8.94	

TABLE 2.13

PROCESS WATER

MISCELLANEOUS SITES - DATA FOR SAMPLE PAR-MINE DUST CONTROL WATER

Element	ppm	Element	ppm	Element	ppm	Element	ppm
Aluminum	>1	Fluorine	≈0.2	Neodymium	< 0.001	Strontium	2
Antimony	< 0.001	Gadolinium	< 0.001	Nickel	0.004	Sulfur	>6
Arsenic	0.005	Gallium	<0.001	Niobium	< 0.001	Tantalum	< 0.001
Barium	0.09	Germanium	< 0.001	Osmium	< 0.001	Tellurium	< 0.001
Beryllium	< 0.001	Gold	< 0.001	Palladium	< 0.001	Terbium	< 0.001
Bismuth	< 0.001	Hafnium	< 0.001	Phosphorus	MC	Thallium	< 0.001
Boron	0.02	Holmium	< 0.001	Platinum	< 0.001	Thorium	< 0.001
Bromine	0.03	Indium	STD	Potassium	MC	Thulium	< 0.001
Cadmium	.003	Iodine	0.002	Praseodymium	< 0.001	Tin	0.002
Calcium	MC	Iridium	< 0.001	Rhenium	< 0.001	Titanium	0.01
Cerium	0.002	Iron	3	Rhodium	< 0.001	Tungsten	< 0.001
Cesium	< 0.001	Lanthanum	0.002	Rubidium	0.009	Uranium	0.02
Chlorine	0.6	Lead	0.01	Ruthenium	< 0.001	Vanadium	0.003
Chromium	0.01	Lithium	0.03	Samarium	< 0.001	Ytterbium	< 0.001
Cobalt	< .001	Lutetium	< 0.001	Scandium	≤0.001	Yttrium	<0.001
Copper	0.03	Magnesium	MC	Selenium	0.005	Zinc	0.9
Dysprosium	< 0.001	Manganese	0.3	Silicon	0.8	Zirconium	0.005
Erbium	< 0.001	Mercury	NR	Silver	< 0.001		
Europium	< 0.001	Molybdenum	0.04	Sodium	>3		

NR - Not Reported

MC - Major Component

3.0 GROUND AND SURFACE WATER

3.1 General

Ground and surface water has been monitored routinely since the start of Paraho operations at Anvil Points in 1974. Thirty-seven parameters have been monitored during most of the operation. These parameters are listed in Table 1.1. and are grouped into four general categories: Major Inorganics, Organics, Trace Elements, Other.

At times, groundwater sampling was carried out in all available Anvil Points drainages. These are shown in Figure 3.1, which has been traced from the USGS Anvil Points quadrangle map. Approximate sample sites are marked A-F. The drainage, labeled "Amphitheater" in Figure 3.1, contains the canyon which lies immediately east of the Paraho retorting operations and the shale disposal area used since the USBM research were begun nearly 35 years ago. This canyon was monitored for ground and surface water throughout the Paraho operations. This monitoring is continuing. Figure 3.2 shows the approximate sampling sites and the depth of the alluvium wells. Because of the need to indicate both detail and distance, Figure 3.2 is a sketch of the Amphitheater drainage area. We have chosen the term "drainage" because the stream located in the bottom of the canyon does not, in normal years, flow throughout the calendar year. The flow represents drainage from snowmelt for the most part and, at times, runoff from storms. These conditions have a pronounced effect on the water quality in a semi-arid region such as Anvil Points.

Ground and surface water data represent perhaps the largest environmental data base obtained during the recent Paraho operations at Anvil Points. These data, arranged in 34 tables, are grouped in this compilation into the four categories described in Table 1.1. In order to better evaluate this cumbersome data base, the individual results, listed in the 34 tables, have been arranged and presented in figures showing the mean values, for upper and lower sites (see Fig. 3.2), for both ground and surface water, over the four-year period from 1974 through 1978. Only those parameters which have been

monitored throughout this period are presented in these figures. Also, those parameters having concentrations below the detection limits of the analytical procedures have not been plotted in the figures. A total of 21 figures are presented.

Monitoring ground and surface water at Anvil Points is continuing. Data collected during 1979 will be compiled in an annual update, planned for 1980.

For the most part, samples were taken at the Anvil Points site and analyzed at the designated laboratories. All samples were obtained by bailing. For the first three years, samples were taken in polyethylene jars and sent directly, without any preservation, for analysis by Rocky Mountain Technology (RMT). Normally, these samples were received by RMT within 24 hours from sampling. After 1977, samples were refrigerated and stabilized (if necessary) before shipment for analysis. Six differing stabilization techniques are employed. They are:

Stabilization	Parameter
1. Glass, cool to 4°C	pH, most anions, total C,N, ans S, dissolved and suspended solids
2. Glass, 2 ml R.G. H_2SO_4/l, cool to 4°C	Ammonia, COD, nitrate
3. Glass, filter (0.45 um), 1.5 ml R.G. HNO_3/l, cool to 4°C	Cations or metals
4. Glass, 2 ml 1.0 N zinc acetate, NaOH to pH > 12, cool to 4°C	Sulfide

5. Plastic, R.G. H_3PO_4 to pH < 4, 1 gm $CuSO_4$/l, cool to 4°C — Phenol

6. Plastic, NaOH to pH > 12, cool to 4°C — Cyanide, Silicon

3.2 Ground and Surface Water - Amphitheater

Samples obtained from this location were taken from the intermittent stream flowing in that canyon and alluvium wells dug in that area (see Fig. 3.2). Samples were taken quarterly, as available, from all sites. Drought, freezing weather, and heavy snow cover prevented sampling during all quarters. Wells 3 and 4, located along the stream bed below the shale disposal area, were not drilled until Aug.-Sept. 1974; Well 2 in that same region was dry until 1978. During a flood in mid-1977, Well 1 was temporarily buried and the well head at Well 3 was broken by rocks, silt, and debris.

Major Inorganics. Parameters which are representative of, or possible contributors to, major inorganics are listed in Tables 3.1-3.9. Below is a compilation of the results from the major inorganic parameters:

Parameter	Surface Water		Groundwater	
	Above	Below	Above	Below
Total Dissolved Solids	1.2	1.7	1.6	3.4
Aluminum	7.7	9.0	2.0	2.3
Chlorine (Total)	8.2	27.8	12.4	75
Calcium	83	116	168	270
Iron	6.0	13.5	1.2	2.2
Magnesium	81	99	111	171
Potassium	4.0	17.0	10.9	23.8
Sodium	188	325	361	863
Sulfate (as S)	206	345	311	616

All results are expressed in milligrams/liter (except TDS in grams/liter). "Above" indicates Stream N or Well 1 above the shale disposal area (see Fig. 3.2); "Below" indicates Stream S or a mean of Wells 2, 3, and 4 below the shale disposal area (see Fig. 3.2). All data are included in the foregoing compilation. The compiled data have been checked to see if the sum of the ions

contributing to major inorganics approximates the total dissolved solids data and if the overall solution approximates electroneutrality. In both cases (total solids and electroneutrality), the percent error of these data checks would be less than 10%. This would indicate that the data are valid. Since the carbonate/bicarbonate data were not available, no quantitative assessment can be made.

Most of the parameters listed in Tables 3.1 - 3.9 show wide variations; calcium seems to be uniquely constant with time. All parameters, when compiled, show some increase when comparing the sites below the retorting and disposal area with those above. This increase was present, for the most part, in the data obtained in mid-1974 before Paraho retorting operations were underway. Total chlorine shows the biggest increase, from 3.4 to 6.0 times as much below the site as above. This increase is also seen in the free chlorine data which may indicate a leak of treated drinking water into the canyon.

Organics. Four parameters were measured to determine organics in the ground and surface water (see Tables 3.10 - 3.13). These data (expressed in milligrams/liter) have been compiled into the following table:

	Surface Water		Groundwater	
Parameter	Above	Below	Above	Below
Chemical Oxygen Demand	42	36	23	72
Oil and Grease	7	11	13	5
Organic Carbon	30	52	54	297
Phenol	2.0	1.7	2.2	3.1

These data must be viewed with caution. First, all parameters vary widely with time and location. Second, in some cases only a few results were available; only 13 organic carbon results were obtained from five sites. Third, many of the results obtained were below the limit of detection; more than three-fourths of all the phenol data in Table 3.13 is listed as "less than". Although, for the most part, these data are quite variable, are few in number, and are below the detection limit, they do indicate no serious impact of organics from Paraho operations on ground and surface water.

Gulf South Research Institute measured semi-volatile organics by liquid-liquid extraction followed by GC/MS. They have detected some chlorinated organics: methylene chloride, 65 ppm; chloroform, 9 ppm; carbon tetrachloride,

400 ppm. Since these are not naturally occurring species and are not used in nor produced by the retorting process, it would appear that they represent laboratory contamination. Other organics detected include: benzene, 2 ppm; toluene, < 1 ppm; some alkylated (C_{3-4}) pyridines (tentative); $C_9H_{10}NO$ (tentative). These compounds, also probably represent laboratory contamination.

Trace Elements. Thirteen potentially toxic materials have been monitored in ground and surface water in the Amphitheater drainage in the canyon east of the Paraho retorting operations (see Tables 3.14 - 3.26). Not all these parameters have been monitored since the start of operations. Others have been added to the list suggested by the consulting analytical laboratory, Rocky Mountain Technology (Golden, CO). The thirteen parameters discussed in this section, while not comprehensive, do include those trace elements that may be present in regional waters or that could be released from oil shale retorting. Results from Tables 3.14 - 3.26 have been averaged as follows:

	Surface Water		Groundwater	
Parameter	Above	Below	Above	Below
Arsenic, µg/l	5.3	4.8	1.2	4.9
Barium	0.3	0.8	1.5	0.3
Boron	0.2	0.4	0.2	0.8
Cadmium, µg/l	< 2	< 2	26.1	27.5
Copper	0.02	0.03	0.03	0.03
Cyanide, µg/l	< 0.2	< 0.2	< 0.2	< 0.2
Fluorine	1.4	1.9	1.0	1.3
Lead	0.02	0.02	0.02	0.05
Mercury, µg/l	1.3	1.8	2.0	1.7
Molybdenum	0.05	0.02	0.04	0.07
Selenium	< 1	< 1	< 1	< 1
Silver	< 1	< 1	< 1	< 1
Zinc	0.07	0.12	0.10	0.06

Unless noted otherwise, the concentrations are expressed in milligrams/liter.

These trace parameters were compiled in the same manner as the major inorganic and organic parameters. "Less than" values were assumed to be zero. Some of the methods used were not sensitive enough, resulting in large numbers of "less than" values. These "less than" values are not included in the means. No trends can be detected with time or location. Most of the compiled values were quite consistent. These trace element parameters did not appear to be affected by the retorting operations.

Other. Parameters which do not fall into the categories discussed previously (major inorganics, organics, or trace elements) are grouped into

Tables 3.27 - 3.34. The last table (Table 3.34) represents a collection of trace metals which have been monitored only a few times by a few laboratories. Results from Tables 3.27 - 3.33 are compiled as follows:

Parameter	Surface Water Above	Surface Water Below	Groundwater Above	Groundwater Below
Alkalinity, as $CaCO_3$	184	227	419	515
pH (pH Units)	8.0	8.0	7.5	7.5
Nitrogen, Total N	1.3	1.7	0.8	1.9
Phosphate, as P, ug/l	39	49	129	111
Sulfide, as S	< 1	1.8	< 1	< 1
Silicon	9.7	12.4	9.2	8.4
Total Suspended Solids	Varied	Varied	Varied	Varied

All compiled results are in milligrams/liter unless otherwise noted. Only total alkalinity and total nitrogen show increase when comparing the sites below the retorting-disposal areas with those above. The alkalinity (as $CaCO_3$) is higher in groundwater samples and pH is lower in those same samples. Most sulfide results were below limits of detection - those limits vary depending upon the laboratory and method. Total suspended particulates vary so widely -- both surface and groundwater -- that no means were compiled.

Data listed in Table 3.34 have not been compiled because there is only one to four results for any parameter at a particular site. Results from Table 3.34 indicate that the concentrations of the following parameters lie below their limits of detection: ammonia, antimony, and nitrate. Uranium concentrations are low (about 50 μg/l). Only lithium and total sulfur produce valid results. Lithium concentrations increase when comparing sites below and above the operations (0.07 to 0.48 mg/l, surface; 0.12 to 0.70 mg/l, ground). When comparing the total sulfur concentrations listed in Table 3.34 with sulfate sulfur listed in Table 3.9, it seems that the sulfur species in the ground and surface water in the Amphitheater drainage is essentially sulfate. Total sulfur and sulfate sulfur are compared in the following table:

		Sulfate S mg/l	Total S mg/l
Surface,	Above	206	223
	Below	345	300
Ground,	Above	311	313
	Below	616	682

This compiled table of valid data suggests that all the sulfur in these water samples exists as sulfate. The percentage of total sulfur as sulfate sulfur varies from 90.0 to 115.0%. The mean is 99.2%. This not only indicates that the total sulfur is sulfate; it also serves as a quality assurance for these data.

Although limited quality assurance procedures, such as the sulfate-total sulfur and those discussed under Major Inorganics, were employed, most of the data listed in Tables 3.1 - 3.34 have not been examined critically. All data judged to be valid by the reporting analytical laboratories are listed in these tables; none have arbitraily been eliminated in this data compilation.

3.3 Surface Water - Anvil Points Region

Researchers examining the quality of ground and surface water found in the Amphitheater drainage (in the canyon east of Anvil Points retorting and shale disposal operations) have attempted to relate the water quality to some recognized standard such as drinking water standards or distilled water standards. In an effort to obtain a better basis for comparison, the surface water obtained from the stream below the retorting-disposal area was compared with samples from other streams in the Anvil Points region (see Figure 3.1). Sample Site D in Figure 3.1 is the lower stream (Stream S) used to produce results listed in Tables 3.1 - 3.34. The data obtained from the streams are listed in Table 3.35. Sample Site A (see Figure 3.1), located in Balzac Gulch below the Anvil Points mine, was always dry; no samples were obtained.

In an effort to assess the results listed in Table 3.35, a collaborative statistical test (W. J. Youden, AOAC Annual Meeting, Washington D.C., 1962) was applied. This is a simple ranking system in which each site (n) is scored for each parameter (M). For this experiment "1" is the highest mean concentration and "5" is the lowest concentration. Mean overall score is $M(n + 1)/2$, or 111. Overall scores for the five sites are:

B	84.0
C	109.5
D	121.0
E	126.5
F	121.0

The concentrations of the 37 parameters in the 5 streams are not significantly different. Site D, the stream below the retorting-shale disposal area, is not significantly higher in overall concentrations than the other streams. Site E, the stream geographically removed from all Anvil Points oil shale operations, is not significantly lower than the other streams. The principal conclusion to be drawn from these comparisons is that the stream below the Paraho retorting operations does not differ from other streams in the vicinity or from the site located upstream of the operations.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.1

GROUND AND SURFACE WATER

Total Dissolved Solids, g/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	1.1	1.7	1.5			
6/26/74 AM	RMT	1.1	1.8	1.6			
6/26/74 Noon	RMT	1.1	1.7				
6/26/74 PM	RMT	1.4	1.9				
6/28/74	RMT	1.1	1.7				
7/22/74	RMT	1.5	0.8	0.9			
7/29/74	RMT	1.0	1.6	1.5			
8/5/74	RMT	1.1	1.6	1.5			
8/13/74	RMT	0.7	1.8	1.4			
10/74	RMT			1.6		2.6	4.2
1/75	RMT			1.9		2.3	4.0
4/75	RMT	1.2	1.4	1.6		2.2	3.8
7/75	RMT	1.0	1.2	1.8		2.4	3.6
9/75	RMT	1.5	2.3	1.6		2.2	3.1
10/75	RMT		1.7				
1/76	RMT	0.6	0.9	1.8		2.4	3.4
4/76	RMT			1.8			3.5
11/76	RMT			1.5		3.0	3.5
1/77	RMT			9.6		4.5	3.7
4/77	NRL			0.8		2.0	1.7
7/77	NRL			0.9		2.2	2.2
10/77	NRL						5.3
1/78	PAR				5.1		2.9
4/78	PAR	1.0	1.7	2.5	10.3		6.2
4/78	CTE		1.1				
6/78	USGS	0.8	1.1				
Fall 78	BNW	1.4	6.2	1.8	12.4		5.4

Method: Gravimetric Analysis

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.2

GROUND AND SURFACE WATER

Aluminum, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	0.1	0.1	2.6			
6/26/74 AM	RMT	0.7	0.1	1.8			
6/26/74 Noon	RMT	0.3	0.1				
6/26/74 PM	RMT	1.4	0.2				
6/28/74	RMT	0.6	0.1				
7/22/74	RMT	23.0	24.6	1.7			
7/29/74	RMT	6.8	3.8	0.4			
8/5/74	RMT	10.0	6.8	0.5			
8/13/74	RMT	6.2	5.3	0.8			
10/74	RMT			0.2		0.2	0.3
1/75	RMT			0.5		0.6	0.2
4/75	RMT	4.3	4.9	1.8		2.5	2.3
7/75	RMT	15.2	7.2	7.4		4.8	4.8
9/75	RMT	3.2	30.5	1.1		1.2	25.1
10/75	RMT		3.4				
1/76	RMT	36.0	68.0	1.5		0.3	0.2
4/76	RMT			0.2			0.4
11/76	RMT			< 0.1		0.2	0.2
1/77	RMT			< 0.1		< 0.1	< 0.1
4/77	NRL			≤ 0.1		≤ 0.1	≤ 0.1
7/77	NRL			5.0		2.5	2.0
10/77	NRL						< 0.5
12/77	GSRI						> 0.9
1/78	PAR				< 0.1		< 0.1
4/78	PAR	8.0	8.0	4.0	7.0		9.0
4/78	CTE		7.9				
6/78	USGS	0.03	< 0.02				
7/78	PAR	< 1	< 1				4.0
Fall 78	BNW	< 0.005	< 0.005	< 0.005	< 0.005		< 0.005

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.3

GROUND AND SURFACE WATER

Chlorine (Total Cl), mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	36	33	23			
6/26/74 AM	RMT	25	23	21			
6/26/74 Noon	RMT	10	40				
6/26/74 PM	RMT	12	21				
6/28/74	RMT	10	22				
7/29/74	RMT	3	7	3			
8/5/74	RMT	3	9	4			
8/13/74	RMT	2	10	3			
10/74	RMT			6		27	43
1/75	RMT			11		63	42
4/75	RMT	9	9	14		46	54
7/75	RMT	13	15	23		33	46
9/75	RMT	8	52	8		35	53
10/75	RMT		93				
1/76	RMT	6	16	4		55	49
4/76	RMT			9			55
11/76	RMT			17		96	79
1/77	RMT			20		134	77
4/77	NRL			0.06*		0.75*	0.60*
7/77	NRL			20		140	120
10/77	NRL						3200
12/77	GSRI						1
1/78	PAR				37		190
4/78	PAR	10	16	19	16		187
4/78	CTE		$\leq$ 2				
6/78	USGS	2	11				
Fall 78	BNW	4	94	6	25		163

* Free Chlorine

Method: T, silver nitrate

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.4

GROUND AND SURFACE WATER

Calcium, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	46	78	46			
6/26/74 AM	RMT	47	71	266			
6/26/74 Noon	RMT	42	62				
6/26/74 PM	RMT	47	73				
6/28/74	RMT	56	89				
7/22/74	RMT	81	90	102			
7/29/74	RMT	59	119	132			
8/5/74	RMT	102	125	260			
8/13/74	RMT	92	132	98			
10/74	RMT			110		126	283
1/75	RMT			197		215	371
4/75	RMT	114	124	151		183	290
7/75	RMT	113	123	182		212	276
9/75	RMT	273	197	164		189	144
10/75	RMT		94				
1/76	RMT	50	146	152		169	220
4/76	RMT			176			254
11/76	RMT			27		13	22
1/77	RMT			550		625	305
4/77	NRL	80	150	140		305	195
7/77	NRL			160		300	280
10/77	NRL						260
12/77	GSRI						> 10
1/78	PAR				343		400
4/78	PAR	83	65	180	240		348
4/78	CTE		144				
6/78	USGS	66	84				440
7/78	PAR	50	132				
Fall 78	BNW	97	215	108	419		420

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.5

GROUND AND SURFACE WATER

Iron, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	0.13	0.05	0.05			
6/26/74 AM	RMT	0.44	0.08	2.07			
6/26/74 Noon	RMT	0.39	0.08				
6/26/74 PM	RMT	1.18	0.35				
6/28/74	RMT	0.44	0.12				
7/22/74	RMT	20.7	24.8	1.24			
7/29/74	RMT	6.8	3.5	0.03			
8/5/74	RMT	10.1	7.1	0.09			
8/13/74	RMT	4.2	3.0	0.5			
10/74	RMT			0.2		0.2	0.6
1/75	RMT			0.3		0.1	1.7
4/75	RMT	111.0	113.0	1.0		2.0	2.4
7/75	RMT	17.0	6.7	7.2		7.2	17.0
9/75	RMT	3.0	25.0	1.1		0.7	19.0
10/75	RMT		1.8				
1/76	RMT	28.3	61.4	2.6		0.7	0.8
4/76	RMT			1.2			0.4
11/76	RMT			< 0.01		< 0.01	0.12
1/77	RMT			0.05		< 0.01	0.05
4/77	NRL			0.07		≤ 0.03	0.45
7/77	NRL			2.2		0.9	2.1
10/77	NRL						0.12
12/77	GSRI						2
1/78	PAR				0.12		1.32
4/78	PAR	3.23	2.86	1.85	2.12		2.73
4/78	CTE		6.1				
6/78	USGS	0.02	0.04				
7/78	PAR	< 0.5	< 0.5				2.3
Fall 78	BNW	< 0.03	< 0.03	< 0.03	< 0.03		< 0.03

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.6

GROUND AND SURFACE WATER

Magnesium, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	73	89	77			
6/26/74 AM	RMT	65	87	156			
6/26/74 Noon	RMT	69	84				
6/26/74 PM	RMT	76	96				
6/28/74	RMT	79	92				
7/22/74	RMT	59	87	73			
7/29/74	RMT	82	101	100			
8/5/74	RMT	81	88	107			
8/13/74	RMT	54	85	75			
10/74	RMT			91		93	193
1/75	RMT			100		94	150
4/75	RMT	65	68	89		82	145
7/75	RMT	74	85	102		101	155
9/75	RMT	273	197	164		189	144
10/75	RMT		66				
1/76	RMT	43	71	90		88	117
4/76	RMT			99			133
11/76	RMT			99		64	110
1/77	RMT			237		166	123
4/77	NRL			106		201	168
7/77	NRL			100		170	170
10/77	NRL						220
12/77	GSRI						> 10
1/78	PAR				277		257
4/78	PAR	75	102	142	275		255
4/78	CTE		76				
6/78	USGS	65	69				
7/78	PAR	70	120				270
Fall 78	BNW	75	223	109	326		226

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.7

GROUND AND SURFACE WATER

Potassium, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	7	36	7			
6/26/74 AM	RMT	9	18	23			
6/26/74 Noon	RMT	11	16				
6/26/74 PM	RMT	7	18				
6/28/74	RMT	11	27				
7/22/74	RMT	14	16	5			
7/29/74	RMT	7	18	7			
8/5/74	RMT	33	20	17			
8/13/74	RMT	5	12	9			
10/74	RMT			8		24	30
1/75	RMT			7		22	23
4/75	RMT	5	8	7		21	28
7/75	RMT	8	9	8		22	19
9/75	RMT	15	17	8		15	8
10/75	RMT		23				
1/76	RMT	19	31	9		28	24
4/76	RMT			7			22
11/76	RMT			13		54	34
1/77	RMT			45		50	28
4/77	NRL	7	7	8		7	8
7/77	NRL			6		37	20
10/77	NRL						22
12/77	GSRI						> 10
1/78	PAR				29		21
4/78	PAR	3	5	4	6		6
4/78	CTE		10				
6/78	USGS	3	5				
7/78	PAR	4	13				16
Fall 78	BNW	8	9	9	37		28

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.8

GROUND AND SURFACE WATER

SODIUM, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	167	319	208			
6/26/74 AM	RMT	172	287	493			
6/26/74 Noon	RMT	179	286				
6/26/74 PM	RMT	172	329				
6/28/74	RMT	186	334				
7/22/74	RMT	277	228	215			
7/29/74	RMT	125	261	186			
8/5/74	RMT	243	276	376			
8/13/74	RMT	143	365	214			
10/74	RMT			200		412	729
1/75	RMT			260		496	799
4/75	RMT	121	157	214		378	684
7/75	RMT	112	175	282		431	638
9/75	RMT	552	372	221		381	244
10/75	RMT		309				
1/76	RMT	83	148	214		367	564
4/76	RMT			227			615
11/76	RMT			570		271	702
1/77	RMT			1950		836	790
4/77	NRL	353	479	240		870	753
7/77	NRL			230		690	680
10/77	NRL						770
12/77	GSRI						> 2
1/78	PAR				2200		800
4/78	PAR	100	250	300	2500		1975
4/78	CTE		115				
6/78	USGS	100	150				
7/78	PAR	120	470				950
Fall 78	BNW	179	1200	253	2500		1000

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.9

GROUND AND SURFACE WATER

Sulfate as S, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	260	320	270			
6/26/74 AM	RMT	260	370	350			
6/26/74 Noon	RMT	270	380				
6/26/74 PM	RMT	330	380				
6/28/74	RMT	270	450				
7/22/74	RMT	100	200	130			
7/29/74	RMT	230	270	270			
8/5/74	RMT	250	300	340			
8/13/74	RMT	210	400	250			
10/74	RMT			250		460	890
1/75	RMT			330		470	750
4/75	RMT	92	150	260		470	670
7/75	RMT	206	320	260		470	700
9/75	RMT	350	410	230		420	540
10/75	RMT		290				
1/76	RMT	47	86	81		240	310
4/76	RMT			200			100
11/76	RMT			270		600	650
1/77	RMT			1300		810	680
4/77	NRL	240	570	310		790	740
7/77	NRL			270		840	840
10/77	NRL						900
1/78	PAR				880		670
4/78	PAR	70	250	190	280		260
4/78	CTE		160				
6/78	USGS	140	160				
Fall 78	BNW	280	1300	350			1200

Method: RMT, turbidimeter; others, gravimetry.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.10

GROUND AND SURFACE WATER

Chemical Oxygen Demand, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	5	15	15			
6/26/74 AM	RMT	25	20	10			
6/26/74 Noon	RMT	15	10				
6/26/74 PM	RMT	15	15				
6/28/74	RMT	< 5	< 5				
7/22/74	RMT	154	79	40			
7/29/74	RMT	114	31	79			
8/5/74	RMT	44	18	13			
8/13/74	RMT	13	31	13			
10/74	RMT			< 1		< 1	
1/75	RMT			44		20	128
4/75	RMT	78	74	28		32	112
7/75	RMT	22	29	29		63	90
9/75	RMT	33	60	7		21	69
10/75	RMT		26				
1/76	RMT	39	100	4		18	46
4/76	RMT			7			66
11/76	RMT			< 5		47	91
1/77	RMT			70		46	60
4/77	NRL			12		54	59
7/77	NRL			2		11	12
10/77	NRL						17
1/78	PAR				17		243
4/78	PAR	28	34	46	74		326

Method: T-dichromate

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.11

GROUND AND SURFACE WATER

Oil and Grease, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/26/74 AM	RMT	< 1	< 1	2			
6/26/74 Noon	RMT	< 1	3	13			
6/26/74 PM	RMT	19	9				
6/28/74	RMT	< 1	10				
7/22/74	RMT	25	60	40			
7/29/74	RMT	14	9	79			
8/5/74	RMT	10	18	13			
8/13/74	RMT	14	12	13			
10/74	RMT			2		4	7
1/75	RMT			8		9	14
4/75	RMT	< 3	< 3	< 3		< 3	< 3
7/75	RMT	< 3	< 3	< 3		< 3	< 3
9/75	RMT	< 3	< 3	< 3		< 3	< 3
10/75	RMT		34				
1/76	RMT	< 3	< 3	< 3		< 3	< 3
4/76	RMT			< 3			< 3
11/76	RMT			< 5		< 5	< 5
1/77	RMT			5		< 5	< 5
7/77	NRL			25		15	50
10/77	NRL						27
6/78	USGS		< 0.1				

Method: IR on $CHCl_4$ ext.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.12

GROUND AND SURFACE WATER

Organic Carbon, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
1/78	PAR				891		495
4/78	PAR	36	19	80	258		31
4/78	CTE		14				
Fall 78	BNW	23	122	27	33		71

Method: instrument or calc. by difference.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.13

GROUND AND SURFACE WATER

Phenols, ug/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	10	< 10	< 10			
6/26/74 AM	RMT	< 10	< 10	< 10			
6/26/74 Noon	RMT	< 10	< 10				
6/26/74 PM	RMT	< 10	< 10				
6/28/74	RMT	< 10	< 10				
7/22/74	RMT	< 10		< 10			
7/29/74	RMT	< 10	< 10	< 10			
8/5/74	RMT	< 10	< 10	< 10			
8/13/74	RMT	< 10	< 10	< 10			
10/74	RMT			< 10		< 10	
1/75	RMT			15		13	13
4/75	RMT	< 1	< 1	4		4	7
7/75	RMT	< 1	< 1	< 1		< 1	< 1
9/75	RMT	< 1	< 1	< 1		5	8
10/75	RMT		2				
1/76	RMT	20	20	10		10	20
4/76	RMT			< 1			3
11/76	RMT			< 1		< 1	< 1
1/77	RMT			< 1		< 1	< 1
4/77	NRL			< 2		< 2	< 2
7/77	NRL			< 3		< 3	< 3
10/77	NRL						< 5
1/78	PAR				< 0.1		< 0.1
4/78	PAR	< 1	< 1	< 1	< 1		< 1
4/78	CTE		6				
6/78	USGS		< 1				
Fall 78	BNW	< 50	< 50	< 50	< 50		< 50

Method: C-aminoantipyrene.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.14

GROUND AND SURFACE WATER

Arsenic, ug/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
4/75	RMT	4	< 2	4		6	36
9/75	RMT	4	6	< 2		< 2	3
10/75	RMT		3				
1/76	RMT	28	31	6		11	20
4/76	RMT			< 2			4
11/76	RMT			< 2		< 2	< 2
1/77	RMT			< 2		< 2	< 2
4/77	NRL			1.6		1.5	1.4
7/77	NRL			< 1		2	5
10/77	NRL						8
12/77	GSRI						20
1/78	PAR				< 2000		< 2000
4/78	PAR	< 2000	< 2000	< 2000	< 2000		< 2000
4/78	CTE		2				
6/78	USGS	1	1				
7/78	PAR	< 2000	< 2000				< 2000
Fall 78	BNW	< 5	< 5	< 5	< 5		< 5

Method: (PAR) AA.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.15

GROUND AND SURFACE WATER

Barium, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
12/77	GSRI						0.1
1/78	PAR				< 0.05		< 0.05
4/78	PAR	1	2	3	1		1
4/78	CTE		2				
6/78	USGS	0.1	0.1				
7/78	PAR	< 0.5	< 0.5				< 0.5
Fall 78	BNW	0.02	0.010	0.005	0.012		0.006

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.16

GROUND AND SURFACE WATER

Boron, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
1/75	RMT			0.4		0.6	0.4
4/75	RMT	0.2	0.2	0.6		2.8	3.7
7/75	RMT	0.4	0.6	< 0.2		0.6	0.4
9/75	RMT	0.7	0.7	< 0.2		0.6	< 0.2
10/75	RMT		< 0.1				
1/76	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
4/76	RMT			0.1			0.2
11/76	RMT			< 0.1		< 0.1	< 0.1
1/77	RMT			< 0.1		< 0.1	< 0.1
4/77	NRL			< 2		< 2	< 2
7/77	NRL			0.7		1.0	0.7
10/77	NRL						0.3
12/77	GSRI						0.07
1/78	PAR				5		4
4/78	PAR	< 15	< 15	< 15	< 15		< 15
4/78	CTE		0.2				
6/78	USGS	0.3	0.3				
7/78	PAR	< 20	< 20				< 20
Fall 78	BNW	0.3	1.8	0.4	0.2		0.5

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.17

GROUND AND SURFACE WATER

Cadmium, ug/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
10/74	RMT			< 2		< 2	
1/75	RMT			< 3		< 2	< 3
4/75	RMT	< 2	< 2	< 2		< 2	< 2
7/75	RMT	< 2	< 2	< 2		< 2	< 2
9/75	RMT	< 2	< 2	< 2		< 2	< 2
10/75	RMT		< 2				
1/76	RMT	< 2	< 2	< 2		7	12
4/76	RMT			9			10
11/76	RMT			< 10		< 10	< 10
1/77	RMT			270		110	50
4/77	NRL			30		50	110
7/77	NRL			30		30	60
10/77	NRL						46
12/77	GSRI						3
1/78	PAR				30		30
4/78	PAR	< 20	30	< 20	90		60
4/78	CTE		≤ 3				
6/78	USGS	1	3				
7/78	PAR	< 50	< 50				100
Fall 78	BNW	< 1	< 1	< 1	< 1		< 1

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.18

GROUND AND SURFACE WATER

Copper, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	0.01	0.01	0.05			
6/26/74 AM	RMT	0.01	0.01	0.11			
6/26/74 Noon	RMT	0.03	0.02				
6/26/74 PM	RMT	0.03	0.02				
6/28/74	RMT	0.01	0.01				
7/22/74	RMT	0.02	0.04	0.06			
7/29/74	RMT	0.01	0.01	0.05			
8/5/74	RMT	0.01	0.01	0.04			
8/13/74	RMT	0.01	0.01	0.06			
10/74	RMT			< 0.01		0.05	
1/75	RMT			< 0.01		< 0.01	< 0.01
4/75	RMT	0.13	0.13	0.02		0.02	0.04
7/75	RMT	0.01	< 0.01	0.01		0.02	0.04
9/75	RMT	0.05	0.05	0.02		0.02	0.06
10/75	RMT		0.02				
1/76	RMT	0.04	0.09	0.02		0.02	0.02
4/76	RMT			0.02			0.03
11/76	RMT			< 0.01		0.06	0.02
1/77	RMT			0.04		< 0.01	< 0.01
4/77	NRL			≤ 0.02		≤ 0.02	≤ 0.02
7/77	NRL			0.08		0.11	0.11
10/77	NRL						0.1
12/77	GSRI						0.03
1/78	PAR				0.04		0.03
4/78	PAR	< 0.09	< 0.09	< 0.09	< 0.09		< 0.09
4/78	CTE		0.02				
7/78	PAR	< 0.05	< 0.05				< 0.05
Fall 78	BNW	0.005	0.02	0.002	0.003		0.006

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.19

GROUND AND SURFACE WATER

Cyanide, ug/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	< 2	3	< 0.2			
6/26/74 AM	RMT	< 2	< 2	< 0.2			
6/26/74 Noon	RMT	< 2	< 2				
6/26/74 PM	RMT	< 2	< 2				
6/28/74	RMT	< 2	< 2				
7/22/74	RMT	0.5	0.5	< 0.2			
7/29/74	RMT	< 0.2	< 0.2	< 0.2			
8/5/74	RMT	0.4	< 0.2	< 0.2			
8/13/74	RMT	1.1	< 0.2	< 0.2			
10/74	RMT			< 0.2			
1/75	RMT			< 0.2		< 0.2	< 0.2
4/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
7/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
9/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
10/75	RMT		< 1				
1/76	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
4/76	RMT			< 1			< 1
11/76	RMT			< 1		< 1	< 1
1/77	RMT			< 2		< 2	< 2
4/77	NRL			< 0.2		< 0.2	1
7/77	NRL			< 10		< 10	< 10
10/77	NRL						< 10
1/78	PAR				< 25		< 25
4/78	PAR	< 25	< 25	< 25	< 25		< 25
4/78	CTE		≤ 10				
Fall 78	BNW	< 10	< 10	< 10	< 10		< 10

Method: RMT, C-pyrazolone; PAR, C-chloramine T.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.20

GROUND AND SURFACE WATER

Fluorine, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	1.1	1.4	0.8			
6/26/74 AM	RMT	0.8	1.4	1.1			
6/26/74 Noon	RMT	1.2	1.6				
6/26/74 PM	RMT	1.4	1.7				
6/28/74	RMT	1.0	1.6				
7/22/74	RMT	1.0	1.9	1.2			
7/29/74	RMT	0.9	1.8	1.3			
8/5/74	RMT	0.5	0.5	1.0			
8/13/74	RMT	0.6	2.1	1.2			
10/74	RMT			1.0		1.2	
1/75	RMT			1.6		2.0	1.8
4/75	RMT	9.8	7.3	3.0		3.6	2.5
7/75	RMT	0.5	0.8	0.8		1.2	1.2
9/75	RMT	1.0	1.7	1.0		1.3	1.2
10/75	RMT		2.7				
1/76	RMT	< 0.2	1.2	0.7		1.8	1.2
4/76	RMT			1.2			0.4
11/76	RMT			0.1		1.1	0.7
1/77	RMT			1.6		1.3	0.8
4/77	NRL			0.9		1.1	1.1
7/77	NRL			0.8		1.1	0.9
10/77	NRL						0.9
12/77	GSRI						0.3
1/78	PAR				1.0		1.1
4/78	PAR	1.0	1.4	1.0	0.9		1.1
4/78	CTE		1.0				
6/78	USGS	1.0	1.0				
Fall 78	BNW	0.9	3.8	0.7	0.7		0.8

Method: RMT, C-SPADNS; PAR, ISE.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.2I

GROUND AND SURFACE WATER

Lead, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	< 0.002	0.007	0.009			
6/26/74 AM	RMT	< 0.002	< 0.002	0.028			
6/26/74 Noon	RMT	0.004	< 0.002				
6/26/74 PM	RMT	0.024	0.006				
6/28/74	RMT	0.014	< 0.002				
7/22/74	RMT	0.014	0.130	0.008			
7/29/74	RMT	0.024	0.002	< 0.002			
8/5/74	RMT	0.027	0.091	0.002			
8/13/74	RMT	0.014	0.078	0.108			
10/74	RMT			< 0.01			0.05
1/75	RMT			< 0.01		< 0.01	< 0.01
4/75	RMT	0.13	0.13	0.02		0.02	0.04
7/75	RMT	0.01	< 0.01	0.01		0.02	0.04
9/75	RMT	0.05	0.05	0.02		0.02	0.06
10/75	RMT		< 0.01				
1/76	RMT	0.04	0.09	0.02		0.02	0.02
4/76	RMT			0.02			0.03
11/76	RMT			< 0.01		0.06	0.02
1/77	RMT			0.04		< 0.01	< 0.01
4/77	NRL			≤ 0.02		≤ 0.02	≤ 0.02
7/77	NRL			0.08		0.11	0.11
10/77	NRL						0.01
12/77	GSRI						0.02
1/78	PAR				0.4		0.3
4/78	PAR	< 1	< 1	< 1	< 1		< 1
4/78	CTE		≤ 0.03				
6/78	USGS	< 0.001	0.004				
7/78	PAR	< 1	< 1				< 1
Fall 78	BNW	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.22

GROUND AND SURFACE WATER

Mercury, ug/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	< 1	< 1	2			
6/26/74 AM	RMT	< 1	< 1	1			
6/26/74 Noon	RMT	4	< 1				
6/26/74 PM	RMT	2	5				
6/28/74	RMT	< 1	< 1				
7/22/74	RMT	4	5	5			
7/29/74	RMT	2	1.7	4			
8/5/74	RMT	< 1	< 1	2			
8/13/74	RMT	1	< 1	< 1			
10/74	RMT			6			4
1/75	RMT			< 0.2		< 0.2	0.5
4/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
7/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
9/75	RMT	6	6	10		12	14
10/75	RMT		5				
1/76	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
4/76	RMT			3			3
11/76	RMT			< 1		< 1	< 1
1/77	RMT			< 1		< 1	< 1
4/77	NRL			2.3		≤ 0.6	≤ 0.6
7/77	NRL			< 0.1		< 0.1	< 0.1
10/77	NRL						10
12/77	GSRI						< 0.4
1/78	PAR				< 5		< 5
4/78	PAR	< 7	< 7	< 7	< 7		< 7
4/78	CTE		6.6				
7/78	PAR	< 7	< 7				< 7

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.23

GROUND AND SURFACE WATER

Molybdenum, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
1/75	RMT			< 0.2		< 0.2	< 0.2
4/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
7/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
9/75	RMT	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2
10/75	RMT		< 0.2				
1/76	RMT	0.2	0.2	0.2		0.2	0.2
4/76	RMT			< 0.07			0.25
11/76	RMT			< 0.1		< 0.1	< 0.1
1/77	RMT			0.2		< 0.2	< 0.2
4/77	NRL			< 0.2		< 0.2	< 0.2
7/77	NRL			0.05		0.08	0.02
10/77	NRL						0.02
12/77	GSRI						0.03
1/78	PAR				< 0.1		< 0.1
4/78	PAR	< 0.5	0.8	< 0.5	1.0		< 0.5
4/78	CTE		0.20				
6/78	USGS	0.08	0.09				
7/78	PAR	< 2	< 2				< 2
Fall 78	BNW	0.10	0.94	0.07	0.06		0.03

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.24

GROUND AND SURFACE WATER

Selenium, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
12/77	GSRI						0.006
1/78	PAR				< 0.1		< 0.1
4/78	PAR	< 0.5	1.0	< 0.5	< 0.5		< 0.5
4/78	CTE		1				
6/78	USGS	10	10				
7/78	PAR	< 1	< 1				< 1
Fall 78	BNW	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.25

GROUND AND SURFACE WATER

Silver, ug/l

Date	Lab	Stream		Wells			
		North	South	1	2	3	4
12/77	GSRI						< 10
1/78	PAR				< 50		< 50
4/78	PAR	< 60	< 60	< 60	< 60		< 60
4/78	CTE		5				
7/78	PAR	< 200	< 200				< 200
Fall 78	BNW	< 1	< 1	< 1	< 1		< 1

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.26

GROUND AND SURFACE WATER

Zinc, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	< 0.01	< 0.01	0.06			
6/26/74 AM	RMT	0.02	< 0.01	0.14			
6/26/74 Noon	RMT	0.02	< 0.01				
6/26/74 PM	RMT	0.03	0.02				
6/28/74	RMT	0.01	< 0.01				
7/22/74	RMT	0.10	0.13	0.09			
7/29/74	RMT	0.03	0.03	0.10			
8/5/74	RMT	0.06	0.04	0.08			
8/13/74	RMT	0.04	0.03	0.05			
10/74	RMT			0.11		0.13	0.02
1/75	RMT			0.04		0.02	0.05
4/75	RMT	0.5	0.6	0.20		0.02	0.02
7/75	RMT	0.05	0.02	0.05		0.04	0.05
9/75	RMT	0.14	0.69	0.20		0.03	0.14
10/75	RMT		0.06				
1/76	RMT	0.15	0.32	0.06		0.03	0.04
4/76	RMT			0.20			0.04
11/76	RMT			0.01		0.03	0.03
1/77	RMT			0.18		0.13	< 0.01
4/77	NRL			0.20		0.03	0.02
7/77	NRL			0.08		0.05	0.11
10/77	NRL						0.4
12/77	GSRI						0.1
1/78	PAR				0.05		0.02
4/78	PAR	0.06	0.05	0.05	0.08		0.08
4/78	CTE		0.03				
6/78	USGS	0.01	0.01				
7/78	PAR	< 0.02	0.18				0.13
Fall 78	BNW	0.003	0.001	< 0.001	0.004		< 0.001

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.27

GROUND AND SURFACE WATER

Alkalinity as $CaCO_3$, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/26/74 AM	RMT	160	197	323			
6/26/74 Noon	RMT	167	195				
6/26/74 PM	RMT	169	167				
6/28/74	RMT	188	200				
7/22/74	RMT	273	202	163			
7/29/74	RMT	182	216	413			
8/5/74	RMT	245	236	352			
8/13/74	RMT	244	265	417			
10/74	RMT			459		401	540
1/75	RMT			478		359	350
4/75	RMT	241	257	356		350	508
7/75	RMT	238	211	399		380	499
9/75	RMT	299	312	341		354	522
10/75	RMT		381				
1/76	RMT	178	219	463		324	497
4/76	RMT			470			540
11/76	RMT			886		742	1033
1/77	RMT			806		827	1059
4/77	NRL			309		271	463
7/77	NRL			470		475	610
10/77	NRL						1500
1/78	PAR				410		505
4/78	PAR	228	252	410	383		503
4/78	CTE		266				
6/78	USGS	190	240				
Fall 78	BNW	49	48	18	8		8

Method: T-acid

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.28

GROUND AND SURFACE WATER

pH

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT		7.8				
6/26/74 AM	RMT	7.7	7.8	7.6			
6/26/74 Noon	RMT	7.9	8.0				
6/26/74 PM	RMT	8.0	7.9				
6/28/74	RMT	7.9	7.8				
7/22/74	RMT	7.9	7.9	7.6			
7/29/74	RMT	8.0	7.8	7.3			
8/5/74	RMT	7.9	7.9	7.3			
8/13/74	RMT	8.4	7.8	7.5			
10/74	RMT			7.3		7.5	
1/75	RMT			7.2		7.6	6.4
4/75	RMT	7.9	7.9	7.3		7.2	7.2
7/75	RMT	7.7	7.8	7.2		7.2	7.2
9/75	RMT	8.1	8.0	7.6		7.8	7.6
10/75	RMT		8.1				
1/76	RMT	7.4	7.4	6.8		7.0	7.1
4/76	RMT			7.6			7.8
11/76	RMT			7.5		7.5	7.3
1/77	RMT			7.6		7.8	7.4
4/77	NRL	7.6	8.2	8.3		7.4	7.4
7/77	NRL			7.3		7.6	7.5
10/77	NRL						7.7
1/78	PAR				7.6		7.2
4/78	PAR	8.4	8.5	7.2	7.4		7.1
4/78	CTE		8.7				
6/78	USGS	8.6	8.6				
Fall 78	BNW	8.4	8.3	8.1	8.3		7.9

Method: instrument

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.29

GROUND AND SURFACE WATER

Total Nitrogen, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	0.6	0.4				
6/26/74 AM	RMT	1.4	0.3	0.2			
6/26/74 Noon	RMT	0.2	0.4				
6/26/74 PM	RMT	0.6	0.6				
6/28/74	RMT	0.4	0.4				
7/22/74	RMT	3.6		2.6			
7/29/74	RMT	0.8	5.2	0.3			
8/5/74	RMT	0.8	1.2	0.3			
8/13/74	RMT	0.6	0.8	< 0.1			
10/74	RMT			0.8		1.6	
1/75	RMT			2.2		1.3	1.1
4/75	RMT	4.3	4.0	1.0		1.0	2.6
7/75	RMT	1.7	0.9	2.0		1.4	3.2
9/75	RMT	1.1	3.2	< 0.1		1.1	3.0
10/75	RMT		< 0.2				
1/76	RMT	0.9	2.5	< 0.1		0.4	1.5
4/76	RMT			0.7			2.3
11/76	RMT			1.0		1.6	2.7
1/77	RMT			< 0.1		< 0.1	3.1
7/77	NRL			< 0.1		2.1	2.1
10/77	NRL						3.0
1/78	PAR				< 100		< 100
4/78	CTE		4.2				

Method: Kjehdall, (PAR) instrument CHN Analyzer.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.30

GROUND AND SURFACE WATER

Phosphate as P, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	< 5	< 5	< 5			
6/26/74 AM	RMT	< 5	40	10			
6/26/74 Noon	RMT	< 5	< 5				
6/26/74 PM	RMT	10	60				
6/28/74	RMT	20	30				
7/22/74	RMT	90	60	40			
7/29/74	RMT	70	90	20			
8/5/74	RMT	70	60	20			
8/13/74	RMT	50	20	40			
10/74	RMT			< 10		< 10	
1/75	RMT			< 10		400	40
4/75	RMT	90	50	< 10		< 10	40
7/75	RMT	< 10	< 10	< 10		< 10	< 10
9/75	RMT	170	260	810		60	< 10
10/75	RMT		20				
1/76	RMT			120		50	70
4/76	RMT	1100	1700	270			120
11/76	RMT			< 20		40	80
1/77	RMT			20		20	< 20
4/77	NRL			30		40	40
7/77	NRL			600		200	200
10/77	NRL						< 50
1/78	PAR				< 1000		< 1000
4/78	PAR	< 10	< 10	10	< 10		< 10
4/78	CTE		40				
6/78	USGS	10	10				
Fall 78	BNW	< 400	720	470	750		620

Method: C-ammonium molybdate.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.31

GROUND AND SURFACE WATER

Sulfide as S, mg/l

Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 3	Wells 4
6/24/74	RMT	< 1.0	< 1.0	< 1.0			
6/26/74 AM	RMT	< 1.0	< 1.0	< 1.0			
6/26/74 Noon	RMT	< 1.0	< 1.0				
6/26/74 PM	RMT	< 1.0	< 1.0				
6/28/74	RMT	< 1.0	< 1.0				
7/22/74	RMT	< 1.0	< 1.0	< 1.0			
7/29/74	RMT	< 1.0	< 1.0	< 1.0			
8/5/74	RMT	< 1.0	< 1.0	< 1.0			
8/13/74	RMT	< 1.0	< 1.0	< 1.0			
10/74	RMT			< 0.05		< 0.05	
1/75	RMT			< 0.05		< 0.05	< 0.05
4/75	RMT	< 0.05	< 0.05	< 0.05		< 0.05	< 0.05
7/75	RMT	< 0.05	< 0.05	< 0.05		< 0.05	< 0.05
9/75	RMT	< 0.05	< 0.05	< 0.05		< 0.05	< 0.05
10/75	RMT		< 0.05				
1/76	RMT	4.7	17.9	3.8		1.0	4.7
4/76	RMT			< 0.05			< 0.05
11/76	RMT			< 0.05		< 0.05	< 0.05
1/77	RMT			< 0.05		< 0.05	< 0.05
4/77	NRL			0.41		0.43	0.38
10/77	NRL						< 1.0
1/78	PAR				0.04		0.53
4/78	PAR	< 0.2	< 0.2	0.7	0.3		1.5
4/78	CTE		13.7				
Fall 78	BNW	< 0.1	< 0.1	< 0.1	< 0.1		< 0.1

Method: RMT, C-methylene blue; P, T-iodine.

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.32

GROUND AND SURFACE WATER

Silicon, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/74	RMT	13	13	14			
6/26/74 AM	RMT	14	14	16			
6/26/74 Noon	RMT	15	13				
6/26/74 PM	RMT	16	14				
6/28/74	RMT	16	14				
7/22/74	RMT	13	11	11			
7/29/74	RMT	13	12	15			
8/5/74	RMT	10	9	10			
8/13/74	RMT	9	8	8			
10/74	RMT			7.4		7.9	
1/75	RMT			9.6		9.4	14.8
4/75	RMT	5.5	6.0	4.5		5.0	9.5
7/75	RMT	6.6	6.4	6.1		5.6	8.4
9/75	RMT	5.0	3.7	6.0		5.6	7.9
10/75	RMT		5.2				
1/76	RMT	< 5.0	< 5.0	11.8		7.3	11.7
4/76	RMT			11.9			18.9
11/76	RMT			13.2		12.6	15.9
1/77	RMT			10.4		7.7	18.2
4/77	NRL			7.0		6.0	10.0
7/77	NRL			4.0		4.0	7.0
10/77	NRL						3.8
12/77	GSRI						> 10.0
1/78	PAR				6.5		6.2
4/78	PAR	7.4	5.4	3.1	1.9		4.6
4/78	CTE		64.7				
6/78	USGS	15.0	14.0				
7/78	PAR	4.0	4.0				≤ 2.0
Fall 78	BNW	2.2	5.6	5.5	5.0		6.2

Method: AA

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.33

GROUND AND SURFACE WATER

Total Suspended Solids, mg/l

		Stream		Wells			
Date	Lab	North	South	1	2	3	4
6/24/64	RMT	15	13	105			
6/26/74 AM	RMT	28	9	134			
6/26/74 Noon	RMT	17	6				
6/26/74 PM	RMT	71	22				
6/28/74	RMT	28	12				
7/22/74	RMT	142	167	7			
7/29/74	RMT	496	295	38			
8/5/74	RMT	665	378	36			
8/13/74	RMT	246	170	24			
10/74	RMT			7		29	82
1/75	RMT			29		11	24
4/75	RMT	20200	15000	58		38	84
7/75	RMT	750	193	184		159	187
9/75	RMT	1046	1240	52		43	216
10/75	RMT		93				
1/76	RMT	1649	1869	97		40	31
4/76	RMT			27			10
11/76	RMT			44		13	15
1/77	RMT			161		25	26
4/77	NRL			798		2135	1908
7/77	NRL			94		64	60
10/77	NRL						48
1/78	PAR				15		16
4/78	PAR	147	340	710	217		135
4/78	CTE		880				

Method: Gravimetry

WATER QUALITY

PARAHO OPERATIONS

TABLE 3.34

GROUND AND SURFACE WATER

Miscellaneous Parameters

Parameter	Date	Lab	Stream North	Stream South	Wells 1	Wells 2	Wells 4
Ammonia as N, mg/l	1/78	PAR				1.3	2.8
	4/78	PAR	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	4/78	CTE		0.1			
	Fall 78	BNW	< 1.0	2.3	< 1.0	< 1.0	< 1.0
Antimony, ug/l	12/77	GSRI					< 1.0
	Fall 78	BNW	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Chromium, ug/l	12/77	GSRI					10
	1/78	PAR				10	20
	4/78	PAR	< 100	< 100	< 100	< 100	< 100
	4/78	CTE		20			
	6/78	USGS		< 1			
	7/78	PAR	< 50	< 50			< 50
	Fall 78	BNW	5	18	2	3	6
Lithium, mg/l	12/77	GSRI					0.9
	6/78	USGS	0.05	0.07			
	Fall 78	BNW	0.08	0.90	0.12	0.84	0.35
Manganese, ug/l	12/77	GSRI					10
	6/78	USGS	< 1	30			
	Fall 78	BNW	< 3	86	< 3	12	19
Nickel, ug/l	12/77	GSRI					20
	Fall 78	BNW	< 5	24	< 5	< 5	12
Nitrate as N, mg/l	1/78	PAR				< 0.02	< 0.02
	4/78	PAR	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	4/78	CTE		18.3			
	6/78	USGS	3.7	3.7			
Sulfur, Total S, mg/l	12/77	GSRI					> 6
	1/78	PAR					900
	4/78	PAR	220	300	300	210	100
	Fall 78	BNW	227	1320	326	2650	1220
Uranium, ug/l	12/77	GSRI					30
	Fall 78	BNW	< 20	50	22	150	50

Method: Ammonia, C-Nessler, ISE; Nitrate, C-Brucine; others, AA.

WATER QUALITY

PARANO OPERATIONS

TABLE 3.35

Special Stream Samples

Parameter	Date	Lab	Stream B	C	D	E	F
Aluminum, mg/l	10/75	RMT	1.6	2.0	3.4	2.2	1.4
	4/78	NRL	1.0	0.5			1.0
	4/78	CTE	0.6	0.65	7.9	4.8	0.49
	6/78	USGS	0.01		0.0		0.0
Arsenic, ug/l	10/75	RMT	4	3	3	2	1
	4/78	NRL	16	6			14
	4/78	CTE	18	7	2	1	18
	6/78	USGS	8		1		2
Barium, mg/l	4/78	CTE	≤ 0.17	0.21	≤ 0.17	≤ 0.15	≤ 0.15
	6/78	USGS	0.1				0.05
Boron, mg/l	10/75	RMT	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	4/78	NRL	1.6	1.1			1.4
	4/78	CTE	2.5	0.4	0.2	0.2	0.8
	6/78	USGS	1.6		0.3		0.14
Cadmium, ug/l	10/75	RMT	< 2	< 2	< 2	< 2	< 2
	4/78	NRL	≤ 20	≤ 20			≤ 20
	4/78	CTE	1	3	≤ 3	≤ 3	3
	6/78	USGS	2		3		2
Calcium, mg/l	10/75	RMT	80	80	94	80	70
	4/78	NRL	94	120			92
	4/78	CTE	87	116	144	93	89
	6/78	USGS	64		84		53
Chromium, ug/l	4/78	CTE	30	20	20	20	20
Copper, ug/l	10/75	RMT	20	40	20	20	30
	4/78	NRL	30	30			30
	4/78	CTE	20	20	20	20	20
Iron, mg/l	10/75	RMT	2.6	0.3	1.8	0.4	0.5
	4/78	NRL	0.2	0.1			0.2
	4/78	CTE	0.3	2.1	6.1	2.7	0.98
	6/78	USGS	< 0.04		0.04		0.0
Lead, ug/l	10/75	RMT	< 100	< 100	< 100	< 100	< 100
	4/78	NRL	30	30			30
	4/78	CTE	≤ 50	≤ 50	≤ 30	≤ 30	≤ 50
	6/78	USGS	< 1		4		2
Magnesium, mg/l	10/75	RMT	97	60	66	67	65
	4/78	NRL	86	87			82
	4/78	CTE	85	91	76	79	86
	6/78	USGS	100		69		46
Mercury, ug/l	10/75	RMT	7	5	5	4	3
	4/78	CTE	0.1	≤ 0.1	0.66	2.8	≤ 0.1
Molybdenum, mg/l	10/75	RMT	2.0	< 0.2	< 0.2	< 0.2	< 0.2
	4/78	NRL	0.55	0.45			0.51
	4/78	CTE	0.89	0.79	0.20	0.23	0.91
	6/78	USGS	0.59		0.09		0.03
Potassium, mg/l	10/75	RMT	10.5	7.1	23.2	4.2	3.7
	4/78	NRL	7.3	8.4			7.9
	4/78	CTE	12.2	14.4	9.7	10.8	13.1
	6/78	USGS	10.0		5.0		2.0
Selenium, ug/l	4/78	CTE	≤ 6	≤ 6	≤ 1	≤ 6	≤ 1
	6/78	USGS	12		10		6
Silver, ug/l	4/78	CTE	9	7	5	4	9
Sodium, mg/l	10/75	RMT	494	214	309	128	125
	4/78	NRL	480	480			480
	4/78	CTE	480	480	115	163	480
	6/78	USGS	680		150		98
Silicon, mg/l	10/75	RMT	6.1	5.0	5.2	5.5	6.6
	4/78	NRL	6.1	5.7			6.0
	4/78	CTE	10.1	10.5	64.7	37.5	9.8
	6/78	USGS	4.5		6.5		6.5
Zinc, ug/ml	10/75	RMT	50	60	60	60	130
	4/78	NRL	8	6			10
	4/78	CTE	20	20	30	20	20
	6/78	USGS	10		10		10

Method: See Tables 3.1 - 3.34.

TABLE 3.35 (Cont'd)

Parameter	Date	Lab	Stream B	C	D	E	F
Alkalinity as $CaCO_3$, mg/l	10/75	RMT	734	336	381	336	452
	4/78	NRL	450	420			440
	4/78	CTE	521	463	266	219	521
	6/78	USGS	540		240		210
Carbonates, mg/l	4/78	CTE	12	12	4.6	3.4	12
	6/78	USGS	65		12		13
Bicarbonates, mg/l	4/78	CTE	612	541	315	259	612
	6/78	USGS	230		270		530
Org. Carbon, mg/l	4/78	CTE	40	24	14	8	46
Chemical Oxygen Demand, mg/l	10/75	RMT	41.5	35.1	26.4	22.3	12.8
	4/78	NRL	13	10			13
	4/78	CTE	38.3	22.2	8.0	28.0	20.8
Chloride, mg/l	10/75	RMT	5	7	93	4	5
	4/78	NRL	4	3			4
	4/78	CTE	3	3.4	< 2	9.5	3.8
	6/78	USGS	5.3		11		2.3
Cyanide, ug/l	10/75	RMT	< 1	< 1	< 1	< 1	< 1
	4/78	NRL	< 50	< 50			< 50
	4/78	CTE	25	41	≤ 10	≤ 10	60
Fluoride, mg/l	10/75	RMT	2.7	0.6	2.7	0.8	1.0
	4/78	NRL	6.4	4.6			5.5
	4/78	CTE	5.4	4.1	1.0	0.9	5.1
	6/78	USGS	4.9		1.0		0.6
Nitrogen, Total, mg/l	10/75	RMT		0.8	< 0.2		< 0.2
	4/78	NRL	1.6	1.9			1.5
	4/78	CTE	25.8	7.9	4.2	3.5	13.3
Ammonia as N, mg/l	4/78	CTE	0.4	0.2	0.1	0.4	0.1
Nitrate as N, mg/l	4/78	CTE	10.9	12.5	18.3	17.8	10.4
	6/78	USGS	4.9		3.7		2.7
pH	10/75	RMT	8.4	8.2	8.1	8.0	7.9
	4/78	NRL	8.4	8.4			8.6
	4/78	CTE	9.0	8.8	8.7	8.7	9.1
	6/78	USGS	8.9		8.6		8.7
Phenol, ug/l	10/75	RMT	5	< 1	2	5	4
	4/78	NRL	9	9			6
	4/78	CTE	< 1	2.4	6.4	6.2	< 1
	6/78	USGS			0.0		
Phosphate as PO_4, ug/l	10/75	RMT	< 20	30	60	< 20	< 20
	4/78	NRL	300	100			200
	4/78	CTE	20	30	130	160	< 10
	6/78	USGS	30		30		30
Total Suspended Solids, mg/l	10/75	RMT	2	9	93	1	8
	4/78	NRL	180	74			160
	4/78	CTE	133	160	880	1143	118
Total Dissolved Solids, g/l	10/75	RMT	2.3	1.4	1.7	1.4	1.0
	4/78	NRL	2.1	2.2			2.0
	4/78	CTE	2.0	2.3	1.1	0.2	2.2
	6/78	USGS	2.5		1.0		0.1
Sulfate as SO_4, g/l	10/75	RMT	0.8	0.6	0.9	0.4	0.7
	4/78	NRL	1.1	1.3			1.1
	4/78	CTE	1.0	1.1	0.5	0.6	1.0
	6/78	USGS			0.5		
Sulfide, mg/l	10/75	RMT	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	4/78	NRL	< 5	< 5			< 5
	4/78	CTE	0.6	0.6	13.7	8.6	0.5
Oil and Grease, mg/l	10/75	RMT	37.0	24.4	33.6	37.2	11.4
	4/78	NRL	30	31			25

Methods: See Tables 3.1 - 3.34.

FIGURE 3.1

Anvil Points Streams

and Drainages

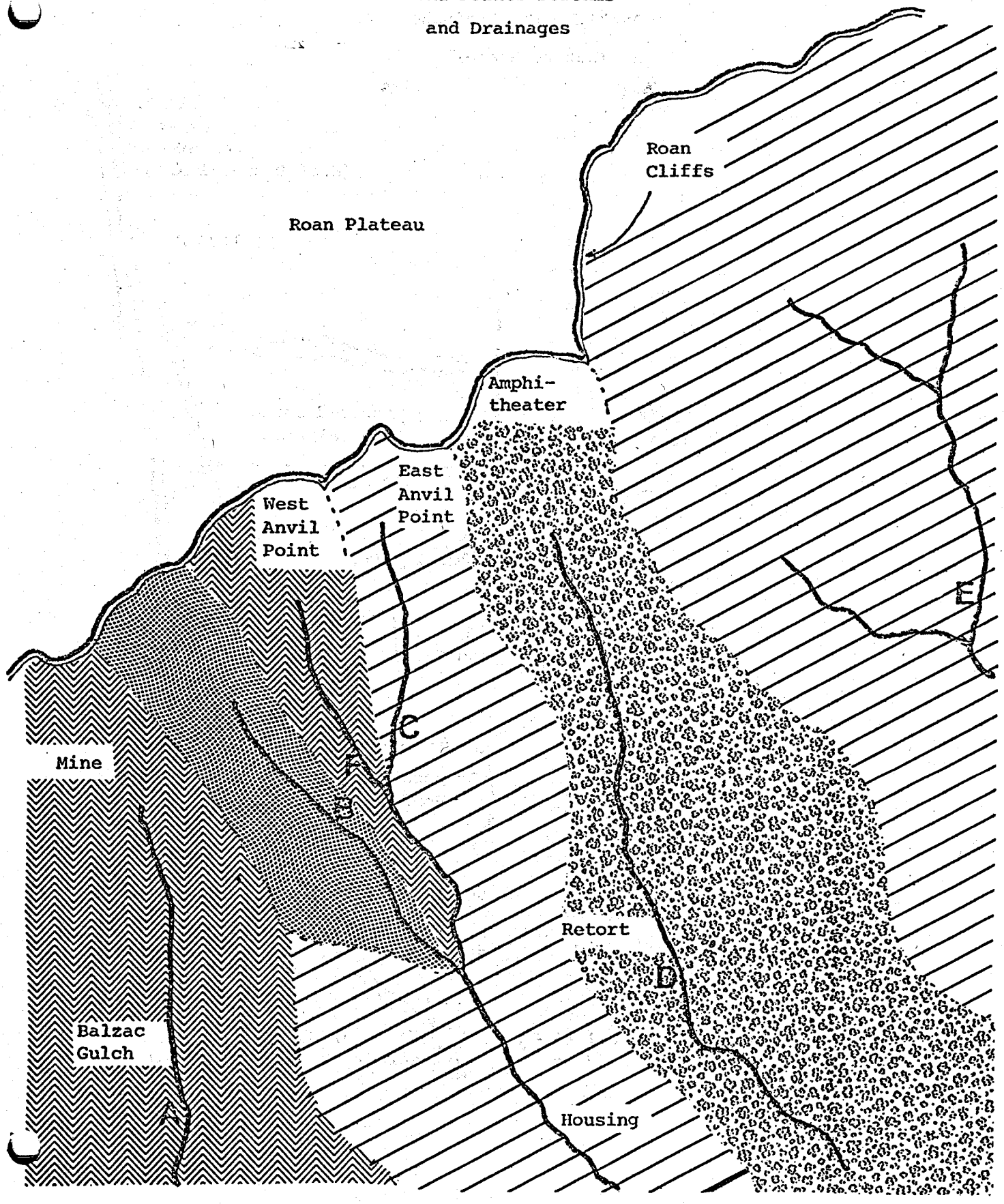


FIGURE 3.2

Ground and Surface Monitoring Sites

Amphitheater Drainage

(Not to Scale)

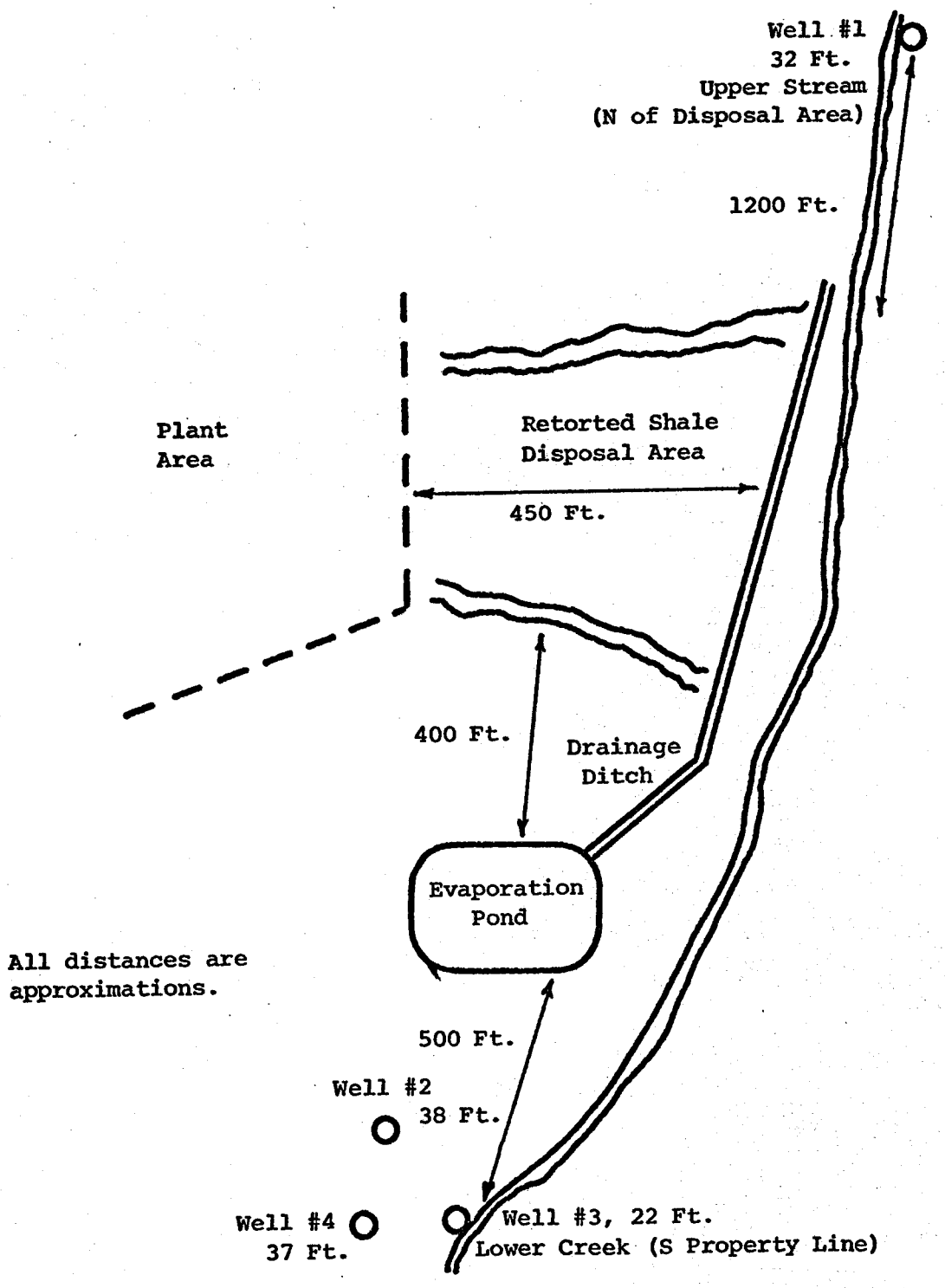
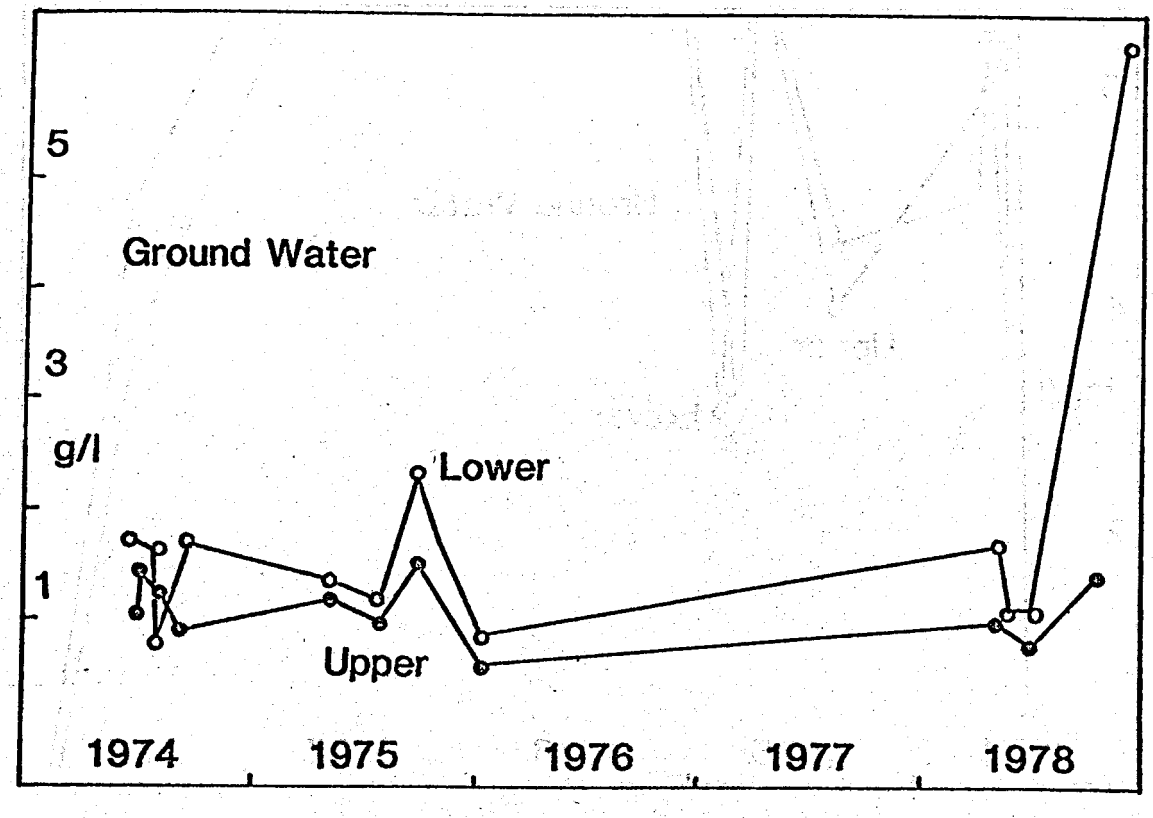


Figure 3.3
Total Dissolved Solids



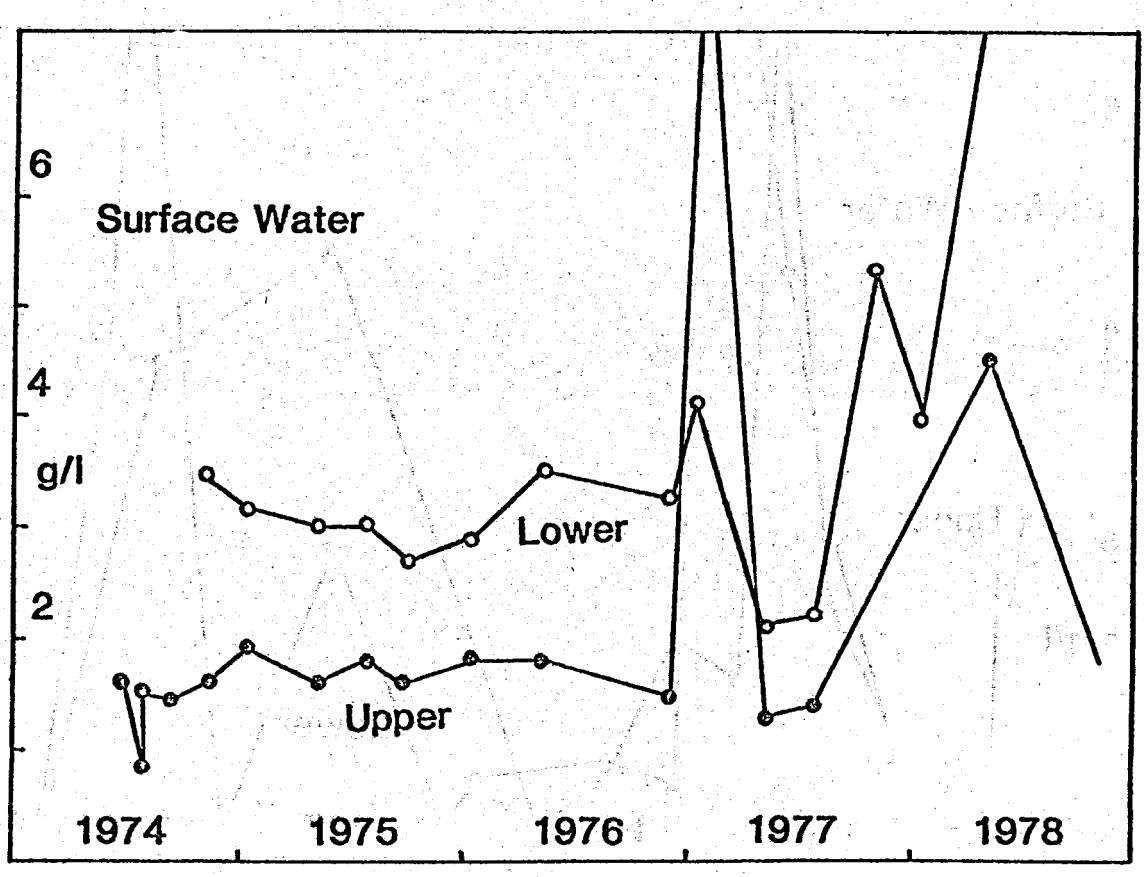


Figure 3.4
Aluminum

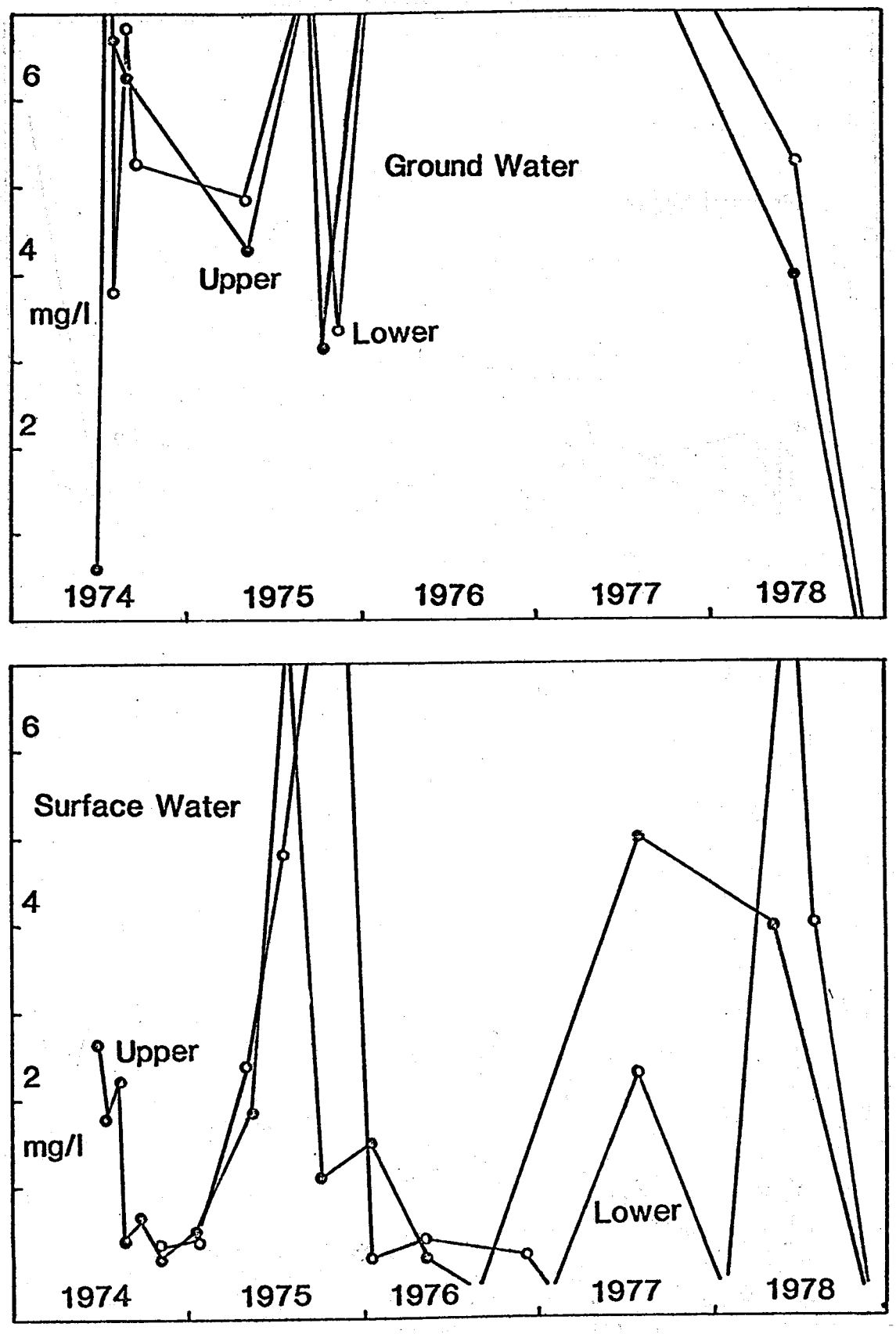
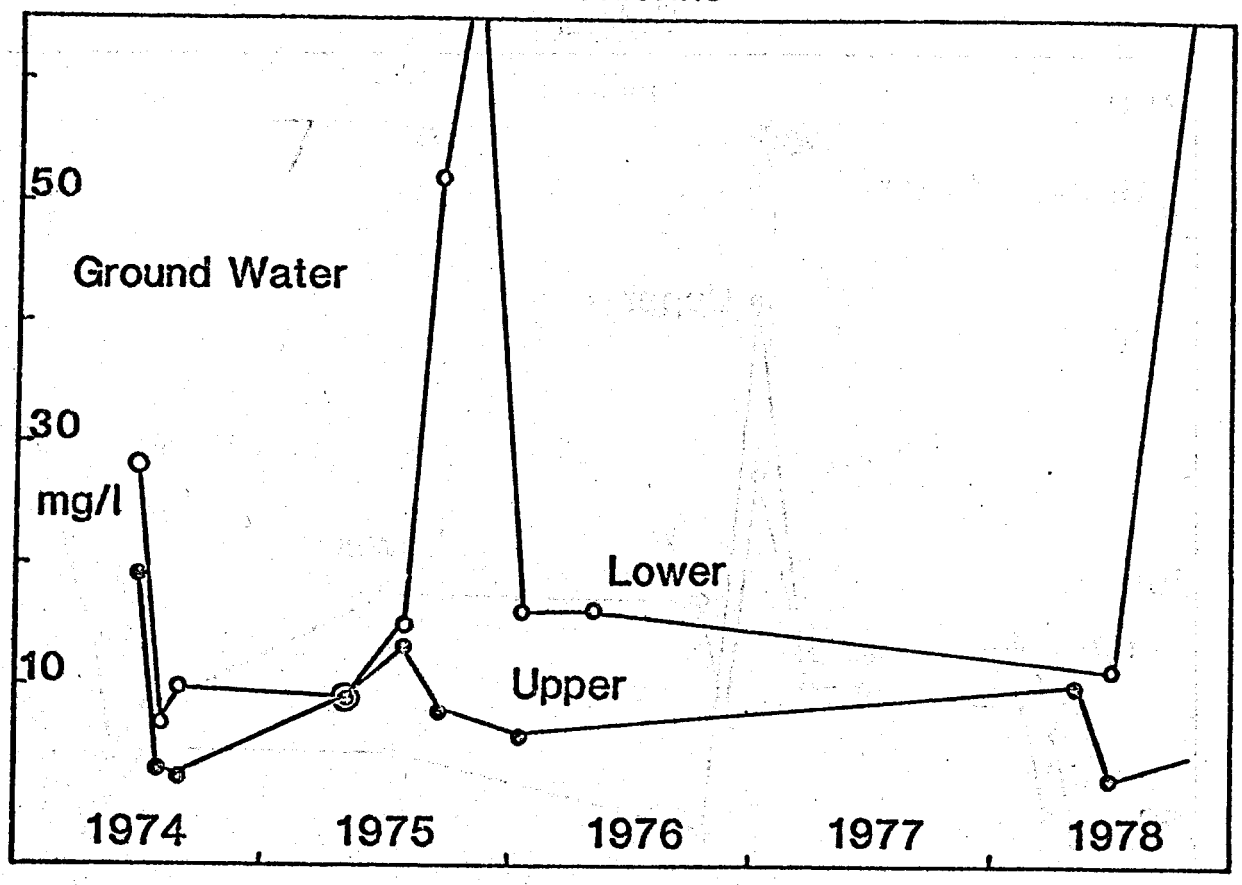


Figure 3.5
Total Chlorine



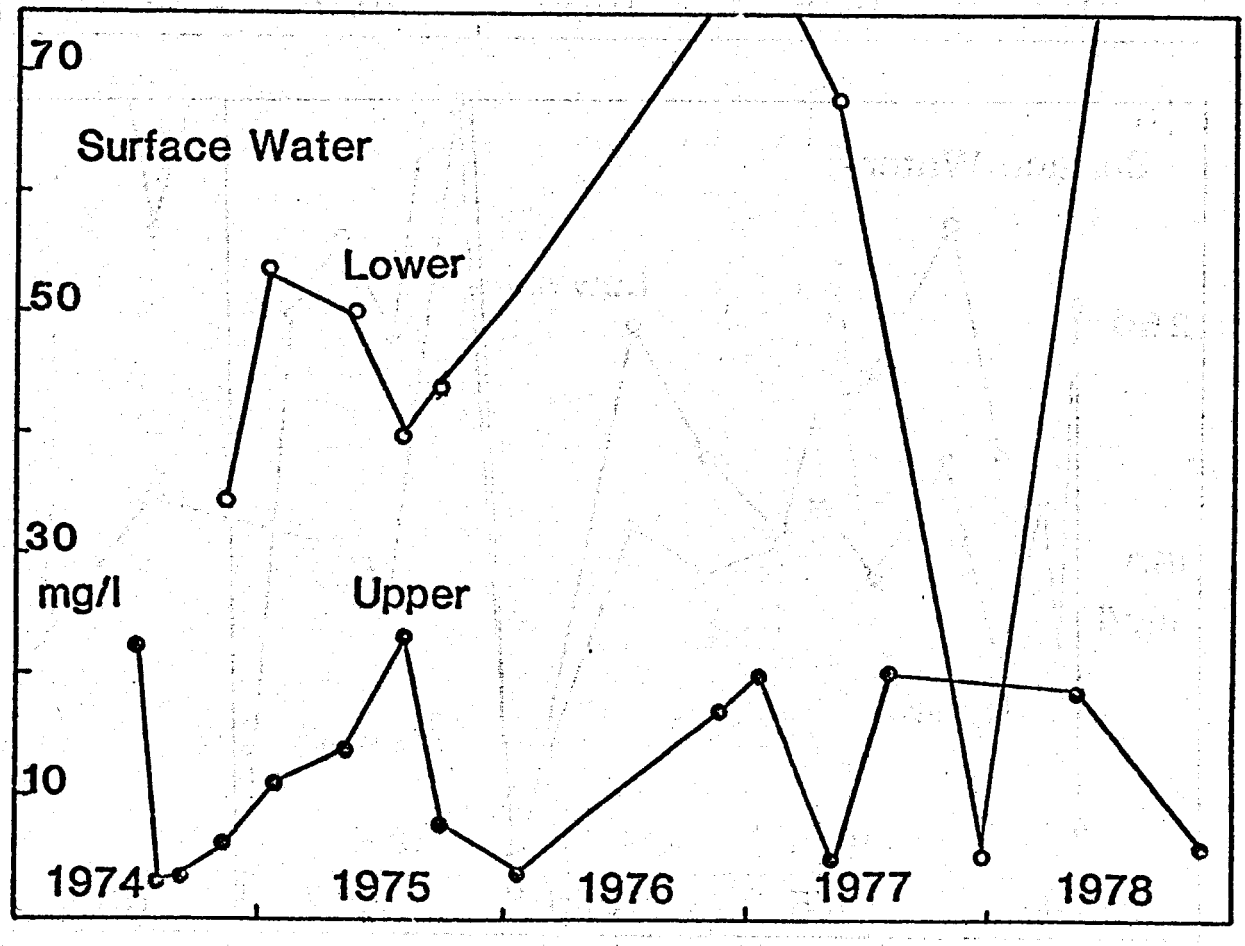
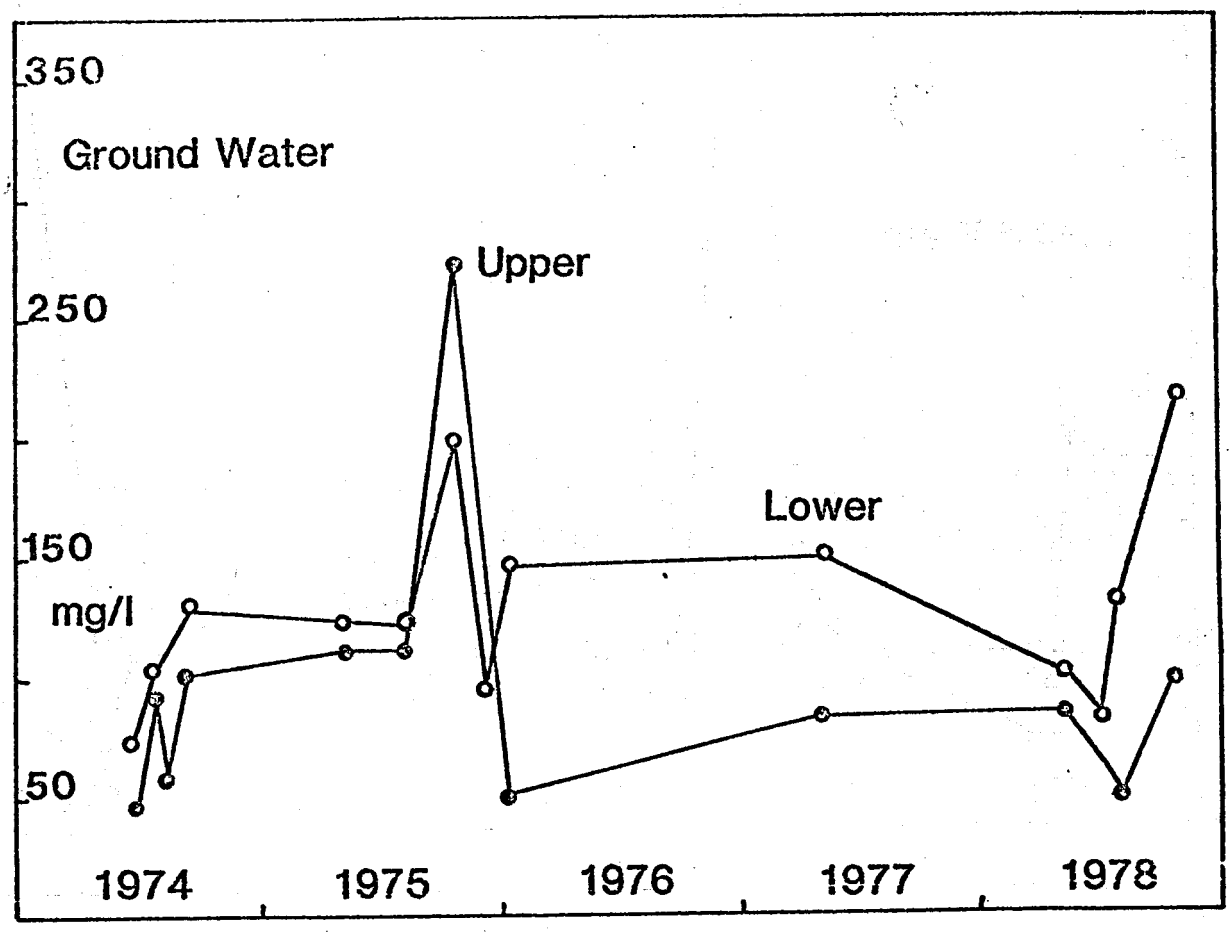


Figure 3.6
Calcium



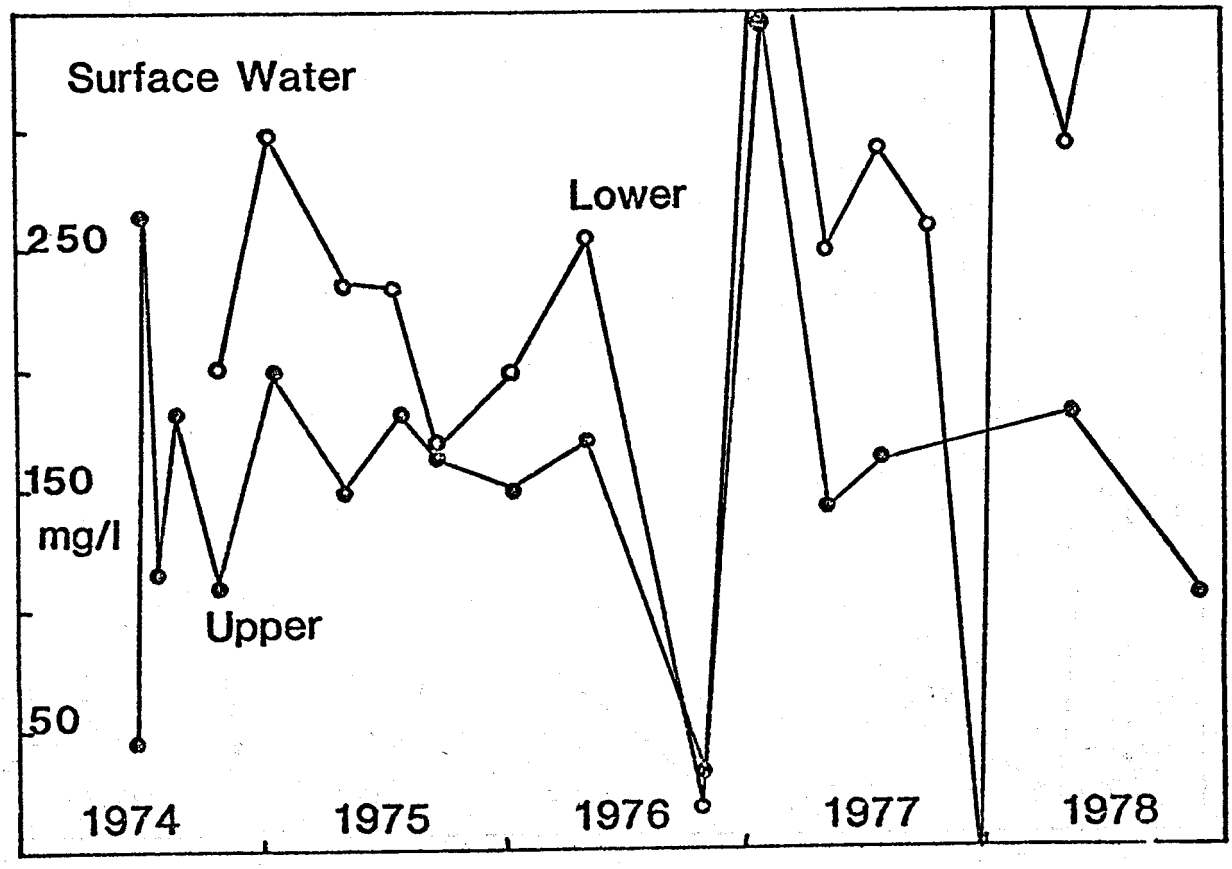
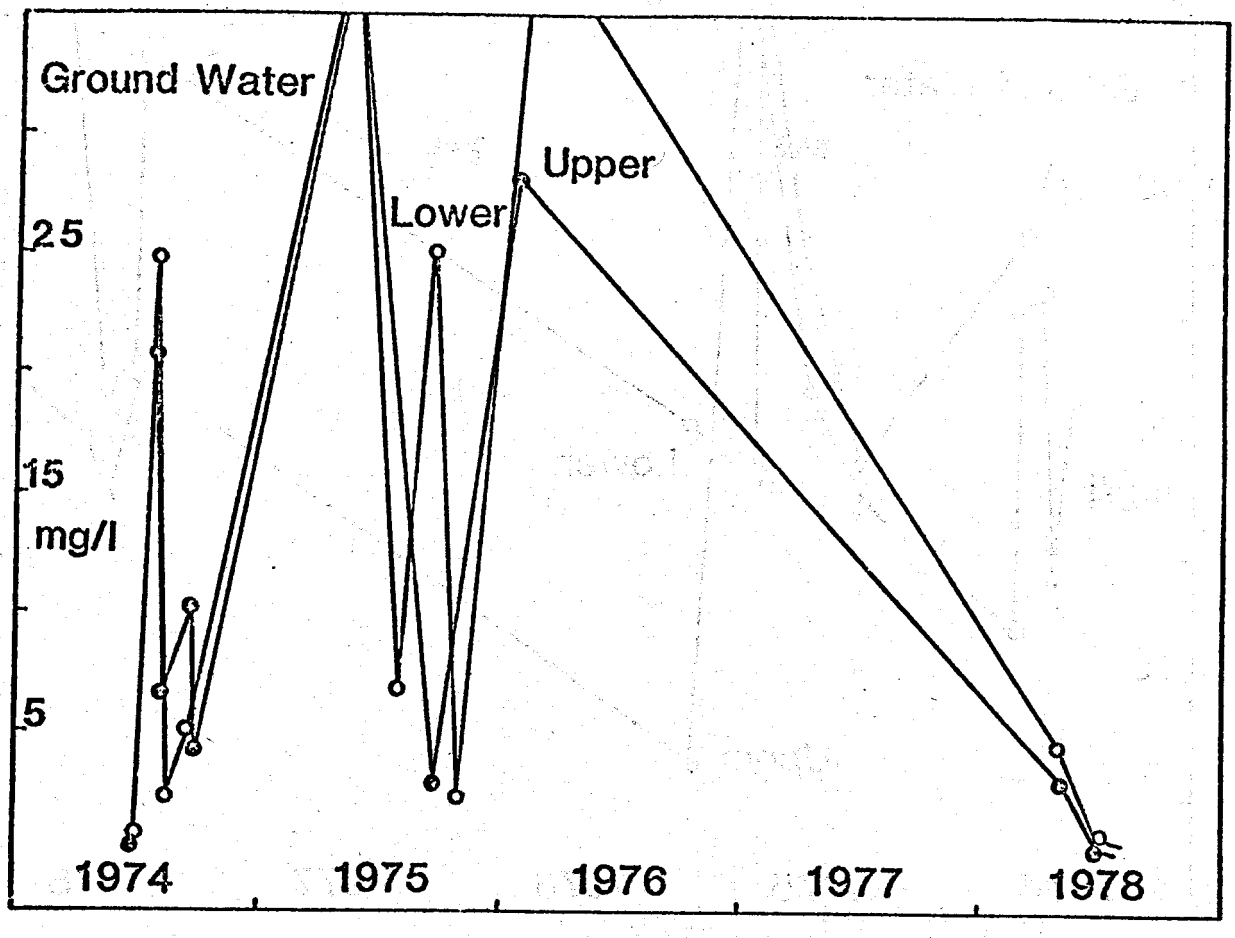


Figure 3.7

Iron



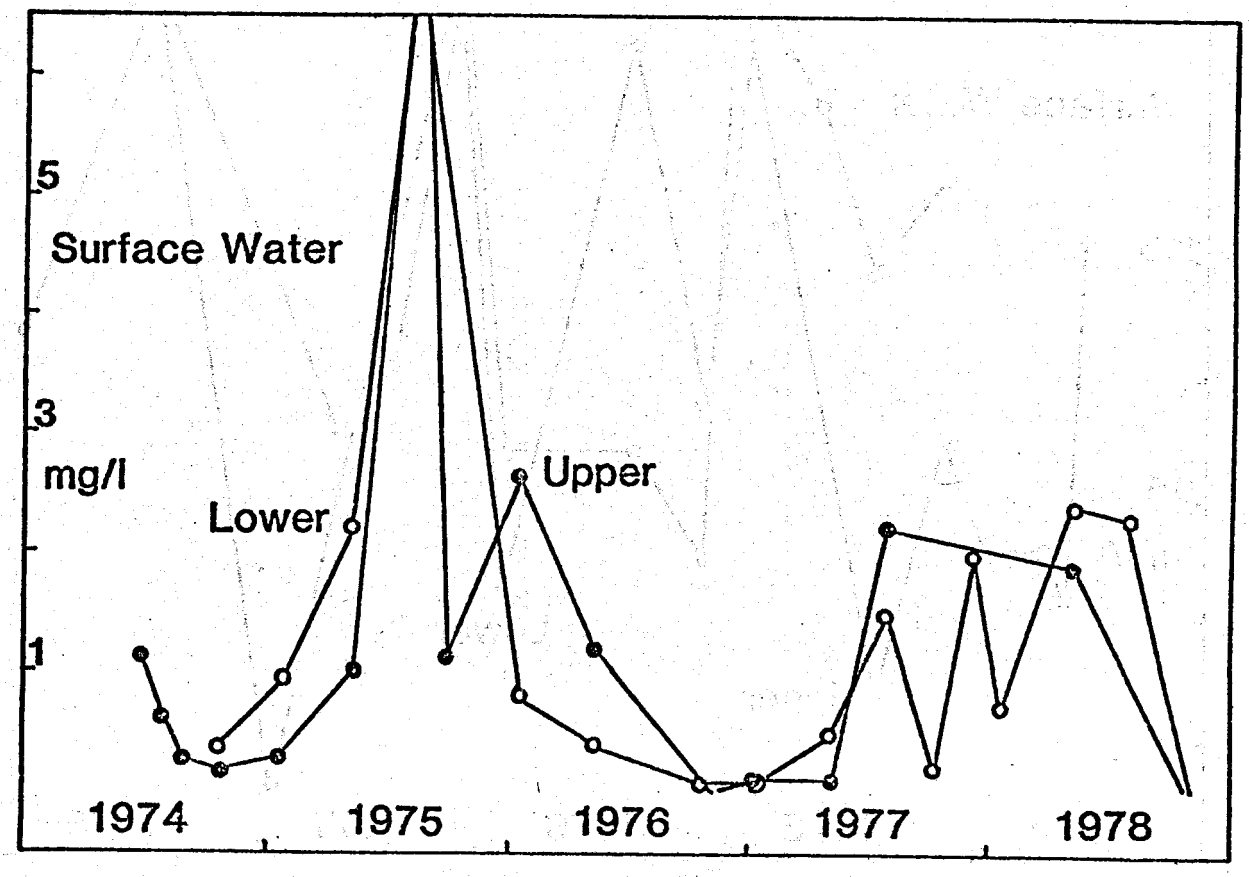
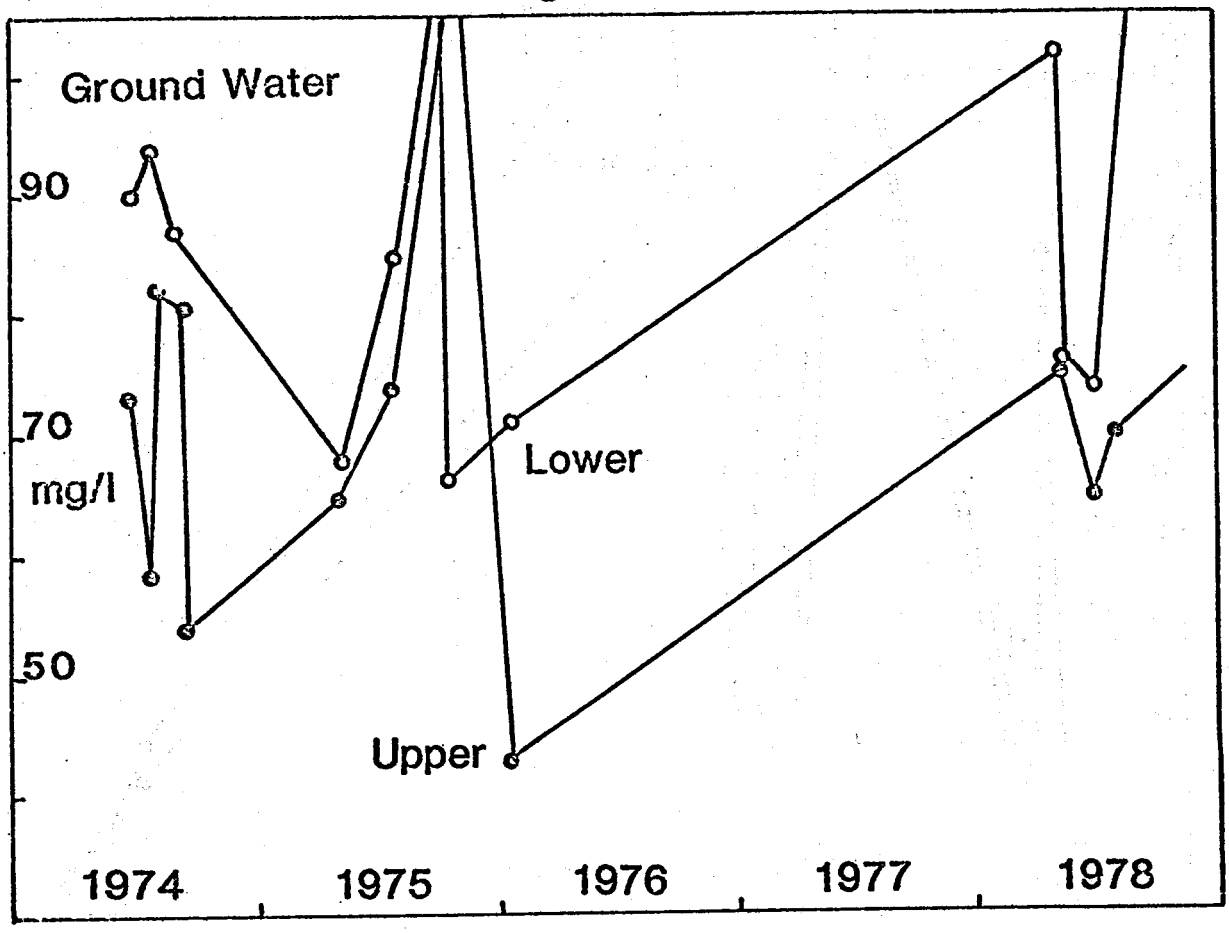


Figure 3.8
Magnesium



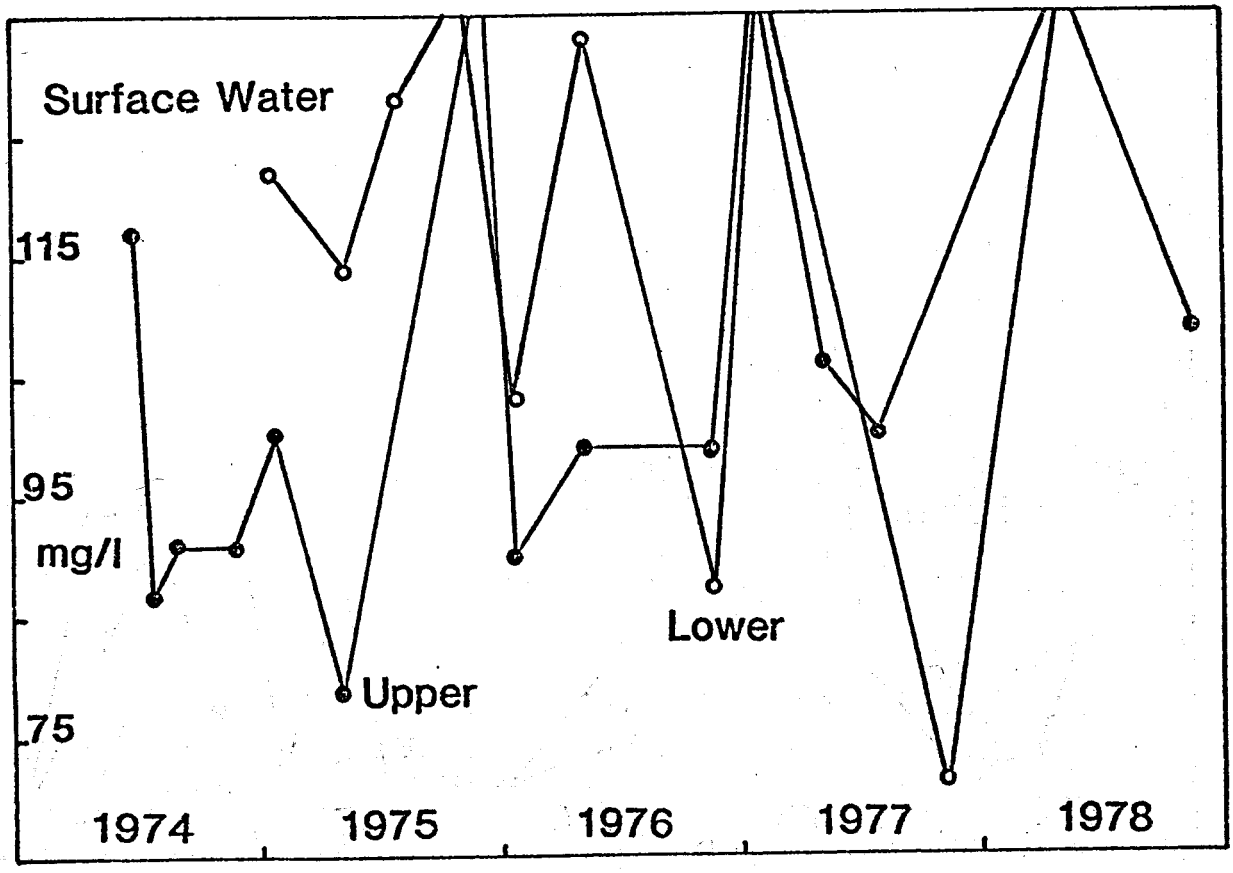
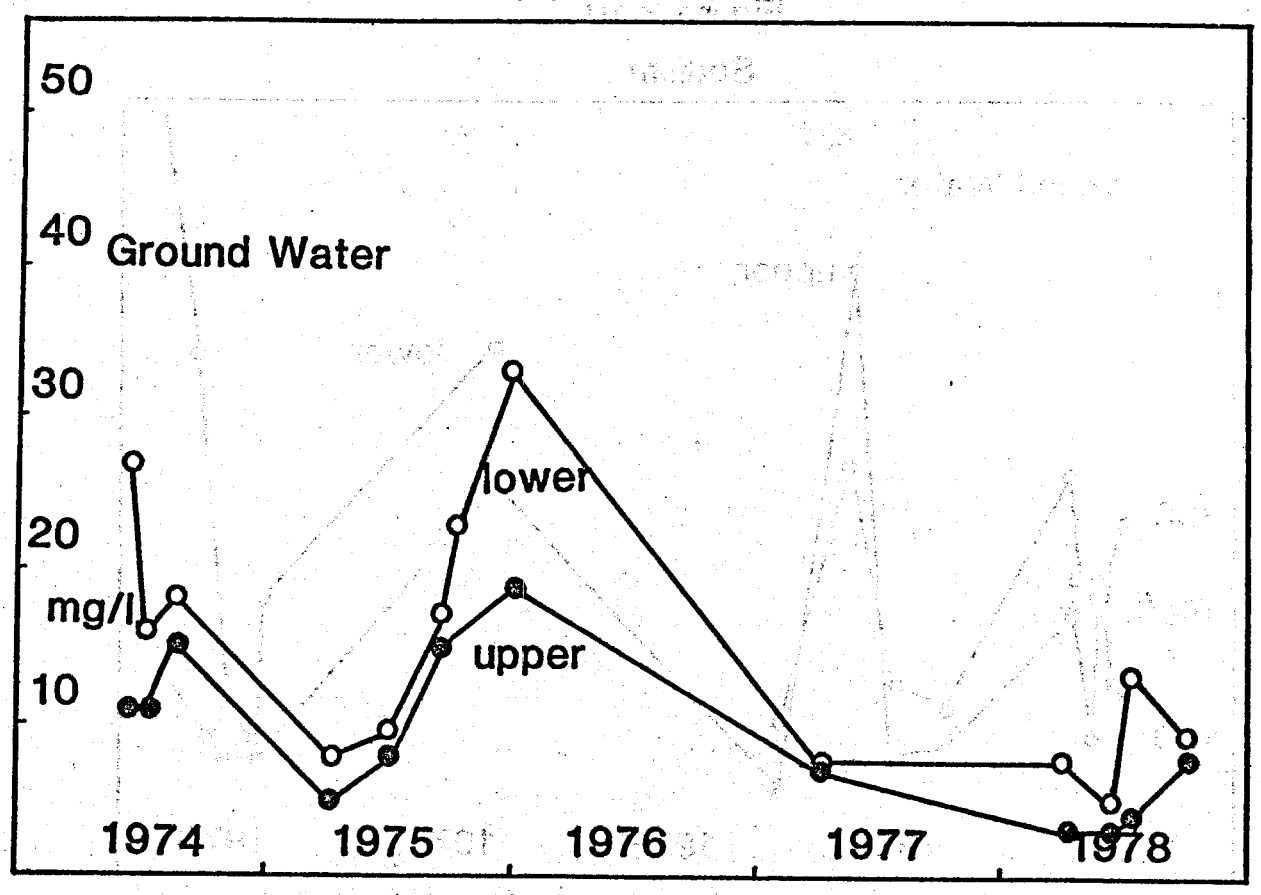


Figure 3.9

Potassium



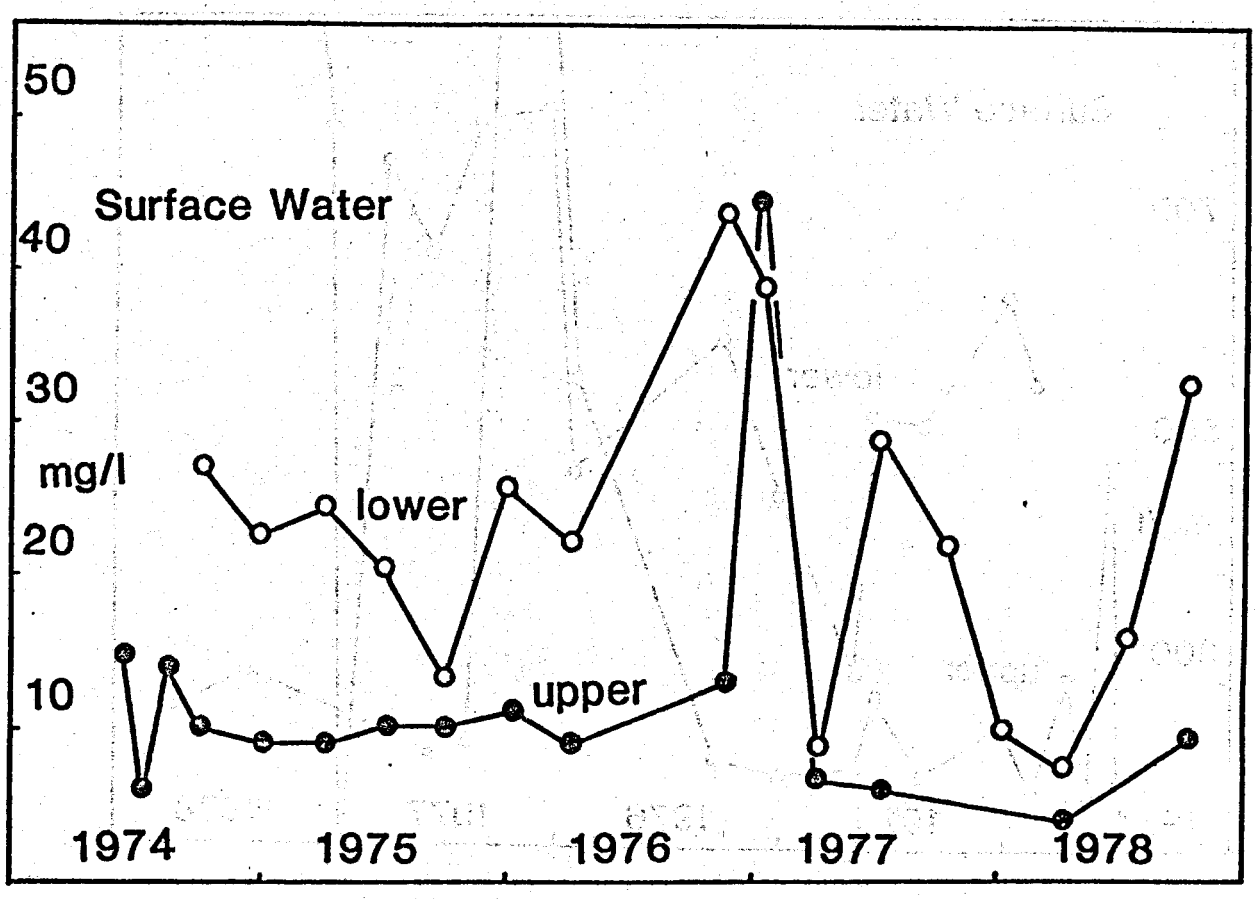
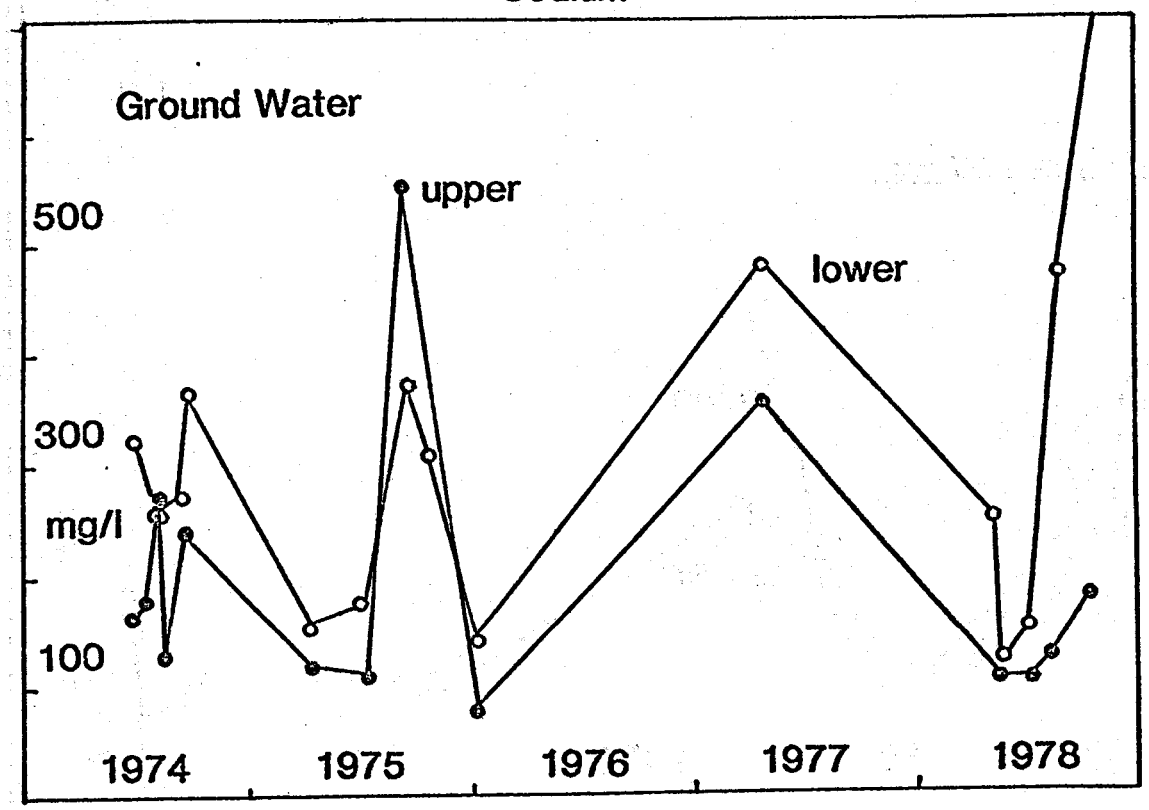


Figure 3.10
Sodium



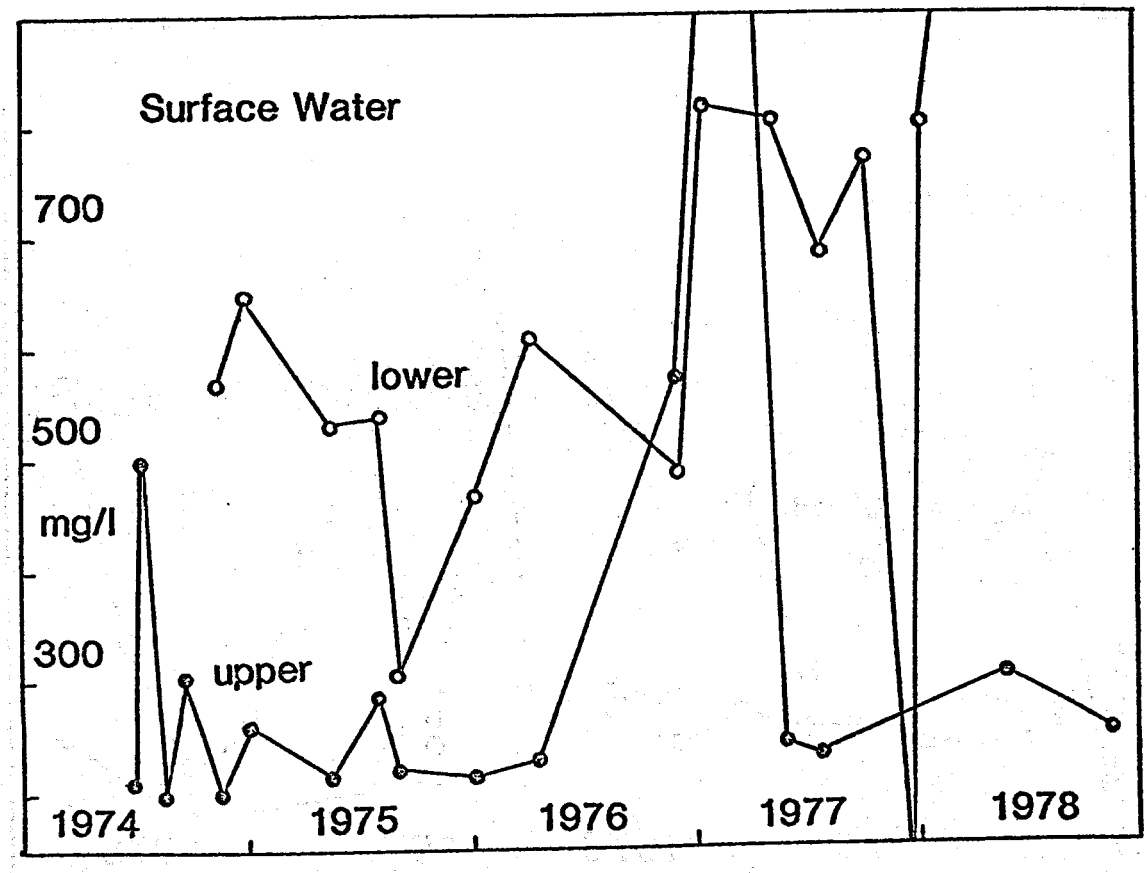
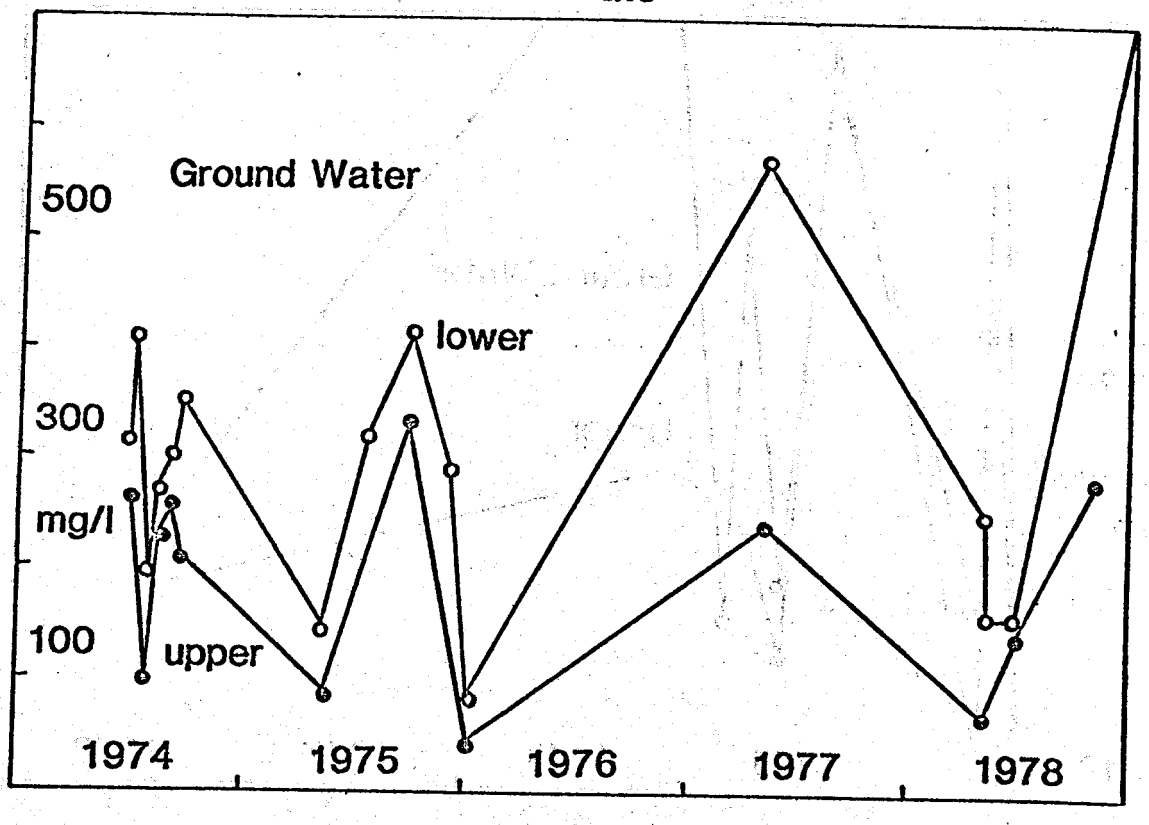


Figure 3.11
Sulfate



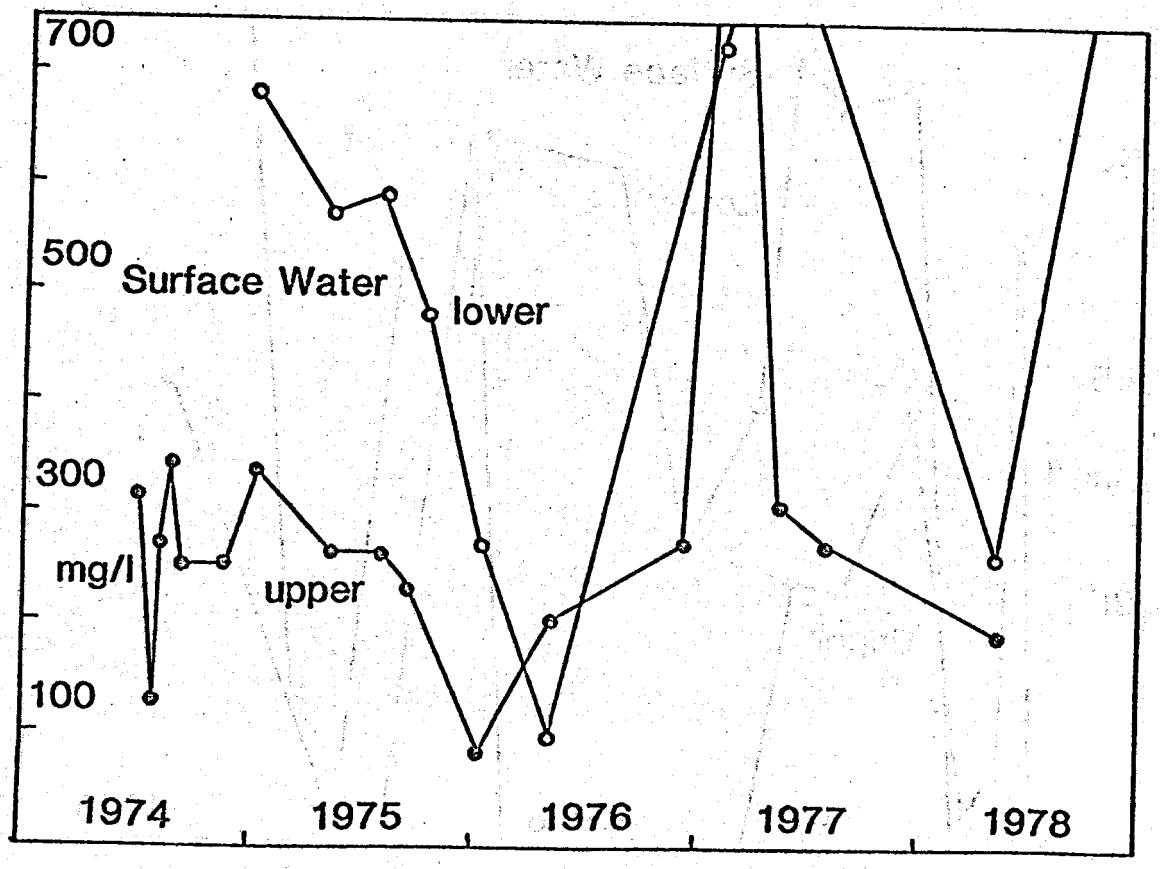
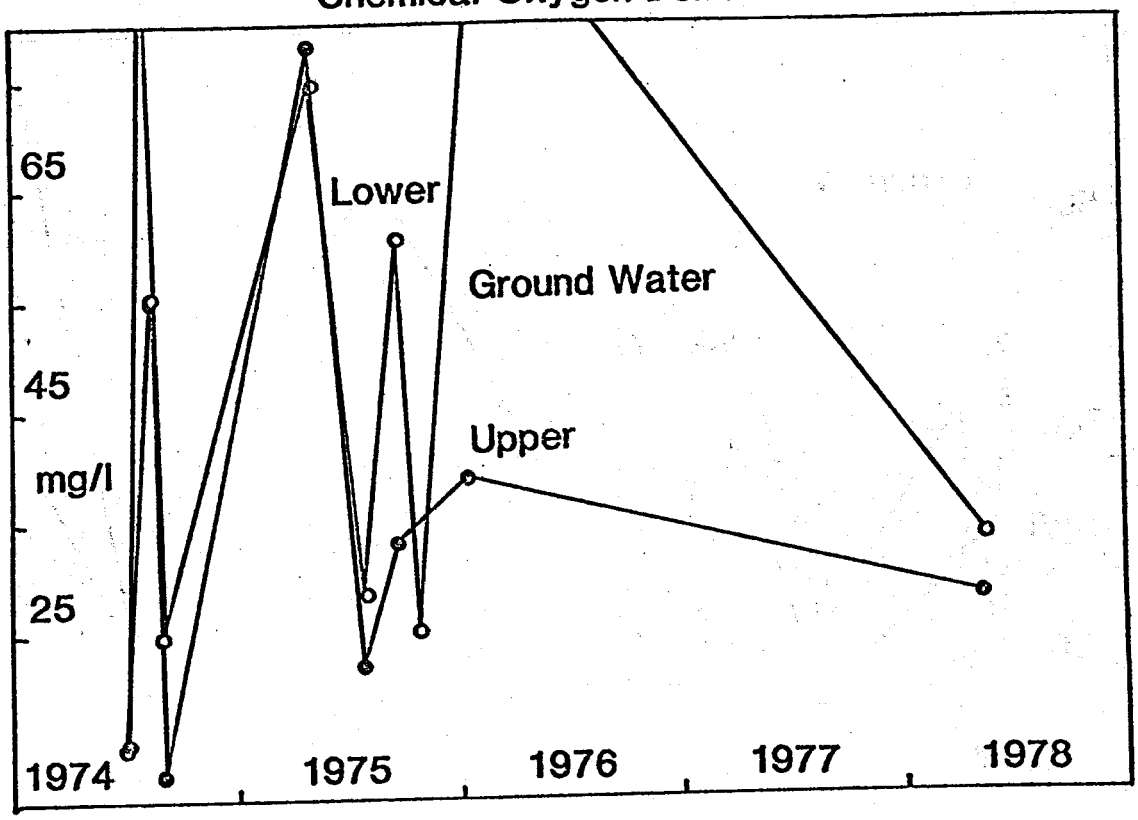


Figure 3.12
Chemical Oxygen Demand



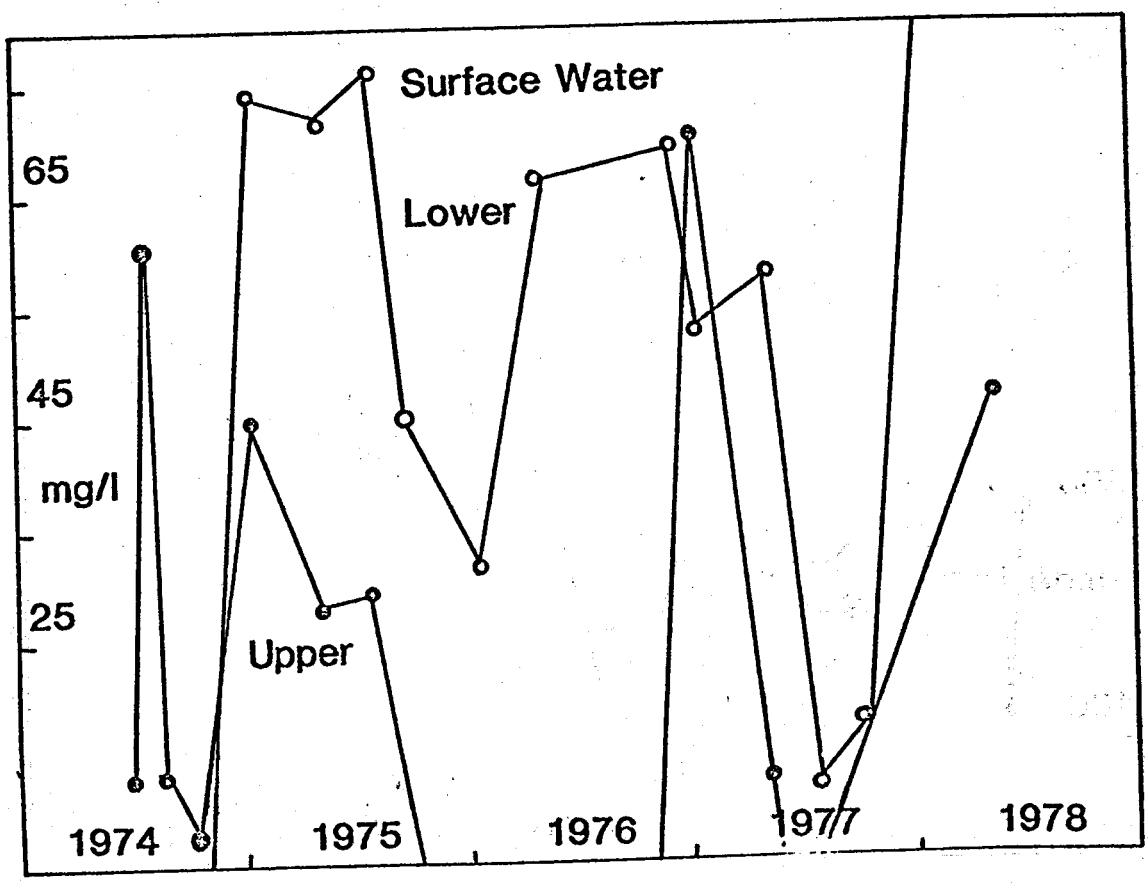
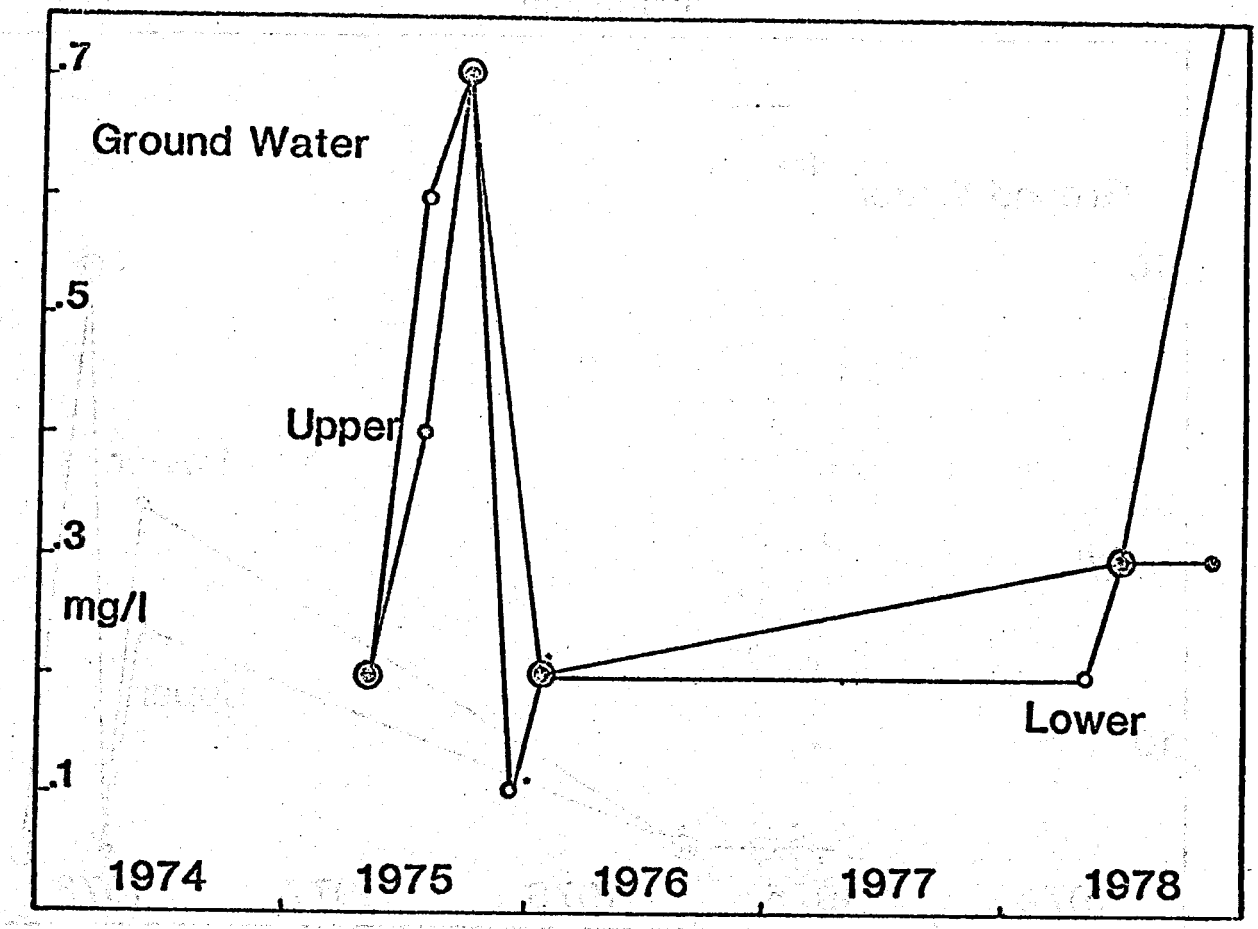


Figure 3.13

Boron



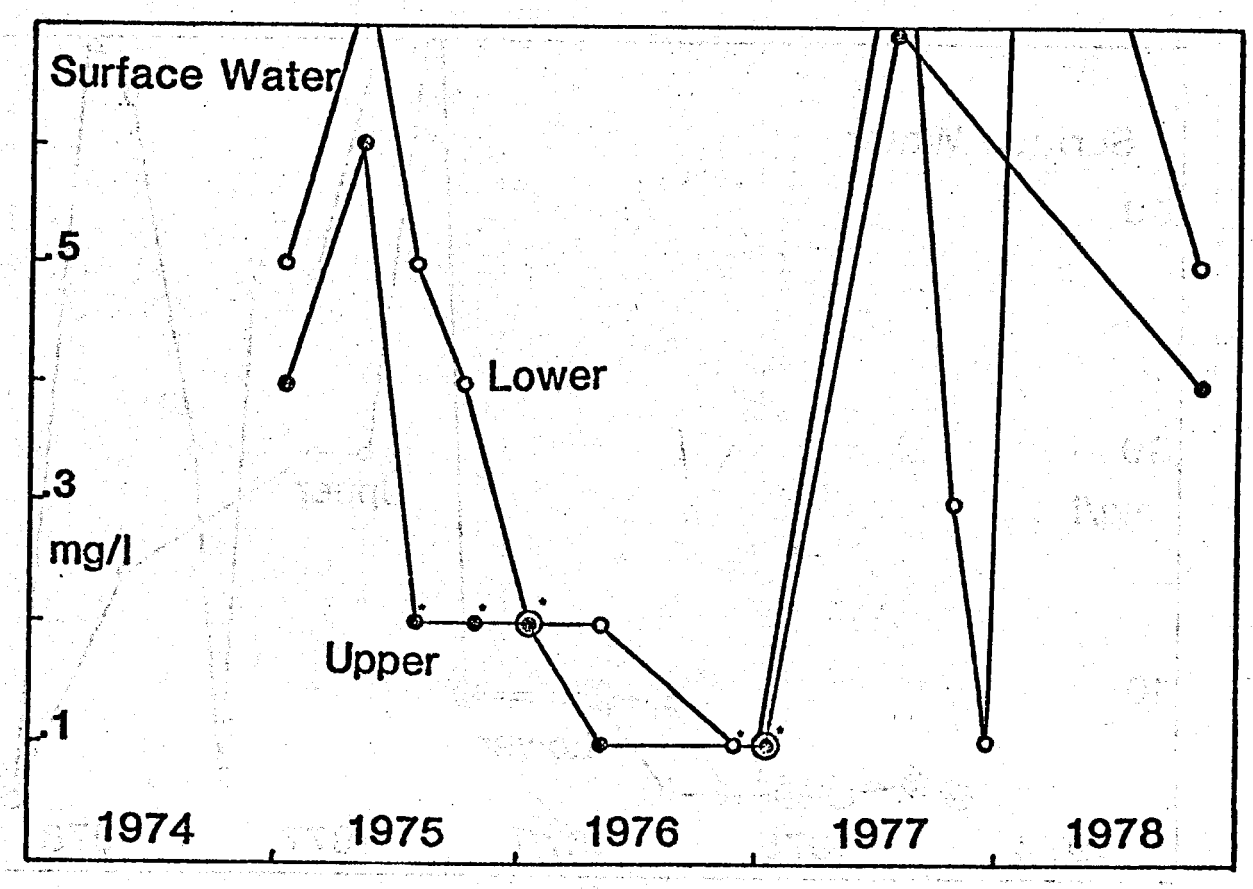


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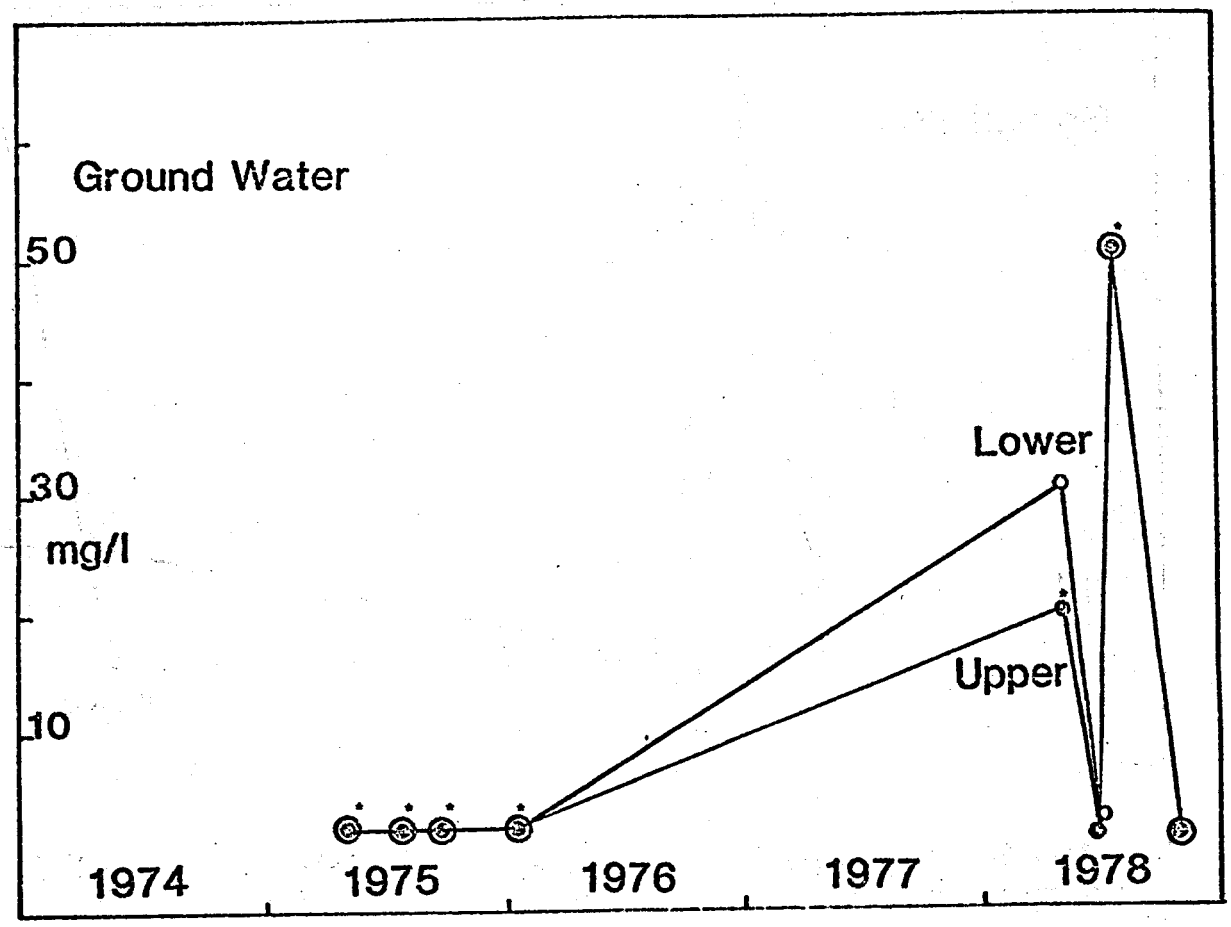
Figure 3.14
Cadmium



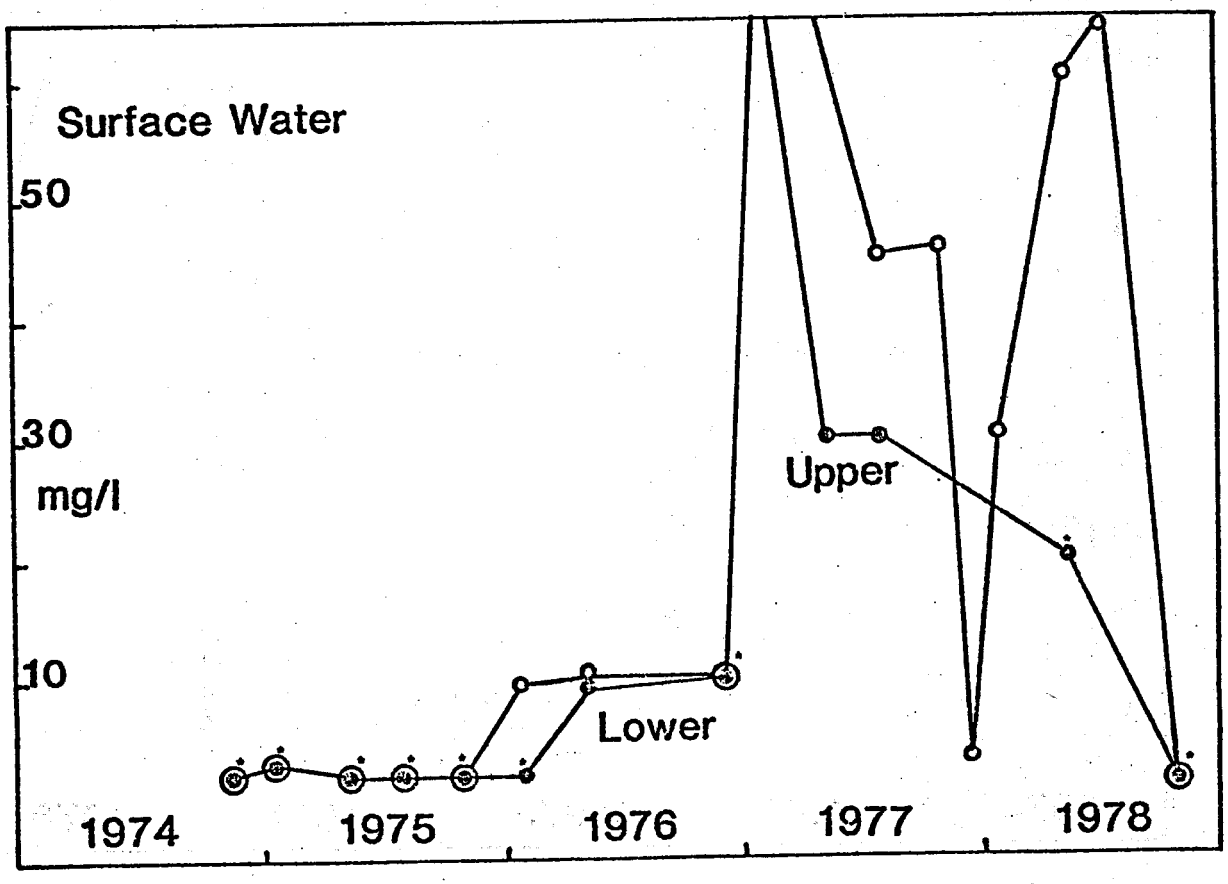


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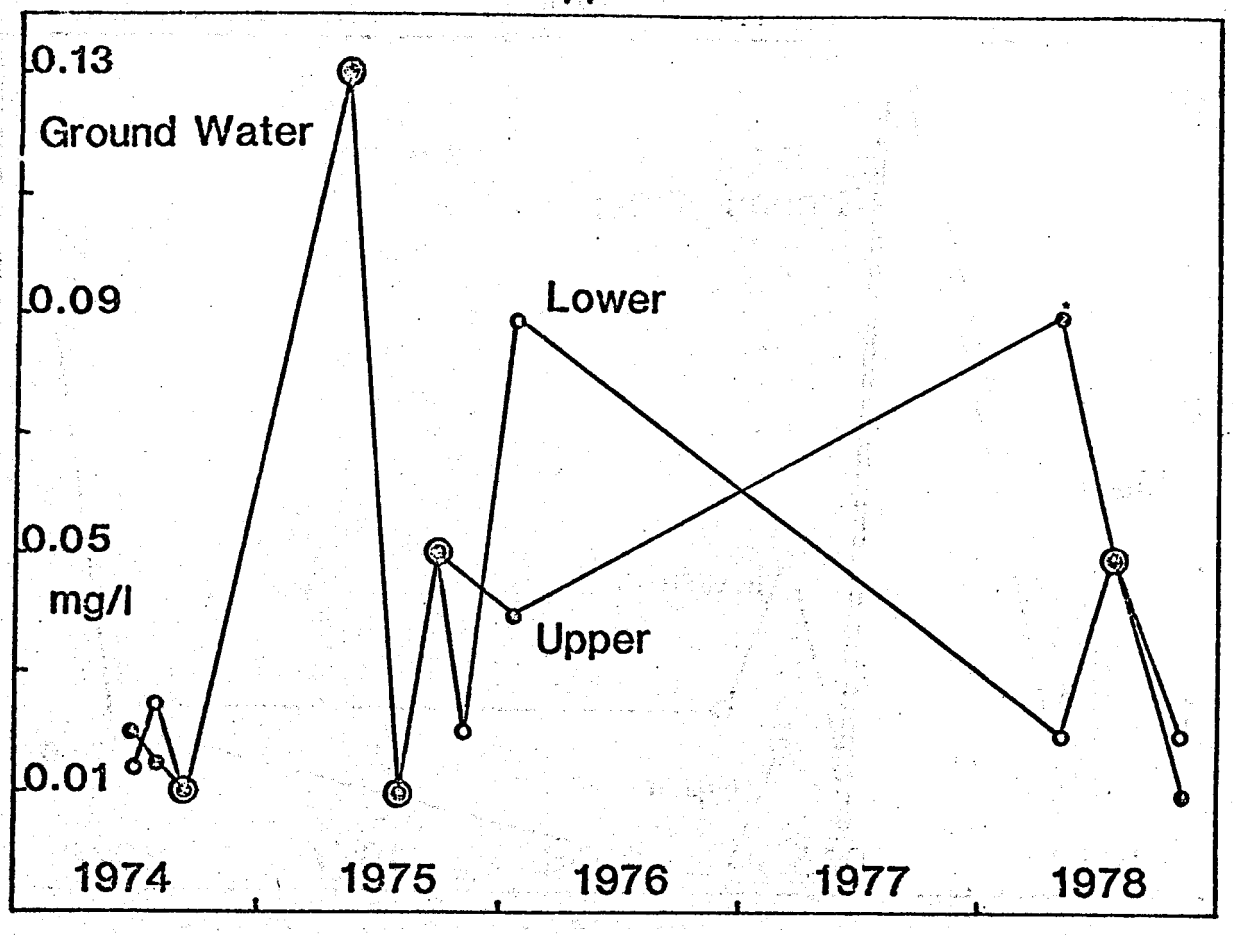
Figure 3.15

Copper



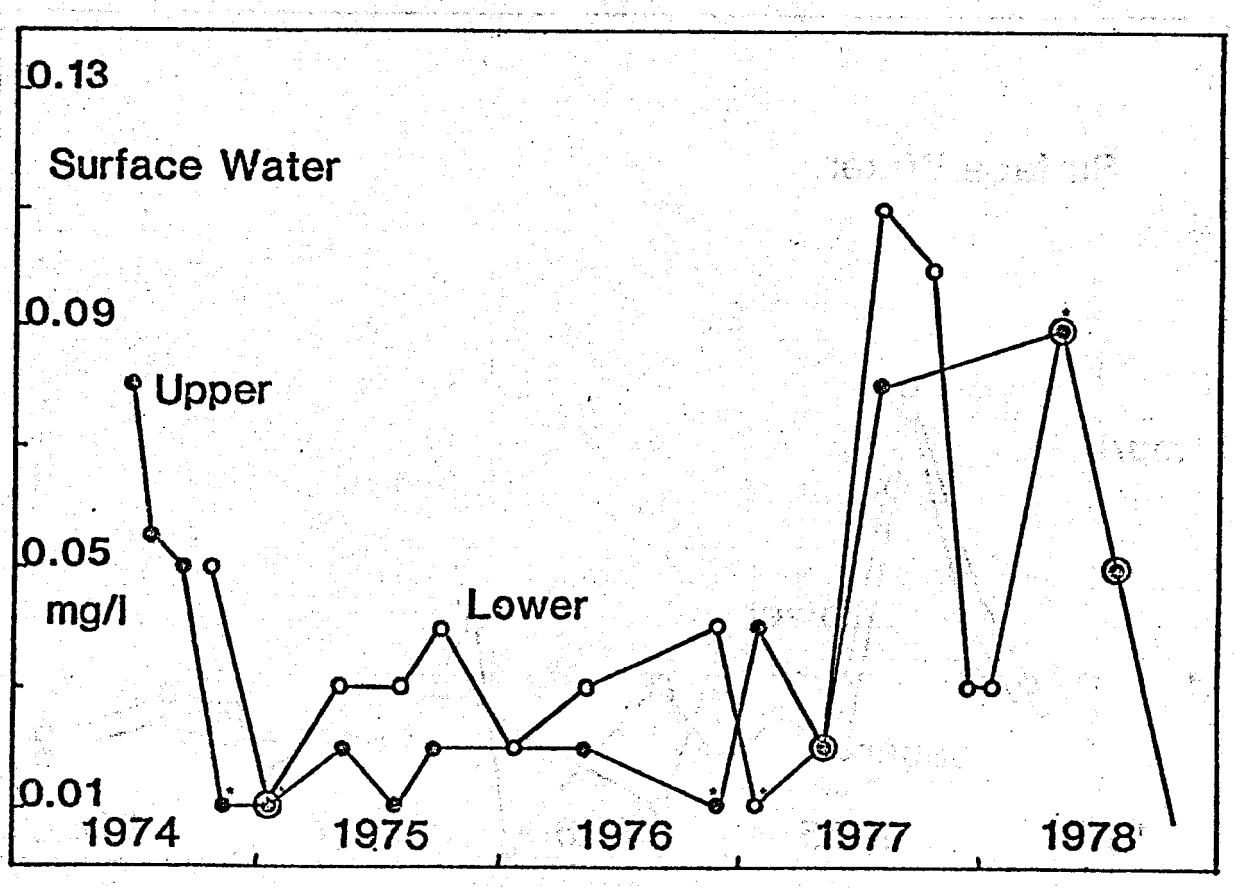


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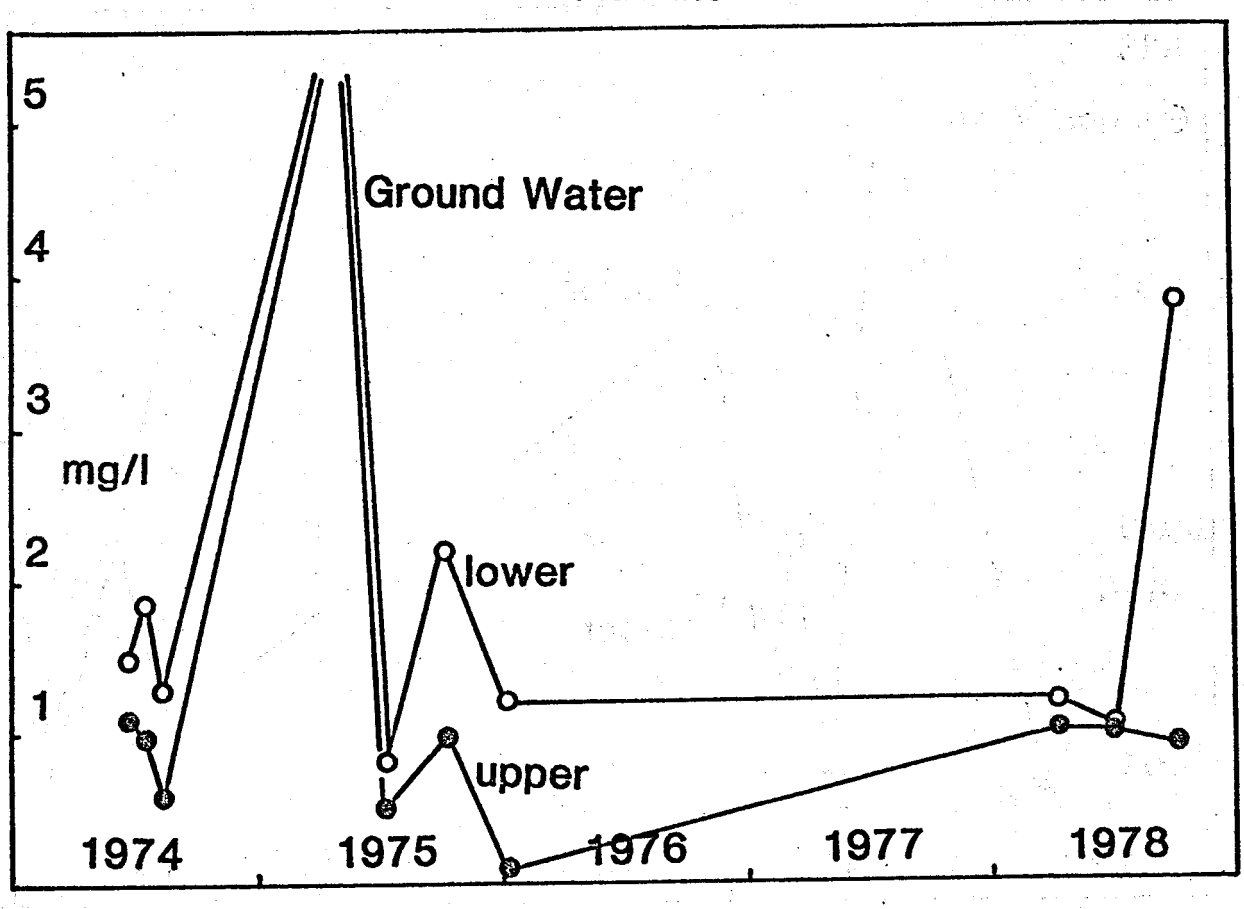
Figure 3.16

Fluorine



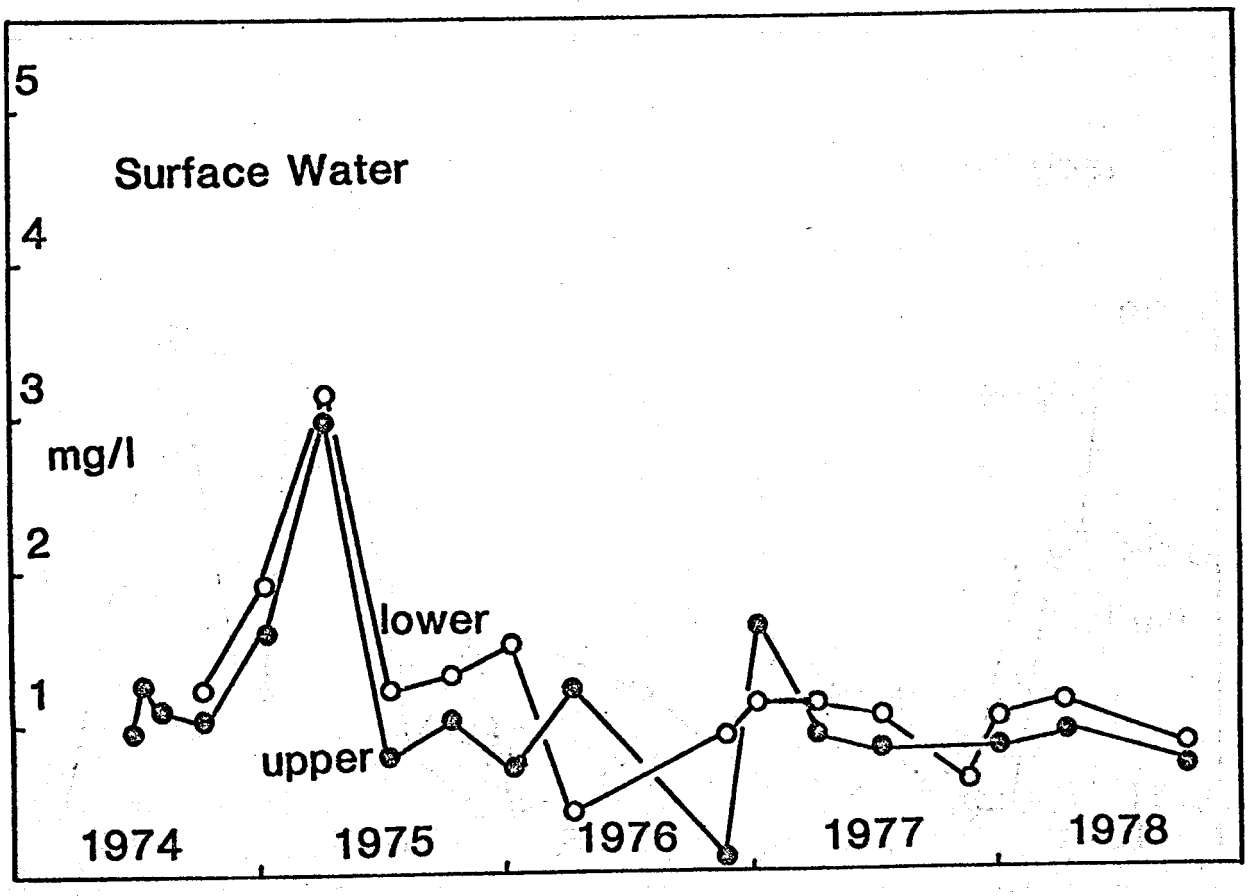
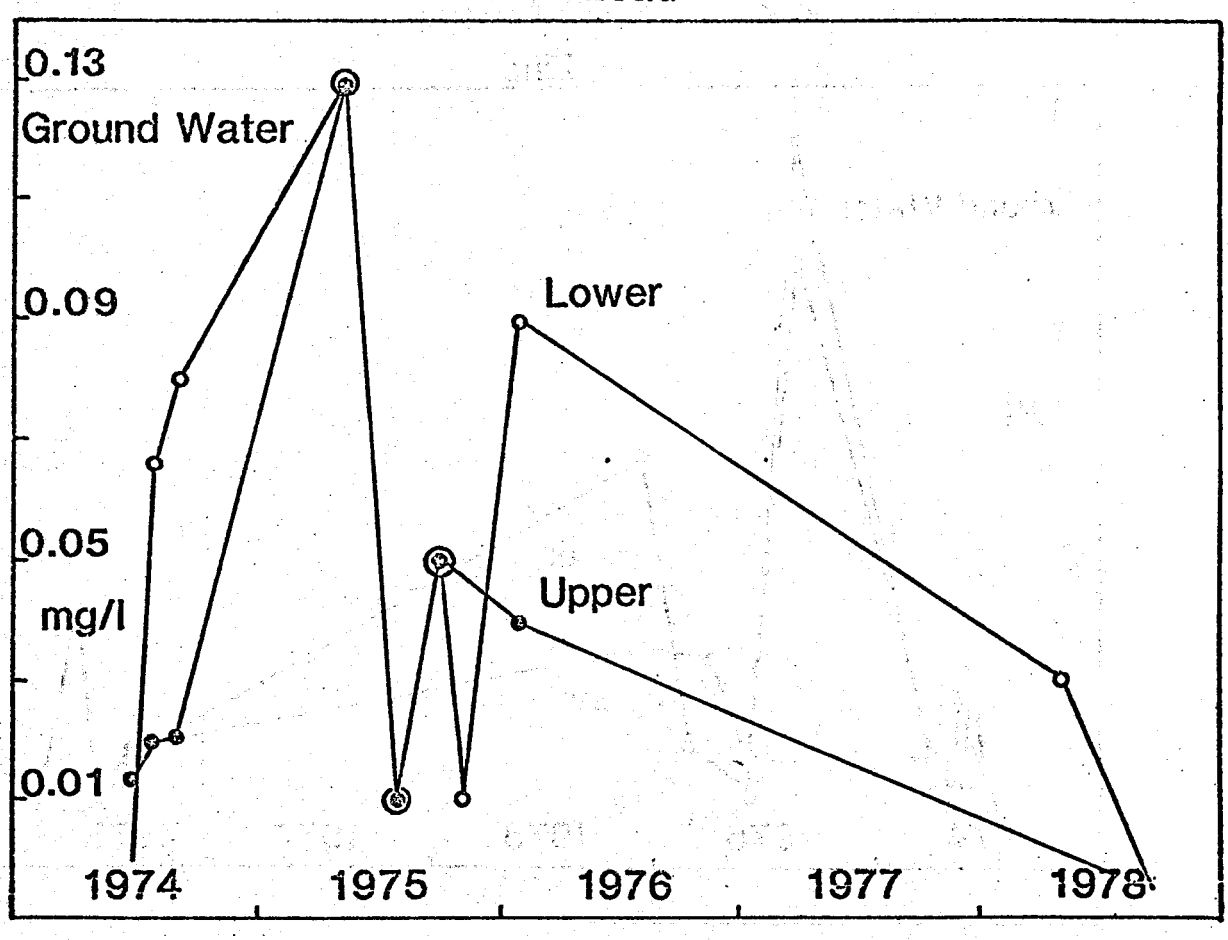


Figure 3.17
Lead



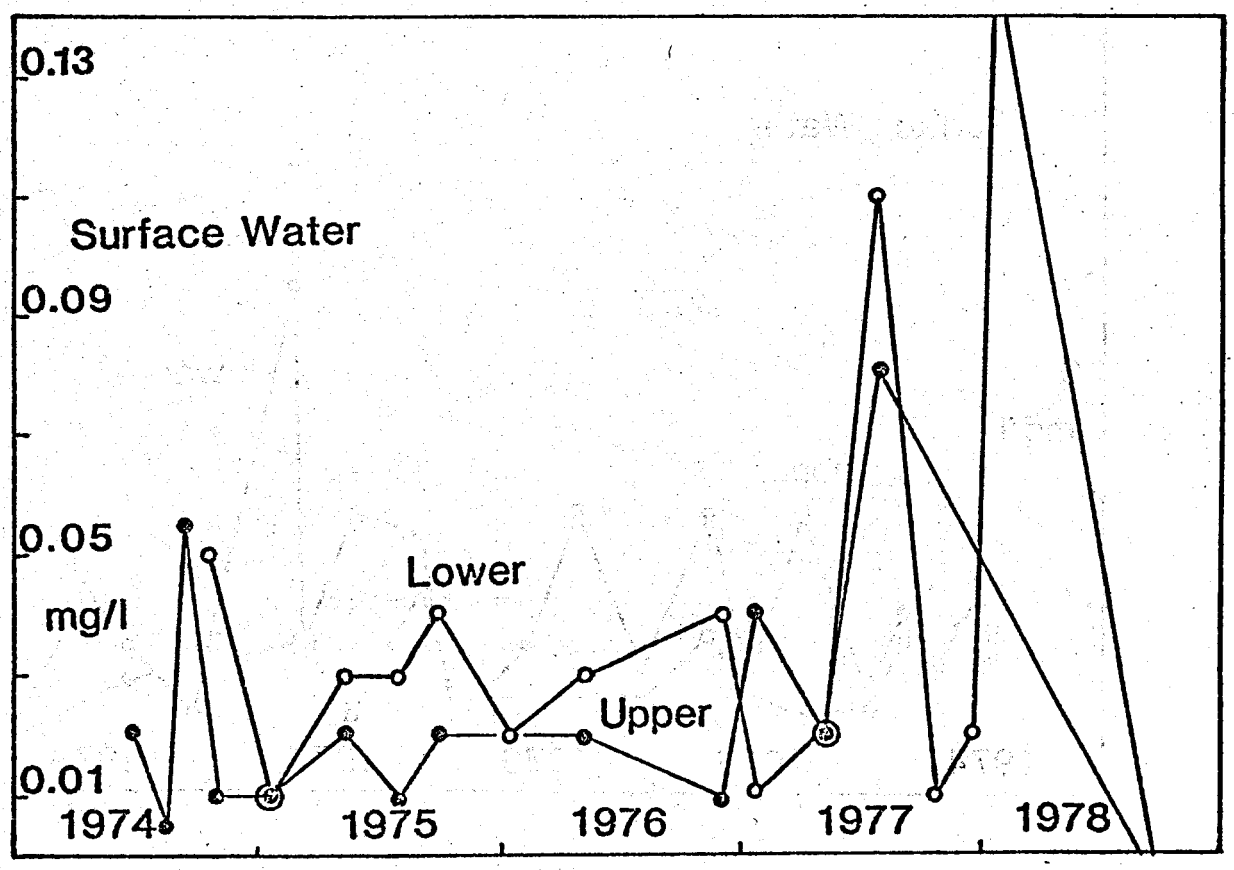
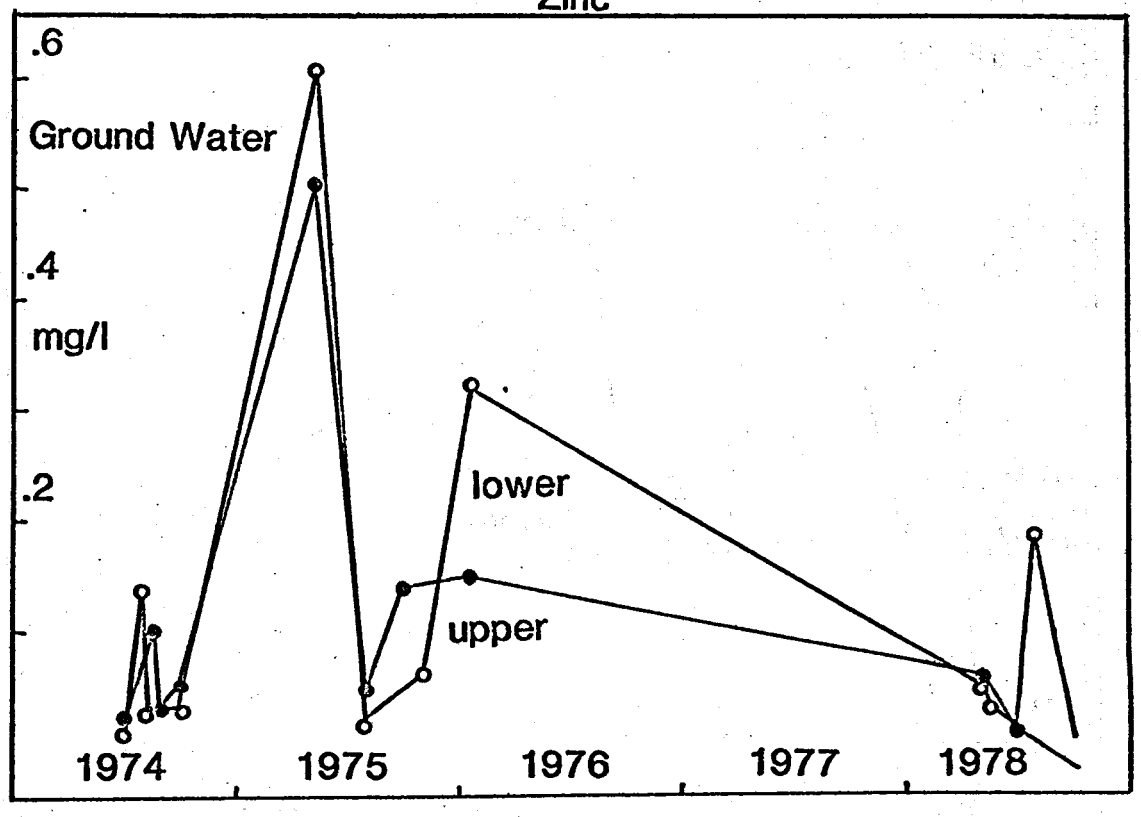


Figure 3.18

Zinc



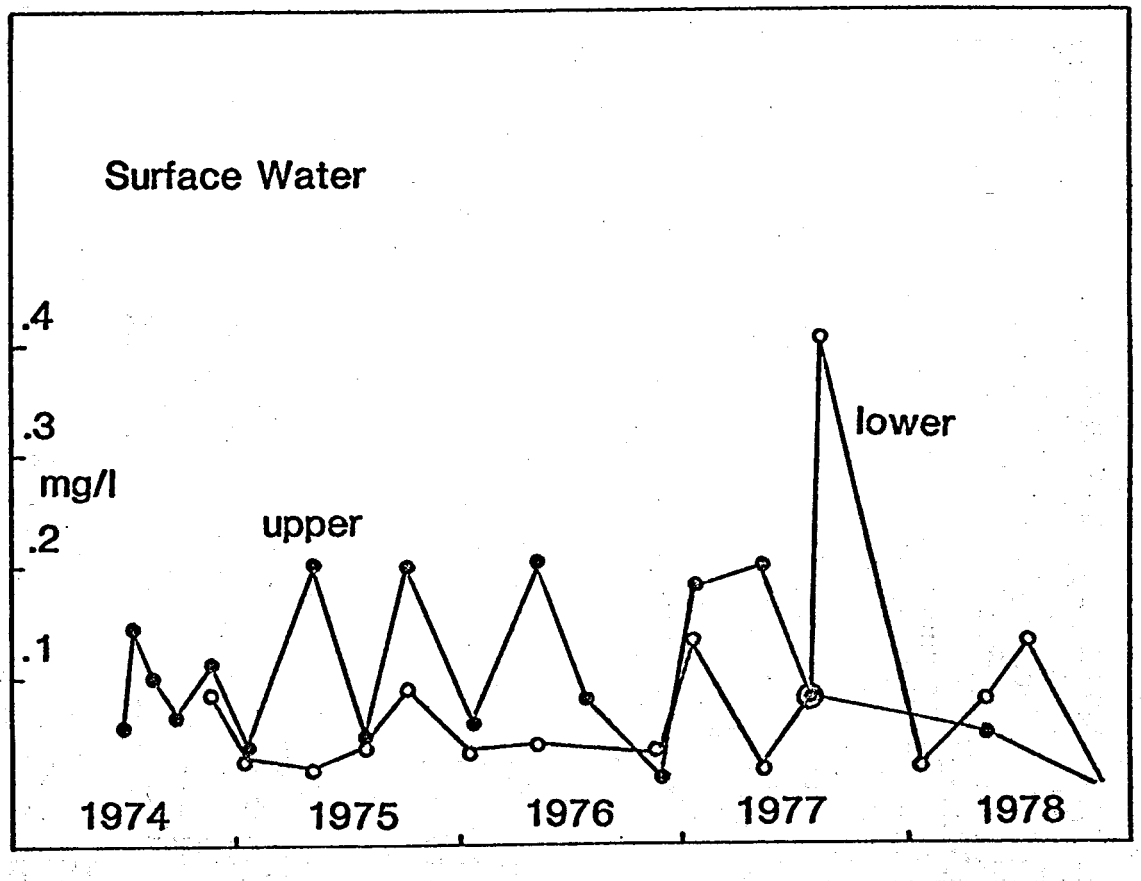
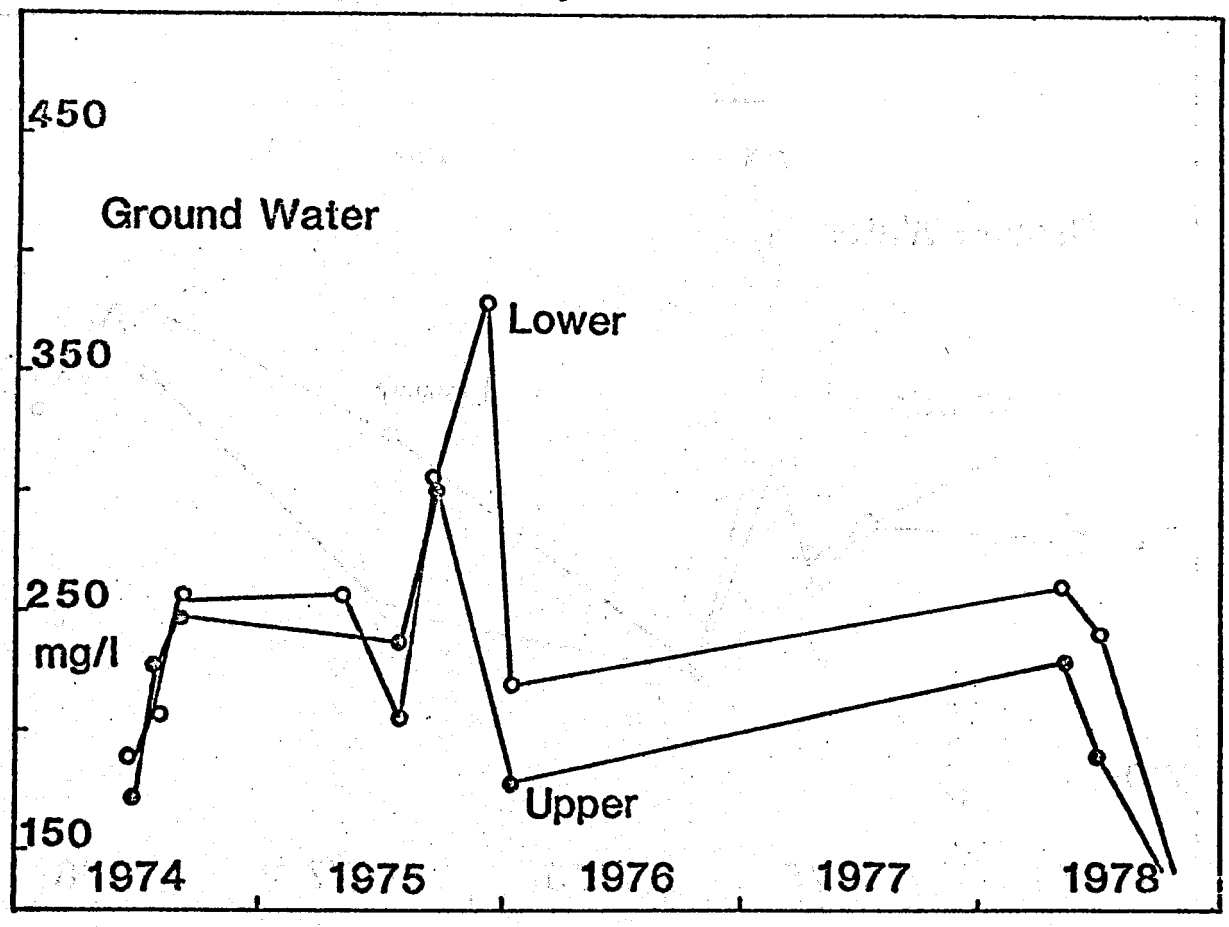


Figure 3.19
Alkalinity as CaCO3



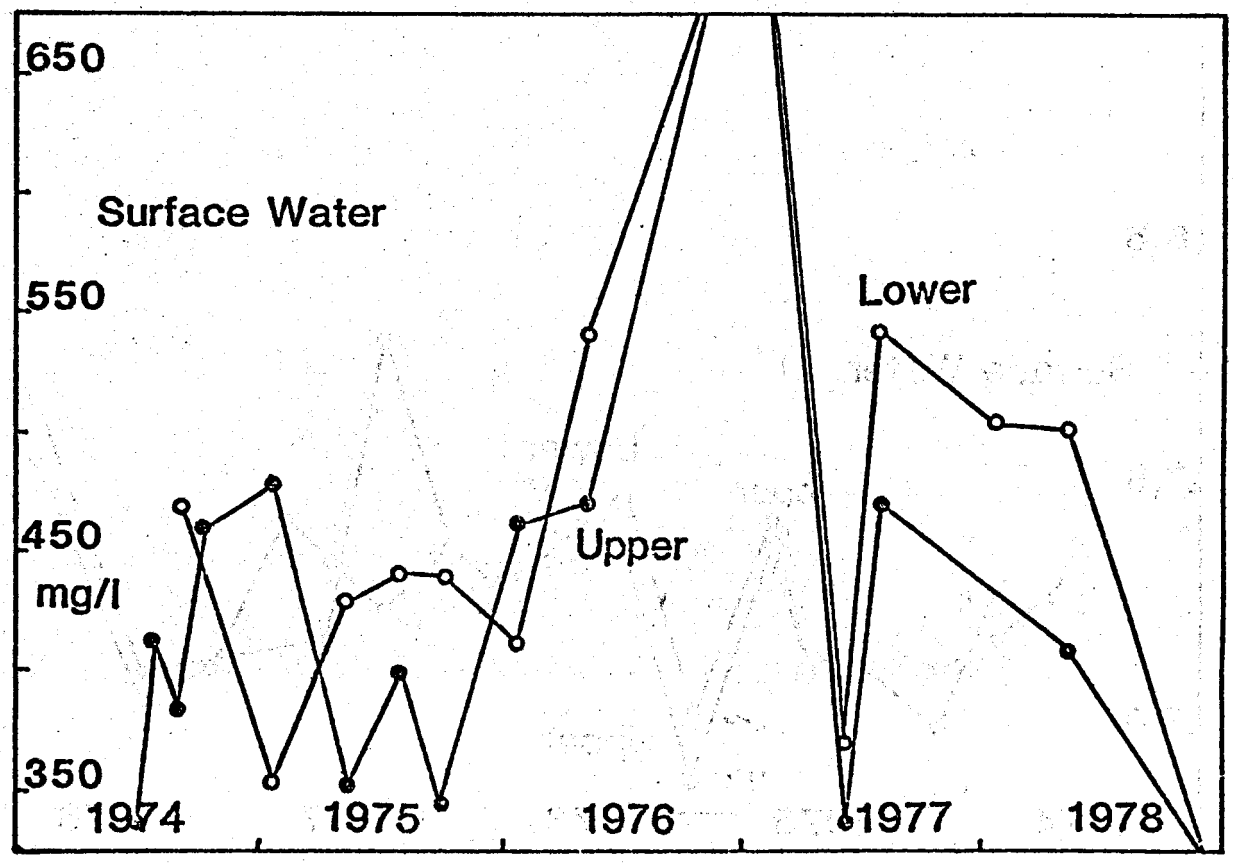
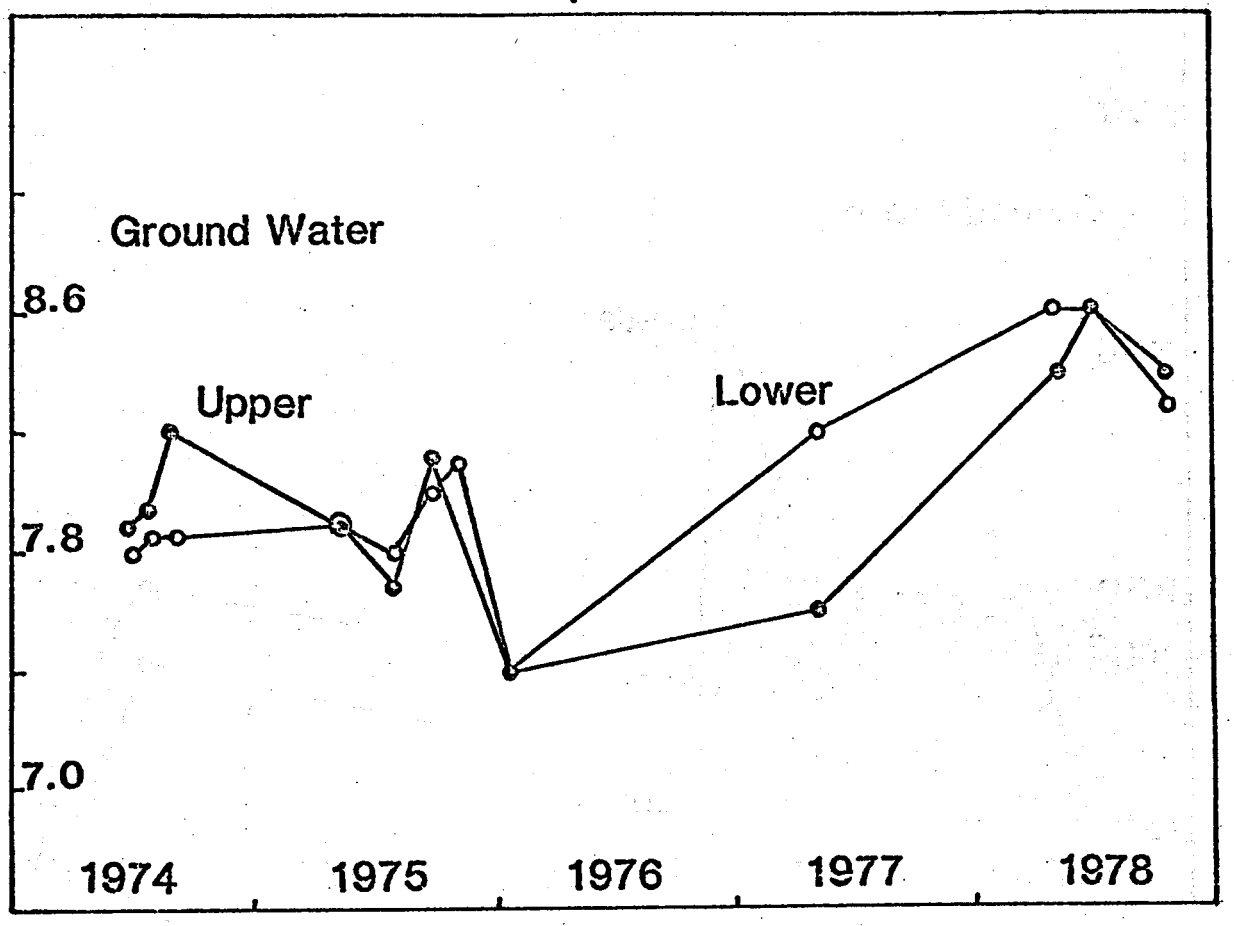


Figure 3.20

pH



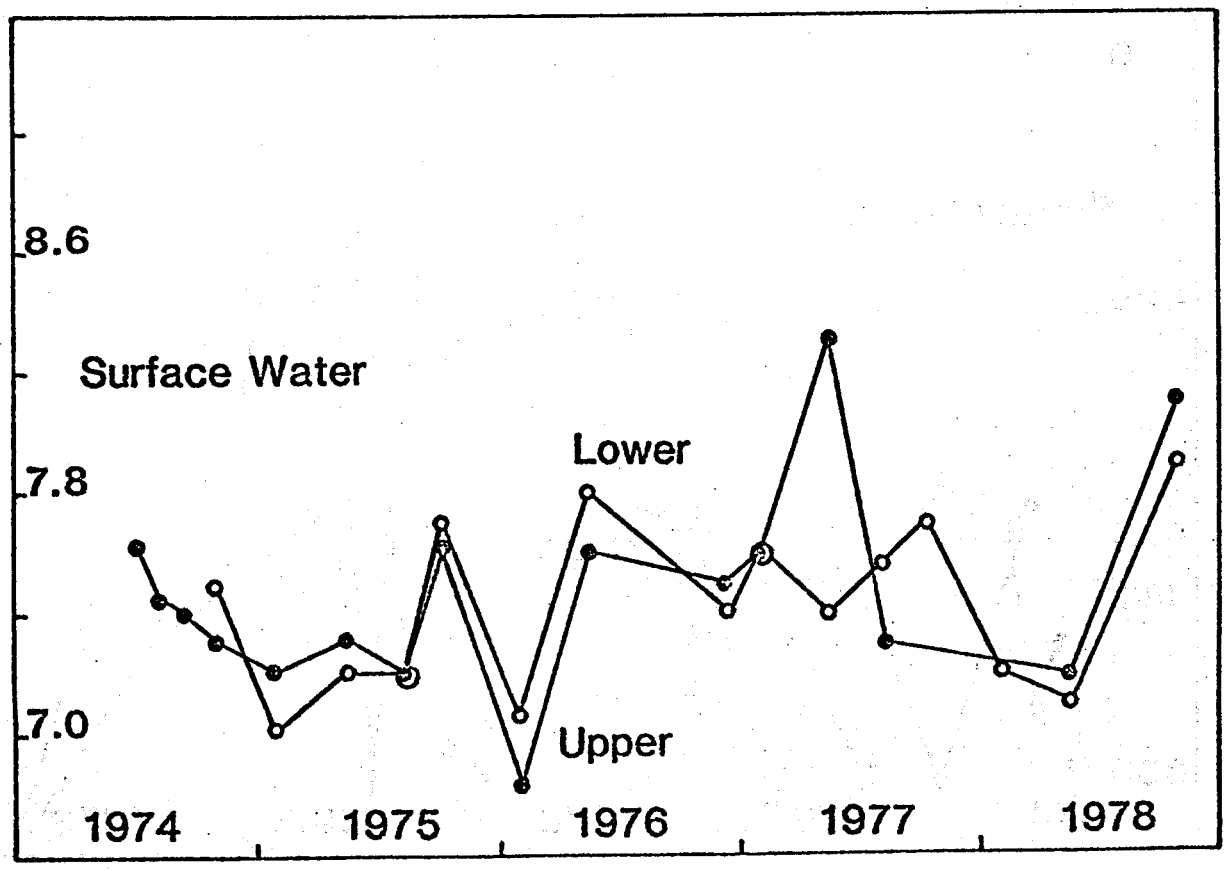
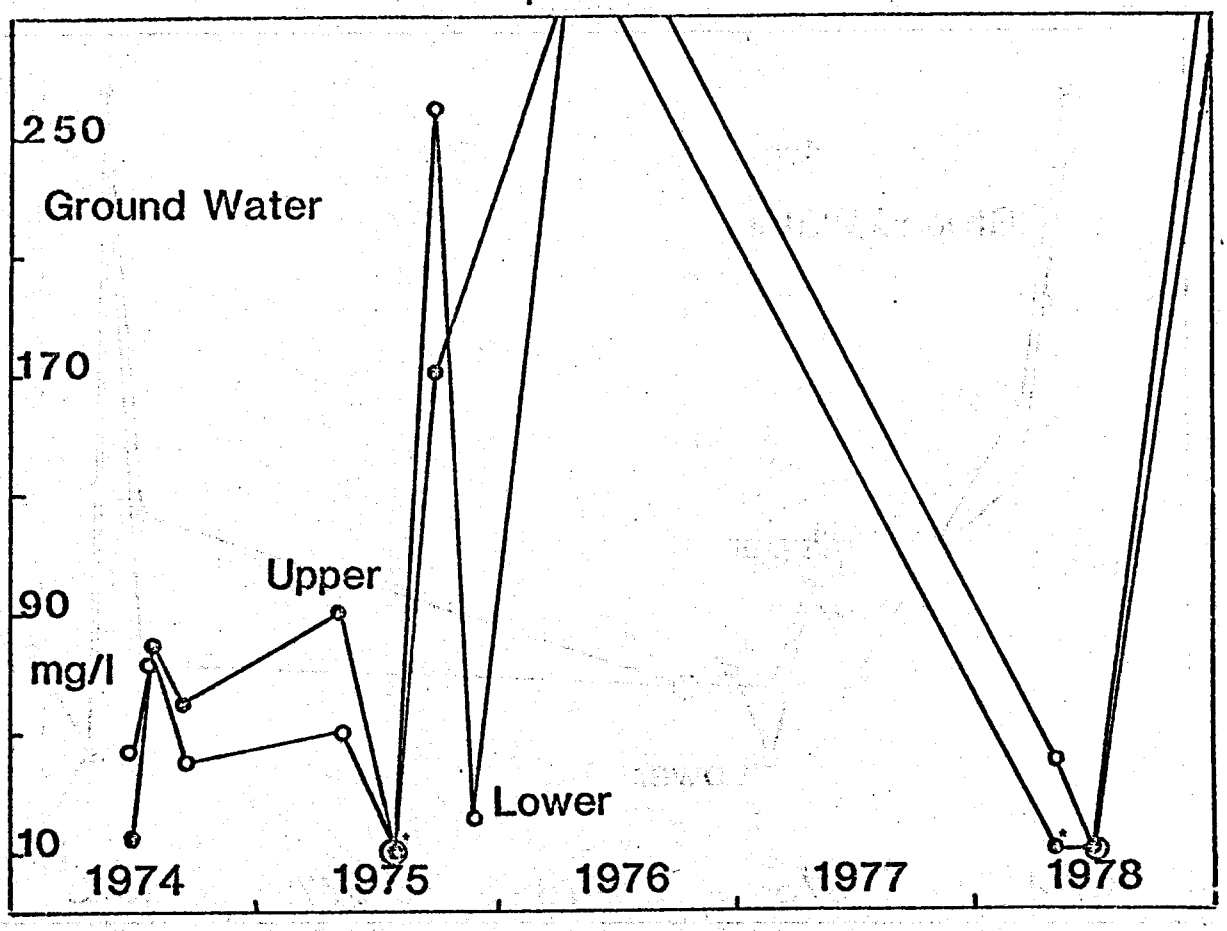


Figure 3.21

Phosphate as P



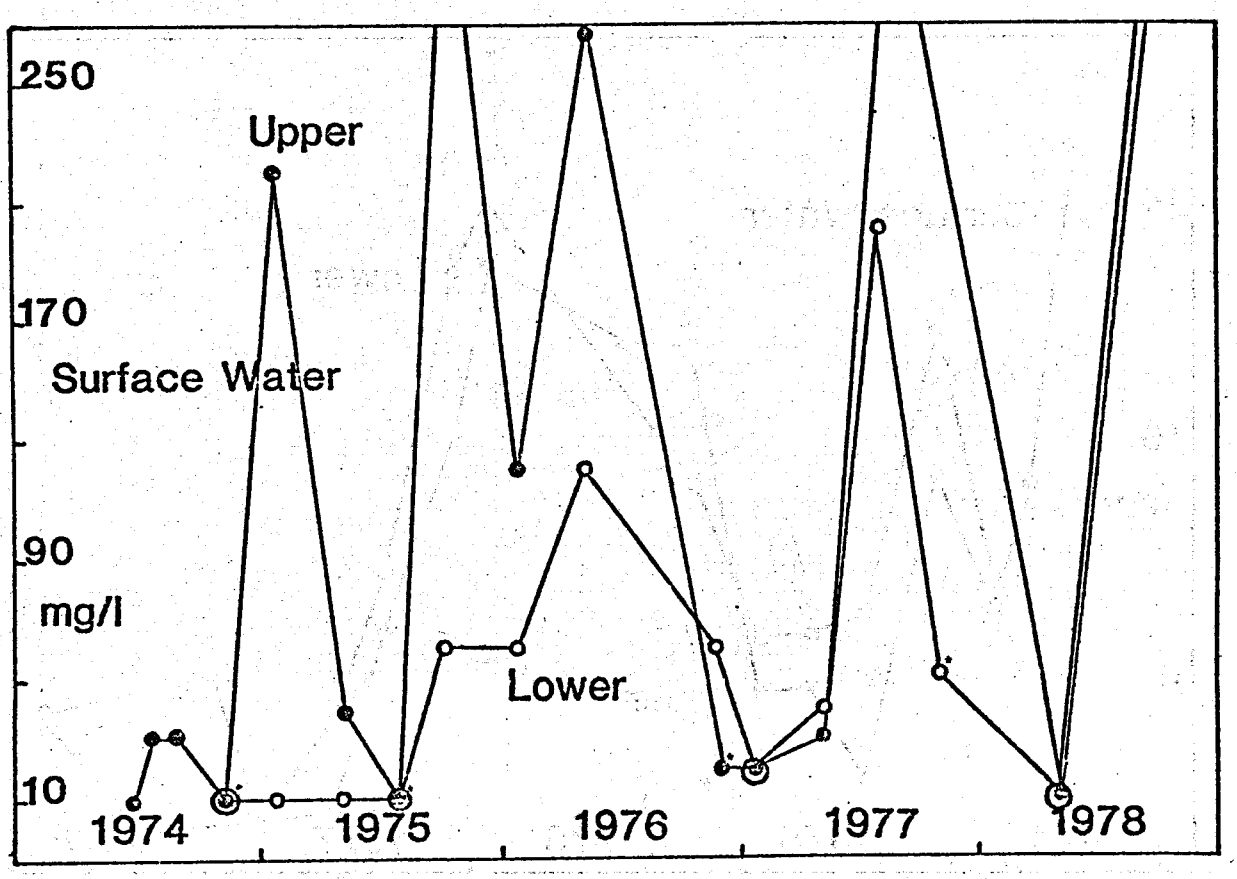


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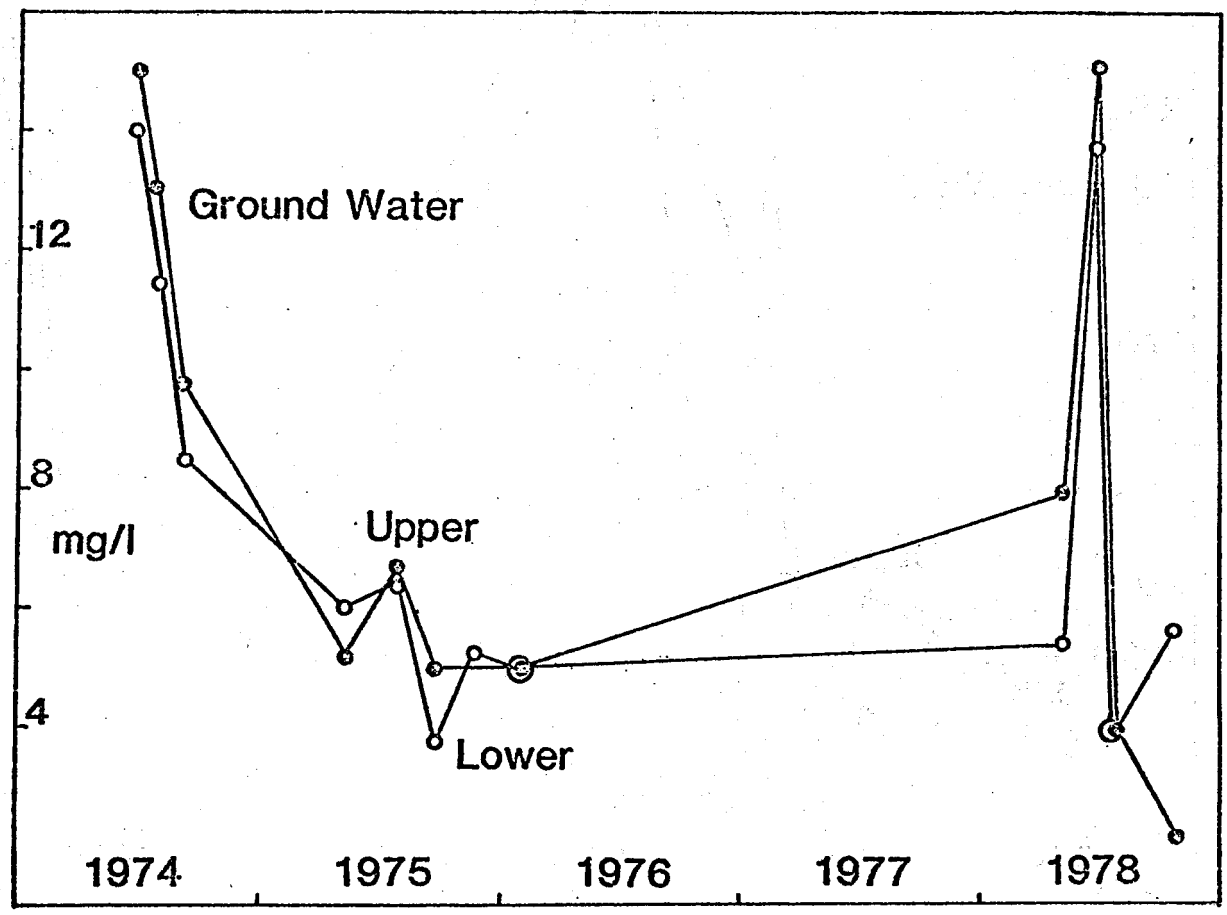
Figure 3.22
Silicon



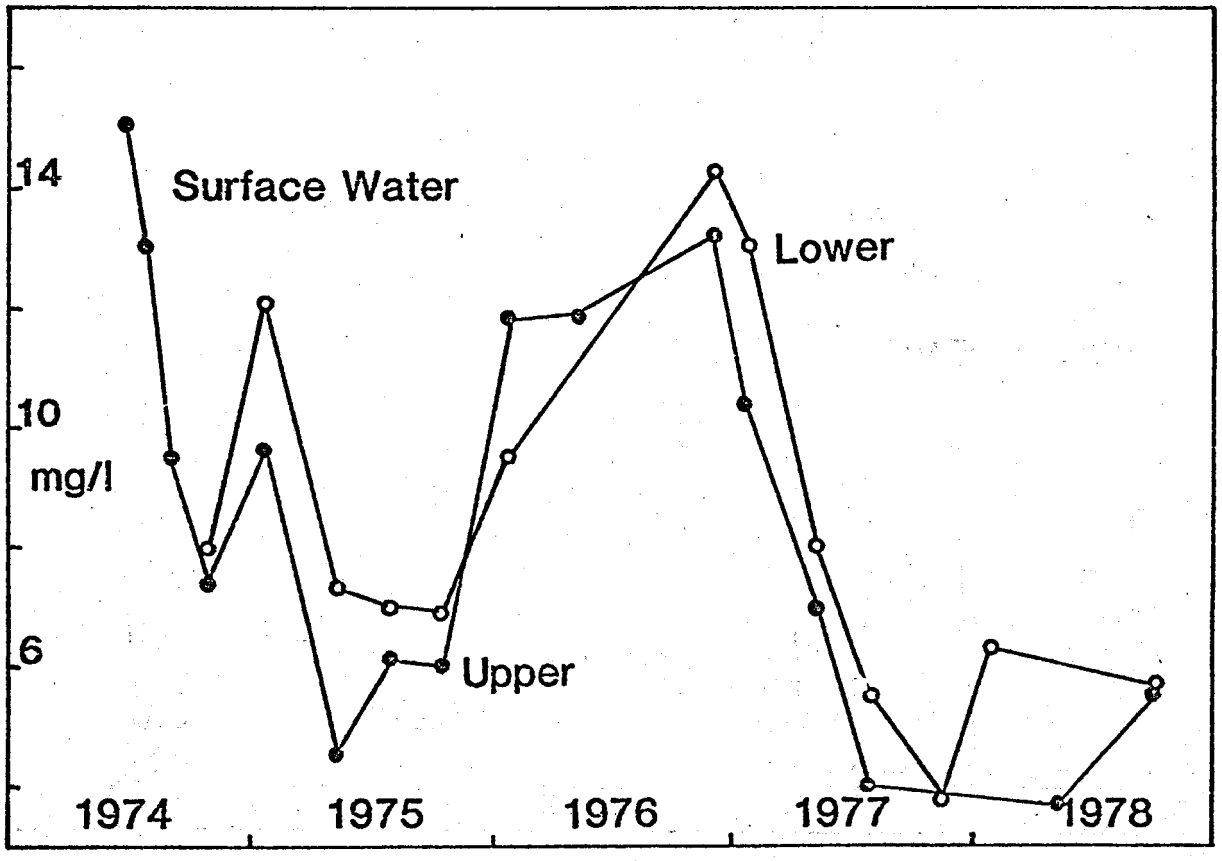
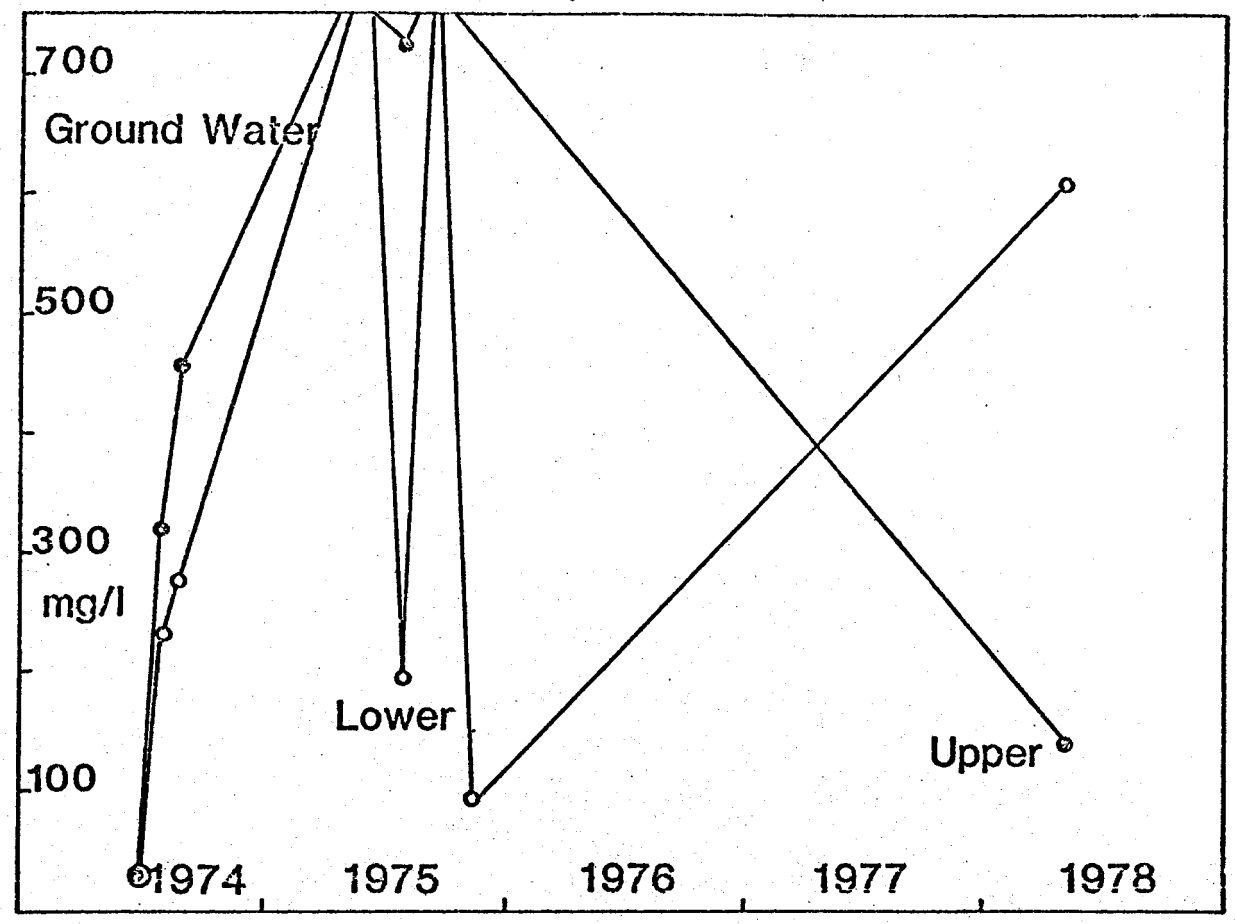
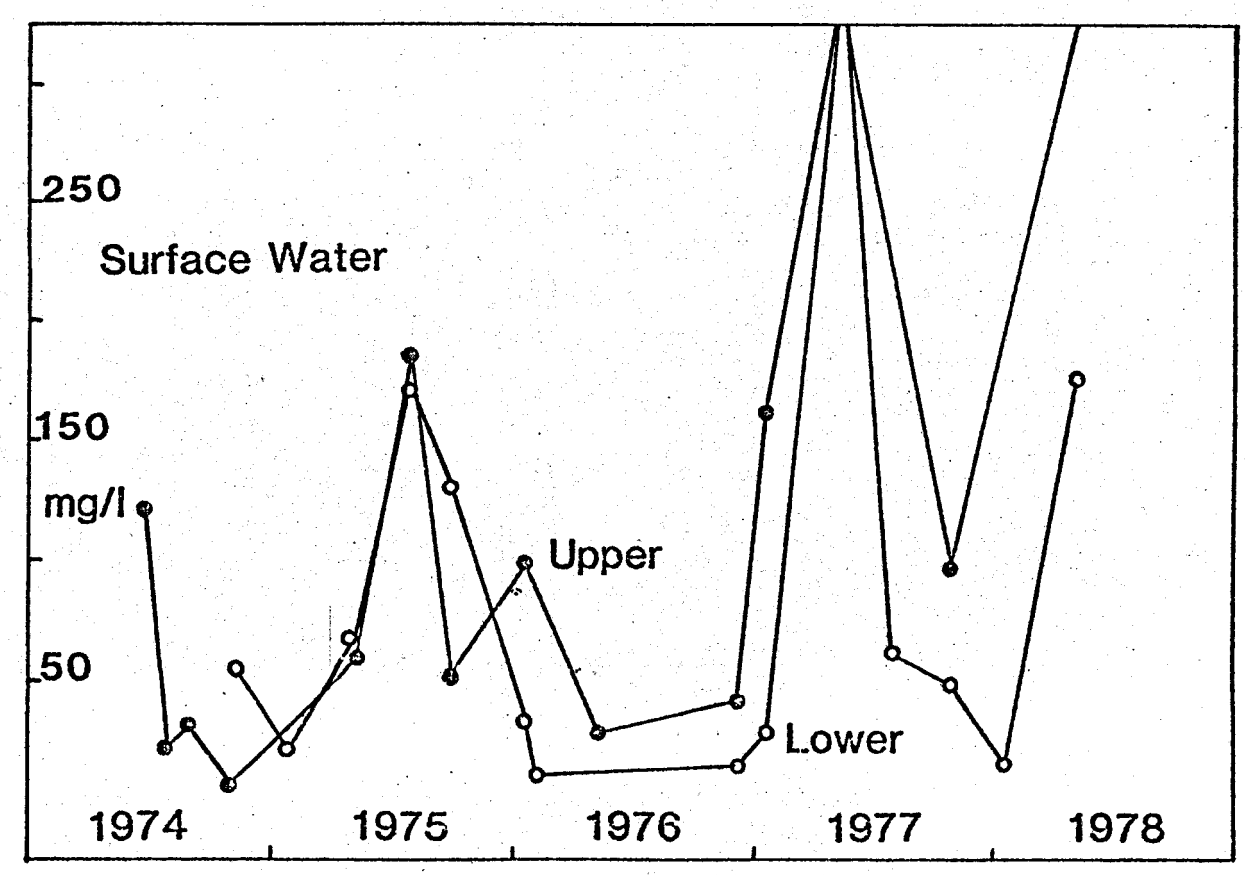


Figure 3.23

Total Suspended Solids





4.0 LEACHATE WATER

A very limited amount of studies concerning the chemical and physical properties of leachate water was conducted during the Paraho operations at Anvil Points, However, studies involving the examination of leachate water from field lysimeters designed to study plant growth on retorted shale and several laboratory leachate studies using Paraho retorted shale and soils and raw shale from the Anvil Points area are currently underway. Since a considerable portion of the data base is still being developed, leachate water data, like ground and surface water data, will be updated annually.

The leachate data compiled in this report has been divided into two broad areas: laboratory studies and field lysimeters. The precise definition and classification of water quality samples is somewhat difficult. For example, the data from the evaporation pond has been grouped with process water data in Section 2.0 even though a major portion of the water entering that pond represents drainage, or leachate, from the shale disposal area.

In addition to some general problems associated with classifying water quality samples, leachate water studies have particular problems in that there is no standard procedure available to conduct laboratory extraction or leaching studies and no uniform, or standard, means of reporting leachate data. For example, some researchers report weight percent of total leachable salts or the pounds of some particular parameter leachable from 100 tons of retorted shale. These data are useful in assessing the soundness or the permeability of a structure such as a retorted shale dam or fill or in assessing particular loadings on the overall environmental impact. Other researchers report findings as concentrations in the leachate liquid that may be related to pore volumes of the solids (shale), mass of the solids (shale), volume of leachate, or time. Data expressed as concentrations in the leachate are useful in assessing the environmental (physiological, toxicological) impact at any given time. Both types of information are needed; neither can be converted into the other without special experimental designs.

Since the leachate data obtained is strongly dependent upon experimental conditions and cannot be readily expressed on a common basis, the data will be presented as prepared by the individual researchers. Since many of these leaching studies are not completed, the conclusions made may change as future data are developed.

4.1 Laboratory Studies

Woodward-Clyde Consultants. As part of a larger field study involving the compaction and permeability of Paraho retorted shale, Woodward-Clyde Consultants performed a series of laboratory leachate studies. These studies included the examination of a standard leach and retorted shale samples compacted under low, medium, and high compactive efforts (see Table 4.1). High compactive efforts are needed to produce impervious materials. Since these materials show low permeabilities, the effluent remains in intimate contact with the solid retorted shale for a long period of time and the concentrations of salts are increased. Conversely, the concentrations in leachates from highly permeable material are lessened by dilution with larger volumes of leachate. A 10:1 (wt:wt) water:shale mixture was used for the standard leach to prevent saturation of any soluble species in the leachate and to assure maximum extraction of all soluble species. Data in Table 4.1 show that permeability decreases as compactive effort increases. Overall salt concentration, total dissolved solids or TDS, are highest for the least permeable material due to more efficient contact between leachate and shale and less dilution by the larger volumes of leachate. Recirculated effluent, representing an event which might take place within a deep disposal pile, reduces the concentrations of most parameters in the leachate. Curing a medium compacted shale at 128°F for 28 days did not seem to affect the permeability or the leachate composition. The most important conclusion to be drawn from these studies is that, with increasing time (and increasing leaching), all leachates (even from the high compaction-low permeability shale) show a marked decrease in the concentration of most parameters and a drop in pH to 7-8.

Paraho. While supplying retorted shale for the Colorado State University lysimeters, some leach studies were done in the Paraho laboratory as part of

the characterization studies (see Tables 4.2 and 4.3). Using a 1:1 (wt:wt) mixture of retorted shale and distilled water (pH, 6-7 and conductivity about 2 μmho/cm), the leachate data were: pH about 11.5; conductivity about 3000 umho/cm. pH values were constant (10.4 to 12.2). The conductivity showed more variation (1700 to > 10,000 μmho/cm). However, for the 84 days listed in Tables 4.2 and 4.3, the conductivity exceeded 5,000 μmho/cm only 12 days.

Utah State University. Two leachate studies were carried out by USU. Extraction studies (see Table 4.4) show pH ranging from 9.0 to 10.8 and electrical conductivity ranging from 17,100 to 22,000 μmho/cm for Colorado retorted shales. A single sample of Utah shale, retorted in the Paraho retort, produced a pH of 11.7 and conductivity of 9,800 μmho/cm. The parameter concentrations confirm these differences in alkalinity and conductivity; the Colorado shales show higher concentrations of the saline parameters (Na, K, Ca, Mg and SO_4) and lower concentrations of the alkaline bicarbonate. The decrease in concentrations of the overall parameters in leachate with successive volumes of leachate is shown in Figure 4.1. Conductivity is plotted against successive leachate increments.

Another laboratory study conducted by USU presented data of parameter concentration as a function of leachate increments (see Table 4.5). Most parameter concentrates dropped significantly from leachate representing 1/10 pore volume to 1 pore volume. Concentrations were reduced to less than 10% of the original values except for calcium and bicarbonate where the reduction averaged 70%. Further reductions in concentration were observed in all cases at leachates equaling 3 pore volume; reductions for all parameters averaged 15% of their original concentrations. No carbonate was detected in these studies.

Denver Research Institute. As part of a broad study involving the assessment of control technologies needed for commercial oil shale operations, the retorted shale leachate was examined. This examination followed the extraction procedure proposed by the U.S. Environmental Protection Agency ("Hazardous Water Guidelines and Regulations", Federal Register, 43, 58956-7 1978). Data presented in Table 4.6 show that the leachate meets the proposed specifications; Paraho retorted shale is not a hazardous waste.

University of Colorado. Interesting observations were made by CU regarding leachate stability (see Table 4.7). Data were presented for pH, B, F, and specific conductance. Only the pH changed with time; the pH dropped from 10.4 to 7.1 in four days and remained constant (7.12 $\pm$ 0.22) for 40 days. The other parameters showed no change: F = 11.0-12.6 ug/ml; B = 0.9 ug/ml; specific conductance = 9745-10610 umho/cm.

4.2 Field Studies

Data from two field studies using Paraho retorted shale have been compiled in this report. Permeability studies, carried out by Woodward-Clyde Consultants, are completed. Plant growth studies, being conducted by Colorado State University, are not complete; data from the first two years are included in this report. A third field study, water harvesting, is being conducted by Utah State University. Initial results from that study will be included in next year's update.

Woodward-Clyde Consultants. Field studies carried out by WCC consisted of constructing two ponds lined with retorted shale - one, lightly compacted, representing the loose fill; and the other highly compacted (see Fig. 4.2). Leachate data are presented in Table 4.8. For the most part, these data confirmed the earlier laboratory studies (see Table 4.1). The field studies show that in a period of nearly 3 months about 9,000 cubic feet of water percolated through the lightly compacted lined pond and about 50 cubic feet of water through the compacted liner. Although it is difficult to make general conclusions, most of the parameter concentrations were higher in the limited quantity of leachate (50 cu. ft.) from the pond having the compacted retorted shale liner.

Colorado State University. Leachate data are being obtained from the field lysimeter, constructed at 6,000 feet elevation by CSU to study plant growth in Paraho retorted shale (see Figs. 4.3 and 4.4). Large quantities of water added to leach the lysimeter surface and aid in plant growth have been collected and analyzed by several researchers.

A study made at CU indicates the cause of poor sulfur balances which occur in leachates and other waters associated with oil shale processing and the cause of the marked decrease of alkaline pH's noted in fresh leachates. Significant amounts of thiosulfate have been determined in the leachates (see Table 4.9). It is postulated that the thiosulfate is the intermediate species in the alkaline oxidation of sulfide (the major sulfur species condensed from the off-gas) to sulfate (the major sulfur species in ground and surface water). CU also examined various plots of the CSU lysimeter. Data shown in Table 4.10 again shows a decrease in concentrations and pH with time for plots H-1/H-3 and H/5-H/7. Data from samples taken 5/10/78 show that higher concentrations of all parameters in the leachates are higher for the shale plots than for the soil control (H-21/H-23).

Collection and detailed analyses of the leachates from the many plots in the CSU lysimeters is being performed annually by Battelle PNL. Results from the first two years of this study are presented in Tables 4.11 and 4.12. Data from 1979 are being developed by Battelle and will be included in the 1980 update of water quality. Because of the voluminous amount of data and because the studies are not complete, it is not possible to draw specific conclusions. Generally, the data show a decrease in parameter concentrations. Battelle has confirmed this trend and noted that, after the second year of this field study, the concentrations of some parameters from the retorted shale plots are lower than those from the soil control plot.

TABLE 4.1

LEACHATE STUDIES

WOODWARD-CLYDE LABORATORY

Description Compactive Effort[2]	Permeability Ft/Yr	Days	pH[1]	TDS ppt	Si ppm	Al ppm	Fe ppm	Ca ppm	Mg ppm	Na ppt	K ppm	Li ppm	$SO_4^{=}$ ppt	$CO_3^{=}$ ppm	HCO_3^{-} ppm	Cl^{-} ppm
(Standard Leach)[3]			11.1	0.001	8	1.3	0.1	200	9	0.2	50	-	.5	180	< 0.1	69
Low	30	1	7.5	6.9	5	< 0.1	0.1	408	47	1.3	289	-	3.3	< 0.1	230	580
	15	5	11.4	2.4	5	0.3	< 0.1	250	8	0.5	74	-	0.3	700	< 0.1	68
	7.5	10	9.0	5.6	9	< 0.2	1.1	18	15	1.4	237	-	2.9	90	290	71
	2.3	20	8.9	4.4	6	1.4	0.8	13	1	1.1	171	17	6.9	98	550	120
Medium	22	1	8.0	7.2	3.7	0.2	0.8	243	7	1.8	312	-	3.1	72	180	670
	7.5	5	11.4	3.3	5	< 0.1	0.1	164	5	0.8	252	-	0.8	410	< 0.1	230
	2.2	10	9.6	5.6	15	< 0.2	1.0	6	2	1.5	245	-	2.6	310	280	36
	0.8	20	8.4	3.7	8	1.6	1.1	6	3	0.8	304	2	1.4	45	710	31
High	3.2	1	7.8	9.2	9	< 0.1	0.3	157	37	2.1	445	-	4.3	< 0.1	330	790
	1.0	5	7.4	8.2	9	< 0.1	0.1	157	42	1.9	334	-	4.0	< 0.1	320	580
	0.4	10	9.0	11.6	9	< 0.2	0.4	16	10	2.9	304	70	6.3	96	630	71
	0.1	20	7.8	6.8	7	0.8	2.2	57	12	1.6	312	10	3.7	< 0.1	300	62
Low[4]	36	10	9.0	2.9	6	1.1	0.6	11	2	0.6	245	11	1.1	100	382	120
	2.2	42	9.1	4.6	15	< 0.1	0.1	16	2	0.9	482	9	1.8	210	630	31
	2.4	49	7.8	1.1	9	< 0.1	< 0.1	3	1	0.2	126	4	0.5	< 0.1	110	20
Medium[4]	22	10	9.8	3.2	14	2.0	0.5	3	3	0.7	289	15	1.1	310	190	210
	8.5	42	7.6	3.3	32	< 0.1	0.1	6	< 1	0.7	378	6	1.7	< 0.1	310	27
	14	49	9.0	1.5	5	< 0.1	0.1	4	2	0.3	96	4	0.6	74	230	17
Medium[5]	14	1	7.8	10.8	5	0.6	1.0	138	13	2.4	749	18	5.7	< 0.1	340	400
	12	5	8.2	7.7	9	1.1	1.3	63	5	1.7	638	13	4.0	18	220	290
	11	10	8.0	2.0	12	0.8	0.5	18	1	0.3	237	7	0.9	12	140	52
	12	20	7.7	0.5	15	2.5	1.5	8	< 1	< 0.1	74	< 1	0.1	< 0.1	76	7

Notes:
(1) All data except pH in parts per million (ppm) or parts per thousand (ppt).
(2) Compactive effort: low, 6200 ft-lb/cu ft; medium, 12375 ft-lb/cu ft; high, 56200 ft-lb/cu ft.
(3) Water:shale, 10:1 (wt:wt), tumbled 6 hours at room temperature.
(4) Recirculated effluent.
(5) Shale cured 28 days at 125°F before permeability/effluent study.

TABLE 4.2

LEACHATE - RETORTED SHALE

CSU - LOWER LEVEL LYSIMETER

Sample Date	pH	Conductivity µMHOS	Background Water pH	Background Water Cond.
3-21-77	11.3	2900	6.4	1.4
3-22-77	11.3	2600	5.6	1.2
3-23-77	11.4	2825	5.6	2.0
3-24-77	11.5	3150	5.7	2.0
3-25-77	11.6	2400	6.1	1.9
3-26-77	11.6	2650	6.0	2.0
3-27-77	11.4	2200	7.0	2.0
3-28-77	11.6	2700	6.3	2.0
3-29-77	11.4	3500	7.8	1.5
3-30-77	11.5	3950	5.7	1.8
3-31-77	11.4	3900	6.2	1.4
4-1-77	11.5	3900	6.7	1.4
4-2-77	11.6	4300	6.7	1.4
4-3-77	11.6	3930	6.0	2.0
4-4-77	11.4	3400	6.2	1.4
4-5-77	11.4	3750	6.2	1.4
4-6-77	11.4	3100	5.6	1.4

Method: direct read instrument.

TABLE 4.3

LEACHATE - RETORTED SHALE

CSU - UPPER LEVEL LYSIMETER

Sample Date	pH	Conductivity µMHOS	Background pH	Water Cond.
7-11-77	11.5	6200	6.8	1.7
7-12-77	11.6	5700	6.3	1.5
7-13-77	11.7	5200	7.2	1.6
7-14-77	11.4	2500	6.2	1.8
7-15-77	11.2	2350	6.2	1.8
7-16-77	11.2	5500	7.4	1.4
7-17-77	11.4	2800	6.6	1.4
7-18-77*	12.2	10000	6.0	1.8
7-19-77*	12.2	10000	6.0	1.8
7-20-77	11.3	4400	7.1	1.8
7-21-77	11.9	5000	5.7	1.7
7-22-77	12.0	5000	5.9	1.8
7-23-77	11.8	3000	6.1	2.6
7-24-77	11.9	5400	6.1	2.6
7-25-77	11.9	6800	6.1	2.6
7-26-77	12.2	> 10000	6.7	1.7
7-27-77	11.8	> 10000	6.2	1.6
7-28-77*	11.6	5200	5.9	1.7
7-29-77*	11.6	5200	5.9	1.7
7-30-77	11.1	3800	5.8	1.6
7-31-77	11.9	5200	6.4	1.8
8-1-77	11.2	3900	5.9	1.8
8-2-77	11.6	3600	6.7	1.8
8-3-77	11.3	5200	6.3	1.8
9-4-77	11.2	1700	6.3	1.4
9-5-77	11.3	2400	6.3	1.4
9-6-77	11.5	2300	6.3	1.4
9-7-77	11.1	2900	6.2	1.3
9-8-77	10.4	3800	6.2	1.3
9-9-77	11.3	3000	6.7	1.4
9-10-77	11.2	2700	6.7	1.4
9-11-77	11.6	3600	6.4	1.6
9-12-77	11.2	2800	6.4	1.6
9-13-77	10.7	2900	6.9	1.6
9-14-77	11.0	4000	6.5	1.8
9-15-77	11.3	3100	6.9	1.5
9-16-77	11.4	3000	6.9	1.5
9-17-77	11.4	3200	6.9	1.5
9-18-77	11.3	2100	6.8	1.5
9-19-77	11.4	2200	6.8	1.5
9-20-77	11.4	2300	6.8	1.5
9-21-77	11.3	2900	6.7	1.4
9-22-77	11.3	2800	6.2	1.5

* Combined Sample

TABLE 4.3 (Cont'd)

Sample Date	pH	Conductivity UMHOS	Background pH	Water Cond.
9-26-77	10.8	1900	6.2	1.6
9-27-77	11.6	2400	6.4	1.4
9-28-77	11.9	4400	6.3	1.8
9-29-77	11.5	2400	6.3	1.6
9-30-77	11.6	2500	6.4	1.5
10-1-77	11.0	1800	6.8	1.6
10-10-77	10.6	3000	6.5	1.3
10-11-77	11.0	2900	6.5	1.3
10-12-77	10.8	3100	6.5	1.3
10-13-77	11.8	3200	6.6	2.1
10-14-77	10.8	2500	6.4	1.4
10-15-77	11.9	3400	6.6	2.1
10-16-77	11.8	3100	6.6	2.1
10-17-77	10.1	3100	6.6	1.8
10-18-77	11.1	3400	6.2	1.8
10-19-77	11.4	3600	6.2	1.8
10-20-77	11.2	3000	6.7	2.3
10-21-77	10.6	2200	6.7	2.3
10-22-77	10.6	2400	7.4	2.3
10-23-77	11.1	3000	6.8	2.3
10-24-77	10.7	1800	7.2	2.5
10-25-77	11.0	2850	6.8	1.5

Method: direct read instrument.

TABLE 4.4

LABORATORY LEACHATES

UTAH STATE UNIVERSITY

COLORADO AND UTAH SHALES

	pH	EC_e mmho/cm	Me/100 g based on 1:1 extract								ppm					
			Na	K	Ca	Mg	SO_4	Cl	HCO_3	CEC	B	P	NO_3	K	Fe	Zn
Colo. Shale #1	9.0	17.1	6.9	0.6	1.4	1.9	11.1	0.1	0.2	4.8	0.7	4.4	0.3	290		
Colo. Shale #2	9.0	10.6	4.0	0.1	0.7	2.8	5.2	0.04	0.2		0.9	1.7		102		
Colo. Shale #3	9.3	19.0	5.3		0.5	1.8	9.0	0.04	0.1			5.2	0.3	460	61	13.4
Colo. Shale #4	9.0	22.0								5.1	0.5	3.8	0.4	480	49.2	8.4
Colo. Shale #5	10.8	9.8	3.0		0.7	0.1					1.5				46	0.5
Utah Shale	11.7	5.2	1.3	0.3	0.6	0.01	1.5	0.2	0.7		0.2					

TABLE 4.5

LABORATORY LEACHATES[1]

UTAH STATE UNIVERSITY

Leachate Increments Pore Volumes	Specific Ion Concentrations[2]							
	Na	K	Ca	Mg	Cl	SO_4	HCO_3	CO_3
0.1	509.0	19.3	23.5	436.0	14.1	882.0	1.64	0
0.6	51.7	11.3	-	-	1.6	139.0	1.43	0
1.0	17.4	1.6	18.8	57.1	.9	46.5	1.00	0
3.0	2.2	.6	15.7	13.4	.4	36.0	.50	0

(1) Experiment used a 90-cm column of retorted shale having 20-cm pore volume

(2) All data expressed in milli-equivalents/liter.

TABLE 4.6

LEACHATE DATA
EPA EP TEST (RCRA)

Arsenic	< 0.1	ppm
Barium	< 10	ppm
Cadmium	< 0.05	ppm
Chromium	< 1	ppm
Mercury	14	ppb
Lead	220	ppb
Selenium	23	ppb
Silver	30	ppb

Method: EPA Standard Procedures.

TABLE 4.7

LABORATORY LEACHATES

UNIVERSITY OF COLORADO

Sample No.	Days after Filtering	pH	F ug/mL	B ug/mL	Specific Conductance umhos/cm
8074	0	10.4	12.0	0.9	10,524
8075	2	9.7	12.8	0.9	10,477
8076	3	9.8	11.3	0.9	9,745
8077	4	7.1	12.6	0.9	10,488
8078	6	7.0	-	-	10,342
8079	8	7.0	12.4	0.9	10,610
8080	10	7.0	11.4	0.9	10,194
8081	40	7.5	11.0	0.9	10,185
8089	0	11.9	~ 10	2.3	10,797

Note: Experiment was carried out by shaking a distilled water/retorted shale mixture (1:1, wt:wt) for 120 hours at room temperature.

TABLE 4.8

FIELD LEACHATE STUDIES

WOODWARD-CLYDE CONSULTANTS

Sample Identification				
Pond	Loose Fill (Uncompacted)			Compacted
Date	12/5/75	12/22/75	1/2/76	1/2/76
Leachate Vol. (Approx), Cu.Ft.	only Dripping	8000	9000	50
Constituent (ppm)				
Total Suspended Solids	22	475	22	44
Total Dissolved Solids	2454	24018	7062	11888
pH	7.2	7.8	10.4	11.4
Oil and Grease	1.6	82	12	1
Sulphate	958	1.05%	1122	1314
Total Phosphorous	0.22	0.36	0.29	0.36
Chloride	10.5	1.68	651	112
Fluoride	2.2	43	9.2	6.8
Oxygen	78.6	1376	395	1426
Nitrogen (Kjeldahl)	5.7	22.8	6.2	13.0
Magnesium	39.6	137	2.6	1.4
Copper	< 0.01	0.14	0.02	0.02
Iron	4.2	0.99	0.11	0.14
Potassium	9.9	539	161	91
Lead	0.05	0.18	0.07	0.07
Aluminum	< 0.1	0.83	0.59	0.88
Zinc	0.10	0.22	0.09	0.69
Cadmium	0.004	0.12	< 0.005	< 0.005
Molybdenum	0.04	8.4	1.7	4.3
Calcium	76	530	480	54.5
Sodium	510	6176	1740	3510
Phenols	0.04	0.01	0.02	0.08
Silica (SiO_2)	10	3.8	6.0	6.6
Alkalinity ($CaCO_3$)	112	626	1.88	454
Mercury	0.002	0.001	0.012	0.010
Cyanide	< 0.001	< 0.005	< 0.001	0.003
Sulphide	< 0.05	5.1	2	4
Boron	0.02	5.4	1.7	1.7
Arsenic	0.002	< 0.3	5.8	3.9

TABLE 4.9

FIELD LEACHATE

UNIVERSITY OF COLORADO

SULFUR SPECIES

Sample #	Date Collected	pH Initial pH	pH 7/5/77	pH 6/22/78	pH 11/22/78	Remaining reduced species on 11/22/78 $S_2O_3^{2-}$ (mg/L)	Remaining reduced species on 11/22/78 SCN^- (mg/L)
RW5279	6/8/77	10.2	5.4	3.6	3.6	3800	-(2)
RW5280	6/8/77	10.5	6.2	6.5	6.4	2200	51
RW5284	6/8/77	8.2	6.4	3.3	3.2	870	30
RW5285	6/9/77	10.8	6.3	6.5	6.4	1350	-
RW5286	6/9/77	10.4	6.9	6.8	7.4	1070	-
RW5287	6/9/77	11.2	8.6	-	6.4	1180	24
RW5288	6/9/77	10.9	5.9	6.4	7.0	1350	-
RW5289	6/9/77	10.7	6.2	7.0	7.0	1250	-
RW5291	6/13/77	10.9	9.7	7.2	7.9	2680	86
RW5292	6/13/77	11.0	10.1	7.2	7.3	2200	57
RW5293	6/13/77	-	6.6	3.5	3.5	2020	-
RW5294	6/13/77	10.9	10.8	7.4	8.0	2940	-
RW5295	6/13/77	10.7	9.1	7.5	7.3	895	-
RW5296	6/13/77	10.4	8.8	6.8	7.5	760	-
RW5297	6/13/77	11.4	10.8	7.2	7.7	980	-
RW5298	6/13/77	11.7	11.5	7.9	7.7	1290	-
RW5299	6/13/77	11.3	10.6	6.9	6.9	1620	-
RW5302	6/14/77	11.3	11.2	7.9	6.7	-	-
RW5303	6/14/77	11.3	11.2	8.4	9.0	1400	-
RW5304	6/14/77	11.6	11.5	9.1	9.2	1820	-
RW5305	6/14/77	10.5	7.8	7.1	8.0	1590	-
RW5307	6/14/77	11.1	11.0	7.6	7.7	2580	-
RW5309	6/10/77	-	8.5	3.9	3.9	1480	-
RW5310	6/10/77	-	6.5	6.5	6.4	770	-
RW5311(3)	6/14/77	10.7	8.8	7.8	-	1250	-
RW5312	6/14/77	11.0	9.2	7.5	7.0	1180	-

(1) Samples obtained from Colorado State University Lysimeters.
(2) - Not determined.
(3) Analyzed 2/19/78 during checkout of thiosulfate procedure. $S_2O_3^{2-}$ = 2,150 mg/L, $S_4O_6^{2-}$ = 720 mg/L.

TABLE 4.10

FIELD LEACHATE[1]

UNIVERSITY OF COLORADO

Date Sampled	Plot #	pH	Specific Conductance (umhos/cm)	B	F	Mo	As	Se	SO_4^{2-}	Volumetric[2] Meter Reading (L)
6/77	H-1/H-3	10.3	22,300	1.5	7.8	3.9	.09	.12	15,900	3570
5/10/78	H-1/H-3	7.5	10,220	.7	4.8	1.4	.023	.069	5,870	4560
6/77	H-5/H-7	11.1	18,900	1.4	7.5	3.0	.07	.10	14,000	700
5/10/78	H-5/H-7	7.2	12,450	.7	5.1	1.2	.044	.071	8,070	1100
5/10/78	H-9/H-11	8.5	23,250	.6	6.6	2.1	.022	.149	14,830	670
5/10/78	H-13/H-15	8.5	18,360	.5	5.4	1.5	.027	.092	10,150	1240
5/10/78	H-17/H-19	8.5	19,530	.5	5.4	2.3	.047	.112	12,660	115
5/10/78	H-21/H-23 (Soil Control)	7.2	10,670	.4	.4	.1	.009	.018	1,400	26

(1) Samples obtained from Colorado State University lysimeters.
(2) Approximate volume of leachate which had already passed through pipe when sample was collected.

TABLE 4.11

FIELD LEACHATES

BATTELLE PNL

Table 2A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+ µg/ml	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
H_1 H_3	6	6/9/77	9.3	21850	5.85	20800	286	241	1280	11.4	10800	NA	NA	<0.1	5360	663	440	6.8
	600	6/12	11.1	21680	9.40	20600	139	130	600	10.9	12000	NA	NA	<0.1	5360	772	513	0.92
	806	6/13	10.7	24000	10.3	22550	148	118	510	12.0	13500	NA	NA	<0.1	5980	916	493	5.9
	1200	6/14	10.5	29000	10.5	26300	208	169	940	12.5	15800	NA	NA	<0.1	7250	1090	480	5.2
	2286	6/16	10.7	30000	10.2	30700	172	153	600	14.2	19700	NA	NA	<0.1	9050	1450	395	3.3
	2427	6/17	10.9	29000	10.1	30850	166	140	510	14.0	20000	NA	NA	<0.1	8090	1460	394	3.0
	4792	7/14	10.7	23460	10.3	19200	44	20	140	8.4	11600	NA	NA	<0.1	5000	853	139	0.42
	6123	8/1	8.4	19074	8.0	21350	46	19	110	9.6	13700	NA	NA	<0.1	5500	1020	414	34.0
	6930	8/8	8.6	17703	9.1	16600	13	<2	80	7.3	10400	NA	NA	<0.1	4270	620	198	13.9
	8421	8/23	9.0	11890	7.95	12200	12	3	80	8.6	7500	NA	NA	<0.1	2550	620	445	23.8
	8471	8/25	9.1	11800	7.45	11800	16	<2	130	8.0	7100	NA	NA	<0.1	2450	607	444	21.3
	9206	4/11/78	7.8	13290	7.60	13040	11	8	100	6.8	8319	<1.0	0.10	4.0	3020	569	387	57.0
	9322	4/12	7.7	12011	6.60	12220	7	6	112	4.3	7140	<1.0	0.115	6.3	2240	565	348	83.5
	9404	4/12	7.8	14180	7.00	12906	21	16	108	5.0	9001	<1.0	0.038	11.4	2860	632	365	138.0
	9530	4/13	7.7	15030	6.60	14900	11	10	112	5.2	9490	<1.0	0.82	7.7	3500	640	377	114.0
	9690	4/13	8.7	13580	6.00	13820	10	10	119	3.8	8680	<1.0	4.15	2.3	2850	590	373	115.0
	9816	4/13	8.6	13460	5.90	13540	8	6	116	4.6	8283	2.4	0.14	1.07	2910	595	387	120.0
	9918	4/13	8.0	14664	5.52	14460	6	5	114	4.9	8888	2.6	0.82	0.55	2940	645	365	87.8
	10042	4/14	8.5	14690	5.10	15120	12	10	102	5.8	9519	<1.0	0.10	0.20	3340	655	367	66.1
	10194	4/14	7.9	15120	5.20	14850	12	11	104	5.1	9098	2.6	0.002	0.33	3450	690	380	60.0
	10254	4/14	8.0	13580	5.60	14230	9	8	106	5.0	9067	2.4	0.19	1.7	3630	667	406	64.6
	10341	4/15	8.0	13467	5.30	13500	49	12	106	4.2	8520	3.3	0.041	<0.1	3190	655	401	56.9
	10439	4/15	7.7	13440	4.70	13280	6	6	104	4.6	8102	2.8	0.78	<0.1	2880	635	391	54.3
	10477	4/15	7.8	13100	4.95	12940	10	8	106	4.9	8206	2.4	1.40	0.62	2620	617	384	56.9
	10499	4/16	7.8	12270	4.90	12320	10	5	108	5.1	7255	2.9	0.83	0.25	2860	584	430	55.1
	10556	4/16	7.7	11820	6.10	10650	7	4	100	3.2	6691	2.0	0.44	1.00	2410	531	404	56.8
	10593	4/17	7.3	10860	7.10	9823	6	6	104	4.0	6279	1.8	1.05	1.48	2400	540	444	57.5
	10631	4/18	7.4	10180	7.00	9823	10	4	106	4.4	5761	1.6	0.16	6.10	2030	505	434	53.4
	10681	4/19	7.2	10120	6.90	9720	54	10	103	4.2	5865	1.9	0.012	2.2	1810	505	423	48.5
	10717	4/20	7.6	10970	6.90	8748	80	8	104	4.6	5754	<1.0	0.38	2.5	1810	495	428	52.5
	10747	4/21	7.5	8390	7.10	9612	17	3	104	4.6	5816	<1.0	0.31	6.1	1790	485	416	55.6
	10773	4/22	7.4	10224	6.90	8748	9	9	101	4.3	5750	<1.0	0.72	5.0	1750	485	410	50.2
	10815	4/24	7.4	9997	6.85	9720	20	6	103	4.6	5803	<1.0	0.64	3.5	1830	495	412	49.4
	10861	4/27	7.8	10217	7.15	10150	21	6	105	4.1	6054	<1.0	0.24	5.3	1880	500	405	57.1
	10911	5/3	7.0	10116	7.35	9610	22	7	104	5.4	5894	<0.2	0.009	4.6	1880	535	331	48.4
	10955	5/9	7.2	10088	7.35	9838	19	3	104	5.1	6132	<0.2	0.009	5.2	1880	525	358	41.6
	11010	5/15	7.3	10675	7.70	9918	22	8	106	5.1	5820	<0.2	0.006	5.3	1840	521	332	54.5
	11044	5/19	7.3	10547	7.40	9988	17	3	102	5.4	6046	<0.2	0.004	4.8	1810	527	322	59.3

TABLE 4.11 (Cont'd)

Table 2B

Sample ID	Gal	Date	Sr	SiO_2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Ca	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
H_1 H_3	6	6/9/77	10.5	24.1	1.1	3.7	0.23	1.09	0.025	0.11	0.07	0.075	NA	0.170	0.020	0.04	0.29	0.11	NA
	600	6/12	11.6	6.6	1.3	3.3	0.30	0.10	<0.020	0.11	0.07	<0.01	NA	0.030	0.003	0.03	<0.01	<0.01	NA
	806	6/13	11.9	11.9	1.5	3.7	0.30	0.09	0.03	0.15	0.05	<0.01	NA	0.060	0.005	0.02	<0.01	<0.01	NA
	1200	6/14	12.0	22.2	1.8	4.6	0.35	0.11	0.03	0.20	0.05	<0.01	NA	0.060	0.008	<0.01	<0.01	0.055	NA
	2286	6/16	11.6	27.3	2.2	5.6	0.35	0.12	0.03	0.15	0.05	<0.01	NA	0.070	0.008	<0.01	<0.01	0.055	NA
	2427	6/17	11.8	25.7	2.1	5.4	0.30	0.13	0.04	0.12	0.13	0.15	NA	0.070	0.016	<0.01	<0.01	0.055	NA
	4792	7/14	6.3	7.7	1.0	2.5	0.18	0.06	<0.02	0.047	0.04	<0.01	NA	0.050	0.004	<0.01	<0.01	<0.01	NA
	6123	8/1	10.1	19.4	1.6	3.0	0.18	0.08	<0.02	0.091	0.06	0.26	NA	0.016	0.005	<0.01	<0.01	<0.01	NA
	6930	8/8	6.1	17.3	0.67	1.0	0.10	0.07	<0.02	0.017	0.04	0.11	NA	0.031	0.003	<0.01	<0.01	<0.01	NA
	8421	8/23	10.0	14.2	1.1	1.6	0.15	0.05	<0.02	0.061	0.04	0.043	NA	0.006	0.002	<0.01	<0.01	<0.01	NA
	8471	8/25	9.9	14.4	1.1	1.6	0.10	0.05	<0.02	0.065	0.04	0.049	NA	0.004	0.002	<0.01	<0.01	<0.01	NA
	9206	4/11/78	7.94	12.50	0.68	1.3	0.17	0.010	0.018	0.035	0.017	0.014	7.13	0.0150	0.001	<0.005	0.015	0.066	0.034
	9322	4/12	6.40	9.90	0.66	0.95	0.10	0.011	0.005	0.031	0.018	0.012	6.15	0.003	0.006	<0.005	0.018	0.016	0.30
	9404	4/12	7.17	10.4	0.66	1.5	0.14	0.008	0.28	0.047	0.022	<0.01	7.25	0.004	0.008	<0.005	0.018	0.017	0.34
	9530	4/13	7.07	11.0	0.74	1.8	0.14	0.020	0.009	0.050	0.015	<0.01	7.57	0.009	0.008	<0.005	0.042	0.030	0.34
	9690	4/13	6.55	10.1	0.68	1.8	0.28	0.016	<0.0005	0.043	0.009	<0.01	7.30	0.006	0.006	<0.005	0.019	<0.005	3.40
	9816	4/13	6.65	11.2	0.71	1.5	0.10	<0.105	0.010	0.043	0.023	<0.01	6.81	0.012	0.005	<0.005	0.017	0.012	0.34
	9918	4/13	6.50	10.5	0.75	1.6	<0.1	<0.005	0.008	0.043	0.027	<0.01	6.61	0.007	0.004	<0.005	<0.01	0.006	0.3
	10042	4/14	6.75	10.6	0.84	1.8	0.25	0.020	<0.0005	0.046	0.012	<0.01	6.87	0.002	0.006	0.006	<0.01	<0.005	1.00
	10194	4/14	6.75	11.2	0.87	1.6	<0.1	0.021	0.007	0.045	0.020	<0.01	6.12	0.004	0.004	0.005	0.060	0.015	<0.3
	10254	4/14	7.66	11.4	0.86	1.9	0.14	0.019	0.002	0.047	0.021	0.011	6.48	0.003	0.003	<0.005	0.014	0.037	<0.3
	10341	4/15	7.03	11.8	0.90	1.8	0.16	0.010	0.0005	0.043	0.011	<0.01	6.57	0.002	0.004	<0.005	<0.01	<0.005	1.65
	10439	4/15	6.85	12.2	0.89	1.5	0.11	<0.005	0.007	0.044	0.025	0.017	6.51	0.008	0.005	<0.005	<0.01	<0.005	<0.3
	10477	4/15	6.93	11.3	0.80	1.5	0.22	0.018	0.014	0.043	0.025	0.018	6.40	0.002	0.002	<0.005	0.019	0.002	<0.3
	10499	4/16	7.35	12.5	0.80	1.3	0.11	0.018	0.006	0.041	0.016	0.019	6.50	0.002	0.002	<0.005	0.002	0.048	<0.3
	10556	4/16	7.18	12.5	0.69	1.4	<0.1	0.069	0.011	0.039	0.017	0.025	6.48	0.003	0.001	<0.005	0.016	0.028	<0.3
	10593	4/17	7.42	12.5	0.72	1.2	<0.1	<0.005	0.006	0.037	0.018	0.022	6.84	<0.001	0.002	<0.005	0.028	0.037	<0.3
	10631	4/18	7.35	12.7	0.68	1.2	<0.1	0.022	0.005	0.036	0.017	0.025	7.21	<0.001	0.002	<0.005	0.030	0.075	<0.3
	10681	4/19	6.76	11.4	0.64	1.3	<0.1	0.021	0.005	0.032	0.005	0.018	7.71	<0.001	0.001	<0.005	<0.01	<0.005	1.02
	10717	4/20	7.61	12.0	0.69	1.3	0.21	0.021	0.004	0.036	0.008	0.017	8.18	<0.001	0.002	<0.005	0.014	<0.005	0.68
	10747	4/21	7.33	12.2	0.64	1.3	<0.1	0.015	0.003	0.035	0.006	0.017	8.28	<0.001	0.001	<0.005	0.010	<0.005	1.00
	10773	4/22	8.50	11.4	0.63	1.3	<0.1	0.015	0.004	0.032	0.006	0.010	8.55	<0.001	0.001	<0.005	<0.01	<0.005	1.19
	10815	4/24	7.25	11.3	0.63	1.3	<0.1	0.010	0.005	0.031	0.008	<0.01	8.37	<0.001	0.002	<0.005	<0.01	<0.005	0.34
	10861	4/27	7.67	12.9	0.70	1.4	<0.1	0.012	0.003	0.036	0.008	0.011	8.67	<0.001	0.002	<0.005	0.010	<0.005	1.00
	10911	5/3	5.92	10.9	0.65	1.2	0.031	0.016	0.007	0.029	0.009	0.005	8.35	0.005	0.002	<0.005	<0.01	<0.005	2.0
	10955	5/9	6.89	10.8	0.69	1.2	0.037	0.007	0.005	0.033	0.009	0.008	7.75	<0.001	0.001	<0.005	<0.01	0.011	<0.3
	11010	5/15	6.55	11.5	0.68	1.2	0.029	0.006	0.006	0.033	0.010	0.005	7.81	<0.001	0.001	<0.005	<0.01	<0.005	<0.3
	11044	5/19	6.58	11.2	0.69	1.3	0.027	0.007	0.007	0.034	0.009	0.008	7.65	<0.001	0.002	<0.005	<0.01	<0.005	<0.3

TABLE 4.11 (Cont'd)

Table 3A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
							µg/ml											
$H_6 H_8$	439	6/17/77																
	459	4/12/78	8.1	10570	5.90	10400	12	11	72	2.8	6173	2.3	0.001	<0.1	2200	440	423	34.8
	510	4/13	9.4	7850	6.30	7560	23	16	50	4.4	4430	2.2	0.010	<0.1	1540	350	458	9.5
	550	4/14	8.62	13820	7.0	14930	13	9	98	2.3	9050	3.5	0.010	<0.1	3710	670		11.3
	563	4/16	8.50	16100	6.90	16200	13	12	138	4.4	8980	4.9	0.012	<0.1	3820	720	378	10.4
$H_{10} H_{12}$	5	4/12/78	9.0	31770	7.75	21300	40	35	34	4.6	18980	7.2	<0.001	0.28	8500	955	444	96.5
	153	4/13	9.08	16110	8.00	17280	27	27	40	4.1	10700	5.4	0.007	<0.1	4200	720	416	32.7
	207	4/13	9.06	17060	6.90	18530	21	21	90	4.9	10760	6.2	0.002	<0.1	4110	760	398	27.7
	248	4/13	8.22	19472	8.00	19190	25	20	90	4.2	11770	12.0	0.004	<0.1	4850	810	420	26.2
	335	4/14	8.78	25630	6.40	24520	104	71	380	6.8	15450	14.5	<0.001	<0.1	7050	1016	410	24.5
$H_{14} H_{16}$	17	4/13/78	8.2	11300	5.90	11130	21	18	116	4.1	6536	3.9	0.004	0.14	2640	415	462	42.5
	26	4/13	7.5	13700	5.50	13610	21	21	142	4.3	8519	1.4	0.008	<0.1	3270	584	462	71.9
$H_{18} H_{20}$	10	4/12/78	8.00	11000	6.20	10960	20	10	113	2.8	6555	1.1	0.006	<0.1	2540	320	319	31.9
	84	4/13	9.0	10580	7.20	10340	23	22	168	4.2	5814	2.4	0.004	<0.1	2300	395	431	39.7
	138	4/14	7.58	15940	6.20	16240	43	32	104	4.4	10360	3.7	0.020	0.32	4570	552	493	44.6
$H_{22} H_{24}$	18	4/12/78	8.3	4448	8.00	4309	82	36	280	0.72	1576	1.0	<0.001	7.40	745	33.	108	185
	44	4/12	8.0	4765	8.20	4659	109	70	300	0.76	1932	1.0	0.003	4.70	725	30.	106	220
	193	4/13	7.9	4832	8.20	4635	180	55	310	0.98	1798	1.0	0.003	16.7	793	27.2	116	215
	275	4/13	8.18	4808	8.15	4876	168	145	330	1.30	2055	1.0	0.025	16.5	895	32.0	133	282
	302	4/14	8.25	4770	8.30	4584	146	102	320	1.05	1915	1.0	0.003	13.0	670	31.6	106	225
IRR																		
	4	4/11/78	7.70	2952	8.10	2789	44	32	140	0.38	1328	1.0	0.013	14.0	383	6.77	176	149
		4/12	8.05	3053	7.80	2895	45	4	140	0.34	1066	1.0	0.015	18.8	372	8.00	174	138
		4/13			7.60	3240	66	29	136	0.53	1336	1.0	0.010	6.5	332	7.23	160	134
		4/18			7.80	3042	31	2	142	0.29	1206	1.0	0.003	19.0	378	8.21	171	142

TABLE 4.11 (Cont'd)

Table 3B

Sample ID	Gal	Date	Sr	SiO2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Cu	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
H_6 H_8	439	6/17/77																	
	459	4/12/78	9.88	9.37	0.38	0.51	0.1	0.012	0.002	0.059	0.010	0.013	10.2	0.006	0.003	<0.005	<0.01	0.026	0.34
	510	4/13	9.10	10.6	0.43	0.90	0.1	0.020	<0.0005	0.038	0.006	<0.01	7.3	0.005	0.005	<0.005	0.025	0.016	0.34
	550	4/14	9.02	11.6	0.51	1.81	0.15	0.016	0.004	0.060	0.021	<0.01	8.4	0.003	0.003	<0.005	0.010	0.016	0.30
	563	4/16	7.95	13.3	0.61	2.22	0.17	0.018	0.001	0.057	0.011	<0.01	8.6	0.005	0.003	0.014	0.014	0.009	0.34
$H_{10}H_{12}$	5	4/12/78	8.56	17.6	0.57	1.67	0.13	0.010	0.005	0.089	0.018	0.019	23.3	0.021	0.012	<0.005	0.020	0.011	0.34
	153	4/13	7.97	9.35	0.65	1.73	0.17	0.041	0.0008	0.044	0.011	0.024	15.1	0.002	0.004	0.006	0.100	0.008	0.43
	207	4/13	7.44	9.21	0.64	1.63	0.11	<0.005	<0.0005	0.046	0.025	0.015	15.3	0.011	0.005	<0.005	<0.01	0.008	<0.30
	248	4/13	7.79	10.2	0.68	1.84	0.1	<0.005	0.001	0.057	0.032	<0.01	15.5	0.026	0.005	<0.005	<0.01	<0.005	<0.30
	335	4/14	8.25	12.2	0.91	2.84	0.24	0.009	0.004	0.086	0.020	0.018	16.6	0.029	0.002	<0.005	<0.01	0.036	<0.30
$H_{14}H_{16}$	17	4/13/78	8.35	8.45	0.49	1.16	0.1	0.020	0.002	0.054	0.016	<0.01	11.5	0.009	0.005	<0.005	0.050	0.059	<0.30
	26	4/13	9.31	4.90	0.48	2.08	0.1	0.042	0.002	0.056	0.014	0.052	14.1	0.003	0.003	<0.005	0.028	0.022	<0.30
$H_{18}H_{20}$	10	4/12/78	4.66	10.3	0.37	0.77	0.1	0.013	0.002	0.061	0.020	0.045	9.3	0.005	0.004	<0.005	0.060	0.020	0.51
	84	4/13	7.82	12.1	0.43	1.92	0.1	0.011	0.003	0.049	0.013	<0.01	11.3	0.001	0.002	<0.005	<0.01	0.039	<0.30
	138	4/14	8.84	12.4	0.53	1.88	0.16	0.094	0.005	0.100	0.021	0.084	15.2	0.009	0.004	<0.005	0.022	0.031	<0.30
$H_{22}H_{24}$	18	4/12/78	1.93	22.2	1.19	0.16	0.11	<0.01	<0.0005	0.035	0.003	<0.01	0.05	0.041	0.009	<0.005	0.025	0.040	1.02
	44	4/12	2.07	20.2	1.20	0.15	0.10	0.019	0.002	0.037	0.004	<0.01	0.04	0.018	0.008	<0.005	<0.01	0.033	1.02
	193	4/13	2.08	21.2	1.28	0.20	0.14	<0.01	0.004	0.032	0.005	<0.01	0.07	0.020	0.007	<0.005	0.020	0.040	0.51
	275	4/13	2.54	22.2	1.37	0.17	0.1	0.044	0.003	0.040	0.004	<0.01	0.07	0.016	0.007	<0.005	0.026	0.045	1.53
	302	4/14	2.08	21.5	1.34	0.20	0.1	0.029	0.002	0.036	0.005	<0.01	0.06	0.016	0.007	<0.005	<0.01	0.009	1.53
IRR																			
	4	4/11/78	2.54	10.3	0.23	.042	0.1	<0.01	<0.0005	0.055	0.001	0.033	0.04	0.005	0.001	<0.005	0.071	0.20	1.02
		4/12	2.36	10.2	0.25	.035	0.1	<0.01	0.007	0.050	0.001	0.060	0.04	0.039	0.001	<0.005	0.02	0.25	0.85
		4/13	2.29	10.8	0.23	.024	0.1	<0.01	0.0009	0.049	0.001	0.049	0.09	0.009	0.001	<0.005	<0.01	0.041	7.14
		4/18	2.46	10.5	0.28	.037	0.1	<0.01	<0.0005	0.051	0.001	0.065	0.04	0.006	0.001	<0.005	0.015	0.12	1.36

TABLE 4.11 (Cont'd)

Table 4A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+ µg/ml	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
H_2H_4	30	6/10/77	11.0	14800	7.40	13910	118	114	590	11.4	7020	NA	NA	<0.1	3300	370	523	11.2
	600	6/12	11.3	13600	6.90	13900	125	109	370	13.2	7100	NA	NA	<0.1	3150	415	510	0.2
	909	6/13	11.0	15100	11.30	15400	126	106	440	13.3	7940	NA	NA	<0.1	3530	480	508	0.7
	1418	6/16	11.1	34200	11.2	34000	429	400	2100	17.5	18600	NA	NA	<0.1	10400	1175	527	0.4
	1506	6/17	11.3	34500	11.3	34100	403	393	2200	18.3	19000	NA	NA	<0.1	10300	1230	528	0.2
	2464	8/10	11.3	17200	11.0	14750	62	37	250	12.0	8260	NA	NA	<0.1	3500	440	216	0.5
	2738	4/12/78	8.6	9018	5.20	8840	21	15	94	4.4	5120	3.5	0.001	0.50	1790	353	321	90.9
	2809	4/12	8.2	8670	5.60	7999	19	18	110	4.2	5039	2.0	0.035	1.05	1460	320	315	66.8
	2881	4/13	8.6	8310	6.35	8316	23	12	120	5.4	4805	NES	0.049	0.65	1570	315	337	60.6
	2982	4/13	9.3	8234	6.60	8640	15	14	25	4.7	4903	5.0	0.004	<0.1	1570	345	340	58.7
	3043	4/13	9.4	8976	7.10	8636	15	12	120	6.2	4983	4.3	0.003	<0.1	1920	365	367	41.7
	3098	4/13	9.2	10070	6.50	9898	17	10	110	6.0	5489	5.5	0.015	<0.1	1720	410	300	30.8
	3158	4/13	9.5	11574	8.20	11170	25	18	84	8.1	6555	5.3	0.019	<0.1	2710	477	331	23.5
	3213	4/14	9.9	12540	8.80	12530	14	14	310	9.8	6897	8.8	0.006	<0.1	2840	515	208	10.4
	3276	4/14	10.0	12050	Sample Lost													
	3327	4/15	10.3	12990	9.30	13500	15	15	220	9.0	7250	11.0	0.035	<0.1	3060	570	169	5.47
	3365	4/15	9.9	13210	9.35	12840	28	17	190	10.2	7299	9.2	0.001	<0.1	3480	548	166	5.26
	3406	4/16	9.8	13040	7.65	12720	17	17	80	10.2	6971	9.9	0.007	<0.1	2750	550	147	4.42
	3427	4/16	9.9	12960	9.00	12280	21	14	128	10.5	7246	9.0	0.001	<0.1	3290	537	145	4.51
	3479	4/18	9.3	12380	7.40	11890	25	21	74	10.3	6550	7.2	0.011	<0.1	2870	525	185	3.85
	3511	4/20	9.6	11470	6.30	10880	17	16	74	10.3	5484	1.8	0.14	<0.1	2650	480	205	5.02

TABLE 4.11 (Cont'd)

Table 4B Sample ID	Gal	Date	Sr	SiO_2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Ca	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
H_2H_4	30	6/10/77	11.7	47.0	1.2	3.4	0.17	0.07	0.02	0.13	0.05	<0.01	NA	0.070	0.004	<0.01	<0.01	<0.01	NA
	600	6/12	10.6	12.0	1.8	3.6	0.18	0.06	0.02	0.09	0.03	<0.01	NA	0.017	0.001	<0.01	<0.01	<0.01	NA
	909	6/13	11.3	17.0	1.8	3.8	0.18	0.06	0.02	0.12	0.02	<0.01	NA	0.017	0.003	<0.01	<0.01	0.12	NA
	1418	6/16	13.1	35.0	3.0	9.5	0.45	0.15	0.035	0.24	0.07	<0.01	NA	0.070	0.011	<0.01	0.05	0.12	NA
	1506	6/17	10.7	40.0	3.2	9.1	0.42	0.15	0.035	0.18	0.08	<0.01	NA	0.070	0.008	<0.01	<0.01	0.14	NA
	2564	8/10	7.0	22.0	1.3	1.2	0.20	0.04	0.02	0.55	0.06	<0.01	NA	0.009	0.003	<0.01	<0.01	0.09	NA
	2738	4/12/78	6.45	9.75	0.53	0.71	<0.1	0.018	0.0050	0.041	0.017	<0.01	6.60	0.002	0.002	<0.01	0.12	0.025	<0.30
	2809	4/12	6.31	9.88	0.56	0.79	0.30	0.021	0.006	0.040	0.017	0.015	6.35	0.007	0.002	<0.01	0.011	0.067	0.34
	2881	4/13	6.55	11.8	0.74	0.94	<0.1	0.12	0.0005	0.042	0.006	0.010	6.30	0.005	0.004	<0.005	0.030	<0.005	1.00
	2982	4/13	6.64	13.1	0.81	1.03	<0.1	0.022	0.0006	0.034	0.005	<0.01	6.27	0.001	0.001	<0.005	<0.01	<0.005	0.68
	3043	4/13	6.83	13.2	0.84	1.06	<0.1	0.01	0.004	0.037	0.026	<0.01	6.15	0.004	0.002	<0.005	0.015	0.011	<0.30
	3098	4/13	6.15	13.4	0.94	1.20	0.12	0.01	0.003	0.037	0.038	<0.01	6.40	0.003	0.002	<0.005	0.051	0.007	<0.30
	3158	4/13	6.98	17.8	1.20	1.57	0.18	0.035	0.005	0.046	0.010	0.006	6.62	0.004	0.002	<0.005	0.011	0.042	<0.30
	3213	4/14	5.24	19.8	1.58	1.67	0.11	0.065	0.0005	0.032	0.009	<0.01	7.54	0.003	0.001	<0.005	<0.01	0.017	0.51
	3276	4/14																	
	3327	4/15	4.67	23.2	1.87	1.72	0.19	0.035	0.0009	0.031	0.007	<0.01	7.10	<0.001	0.003	<0.005	<0.01	<0.005	<0.30
	3365	4/15	4.80	24.4	1.87	1.85	0.20	0.020	0.0005	0.030	0.015	<0.01	6.94	0.003	0.002	<0.005	0.024	<0.005	<0.30
	3406	4/16	4.15	23.5	1.91	1.48	0.12	0.010	0.005	0.030	0.085	<0.01	6.60	0.003	0.003	<0.005	<0.01	0.006	<0.30
	3427	4/16	4.61	23.8	1.79	1.60	0.17	0.005	0.0005	0.030	0.016	<0.01	6.31	0.002	<0.001	<0.005	0.044	<0.005	<0.30
	3479	4/18	4.55	24.5	1.79	1.35	0.10	0.097	0.006	0.039	0.050	<0.01	6.92	0.005	0.003	<0.005	0.12	0.031	<0.30
	3511	4/20	5.03	21.0	1.71	1.23	0.10	0.051	0.005	0.040	0.055	<0.01	7.25	0.005	0.001	<0.005	0.065	0.019	9.01

TABLE 4.1D (Cont'd)

Table 5A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
							µg/ml											
$H_{13}H_{15}$	401	4/11/78	8.55	7062	8.60	6867	82	47	106	1.00	3764	<1.0	0.46	13.0	1290	222	139	139
	408	4/12	8.20	9920	7.40	9045	65	13	94	2.40	5720	<1.0	0.20	15.4	2130	355	191	141
	467	4/13	8.70	16590	5.95	17820	26	12	85	4.00	11750	<1.0	2.45	3.8	4120	645	304	237
	535	4/13	3.28	17550	6.45	17080	22	22	96	4.70	11426	<1.6	0.17	0.22	4740	672	397	277
	655	4/15	8.31	20900	4.60	20080	23	23	84	4.80	13660	3.0	0.004	0.20	5650	795	358	159
	708	4/16	8.20	20750	5.80	20510	21	8	84	4.40	13275	3.6	0.30	0.70	5700	825	391	139
	758	4/17	8.0	20000	6.65	19650	19	15	82	3.90	13682	2.7	0.27	0.86	4900	806	378	131
	832	4/20	7.7	19880	7.50	19800	27	22	85	4.20	12437	1.2	1.20	0.22	4720	775	402	116
	868	4/22	7.7	19028	6.80	18360	29	24	85	4.80	12108	<1.0	2.70	0.73	4670	740	407	118
	917	4/26	7.8	18461	7.00	17280	35	10	84	5.40	11648	1.4	0.83	0.35	4460	710	400	112
	963	5/2	7.9	17262	7.60	17280	28	15	82	4.70	11574	2.5	1.00	0.38	4260	710	381	93.5
	1005	5/15	8.6	17325	7.65	17190	38	23	84	5.10	11097	<0.2	0.006	3.2	4300	666	336	104

TABLE 4.11 (Cont'd)

Table 5B

Sample ID	Gal	Date	Sr	SiO_2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Cu	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
$H_{13}H_{15}$	401	4/11/78	2.48	16.3	0.24	0.40	0.13	0.90	0.013	0.098	0.010	0.007	4.4	0.009	0.005	<0.005	0.054	0.050	1.19
	408	4/12	3.65	16.4	0.32	0.51	0.13	0.57	0.002	0.068	0.005	0.016	8.6	0.009	0.005	<0.005	0.052	0.020	0.85
	467	4/13	6.47	10.6	0.46	1.30	<0.1	0.015	0.001	0.073	0.008	0.018	16.2	0.001	0.008	<0.005	0.019	<0.005	3.74
	535	4/13	8.34	10.4	0.43	1.47	0.13	0.29	0.009	0.077	0.011	0.056	13.4	<0.001	0.007	<0.005	0.080	0.048	0.34
	655	4/15	7.55	12.0	0.47	1.39	<0.1	0.043	0.006	0.082	0.020	0.051	15.6	0.005	0.007	<0.005	0.074	0.042	<0.3
	708	4/16	7.76	12.9	0.49	1.33	<0.1	0.147	0.009	0.086	0.032	0.061	14.8	0.003	0.007	<0.005	0.025	0.026	0.51
	758	4/17	8.36	12.5	0.46	1.45	0.20	0.058	0.009	0.088	0.026	0.065	14.6	0.008	0.008	<0.005	<0.01	0.032	0.34
	832	4/20	8.52	14.2	0.53	1.66	0.13	0.037	0.006	0.098	0.011	0.090	14.9	0.001	0.005	0.011	<0.01	<0.005	2.89
	868	4/22	8.82	13.1	0.52	1.65	0.50	0.021	0.005	0.085	0.015	0.080	14.9	0.002	0.006	<0.005	0.022	<0.005	3.40
	917	4/26	9.58	11.7	0.56	1.56	<0.1	0.033	0.005	0.074	0.011	0.053	15.2	0.001	0.005	<0.005	0.013	<0.005	2.00
	963	5/2	8.54	10.6	0.49	1.52	0.10	0.038	0.005	0.058	0.011	0.028	15.3	<0.001	0.004	0.011	<0.01	<0.005	1.85
	1005	5/15	8.25	9.8	0.50	1.24	0.030	0.039	0.007	0.045	0.010	0.019	19.0	0.006	0.008	<0.005	0.053	0.023	<1.0

TABLE 4.11 (Cont'd)

Table 6A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
							µg/ml											
$H_{17}H_{19}$	406	4/11/78	7.75	9895	6.20	9839	25	21	164	1.0	5584	1.6	1.50	9.10	2050	375	291	77.5
	412	4/12	8.65	10220	7.20	10190	50	29	220	2.7	6098	1.0	1.30	16.0	1930	290	371	28.2
	500	4/13	8.70	11880	6.60	11880	18	14	135	3.3	7838	2.0	0.011	0.90	2570	445	350	110.0
	594	4/13	8.20	15145	5.95	13030	21	19	156	5.5	8294	1.4	0.014	0.22	3177	444	462	140.0
	653	4/14	8.40	13943	5.80	14040	30	29	140	4.2	8828	2.7	0.020	1.60	3220	475	417	128.0
	729	4/14	8.35	14410	5.65	13910	26	19	136	3.2	9023	1.9	1.43	2.20	3710	494	462	115.0
	824	4/15	8.50	14840	6.20	14930	21	20	132	3.0	9732	1.9	0.013	1.20	3910	541	442	88.9
	867	4/16	8.86	16000	5.80	15640	27	26	140	3.1	9913	1.8	0.006	0.25	4120	580	454	82.2
	898	4/16	8.42	16110	5.30	16520	21	19	134	3.5	9885	1.6	0.010	1.00	4040	565	456	82.6
	932	4/17	8.50	15820	5.80	15300	23	14	140	3.4	9613	2.1	0.002	0.45	3730	575	439	68.3
	988	4/18	8.00	15870	5.25	15360	22	12	140	3.4	9530	1.4	0.002	0.60	3490	590	427	61.4
	1037	4/19	7.90	15350	5.72	14990	27	27	146	3.8	9382	1.7	0.010	0.50	3700	568	452	59.0
	1080	4/20	8.40	15790	6.40	15120	22	17	144	3.8	9704	2.4	0.005	0.25	3770	595	466	55.4
	1115	4/21	7.90	16060	6.20	14580	27	17	145	4.1	9913	1.7	0.010	1.17	3570	575	450	52.2
	1150	4/22	7.90	16245	6.35	15120	25	18	145	4.8	9872	1.7	0.020	1.10	3600	580	449	60.2
	1183	4/23	7.60	16358	6.40	15440	26	26	147	4.1	9937	1.6	0.007	1.17	3660	580	447	60.2
	1213	4/24	8.00	16245	6.40	15660	28	28	146	3.9	10180	1.8	0.011	0.90	3870	605	461	49.9
	1241	4/25	8.70	16347	6.60	16200	28	28	146	4.8	10353	1.6	0.011	1.05	4010	651	464	63.9
	1291	4/27	8.40	16828	5.95	22260	24	20	146	4.6	10949	1.4	0.007	0.95	3940	635	454	64.1
	1333	4/29	8.50	17108	5.70	16610	22	21	144	4.5	10588	1.8	0.165	0.69	4340	660	458	64.5
	1366	5/1	8.30	16989	6.10	17280	23	23	141	4.6	11467	1.7	0.029	0.80	6120	680	452	71.0
	1416	5/5	7.70	17780	6.40	17917	20	19	136	5.1	11508	0.54	0.155	0.60	4400	662	380	75.9
	1459	5/10	7.70	18789	6.80	18744	20	18	132	5.1	12104	0.78	0.200	0.20	4800	710	368	86.7
	1497	5/17	7.70	21528	7.20	20221	21	20	120	4.9	13493	0.70	0.690	0.1		725	346	98.6

TABLE 4.11 (Cont'd)

Table 6B Sample ID	Gal	Date	Sr	SiO2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Ca	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
$H_{17}H_{19}$	406	4/11/78	6.75	9.25	0.10	0.54	<0.1	0.025	0.006	0.044	0.008	0.01	7.55	0.008	0.024	<0.005	0.025	0.016	<0.3
	412	4/12	6.65	13.1	0.22	0.75	<0.1	0.014	0.006	0.044	0.010	0.011	6.56	0.004	0.004	<0.005	0.018	0.072	<0.3
	500	4/13	6.86	12.9	0.33	0.81	<0.1	0.030	0.0005	0.031	0.007	0.015	11.1	0.005	0.005	<0.005	<0.01	<0.01	1.40
	594	4/13	9.31	12.6	0.34	0.98	0.12	0.21	0.0005	0.070	0.018	0.047	10.6	0.001	0.007	<0.005	0.091	0.080	<0.3
	653	4/14	8.73	11.5	0.38	1.06	0.19	0.042	0.003	0.057	0.011	0.023	11.6	0.002	0.005	<0.005	0.018	0.008	1.70
	729	4/14	9.59	12.4	0.35	1.05	<0.1	0.031	0.013	0.057	0.018	0.025	11.2	0.003	0.004	<0.005	0.011	0.021	<0.3
	824	4/15	9.54	12.3	0.38	1.08	0.10	0.045	0.014	0.059	0.021	0.029	11.1	0.002	0.006	<0.005	0.020	0.016	<0.3
	867	4/16	9.33	13.8	0.39	1.01	<0.1	0.027	0.006	0.059	0.031	0.027	11.4	0.003	0.006	<0.005	0.022	0.022	1.87
	898	4/16	10.2	13.1	0.37	1.09	0.12	0.067	0.013	0.063	0.024	0.034	10.8	0.004	0.009	<0.005	0.038	0.021	0.68
	932	4/17	9.25	12.7	0.42	1.03	0.10	0.011	0.003	0.056	0.028	0.022	11.2	0.004	0.006	<0.005	0.043	<0.01	0.34
	988	4/18	9.62	12.7	0.43	1.06	<0.1	0.024	0.004	0.055	0.055	0.026	11.0	0.007	0.005	<0.005	0.026	0.053	<0.3
	1037	4/19	8.83	13.2	0.41	1.03	<0.1	0.031	0.003	0.050	0.028	0.024	10.9	0.001	0.004	<0.005	0.015	0.024	<0.3
	1080	4/20	9.61	13.3	0.41	1.26	0.13	0.022	<0.0005	0.049	0.011	0.025	11.3	0.001	0.005	<0.005	<0.01	0.007	0.85
	1115	4/21	8.58	12.8	0.39	1.44	<0.1	0.020	0.0008	0.045	0.012	0.026	11.2	0.001	0.004	<0.005	<0.01	<0.005	0.68
	1150	4/22	10.7	13.7	0.48	1.37	0.11	0.023	<0.0005	0.055	0.013	0.031	11.9	0.001	0.005	<0.005	0.028	<0.005	1.00
	1183	4/23	10.6	13.5	0.46	1.40	0.21	0.020	<0.0005	0.053	0.013	0.030	11.6	0.001	0.003	<0.005	0.012	<0.005	0.85
	1213	4/24	9.15	12.2	0.37	1.45	<0.1	0.031	<0.0005	0.041	0.011	0.025	11.5	0.001	0.004	0.006	0.028	<0.005	0.68
	1241	4/25	11.3	13.9	0.50	1.54	<0.1	0.024	0.0010	0.057	0.012	0.031	11.6	0.002	0.003	<0.005	0.014	<0.005	1.36
	1291	4/27	11.1	13.8	0.48	1.55	0.19	0.082	0.0006	0.058	0.013	0.039	12.9	0.001	0.003	<0.005	0.014	<0.005	1.00
	1333	4/29	10.5	13.1	0.43	1.30	<0.1	0.010	0.0100	0.049	0.032	0.029	12.1	0.001	0.003	<0.005	0.023	0.007	<0.3
	1366	5/1	11.2	14.1	0.50	1.68	<0.1	0.023	0.0010	0.060	0.012	0.037	12.3	0.001	0.003	<0.005	<0.01	<0.005	1.53
	1416	5/5	8.65	12.2	0.45	1.37	0.031	0.011	0.008	0.046	0.022	0.035	15.4	0.005	0.005	<0.005	<0.01	0.042	1.0
	1459	5/10	9.20	12.5	0.46	1.55	0.022	0.015	0.012	0.047	0.125	0.040	16.4	0.004	0.004	<0.005	0.040	0.010	2.0
	1497	5/17	9.5	12.8	0.45	1.70	0.025	0.027	0.014	0.059	0.021	0.050	17.1	0.004	0.004	<0.005	0.030	0.013	2.0

TABLE 4.11 (Cont'd)

Table 7A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C (µg/ml)	Organic C (µg/ml)	Total Cl^- (µg/ml)	Total F^- (µg/ml)	$SO_4^=$ (µg/ml)	N as NH_4^+ (µg/ml)	N as NO_2^- (µg/ml)	N as NO_3^- (µg/ml)	Na (µg/ml)	K (µg/ml)	Ca (µg/ml)	Mg (µg/ml)
$H_{21}H_{23}$	1	8/1/77	7.2	5360	7.3	5295	48	28	260	1.3	1600	NA	NA	9.5	571	90.2	138.0	76.5
	176	8/10	7.8	6200	7.8	6130	85	55	470	1.3	1900	NA	NA	36.5	685	57.3	169.0	201.0
	1269	8/23	7.9	5560	7.8	5550	149	82	530	1.3	2050	NA	NA	43.5	846	51.0	142.0	256.0
	1320	8/25	7.9	5340	7.9	5500	142	73	520	1.5	2020	NA	NA	41.0	837	51.3	131.0	252.0
	1437	4/11/78	8.3	3870	8.2	3795	105	46	346	0.74	1210	<1.0	0.001	28.8	640	45.6	73.0	187.0
	1439	4/11	8.3	4134	8.5	4046	324	102	364	0.77	1484	<1.0	0.017	21.0	603	43.0	72.0	197.0
	1479	4/12	8.4	3421	8.0	3289	74	40	244	0.65	1074	<1.0	0.017	14.1	500	16.7	130.0	178.0
	1542	4/13	8.1	3650	7.7	3652	138	67	280	0.92	1360	<1.0	0.024	9.8	470	28.3	152.0	193.0
	1602	4/13	8.0	4134	7.7	4320	74	51	330	0.86	1550	<1.0	0.003	7.5	606	42.5	109.0	171.0
	1649	4/13	7.9	4488	7.9	4509	159	56	360	0.70	1444	<1.0	0.003	16.5	784	62.4	123.0	190.0
	1702	4/13	8.1	4547	7.9	4570	156	46	372	0.62	1465	<1.0	0.002	15.0	647	62.6	106.0	181.0
	1775	4/13	8.1	4628	8.1	4543	130	112	374	0.82	1615	<1.0	0.049	9.9	746	49.0	123.0	235.0
	1875	4/14	8.1	4676	7.8	4644	154	66	400	1.1	1591	<1.0	0.024	12.8	700	42.5	110.0	236.0
	1915	4/14	8.1	4960	8.0	4627	137	46	380	0.71	1560	<1.0	0.008	19.7	718	45.6	110.0	211.0
	1981	4/14	8.2	4960	8.2	4455	135	110	376	0.56	1626	<1.0	0.013	15.5	851	44.0	120.0	252.0
	2050	4/15	8.0	4960	8.0	4472	188	57	382	0.78	14161	<1.0	0.006	21.4	751	46.2	110.0	236.0
	2100	4/15	8.3	4750	8.1	4354	124	95	376	0.58	1677	<1.0	0.013	9.2	805	45.0	107.0	242.0
	2149	4/16	8.2	4606	8.1	4455	113	60	380	0.62	1399	<1.0	0.010	17.7	785	47.1	109.0	223.0
	2182	4/16	8.2	4680	8.4	5508	130	88	370	0.58	1533	<1.0	0.027	12.8	764	47.0	101.0	240.0
	2215	4/17	8.2	4311	8.2	4429	104	54	372	0.84	1448	<1.0	0.015	16.0	721	50.3	100.0	206.0
	2269	4/18	8.3	4520	8.1	4343	146	36	368	0.88	1473	<1.0	0.003	15.0	664	52.3	85.8	195.0
	2303	4/19	8.2	4660	7.9	4334	122	64	370	0.75	1407	<1.0	0.009	16.0	717	50.3	91.5	203.0
	2336	4/20	8.2	4540	7.9	4368	190	62	360	0.82	1383	<1.0	0.003	14.1	766	50.3	94.4	225.0
	2387	4/22	8.5	4544	7.9	4320	198	63	360	1.40	1681	<1.0	0.004	11.0	666	44.3	81.3	215.0
	2425	4/24	8.4	4317	7.9	4860	188	55	360	1.01	1488	<1.0	0.004	6.3	633	40.9	63.7	185.0
	2485	4/28	8.2	4095	7.9	4212	193	60	360	1.05	1439	<1.0	0.020	4.2	631	32.4	71.1	215.0
	2529	5/2	8.3	3906	8.1	4320	191	115	350	1.20	1406	<1.0	0.004	2.0	620	25.8	72.6	215.0
	2578	5/8	8.4	3584	8.50	3584	75	58	302	1.0	1373	<0.2	0.019	3.4	620	19.4	49.7	186.0
	2614	5/12	8.4	4329	8.45	3795	86	62	346	1.1	1439	<0.2	0.015	3.8	630	19.7	52.7	218.0
	2666	5/22	8.5	4485	8.30	4056	89	65	348	0.9	1439	<0.2	0.006	3.0	675	19.8	64.2	236.0

TABLE 4.11 (Cont'd)

Table 7B Sample ID	Gal	Date	Sr	SiO2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Ca	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
$H_{21}H_{23}$	1	8/1/77	2.7	27	0.34	0.61	<0.1	0.06	<0.02	0.082	0.06	0.10	NA	0.012	0.004	<0.01	0.01	<0.01	NA
	176	8/10	2.5	20	1.1	0.43	<0.1	0.03	<0.02	0.069	0.01	0.026	NA	0.016	0.006	<0.01	0.01	0.025	NA
	1269	8/23	3.0	26	1.7	0.34	<0.1	0.04	<0.02	0.073	0.01	0.021	NA	0.018	0.006	<0.01	0.01	<0.01	NA
	1320	4/25	2.9	27	1.7	0.38	<0.1	0.04	<0.02	0.077	0.01	0.024	NA	0.021	0.006	<0.01	0.01	<0.01	NA
	1437	4/11/78	2.1	30	1.35	0.054	<0.1	0.017	<0.0005	0.048	0.006	0.015	0.04	0.022	0.004	<0.005	0.027	0.017	0.34
	1439	4/11	2.2	30	1.26	0.049	<0.1	0.005	0.002	0.049	0.005	0.011	0.06	0.010	0.004	<0.005	0.01	<0.005	1.70
	1479	4/12	2.4	27	1.01	0.044	<0.1	0.01	0.003	0.043	0.004	<0.01	0.05	0.008	0.002	<0.005	0.028	0.050	1.19
	1542	4/13	2.5	25	0.98	0.019	<0.1	0.01	0.0009	0.061	0.006	<0.01	0.06	0.009	0.003	<0.005	0.015	<0.005	8.70
	1602	4/13	2.0	24	1.05	0.024	<0.1	0.01	0.002	0.045	0.005	<0.01	0.07	0.012	0.012	<0.005	0.01	0.005	16.7
	1649	4/13	2.2	27	1.42	0.040	<0.1	0.01	0.001	0.052	0.005	<0.01	0.02	0.017	0.014	<0.005	0.01	0.015	2.7
	1702	4/13	2.1	26	1.53	0.046	<0.1	0.01	0.001	0.055	0.005	<0.01	0.04	0.017	0.011	<0.005	0.019	0.010	2.6
	1775	4/13	2.4	26	1.42	0.043	<0.1	0.12	0.002	0.057	0.003	<0.01	0.05	0.013	0.008	<0.005	0.018	0.021	1.5
	1875	4/14	2.2	26	1.53	0.023	<0.1	0.01	0.0006	0.050	0.005	<0.01	0.05	0.014	0.004	<0.005	0.01	<0.005	16.7
	1915	4/14	2.2	27	1.60	0.038	<0.1	0.01	0.001	0.050	0.004	<0.01	0.03	0.016	0.005	<0.005	0.031	0.021	1.9
	1981	4/14	2.4	28	1.44	0.045	<0.1	0.014	0.012	0.052	0.002	<0.01	0.03	0.012	0.004	<0.005	0.01	<0.005	1.5
	2050	4/15	2.2	28	1.45	0.037	<0.1	0.036	0.001	0.049	0.004	<0.01	0.03	0.015	0.004	<0.005	0.018	0.005	1.4
	2100	4/15	2.5	28	1.52	0.041	<0.1	0.043	0.002	0.051	0.002	<0.01	0.03	0.013	0.005	<0.005	0.020	<0.005	1.0
	2149	4/15	2.2	28	1.51	0.034	<0.1	0.030	0.001	0.046	0.004	<0.01	0.04	0.016	0.004	<0.005	0.030	0.055	1.2
	2182	4/16	2.4	27	1.40	0.040	<0.1	0.028	0.002	0.049	0.003	<0.01	0.04	0.013	0.005	<0.005	0.006	0.005	1.2
	2215	4/17	2.2	29	1.50	0.035	<0.1	0.01	<0.0005	0.046	0.004	<0.01	0.03	0.016	0.004	<0.005	0.025	0.066	1.4
	2269	4/18	2.1	28	1.50	0.035	<0.1	0.018	0.001	0.044	0.006	<0.01	0.03	0.015	0.004	<0.005	0.026	0.029	1.5
	2303	4/19	2.2	30	1.43	0.037	<0.1	0.030	0.001	0.044	0.004	<0.01	0.03	0.014	0.004	<0.005	0.020	0.051	5.1
	2336	4/20	2.2	29	1.45	0.034	<0.1	0.015	0.001	0.045	0.003	<0.01	0.05	0.013	0.004	<0.005	0.018	0.017	1.4
	2387	4/22	2.2	32	1.54	0.021	<0.1	0.01	0.002	0.047	0.005	<0.01	0.09	0.010	0.002	<0.005	0.010	<0.005	15.0
	2425	4/24	1.9	29	1.25	0.026	<0.1	0.01	0.001	0.037	0.005	<0.01	0.07	0.011	0.003	<0.005	0.01	<0.005	16.0
	2485	4/28	2.3	31	1.40	0.020	<0.1	0.010	0.0008	0.043	0.005	<0.01	0.06	0.010	0.002	<0.005	0.013	<0.005	16.7
	2529	5/2	2.4	34	1.46	0.022	<0.1	0.01	0.001	0.043	0.005	<0.01	0.05	0.009	0.003	<0.005	0.01	<0.005	12.8
	2578	5/8	2.0	29	1.20	0.023	0.014	0.005	<0.001	0.032	0.005	<0.003	0.04	0.009	0.002	<0.005	0.01	<0.005	16.0
	2614	5/12	2.3	30	1.34	0.032	0.020	0.001	<0.001	0.032	0.005	<0.003	0.04	0.009	0.002	<0.005	0.01	<0.007	18.0
	2666	5/22	2.5	33	1.49	0.040	0.011	0.001	<0.001	0.033	0.005	<0.003	0.03	0.010	0.002	<0.005	0.01	<0.005	17.0

TABLE 4.11 (Cont'd)

Table 8A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
							µg/ml											
H_5H_7	3.5	6/9/77	9.7	24800	6.50	24800	267	220	1580	12.3	11800	NA	NA	<0.1	6240	714	463	35.2
	600	6/14	10.9	18600	NA	NA	128	110	620	11.6	8510	NA	NA	<0.1	3700	610	463	1.3
	1136	6/16	10.8	26100	NA	NA	227	192	840	12.4	15200	NA	NA	<0.1	7400	995	529	6.1
	3021	7/14	10.9	22200	NA	NA	104	77	480	11.8	12900	NA	NA	<0.1	5530	845	461	1.1
	3693	7/23	10.8	20200	NA	NA	35	26	210	8.8	11700	NA	NA	<0.1	5130	757	155	1.2
	4167	8/1	10.5	19800	NA	NA	47	37	250	9.6	11000	NA	NA	<0.1	4690	795	309	13.2
	5932	8/17	10.3	16400	NA	NA	28	13	200	9.1	9440	NA	NA	<0.1	3770	689	417	10.0
	6166	8/23	10.4	15100	NA	NA	30	8	190	9.0	8980	NA	NA	<0.1	3520	662	481	5.2
	6210	8/25	10.2	15000	NA	NA	31	9	200	9.0	9080	NA	NA	<0.1	3520	665	480	4.6
	6758	4/11/78	7.9	12500	6.95	12400	15	9	96	4.7	8197	1.8	0.61	0.85	3160	610	412	27.7
	6781	4/12	8.5	11365	6.85	11340	35	10	115	4.0	6942	<1.0	1.55	2.25	2580	500	333	41.9
	6852	4/13	7.8	13980	6.20	14360	10	10	106	4.4	8918	2.5	2.45	4.50	3230	610	348	38.9
	6911	4/13	9.1	13580	6.30	14360	18	18	107	4.4	8837	2.3	1.40	4.20	3290	600	397	60.2
	7001	4/13	9.0	14760	6.30	14280	11	8	114	4.2	8654	2.1	0.14	1.06	3040	610	401	63.2
	7088	4/13	8.6	17124	5.90	15630	8	7	110	4.9	9740	2.2	0.34	5.00	3500	680	351	66.7
	7190	4/13	8.6	17430	5.80	16910	18	12	108	4.6	10830	1.8	1.30	2.00	4480	733	448	66.7
	7317	4/14	8.5	17550	5.80	16200	12	12	105	5.2	11397	1.8	0.026	0.20	4300	730	402	57.1
	7372	4/14	8.4	17830	5.10	17340	16	8	102	4.9	11061	1.8	0.002	0.16	4190	770	384	49.9
	7457	4/14	8.3	17600	5.20	16940	18	11	104	4.4	11330	1.7	0.009	0.57	4830	776	441	48.9
	7554	4/15	8.6	17240	5.40	16700	15	14	104	8.4	10427	2.7	0.003	0.35	4400	930	421	40.5
	7595	4/15	8.1	15880	5.10	15990	8	8	102	4.8	10082	1.7	0.002	1.30	3750	710	388	36.0
	7618	4/15	8.1	15650	5.25	15720	19	12	104	3.9	10090	1.3	<0.001	0.46	3520	692	386	35.1
	7688	4/16	8.5	15410	5.30	14960	10	8	104	4.0	9210	2.0	0.005	0.69	3610	664	415	32.1
	7728	4/16	8.0	14370	5.70	13940	11	7	102	3.9	8910	1.2	0.040	0.63	3600	628	433	29.7
	7774	4/17	8.2	13580	5.50	13550	<2	<2	102	4.4	8037	1.5	0.100	0.56	3100	605	428	23.3
	7805	4/17	7.4	13340	6.40	12730	18	14	104	5.0	3972	2.0	0.31	0.72	3150	573	440	24.0
	7844	4/18	7.7	12730	7.00	14210	12	7	100	4.5	7407	2.4	0.64	0.61	2730	560	434	19.2
	7900	4/19	7.7	12680	6.20	11880	8	7	102	3.9	7517	3.4	0.34	0.41	2740	555	442	16.7
	7949	4/20	8.3	12270	6.50	11800	8	6	101	4.1	7616	2.5	0.54	0.56	2540	550	432	13.6
	7993	4/21	8.0	10980	6.1	12310	20	20	102	5.7	7394	1.8	0.35	1.10	2580	545	427	14.8
	8032	4/22	7.4	12042	6.35	12850	5	8	102	4.3	7760	<1.0	0.88	0.60	2650	560	426	15.5
	8066	4/23	7.4	12837	6.40	12310	8	6	102	4.9	7402	3.0	0.14	0.47	2590	535	427	14.8
	8096	4/24	7.4	12732	6.35	12420	10	8	103	4.7	7525	1.0	0.38	0.50	2700	560	440	15.2
	8127	4/25	7.9	12621	6.25	12310	10	10	103	4.3	7686	1.5	0.75	0.53	2560	540	423	15.3
	8170	4/27	7.6	12741	6.35	12850	5	8	102	4.3	7760	1.0	0.88	0.60	2650	560	426	15.5
	8208	4/29	7.7	12831	6.60	12740	8	5	106	4.8	7629	2.7	0.36	0.35	2940	570	446	16.5
	8236	5/1	7.4	12220	6.60	12740	20	20	105	4.8	7597	4.0	2.80	0.75	2850	570	434	17.3
	8278	5/5	7.0	12635	7.20	12792	20	8	102	4.9	7813	1.48	0.003	4.6	2600	560	334	18.2
	8320	5/11	6.98	12862	7.20	12949	18	11	102	5.0	8019	1.30	0.009	1.8	2700	580	377	19.2
	8365	5/19	7.16	13908	7.00	13244	18	14	102	4.8	8105	<0.2	0.004	4.9	2670	625	360	23.4

TABLE 4.11 (Cont'd)

Table 8B

Sample ID	Gal	Date	Sr	SiO_2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Ca	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
H_5H_7	3.5	6/9/77	10.1	23.0	1.3	3.7	0.30	0.17	0.03	0.18	0.08	0.025	NA	0.32	0.017	0.03	0.01	0.023	NA
	600	6/14	12.1	17.0	1.2	2.7	0.20	0.06	0.03	0.11	0.05	0.01	NA	0.022	0.004	<0.01	0.01	<0.01	NA
	1136	6/16	13.1	18.0	1.6	4.3	0.35	0.08	0.03	0.25	0.07	0.025	NA	0.060	0.009	<0.01	0.01	<0.01	NA
	3021	7/14	19.3	20.0	1.3	2.3	0.35	0.05	<0.02	0.079	0.05	0.01	NA	0.010	0.007	<0.01	0.01	0.075	NA
	3693	7/23	6.3	22.0	0.94	1.7	0.25	0.05	<0.02	0.069	0.03	0.01	NA	0.020	0.005	<0.01	0.01	<0.01	NA
	4167	8/1	9.2	16.0	1.2	1.9	0.20	0.05	<0.02	0.073	0.04	0.01	NA	0.008	0.005	<0.01	0.01	<0.01	NA
	5932	8/17	11.2	17.0	1.1	1.6	0.18	0.07	<0.02	0.069	0.04	0.01	NA	0.008	0.003	<0.01	0.01	0.12	NA
	6166	8/23	12.4	17.0	1.0	1.5	0.15	0.06	<0.02	0.063	0.04	0.01	NA	0.016	0.003	<0.01	0.01	0.02	NA
	6210	8/25	12.4	16.0	1.0	1.5	0.15	0.07	<0.02	0.062	0.03	0.01	NA	0.007	0.003	<0.01	0.01	0.11	NA
	6758	4/11/78	7.92	16.2	0.63	0.86	<0.1	0.010	0.006	0.040	0.029	0.033	6.4	0.006	0.006	<0.005	0.025	0.016	<0.3
	6781	4/12	6.31	15.9	0.53	0.90	<0.1	0.020	0.0005	0.036	0.012	0.023	5.2	0.001	0.004	<0.005	0.01	<0.005	2.20
	6852	4/13	7.30	14.7	0.66	1.16	0.16	0.018	0.0005	0.040	0.014	0.010	6.3	0.006	0.014	<0.005	0.010	<0.005	1.19
	6911	4/13	7.60	14.0	0.63	1.40	0.37	<0.01	0.0005	0.043	0.011	0.01	6.9	0.004	0.008	<0.005	0.037	<0.005	1.70
	7001	4/13	7.53	12.7	0.61	1.27	0.10	<0.01	0.0070	0.046	0.023	0.01	6.7	0.007	0.006	<0.005	0.028	0.017	<0.3
	7088	4/13	7.54	12.7	0.63	1.36	0.11	0.012	0.007	0.048	0.027	0.01	7.2	0.006	0.005	<0.005	0.027	0.031	<0.3
	7190	4/13	8.65	12.4	0.62	1.61	0.16	0.025	0.035	0.051	0.021	0.012	6.6	0.003	0.004	<0.005	0.013	0.014	<0.3
	7317	4/14	7.73	12.2	0.70	1.70	0.35	0.015	0.0005	0.050	0.016	0.012	6.8	0.003	0.007	<0.005	0.010	0.008	0.68
	7372	4/14	7.35	12.2	0.73	1.55	0.10	0.019	0.0013	0.048	0.027	0.016	6.1	0.003	0.004	<0.005	0.027	0.024	0.3
	7457	4/14	8.44	12.6	0.66	1.67	0.16	0.020	0.013	0.050	0.025	0.018	6.0	0.002	0.003	<0.005	0.015	0.010	0.3
	7554	4/15	7.90	13.1	0.71	1.45	0.14	0.014	0.005	0.047	0.025	0.020	5.8	0.004	0.003	<0.005	0.01	0.008	0.3
	7595	4/15	7.50	12.8	0.72	1.44	<0.1	0.017	0.005	0.048	0.032	0.025	5.9	0.003	0.003	<0.005	0.01	<0.005	0.3
	7618	4/15	7.69	12.3	0.65	1.43	0.20	0.021	0.003	0.047	0.030	0.025	5.7	0.002	0.003	<0.005	0.015	0.011	0.3
	7688	4/16	7.95	13.7	0.69	1.30	<0.1	0.018	0.006	0.046	0.018	0.026	5.9	<0.001	0.003	<0.005	0.014	0.013	0.3
	7728	4/16	8.51	14.3	0.67	1.37	0.14	0.032	0.015	0.048	0.020	0.030	6.0	<0.001	0.002	<0.005	0.016	0.014	0.3
	7774	4/17	7.91	14.3	0.65	1.09	<0.1	0.015	0.006	0.042	0.026	0.024	6.2	<0.001	0.003	<0.005	0.026	0.024	0.3
	7805	4/17	7.87	15.1	0.60	1.07	0.15	0.018	0.009	0.042	0.022	0.022	6.6	<0.001	0.002	<0.005	0.013	0.017	0.3
	7844	4/18	8.35	15.4	0.66	0.97	0.13	0.015	0.004	0.042	0.022	0.021	6.2	<0.001	0.003	<0.005	0.026	0.022	0.3
	7900	4/19	8.48	16.1	0.65	1.03	0.13	0.015	<0.0005	0.040	0.009	0.018	6.7	<0.001	0.003	<0.005	0.01	<0.005	0.80
	7949	4/20	8.20	15.2	0.56	1.08	<0.1	0.012	<0.0005	0.034	0.009	0.015	6.6	<0.001	0.003	<0.005	0.01	0.005	0.68
	7993	4/21	8.52	15.7	0.63	1.05	0.34	0.020	0.0005	0.039	0.009	0.015	7.3	<0.001	0.002	<0.005	0.016	<0.005	0.68
	8032	4/22	8.65	16.7	0.65	1.12	0.22	0.027	0.004	0.041	0.009	0.021	7.5	<0.001	0.002	<0.005	0.010	<0.005	0.34
	8066	4/23	8.50	16.2	0.63	1.06	0.14	0.014	0.003	0.040	0.011	0.017	7.3	<0.001	0.002	<0.005	0.01	<0.005	1.00
	8096	4/24	8.80	16.9	0.66	1.06	0.40	0.016	0.004	0.042	0.011	0.020	7.4	<0.001	0.002	<0.005	0.012	<0.005	0.51
	8127	4/25	8.86	17.1	0.69	1.09	0.19	0.020	0.004	0.043	0.010	0.020	7.3	<0.001	0.002	<0.005	0.068	<0.005	0.85
	8170	4/27	8.65	16.7	0.65	1.12	0.22	0.027	0.004	0.041	0.009	0.021	7.5	<0.001	0.002	<0.005	0.010	<0.005	0.34
	8208	4/29	8.97	17.3	0.62	0.94	0.10	0.017	0.005	0.039	0.030	0.021	6.7	<0.001	0.003	<0.005	0.017	0.006	7.31
	8236	5/1	8.69	17.6	0.66	1.13	0.37	0.015	0.004	0.43	0.010	0.025	7.5	<0.001	0.002	<0.005	0.015	<0.005	0.68
	8278	5/5	6.97	16.7	0.64	1.00	0.065	0.011	0.008	0.040	0.020	0.026	7.1	<0.001	0.002	<0.005	0.039	0.008	<0.3
	8320	5/11	7.27	16.7	0.66	0.96	0.62	0.012	0.008	0.041	0.024	0.029	7.2	<0.001	0.002	<0.005	0.03	0.007	<0.3
	8365	5/19	7.25	17.1	0.66	1.00	0.060	0.011	0.060	0.044	0.008	0.044	7.3	<0.001	0.002	<0.005	0.13	<0.005	<0.3

TABLE 4.11 (Cont'd)

Table 9A

Sample ID	Gal	Date	At time of sampling pH	At time of sampling Cond. µmhos/cm	At time of analysis pH	At time of analysis Cond. µmhos/cm	Total C	Organic C	Total Cl^-	Total F^-	$SO_4^=$	N as NH_4^+ µg/ml	N as NO_2^-	N as NO_3^-	Na	K	Ca	Mg
H_9 H_{11}	474	8/10/77	10.1	16800			41	24	190	8.6	8820			<0.1	3760	420	194	6.1
	940	8/25	10.2	17800			24	10	190	8.8	10900			<0.1	4360	775	460	12.4
	1167	4/11/78	9.2	20670	8.6	22260	20	13	116	5.5	14555	<1.0	2.55	1.90	6050	1050	294	73.5
	1194	4/12	9.1	17480	8.4	17280	49	12	148	3.5	11134	1.2	0.094	4.10	4350	705	220	151.0
	1291	4/13	8.3	18630	5.6	18360	20	20	127	5.2	12067	2.5	0.69	6.70	4530	730	367	131.0
	1377	4/13	8.6	16110	5.6	16740	22	22	125	4.8	10998	3.0	0.20	6.00	3890	680	388	179.0
	1448	4/13	8.6	16040	5.1	16670	14	14	130	4.2	10748	2.6	0.002	6.40	4360	720	429	176.0
	1519	4/13	8.3	17010	5.8	16867	11	10	124	4.2	10835	2.6	0.55	4.46	3770	730	377	152.0
	1598	4/13	8.2	18870	5.9	18820	20	18	116	4.6	12671	2.6	0.027	0.15	5000	792	436	167.0
	1689	4/14	8.3	21400	4.7	18360	28	19	124	5.9	14167	2.5	0.020	0.07	5400	835	397	118.0
	1726	4/14	7.9	21970	9.3	21930	25	16	108	6.1	14563	2.5	0.001	3.40	6050	910	394	97.5
	1844	4/15	8.1	24210	4.1	23400	25	25	116	6.1	15410	2.8	0.005	2.8	5900	950	437	80.5
	1889	4/15	7.8	23760	4.8	23070	23	21	112	8.0	15893	2.7	0.001	0.45	6400	1003	444	72.4
	1835	4/16	8.0	23640	4.2	23830	34	25	116	5.9	15600	2.7	0.035	0.70	6650	980	435	62.4
	1969	4/16	7.6	22830	4.4	23210	24	20	116	5.2	15791	2.6	0.012	0.57	6500	1003	452	64.1
	2004	4/17	7.6	23030	4.1	23270	18	18	114	5.4	15250	2.2	0.012	0.68	6550	975	446	54.7
	2064	4/18	7.4	23320	4.2	22440	24	14	116	4.8	15086	2.0	0.008	0.52	6340	965	466	52.7
	2101	4/19	7.4	21350	4.3	22970	24	24	130	6.1	15044	3.4	0.002	0.60	6350	960	473	49.5
	2139	4/20	7.7	23990	5.7	23220	23	16	118	10.1	15248	3.1	0.011	0.45	6280	960	470	42.9
	2173	4/21	7.5	23020	6.2	22680	17	15	118	5.5	15080	2.7	1.60	0.75	6000	930	456	48.9
	2203	4/22	7.5	22440	6.3	21200	20	16	140	5.1	14710	<1.0	3.15	0.75	5750	895	488	48.2
	2250	4/24	7.5	21930	6.8	21600	34	24	116	5.9	14270	<1.0	3.15	0.59	5820	895	451	48.3
	2303	4/27	8.5	21640	7.1	21200	22	16	122	5.8	14064	<1.0	2.58	0.60	5750	895	438	48.2
	2333	4/29	8.9	21390	7.2	20940	31	16	124	6.0	13728	2.0	1.28	0.45	5900	920	432	48.7
	2376	5/3	8.5	21684	7.4	21055	29	25	120	6.2	14221	0.64	1.50	0.60		875	362	47.9
	2410	5/8	8.7	22000	7.4	22003	27	22	118	6.5	14977	0.56	1.84	1.0		1065	343	48.9
	2456	5/23	7.0	25554	7.1	24156	20	17	124	5.9	16555	0.26	0.009	4.9		1050	345	46.4

TABLE 4.11 (Cont'd)

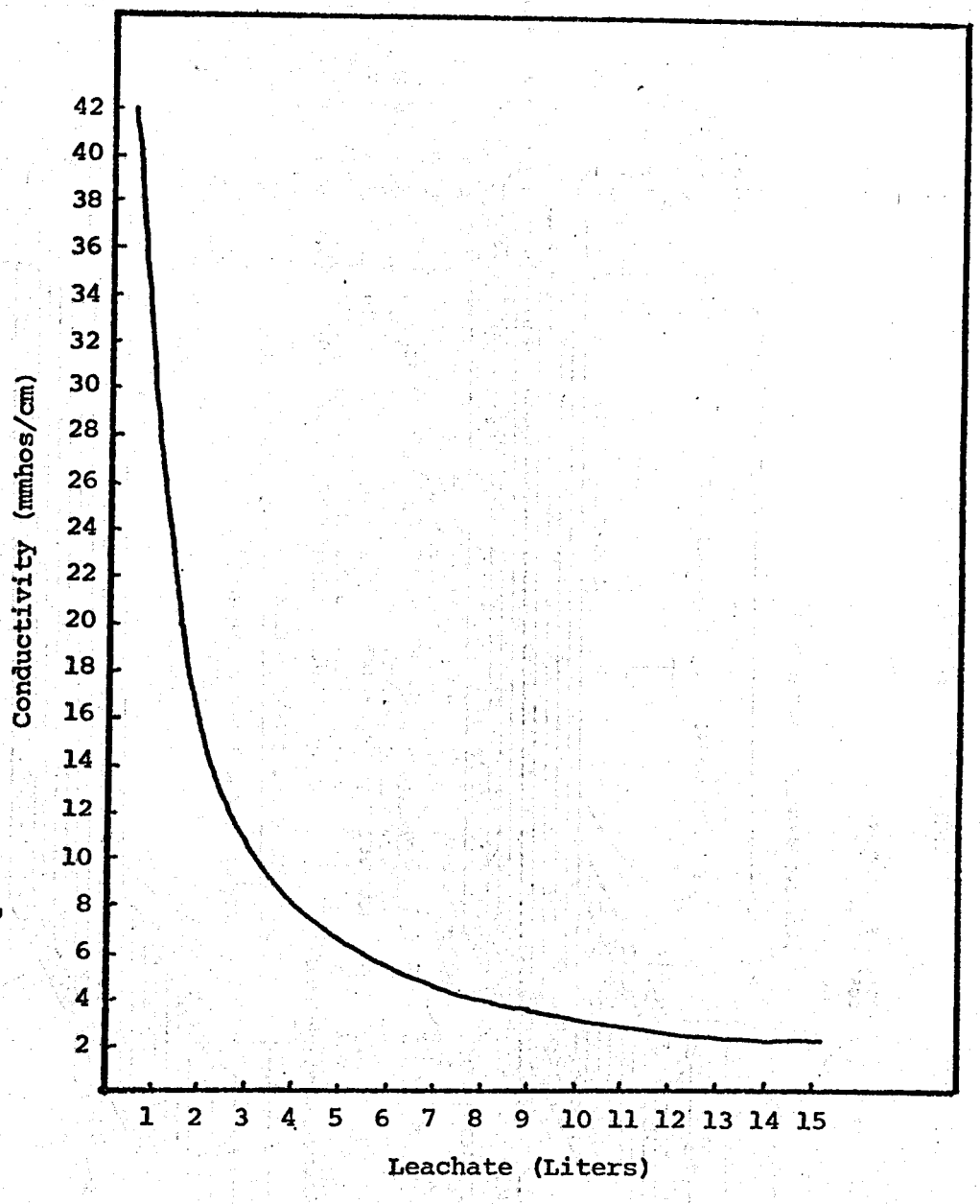
Table 9B

Sample ID	Gal	Date	Sr	SiO_2	B	Mo	V	Zn	Se	Ba	As	Mn	Li	Ca	Cr	Ni	Fe	Al	U
			μg/ml																μg/l
H_9 H_{11}	474	8/10/77	7.0	13.0	0.53	0.70	0.15	0.08	<0.02	0.069	0.030	0.011		0.012	0.005	<0.01	<0.01	<0.01	
	940	8/25	13.0	11.0	0.82	1.58	0.15	0.08	<0.02	0.093	0.040	0.011		0.009	0.010	<0.01	<0.01	<0.01	
	1167	4/11/78	7.1	5.8	0.63	1.37	<0.1	0.039	0.004	0.049	0.022	<0.01	15.1	0.007	0.013	<0.005	0.020	0.060	<0.3
	1194	4/12	5.1	13.0	0.38	1.34	<0.1	0.012	0.005	0.038	0.010	<0.01	11.0	0.004	0.006	0.015	<0.01	<0.005	4.25
	1291	4/13	7.0	11.0	0.51	1.54	0.27	0.055	0.008	0.050	0.020	0.026	13.5	0.003	0.014	<0.005	0.018	0.012	1.70
	1377	4/13	7.7	10.7	0.56	1.62	<0.1	0.059	0.006	0.058	0.014	0.023	12.8	0.003	0.013	<0.005	0.029	<0.005	3.91
	1448	4/13	7.9	10.3	0.56	1.49	<0.1	0.027	0.007	0.056	0.026	0.030	12.4	0.003	0.008	<0.005	0.047	0.039	0.51
	1519	4/13	7.3	10.2	0.56	1.47	<0.1	<0.01	0.007	0.057	0.028	0.030	13.1	0.003	0.008	<0.005	<0.01	<0.005	0.68
	1598	4/13	8.6	11.1	0.54	1.68	0.12	0.029	0.018	0.068	0.021	0.032	12.6	0.003	0.011	<0.005	0.018	0.019	0.34
	1689	4/14	7.8	11.5	0.60	1.73	0.55	0.024	0.006	0.077	0.022	0.034	15.0	0.004	0.008	0.009	0.014	0.008	3.40
	1726	4/14	7.5	11.8	0.62	1.54	0.10	0.025		0.075	0.038	0.036	12.4	0.006	0.007	<0.005	0.100	0.045	0.51
	1844	4/15	8.4	13.5	0.61	1.54	<0.1	0.037	0.006	0.080	0.031	0.052	12.3	0.008	0.006	<0.005	0.043	0.032	<0.3
	1889	4/15	8.5	13.6	0.58	1.73	0.16	0.034	0.010	0.083	0.045	0.061	11.8	0.005	0.005	<0.005	0.023	0.028	<0.3
	1835	4/16	8.9	14.9	0.59	1.52	<0.1	0.035	0.004	0.082	0.050	0.074	12.4	0.004	0.006	<0.005	0.053	0.042	<0.3
	1969	4/16	8.8	15.5	0.61	1.84	0.17	0.100	0.012	0.090	0.047	0.085	12.3	0.004	0.004	<0.005	0.034	0.024	<0.3
	2004	4/17	15.8	16.3	0.60	1.56	<0.1	0.048	0.006	0.082	0.050	0.086	12.3	0.004	0.006	<0.005	0.065	0.044	<0.3
	2064	4/18	9.4	16.2	0.61	1.65	0.10	0.061	0.005	0.087	0.039	0.096	12.5	0.008	0.007	<0.005	0.110	0.077	<0.3
	2101	4/19	9.3	13.9	0.59	1.59	0.12	0.059	0.008	0.085	0.035	0.093	12.9	0.006	0.015	<0.005	0.094	0.059	<0.3
	2139	4/20	8.2	14.5	0.57	2.04	0.24	0.095	0.006	0.080	0.013	0.094	12.6	0.003	0.008	0.006	0.032	<0.005	1.0
	2173	4/21	9.8	14.8	0.66	1.99	0.18	0.037	0.006	0.096	0.015	0.100	13.1	0.001	0.006	<0.005	0.021	<0.005	0.85
	2203	4/22	9.8	13.3	0.60	1.93	0.60	0.029	0.005	0.083	0.076	0.089	15.1	0.003	0.005	<0.005	0.012	<0.005	0.51
	2250	4/24	9.9	12.2	0.64	1.95	0.17	0.021	0.005	0.072	0.017	0.067	14.4	<0.001	0.006	0.006	0.013	<0.005	1.00
	2303	4/27	9.8	10.3	0.60	1.81	0.55	0.025	0.005	0.057	0.020	0.039	15.1	<0.001	0.005	<0.005	<0.01	<0.005	1.19
	2333	4/29	9.5	9.3	0.59	1.52	<0.10	0.024	0.006	0.051	0.028	0.023	15.4	0.001	0.005	<0.005	0.020	0.065	3.40
	2376	5/3	8.5	7.1	0.59	1.51	0.029	0.016	0.016	0.043	0.021	0.010	19.2	0.005	0.004	<0.005	0.062	0.007	<0.3
	2410	5/8	6.2	7.8	0.57	1.54	0.028	0.035	0.008	0.042	0.018	0.008	19.3	0.004	0.006	<0.005	<0.03	0.033	1.0
	2456	5/23	4.8	8.5	0.56	1.60	0.032	0.015	0.012	0.046	0.021	0.016	19.8	0.006	0.006	<0.005	0.21	0.015	<0.3

FIGURE 4.1

LEACHATE

UTAH STATE UNIVERSITY



Conductivity of 1/2 liter leachate increments from a 90 cm column of Paraho processed shale.

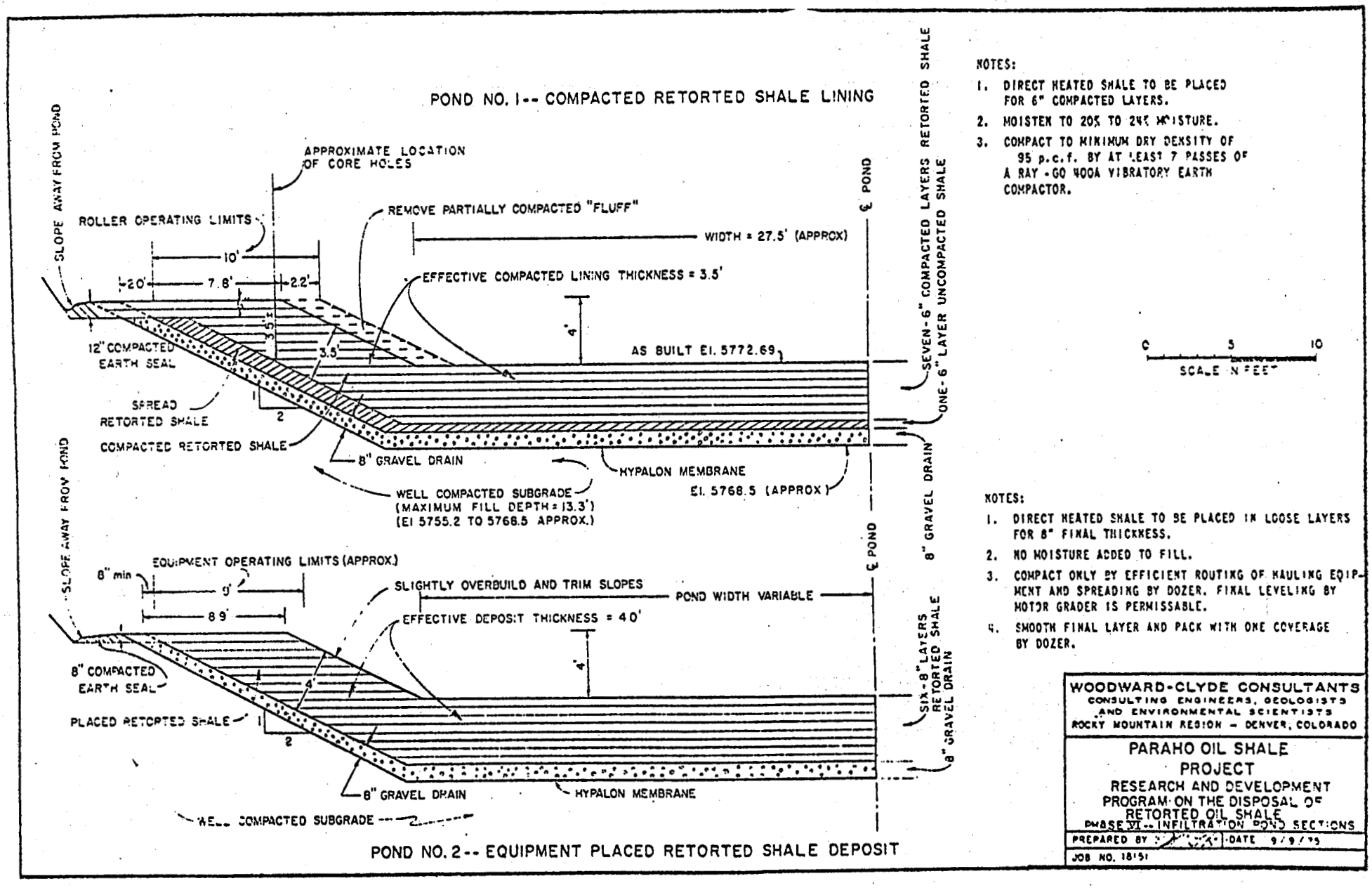

POND NO. 1-- COMPACTED RETORTED SHALE LINING
APPROXIMATE LOCATION OF CORE HOLES
SLOPE AWAY FROM POND
ROLLER OPERATING LIMITS
REMOVE PARTIALLY COMPACTED "FLUFF"
WIDTH = 27.5' (APPROX)
10'
2.0'
7.8'
2.2'
EFFECTIVE COMPACTED LINING THICKNESS = 3.5'
4'
3.5'
12" COMPACTED EARTH SEAL
AS BUILT El. 5772.69
SEVEN-6" COMPACTED LAYERS RETORTED SHALE
ONE-6" LAYER UNCOMPACTED SHALE
SPREAD RETORTED SHALE
COMPACTED RETORTED SHALE
8" GRAVEL DRAIN
HYPALON MEMBRANE
El. 5768.5 (APPROX)
WELL COMPACTED SUBGRADE (MAXIMUM FILL DEPTH = 13.3') (El 5755.2 TO 5768.5 APPROX.)
℄ POND
EQUIPMENT OPERATING LIMITS (APPROX.)
8" min
9'
8.9'
SLIGHTLY OVERBUILD AND TRIM SLOPES
POND WIDTH VARIABLE
EFFECTIVE DEPOSIT THICKNESS = 4.0'
8" COMPACTED EARTH SEAL
PLACED RETORTED SHALE
SIX-8" LAYERS RETORTED SHALE
8" GRAVEL DRAIN
WELL COMPACTED SUBGRADE
POND NO. 2-- EQUIPMENT PLACED RETORTED SHALE DEPOSIT
NOTES:
1. DIRECT HEATED SHALE TO BE PLACED FOR 6" COMPACTED LAYERS.
2. MOISTEN TO 20% TO 24% MOISTURE.
3. COMPACT TO MINIMUM DRY DENSITY OF 95 p.c.f. BY AT LEAST 7 PASSES OF A RAY-GO 400A VIBRATORY EARTH COMPACTOR.
0 5 10
SCALE IN FEET
NOTES:
1. DIRECT HEATED SHALE TO BE PLACED IN LOOSE LAYERS FOR 8" FINAL THICKNESS.
2. NO MOISTURE ADDED TO FILL.
3. COMPACT ONLY BY EFFICIENT ROUTING OF HAULING EQUIPMENT AND SPREADING BY DOZER. FINAL LEVELING BY MOTOR GRADER IS PERMISSABLE.
4. SMOOTH FINAL LAYER AND PACK WITH ONE COVERAGE BY DOZER.
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
ROCKY MOUNTAIN REGION - DENVER, COLORADO
PARAHO OIL SHALE PROJECT
RESEARCH AND DEVELOPMENT PROGRAM ON THE DISPOSAL OF RETORTED OIL SHALE
PHASE VI -- INFILTRATION POND SECTIONS
PREPARED BY
DATE 9/9/75
JOB NO. 18151

FIGURE 4.2

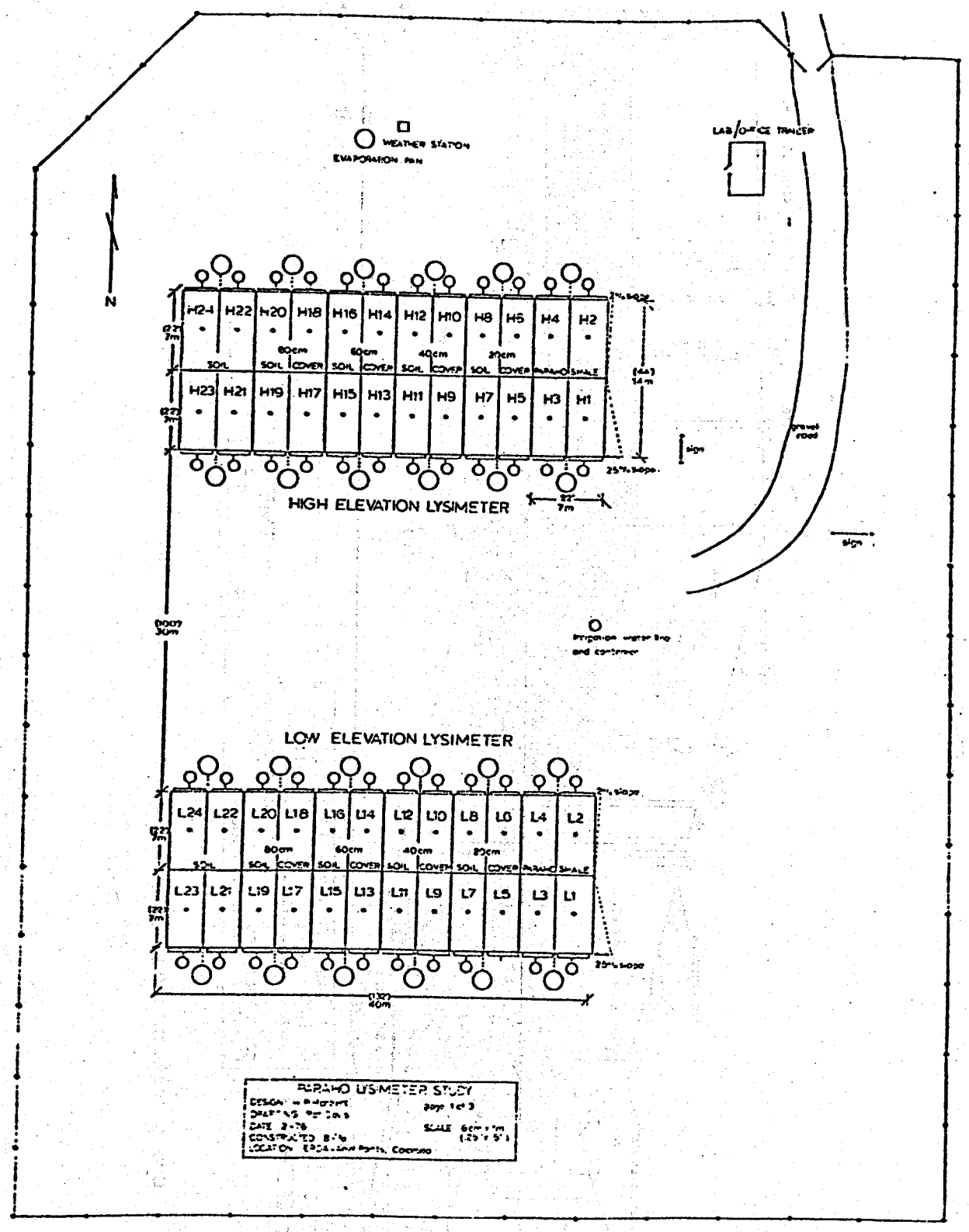
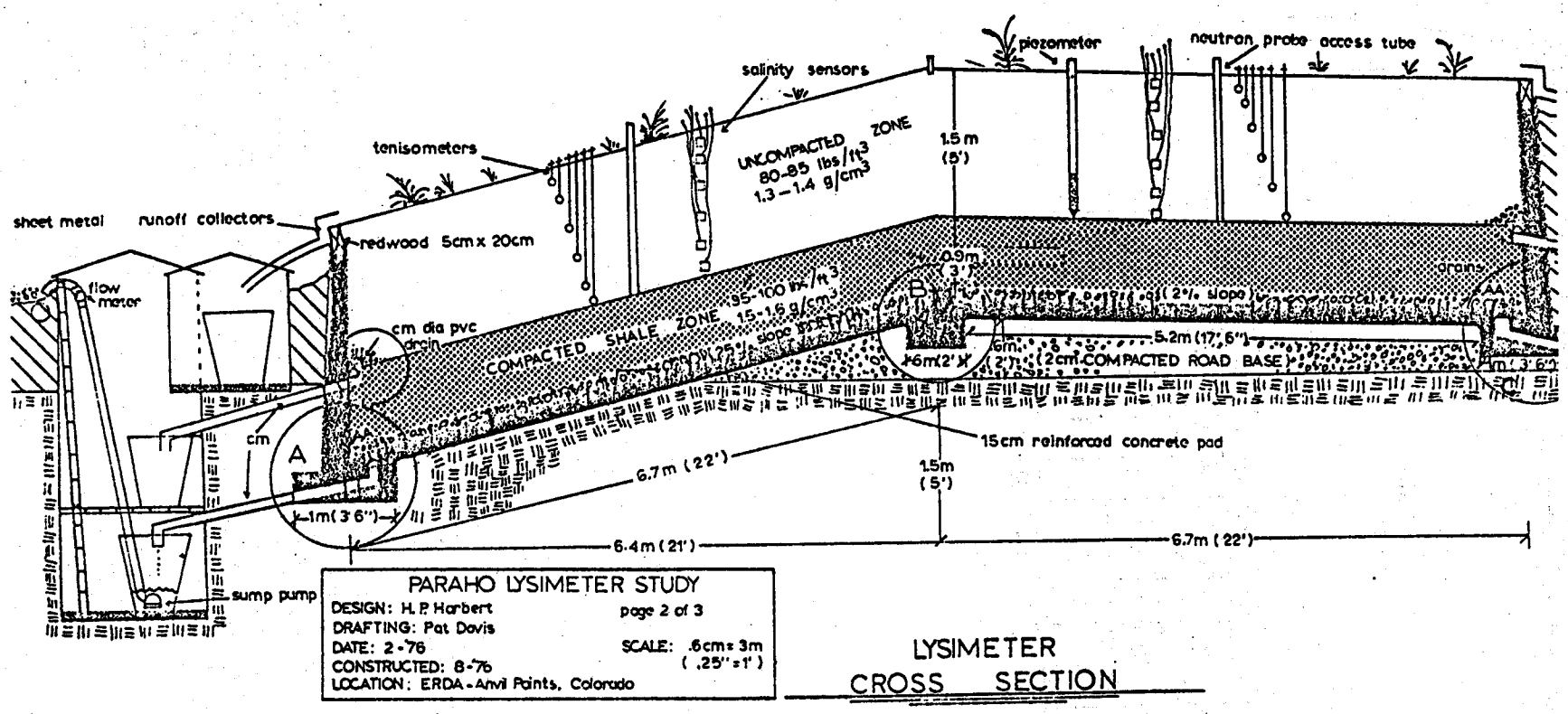


FIGURE 4.3

Plot plan of lysimeter study site.

FIGURE 4.4



Cross section showing the design of the lysimeters.