m m SF
2.7 v2

FINAL REMEDIAL INVESTIGATION REPORT

VOLUME 1

Martin Marietta Reduction Facility
The Dalles, Oregon

GERAGHTY & MILLER, INC.
Ground-Water Consultants

PRELIMINARY REMEDIAL INVESTIGATION REPORT

Martin Marietta Reduction Facility
The Dalles, Oregon

Prepared for

MARTIN MARIETTA CORPORATION
Bethesda, Maryland

G&M Project Number: TF0487P004

March 1988

MAR 14 1988
Superfund Branch

Prepared by

GERAGHTY & MILLER, INC.
Ground-Water Consultants
Tampa, FL; Aiken, SC

EXECUTIVE SUMMARY

Purpose

This report describes the remedial investigation performed by Geraghty & Miller, Inc., at the Martin Marietta Reduction Facility at The Dalles in Wasco County, Oregon. The site covers 350 acres and is located just west of the Columbia River.

The remedial investigation was carried out on behalf of Martin Marietta and was overseen by Region X of the U.S. Environmental Protection Agency under a Consent Order (No. 1085-04-02-106) dated September 1985. The investigation was implemented in accordance with the Remedial Investigation Work Plan dated December 1985, as modified in May 1987, and is consistent with the requirements of the National Contingency Plan and available CERCLA guidance documents.

The objectives of the remedial investigation were to: characterize site conditions and the extent and nature of site-related constituents released to the environment; to gather site data necessary to evaluate potential remedial responses; and, to determine the nature and extent of the risk to public health, welfare, or the environment posed by the release of site-related constituents. This report summarizes the results of data collected during remedial investigation activities and includes a risk assessment prepared by ICF/Clement Associates based on collected data and analysis. A separate feasibility study report, scheduled for completion in the first half of 1988, is to be prepared based on the findings of the remedial investigation and the risk assessment.

Background

The Martin Marietta Reduction Facility is designed to produce approximately 90,000 tons of aluminum annually. The plant was operated from 1958 through December 1984, at which time the facility closed. In September 1986, Martin Marietta leased the plant and some adjacent property to Northwest Aluminum Company. Primary aluminum operations were resumed at a reduced rate by Northwest Aluminum Company in late 1986.

During the period of operation by Martin Marietta, waste constituents derived from alumina reduction were stored, treated, and disposed of at the facility. Although waste management techniques acceptable at the time were employed and although all necessary environmental operating permits were obtained, some waste constituents consisting principally of fluoride, sodium, sulfate, cyanide, and polynuclear aromatic hydrocarbons were released to the natural environment.

A number of remedial actions were taken prior to initiating the remedial investigation in order to diminish the environmental effects of plant activities. These include: construction of a lined pond for storage of scrubber sludges; relocation of the old cathode waste pile to a new lined cathode waste pad containing a leachate-collection system; fencing of the landfill to restrict access (performed as an interim remedial measure); construction at the landfill of a leachate-collection system consisting of gunite-lined perimeter ditches and a collection sump; and, construction of a concrete-lined pad in the cathode wash area.

The Consent Order directed Martin Marietta to perform a remedial investigation and feasibility study. A work plan for the study, prepared for Martin Marietta by Geraghty & Miller, Inc., was submitted to the Environmental Protection Agency in December 1985, modified in February 1986, and approved and implemented in March 1986. Remedial investigation activities were carried out from March 1986 to September 1987.

Investigative Phases

The remedial investigation was divided into two separate data-collection events, the first of which was conducted primarily during the second and third quarters of 1986. An interim report prepared from the information collected in 1986 concluded that additional data were required to satisfy the needs of the feasibility study. In March 1987, a work plan addendum was submitted to the Environmental Protection Agency describing the work needed to acquire the additional information for the second phase. The addendum was modified in May 1987 and approved by the EPA in June 1987, at which time field activities were initiated.

The first phase of the investigation consisted of waste characterization at the landfill and sampling of sediment, soil, air, surface water, and ground water to: characterize site conditions and the extent and nature of site-related constituents released to the environment; gather site data necessary to evaluate potential remedial responses; and, determine the nature and extent of the risk posed to public health, welfare, or the environment by the release of site-related constituents. During this phase, in order to determine geologic and hydrogeologic conditions at the facility, new monitor wells were installed, aquifer tests were conducted, and water-level measurements were made.

The second phase of the investigation consisted of sediment, soil, air, surface-water, and ground-water sampling to confirm and to further define the extent of constituents reported during the first phase. Selected monitor wells installed at the site prior to the remedial investigation appeared to be producing water-quality and water-level data of questionable value due to well-construction deficiencies, and as a result, the improperly constructed wells were replaced. In addition, new monitor wells were installed in on-site and off-site areas to better define hydrogeologic conditions and the areal extent of waste constituents. Additional aquifer testing was conducted, and water-level measurements were collected to better define the direction of ground-water movement and hydraulic relationships between the various aquifer systems.

Findings

During the investigation, 23 potential source areas were investigated. The types of constituents found in the source areas were consistent with the nature of materials treated, stored, or disposed of at the site. These constituents consist principally of fluoride, sodium, sulfate, cyanide, and polynuclear aromatic hydrocarbons.

Cyanide was detected above background levels in the landfill waste and leachate, soils, perched water associated with the cathode management area, and in the discharge channel sediments. Fluoride concentrations above background were reported in cathode wash area soils, landfill leachate, recycle pond and lined pond sediments, and in perched water underlying the old cathode management area. Polynuclear aromatic hydrocarbons were reported in landfill waste materials, the cathode waste-management area soils, and scrubber sludge pond soils and sediments.

Four aquifer systems were identified beneath the facility; from shallowest to deepest, these aquifers were labeled the S, A, B, and Dalles Ground Water Reservoir. Perched water was encountered in locations that had been filled in the old cathode management areas. In addition, an alluvial aquifer of limited areal extent was identified north of the plant near Chenoweth Creek.

Concentrations of some constituents were reported as present in the various aquifer systems underlying the site. The concentrations were generally localized near the source areas, being highest in the perched water and at decreased concentrations at depth and distance from the source. The major sources of these constituents were the scrubber sludge ponds, runoff and leachate generated at the landfill, and the old cathode waste pile. Generation and migration of leachate has been remedied to a large extent by relocating the old cathode waste pile to the new concrete lined pad and by installing a leachate-collection system around the perimeter of the landfill.

A degree of hydraulic connection exists between the upper aquifers underlying the site. The Dalles Ground Water Reservoir is separated from overlying units by low permeability sediments which effectively preclude the exchange of water between the Dalles Ground Water Reservoir and the B aquifer. No water-quality impacts were identified in the Dalles Ground Water Reservoir.

No concentration of any constituents in the S, A, B, or Dalles Ground Water Reservoir exceeded ARARs (applicable, relevant, and appropriate requirements) with the exception of fluoride in the S aquifer near the scrubber sludge ponds, the recycle pond, and the alumina unloading building, and in one sample each from the A and B aquifers at monitor-well cluster MW-9. As discussed in the text, the results at MW-9 appear to be an artifact of well construction and not representative of ambient water quality at this location.

Six water-supply wells in the immediate vicinity and three Chenoweth Irrigation wells were sampled. No constituents were reported above laboratory detection limits in any of the Chenoweth wells. Although traces of selected constituents were reported as present in several of the water-supply wells, no constituents were reported to exceed ARARs with the exception of fluoride at the Old Residence Well. This well is owned by Martin Marietta and is not used as a potable water-supply source.

Samples collected from Chenoweth Creek showed no impacts from plant activities and, in general, constituents analyzed were below laboratory detection limits. Impacts to the Columbia River due to the source areas investigated were not evaluated during the RI but are expected to be below detection limits due to dilution.

The risk assessment performed for the site evaluated the potential impacts of site-related constituents in ground water, surface water, soil, sediment, and air on human and environmental populations in the area under current as well as hypothetical future land-use conditions. Exposures evaluated were direct contact with soil and inhalation of dust, and exposures to ground water and surface water. Of the exposures evaluated in the risk assessment, only the following are of potential concern: (1) use of the S aquifer as a sole drinking-water resource may pose adverse health effects based on fluoride concentrations in several wells at the site that exceeded ARARs; and (2) exposure of hypothetical future on-site construction workers and future workers who work outdoors via direct contact with soils containing arsenic and PAHs in the following areas: landfill, landfill runoff areas, potliner handling area, and the scrubber sludge ponds. In addition, concentrations of constituents in the landfill leachate may result in adverse effects to wildlife drinking this water.

Unresolved Data Needs

The remedial investigation satisfied the objectives of the work plan and addendum, which were based on an understanding of hydrogeologic conditions and source areas apparent at the time. However, during the course of the investigation, new information became available which modified the current interpretation of conditions. Most of the modifications were handled in the field as they occurred; however, one area was noted which requires additional data collection. This area is located near the alumina unloading building upgradient of the new cathode waste pad where elevated levels of fluoride and cyanide were reported as present in the S aquifer. These elevated levels may be a result of a recently identified source of cathodic material and/or the result of pipeline leakage of water rerouted from the duck pond to the discharge channel (a rise in water levels noted in the area of the new cathode waste pad during the investigation was a likely result of this leakage). Conditions in this area do not pose a risk to human health and the environment; however, in order to evaluate source control measures during the feasibility study, additional data are necessary to define the character of this potential source area.

566/6

Table of Contents

CONTENTS

APPENDICES

FIGURES

TABLES

563/3

GLOSSARY

A Aquifer. First unit underlying the site capable of supplying appreciable ground-water yields to wells. Located in the Middle Rosalia Flow.

Aerobic. Conditions that exist under free oxygen.

Air-impinger. Glass device containing liquid solution through which air is percolated using a pumping device.

Alluvial. A general term for unconsolidated material deposited by a stream or other body of running water.

Alumina Reduction Process. Manufacturing process of reducing alumina to aluminum electrolytically.

Anaerobic. Conditions that exist in the absence or near absence of free oxygen.

Animal Shelter Well. Water-supply well located offsite at Wasco County Animal Shelter located north of the MMRF.

Anode. A positive electrode. A pitch/coke mixture.

Anticline. A fold, the core of which contains the stratigraphically older rock; it is convex upward.

Aquifer. A formation that contains saturated permeable material and yields significant quantities of water to wells or springs.

Aquitard. A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.

Artesian. Ground water confined under hydrostatic pressure.

Authigenic. Formed or generated in place.

B Aquifer. Lower zone of the Rosalia Flow comprised of a pillow lava and present below the MMRF from about 170 to 200 feet below land surface. May produce from 300 to 500 gpm.

Barometric Efficiency. Ratio of water-level change to atmospheric pressure change.

Basalt. General term for dark-colored iron and magnesium rich extrusive volcanic rock.

Basalt Pinnacles. Spire-shaped pillars of basalt.

Bath. The process of softening the spent cathode by quenching with water for several days.

Bingen Anticline. A concave downward fold to the north of the Mossier syncline.

Briquettes. A brick made of compressed coal dust.

Bus Bars. Aluminum bars which transmit electrical power to the studs in the anode.

Byron Interbed. Weathered basalts and alluvial deposits present between the Lola and Rosalia basalt flows.

Cast House. Area of plant where molten aluminum is solidified in various forms and sizes.

Cathode. A negative electrode. The cathode is composed mainly of carbon blocks and refractory bricks.

Cathode Waste Management Area (Former). Includes Cathode Wash Area, Potliner Handling Area, Old Cathode Waste Pile, Salvage Area, Bath Recovery Area, and Metal Pad Storage Area.

Chain-of-Custody. Written record which accompanies samples from the time of collection to the time of analyses.

Chenoweth Fault. A reverse fault in the area of the Chenoweth Creek.

Chenoweth Formation. Geologic formation above the Columbia River Basalt Group consisting of volcanoclastics.

Coke. Combustible material consisting of fused ash and fixed carbon of bituminous coal.

Collector Bars. Steel bars inserted through the carbon black to complete the electric circuit.

Colluvium. Aluvium deposited by surface run-off or sheet erosion.

Colonnade. The lower, thicker, and better formed zone in columnar jointing.

Columbia Hills Anticline. A concave downward fold north of The Dalles syncline.

Columbia River Basalt Group (CRBG). A geologic group of Miocene age comprised of approximately 300 basalt flows.

Columnar Joints. Parallel, prismatic columns, either hexagonal or pentagonal in basalt flows.

Confined Aquifer. An aquifer bounded above and below by impermeable beds.

Constant-Rate Pumping Test. An aquifer test in which a well is pumped at a constant rate for a period of time.

Cryolite. A white or colorless monoclinic mineral (Trisodium-Aluminum-Hexa fluoride [Na_3AlF_6]) used in the manufacture of aluminum.

Dalles Ground-Water Resevoir (DGWR). High capacity aquifer supplying municipal, industrial, and agricultural demands in The Dalles area. Located in the Frenchman Springs Member of the Columbia River Basalt.

Draeger Tube. Glass tube with porous receptor media utilized for monitoring air quality.

Drawdown. A lowering of the potentiometric surface caused by pumping of ground water from wells.

Evapotranspiration. Loss of water from a land area through transpiration of plants and evaporation from the soil.

Extraction Procedure (EP) Toxicity Metals. List of metals including arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.

Fault. A fracture along which there has been displacement of the sides relative to one another.

Field Blank. Sample prepared in the field from a clean source. Used to indicate background sources of contamination during sampling.

Foreset. A steep and advancing frontal slope.

Formation. A geologic unit possessing distinctive lithologic features.

Frenchman Springs Member. Lowest member of the Wanapum Basalt Group.

Grande Ronde Basalt. The basalt flow in the CRBG that underlies the Frenchman Springs member.

Gunite. Mixture of Portland cement, sand, and water applied by pneumatic pressure and used as a sealing agent.

Hesslan-Skyline Complex. A soil complex that consists of loess, volcanic ash, and alluvium.

GLOSSARY continued

Homogeneity. The quality or condition of being similar or identical.

Homogeneous. The same in structure or quality, uniform.

Hyaloclastite. A deposit resembling tuff formed by the flowing of basalt under water.

Hydraulic conductivity. A value of proportionality describing the rate at which water can move through a permeable medium.

Hydraulic gradient. Change in total head with a change in distance in a direction that provides the highest value.

Hydrograph. A graph showing water levels as a function of time.

Isotropic. Said of medium whose properties are the same in all directions.

Lacustrine. Produced by or formed in a lake.

Laurel Fault. Northeast trending, strike-slip fault to the east of The Dalles.

Lignite. Brownish-black low-grade coal.

Lola Flow. Uppermost basalt unit at the MMRF. Part of the Priest Rapids Member.

Matrix Spike. Sample media injected with a standard of known concentration and volume.

Metal Pad. Slag material produced during disassembly of the potliners. It consists of alumina, aluminum, and impurities.

Metallo-Cyanide. Describes a compound in which an atom of metal is bound to cyanide.

Monovalent. Having a valence of one.

Montmorillonite. A group of expanding-lattice clay minerals.

Mossier Syncline. Concave upwards fold north of the Columbia Hills anticline.

Observation Well. Any nonpumping well used to observe the elevation of the potentiometric surface.

Ore. Naturally occurring material from which minerals of economic value can be extracted.

Paleomagnetism. Natural remnant magnetism.

Paleotopography. Topographic relief of an area at a particular time in the geologic past.

Pasco Basin. A geologic basin formed by a series of east-to-northeast trending folds.

Perched Ground Water. Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

Photovac Tip. An instrument which measures total ionizational pollutants.

Phyric. Containing numerous crystals.

Pillow Lavas. A general term for those lavas displaying discontinuous pillow-shaped masses formed in subaqueous environments.

Pitch. A dark-colored, viscous to solid, nonvolatile, fusible substance. The pitch contains polynuclear aromatic hydrocarbons.

Plagioclase Phenocrysts. Large crystals of triclinic feldspars.

Pleistocene. An epoch of geologic time of the Quaternary period.

Plio-Pleistocene. A period of geologic time that includes the Pliocene and Pleistocene epochs.

Pomona Member. A basalt flow in the CRBG above the Wanapum Basalt.

Potentiometric Surface. A surface that represents the level to which water will rise in a well.

Priest Rapids Member. Uppermost unit of the Wanapum basalt containing the Lola Flow, Byron Interbed, and the Rosalia Flow.

Production Well. A water-supply well used for municipal, industrial, or agricultural purposes.

Pyrite. Iron sulfide.

Pyroclastic. Pertaining to clastic rock material formed by volcanic explosion or aerial expulsion from a volcanic vent.

GLOSSARY continued

Quaternary. The second period of the Cenozoic era thought to cover the last two to three million years.

Quincy Loam Fine Sand. A soil complex consisting of sandy alluvium.

Quincy/Squaw Creek Interbed. Depositional clays that form the aquitard above the D aquifer.

Rosalia Flow. Basalt unit at the MMRF site. Lower flow of the Priest Rapids Member.

Rosa Member. Middle geologic unit in the Wanapum Basalt. The Rosa occurs between the Quincy and Squaw Creek Interbeds. In the area of the MMRF, the Rosa is absent.

S Aquifer. Uppermost aquifer comprised of the Lolo Flow, Byron Interbed, and subaerial part of the Rosalia Flow included in the transition zone.

Saddle Mountain Basalt. A basalt flow of the CRBG and uppermost member of the Yakima Basalt subgroup.

Sentinel Gap Flow. Uppermost basalt flow of the Frenchman Springs Member and which contains the DGWR.

Surrogate Spike. Mixture of standard compounds of known concentration from which a known volume is extracted and added to each sample.

Syncline. A fold, the core of which contains the stratigraphically younger rocks; it is concave upward.

Target Waste. Waste materials which include spent cathode waste, refractory bricks, and off-specification carbon block, pitch, and coke.

Tectonic Fracturing. Fractures in bedrock attributed to mountain building.

The Dalles Syncline. The folded concave upwards bedrock in The Dalles area.

Three Mile Fault. A lateral strike-slip fault in the vicinity of The Dalles Dam.

Transmissivity. The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Trip Blank. Sample prepared in the laboratory which accompanies sample bottles in transit.

GLOSSARY continued

Tuffaceous. Sediments containing at least some pyroclastic volcanic ash and dust.

Van Horn Loam. Soil complex consisting of dark loam to clay loam.

Vesicular. The texture of a volcanic rock containing abundant bubbles.

Volcanoclastics. Pertaining to clastic rock material formed by volcanic activity.

Wanapum Basalt. Basalt unit containing numerous flows of the Columbia Basalt Group. Contains the Priest Rapids Member, Rosa Member, and Frenchman Springs Member.

Water Table. The surface in an aquifer at which the pore water pressure is atmospheric.

Weathering. The physical and chemical breakdown of rocks.

Xeropsamments. A soil consisting of rocks and weathered material.

Yakima Basalt. A subgroup of the CRBG, middle to upper Miocene in age, comprised of several basalt flows.

548/9

ACRONYMS

ARAR	Applicable, relevant, and appropriate requirement
BN/A	Base neutral/acid extractable organic
BRPA	Bath recovery pad area
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980. Also known as "Superfund"
CRBG	Columbia River Basalt Group
CWA	Cathode wash area
DEQ	State of Oregon, Department of Environmental Quality
DGWR	Dalles Ground-Water Reservoir
EP	Extraction procedure
EPA	Environmental Protection Agency
FS	Feasibility Study
G&M	Geraghty & Miller, Inc.
MMRF	Martin Marietta Reduction Facility
MPSA	Metal pad storage area
NCP	National Contingency Plan
NCWP	New cathode waste pad
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NWA	Northwest Aluminum Company
OCWP	Old cathode waste pile
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl

PHA	Potliner handling area
QAPP	Quality Assurance Project Plan
RA	Risk Assessment
RCRA	Resource Conservation and Recovery Act
RfDs	Reference doses
RI	Remedial Investigation
SOP	Standard operating procedure
SSP	Scrubber sludge pond
USGS	U.S. Geological Survey
VOC	Volatile organic compound

548/10

Section One

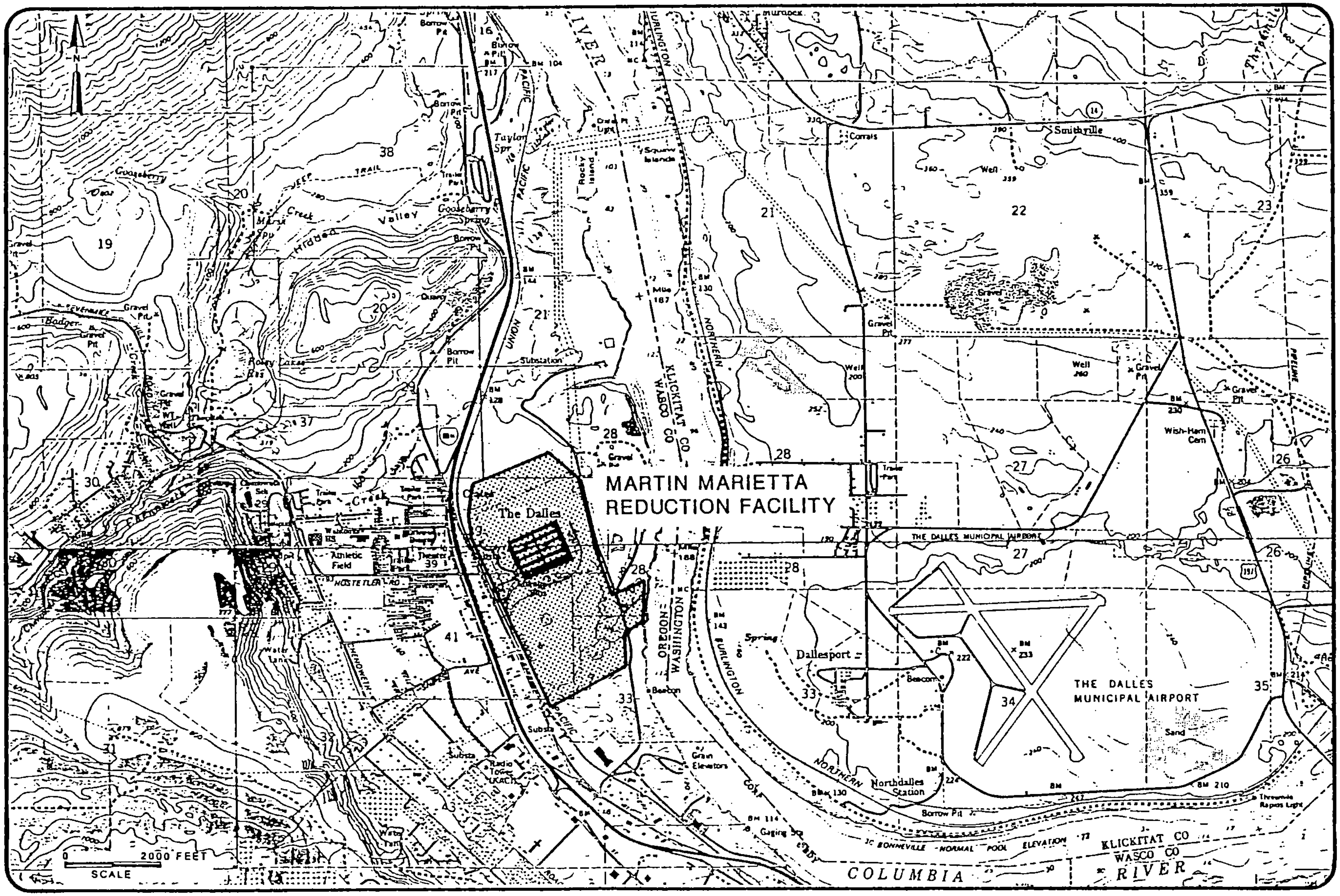
1.0 INTRODUCTION

1.1 GENERAL

This report describes the Remedial Investigation performed in 1986-87 by Geraghty & Miller, Inc., (G&M) at the Martin Marietta Reduction Facility (MMRF) located in The Dalles, Wasco County, Oregon (Figure 1.1). The facility, used for processing of aluminum, covers 350 acres and is located just west of the Columbia River (Figure 1.2).

Operations were begun at the site by Harvey Aluminum, Inc., in 1958 prior to their becoming a wholly-owned subsidiary of Martin Marietta Corporation (Martin) in the early 1970's. The MMRF continued operating until 1984, when the plant was shut down; at approximately the same time, Martin acquired legal title to the property from Martin Marietta Aluminum, Inc. In 1986, Martin leased the plant and portions of the adjacent areas to Northwest Aluminum Company, which resumed primary aluminum operations in 1987.

During the period of operation, waste constituents derived from alumina reduction were stored, treated, and disposed of at the MMRF. Although waste management techniques acceptable at the time were employed and although all necessary environmental operating permits were obtained, some waste constituents consisting principally of fluoride, sodium, sulfate, cyanide, and polynuclear aromatic hydrocarbons (PAHs) were released to the natural environment. As a result, Martin entered into a Consent Order (No. 1085-04-02-106), with Region X of the U.S. Environmental Protection Agency (EPA) in September 1985 that directed Martin to perform a remedial investigation and feasibility study (RI/FS) for the study area (Figure 1.3). The objective of the RI was to determine the nature and extent of the threat to the public health, welfare, or the environment



CLIENT NAME:

Martin Marietta Corporation

Figure 1.1 Location Map Showing the MMRF and Vicinity.

Figure 1.2 Aerial Photograph of the MMRF and Vicinity.

CLIENT NAME:

Martin Marietta Corporation

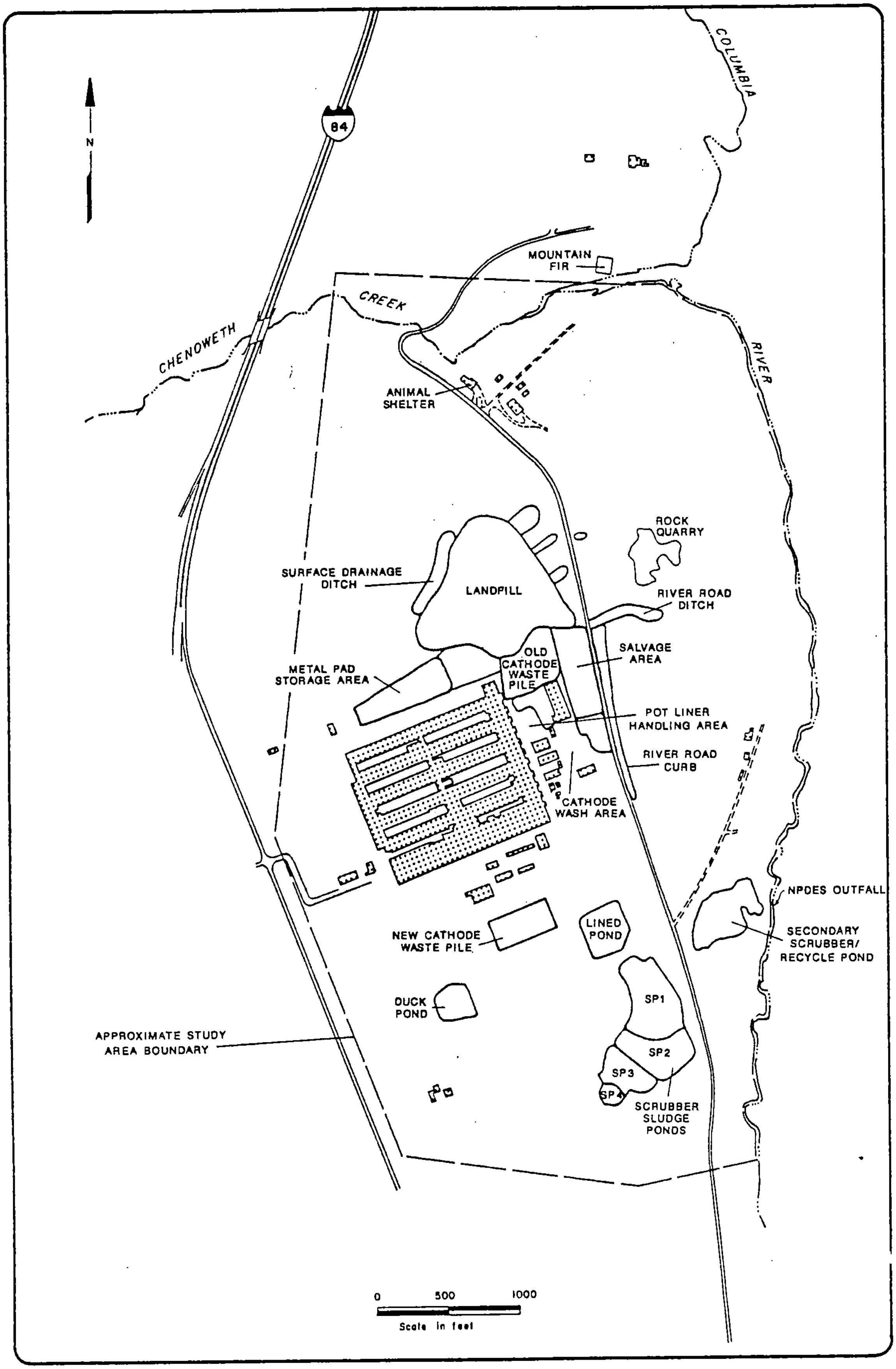


Figure 1.3 Site Map Showing Approximate Study Area Boundaries.

CLIENT NAME:

Martin Marietta Corporation

caused by the release of constituents from the MMRF. The objective of the FS is to evaluate remedial-action alternatives to prevent or mitigate the migration, the release, or the threatened release of constituents of concern from the facility as identified in the risk assessment.

The work plan for the study, prepared for Martin by G&M, was submitted to the EPA in December 1985, modified in February 1986, and implemented by G&M in March 1986. The work plan described the techniques and scope of the field investigation, which included waste characterization at specific source areas (see Section 3.0), monitor-well installation, and sampling and analysis of soil, surface water, and ground water (Appendix C). The information collected during the RI supplements the existing data base of ground-water and surface-water quality data which is presented in Appendix A.

The key areas investigated included:

- Landfill and adjacent areas
- Former Cathode Waste Management Area
- New Cathode Waste Pad
- Duck Pond
- Lined Pond
- Recycle Pond
- Scrubber Sludge Ponds
- Wastewater and surface-water transport ditches

Each source is described in Section 3.0 with additional detail provided in Appendix A.

The primary parameters of concern are those associated with the alumina reduction process: total and free cyanide, fluoride, sodium, and polynuclear aromatic hydrocarbons (PAHs). However, the work plan included characterization of the presence of other parameters: metals (including arsenic), base/neutral and acid extractable compounds (BNAs), volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs).

Results of the initial data-collection activities were summarized in a report entitled "Interim Report - Remedial Investigation, Martin Marietta Reduction Facility, The Dalles, Oregon," which was submitted to the EPA in November 1986.

The Interim Report identified several data deficiencies, and in March 1987, a work plan addendum was submitted to the EPA describing the work needed to acquire the additional information. The addendum was modified in May 1987 and approved by the EPA in June 1987, at which time field activities were initiated. The additional work included further sampling and analysis of surface water and soils at some of the source areas, characterization of perched water within the former cathode waste management area, reconstruction of pre-existing monitor wells determined to yield non-representative ground-water quality and potentiometric data, and additional ground-water sampling and analysis.

This report describes the findings of the RI, includes a Risk Assessment for the site, and presents applicable, relevant, and appropriate requirements (ARARs) (see Appendix B). A separate FS report is scheduled for completion in the first half of 1988. A community relations plan for the site was prepared for the EPA by Camp, Dresser, & McKee, Inc., in December 1985.

1.2 BACKGROUND INFORMATION

1.2.1 Physiographic Features

The dominant physiographic features of The Dalles area are the Columbia River Gorge and the adjacent extensive undulating plateaus that are deeply incised by streams. The land surface rises from approximately 100 ft (feet) above mean sea level (msl) at the Columbia River to more than 3,000 ft msl on the plateau (Grady, 1983). The major streams in the area originate in the west and flow to the northeast, ultimately discharging to the Columbia River.

The channel of the Columbia River has been eroded along joints and fractures of the Columbia River Basalt. In some places, the Columbia River descends over massive layers of basalt, creating pronounced falls. The largest such fall, at Celilo, descended a total of 50 ft (Newcomb, 1969) but is now submerged behind The Dalles Dam.

The major land uses in the area are agricultural, including orchards, grazing, and forestry. Industry is limited and is restricted to the area of The Dalles. Approximately 60 percent of the population of Wasco County lives in the cities of The Dalles, Dufur, and Mosier.

1.2.2 General Historical Overview

A summary of the history of waste generation, storage, and disposal activities at the plant is presented below; further discussion, including an historical description of potential source areas, is given in Appendix A. A detailed description of the various source areas is presented in Section 3.1.

1.2.2.1 Background

The MMRF plant consists of 300 alumina reduction cells housed in five production buildings. When at full capacity, MMRF produced approximately 90,000 tons of aluminum annually, using the Hall-Heroult reduction process illustrated in Figure 1.4. As described in Appendix A, wastes generated from the process came from the reduction cells, air emission controls, water treatment, and other activities that supported the manufacturing process.

In 1983, routine sampling of Production Well #2 at the site reported levels of cyanide above detection limits. The well was thought to be improperly grouted, allowing contaminants to migrate downward along the annular space into the Dalles Groundwater Reservoir (DGWR), and it was subsequently properly abandoned. None of the other three production wells, which are monitored on a regular basis, have reported any water-quality problems.

In early 1983, leachate was detected migrating from the landfill area across River Road to the Rockline quarry area. A design for a leachate-collection system around the landfill perimeter was prepared by Century West Engineering in 1983 and constructed by Martin in 1984.

In 1983, the EPA evaluated the MMRF and determined that it had a hazardous waste ranking of 43.7, sufficient to place it on the National Priorities List (NPL). The site was subsequently designated as a Superfund site in January 1987.

In December 1984, the plant ceased production, leaving a skeleton crew to continue the water-monitoring program and to operate and maintain essential elements such as the rectifiers, sewage-treatment plant, and the leachate-collection system. In September 1986, as noted previously, Northwest

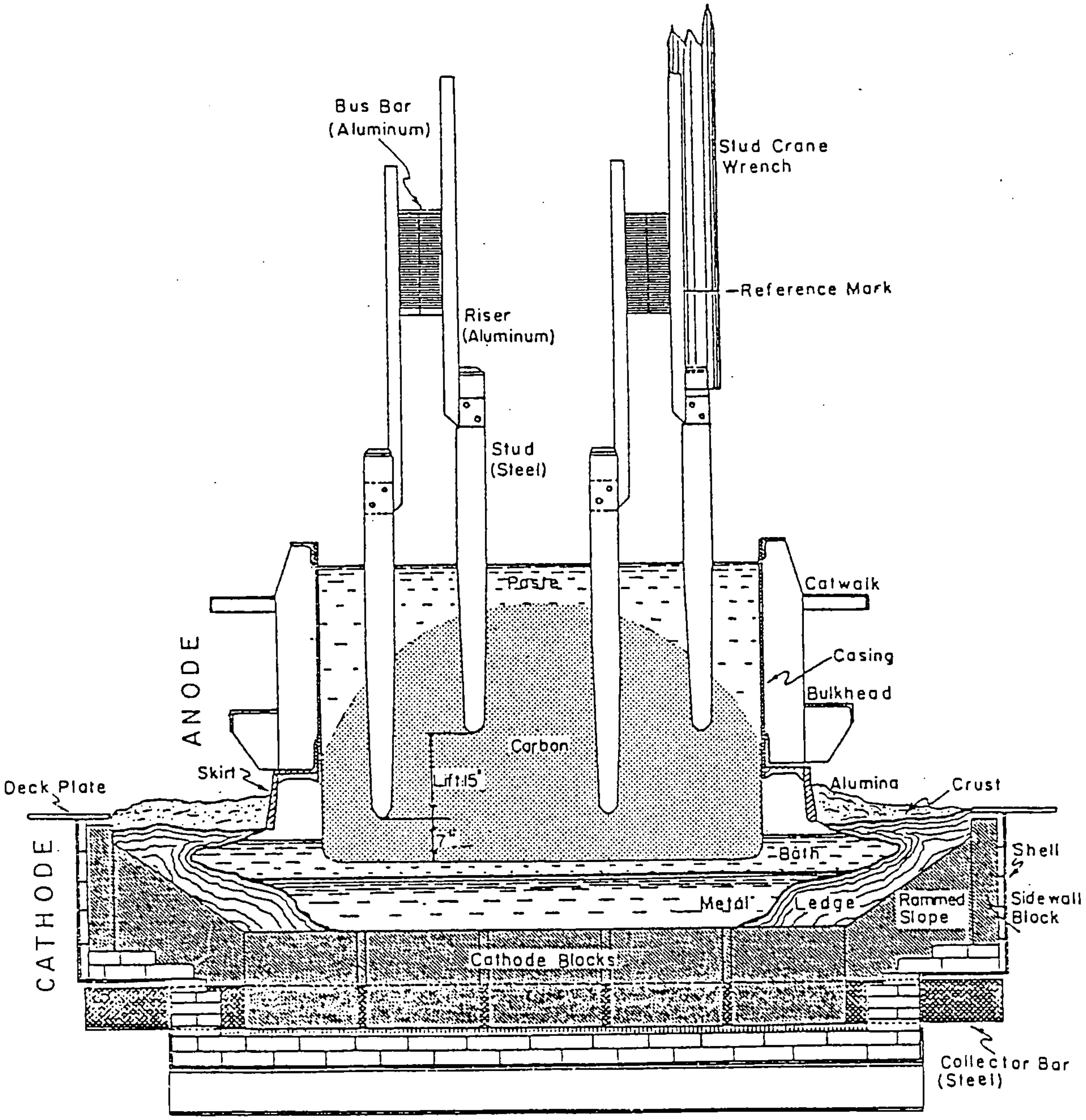


Figure 1.4 The Hall-Heroult Reduction Process.

CLIENT NAME:

Martin Marietta Corporation

Aluminum Company leased the facility and presently operates the plant under a five-year lease/sale agreement, which is subordinate to the EPA Consent Order.

1.2.2.2 Routine Cathode Handling

The cathode handling procedure is detailed in Appendix A. The expected life of a cathode was approximately five years, after which it was usually removed from service due to poor metal grades. The hot cathodes removed from service were transported to the cathode wash area where they were sprayed with water for approximately two days. After soaking, the bath and metal pad were removed from the cathode. The metal pad was placed in the metal pad storage area and the cathode was brought back inside the plant where it was dismantled and the lining was removed.

From 1963 to 1968, cathode waste was shipped off-site for processing by a Reynolds Aluminum facility in the State of Washington. Except during this period, cathode waste was retained on-site and stored in the old cathode waste pile. When shipping the waste off-site, the bricks from the pots were separated from the rest of the waste and placed in the landfill. The bricks put into the landfill comprise about one-half of the total waste volume.

In 1983, the State of Oregon Department of Environmental Quality listed cathode (potliner) waste as hazardous. Since the state regulations were promulgated, Martin built an approved and permitted cathode waste pad to store its waste potliner. The cathode waste previously stored at the old cathode waste pile was relocated to the permitted storage facility and any waste generated thereafter was placed on the new pile.

1.2.2.3 Air Emissions Scrubber System

When the plant was built in 1958, a scrubber was added to the design. The scrubber collected emissions from the reduction cells and "scrubbed" fluorides in a dry system. Some of the scrubbed particles were recycled back into the cells and the rest were disposed of by making a slurry and pumping the resulting sludge into the unlined scrubber sludge ponds. This system was called the primary system. In 1980, the lined pond was built to replace the scrubber sludge ponds.

In 1969, a second scrubber, called the secondary system, was added to control air emissions. This scrubber collected emissions from the pot rooms through roof fans that "scrubbed" the particles in a wet system. The water collected from the roof scrubber was routed through the discharge channel into the recycle pond. Some sludges from the secondary system were also discharged to the scrubber sludge ponds.

1.3 NATURE AND EXTENT OF THE PROBLEM

1.3.1 Constituents Found in Soil/Sediment/Ground Water/Surface Water

Waste constituents consisting principally of fluoride, sodium, sulfate, cyanide, and PAHs were reported as present at various locations around the MMRF. The types of constituents found were consistent with the nature of materials treated, stored, or disposed of at the site. Cyanides (complex and free) are associated with potliner material (spent cathodes), for example, and fluoride and sodium, found in roof scrubber effluent and spent cathodes are components of cryolite, the raw material used in the alumina reduction process. PAHs are associated with pitch and coke.

Levels of cyanide were found at the landfill (in the waste and landfill leachate), the cathode management area (soils and underlying perched water), and the discharge channel (sediments). Free cyanide was not identified in samples of scrubber sludge pond sediments, the lined pond, recycle pond sediments, or the duck pond.

Fluoride concentrations were reported at the cathode wash area (soils), landfill (leachate), recycle pond (sediments), lined pond (sediments), and in perched water underlying the old cathode management area. PAHs were reported at the landfill (waste materials), the cathode waste-management areas (soils), and the scrubber sludge ponds (soils and/or sediments). In general, no PAHs were reported as present in any ground-water or surface-water samples.

Concentrations of cyanides and sodium were reported as present in the various aquifer systems underlying the landfill, cathode waste-management areas, and areas east of River Road toward the Columbia River. With the exception of perched water found in the old cathode management area, free cyanide concentrations in the underlying aquifers were below ARARs, which are described in Section 6 and are summarized in Table 1.1. Appendix B provides additional detail regarding ARARs.

Concentrations of fluorides were reported as present in the aquifer systems underlying the recycle pond and scrubber sludge ponds. The distribution of fluorides in ground water is generally restricted to this area, and no concentrations were reported to exceed ARARs except in the uppermost aquifer (S aquifer). With the exception of one sample each from the A and B aquifers at well cluster MW-9, no other fluoride analyses were reported above ARARs. The values from well cluster MW-9 are felt to be an artifact of well construction,

TABLE 1.1

POTENTIAL ARARS AND OTHER GUIDANCE FOR THE PROTECTION OF HUMAN HEALTH AND AQUATIC LIFE

for GROUNDWATER:

Chemical	Federal MCL (SMCL) [a]	Federal MCLG [b]	Oregon MCL [c]	Other
Bicarbonate	---	---	---	---
Calcium	---	---	---	---
Carbonate	---	---	---	---
Cyanide (free)	---	---	---	220 ug/L (child) [d] 770 ug/L (adult) [e]
Fluoride	4 mg/L (2 mg/L) [f]	---	1.4-2.4 mg/L [g]	---
Magnesium	---	---	---	---
Sodium	---	---	---	---
Sulfate	(250 mg/L)	---	250 mg/L	400 mg/L [h]
Zinc	(5 mg/L)	---	5 mg/L	---

for SURFACE WATER:

Chemical	Water Quality Criteria for Protection of Human Health [i]		Water Quality Standard for the Hood Basin [j]	Water Quality Criteria for Protection of Aquatic Life [k]	
	Water & Fish Ingestion	Fish Consumption Only		Acute	Chronic
Cyanide	200 ug/L	---	0.005 mg/L	0.022 mg/L	0.0052 mg/L
Flucride	---	---	1.0 mg/L	---	---
Zinc	5 mg/L [l]	5 mg/L [l]	0.01 mg/L	0.12 mg/L [e]	0.11 mg/L [m]

TABLE 1.1, continued

[a] Maximum Contaminant Levels are enforceable drinking water standards from 40 CFR 141.11. These levels are based on health, technical feasibility, and cost benefit analysis. Secondary Maximum Contaminant Levels are shown in ( ) and are goals for drinking water quality based on aesthetic considerations such as taste, odor or straining ability, 40 CFR 143.3.

[b] Final and proposed MCLGs (maximum contaminant level goals) are developed as part of the process for developing final drinking water standards, (i.e., MCLs), under the Safe Water Drinking Act. MCLGs are entirely health-based and are always less than or equal to the proposed or final MCLs subsequently developed. Proposed MCLGs may be changed before they are promulgated as final requirements. Proposed MCLGs are in parentheses.

[c] Oregon Administration Rule 333-61

[d] Health advisory by USEPA Office of Drinking Water for longer-term exposure, March 1987; based on exposure to free cyanide.

[e] Health advisory by USEPA Office of Drinking Water for life time exposure for adults, March, 1987; based on exposure to free cyanide.

[f] National Primary and Secondary Drinking Water Regulations. Federal Register 51: 11396-11412, April 1986.

[g] Temperature dependent

[h] Guidance level proposed by USEPA Office of Drinking Water 50 FR 46936, 13 Nov. 1985.

[i] Oregon Water Quality Standards. Oregon Administrative Rule 340-41-525, August 28, 1987.

[j] Oregon Administrative Rule 340-41-525

[k] Quality criteria for water, USEPA, 1987 (EPA 1987c)

[l] Based on taste and odor effects

[m] Assuming a hardness of 100 mg/L calcium carbonate in water

as described in Section 4.7.2.4, and not necessarily related to previous disposal activities.

1.3.2 Current Conditions

At present, the plant is being operated at a reduced capacity by Northwest Aluminum. Two potential sources studied, the recycle pond and lined pond, are required for plant activities and are in use. In addition, the discharge channel, used to convey water to the recycle pond, is integral to plant activities. The new cathode waste pad, a permitted RCRA storage facility, is used to store spent cathodes resulting from plant operation. The other treatment, storage, and disposal areas are not necessary for plant activities, and therefore, are not in use.

The recycle pond, used to treat water used in the reduction process, operates under an NPDES permit. The NPDES permit regulates the amount of waste constituents, principally cyanides, fluorides, and PAHs, that can be discharged to the Columbia River. Because the pond is unlined, some of these constituents would be expected to leak out of the pond into the underlying aquifer system. In addition, sediment accumulates on the pond bottom during the treatment process. In the past, this sediment was dredged and placed into the unlined scrubber sludge ponds.

The lined pond is used to settle out particulates scrubbed from the air pollution control system. This material collects on the pond bottom and will periodically need removal. Analyses of ground-water samples collected from around the pond do not appear to reflect the influence of waste constituents discharged to the pond, which seems to be functioning properly with no evidence of a major tear in the liner. However, patches and small tears are present in the liner.

Other sources not integral to plant activities were excluded from use in the terms of the lease between Martin and Northwest Aluminum. These sources have been fenced by Martin to preclude their use.

1.3.3 Summary of Previous and Current Remedial Actions

The MMRF was operated under the conditions specified in the various environmental permits issued to the plant at the time. Those permits required that waste constituents produced during plant activities be treated, stored, or consolidated on site. A discussion of the relevant enforcement history is included in Appendix A.

A number of remedial actions have been taken to diminish the environmental effects of plant activities. These include: construction of the lined pond; relocation of the old cathode waste pile to a new lined cathode waste pad containing a leachate-collection and treatment system; fencing of the landfill to restrict access (an interim remedial measure taken during the RI); construction at the landfill of a leachate-collection system consisting of perimeter ditches and a collection sump; and construction of a lined pad in the cathode wash area.

1.4 INVESTIGATION SUMMARY

The RI was divided into two separate data-collection events, the first of which was conducted primarily during the second and third quarters of 1986. An interim report prepared from the information collected in 1986 concluded that additional data were needed to satisfy the needs of the FS; this second data-collection event occurred during the second and third quarters of 1987.

The initial investigation consisted of waste characterization at the landfill and sampling of sediment, soil, air, surface water, and ground water to determine the nature and extent of impacts to the surrounding environment. During this phase, new monitor wells were installed, aquifer tests were conducted, and water-level measurements were made to determine geologic and hydrogeologic conditions at the MMRF.

The second phase of the investigation consisted of sediment, soil, air, surface-water, and ground-water sampling to confirm and to further define the extent of constituents reported during the first phase. Selected monitor wells previously installed at the site appeared to be producing water-quality and water-level data of questionable value due to well-construction deficiencies, and as a result, the improperly constructed wells were replaced. In addition, new monitor wells were installed in on-site and off-site areas to better define hydrogeologic conditions and the areal extent of waste constituents. Additional aquifer testing was conducted, and water-level measurements were collected to better define the direction of ground-water movement and hydraulic relationships between the various aquifer systems.

1.5 REPORT OVERVIEW

This RI report summarizes the site information collected and analyzed during the investigation, following the format suggested by the EPA in its RI guidance documents (1985). As recommended by the EPA, the report describes site conditions and in general presents only the data generated during the study that support analysis of remedial alternatives for the FS. In order to focus the report so that it presents site characteristics and major analysis features clearly and logically, detailed discussions of several topics and compilations of basic supporting data are presented as appendices.

The main report, divided into nine sections, has two major components, the first of which is a summary of site conditions and a discussion of the nature of constituents found, their distribution, and to the extent possible, the mechanisms affecting their fate and transport. This information forms the basis of the second component, which is an interpretation of the public health and environmental significance of the nature and extent of constituents reported to be present. This component of the study is presented in Appendix B and summarized in Section 7, Risk Assessment. The write-up and interpretation of the first major component of the report was prepared principally by G&M, with input on historical conditions and detailed source descriptions by Martin and G&M Consulting Engineers, Inc. ICF/Clement Associates prepared the Risk Assessment in its entirety as well as the information pertaining to chemical characteristics and fugitive particulate modeling.

566/3

Section Two

2.0 SITE FEATURES

2.1 DEMOGRAPHY AND LAND USE

Information concerning land use and demography was obtained from several sources including U.S. Geological Survey (USGS) topographic maps (7.5-minute series), recent aerial photographs, a City of The Dalles zoning map (R and R Drafting 1982), G&M reports (1985, 1986, and 1987), and information provided by Martin employees.

2.1.1 Demography

According to The Dalles City Chamber of Commerce, the City of The Dalles, located 1.5 to 2 miles southeast of the MMRF, has a population of 10,600 persons. In the residential areas directly west of the MMRF, there are approximately 405 homes and 2 trailer parks with approximately 100 mobile homes. Assuming that 2.5 to 3.5 persons reside in each home, the population for these residential areas would be 1,300 to 1,800 persons. An additional 235 homes are located in the residential areas southwest of the MMRF, and using the per-house assumption noted above, the population for these southwesterly residential areas would be 600 to 1,000 persons.

2.1.2 Land Use

The MMRF is located in an 800-acre area zoned for heavy industry and manufacturing (Figure 2.1). The northern boundary of the zoning district is along the northern edge of the Mountain Fir facility, which is owned by a wood hauling company that operates a chip mill on this property. This boundary is approximately 0.8 mile north of the MMRF. Weber Street, located 0.8 mile from the MMRF, constitutes the southern boundary. The Columbia River, 0.4 mile from the

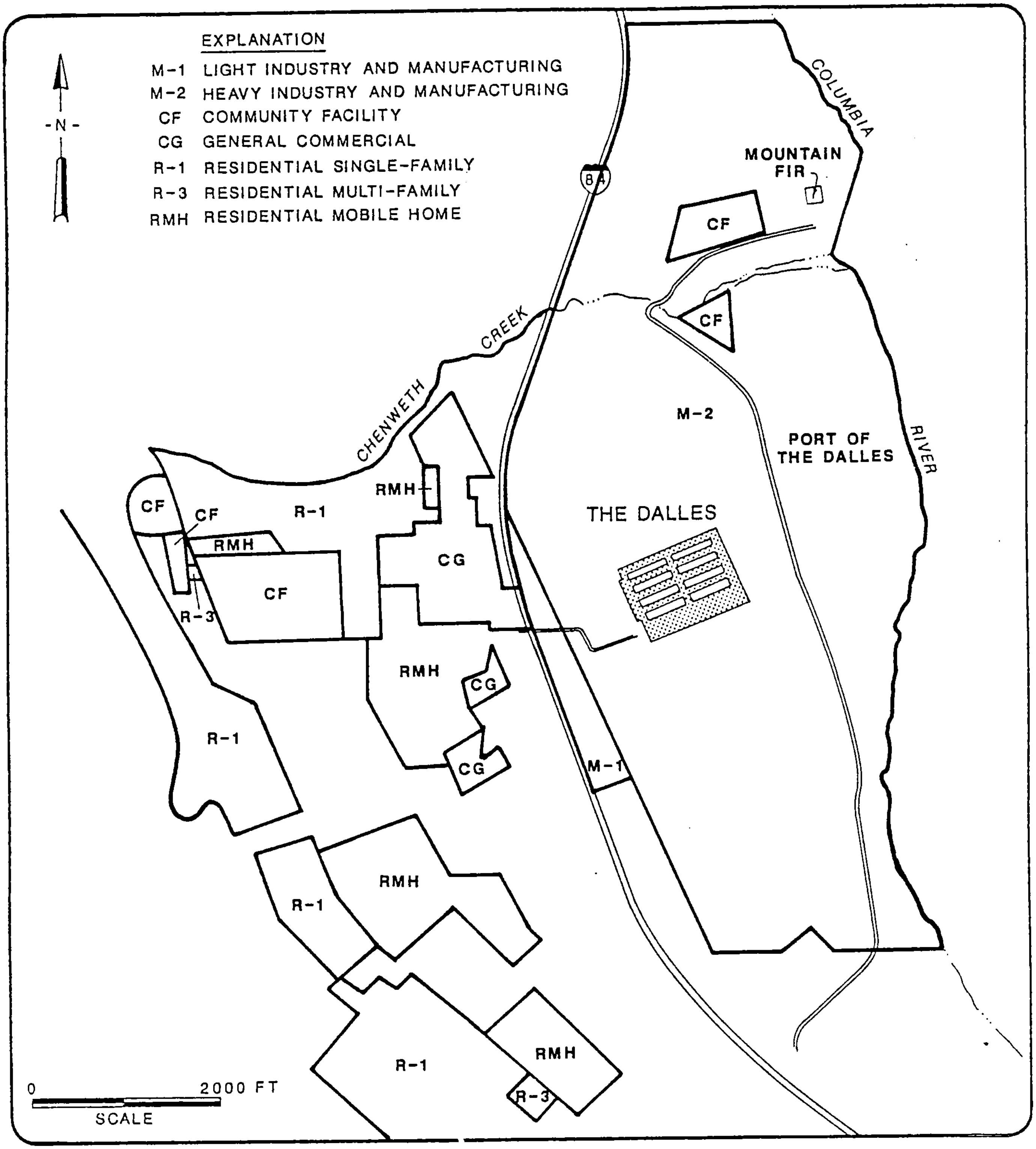


Figure 2.1 Zoning Map.

Martin Marietta Corporation

MMRF, serves as the eastern boundary, and the Union Pacific Railroad line and West Second Street (less than one-third of a mile from the facility) are the western boundaries. Northwest Aluminum is currently the largest industry in this zoning area, employing 250 to 300 persons.

A small facility (used by a trucking company for pick up and drop off of freight), the MMRF recreation area (which includes tennis courts, a golf course, and a baseball diamond), and the rodeo grounds are located near the southern boundary of this zoning area. The northern part of the zoning area contains the Mountain Fir facility (employing ten to twelve people) and two small areas (8,000 ft^2 and 20 acres in size) zoned as community facilities. Located within these community facilities are the Wasco County Animal Shelter, Rockline (which consists primarily of a machine shop and employs about four people), and an electric power substation. A gravel pit owned by Munson Paving, which employs approximately ten people, is also located in the northern part of this zoning area.

Currently, there is little development along the Columbia River waterfront in the vicinity of the MMRF. A small barge company, with two to three employees, is located on the waterfront approximately 0.5 mile to the southeast of the MMRF. There are plans to use an area between the site and the Columbia River for industrial development. That area has been leveled, graded, and landscaped in preparation for this future development. Currently, five people are estimated to be employed by the Port of The Dalles in this area. The future workers at the Port of The Dalles will be considered as potential receptors. Municipal water lines have been run to the port and water-supply wells are not planned. Waste constituent concentrations in soils at the port are expected to be similar to concentrations reported for the River Road ditch (Section 3.2), or less. These soils have been covered with fill material during construction of the port.

The remainder of the zoning area is lightly vegetated or wooded with no other industrial development; however, MMRF land that is not used for industrial processes is leased for agricultural uses such as cattle grazing. Cattle grazing takes place primarily in the vegetated areas northwest of the facility and in the area near the rodeo grounds.

A strip of land zoned for light industrial and manufacturing development is located between the railroad tracks and Interstate 84 directly west of the MMRF main building. In addition to several small businesses, this area currently includes a few residential homes. These homes have been "grandfathered", and upon new ownership or destruction of the homes, the area will be used strictly for light industrial and manufacturing development. Based on recent aerial photographs, there appear to be less than 20 homes and businesses in the area west of the site.

Interstate 84 separates the light and heavy industrial/-manufacturing area discussed above from residential areas. Directly west of I-84 and approximately one-third of a mile from the MMRF site are several areas zoned for residential development, including areas upon which single family homes, multi-family homes, and mobile homes are currently located. These residential areas are generally located between Chenoweth Road and Second Street, north of Snipes Avenue. General commercial sites, such as a drive-in theater, are located in and around these residential areas, approximately two-thirds of a mile west of the MMRF. More residential areas zoned for single-family, multi-family, and mobile home dwellings are located southwest of the site, in the rectangular area bounded by Snipes Avenue, Cherry Heights Road, Chenoweth Road, and Second Street.

2.2 CLIMATE

The MMRF is located within the semi-arid temperate climate of eastern Oregon and is characterized by warm, dry summers and rather cold, relatively wet winters. At The Dalles, the mean annual temperature is about 54°F. July is generally the warmest month with a mean maximum temperature of 86°F. The mean minimum temperature is 34°F in January, which is generally the coldest month. The frost-free season for The Dalles area varies from 100 to 217 days depending on elevation and location (Piper, 1932; and Oregon Water Resources Board, 1965).

The area receives from 10 to 15 inches of precipitation annually with a mean annual precipitation at The Dalles of 13.7 inches. The highest annual precipitation reported at The Dalles was 21.8 inches in 1950; the lowest was 5.1 inches reported in 1935.

Figure 2.2 shows average monthly precipitation and estimated potential evapotranspiration for The Dalles station (Johnsgard, 1963). Months in which precipitation exceeds potential evapotranspiration are moisture-surplus months and months in which evaporation exceeds precipitation are moisture-deficient months. Totaling the monthly values provides an average annual moisture balance. Records from The Dalles indicate a cumulative moisture deficit of about 15 inches per year.

Average annual evaporation from shallow lakes in the area is approximately 40 inches (Linsley, and others, 1982). The annual evaporation rate is much higher than total annual precipitation at The Dalles, a relationship typical of semi-arid and arid regions.

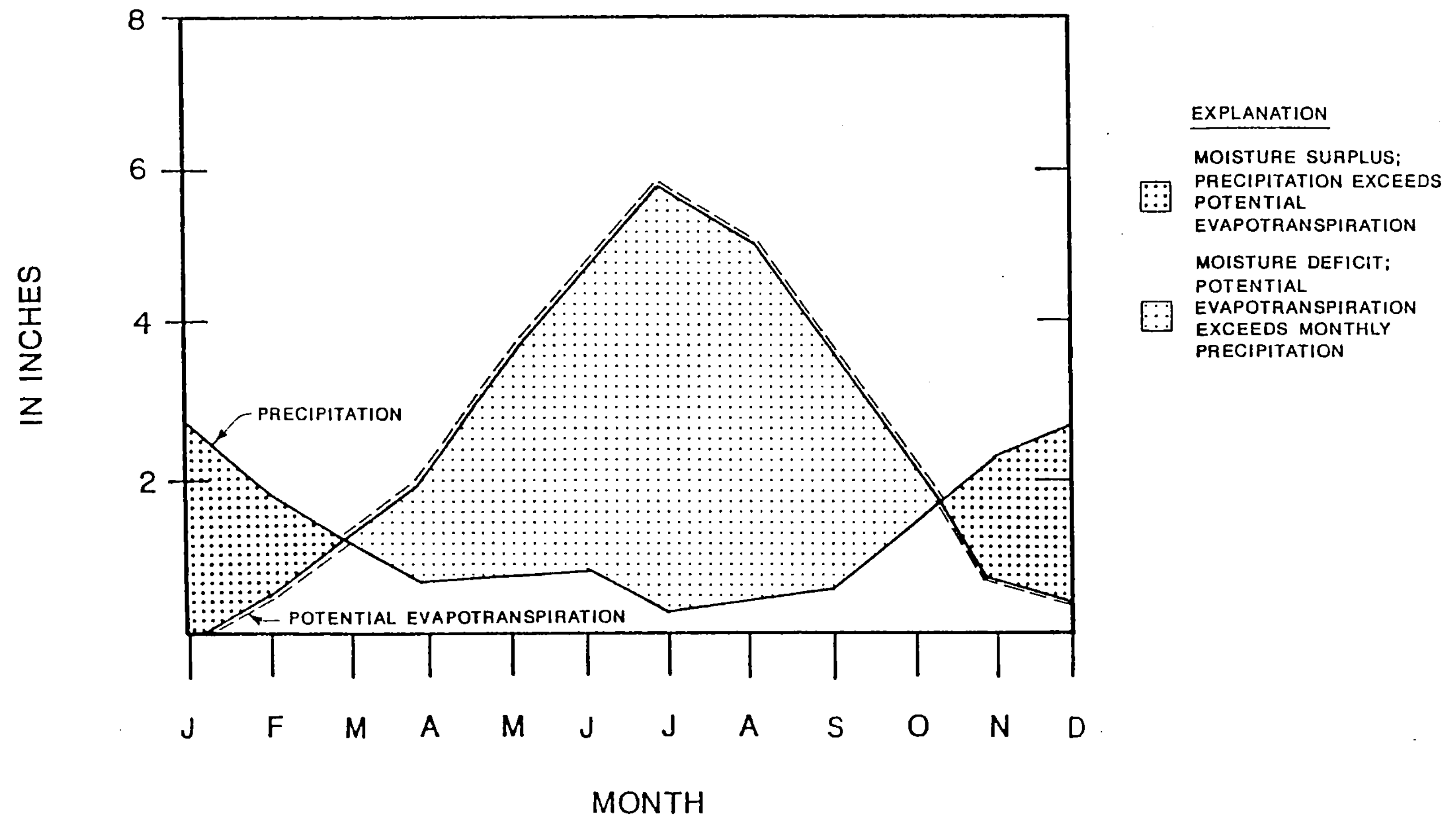


Figure 2.2 Average Monthly Precipitation and Estimated Evapotranspiration at The Dalles (1931-1955).

CLIENT NAME:

Martin Marietta Corporation

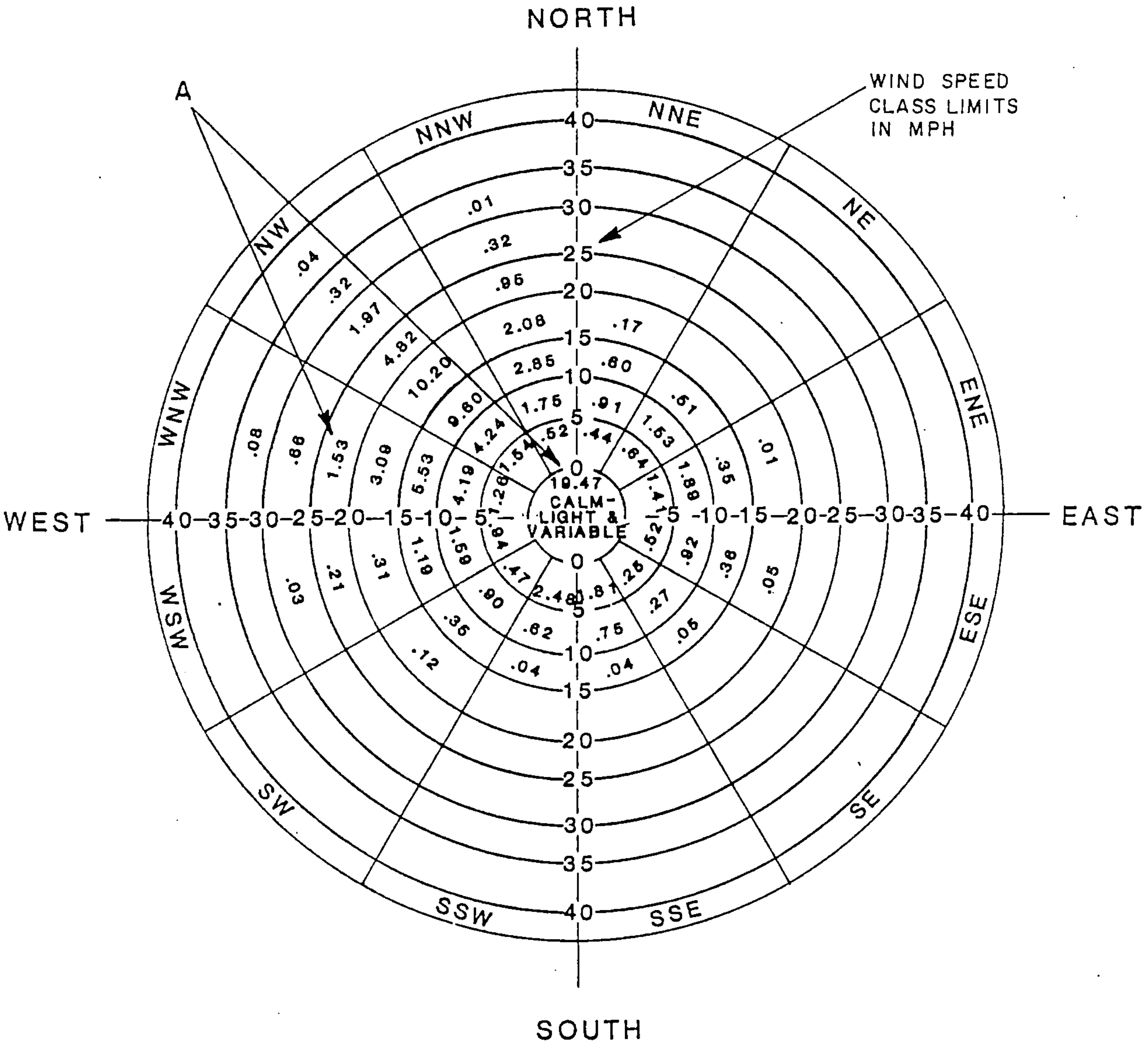
Wind is a predominant climatic factor at The Dalles. The persistent winds are related to pressure differentials on either side of the Cascade Range, with the Columbia River Gorge providing an avenue for air transport between the pressure differentials. Typically, meteorologic highs are present on the west side of the Cascades and lows are present on the east (The Dalles) side of the Cascades.

A wind rose was constructed from data collected at The Dalles airport over a 13-year period (Appendix B, Figure 1). These data reveal long-term trends for the general site vicinity. In order to characterize site-specific wind conditions, wind velocity was measured at the on-site meteorological station during the months of June and July 1987. Figure 2.3 is a wind rose developed from these measurements. Maximum wind speeds of up to 60 mph (miles per hour) were recorded and gusts of up to 30 mph are common. Highest wind speeds are associated with northwest winds. Typical wind speeds range from 5 to 20 mph and the predominant wind direction is from the northwest.

Wind speeds vary throughout the day according to a definitive pattern. Maximum wind speeds (generally between 15 and 35 mph) are observed between 10:00 am and 7:00 pm. Between 7:00 pm and 9:00 am, wind speeds generally decrease and are predominantly light and variable. Wind speeds generally remain at less than 10 mph from 9:00 am to 10:00 am.

2.3 NATURAL RESOURCES

Ground water is an important source of water supply in The Dalles area for domestic, industrial, and agricultural uses. Two primary aquifers are in use, namely The Dalles Ground Water Reservoir (DGWR) located in the Columbia River Basalt Group (CRBG) and aquifers occurring in the sediments



A - Percentage of time, between 5 June 1987 and 31 July 1987, that wind prevailed from given direction within specific wind speed class.

Figure 2.3 Wind Rose for the MMRF Site.

CLIENT NAME:

Martin Marietta Corporation

associated with the overlying Chenoweth formation. Surface waters are used for water-supply sources, hydroelectric power generation, navigable waters, fisheries habitat, and recreation.

The Columbia River and its tributaries represent the major surface-water resources in the area, with an impoundment on Mill Creek being used as the principal source of water supply for the City of The Dalles. The flow characteristics of the Columbia River are discussed in Section 5.0.

The Columbia River and its tributaries provide habitat for major commercial and sport fisheries, with salmon, trout, steel head, walleye, and bass being among the many game fish common to the river. In addition to commercial and sport fishing in the area of the plant, tribal fishing rights are exercised by the native Americans in the area. The fish that are harvested are used mainly for sustenance. Many of the tributaries serve as hatcheries for the salmonoids.

A gravel pit is operated within the quaternary gravels of the alluvial aquifer northeast of the MMRF. This operation is relatively small, and probably could not be expanded significantly owing to the limited extent of the alluvium.

567/2

Section Three

3.0 HAZARDOUS SUBSTANCES INVESTIGATION

3.1 DETAILED SOURCE DESCRIPTION

At the MMRF, there are numerous areas that were used during production to support overall plant activities and other areas designated specifically to manage or store wastes generated as part of the alumina reduction process. The potential source areas investigated as part of the RI include:

- Landfill and Adjacent Areas
  - Landfill
  - Landfill Runoff Areas (four)
- Former Cathode Waste Management Area
  - Bath Recovery Pad Area
  - Old Cathode Waste Pile Area
  - Salvage Area
  - Potliner Handling Area
  - Cathode Wash Area
  - Metal Pad Storage Area
- New Cathode Waste Pad
- Duck Pond
- Lined Pond
- Recycle Pond
- Scrubber Sludge Ponds (four)
- Wastewater and Surface-Water Transport Areas
  - Surface Drainage Ditch
  - Leachate Collection Ditch
  - Landfill Ditch
  - North Ditch
  - River Road Ditch
  - River Road Curb
  - Discharge Channel
  - Drainage Ditch
  - Old NPDES Discharge Channel
  - Abandoned Scrubber Sludge Channel.

A detailed history of the major source areas under investigation is presented in Appendix A. The following discussion focuses on each source area and its relationship to MMRF operations; construction and disposal techniques; containment systems; and basic composition. Information on the constituents found in each area is presented in Section 3.2, Source Characterization.

3.1.1 Landfill

The landfill occupies approximately 15 acres and is located just north of the reduction buildings (Figure 3.1). The landfill is bounded by the leachate collection ditch to the north and east, surface drainage ditch to the west, and the landfill ditch, bath recovery pad area, old cathode waste pile, and salvage area to the south.

Having been developed more than 30 years ago, the landfill was constructed without any containment system as would be required by current regulations. The debris was placed directly on the ground surface and filled to the current elevation.

Five test pits were excavated during the RI at the landfill, but none of the pits fully penetrated the fill material and were stopped at a depth of 10 ft for safety reasons. Century West Engineering Corp. (1983) conducted a shallow boring investigation for Martin in the landfill and determined an approximate range of material thickness of from 5 to 21 ft at the drilling locations. Utilizing the boring information and the topographic map developed by Horizons, Inc., (April 1986), the average-end area method was used to calculate a volume of approximately 200,000 cubic yards of mixed solid waste in the landfill.

The landfill contains several different types of solid waste. A large volume of the landfill consists of basalt fragments excavated from building construction which vary in size from fines to very large boulders. Wastes generated from spent cathodes consist of unsalvaceable metallic materials (bus bars, studs, collector bars), carbon block, and refractory bricks. Other materials disposed of in the landfill consist of off-specification carbon block, pitch,

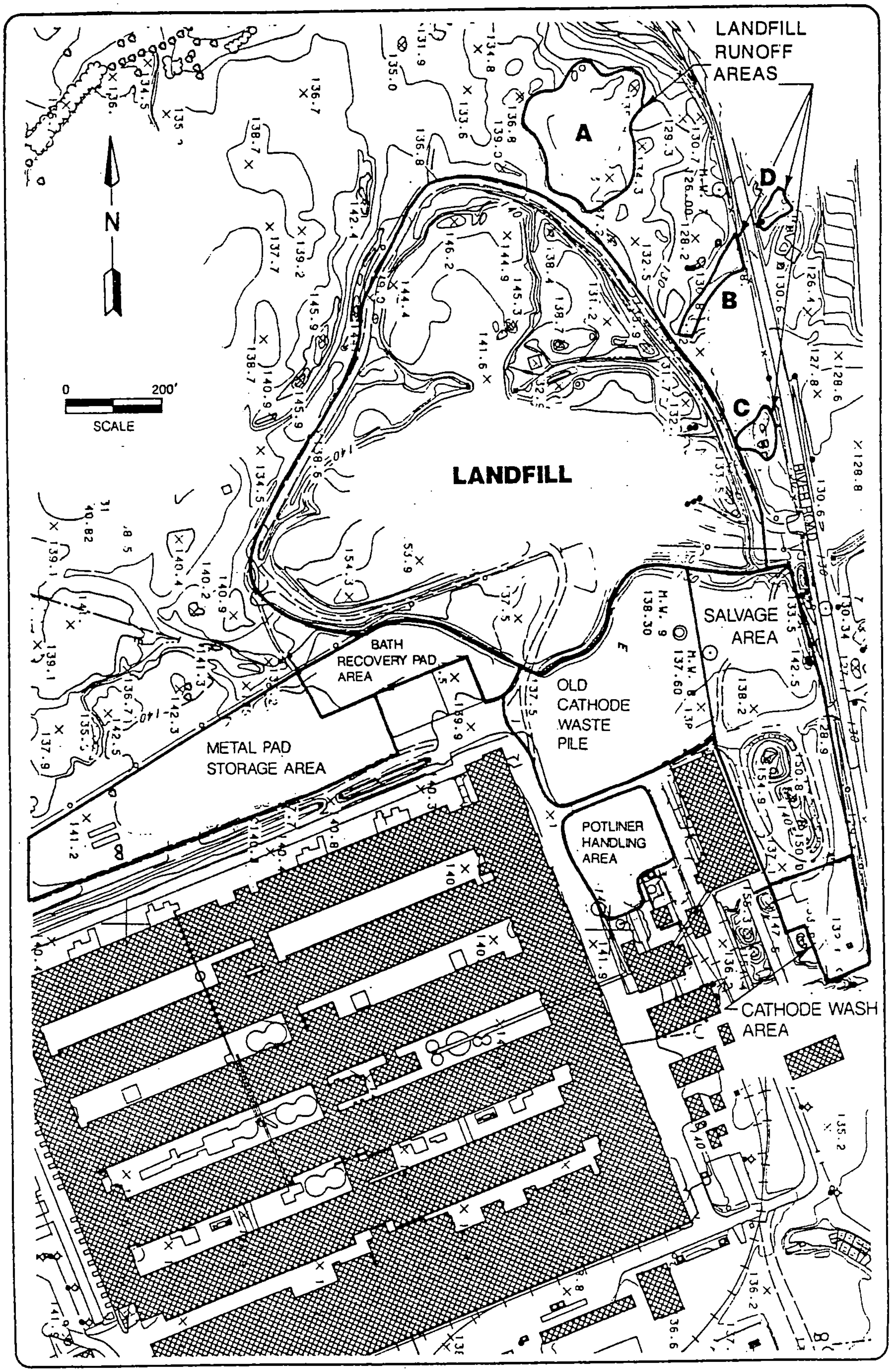


Figure 3.1 Locations of the Landfill and Former Cathode Waste Management Area.

CLIENT NAME:

Martin Marietta Corporation

coke, pallets, cans, rags, and some empty drums. Putrescible waste and garbage were hauled off-site for disposal. Total quantities of each type of waste disposed of in the landfill have not been estimated. However, based on visual observation, it appears that basalt from building excavations makes up the majority of the material in the landfill, and that the wastes were deposited randomly throughout.

Because the alumina reduction process occurs under intense heat, asbestos and other materials containing asbestos were used throughout the plant for their insulating and non-combustible properties. Initially, asbestos was randomly placed in the landfill. When it became evident that asbestos was a health hazard, asbestos and asbestos-containing materials were disposed of in three specific areas within the landfill.

In order to contain leachate generated from the landfill, Martin installed a leachate collection ditch and sump in 1980. In addition, a surface drainage ditch was installed to intercept runoff onto the landfill from the area immediately to the west. Historical information regarding the landfill is included in Appendix A, Section II.

3.1.2 Landfill Runoff Areas

Four areas (A, B, C, and D) around the landfill which potentially received landfill runoff were investigated; their locations are shown on Figure 3.1. Areas A through D occupy about 0.22, 0.10, 0.14, and 0.09 acres, respectively, or a total of 0.6 acre. Average soil thickness for these areas is approximately 11, 11, 12, and 12 inches, respectively, resulting in an estimated volume of 510, 150, 230, and 140 cubic yards for each respective area. However, the actual volume of soil is expected to be much less due to the presence of numerous basalt pinnacles and boulders present in these areas.

These areas are low-lying places where seepage exited from the landfill as a result of runoff of rainfall and snow melt or percolation of water through the landfill. As such, they are not a direct result of, or part of, plant activities. The materials in these areas are fine-grained soils consisting of a mixture of sands, silts, and clays resulting from the natural weathering of basalt. The fine-grained soil is underlain by hard basalt. Historical information regarding the landfill runoff areas is included in Appendix A, Section II.

3.1.3 Metal Pad Storage Area

The metal pad storage area (MPSA), located just north of the reduction buildings (Figure 3.1), is bounded by a fence on the north, the bath recovery pad area to the east, the north drainage ditch to the south, and the end of the reduction buildings on the west. The approximate surface area of the MPSA is 3.1 acres. A very thin soil mantle, approximately 4-inches thick, covers the area and represents 1,690 cubic yards of soil. This area was investigated because of the possibility that minor amounts of material adhered to the metal pads and dislodged or came off due to exposure and weathering while awaiting recycling.

The various components making up the metal pad consisted of aluminum, unrefined alumina, cryolite (bath), and impurities from the ore, cathode, and anode. The cryolite (bath) was recovered to the extent possible and stored on the bath recovery pad until it was recycled.

Storage of the metal pads in the MPSA was random and subject to available space and number of pads being generated. Most of the metal pads were stored on the ground just north of the north ditch but periodically would be scattered throughout the area. Due to the proximity of the pads to the north ditch and the relative flatness of the area, most of the runoff entered the north ditch. Historical information regarding the metal pad storage area is included in Appendix A, Section II.

3.1.4 Bath Recovery Pad Area

The bath recovery pad area (BRPA) is located just north of the reduction buildings (Figure 3.1). The BRPA covers approximately 1.0 acre and is bounded to the north and east by the landfill and landfill ditch, to the south by the north ditch, and to the west by the metal pad storage area. The area along the landfill ditch was filled with material similar to that disposed of in the landfill, to a distance of from 10 to 20 ft from the existing edge of the landfill ditch. In 1983, Century West Engineering Corp. drilled a shallow boring in the area adjacent to the landfill ditch and determined a depth to hard basalt of approximately 8 ft. The shallow soils range in thickness from a couple of inches to approximately 1 ft. Taking into account the boring information and shallow soil depths, approximately 1,660 cubic yards of fill material and soils are estimated to exist in this area.

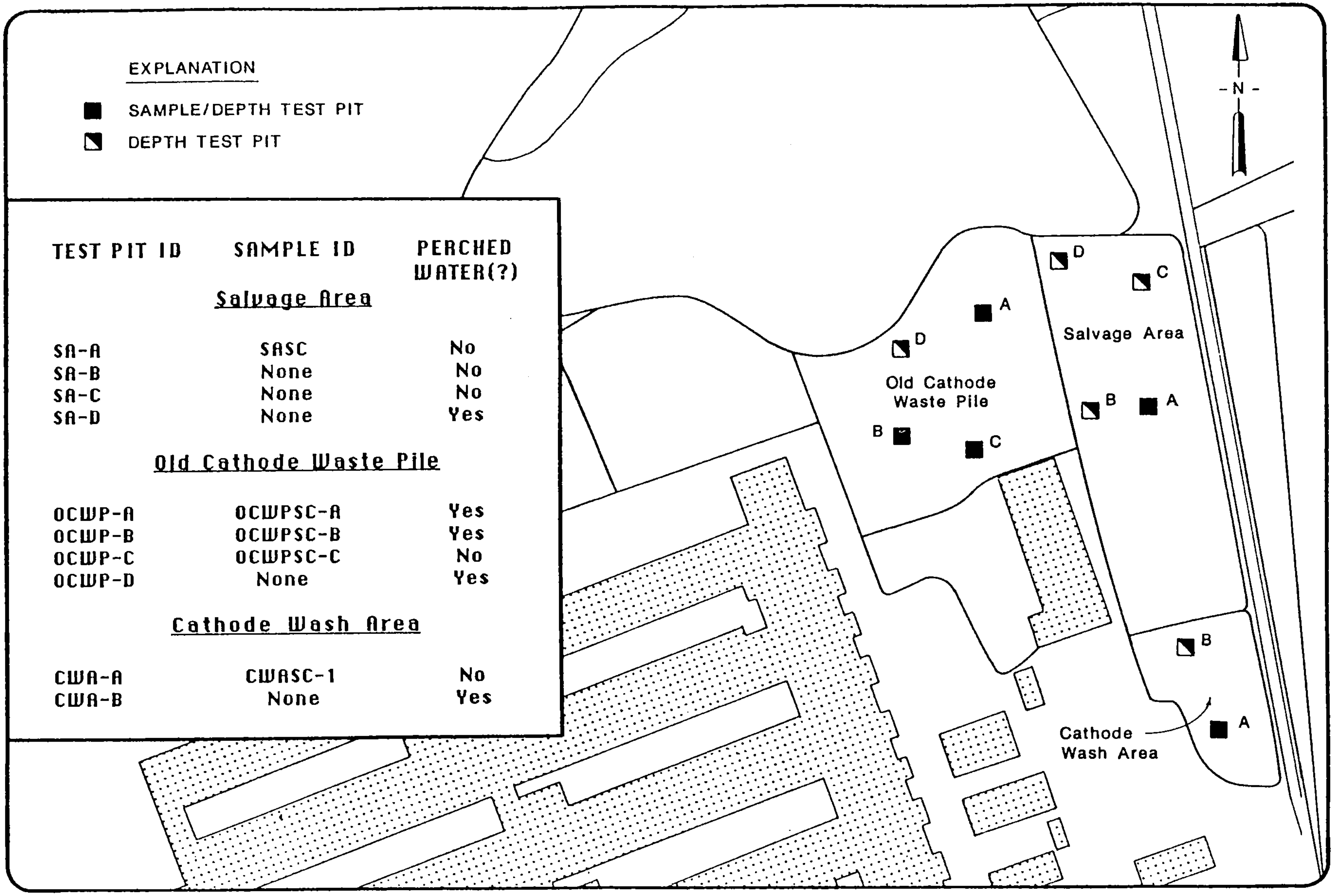
The BRPA was created by filling low areas and the drainage swale now referred to as the landfill ditch. Solid wastes generated from the plant were placed directly on the ground surface and graded accordingly. In places, solid waste material is exposed at the surface; a vegetative cover has not been successfully established. Surface runoff from the BRPA is collected by the landfill ditch. Historical information regarding the bath recovery pad area is included in Appendix A, Section II.

3.1.5 Old Cathode Waste Pile

The old cathode waste pile (OCWP) is an open area located just off the northeast corner of the reduction building and occupies approximately 2.0 acres (Figure 3.1). The OCWP is bounded by the landfill to the north, salvage area to the east, the potliner handling area to the south, and the reduction facility and bath recovery pad area to the west. Four test pits (Figure 3.2) excavated in July 1987 as part of the investigation of the OCWP area showed that the depth to hard basalt ranged from just under 5 ft to approximately 9 ft. The test pits revealed an approximately 6-inch-thick layer containing cathodic materials. The estimated volume of residual contamination is 2,420 cubic yards to a depth of 9 inches and approximately 24,200 cubic yards to hard basalt.

The test pit excavations showed the OCWP area to be filled with a variety of well-graded material consisting of soils and boulders up to several feet in diameter. The fill material appeared to be typical of that resulting from blasting operations commonly used to excavate foundations, sumps, shafts, etc., at the plant. The fine-grained materials encountered near the bottom of the excavations appeared to be native soils. These soils were in turn underlain by hard basalt.

Waste placed in the OCWP was stored directly on top of the fill material. The nature of the solid wastes stored in the OCWP allowed vertical moundings and grading of the material for containment. In 1984, a new cathode waste pad was constructed to store accumulated waste cathode components in the OCWP area. A thin soil cover consisting of silt,



TEST PIT ID	SAMPLE ID	PERCHED WATER(?)
	Salvage Area	
SA-A	SASC	No
SA-B	None	No
SA-C	None	No
SA-D	None	Yes
	Old Cathode Waste Pile	
OCWP-A	OCWPSC-A	Yes
OCWP-B	OCWPSC-B	Yes
OCWP-C	OCWPSC-C	No
OCWP-D	None	Yes
	Cathode Wash Area	
CWA-A	CWASC-1	No
CWA-B	None	Yes

Figure 3.2 Test Pit Locations.

CLIENT NAME:

Martin Marietta Corporation

sand, and small basalt fragments was placed over the area in an effort to cover the area and establish vegetation. The current composition of the OCWP area is a shallow soil mantle, a thin layer of residual cathodic material, and leached contamination below.

The OCWP area is relatively flat and any runoff from precipitation or snow melt would have entered the landfill ditch. Rainfall or snow melt percolating through the pile would produce leachate that could migrate through the fill down to hard basalt. The perched water observed in the test pits represents leachate which accumulated in depressions or irregularities in the top of the underlying basalt. Historical information regarding the old cathode waste pile is included in Appendix A, Section II.

3.1.6 Salvage Area

The salvage area (Figure 3.1) is contiguous with the old cathode waste pile on the west and is bounded by the landfill and landfill ditch to the north and River Road to the east. Various types of pitch are stockpiled to the south of the salvage area. The salvage area occupies approximately 2.6 acres, about 1 acre of which is covered with anode briquettes used in plant operations.

Four test pits (Figure 3.2) excavated in July 1987 as part of the investigation of the salvage area indicated that the depth from ground surface to hard basalt ranged from approximately 3 ft to over 8 ft. Monitor wells installed in the area (MW-11, MW-15) provided similar data except on the eastern edge near River Road, where fill material was found to a depth of about 12 ft below land surface. Visual observation of the test pits showed contamination from the land surface to a depth of 6 to 12 inches. The estimated volume of residual contamination is approximately 5,300 cubic yards to a depth of 15 inches and approximately 28,700 cubic yards to hard basalt.

Data from the test pits showed the salvage area to consist of fill material similar to that of the old cathode waste pile. The fill is a well-graded material varying from fine-grained soils to boulders up to several feet in diameter. A majority of the fill appeared to be demolition debris from plant excavation activities underlain by native soils of variable thickness which in turn are underlain by hard basalt.

The current topography of the salvage area is rather flat, sloping slightly to the north toward the landfill ditch and a steep sloping face towards River Road. Runoff from the area enters the north ditch and the ditch paralleling River Road. The ditch adjacent to River Road is graded to flow to the north, discharging to the landfill ditch in the vicinity of the sump pump. Historical information regarding the salvage area is included in Appendix A, Section II.

3.1.7 Potliner Handling Area

The potliner handling area (PHA) is an open area located south of the old cathode waste pile and just east of the reduction building (Figure 3.1). The PHA is approximately 0.9 acre in size. The PHA was used extensively to grind waste generated from the disassembly of cathodes when this material was sent off site for recycling. The crushed fragments were loaded directly into open top railroad hopper cars. Over the years, dust from these operations settled and accumulated throughout the PHA. Drainage in the area was provided by a storm drain located in the southeast corner next to the soft pitch unloading building.

The present composition of the PHA consists of a layer of residual cathodic material underlain by fill and hard basalt. Surface sampling identified a layer of mixed cathode waste and soil at least 6 inches thick. Since crushing of cathode waste and loading of the crushed material onto railroad cards occurred in this area, it is expected that dust from these activities has settled and accumulated in the PHA. A thickness of 24 inches of residual cathode waste material has been assumed for volumetric estimates. Test pits were not opened in the PHA; however, it is anticipated that the area is filled with materials similar to that of the old cathode waste pile. Therefore, a 5-foot depth of fill material has been assumed. Based on these assumed depths of residual and fill materials, an estimated volume of 2,830 cubic yards and 7,260 cubic yards are present, respectively. Historical information regarding the potliner handling area is included in Appendix A, Section II.

3.1.8 Cathode Wash Area

The cathode wash area (CWA) was constructed to cool and soften spent cathodes prior to disassembly. The CWA, located east of the pitch storage area and west of River Road (Figure 3.1), occupies approximately 0.32 acre. The types of wastes generated in the CWA consisted of contact cooling water and fines washed from the surface of the spent cathode. The CWA was also used to clean mixers which contained mortar from cathode re-lining activities. This resulted in a small area with a white residue on the surface just to the east of the CWA.

As detailed in Appendix A, the CWA is paved with concrete and consists of a curbed spray area, water collection ramp, and a sump/pond upstream of the sewer invert to remove sediments prior to routing cooling waters to the discharge channel. The pavement and curbing provide containment for the CWA contact cooling waters and direct precipitation while diverting runoff onto the CWA from adjacent areas. At the time of the investigation, the CWA was dry and there did not appear to be any measurable amounts sediments in the sump.

Two test pits were excavated in July 1987 in the fill area between the CWA and River Road (Figure 3.2). Perched water appeared at the contact between the fill material and hard basalt in one of the two pits (CWA-B). Fill depths ranged in thickness from approximately 6 to 11.5 ft. The fill consists of a range of material from fines to large basalt boulders several feet in size. These materials appear to be typical of the materials expected from excavation of building basements, shafts, or sumps at the site. Based on these results, approximately 4,500 cubic yards of fill material are present above the bedrock. Historical information regarding the cathode wash area is included in Appendix A, Section II.

3.1.9 New Cathode Waste Pad

The new cathode waste pad (NCWP) was constructed specifically to contain the material moved from the old cathode waste pile area. The NCWP is located south of the reduction buildings, as shown in Figure 3.3. Based on its physical dimensions and the topographic survey performed by Horizons, Inc., in April 1986, the pad is estimated to contain approximately 34,000 cubic yards of material.

Part A and B hazardous waste permit applications for the NCWP have been filed with the Oregon DEQ. The NCWP is a state permitted waste pile under interim status regulated under RCRA. Therefore, the NCWP was not evaluated in detail as part of the overall facility investigation. Historical information regarding the new cathode waste pad is included in Appendix A, Section II.

3.1.10 Duck Pond

The duck pond, located south of the plant and southwest of the new cathode waste pad (Figure 3.3), is a natural feature which occupies approximately 1.5 acres. An earthen dike provides containment of impounded waters on the south and there is no evidence that a liner exists other than native materials. A control structure in the southeast part of the duck pond regulated discharges when required. When discharges from the pond occurred, the flows followed a series of underground pipes and natural drainage paths.

During sampling of the pond, it was found that approximately 1 ft of sediment had accumulated on the pond bottom. The volume of sediments in the pond has been estimated to be approximately 2,430 cubic yards.

When Northwest Aluminum began operation, a new drain line was installed, and flows are now diverted from the duck pond to the discharge channel. The sediment volume has not changed although since flows were diverted, the volume of water has decreased to a few hundred gallons due mainly to evaporation.

Waters diverted to the duck pond consisted of non-contact cooling water from the cast house, a sump in the alumina unloading building, and runoff from rainfall events or snow melt collected by the storm drains. Historical information regarding the duck pond is included in Appendix A, Section II.

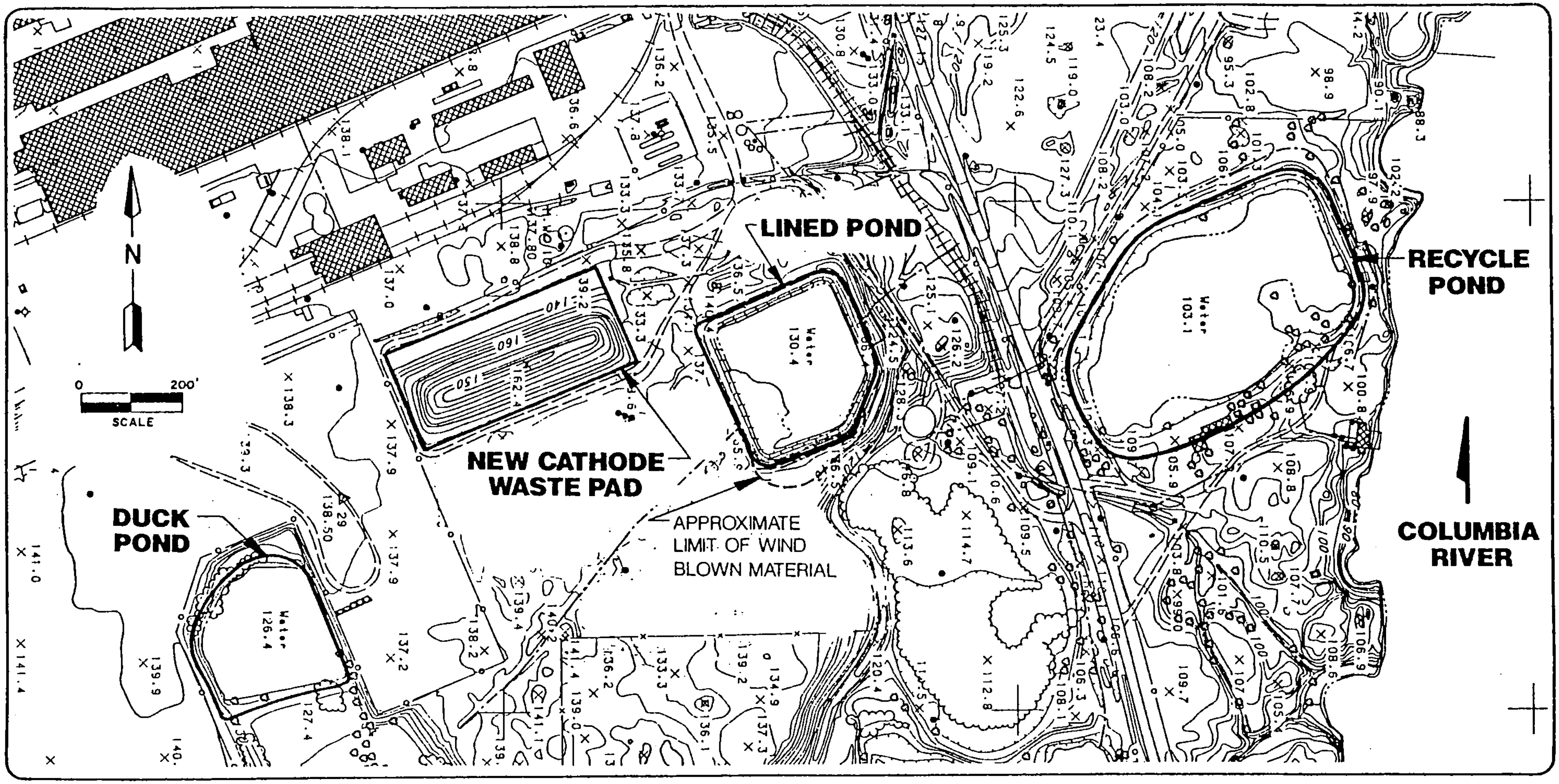


Figure 3.3 Location of Operating Units and the Duck Pond.

CLIENT NAME:

Martin Marietta Corporation

3.1.11 Lined Pond

The lined pond, located southeast of the new cathode waste pad (Figure 3.3), is approximately 1.6 acres in size and has a capacity of 4 million gallons with 2 ft of freeboard. This pond can contain both solids and liquids, and at the time of the remedial investigation sampling, contained approximately 7,570 cubic yards of solids. Only a small amount of water was present during the investigation because the facility was shut down and the pond was not in use.

The pond was constructed using a basic cut and fill approach followed by the installation of a 45-millimeter scrim reinforced Hypalon liner. Physical inspection of the liner indicates that minor patches had been applied to the exposed portions of the liner. The only component stored in the lined pond consists of particulates collected from primary air emission controls. Water was added to help minimize fugitive dust emissions.

In 1982, the lined pond was dredged and the solids were placed in scrubber sludge pond 3. The present volume of accumulated solids was generated during the plant operation from 1982 through 1984, at which time the reduction facility was closed. At the present time, Northwest Aluminum is using the lined pond for storage of primary scrubber particulates and has placed an unknown quantity of material into the pond. Northwest Aluminum is inundating the lined pond with water to control dust emissions. Currently, water levels are approximately 1 ft from the top.

There is a small amount of wind blown-material south of the lined pond which accumulated during the period when the plant was shut down. The wind-blown sediments cover about 0.16 acre to a depth of approximately 6 inches, amounting to about 130 cubic yards of material outside the lined pond area. Historical information regarding the lined pond is included in Appendix A, Section II.

3.1.12 Recycle Pond

The recycle pond, located between River Road and the Columbia River (Figure 3.3), occupies approximately 3.0 acres. The pond, with an average depth of approximately 8 ft, has a capacity of 8 million gallons and a surge capacity of approximately 1 million gallons. Components of the recycle pond consist of water and sludge underlain by hard basalt. The recycle pond is not equipped with an artificial liner.

In 1982 the recycle pond was dredged and the sediments were pumped to scrubber sludge ponds 2 and 3. The current volume of sludge has accumulated since the dredging occurred. Sounding of the pond bottom indicated a sediment thickness of from 0.1 to 4.5 ft with a calculated volume of about 8,920 cubic yards. An undetermined quantity of sludge has been generated by Northwest Aluminum since it resumed plant operations.

The recycle pond initially existed as a natural low lying area prior to construction of the plant. When the recycle pond was put into operation, dikes were constructed from on-site fine grained soils and blasting of the basalt was performed to construct the pond to current configuration and depth. Containment, therefore, is being provided by these materials.

The recycle pond receives water from the secondary roof scrubbers used to control fugitive gaseous and particulate emissions from the reduction process. The primary gaseous constituent removed is fluoride. Roof scrubber water would be continuously recycled and periodically treated when necessary. Treatment consisted of the addition of selected chemicals to precipitate fluoride. Other waters discharged to the recycle pond include rectifier cooling water, sewage plant effluent, landfill leachate, clarifier overflow, and treated leachate from the new cathode waste storage pad. The recycle pond provided sufficient retention time to act as a sedimentation pond prior to recycling or discharging to the Columbia River. Historical information regarding the recycle pond is included in Appendix A, Section II.

3.1.13 Scrubber Sludge Ponds

There are four unlined ponds which collectively are referred to as the scrubber sludge ponds (SSPs). The SSPs are located south of the lined pond and west of River Road (Figure 3.4) and all are currently inactive. SSP1 covers approximately 5.0 acres and has an average depth of approximately 9 ft, resulting in an estimated quantity of 71,700 cubic yards of sludge. SSP2 is approximately 3.4 acres in size with an average depth of 1.3 ft and contains an estimated 6,840 cubic yards of sludge. There is approximately 0.5 ft of subsoil below SSP2 which results in an additional 2,740 cubic yards, bringing the total volume of material contained in SSP2 to approximately 9,580 cubic yards. SSP3 is approximately 4.5 acres in size with an average sludge depth of approximately 6 ft and contains an estimated 43,600 cubic yards. There are approximately 2 ft of subsoil below SSP3 which results in an additional 14,500 cubic yards, bringing the total volume of material contained in SSP3 to approximately 58,100 cubic yards. The size of SSP4 is approximately 1.9 acres with a 7-ft average depth of sludge material and soil cover, resulting in approximately 22,300 cubic yards of material. SSP4 is also underlain by approximately 2 ft of subsoils which result in an additional 6,200 cubic yards, bringing the total volume of material for SSP4

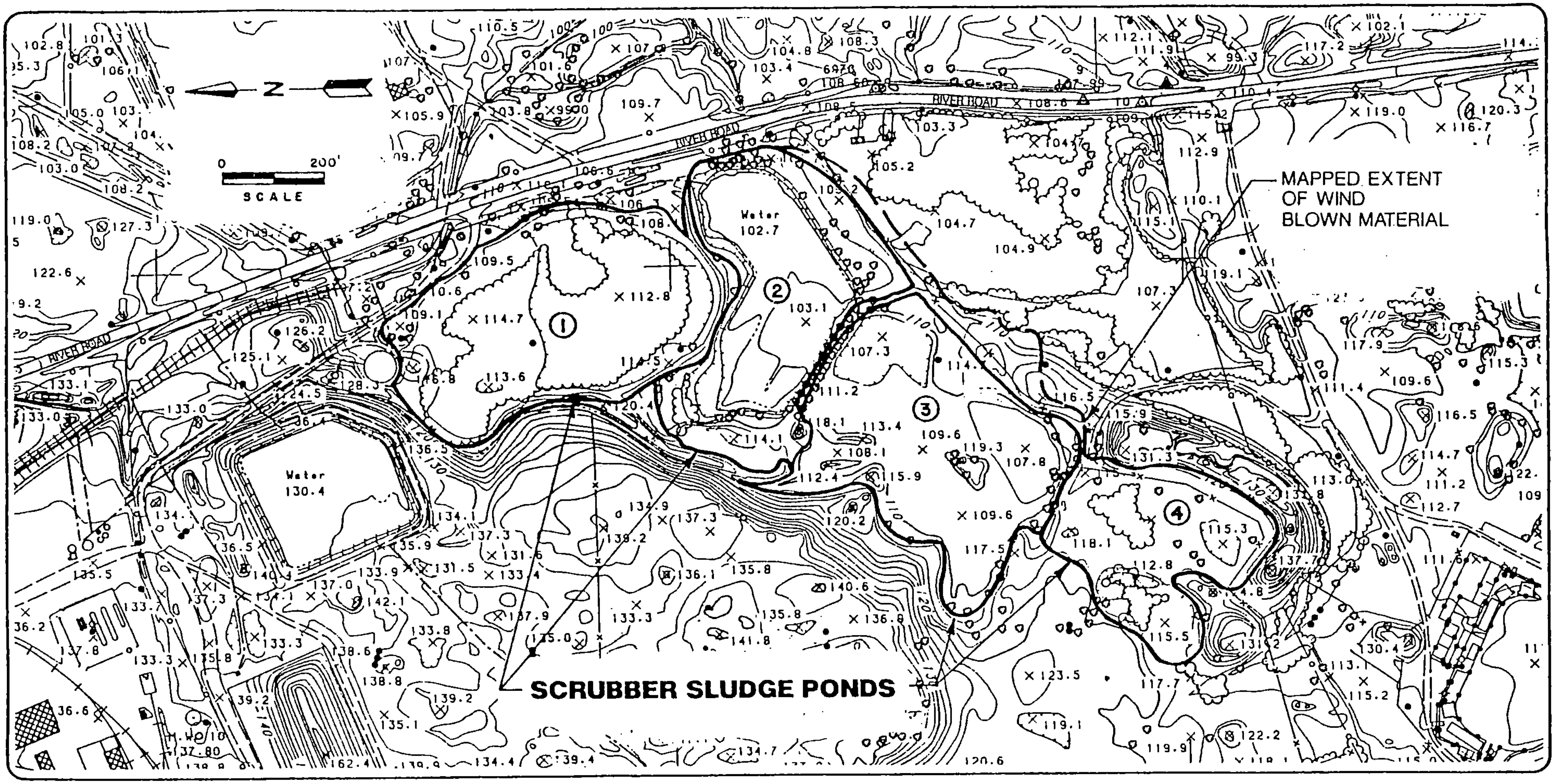


Figure 3.4 Location of Scrubber Sludge Ponds.

CLIENT NAME:

Martin Marietta Corporation

to approximately 28,500 cubic yards. The total estimated volume of sludges and subsoils for the four ponds is approximately 168,000 cubic yards.

The SSP area was selected for its natural features as an area where flows from the plant could be discharged by gravity and which easily allowed impoundment of surface waters. Being a natural drainage feature, the SSP area contained an accumulation of fine-grained sediments intermixed with basalt outcroppings. The west side of River Road was dammed to settle suspended particulates and control flows. As waste accumulated, the levee between SSP2 and SSP3 was constructed to provide additional capacity. Similarly, the levee between SSP3 and SSP4 was constructed to retain sediments from the dredging of SSP2 and SSP3. This type of construction has stair-stepped the elevation of each pond (Figure 3.4). SSP1 and SSP4 have established vegetative covers; SSP2 and SSP3 remain uncovered.

The SSPs were used as sedimentation basins for primary and secondary air emission control sludges from both dry and wet processes, as well as dredgings from the recycle pond and lined pond. The ponds designated SSP2 and SSP3 were actually the first two ponds put into service. In 1977, SSP2 and SSP3 were dredged and the materials placed into SSP4. This was the only specific time SSP4 was used, and in 1982 it was covered with approximately 18 inches of soil. In 1982, the recycle pond and lined pond were dredged and this material was placed throughout SSP2 and SSP3. SSP1 was constructed in 1972 to contain the precipitate resulting from treatment of secondary roof scrubber waters. SSP1 was removed from service in 1981 and was covered with approximately 1 ft of soil.

The sludge in SSP1 consists of sediment from air emission controls and calcium fluoride precipitate resulting from treating recycled water. SSP2 and SSP3 contain sediments from air emission controls and dredgings from the lined pond and recycle pond. The lined pond contains similar air emission control sludges; the recycle pond is a mixture of particulates and calcium fluoride precipitate. SSP4 contains dredgings of air emission control sludges from ponds SSP2 and SSP3. SSP2 and SSP3 occasionally have water present which is seasonally dependent.

An area approximately 1.0 acre in size to the south of SSP2 and SSP3 contains wind-blown sediments derived from the ponds (Figure 3.4). A field investigation performed in July 1987 determined the average depth of sediment in that area was 4 inches. The accumulated volume of wind-blown sediment in this area has been estimated to be approximately 540 cubic yards. Historical information regarding the scrubber sludge ponds is included in Appendix A, Section II.

3.1.14 Ditches

The MMRF used numerous ditches to route process waters and facilitate drainage. The function of each ditch is discussed in the following text; the detailed history of the various ditches investigated is presented in Appendix A and the locations of the ditches are shown in Figure 3.5.

3.1.14.1 Surface Drainage Ditch

The surface drainage ditch functions as an interceptor ditch for surface runoff from the landfill flowing to the northwest. The slope of the ditch is fairly flat and collected flows are routed to the leachate collection ditch. Vegetation is scattered and the channel is filled with fine-grained soils and fragments of basalt. Flows are generally present only during rainfall or snow melt conditions and the ditch is dry otherwise.

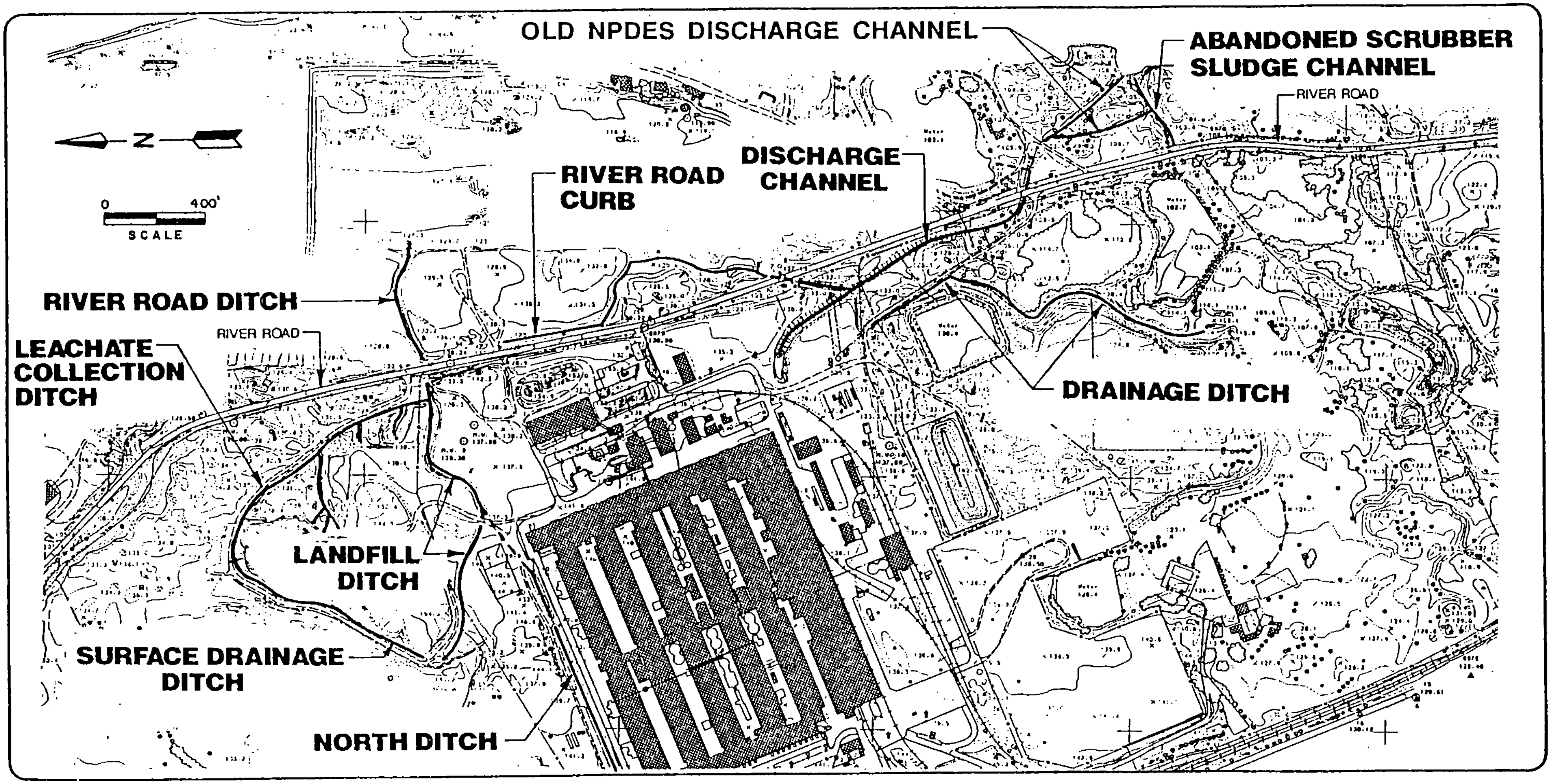


Figure 3.5 Location of Ditches and Other Drainage Features.

CLIENT NAME:

Martin Marietta Corporation

The surface drainage ditch was probed at several locations along the center line and an average sediment thickness of approximately 10 inches was determined. An estimated volume of 1,240 cubic yards of sediment is present in the surface drainage ditch.

3.1.14.2 Leachate Collection Ditch

The leachate collection ditch is gunite lined and collects surface runoff flowing to the northeast off the landfill. Surface flows are routed to the landfill ditch. There are three feeder ditches off the leachate collection ditch; these are also gunite lined. Vegetation adjacent to the leachate collection ditch is scattered and soils consist of a mixture of fines and basalt fragments. The slope of the ditch is very gradual and ponding is evident in the low places.

3.1.14.3 Landfill Ditch

The landfill ditch is located on the south side of the landfill; its center line is that of a former surface drainage feature. To provide additional work area, the shoulders of the original drainage swale were filled from both banks resulting in the current configuration of the ditch. The fill material consisted of basalt rubble from excavation activities and other debris similar to that disposed of in the landfill. The materials in the bottom and along the banks of the landfill ditch appear to be fine-grained soils and basalt. Cathodic material is exposed along both banks of the ditch. The liquid within the ditch resembles landfill leachate.

Before 1980, flow within the landfill ditch was generally from the west to the east toward the Columbia River by way of the River Road ditch. A levee was constructed across the ditch just upstream of River Road and a pump station was constructed to divert collected runoff to the process sewer containing secondary roof scrubber water. The slope of the ditch invert is very gradual and ponding occurs in localized areas. The bottom of the landfill ditch consists mainly of sediments and is sparsely vegetated.

The bottom of the ditch was probed along its center line and an average sediment thickness of 16 inches was determined, representing an estimated volume of approximately 2,050 cubic yards of sediment. The fill material used to narrow the landfill ditch to its current cross-section was included in the volume estimate of the adjacent source areas (old cathode waste pile area, salvage area, landfill, and bath recovery pad area).

3.1.14.4 North Ditch

The north ditch, a man-made ditch providing surface drainage, parallels the north side of the reduction building and the metal pad storage area and drains to the landfill ditch. The north ditch received surface runoff as well as flows from sumps collecting water from under the reduction buildings and non-contact cooling water from the rectifiers. The ditch has a relatively flat slope and the bottom and sides are covered with vegetation. Sediment depths in the bottom of the north ditch average 9 inches, resulting in an estimated volume of approximately 610 cubic yards.

3.1.14.5 River Road Ditch

The River Road ditch was the continuation of the landfill ditch before construction of the levee and pump station disconnected the flows. Since that time, the River Road ditch collects surface runoff from the east side of River Road and routes it toward the Columbia River. The bottom of the ditch is a mixture of fine sediments, vegetative cover, and basalt pinnacles. In July 1987, the center line of the ditch was probed in several places and was found to contain an average sediment thickness of approximately 9 inches. This results in approximately 200 cubic yards of fine-grained sediments that have accumulated in the ditch.

3.1.14.6 River Road Curb

The River Road curb is a surface drainage feature located east of River Road. The area was disturbed in late 1986 by construction activities performed by The Dalles Public Works Department expansion of the city drinking water service area. The ditch parallels River Road and contains crushed basalt used for the road bed, fine-grained soils, vegetative cover, and basalt pinnacles. Flows from this area are routed southward to a culvert passing under River Road with discharge to the discharge channel (Figure 3.5).

3.1.14.7 Discharge Channel

The discharge channel is the primary drainage feature that handles collected storm water and process and sanitary flows. Some of the major sources contributing to the discharge channel are: (1) storm water and leachate collected by the surface drainage ditch, leachate collection ditch, landfill ditch, and north ditch routed to the pump station; (2) process waters including secondary roof scrubber water, non-contact once-through rectifier cooling water, and storm water; (3) effluent from the wastewater treatment facility; and (4) other contact and non-contact process flows from casting operations. These flows are routed to the recycle pond where they are either routed back to the plant secondary roof scrubber system or to the Columbia River under a National Pollutant Discharge Elimination System (NPDES) discharge permit (Figure 3.5). When treatment of the recycled water is required, chemicals (lime and caustic) are slurried to the discharge channel, which provides the mixing necessary to condition the water, with sedimentation occurring primarily in the recycle pond. Sediments which accumulate within the discharge channel are periodically removed in order to maintain adequate flows.

The discharge channel is not a natural surface feature and required excavation for removal of basalt. Therefore, the bottom of the discharge channel would have been for the most part exposed basalt. The sediments currently present in the channel are probably the result of plant activities and natural weathering processes. The center line of the channel was probed and an average sediment thickness of approximately 22 inches was determined in the locations investigated, resulting in approximately 1,100 cubic yards of sediment.

3.1.14.8 Drainage Ditch

The drainage ditch was used to transport by gravity the air emission control slurry from the secondary roof scrubber system to the scrubber sludge ponds prior to construction of the lined pond. The drainage ditch flows in a southerly direction and is just east of the lined pond and north of SSPs 1, 2, and 3 (Figure 3.5).

The ditch is not a natural drainage feature and required construction in a manner similar to that for the discharge channel. There are two weirs constructed in the drainage ditch to provide flexibility in routing process water at these points to the discharge channel, scrubber sludge ponds, or the clarifier (near SSP1). The center line of the drainage ditch was probed and an average sediment thickness of approximately 19 inches was determined. This represents approximately 920 cubic yards of sediments that have accumulated in the drainage ditch.

3.1.14.9 Old NPDES Discharge Channel

The old NPDES discharge channel was used to direct flows to the Columbia River prior to construction of the recycle pond in early 1974. It is located where the discharge channel is directed from the recycle pond to the Columbia River just south of the pond (Figure 3.5). The discharge channel and scrubber sludge channel discharged at two locations, while the NPDES permit allowed for only one discharge point. Therefore, the extension of the drainage channel connecting it with the scrubber sludge channel was constructed to comply with NPDES permit conditions. After the construction of the extension, flows were diverted to the scrubber sludge channel.

3.1.14.10 Abandoned Scrubber Sludge Channel

The abandoned scrubber sludge channel is an existing surface drainage feature which routed overflow waters from the scrubber sludge ponds discharged through SSP2. Flow in the abandoned scrubber sludge channel was due east from SSP2 under River Road to the Columbia River and is south of the old NPDES discharge channel (Figure 3.5). Supernatant overflowed the levee constructed for SSP2 adjacent to River Road, entered the channel, and discharged to the Columbia River through the NPDES discharge. The volume of sediments in the abandoned scrubber sludge channel has not been quantified.

3.1.15 Source Description Summary

As described in this section, a number of potential sources were evaluated during the remedial investigation. The approximate volumes contained in each of the source areas is summarized in Table 3.1. A discussion of the nature and

Table 3.1 Summary of Volume Estimates

Area of Investigation	Estimated Volume (cubic yards)	(gallons)
Landfill	200,000	-
Landfill Runoff Areas		
Area A	510	-
Area B	150	-
Area C	230	-
Area D	138	-
Metal Pad Storage Area	1,690	-
Bath Recovery Pad Area	1,660	-
Old Cathode Waste Pile Area	24,200	-
Salvage Area	28,700	-
Potliner Handling Area	9,910	-
Cathode Wash Area	4,530	-
Duck Pond	2,430	-
Lined Pond	7,700	4,000,000
Lined Pond (Wind Blown)	-	-
Recycle Pond	8,915	8,000,000
Scrubber Sludge Ponds		
SSP1	71,700	-[1]
SSP2	9,850	-
SSP3	58,100	-
SSP4	28,500	-
Wind Blown	538	-
Ditches		
Surface Drainage Ditch	1,240	-
Leachate Collection Ditch(2)	-	-
Landfill Ditch	2,050	-
North Ditch	610	-
River Road Ditch	200	-
River Road Curb	-	-
Discharge Channel	1,100	-
Drainage Ditch	920	-
Old NPDES Discharge Channel	-	-
Abandoned Scrubber Sludge Channel	-	-

---

[1] Seasonally affected

[2] Lined with concrete; unable to proble soils underneath.

\- Not relevant

568/4

distribution of constituents detected in the source areas as well as their chemical characteristics are presented in the following sections. Historical information regarding the ditches and channels is included in Appendix A, Section II.

3.2 SOURCE CHARACTERIZATION

The distribution of waste constituents at the MMRF was evaluated by analyzing waste materials and various environmental media, e.g., soil, surface water, and ground water. Samples were collected from the various sources, as identified in the RI/FS Work Plan and addendum, and were analyzed for a variety of potential waste constituents. The results of all analyses performed during the remedial investigation are contained in Appendix C, along with the quality assurance summary (Appendix D).

Cyanide, fluoride, sodium, sulfate, and PAHs are the primary constituents identified at the potential source areas (Tables 3.2 and 3.3). Cyanide (complex and free) is associated with potliner (spent cathodes). Fluoride and sodium are components of cryolite and alumina and are found in roof-scrubber effluent and spent cathodes. PAHs are identified with pitch and coke.

Cyanide was identified in the landfill area (including landfill leachate), the former cathode management area (including in underlying "perched water"), the upper part of the drainage ditch, the north ditch, and the discharge channel. Cyanides are generally absent at the scrubber sludge ponds, the lined pond, the recycle pond, and the duck pond. Fluoride is characteristic of the former cathode management area soils, the landfill area, recycle pond, lined pond, discharge channel, perched water underlying the cathode management area, and the S aquifer near the scrubber sludge ponds. PAHs are present in the landfill area and the cathode

Table 3.2 Inorganic Analytical Result Summary
(Soil and sediment results reported as mg/kg, aqueous as mg/L)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	% SOLIDS	TOTAL CYANIDE	FREE CYANIDE	FLUORIDE	SODIUM	SULFATE
BATH RECOVERY	BRASC	SOIL	24-JUN-87	99	17	17	808	51800	-
BATH RECOVERY	SOILREP 4R	SOIL	24-JUN-87	99	26	12	869	36400	-
BATH RECOVERY	BRFB 1/	AQUE *	24-JUN-87	- 2/	<0.5	<0.5	<10	<10	-
CATHODE WASH	CWASG	SOIL	24-JUN-87	98	20	9.6	1170	6630	-
CATHODE WASH	CWBSG	SOIL	24-JUN-87	98	17	4.8	1330	6690	-
CATHODE WASH	CWCSG	SOIL	24-JUN-87	98	19	15	796	16900	-
CATHODE WASH	CWASC-1	SOIL	26-JUN-87	90	7.3	0.56	-	2930	-
DISCHARGE CHANNEL	DCAW	AQUE	25-MAR-86	-	6.5	0.06	33	632	66
DISCHARGE CHANNEL	DCFBW	AQUE	25-MAR-86	-	0.21	<0.017	<5	0.20	500
DISCHARGE CHANNEL	DCAQ	AQUE	30-AUG-86	-	<0.010	<0.010	-	-	
DISCHARGE CHANNEL	DCAG	SEDI	19-MAR-86	50	-	<1.0	492	2180	-
DISCHARGE CHANNEL	DCBG	SEDI	19-MAR-86	48	-	3.5	1020	4080	-
DISCHARGE CHANNEL	DCCG	SEDI	19-MAR-86	55	-	2.8	385	8200	-
DISCHARGE CHANNEL	DCDG	SEDI	19-MAR-86	48	-	4.7	1240	7810	-
DISCHARGE CHANNEL	DCEG	SEDI	19-MAR-86	41	-	<1.2	767	3250	-
DISCHARGE CHANNEL	DCFBS 1/	AQUE *	19-MAR-86	-	-	<0.5	<10	40	-
DRAINAGE DITCH	DDASG	SEDI	25-MAR-86	50	-	1.3	926	15400	-
DRAINAGE DITCH	DDBSG	SEDI	25-MAR-86	43	-	3.2	271	1070	-
DRAINAGE DITCH	DDCSG	SEDI	25-MAR-86	64	-	<0.78	330	5490	-
DRAINAGE DITCH	DDDSG	SEDI	25-MAR-86	68	-	<0.74	312	5530	-
DRAINAGE DITCH	DDESG	SEDI	25-MAR-86	50	-	<1.0	416	9220	-
DRAINAGE DITCH	DDFBS 1/	AQUE *	25-MAR-86	-	-	<2.5	<1.0	70	-
DUCK POND	DPAW	AQUE	24-MAR-86	-	<0.017	<0.017	12	21	42
DUCK POND	DPBW	AQUE	24-MAR-86	-	<0.017	<0.017	11	29	42
DUCK POND	DPCW	AQUE	24-MAR-86	-	<0.017	<0.025	12	30	43
DUCK POND	DPDW	AQUE	24-MAR-86	-	<0.017	<0.017	12	28	43
DUCK POND	DPEW	AQUE	24-MAR-86	-	<0.017	<0.017	12	26	43
DUCK POND	DPFW	AQUE	24-MAR-86	-	<0.017	<0.017	13	26	43
DUCK POND	DPGW	AQUE	24-MAR-86	-	<0.017	<0.017	12	33	43
DUCK POND	DPHW	AQUE	24-MAR-86	-	<0.017	<0.017	12	31	42
DUCK POND	DPIW	AQUE	24-MAR-86	-	<0.017	<0.017	11	25	43
DUCK POND	DPIW	AQUE	02-SEP-86	-	<0.01	<0.01	-	-	-
DUCK POND	DPAS1	SEDI	24-MAR-86	14	-	<3.6	91	463	-
DUCK POND	DPAS2	SEDI	24-MAR-86	18	-	<2.8	76	311	-
DUCK POND	DPBS	SEDI	24-MAR-86	14	-	<0.5	108	1037	-
DUCK POND	DPCSG	SEDI	24-MAR-86	16	-	<0.5	644	1105	-
DUCK POND	DPFBS 1/	AQUE *	24-MAR-86	-	-	<1.7	<10	28	-

1/ Aqueous field blank results are expressed in mg/kg, not in ug/L.
2/ " - " means test not performed on that sample
(All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

Table 3.2 (continued)

Table 3.2 Inorganic Analytical Result Summary
(Soil and sediment results reported as mg/kg, aqueous as mg/L)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	% SOLIDS	TOTAL CYANIDE	FREE CYANIDE	FLUORIDE	SODIUM	SULFATE
BATH RECOVERY	BRASC	SOIL	24-JUN-87	99	17	17	808	51800	-
BATH RECOVERY	SOILREP 4R	SOIL	24-JUN-87	99	26	12	869	36400	-
BATH RECOVERY	BRFB 1/	AQUE *	24-JUN-87	- 2/	<0.5	<0.5	<10	<10	-
CATHODE WASH	CWASG	SOIL	24-JUN-87	98	20	9.6	1170	6630	-
CATHODE WASH	CWBSG	SOIL	24-JUN-87	98	17	4.8	1330	6690	-
CATHODE WASH	CWCSG	SOIL	24-JUN-87	98	19	15	796	16900	-
CATHODE WASH	CWASC-1	SOIL	26-JUN-87	90	7.3	0.56	-	2930	-
DISCHARGE CHANNEL	DCAW	AQUE	25-MAR-86	-	6.5	0.06	33	632	66
DISCHARGE CHANNEL	DCFBW	AQUE	25-MAR-86	-	0.21	<0.017	<5	0.20	500
DISCHARGE CHANNEL	DCAQ	AQUE	30-AUG-86	-	<0.010	<0.010	-	-	
DISCHARGE CHANNEL	DCAG	SEDI	19-MAR-86	50	-	<1.0	492	2180	-
DISCHARGE CHANNEL	DCBG	SEDI	19-MAR-86	48	-	3.5	1020	4080	-
DISCHARGE CHANNEL	DCCG	SEDI	19-MAR-86	55	-	2.8	385	8200	-
DISCHARGE CHANNEL	DCDG	SEDI	19-MAR-86	48	-	4.7	1240	7810	-
DISCHARGE CHANNEL	DCEG	SEDI	19-MAR-86	41	-	<1.2	767	3250	-
DISCHARGE CHANNEL	DCFBS 1/	AQUE *	19-MAR-86	-	-	<0.5	<10	40	-
DRAINAGE DITCH	DDASG	SEDI	25-MAR-86	50	-	1.3	926	15400	-
DRAINAGE DITCH	DDBSG	SEDI	25-MAR-86	43	-	3.2	271	1070	-
DRAINAGE DITCH	DDCSG	SEDI	25-MAR-86	64	-	<0.78	330	5490	-
DRAINAGE DITCH	DDDSG	SEDI	25-MAR-86	68	-	<0.74	312	5530	-
DRAINAGE DITCH	DDESG	SEDI	25-MAR-86	50	-	<1.0	416	9220	-
DRAINAGE DITCH	DDFBS 1/	AQUE *	25-MAR-86	-	-	<2.5	<1.0	70	-
DUCK POND	DPAW	AQUE	24-MAR-86	-	<0.017	<0.017	12	21	42
DUCK POND	DPBW	AQUE	24-MAR-86	-	<0.017	<0.017	11	29	42
DUCK POND	DPCW	AQUE	24-MAR-86	-	<0.017	<0.025	12	30	43
DUCK POND	DPDW	AQUE	24-MAR-86	-	<0.017	<0.017	12	28	43
DUCK POND	DPEW	AQUE	24-MAR-86	-	<0.017	<0.017	12	26	43
DUCK POND	DPFW	AQUE	24-MAR-86	-	<0.017	<0.017	13	26	43
DUCK POND	DPGW	AQUE	24-MAR-86	-	<0.017	<0.017	12	33	43
DUCK POND	DPHW	AQUE	24-MAR-86	-	<0.017	<0.017	12	31	42
DUCK POND	DPIW	AQUE	24-MAR-86	-	<0.017	<0.017	11	25	43
DUCK POND	DPIW	AQUE	02-SEP-86	-	<0.01	<0.01	-	-	-
DUCK POND	DPAS1	SEDI	24-MAR-86	14	-	<3.6	91	463	-
DUCK POND	DPAS2	SEDI	24-MAR-86	18	-	<2.8	76	311	-
DUCK POND	DPBS	SEDI	24-MAR-86	14	-	<0.5	108	1037	-
DUCK POND	DPCSG	SEDI	24-MAR-86	16	-	<0.5	644	1105	-
DUCK POND	DPFBS 1/	AQUE *	24-MAR-86	-	-	<1.7	<10	28	-

1/ Aqueous field blank results are expressed in mg/kg, not in ug/L.
2/ " - " means test not performed on that sample
(All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

Table 3.2 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	% SOLIDS	TOTAL CYANIDE	FREE CYANIDE	FLUORIDE	SODIUM	SULFATE
LANDFILL (SE)	LFAS	SOIL	10-MAY-86	93	0.52	<0.27	1160	63000	-
LANDFILL (NE)	LFBS	SOIL	10-MAY-86	82	0.32	<0.30	2010	66200	-
LANDFILL (SW)	LFCS	SOIL	10-MAY-86	88	11	<0.28	204	3440	-
LANDFILL (NW)	LFDS	SOIL	10-MAY-86	87	1.4	<0.29	1250	69050	-
LANDFILL (NC)	LFES	SOIL	10-MAY-86	81	70	54	2880	82200	-
LANDFILL	LFFBS 1/	AQUE *	10-MAY-86	-	-	<0.5	<100	100	-
LANDFILL DITCH	LDAWG	AQUE	23-JUN-87	-	-	-	7620	36600	10500
LANDFILL DITCH	LDBWG	AQUE	23-JUN-87	-	-	-	5750	37300	12000
LANDFILL DITCH	DLSW-	AQUE	23-JUN-87	-	-	-	5400	37600	11000
LANDFILL DITCH	REP1E								
LANDFILL DITCH	LDAWG	AQUE	2-AUG-87	-	373	34.2	6880	68000	15200
LANDFILL DITCH	LDBWG	AQUE	2-AUG-87	-	1090	77.2	8000	79200	39900
LANDFILL DITCH	DLSW- REP1E	AQUE	2-AUG-87	-	1280	59.7	7750	99800	49300
LANDFILL DITCH	LDFB	AQUE	23-JUN-87	-	-	-	<1.0	-	<5.0
LANDFILL DITCH	LDFB	AQUE	02-AUG-87	-	<0.010	<0.01	<1.0	1.05	<5.0
LANDFILL DITCH	NDAW	AQUE	25-MAR-86	-	5.15	0.82	190	513	146
LANDFILL DITCH	NDBW	AQUE	25-MAR-86	-	1.6	0.59	196	444	148
LANDFILL DITCH	NDAW	AQUE	01-SEP-86	-	0.16	0.066	-	-	
LANDFILL DITCH	NDBW	AQUE	01-SEP-86	-	0.26	0.18	-	-	
LANDFILL DITCH	NDAS	SEDI	19-MAR-86	76	-	<0.66	204	3030	-
LANDFILL DITCH	NDBS	SEDI	19-MAR-86	53	-	3.6	189	2720	-
LANDFILL LEACHATE	LLAW	AQUE	26-MAR-86	-	10	0.25	1490	4270	840
LANDFILL LEACHATE	LLBW	AQUE	26-MAR-86	-	31	0.39	2090	5780	2130
LANDFILL LEACHATE	LLCW	AQUE	26-MAR-86	-	9.4	0.91	2440	5900	2660
LANDFILL LEACHATE	LLDW	AQUE	26-MAR-86	-	19	1.0	1740	4780	1890
LANDFILL LEACHATE	LLAW	AQUE	18-SEP-86	-	0.11	<0.010	-	-	-
LANDFILL LEACHATE	LLBW	AQUE	18-SEP-86	-	29	4.7	-	-	-
LANDFILL LEACHATE	LLCW	AQUE	18-SEP-86	-	14	3.6	-	-	-
LANDFILL LEACHATE	LLCW-D	AQUE	18-SEP-86	-	15	2.5	-	-	-
LANDFILL LEACHATE	LLDW	AQUE	18-SEP-86	-	14	1.6	-	-	-
LANDFILL RUNOFF A	LRASC	SOIL	22-JUN-87	98	10.00	0.66J	2300	10500	<510J
LANDFILL RUNOFF B	LRBSC	SOIL	22-JUN-87	93	7.4	0.80J	1830	12400	3440J
LANDFILL RUNOFF C	LRCSC	SOIL	22-JUN-87	96	60.00	5.00J	604	12900	3440J
LANDFILL RUNOFF D	LRDSC	SOIL	22-JUN-87	98	4.0	0.50J	347	5030	<510J
LANDFILL RUNOFF	REP 1E	SOIL	22-JUN-87	93	3.8	0.68J	1510	11600	3330J
LANDFILL RUNOFF	LRFB 1/	AQUE *	22-JUN-87	-	<0.5	<0.5	<10	<100	<100

1/ Aqueous field blank results are expressed in mg/kg, not in ug/L.
2/ " - " means test not performed on that sample
(All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

Table 3.2 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	% SOLIDS	TOTAL CYANIDE	FREE CYANIDE	FLUORIDE	SODIUM	SULFATE
LINED POND	LPAW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPBW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPCW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPDW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPEW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPFW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPGW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPHW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPIW	AQUE	20-MAR-86	-	-	-	-	-	-
LINED POND	LPW **	AQUE	20-MAR-86	-	<0.01	<0.025	31.5	881	2360
LINED POND	LPW	AQUE	02-SEP-86	-	<0.01	<0.01	-	-	-
LINED POND	LPFBW	AQUE	20-MAR-86	-	<0.01	<0.025	<0.5	<0.6	<1.0
LINED POND	LPS	SEDI	20-MAR-86	62	-	<0.02	3730	-	-
LINED POND	LPFB 1/	AQUE *	20-MAR-86	-	-	<0.5	<5.0	-	-
METAL PAD STORAGE	MPAS	SOIL	26-MAR-86	84	-	<0.59	465	10100	-
METAL PAD STORAGE	MPASG	SOIL	24-JUN-87	97	1.5	<0.52	856	49800	-
METAL PAD STORAGE	MPBSG	SOIL	24-JUN-87	99	0.62	<0.52	687	19900	-
METAL PAD STORAGE	MPCSG	SOIL	24-JUN-87	99	0.54	<0.50	778	19500	-
METAL PAD STORAGE	SOILREP 3R	SOIL	24-JUN-87	98	2.3	<0.52	714	50000	-
NORTH DRAINAGE DITCH	NDCW	AQUE	25-MAR-86	-	0.37	<0.017	<10	51	37
NORTH DRAINAGE DITCH	NDDW	AQUE	25-MAR-86	-	0.39	<0.02	3.8	88	33
NORTH DRAINAGE DITCH	NDEW	AQUE	25-MAR-86	-	0.037	<0.017	3.7	35	35
NORTH DRAINAGE DITCH	NDFBW	AQUE	25-MAR-86	-	<0.017	<0.017	<0.1	0.3	<10
NORTH DRAINAGE DITCH	NDCW	AQUE	01-SEP-86	-	<0.010	<0.010	-	-	
NORTH DRAINAGE DITCH	NDDW	AQUE	01-SEP-86	-	<0.010	<0.010	-	-	
NORTH DRAINAGE DITCH	NDEW	AQUE	01-SEP-86	-	<0.010	<0.010	-	-	
NORTH DRAINAGE DITCH	NDCS	SEDI	19-MAR-86	48	-	<1.0	92	4160	-
NORTH DRAINAGE DITCH	NDDS	SEDI	19-MAR-86	25	-	<2.0	92	10400	-
NORTH DRAINAGE DITCH	NDES	SEDI	19-MAR-86	55	-	<0.91	172	1210	-
NORTH DRAINAGE DITCH	NDFBS 1/	AQUE *		-	-	<0.5	<5.0	36	-
OLD CATHODE WASTE PILE	OCS	SOIL	26-MAR-86	89	-	23	475	7919	-
OLD CATHODE WASTE PILE	OCFBS 1/	AQUE *	26-MAR-86	-	-	<0.5	<0.5	-	-
OLD CATHODE WASTE PILE	OCWPSC-A	SOIL	26-JUN-87	86	29	0.72	-	4600	-
OLD CATHODE WASTE PILE	OCWPSC-B	SOIL	26-JUN-87	90	26	<0.56	-	4380	-
OLD CATHODE WASTE PILE	OCWPSC-C	SOIL	26-JUN-87	93	19	5.2	-	10900	-
OLD CATHODE WASTE PILE	OCWP PITB-H20	AQUE	26-JUN-87	-	294	3.01	3000	10500	-
OLD NPDES DISCHARGE CHANNEL	ODCSC-1	SOIL	24-JUN-87	-	-	-	-	-	-
POTLINER HANDLING	PHASC	SOIL	23-JUN-87	98	14	4.0	673	29600	-
POTLINER HANDLING	SOILREP 2	SOIL	23-JUN-87	98	16	4.8	898	28600	-

1/ Aqueous field blank results are expressed in mg/kg, not in ug/L.

2/ " - " means test not performed on that sample
(All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

Table 3.2 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	% SOLIDS	TOTAL CYANIDE	FREE CYANIDE	FLUORIDE	SODIUM	SULFATE
RECYCLE POND	RPAW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPBW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPCW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPDW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPEW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPFW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPGW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPHW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPIW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPJW	AQUE	22-MAR-86	-	-	-	-	-	-
RECYCLE POND	RPW **	AQUE	22-MAR-86	-	0.190	<0.017	21.6	100	94.4
RECYCLE POND	RPFBW	AQUE	22-MAR-86	-	<0.017	<0.017	<0.05	16	<0.5
RECYCLE POND	RPAS	SEDI	22-MAR-86	46	-	<1.1	856	12000	-
RECYCLE POND	RPBS	SEDI	22-MAR-86	43	-	<1.2	1260	11800	-
RECYCLE POND	RPCS	SEDI	22-MAR-86	44	-	<1.1	1320	14200	-
RECYCLE POND	RPDS	SEDI	22-MAR-86	45	-	<1.1	1020	11800	-
RECYCLE POND	RPFBS 1/	AQUE *	22-MAR-86	-	-	<0.85	<10	-	-
RECYCLE POND	RPS-1	SEDI	04-SEP-86	-	-	-	-	-	-
RECYCLE POND	RPS-2	SEDI	04-SEP-86	-	-	-	-	-	-
RECYCLE POND	RPS-3	SEDI	04-SEP-86	-	-	-	-	-	-
RECYCLE POND	RPS-4	SEDI	04-SEP-86	-	-	-	-	-	-
RECYCLE POND	RPS-5	SEDI	04-SEP-86	-	-	-	-	-	-
RECYCLE POND	RPS-6	SEDI	04-SEP-86	-	-	-	-	-	-
RIVER ROAD DITCH	RRAS	SOIL	26-MAR-86	52	-	<0.96	232	3620	-
RIVER ROAD CURB	RRBS	SOIL	26-MAR-86	62	-	<0.81	166	1480	-
SALVAGE AREA	OCAS	SOIL	26-MAR-86	75	-	4.4	67.3	8704	-
SALVAGE AREA	SASC	SOIL	26-JUN-87	95	196	86	-	54500	-
SALVAGE AREA	SAFB 1/	AQUE *	26-JUN-87	-	-	<0.85	<0.5	100	-
SCRUBBER SLUDGE PONDS	SSP1AS	SEDI	28-MAR-86	50	-	<1.0	204	15400	-
SCRUBBER SLUDGE PONDS	SSP1BS	SEDI	28-MAR-86	45	-	<1.1	291	20600	-
SCRUBBER SLUDGE PONDS	SSP1CS	SEDI	28-MAR-86	44	-	<1.1	407	20700	-
SCRUBBER SLUDGE PONDS	SSP1DS	SEDI	28-MAR-86	39	-	<1.3	285	18700	-
SCRUBBER SLUDGE PONDS	SSP2ES	SEDI	28-MAR-86	38	-	<1.3	263	17700	-
SCRUBBER SLUDGE PONDS	SSP2FS	SEDI	28-MAR-86	60	-	<0.83	317	14500	-
SCRUBBER SLUDGE PONDS	SSP3GS	SEDI	28-MAR-86	39	-	<1.3	613	45000	-
SCRUBBER SLUDGE PONDS	SSP3HS	SEDI	27-MAR-86	47	-	<1.1	387	18400	-
SCRUBBER SLUDGE PONDS	SSP4IS	SEDI	27-MAR-86	53	-	<0.94	258	13600	-
SCRUBBER SLUDGE PONDS	SSP4JS	SEDI	27-MAR-86	68	-	<0.74	212	6250	-
SCRUBBER SLUDGE PONDS	SSPFBS 1/	AQUE *	28-MAR-86	-	-	<0.85	0.5	52	-
SCRUBBER SLUDGE PONDS	SCRUBBER PIPE-EFF	AQUE	26-JUN-87	-	0.053	<0.01	120	2550	-

1/ Aqueous field blank results are expressed in mg/kg, not in ug/L.
2/ " - " means test not performed on that sample
(All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

Table 3.2 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	% SOLIDS	TOTAL CYANIDE	FREE CYANIDE	FLUORIDE	SODIUM	SULFATE
SURFACE DRAINAGE DITCH	SDAS	SEDI	26-MAR-86	80	-	<0.62	519	5600	-
SURFACE DRAINAGE DITCH	SDFBS	AQUE *	26-MAR-86	-	-	<0.5	0.5	31	-
SURFACE DRAINAGE DITCH	SSD-1	SEDI	03-SEP-86	-	-	-	-	-	-
SURFACE DRAINAGE DITCH	SSD-2	SEDI	03-SEP-86	-	-	-	-	-	-
SURFACE DRAINAGE DITCH	SSD-3	SEDI	03-SEP-86	-	-	-	-	-	-

1/ Aqueous field blank results are expressed in mg/kg, not in ug/L.

2/ " - " means test not performed on that sample (All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

* Aqueous field blank for soil and sediment samples.

** Reported concentrations are from several composite samples tested for different constituents. When two or more samples were tested for the same constituent the average was reported.

(MM.T3-2IARS)

Table 3.3 Organic Analytical Result Summary
(Soil and sediment results reported as mg/kg, aqueous as mg/L)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	DIBENZO (a,h) ANTHRACENE	FLOUR-ANTHENE	FLUORENE	INDENO-1,2,3 (c,d) PYRENE	NAPHTHALENE	PHENANTHRENE	PYRENE	ACENAPHTHENE	ANTHRA-CENE	BENZO (a) ANTHRACENE	BENZO (a) PYRENE	BENZO (b&k) FLUORANTHENES	BENZO (g,h,i) PERYLENE	BIS (2-ETHYLHEXYL) PHTHALATE	CHRYSENE
ABANDONED SCRUBBER SLUDGE	ODCSC-1	SOIL	24-JUN-87	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	3.70	<1.67	<1.67	2.71
BATH RECOVERY	BRASC	SOIL	24-JUN-87	- 2/	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BATH RECOVERY	SOILREP 4R	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BATH RECOVERY	BRFB	AQUE*	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CATHODE WASH	CWASG	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CATHODE WASH	CWBSG	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CATHODE WASH	CWCSG	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CATHODE WASH	CWASC-1	SOIL	26-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DISCHARGE CHANNEL	DCAW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DISCHARGE CHANNEL	DCFBW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DISCHARGE CHANNEL	DCAQ	AQUE	30-AUG-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DISCHARGE CHANNEL	DCAG	SEDI	19-MAR-86	120	1020	-	210	-	190	640	<50	54	410	310	640	320	-	560
DISCHARGE CHANNEL	DCBG	SEDI	19-MAR-86	<100	1540	-	170	-	110	980	<50	<50	460	200	540	210	-	610
DISCHARGE CHANNEL	DCCG	SEDI	19-MAR-86	<10	120	-	<10	-	10	100	<5	<5	24	<5	30	12	-	38
DISCHARGE CHANNEL	DCDG	SEDI	19-MAR-86	<100	1080	-	150	-	200	830	<50	<50	350	180	440	210	-	470
DISCHARGE CHANNEL	DCEG	SEDI	19-MAR-86	<100	830	-	150	-	<50	650	<50	<50	280	180	470	270	-	430
DISCHARGE CHANNEL	DCFBS 2/	AQUE*	19-MAR-86	<10	<5.0	<5.0	<10	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
DRAINAGE DITCH	DDASG	SEDI	25-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRAINAGE DITCH	DDBSG	SEDI	25-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRAINAGE DITCH	DDCSG	SEDI	25-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRAINAGE DITCH	DDDSG	SEDI	25-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRAINAGE DITCH	DDESG	SEDI	25-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DRAINAGE DITCH	DDFBS	AQUE*	25-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUCK POND	DPAW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	0.61	<0.005
DUCK POND	DPBW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	0.016	<0.005
DUCK POND	DPCW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DUCK POND	DPDW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DUCK POND	DPEW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DUCK POND	DPFW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DUCK POND	DPGW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	0.084	<0.005
DUCK POND	DPHW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DUCK POND	DPIW	AQUE	24-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
DUCK POND	DPIW	AQUE	02-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUCK POND	DPAS1	SEDI	24-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUCK POND	DPAS2	SEDI	24-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUCK POND	DPBS	SEDI	24-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUCK POND	DPCSG	SEDI	24-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUCK POND	DPFBS	AQUE*	24-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ " - " means test not performed on that sample.
2/ Aqueous field blank parameters for soils are expressed in mg/kg, not in ug/L; conversion calculations are based on worst case conditions (i.e., using the least sample weight analyzed for each batch of samples) without applying any dilution or concentration factors. It should be understood that sample dilutions and concentrations will also affect detection limits for each sample because they vary from sample to sample and could not be included in conversion calculations of field blanks. (All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

* Aqueous field blank.

Table 3.3 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	DIBENZO (a,h) ANTHRACENE	FLOUR-ANTHENE	FLUORENE	INDENO-1,2,3 (c,d) PYRENE	NAPHTHALENE	PHENANTHRENE	PYRENE	ACENAPHTHENE	ANTHRA-CENE	BENZO (a) ANTHRACENE	BENZO (a) PYRENE	BENZO (b&k) FLUORANTHENES	BENZO (g,h,i) PERYLENE	BIS (2-ETHYLHEXYL) PHTHALATE	CHRYSENE
LANDFILL (SE)	LFAS	SOIL	10-MAY-86	83	340	15	210	10	170	260	19	19	230	200	440	200	-	210
LANDFILL (NE)	LFBS	SOIL	10-MAY-86	40	240	16	110	7	180	200	28	40	120	120	210	96	-	110
LANDFILL (SW)	LFCS	SOIL	10-MAY-86	<8.4	48	5	15	7	38	37	<4.2	7	22	22	36	14	-	28
LANDFILL (NW)	LFDS	SOIL	10-MAY-86	36	150	9	100	<4.2	82	120	11	11	100	110	210	91	-	110
LANDFILL (NC)	LFES	SOIL	10-MAY-86	13	100	<4.2	42	<4.2	73	95	6	16	47	45	79	37	-	58
LANDFILL	LFFBS 1/	AQUE*	10-MAY-86	<2.5	<1.25	<1.25	<2.5	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<2.5	<2.5	<1.25
LANDFILL DITCH	LDAWG	AQUE	23-JUN-87	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.021	<0.02	<0.02	<0.02	<0.02	0.023	<0.02	0.077	0.024
LANDFILL DITCH	LDBWG	AQUE	23-JUN-87	<0.02	0.028	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
LANDFILL DITCH	DLSW-	AQUE	23-JUN-87	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.032	<0.02	<0.02	0.025	<0.02	0.041	<0.02	0.064	0.025
LANDFILL DITCH	REP1E	AQUE																
LANDFILL DITCH	LDAWG	AQUE	2-AUG-87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
LANDFILL DITCH	LDBWG	AQUE	2-AUG-87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
LANDFILL DITCH	DLSW-REP1E	AQUE	2-AUG-87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
LANDFILL DITCH	LDFB	AQUE	23-JUN-87	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LANDFILL DITCH	LDFB	AQUE	02-AUG-87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.206	<0.1
LANDFILL DITCH	NDAW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LANDFILL DITCH	NDBW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LANDFILL DITCH	NDAW	AQUE	01-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL DITCH	NDBW	AQUE	01-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL DITCH	NDAS	SEDI	19-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL DITCH	NDBS	SEDI	19-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL LEACHATE	LLAW	AQUE	26-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LANDFILL LEACHATE	LLBW	AQUE	26-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	0.016	<0.005
LANDFILL LEACHATE	LLCW	AQUE	26-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LANDFILL LEACHATE	LLDW	AQUE	26-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LANDFILL LEACHATE	LLAW	AQUE	18-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL LEACHATE	LLBW	AQUE	18-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL LEACHATE	LLCW	AQUE	18-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL LEACHATE	LLCW-D	AQUE	18-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL LEACHATE	LLDW	AQUE	18-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL RUNOFF A	LRASC	SOIL	22-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL RUNOFF B	LRBSC	SOIL	22-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL RUNOFF C	LRCSC	SOIL	22-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL RUNOFF D	LRDSC	SOIL	22-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL RUNOFF	REP 1E	SOIL	22-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LANDFILL RUNOFF	LRFB	AQUE*	22-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ " - " means test not performed on that sample.

2/ Aqueous field blank parameters for soils are expressed in mg/kg, not in ug/L; conversion calculations are based on worst case conditions (i.e., using the least sample weight analyzed for each batch of samples) without applying any dilution or concentration factors. It should be understood that sample dilutions and concentrations will also affect detection limits for each sample because they vary from sample to sample and could not be included in conversion calculations of field blanks. (All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

* Aqueous field blank.

Table 3.3 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	DIBENZO (a,h) ANTHRACENE	FLOUR-ANTHENE	FLUORENE	INDENO-1,2,3 (c,d) PYRENE	NAPHTHALENE	PHENANTHRENE	PYRENE	ACENAPHTHENE	ANTHRA-CENE	BENZO (a) ANTHRACENE	BENZO (a) PYRENE	BENZO (b&k) FLUORANTHENES	BENZO (g,h,i) PERYLENE	BIS (2-ETHYLHEXYL) PHTHALATE	CHRYSENE
LINED POND	LPAW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPBW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPCW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPDW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPEW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPFW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPGW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPHW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPIW	AQUE	20-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPW**	AQUE	20-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LINED POND	LPW	AQUE	02-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LINED POND	LPFBW	AQUE	20-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
LINED POND	LPS	SEDI	20-MAR-86	110	1460	<6.25	290	<6.25	19	640	<6.25	10	1030	500	2120	270	-	1310
LINED POND	LPFB 1/	AQUE*	20-MAR-86	<2.5	<1.25	<1.25	<2.5	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<2.5	<2.5	<1.25
METAL PAD STORAGE	MPAS	SOIL	26-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
METAL PAD STORAGE	MPASG	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
METAL PAD STORAGE	MPBSG	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
METAL PAD STORAGE	MPCSG	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
METAL PAD STORAGE	SOILREP 3R	SOIL	24-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDCW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
NORTH DRAINAGE DITCH	NDDW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
NORTH DRAINAGE DITCH	NDEW	AQUE	25-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
NORTH DRAINAGE DITCH	NDFBW	AQUE	25-MAR-86															
NORTH DRAINAGE DITCH	NDCW	AQUE	01-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDDW	AQUE	01-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDEW	AQUE	01-SEP-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDCS	SEDI	19-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDDS	SEDI	19-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDES	SEDI	19-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTH DRAINAGE DITCH	NDFBS	AQUE*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ " - " means test not performed on that sample.

2/ Aqueous field blank parameters for soils are expressed in mg/kg, not in ug/L; conversion calculations are based on worst case conditions (i.e., using the least sample weight analyzed for each batch of samples) without applying any dilution or concentration factors. It should be understood that sample dilutions and concentrations will also affect detection limits for each sample because they vary from sample to sample and could not be included in conversion calculations of field blanks. (All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

* Aqueous field blank.

** Reported concentrations are from several composite samples tested for different constituents. When two or more samples were tested for the same constituent the average was reported.

Table 3.3 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	DIBENZO (a,h) ANTHRACENE	FLOUR-ANTHENE	FLUORENE	INDENO-1,2,3 (c,d) PYRENE	NAPHTHALENE	PHENANTHRENE	PYRENE	ACENAPHTHENE	ANTHRA-CENE	BENZO (a) ANTHRACENE	BENZO (a) PYRENE	BENZO (b&k) FLUORANTHENES	BENZO (g,h,i) PERYLENE	BIS (2-ETHYLHEXYL) PHTHALATE	CHRYSENE
OLD CATHODE WASTE PILE	OCS	SOIL	26-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OLD CATHODE WASTE PILE	OCFBS	AQUE*	26-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OLD CATHODE WASTE PILE	OCWPSC-A	SOIL	26-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OLD CATHODE WASTE PILE	OCWPSC-B	SOIL	26-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OLD CATHODE WASTE PILE	OCWPSC-C	SOIL	26-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OLD CATHODE WASTE PILE	OCWP PITB-H20	AQUE	26-JUN-87	<0.02	0.050	<0.02	<0.02	<0.02	0.029	0.066	<0.02	<0.02	0.024	<0.02	0.048	<0.02	<0.02	0.038
POTLINER HANDLING	PHASC	SOIL	23-JUN-87	274	1600	-	559	-	696	893	114	-	989	778	1800	466	-	872
POTLINER HANDLING	SOILREP 2	SOIL	23-JUN-87	451	1200	-	444	-	553	783	91.3	-	820	585	1500	700	-	815
8888																		
RECYCLE POND	RPAW	AQUE	22-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
RECYCLE POND	RPBW	AQUE	22-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
RECYCLE POND	RPCW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPDW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPEW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPFW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPGW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPHW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPIW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPJW	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	LPW**	AQUE	22-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RECYCLE POND	RPFBW	AQUE	22-MAR-86	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.005
RECYCLE POND	RPAS	SEDI	22-MAR-86	<125	2170	<6.25	150	<6.25	140	1230	<62.5	<62.5	470	190	470	140	-	710
RECYCLE POND	RPBS	SEDI	22-MAR-86	<125	1580	<6.25	<125	<6.25	130	1000	<62.5	<62.5	370	145	400	<125	-	580
RECYCLE POND	RPCS	SEDI	22-MAR-86	<50	2410	<25	160	<25	270	1330	<25	<25	790	310	920	140	-	1040
RECYCLE POND	RPDS	SEDI	22-MAR-86	<125	1220	<6.25	<125	<6.25	98	770	<62.5	<62.5	340	130	380	<125	-	510
RECYCLE POND	RPFBS 1/	AQUE*	22-MAR-86	<2.5	<1.25	<1.25	<2.5	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<2.5	<2.5	<1.25
RECYCLE POND	RPS-1	SEDI	04-SEP-86	603	884	<50	141	<50	147	692	<50	52	380	182	527	106	-	594
RECYCLE POND	RPS-2	SEDI	04-SEP-86	79.5	1100	<50	156	<50	173	921	<50	59.9	491	228	649	145	-	742
RECYCLE POND	RPS-3	SEDI	04-SEP-86	82.4	941	<50	149	<50	199	781	<50	57.6	488	209	623	148	-	728
RECYCLE POND	RPS-4	SEDI	04-SEP-86	<50	775	<50	139	<50	138	599	<50	50.8	394	194	571	126	-	698
RECYCLE POND	RPS-5	SEDI	04-SEP-86	75.4	968	<50	174	<50	157	883	<50	60.1	450	200	588	147	-	700
RECYCLE POND	RPS-6	SEDI	04-SEP-86	76.3	935	<50	170	<50	161	712	<50	57.6	429	197	608	137	-	692

1/ " - " means test not performed on that sample.

2/ Aqueous field blank parameters for soils are expressed in mg/kg, not in ug/L; conversion calculations are based on worst case conditions (i.e., using the least sample weight analyzed for each batch of samples) without applying any dilution or concentration factors. It should be understood that sample dilutions and concentrations will also affect detection limits for each sample because they vary from sample to sample and could not be included in conversion calculations of field blanks. (All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

* Aqueous field blank.

** Reported concentrations are from several composite samples tested for different constituents. When two or more samples were tested for the same constituent the average was reported.

Table 3.3 (continued)

SAMPLE LOCATION	SAMPLE ID	SAMPLE TYPE	DATE	DIBENZO (a,h) ANTHRACENE	FLOUR- ANTHENE	FLUORENE	INDENO-1,2,3 (c,d) PYRENE	NAPHTHALENE	PHENANTHRENE	PYRENE	ACENAPHTHENE	ANTHRA- CENE	BENZO (a) ANTHRACENE	BENZO (a) PYRENE	BENZO (b&k) FLUORANTHENES	BENZO (g,h,i) PERYLENE	BIS (2-ETHYLHEXYL) PHTHALATE	CHRYSENE
RIVER ROAD DITCH	RRAS	SOIL	26-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIVER ROAD CURB	RRBS	SOIL	26-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SALVAGE AREA	OCAS	SOIL	26-MAR-86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SALVAGE AREA	SASC	SOIL	26-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SALVAGE AREA	SAFB	AQUE*	26-JUN-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SCRUBBER SLUDGE PONDS	SSP1AS	SEDI	28-MAR-86	<50	970	-	140	-	<25	560	<25	<25	270	280	690	150	-	670
SCRUBBER SLUDGE PONDS	SSP1BS	SEDI	28-MAR-86	<125	2310	-	320	-	130	2000	<62.5	<62.5	530	360	1310	380	-	1230
SCRUBBER SLUDGE PONDS	SSP1CS	SEDI	28-MAR-86	<50	770	-	130	-	<25	540	<25	<25	250	170	610	130	-	640
SCRUBBER SLUDGE PONDS	SSP1DS	SEDI	28-MAR-86	<50	700	-	<50	-	140	590	<25	<25	200	200	450	<50	-	480
SCRUBBER SLUDGE PONDS	SSP2ES	SEDI	28-MAR-86	<125	1780	-	370	-	<62.5	1220	<62.5	<62.5	340	330	1430	470	-	1240
SCRUBBER SLUDGE PONDS	SSP2FS	SEDI	28-MAR-86	<50	560	-	<50	-	100	280	<25	<25	120	160	360	<50	-	360
SCRUBBER SLUDGE PONDS	SSP3GS	SEDI	28-MAR-86	<125	630	-	180	-	260	530	<62.5	<62.5	300	180	790	250	-	830
SCRUBBER SLUDGE PONDS	SSP3HS	SEDI	27-MAR-86	<125	2590	-	260	-	880	1400	<62.5	<62.5	430	430	1090	260	-	1020
SCRUBBER SLUDGE PONDS	SSP4IS	SEDI	27-MAR-86	<125	1130	-	<125	-	<62.5	870	<62.5	<62.5	280	160	670	244	-	625
SCRUBBER SLUDGE PONDS	SSP4JS	SEDI	27-MAR-86	<125	450	-	220	-	<62.5	260	<62.5	<62.5	<62.5	160	700	290	-	590
SCRUBBER SLUDGE PONDS	SSPFBS 1/	AQUE*	28-MAR-86	<2.5	<1.25	<1.25	<2.5	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<2.5	<2.5	<1.25
SCRUBBER SLUDGE PONDS	SCRUBBER PIPE-EFF	AQUE	26-JUN-87	<0.02	0.616	<0.02	0.025	<0.02	<0.02	0.36	0.028	<0.02	0.118	0.024	0.096	<0.02	<0.02	0.134
SURFACE DRAINAGE DITCH	SDAS	SEDI	26-MAR-86	<0.5	0.27	-	<0.5	-	<0.25	0.28	<0.25	<0.25	0.27	<0.25	0.54	<0.5	-	0.43
SURFACE DRAINAGE DITCH	SDFBS 1/	AQUE*	26-MAR-86	<0.50	<0.25	<0.25	<0.50	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.50	<0.50	<0.25
SURFACE DRAINAGE DITCH	SSD-1	SEDI	03-SEP-86	<1.67	<1.67	-	<1.67	-	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	-	<1.67
SURFACE DRAINAGE DITCH	SSD-2	SEDI	03-SEP-86	<1.67	<1.67	-	<1.67	-	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	-	<1.67
SURFACE DRAINAGE DITCH	SSD-3	SEDI	03-SEP-86	3.17	7.89	-	7.29	-	2.02	9.16	<1.67	<1.67	5.0	4.66	<1.67	6.36	-	8.26

1/ " - " means test not performed on that sample.
2/ Aqueous field blank parameters for soils are expressed in mg/kg, not in ug/L; conversion calculations are based on worst case conditions (i.e., using the least sample weight analyzed for each batch of samples) without applying any dilution or concentration factors. It should be understood that sample dilutions and concentrations will also affect detection limits for each sample because they vary from sample to sample and could not be included in conversion calculations of field blanks. (All analyses performed by Versar Laboratories; results of split samples are included in Appendices C and D.)

* Aqueous field blank.
** Reported concentrations are from several composite samples tested for different constituents. When two or more samples were tested for the same constituent the average was reported.

(MM.T3-30ARS)

waste-management area soils, and the scrubber sludge pond, recycle pond, discharge channel, and lined pond sediments.

3.2.1 Landfill Characterization

The landfill area includes the landfill, the leachate collection system, the landfill ditch, the surface drainage ditch, and landfill runoff areas (see Figure 3.1). Waste constituent concentrations at each of these sub-areas were evaluated during the RI as described below.

Samples were collected in March 1986 to characterize waste materials at the landfill. The samples were obtained from five, 10-ft-deep test pits (Figure 3.6). Two subsamples were collected from each test pit and composited. The five composited samples and an aqueous field blank were analyzed for total cyanide, fluoride, sodium, EP toxicity metals, VOCs (volatile organic compounds), and base/neutral and acid extractable organics. In addition, part of each composite sample was combined into one sample to be analyzed for the presence of PCBs (polychlorinated biphenyls).

The analytical results indicate that no VOCs, acid extractables, or PCBs were present. The presence of one EP toxicity metal (barium) was reported at a concentration of 234 mg/kg (milligrams per kilogram) in one sample (LFCS). Total cyanide (0.32 to 70 mg/kg), sodium (3,440 to 82,200 mg/kg), fluoride (204 to 2,880 mg/kg), and selected PAHs were identified (up to 440 mg/kg). The analytical results of the landfill samples support the history of the nature of materials deposited in the landfill.

As part of the RI, samples of landfill leachate were collected from the leachate-collection system, upstream from the sump. These samples were analyzed for VOCs, base/neutral

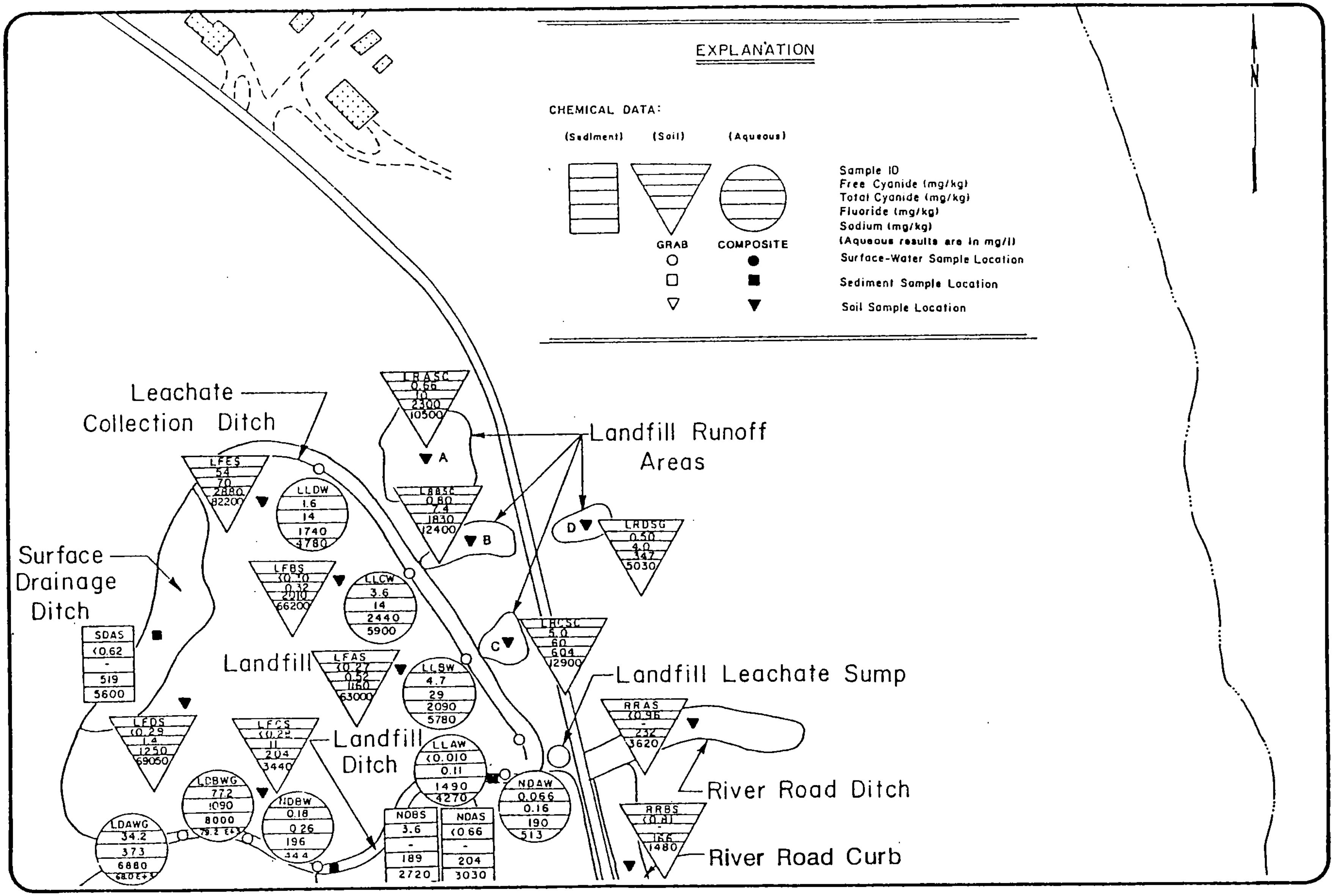


Figure 3.6 Sample Locations and Analytical Results - Landfill Area.

CLIENT NAME:

Martin Marietta Corporation

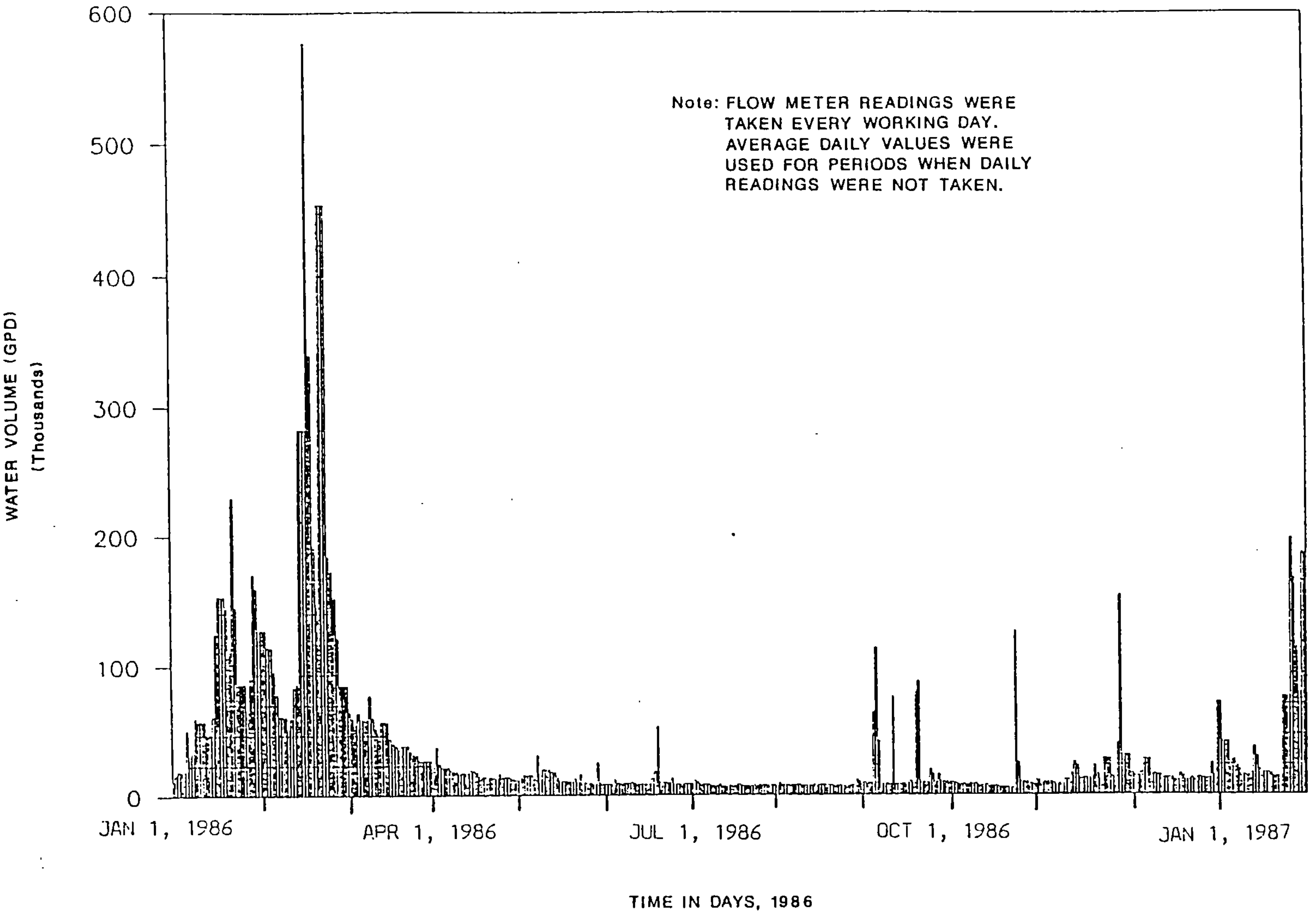
and acid extractable organics, free and total cyanide, sodium, fluoride, EP toxicity metals, PCBs, arsenic, and sulfate. No base/neutrals, acid extractables, or PCBs were detected in any of the samples. None of the metals analyzed by EP toxicity exceeded the levels which are used to classify the waste as hazardous by EP toxicity. Results of analyses for total arsenic were similar to the EP toxicity test results for arsenic.

One VOC (trichloroethylene) was reported at a concentration of 8 μg/L (micrograms per liter) in one sample. Concentrations of total and free cyanide, fluoride, sodium, and sulfate were reported to be present in all samples. Fluoride concentrations ranged from 1,490 to 2,440 mg/L (milligrams per liter), sodium from 4,270 to 5,900 mg/L, and sulfate from 840 to 2,660 mg/L. Total and free cyanide ranged from 0.11 to 29 mg/L and <0.01 to 4.7 mg/L, respectively.

These analytical results supplement the extensive data base relative to cyanide (total and free) and fluoride concentrations of landfill leachate. Appendix A includes the analytical results of landfill leachate samples collected since installation of the leachate collection system.

The volume of leachate generated at the landfill is primarily a function of precipitation. Available records of leachate pumped from the collection sump range from 0 to more than 50,000 gpd (gallons per day). Figure 3.7 is an example of the variability in the volume of leachate pumped from the collection sump.

It appears that some of the leachate generated by the landfill is capable of by-passing the existing leachate collection system. The collection system is most effective in intercepting overland runoff; however, precipitation that



Note: FLOW METER READINGS WERE TAKEN EVERY WORKING DAY. AVERAGE DAILY VALUES WERE USED FOR PERIODS WHEN DAILY READINGS WERE NOT TAKEN.

Figure 3.7 Volume of Water Pumped from the Landfill Leachate Sump.

CLIENT NAME:

Martin Marietta Corporation

percolates through the landfill may migrate beneath the collection system and exit as seepage in areas downgradient or continue to percolate downward to recharge the uppermost aquifer.

The landfill ditch is an area not formally defined in the RI/FS Work Plan. In the Work Plan, the lower part of the landfill ditch was included as part of the north ditch. As currently defined, the landfill ditch borders the southern part of the landfill and includes the lower part of the north ditch (Figure 3.5). The landfill ditch drains to the leachate-collection sump. Cathodic material and pitch are visible on the northern side of the upper part of the landfill ditch. Although not part of the engineered leachate collection system, the landfill ditch apparently receives a component of landfill leachate. Surface-water flow through the landfill ditch is collected at the leachate-collection system sump.

Samples of liquid from the landfill ditch were collected in March and September 1986 (four) and June and August 1987 (eight including two replicate samples). In samples from the upper part of the ditch, sodium (36,600 to 99,800 mg/L), fluoride (5,400 to 8,000 mg/L), sulfate (10,500 to 49,300 mg/L), and chloride (1,210 to 3,430 mg/L) were reported. Base/neutral compounds detected included benzo(a)pyrene (25 μg/L), benzo(b&k)fluoranthenes (23 and 41 μg/L), chrysene (24 and 25 μg/L), and pyrene (21 and 32 μg/L). Three of the samples from the upper ditch were analyzed for total and free cyanide, and reported concentrations ranged from 373 to 1,280 mg/L and 34.2 to 77.2 mg/L, respectively.

Two aqueous samples were collected from the landfill ditch downgradient of the juncture with the north ditch. In the work plan, these samples were designated as north ditch samples (NDAW and NDBW). The analytical results identified

190 to 196 mg/L fluoride, 0.16 to 0.26 mg/L total cyanide, and 444 to 513 mg/L sodium.

Two composite sediment samples were collected in March 1986 from the lower part of the landfill ditch (NDAS and NDBS). Free cyanide was detected in one sample at a concentration of 3.6 mg/L but was not detected in the other. Fluoride (189 and 204 mg/L) and sodium (2,720 and 3,030 mg/L) were reported in both composite samples.

Prior to construction of the leachate collection system, surface-water runoff from the landfill discharged by overland flow to the east, through the River Road ditch, and to the east-northeast, through the landfill runoff areas. At the present time, surface-water flow from the north ditch, landfill ditch, and the leachate-collection system is intercepted by the leachate collection system sump. Analytical results for the leachate collection system sump are included in Appendix A.

Before construction of the leachate collection system, leachate discharging to the landfill ditch flowed eastward, through a culvert beneath River Road. The leachate continued to flow eastward through the River Road ditch to a point about 300 ft west of the Columbia River. From this point the leachate flowed northward, following the ditch, until reaching the Pleistocene gravel deposits, into which it infiltrated to recharge the alluvial aquifer.

A composite sediment sample collected from the upper part of the River Road ditch was analyzed for free cyanide, sodium, and fluoride. The analytical results reported free cyanide below detection limits, sodium at a concentration of 3,620 mg/kg, and fluoride at 232 mg/kg. The lower part of the River Road ditch, located on Port of The Dalles property, was graded during construction of the Port, and the area formerly occupied by the ditch is covered with fill.

Another component of landfill leachate migrated off site to the east-northeast prior to construction of the leachate-collection system. To the west of River Road, this flow component was channelized to some degree, and it was predominantly contained in topographically low areas. The leachate crossed River Road and was a source of recharge to the alluvial aquifer. Soil samples from landfill runoff areas A, B, and C, west of River Road, and runoff area D, east of River Road (Figure 3.6), were collected in June 1987 and analyzed for cyanide (total and free), fluoride, and sodium. Other areas east of River Road that may have been in contact with landfill runoff are now covered with fill emplaced during construction of the Port of The Dalles.

The analytical results of the soil samples from the landfill runoff areas reported sodium (5,030 to 12,900 mg/kg), fluoride (347 to 2,300 mg/kg), sulfate (<510 to 3,440 mg/kg), total cyanide (3.8 to 60 mg/kg), and free cyanide (0.50 to 5.0 mg/kg). Generally, waste-constituent concentrations are highest at runoff area C, moderate at areas A and B, and low at area D.

The surface drainage ditch borders the landfill to the west (Figures 3.5 and 3.6). Runoff from the western part of the landfill may discharge periodically to the surface drainage ditch. One composite sediment sample was collected from the surface drainage ditch in March 1986 and analyzed for free cyanide, sodium, fluoride, EP toxicity metals, base/neutral and acid extractable organics, and VOCs. Sodium (5,600 mg/kg), fluoride (519 mg/kg), and PAHs (up to 0.28 mg/kg) were reported as present in the sediment sample. Holding times for base/neutral and acid extractable organics for this sample were exceeded and three grab samples were recollected from the drainage ditch in September 1986 to be analyzed for the same parameters. PAHs were reported as present in one sample (SSD-3) with a maximum individual concentration of 9.16 mg/kg.

3.2.2 Former Cathode Waste Management Area

As described in Section 3.1, past cathode waste management activities were concentrated near the northeast corner of the process building. Included within the former cathode waste management area are the metal pad storage area, the bath recovery area, the salvage area, the cathode wash area, the potliner handling area, and the old cathode waste pile (Figure 3.8). The north ditch borders the metal pad storage area and the River Road curb bounds the former cathode waste management area to the west. The specific waste management activities conducted in these areas are described in Section 3.1. The characterization of the cathode waste management area is described below.

3.2.2.1 Metal Pad Storage Area

One composite (March 1986) and four grab soil samples (June 1987) were collected from the metal pad storage area, including a replicate. The grab samples were analyzed for sodium, fluoride, and total and free cyanide. For the grab samples, sodium concentrations ranged from 19,500 to 50,000 mg/kg; fluoride from 687 to 856 mg/kg; and free cyanide concentrations were less than the laboratory detection limit, which ranged from 0.50 to 0.52 mg/kg. Total cyanide ranged from 0.54 to 2.3 mg/kg. The composite sample (MPSA) was analyzed for free cyanide, sodium, and fluoride. Sodium was reported at a concentration of 10,100 mg/kg, and fluoride was reported at 465 mg/kg. Free cyanide was not detected in the grab or composite samples.

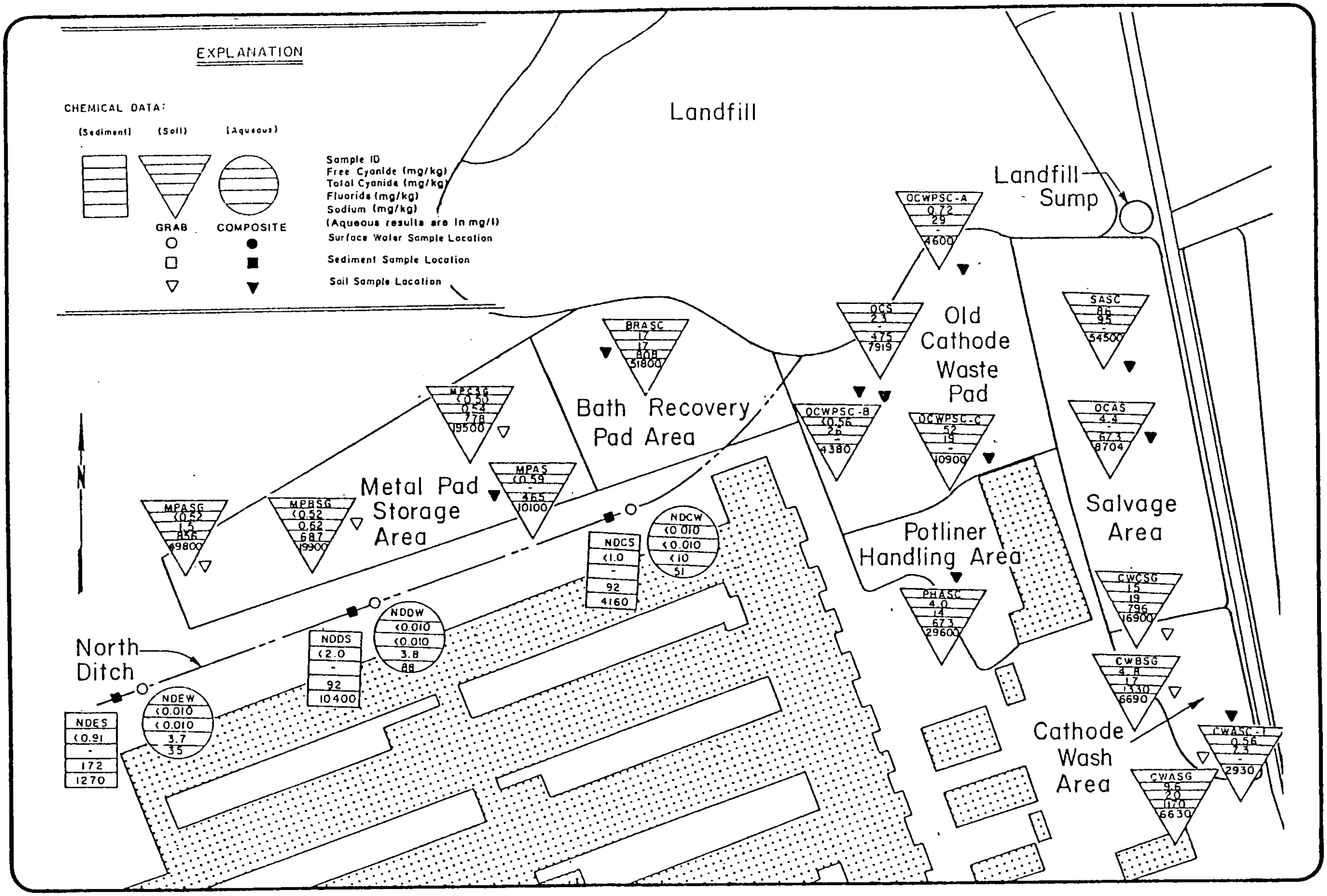


Figure 3.8 Sample Locations and Analytical Results - Former Cathode Waste Management Area.

CLIENT NAME:

Martin Marietta Corporation

3.2.2.2 Bath Recovery Pad Area

One composite sample of surficial soils was collected from the bath recovery area in June 1987; the analyses reported elevated levels of sodium (51,800 mg/kg), fluoride (808 mg/kg), total cyanide (17 mg/kg), and free cyanide (17 mg/kg).

3.2.2.3 Salvage Area

Two composite soil samples were collected from the salvage area, a composite from the surficial soils (March 1986), and a composite from test pit SA-A (June 1987). Visual examination of the four test pits dug in the salvage area indicate the presence of a thin zone of cathode waste material concentrated below a 6-in layer of soil. The composite sample of the salvage area surficial soils contained levels of free cyanide (4.4 mg/kg), fluoride (67.3 mg/kg), and sodium (8704 mg/kg). The composite sample from the test pit indicated higher free cyanide (86 mg/kg) and sodium (54,500 mg/kg), as well as concentrations of total cyanide (196 mg/kg).

Perched water was encountered in one of the test pits excavated in the salvage area. A shallow well (OW-4) had been previously installed by Century West (1983) in the perched water. Historical data from this well (Appendix A) reported the presence of cyanide and fluoride in the perched water.

A shallow sump was installed in test pit SA-D to collect samples of perched water in the salvage area. The sump has been evacuated periodically (generally weekly) and samples collected for analysis of total and free cyanide and fluoride. Test pit SA-D yields very little water (one gallon or less) and has been essentially dry since October 15, 1987.

Fluoride concentrations in water evacuated from the sump are about 300 mg/L, total cyanide concentrations are about 100 mg/L, and free cyanide concentrations range from 0.365 to over 10 mg/L.

3.2.2.4 Cathode Wash Area

A total of four soil samples were collected in June 1987 from the cathode wash area (Figure 3.8). Three of the samples were grab samples of surficial soils and one sample was a composite from test pit CWA-A (Sample CWASC-1). The samples were analyzed for total and free cyanide, fluoride, and sodium. The analytical results reported levels of total cyanide (7.3 to 20 mg/kg), free cyanide (0.56 to 15 mg/kg), fluoride (796 to 1,330 mg/kg), and sodium (2,930 to 16,900 mg/kg).

3.2.2.5 Potliner Handling Area

At the potliner handling area, cathodes were crushed and loaded onto rail cars for off-site shipment. Scattered pieces of cathodic material and pitch and coke are visible at the potliner handling area.

Two composite soil samples, including a replicate, were collected from this area in June 1987 and analyzed for total and free cyanide, fluoride, sodium, and PAHs. Concentrations of total cyanide (14 and 16 mg/kg), free cyanide (4.0 and 4.8 mg/kg), fluoride (673 and 898 mg/kg), and sodium (28,600 and 29,600 mg/kg) were reported. Concentrations of individual PAHs ranged from 274 to 1,800 mg/kg.

3.2.2.6 Old Cathode Waste Pile

One composite sample of surficial soils (OCS) was collected in March 1986 from the old cathode storage area and analyzed for free cyanide, sodium, and fluoride. Four test pits were excavated in the old cathode waste pile area in June 1987 (Figure 3.2). Composite soil samples (OCWPSC-A, B, and C) collected from three of the test pits were analyzed for total and free cyanide and sodium. The analytical results for the test pit soils reported concentrations of total cyanide (19 to 29 mg/kg) and sodium (4,380 to 10,900 mg/kg). Free cyanide was reported at 0.72 mg/kg at test pit OCWP-A and 5.2 mg/kg at test pit OCWP-C, but was reported at less than the laboratory detection limit of 0.56 mg/kg at test pit OCWP-B. Visual examination of the test pits indicated a thin zone of cathodic waste material below a 2- to 4-inch-thick layer of clean soil.

In test pits OCWP-B and OCWP-D, a saturated zone (perched water) was encountered and sumps were installed in these test pits. An aqueous sample was collected from pit OCWP-B and analyzed for total and free cyanide, fluoride, sodium, and base/neutral and acid extractable organics. The analytical results reported levels of total cyanide (294 mg/L), free cyanide (3.01 mg/L), fluoride (3,000 mg/L), sodium (10,500 mg/L), and PAHs (summed at 0.255 mg/L). Two additional samples were collected from the test pit OCWP-B sump. One sample was filtered and the other was not filtered and both were analyzed for PAHs. PAHs were not detected in either sample.

The test pit sumps have been evacuated periodically (generally on a weekly basis) and samples collected from each sump have been analyzed for total and free cyanide and fluoride. Test pit OCWP-D consistently produces about 10 gallons before being pumped dry. Fluoride concentrations are about 2,000 mg/L, total cyanide 300 mg/L, and free cyanide about 2 to 8 mg/L. Total volumes pumped from test pit OCWP-B have declined with time. In August 1987, volumes pumped before dewatering the sump were on the order of 10 to 15 gallons. During September 1987, volumes pumped before dewatering were between 5 and 10 gallons, declining to about 0.5 gallons by the end of October 1987. Fluoride concentrations in the sump water sample ranged from 1,300 to 1,500 mg/L during August and declined to about 700 to 800 mg/L by October. Total cyanide concentrations remained relatively constant at about 300 mg/L. Free cyanide concentrations generally declined from about 6 mg/L in August to about 2 mg/L in October.

3.2.2.7 River Road Curb

A composite soil sample (RRBS) was collected from the River Road curb area in March 1986 (Figure 3.6), and was analyzed for free cyanide, fluoride, and sodium. Free cyanide was reported below detection limits. Sodium (1,480 mg/kg) and fluoride (166 mg/kg) were reported to be present.

3.2.3 Scrubber Sludge Management Areas

3.2.3.1 Drainage Ditch

Five sediment samples collected in March 1986 from the drainage ditch were analyzed for free cyanide, sodium, and fluoride (Figure 3.9). Free cyanide ranged from <0.74 to 3.2 mg/kg; fluoride from 271 to 926 mg/kg; and sodium from 1,070 to 15,400 mg/kg.

3.2.3.2 Scrubber Sludge Ponds

Ten composite sediment samples were collected in March 1986 from the scrubber sludge ponds (Figure 3.9). Each composite was prepared from a hand-auger boring advanced through 10 ft of the scrubber sludge, or to the base of the sludge if it was less than 10-ft thick. Each composite

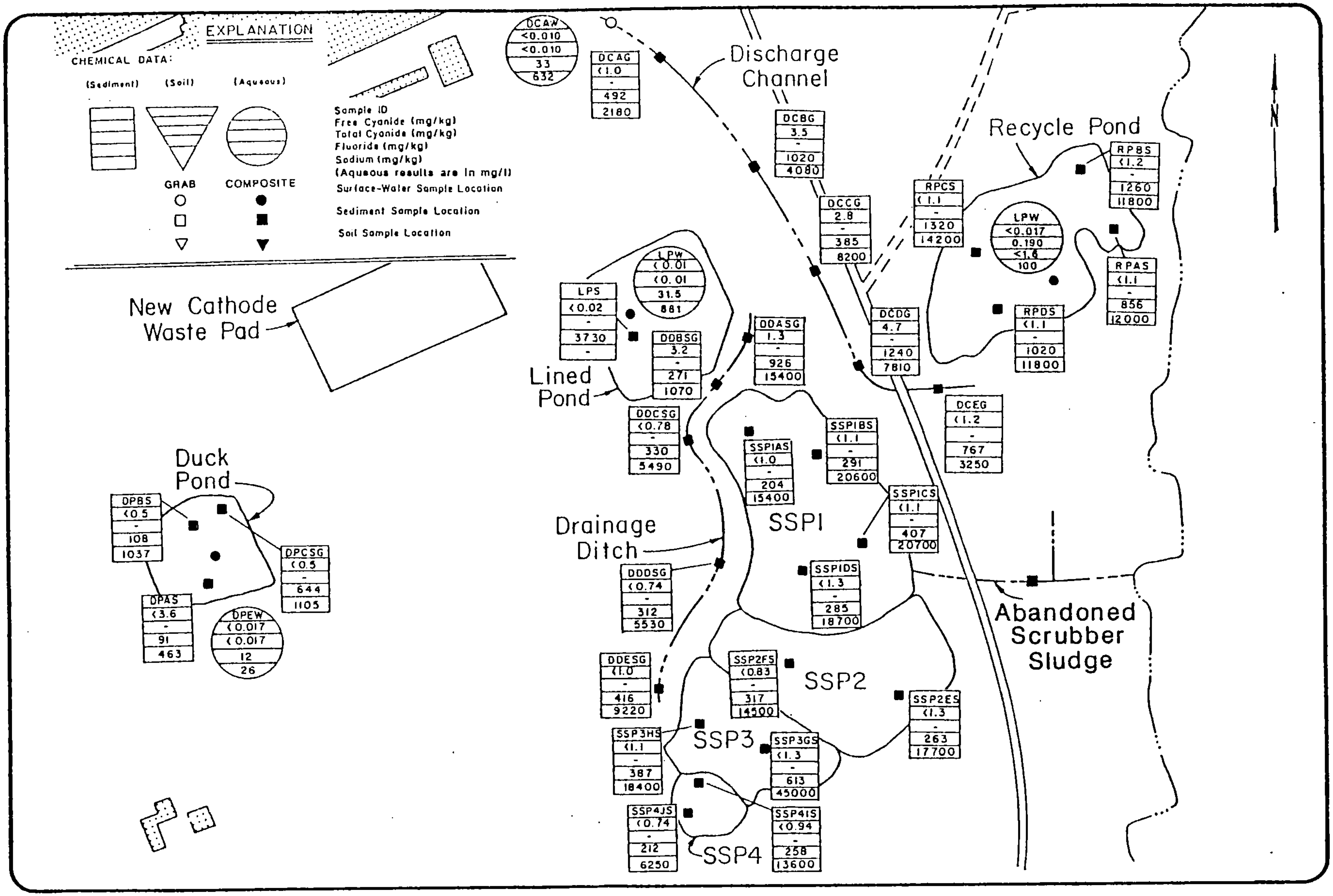


Figure 3.9 Sample Locations and Analytical Results

CLIENT NAME:

Martin Marietta Corporation

sample was analyzed for free cyanide, fluoride, arsenic, sodium, VOCs, base/neutrals, and acid extractables. PAHs (individual concentrations ranging from 120 to 2,000 mg/kg), sodium (6,250 to 45,000 mg/kg), fluoride (204 to 613 mg/kg), and arsenic (<12 to 77 mg/kg) were reported as present in the scrubber sludge pond sediments. Free cyanide was not detected in any of the scrubber sludge pond samples.

3.2.3.3 Old NPDES Discharge Channel

The primary potential source of site-derived constituents in the old NPDES discharge channel, if present, is from the abandoned scrubber sludge channel. Therefore, in order to evaluate this area, a composite sample was collected from the abandoned scrubber sludge channel above and below the confluence with the old NPDES discharge channel.

3.2.3.4 Abandoned Scrubber Sludge Channel

A composite soil sample was collected from the abandoned scrubber sludge channel and analyzed for base/neutral and acid extractable organic compounds. None were detected.

3.2.4 North Ditch

Three surface-water samples collected in March 1986 from the north ditch (Figure 3.8) were analyzed for PCBs, VOCs, base/neutral and acid extractable organics, free and total cyanide, sodium, fluoride, EP toxicity metals, total arsenic, and sulfate. Three additional surface-water samples were collected in September 1986 from this ditch and were analyzed for total and free cyanide.

No PCBs, VOCs, acid extractable organics, free cyanide, or arsenic were reported in surface water from the north ditch. One base/neutral extractable, bis 2-ethylhexyl phthalate, a chemical widely distributed throughout the environment, was reported in one of the samples. All EP toxicity test results for metals were below levels used to classify a waste as hazardous by EP toxicity.

Sodium (35 to 88 mg/L) and sulfate (33 to 37 mg/L) were reported as present in the samples. Fluoride was reported in two samples at concentrations of 3.7 and 3.8 mg/L; fluoride concentrations in the third sample were reported at <10 mg/L. Total cyanide was reported as present in the three samples collected in March 1986 at concentrations of from 0.037 to 0.39 mg/L. However, these samples were not screened for sulfide interference and the results were invalidated. No total or free cyanide was reported in additional surface-water samples collected from the north ditch in September 1986.

Three composite sediment samples were collected in March 1986 from the north drainage ditch. Each composite was analyzed for free cyanide, fluoride, sodium, and EP toxicity metals. Free cyanide was not detected in the samples. Sodium (1,210 to 10,400 mg/kg) and fluoride (92 to 172 mg/kg) were reported in all samples. EP toxicity metals were not present above levels used to classify a waste as hazardous by EP toxicity.

3.2.5 Duck Pond

A total of nine surface-water samples were collected in March 1986 from the duck pond (Figure 3.9) and analyzed for PCBs, VOCs, base/neutral and acid extractable organics, free and total cyanide, sodium, fluoride, EP toxicity metals, arsenic, and sulfate. All analytical results for PCBs, VOCs, acid extractable organics, total and free cyanide, and arsenic were below laboratory detection limits. The base/neutral extractable bis-2-ethylhexyl phthalate, a chemical widely distributed throughout the envvironment, was reported in three of the nine samples. Sodium (21 to 33 mg/L), fluoride (11 to 13 mg/L), and sulfate (42 to 43 mg/L) were reported as present in all samples. EP toxicity test results for metals were below applicable standards.

Cyanide (total or free) was not detected in surface-water samples collected in March 1986 from the duck pond, but the analyses were invalidated due to a failure to screen for sulfides (Appendix D). The duck pond was resampled in September 1986 and one composite water sample was collected and analyzed for total and free cyanide. No cyanide was reported as present in this sample.

Four sediment samples, two composite and one grab, and a replicate were collected from the duck pond (March 1986) and analyzed for free cyanide, fluoride, and sodium. Sodium (311 to 1,105 mg/kg) and fluoride (76 to 644 mg/kg) were reported as present; free cyanide was not detected.

3.2.6 Operating Units

Several areas originally included in the RI are currently being used by Northwest Aluminum as part of their operations. These units include the discharge channel, the recycle pond, and the lined pond. The characterization of these operating units made during the RI is described below.

3.2.6.1 Discharge Channel

A surface-water sample was collected from the discharge channel in March 1986 (Figure 3.9), while the plant was not operating, and analyzed for PCBs, VOCs, base/neutral and acid extractable organics, free and total cyanide, sodium, fluoride, and EP toxicity metals. All analytical results for PCBs, VOCs, base/neutral and acid extractable organics, and

EP toxicity metals were below laboratory detection limits, but free cyanide (0.06 mg/L), total cyanide (6.5 mg/L), sodium (632 mg/L), and fluoride (33 mg/L) were reported as present in the sample. A second surface-water sample was collected in August 1986, also when the plant was not operating, and analyzed for free and total cyanide. No cyanide was detected.

Five composite sediment samples were collected in March 1986 from the discharge channel and analyzed for free cyanide, sodium, fluoride, EP toxicity metals, VOCs, acid extractable organics, and base/neutral extractable organics. The only organic compounds detected were PAHs (concentrations of individual PAHs ranged from 10 to 1,540 mg/kg). Two of the samples (DCDG and DCEG) exceeded holding times for VOCs (Appendix D). Additional sediment samples were collected at these locations in September 1986 and analyzed for VOCs; none were detected. Sodium (2,180 to 8,200 mg/kg), fluoride (385 to 1,240 mg/kg), and free cyanide (<1.0 to 4.7 mg/kg) were reported as present. EP toxicity metal concentrations were less than levels used to classify a waste as hazardous by EP toxicity.

3.2.6.2 Recycle Pond

Ten composited surface-water samples from the recycle pond were collected in March 1986 (Figure 3.9), while the plant was not operating, and were combined to create one composite sample for analysis for PCBs, base/neutral and acid extractable organics, EP toxicity metals, cyanide (total and free), sodium, fluoride, arsenic, and sulfate. No free cyanide, arsenic, PCBs, base/neutral and acid extractables, or EP toxicity metals were detected; total cyanide (0.190 mg/L), sodium (100 mg/L), sulfate (94.4 mg/L), and fluoride (21.6 mg/L) were reported as present.

A separate sample for VOC analyses was collected at each of the ten sampling stations. No VOCs were detected.

The analytical results for cyanide from the March 1986 samples were invalidated due to a failure to screen for sulfides. An additional composite water sample of the recycle pond was collected in August 1986 and was analyzed for total and free cyanide; total cyanide was reported as present at a concentration of 0.02 mg/L, while free cyanide was below the detection limit.

Four composite sediment samples were collected from the recycle pond in March 1986 and analyzed for free cyanide, fluoride, sodium, EP toxicity metals, VOCs, base/neutral and acid extractable organics, and PCBs. Fluoride (856 to 1,320 mg/kg), sodium (11,800 to 14,200 mg/kg), and PAHs (individual PAH concentrations ranged from 98 to 2,410 mg/kg) were reported as present. Holding times were exceeded for the PCBs and the base/neutral and acid extractable organics and six additional composite samples were collected in September 1986 and analyzed for these parameters. No PCBs were detected; PAHs were reported as present at individual concentrations from 52 to 1,100 mg/kg.

3.2.6.3 Lined Pond

Nine composited surface-water samples were collected from the lined pond in March 1986 (Figure 3.9), while the plant was not operating, and were combined by the laboratory to create one composite sample for analysis. This composite was analyzed for PCBs, base/neutral and acid extractable organics, total and free cyanide, sodium, fluoride, arsenic, and sulfate. All results were reported at less than detection limits except for sodium (881 mg/L), fluoride (31.5 mg/L), arsenic (0.039 mg/L), and sulfate (2,360 mg/L).

A separate sample for VOC analyses was collected at each of the nine sampling stations. No VOCs were detected.

The March 1986 analyses for total and free cyanide were invalidated due to a failure to screen for sulfides, and the lined pond was resampled for these parameters in September 1986. No cyanide (total or free) was detected in these samples.

One composite sediment sample was collected from the lined pond in March 1986 and analyzed for free cyanide, fluoride, EP toxicity metals, VOCs, base/neutrals, PCBs, and acid extractables. PAHs (individual concentrations ranging from 19 to 2,120 mg/kg) and fluorides (3,730 mg/kg) were reported as present. No VOCs, acid extractables, PCBs, or free cyanide were detected. EP toxicity metal concentrations were lower than the levels used to classify a waste as hazardous by EP toxicity.

3.3 CHEMICAL CHARACTERISTICS

The behavior of a chemical in the environment is determined by both its physio-chemical properties and external environmental characteristics. This section discusses general physical-chemical properties as they relate to potential fate and transport mechanisms relevant to the primary constituents of potential concern (cyanide, PAHs, fluoride, sodium, and sulfate) reported as present in wastes or environmental media sampled at the MMRF. Appendix B (Section B.4.1) will relate these potential mechanisms to site-specific environmental factors in order to determine the influence of certain mechanisms on the past and future migration of waste constituents.

3.3.1 Cyanide

The term cyanide, as used here, refers to the class of inorganic compounds containing the CN functional group. Cyanide at the MMRF is found as a by-product of the alumina reduction process. High temperatures achieved during the reduction process produce a reaction between carbon in the cathode and ambient nitrogen and result in the formation of inorganic cyanide compounds in the potliner.

Inorganic cyanides contain compounds with widely varying physical/chemical and toxicological properties. As a result, inorganic cyanides are often classified as free, simple, or complexed. Hydrogen cyanide (HCN) is a weak acid and can dissociate in water into its corresponding conjugate base or anion (CN^-). Together, these two species (HCN and CN) are referred to as free cyanide. The term free cyanide used in this report includes these two species as well as weak acid dissociable cyanide (Appendix D).

Under most environmental conditions, the form of free cyanide encountered in water will be hydrogen cyanide (HCN). HCN is a volatile compound and can be expected to exist in the gaseous state in the environment. This implies that HCN may be more mobile in the environment since it can volatilize from the soil or water, or hydrolyze to form the CN^- ion.

The simple cyanides are comprised of cyanide salts (metal bound to the cyanide anion) with widely varying solubilities. Alkali and alkaline earth cyanides such as sodium and barium cyanide dissolve readily in water, whereas transition metal cyanides such as nickel and copper cyanide have low solubilities and are more stable.

Complex cyanides are compounds in which cyanide (as CN) is covalently bound to a metal, forming a large "complex" with a negative charge (anion). Such anions can subsequently bind with a metal of positive charge (cation). Sodium ferrocyanide, $Na_4[Fe(CN)_6]$, is an example of a compound in this class. In addition, iron, gold, cadmium, copper, nickel, silver, and zinc have been found to form metallocyanide complexes (Fuller, 1977). Metallocyanide complexes have varying stabilities and when they dissociate in water can release free cyanides. The cadmium and zinc complexes are found to readily dissociate in water while the stability of copper and nickel cyanide complexes depends on pH. Iron and cobalt cyanide complexes are very stable (U.S. EPA 1985a; Callahan, et al, 1979). The solubility of iron cyanide depends on the complex. For example, the ferric salt of ferricyanide, or prussian blue, $Fe_4[Fe(CN)_6]_3$, is insoluble, whereas the sodium salt of ferrocyanide, $Na_4[Fe(CN)_6]$, is 10% soluble in water by weight (American Cyanamid, 1953).

Biological utilization of cyanide in soil has been studied by a number of authors (Raef, et al, 1977a,b; Strobel, 1967; Ware and Printer, 1955). Both anaerobic and aerobic degradation of cyanide can occur with the ultimate breakdown products being carbon dioxide (CO_2) and ammonia (NH_3). In the aerobic microbial environment, cyanide first undergoes enzymatic conversion to cyanate, which is then converted to carbon dioxide and ammonia (VanZyl, 1985). The rate at which such biodegradation occurs will be highly variable and will depend on many factors including the types of microbial colonies present and the nature and concentration of the waste. Activated sludge, which consists of acclimated microorganisms, is used to degrade cyanide waste, although Fuller (1977) reported that these microorganisms are sensitive to the quantity of cyanide present in the waste. Towill, et al, (1978) concluded that microorganisms should be used in the treatment of cyanide wastes and in the purification of aquatic environments containing such waste.

In evaluating the fate and transport of cyanides in this section of the report and their potential impacts in later sections, it is necessary to consider the form in which cyanide is likely to be present in potliner wastes and how the soil environment will influence its fate and transport. First, cyanide can be present as an iron cyanide complex formed during the electrolytic smelting process. Spent potliner can contain between 0.3 and 2.8% iron (Hurt, 1981). Since free cyanide is also present in this matrix, it can react with available iron to form various iron cyanide complexes. Secondly, any free cyanide that is present in the spent potliner can react with any iron or other metals present in the soils to form a relatively stable complex. For example, the soils at the MMRF are formed from basalt, a rock containing high concentrations of iron. Thus, any free cyanide migrating from the waste could react with naturally occurring iron to form a stable iron cyanide complex.

Iron cyanide complexes vary in solubility and undergo complex attenuation reaction in soil. In addition, they are also relatively stable and not readily degraded. It is likely that any free cyanide that is present in the soil could volatilize from the soil, react with the minerals to form a more stable complex, or become biodegraded by the microorganisms present in the soil. These relationships are supported by the analytical data, presented in detail later in the report, which show that most of the cyanide is present at the MMRF site as total cyanide and not as free cyanide. The mobility of cyanide in the type of soil present at the MMRF site is discussed in Appendix B, Section 4.1.

Once in the soil, the cyanide may be present as complexes that are soluble in the ground water. Based on analyses of MMRF site ground-water samples by Rocky Mountain Analytical Laboratory (RMAL) for iron cyanides (Enseco, 1987), it is estimated that total iron cyanides may comprise up to 40 percent of the total cyanide present, while free cyanide may comprise 1 to 6 percent of the total cyanide present. The pH of the ground water has been found to range from approximately 7 to 9. Within this range, any free cyanide will be present predominantly as HCN. The cyanide that is present in the ground water is expected to be mobile based on the soil characteristics which would favor retardation of its movement only at low pH.

As discussed in other sections of this report, some of the ground water in the S aquifer may discharge into the Columbia River. The fate of cyanide in the river would depend on the type of cyanide present upon discharge. Volatilization of free cyanide is an important process in determining the fate of this chemical in surface-water bodies. Cyanide has been reported to volatilize at a rate of 0.021 mg CN/ft^2-hr (temperature unknown) from still surface-water bodies containing a concentration range of 0.1 to 0.5 mg/L (VanZyl, 1985). This attenuation mechanism would be of far less importance at pH values greater than 9.2, since the solvated CN^- ion is not as volatile as HCN.

Cyanide may also be discharged into surface-water bodies as an iron cyanide complex. Both ferro- and ferricyanide complex anions, ($Fe[CN]_6^{-4}$ and $Fe[CN]_6^{-3}$, respectively), are of particular interest in surface-water environments since it has been shown that ferricyanide, or ferrocyanide once it has been oxidized to ferricyanide, photochemically liberates free cyanide. The rate of this photolysis in natural water bodies will be extremely variable and will depend on such factors as the turbidity of the water and the intensity and duration of the sunlight.

In summary, cyanides in the environment are capable of a wide range of behavior including solubility and migration in ground water; volatilization from soil and surface water;

complexation with other chemicals; photolytic transformations; and microbial degradation. The potential significance of these behaviors in determining the site-specific past and future migration of chemicals at this site are discussed in detail in Appendix B.

3.3.2 Polynuclear Aromatic Hydrocarbons

The term polynuclear aromatic hydrocarbons (referred to as PAHs or PNAs) describes a diverse class of chemicals consisting of two or more fused benzene rings, which vary widely in arrangement. PAHs are chiefly formed from the combustion of organic material. They are present in scrubber sludge wastes at the MMRF, captured from emissions generated during anode preparation or electrolytic reduction. The anode that is sacrificed during the reduction process consists of briquettes produced from a variable mixture of petroleum pitch and coke. The PAHs in the scrubber sludge ponds consist primarily of the 4- and 5-membered ring compounds (e.g., fluoranthene, pyrene, chrysene, and benzo (b & k) fluoranthenes), although other PAHs, including benzo(a)-pyrene, are also present.

The physical properties of PAHs, which in turn affect their mobility in the environment, depend greatly on the size and shape of the molecule. Properties such as vapor pressure and solubility vary widely within the class and can be correlated with molecular weight.

The lower molecular weight PAHs, such as naphthalene, acenaphthylene, acenaphthene, and fluorene, have relatively high solubilities, and therefore would migrate from soils into the ground water. The higher molecular weight PAHs, with high organic carbon partition coefficients (Koc) and low aqueous solubilities (such as benzo[a]pyrene), tend to be adsorbed onto soil or particulate surfaces and do not readily migrate. For this reason, soil erosion, surface runoff, and wind dispersion of particulates are potential mechanisms of migration for these chemicals.

All of the PAHs are capable of undergoing photolytic transformations in the environment, and their degradation half-lives vary widely. These transformations would be restricted to the PAHs near the surface and would not likely result in considerable degradation in wastes or sludges at lower depths.

Biodegradation of PAHs does occur in the environment. In general, the di- and tricyclic PAHs are more readily biodegraded than the tetracyclic and higher polycyclic hydrocarbons (Tabak, et al, 1981). Biodegradation is dependent on numerous factors such as the species of microorganism, availability of nutrients, presence or absence of oxygen, degree of acclimation, nature of the medium, concentration of the chemical, temperature, and pH.

In summary, the PAHs may not pose a problem to ground-water supplies or to surface-water bodies into which ground water discharges. The PAHs contained in concentrated waste streams would be expected to be resistant to biodegradation. Dust dispersion of tightly bound compounds may be considered a significant mechanism of migration.

3.3.3 Fluoride

Fluoride (F) most probably is present at the MMRF because of the molten fluoride salts, such as cryolite and calcium fluoride, used in the reduction process. Gaseous fluoride emissions from the manufacture of aluminum include hydrogen fluoride and silicon tetrafluoride, while particulate fluoride emissions include cryolite, aluminum fluoride, calcium fluoride, and chiolite (NRC, 1971). In addition, the fluoride composition of spent potliner can range between 7.5 and 22 percent (Hurt, 1981).

Fluoride is the monovalent anion of the element fluorine, the most reactive element in the periodic table. Fluoride exists in soils and natural waters. Basalt formations of the type found at The Dalles can contain on average up to 470 ppm (parts per million) fluoride (U.S. Geological Survey, 1975), and ground-water supplies in the area are known to contain approximately 2 mg/L of naturally occurring fluoride.

Fluoride forms simple compounds with metals and many complex ions. Many inorganic fluorides, such as sodium fluoride, are rapidly hydrolyzed and are very soluble in water; others, such as fluorapatite are less soluble. The solubilities of sodium fluoride, and calcium fluoride at 18°C are 42,000 mg/L and 16 mg/L, respectively (Weast, 1978). Thus, the presence of calcium would tend to reduce the mobility of fluoride.

Fluoride salts present as particulates in surface materials can migrate by wind dispersion or with surface runoff during rainfall events. The salts that are present in these materials may not be readily soluble and would not be expected to migrate to the ground water. These airborne salts may, however, be sodium fluoride recrystallized upon water evaporation, which would readily dissolve when deposited in an aqueous area.

3.3.4 Sodium

Sodium is a component of the cryolite (Na_3AlF_6), which in the molten state functions as the electrolytic medium during the reduction of alumina. Sodium (Na) is found in the +1 oxidation state in the environment. Because of the ease of removal of its single outer shell electron, sodium is exclusively monovalent in its compounds. Like the other alkali metals, sodium forms compounds with virtually all the anions, organic as well as inorganic. Sodium ranks as the sixth most common element occurring in the earth's crust, with an average of 3.27 weight percent Na_2O reported in basalts (U.S. Geological Survey, 1975).

In their evaluation of the potential of clay minerals for attenuating landfill leachate, Griffin, et al, (1976) found that sodium attenuation was relatively low, only 15.4 percent. The attenuation of sodium follows the general order of cation replaceability in soils: $Li^+ < Na^+ < K^+ < Cs^+$. Studies comparing the exchange of mono-, di-, and trivalent cations on clay have shown that cations of higher charge are more tightly bound (Bolt and Bruggenwert, 1976). Thus, sodium is likely to be mobile in the soil environment and should migrate with the ground water.

3.3.5 Sulfate

Sulfate is a by-product of the alumina reduction process and is associated with cathodic waste material and scrubber sludge. Sulfate (SO_4^{2-}), a divalent anion, is found as a free anion or associated with cations in minerals. The dissolution of these minerals will result in the introduction of sulfate ions into the environment. The solubility of sulfate salts (the form in which sulfate is generally found) varies. The sodium, potassium, and magnesium salts are readily soluble in water and thus the presence of these salts would result in the introduction of sulfate into the ground-water regime (U.S. Environmental Protection Agency, 1985b). Aluminum, calcium, and iron salts form under oxidizing conditions. Their solubility and hence their stability is dependent on the soil conditions (Kabata-Pendias and Pendias, 1984). The ferric sulfate salt would release sulfate under reducing conditions, for example. Barium and lead sulfates are insoluble and should, therefore, tend to hinder sulfate transport (NRC, 1977).

The more common sulfate salts are water-soluble and generally remain dissolved once they are introduced into surface waters and ground water. Thus, under oxidizing conditions, sulfate tends to be very mobile. Under reducing conditions in ground water or sediments, however, sulfate is reduced to sulfide. The sulfide anion can then react with heavy metal cations to form insoluble precipitates, or it can form hydrogen sulfide (H_2S) which can volatilize to the atmosphere (NRC, 1977). Thus, reducing environments will reduce the sulfate burden in the environment but not the sulfide burden since salts will be present in a reduced form.

3.3.6 Arsenic

Arsenic is an impurity in pitch and is associated with cathodic waste material. Arsenic (As) has four stable oxidation states, +5, +3, 0, and -3. The oxidized forms, As(V) and As(III), are the most common under environmental conditions. The free element As(0) is rarely found, and the reduced form As^{-3}, occurs only when the Eh is very low (Callahan, et al, 1979). Metal arsenates $(AsO_4)^{-3}$ and arsenite $(AsO_3)^{-3}$ are formed with calcium, magnesium, and other uni- or divalent cations. In the environment, as a solution or soil becomes more anaerobic, arsenate will be reduced to arsenite. In this study, total arsenic measurements were taken, which would include both the oxidized and reduced forms.

Arsenate can form relatively insoluble complexes with a variety of cations; consequently, its solubility depends on the ionic composition of the water. Barium is the cation that produces the least soluble arsenate complex and is likely to control arsenic concentrations to very low levels. In the absence of barium, other metal arsenate complexes will control arsenic transport.

In addition to removal by precipitation of salts, arsenic is removed from solution by adsorbing to iron and aluminum oxides. Adsorption to iron oxide should be favored by low pH levels (Lemmo, et al, 1983). Arsenic can also complex with dissolved organic matter having low molecular weight. As a result of these processes, typical concentrations of arsenic in fresh water are at ug/L levels (Woolson, 1977).

The fate of arsenic in soils depends on the adsorption of arsenic to soil particles. Korte, et al, (1976) found that clay content, surface area, and free iron oxide content of soil could be used to predict sorption. Because the potliner material at the MMRF has a high iron content, arsenic present in the areas containing potliner, such as the landfill, is likely to be relatively immobile. In addition, arsenic can undergo redox reactions under conditions found in some soils. In aerated soils, arsenate may be formed, while in flooded or nonoxidized soils, arsenite may be produced. Biological activity may contribute to the oxidation of As(III) back to As(V), and vice versa (Walsh, et al, 1977).

568/3

Section Four

4.0 HYDROGEOLOGIC INVESTIGATION

4.1 SURFACE SOILS

Surface soils at The Dalles are poorly developed and in most places are non-existent. A review of the soil survey for Wasco County, Oregon, published by the United States Department of Agriculture Soil Conservation Service (1982), indicates that four major native soil groups (Table 4.1) are present on distinct areas of the MMRF (Figure 4.1). These groups, in order of decreasing surface extent, are:

1. Rock Outcrop-Xeropsamments Complex,
2. Hesslan-Skyline Complex,
3. Van Horn Loam,
4. Quincy Loamy Fine Sand.

As shown on Figure 4.1, a large part of the native soils at the MMRF have been covered during construction and operation. In addition, the Port of The Dalles has filled a large area east of River Road.

4.1.1 Rock Outcrop-Xeropsamments Complex

This is the predominant soil complex at the MMRF. It extends from Chenoweth Creek south to the duck pond and scrubber sludge ponds and from Interstate 84 east to River Road. This area was previously part of the Columbia River channel but now constitutes a terrace above the river. Past stream action had scoured holes in the basalt beds and subsequently deposited sand and water-worn gravel. Numerous large and small outcrops of bedrock protrude from a few inches to as much as 15 ft above the soil and make up 50 to 75 percent of the complex. Where present, the soil is generally from 5 to more than 60 inches deep and consists mostly of sandy,

Table 4.1 Soil Summary

Soil Type	Maximum Thickness (inches)	Permeability	Erodibility
Rock Outcrop - Xeropsamments	60	High	Moderate
Hesslan-Skyline	16	Moderate	Slight to Moderate
Van Horn Loam	50	Moderate	Slight
Quincy Loamy Fine Sand	60	High	Slight

569/5

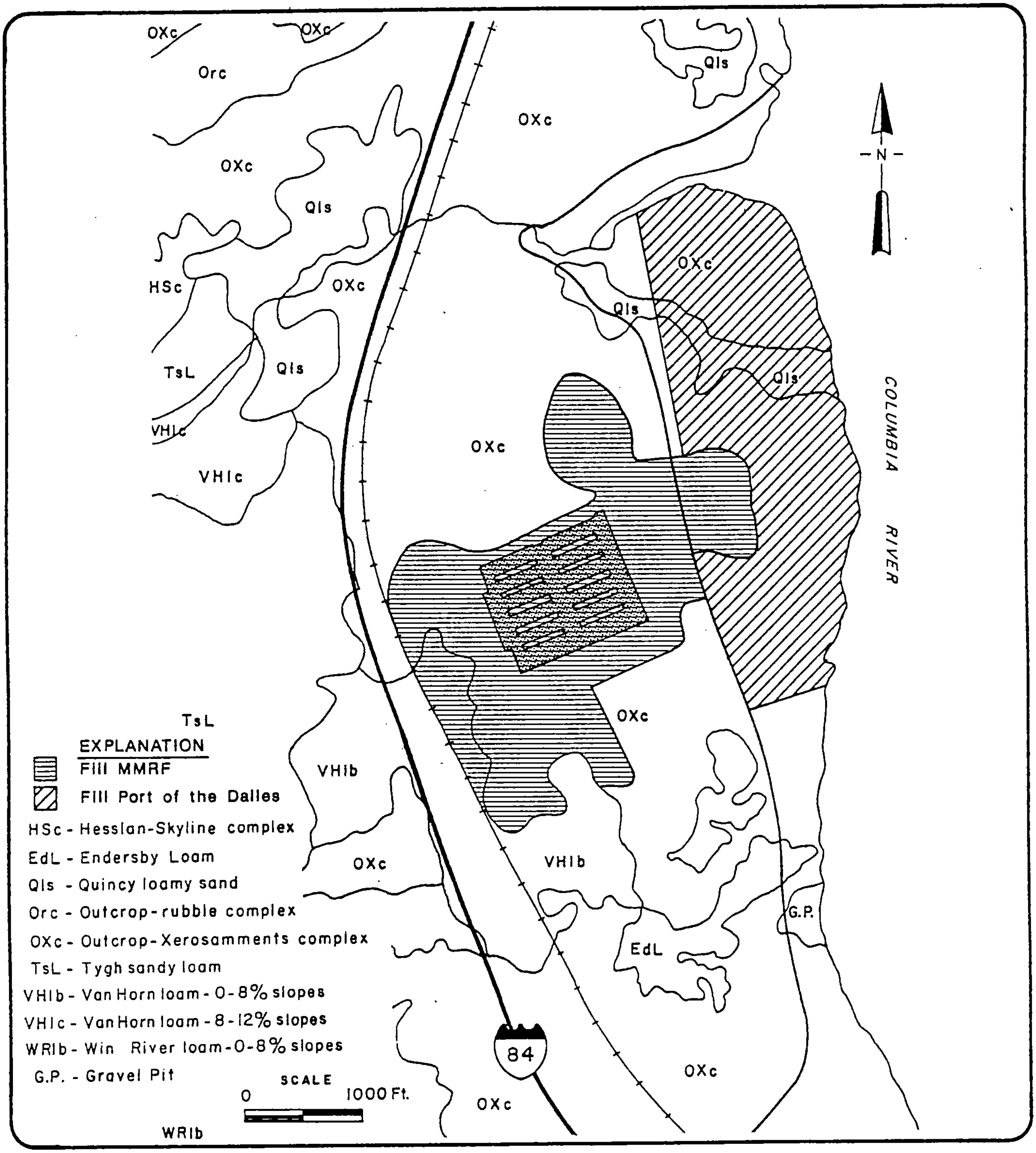


Figure 4.1 Soils Map.

CLIENT NAME:

Martin Marietta Corporation

light colored, water-laid and wind-laid material containing little organic matter.

4.1.2 Hesslan-Skyline Complex

The second largest soil complex mapped in the area extends east from River Road to the Columbia River, and south from Chenoweth Creek to the recycle pond. Most of this area has been subjected to excavation and grading and as a result, most of the native soils have been removed. Where present, the complex consists of well drained soil formed in loess, volcanic ash, and alluvium weathered from sandstone on uplands.

In a representative profile, the surface layer is a very dark grayish brown stony loam. The upper 9 inches of the subsoil is dark brown loam and the lower 5 inches is dark brown cobbled loam. Semi-consolidated sandstone is encountered at a depth of about 23 inches. The soil material throughout the profile is neutral and the permeability is moderate.

4.1.3 Van Horn Loam Complex

The third soil complex is located in the area of the duck pond, the recreation area, and the scrubber sludge ponds. Where the soil complex is fully developed, it consists of well-drained materials formed in stratified alluvial deposits on uplands.

In a representative profile, the surface layer is a very dark, grayish-brown and dark brown loam about 11 inches thick. The subsoil is a dark brown loam and clay loam about 38 inches thick. The substratum is dark brown loam 11 inches or more in thickness. The soil material in the profile is slightly acidic to neutral, the permeability is moderate, runoff is slow, and the hazard of erosion is slight.

4.1.4 Quincy Loamy Fine Sand

The fourth and smallest of the soil complexes is associated with the Chenoweth Creek and Chenoweth fault areas. This complex consists of soils formed in sandy alluvium from mixed material on bottom lands.

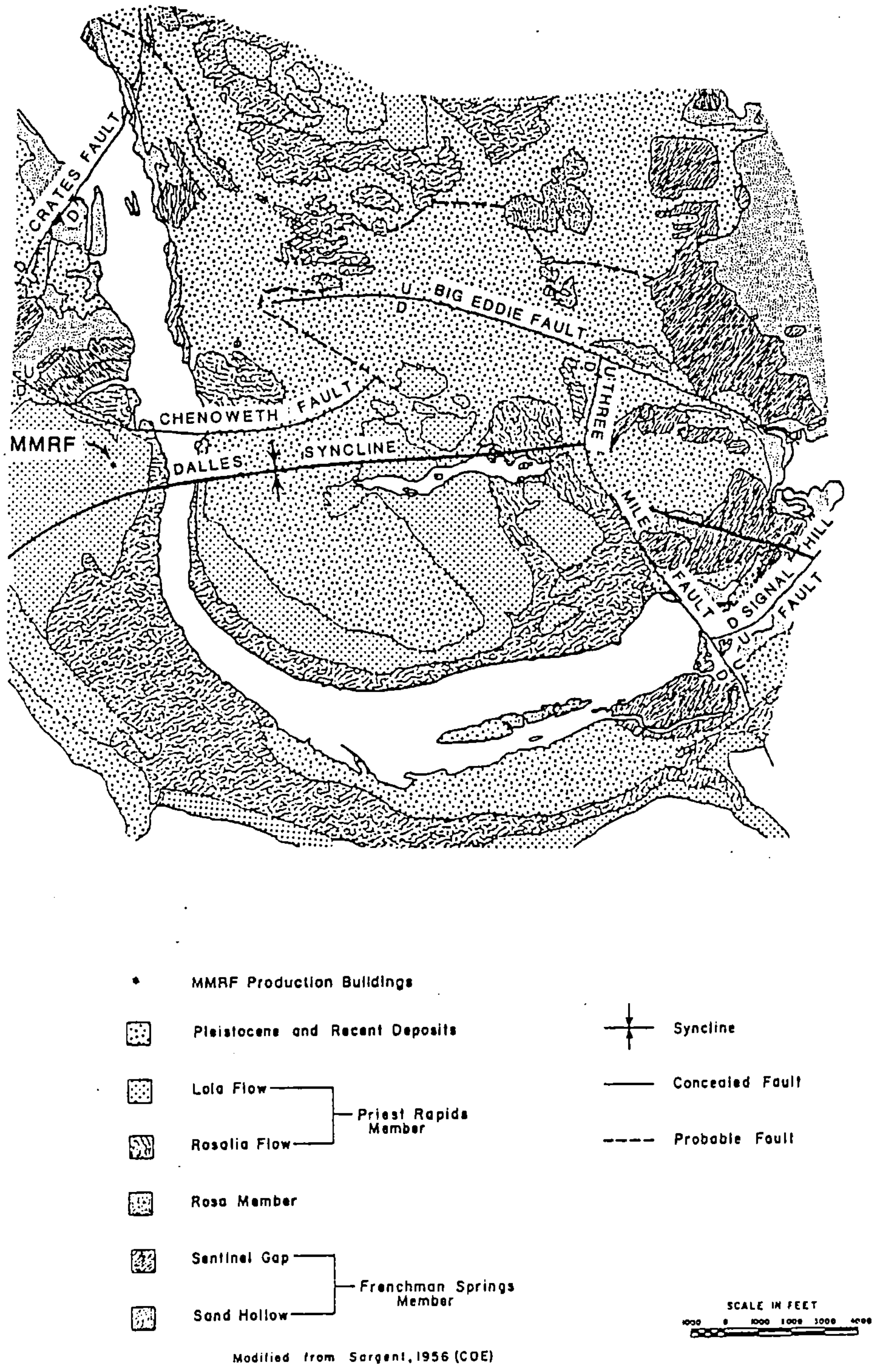
In a representative profile, the surface layer is very dark gray, loamy fine sand about 6 inches thick. The underlying material is very dark grayish-brown sand to a depth of 35 inches; the next 9 inches is dark gray, fine sand; and below this is dark gray, very fine sand to a depth of 60 inches or more. The surface layer is fairly acidic, and the underlying material is slightly acidic to neutral. Permeability is relatively high, runoff is slow, and the hazard of erosion is slight.

4.2 GEOLOGY

Two primary geologic units are present in the general study area, the Chenoweth Formation and the Columbia River Basalt Group (CRBG). Figure 4.2 is a geologic map of the area modified from that prepared by Sam Sargent of the Corps of Engineers. The map shows the distribution of CRBG basalt flows in the area and the distribution of alluvial deposits. The volcanoclastic deposits of the Chenoweth Formation, being restricted to the terraces, are located east of the area reproduced in Figure 4.2.

4.2.1 Regional Geology

The Columbia River Basalt Group is comprised of approximately 300 flood basalt flows that erupted from linear



Modified from Sargent, 1956 (COE)

Figure 4.2 Surficial Geologic Map of The Dalles Area.

CLIENT NAME:

Martin Marietta Corporation

fissures in the eastern third of the Columbia Plateau from about 17 to 6 million years ago. The total area of the CRBG has been calculated to be approximately 63,000 mi^2 (square miles) and the total volume to be 41,000 mi^3 (cubic miles) (Tolan, and others, 1987). Individual flows are typically tens of mi^3 to more than 100 mi^3 in volume. Some flows extend from the eastern part of the plateau all the way to the Pacific Coast. A detailed discussion of the regional and site geology is included in Appendix E.

4.2.2 Site Stratigraphy

The site stratigraphy presented in this report is based on the geologic samples from boreholes of production and observation wells at the MMRF, geologic maps (Bela, 1982; Sargent, 1956), and geologic mapping conducted during the RI. One drill hole (MW-16D) installed during the RI was continuously cored to a depth of 272 ft. The core was described lithologically, checked for magnetic polarity (top and bottom), and analyzed for chemical constituents (Appendix E). Cutting samples from 32 other drill holes installed during the RI were collected and described lithologically and lithologic descriptions of on-site production wells and pre-existing monitor wells are also available (Appendix E). Cutting samples selected for chemical analysis were hand-picked and ultrasonically cleaned. The chemical analyses (Appendix E) were performed by the X-Ray Fluorescence (XRF) laboratory at Washington State University in Pullman, Washington.

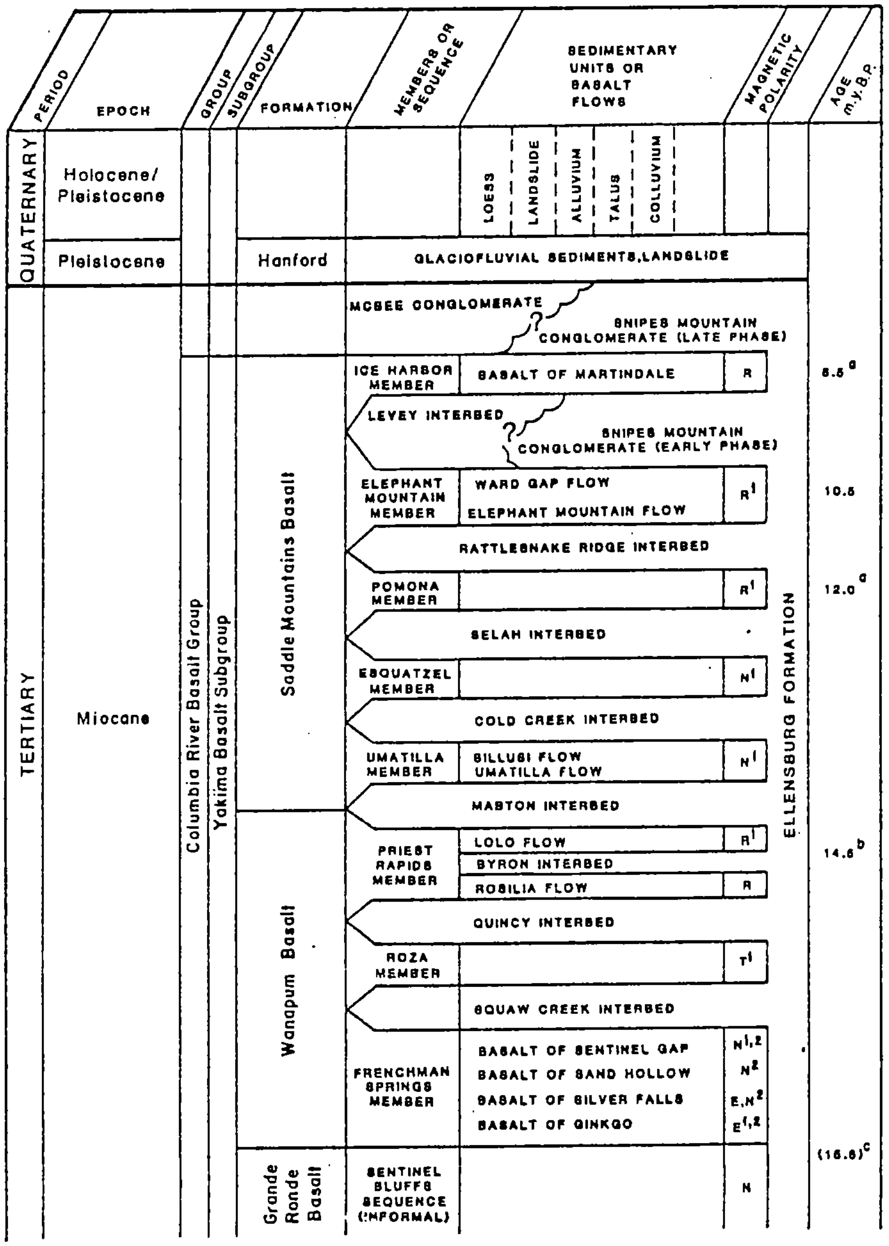
Samples from borehole MW-16D at the MMRF were analyzed for major oxides, magnetic polarity, and lithologic composition. These data were used to correlate the sequence identified beneath the MMRF with the CRBG stratigraphy. The sedimentary interbeds between the lava flows have been assigned names based on a stratigraphic column developed from measured sections near the center of the Columbia Plateau (Figure 4.3).

Correlations of the CRBG flows in the drill holes at the MMRF were initially based on the lithologic descriptions of the core and chip samples. Lithologic descriptions also allowed correlation of several irregular and crudely defined zones within the Rosalia flow. Confirmation of the original correlations was based on the results of the XRF analytical data (Appendix E) for 19 samples selected from the 9 chip-sample holes and for 6 samples from the core hole at MW-16D.

The 272-ft-deep core hole (MW-16D) provides a detailed base-line stratigraphic section (Figure 4.4) to which the other drill holes have been correlated. The stratigraphy identified and bed thickness at this borehole, from top to bottom, is as follows:

Lolo flow of Priest Rapids Member	54 ft
Sedimentary Interbed (Byron Interbed)	2.5 ft
Rosalia flow of Priest Rapids Member	141 ft
Sedimentary Interbed (Quincy/Squaw Creek)	25 ft
Sentinel Gap flow of Frenchman Springs Member	49+ ft

The Lolo flow is a slightly open-textured (diktytaxitic) to dense, coarse-grained basalt that contains some large plagioclase phenocrysts with few vesicles. In outcrop, this flow exhibits a blocky/columnar type of jointing. The joints are generally vertical and commonly contain clay or manganese oxide fillings. In the vicinity of The Dalles, the Lolo flow narrows to form a tongue extending westward toward Mount Hood.



N = normal magnetic polarity
R = reversed magnetic polarity
T = transitional magnetic polarity
E = excursional magnetic polarity
[1] magnetic polarities from Van Alstine and Gillett (1981)
[2] magnetic polarities from Besson et al. (1985)

[a] K-Ar dates from McKee et al. (1977)
[b] K-Ar dates from Watkins and Baksi (1974)
[c] Ar-Ar dates from Long and Duncan (1982)

Figure 4.3 Stratigraphy of the Columbia River Basalt Group.

CLIENT NAME:

Martin Marietta Corporation

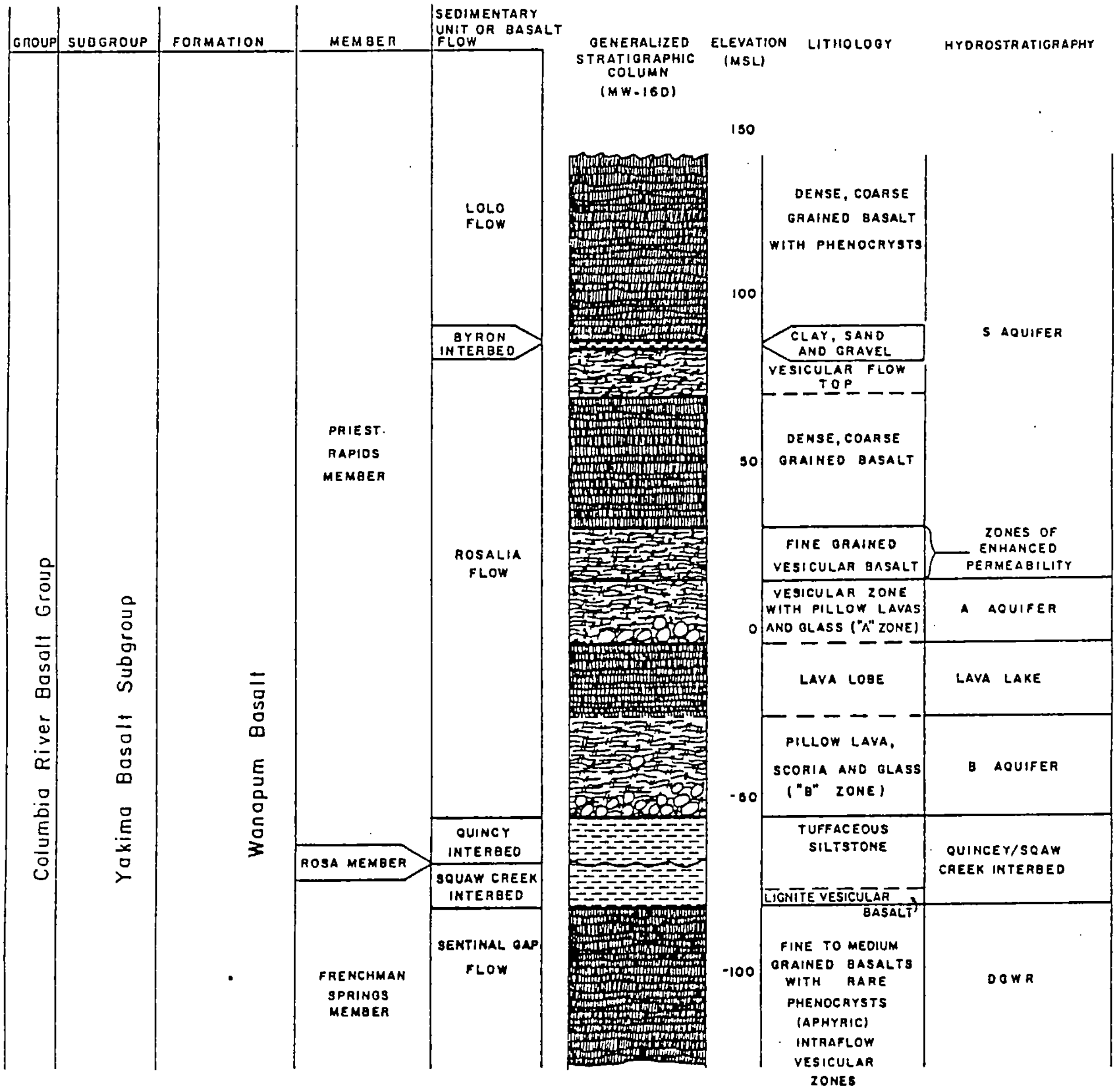


Figure 4.4 Site-Specific Stratigraphic Column.

CLIENT NAME:

Martin Marietta Corporation

The Byron Interbed contains about 1 ft of gravel overlying a clay-rich sediment that ranges in thickness from 1 to 3 ft. The Rosalia flow is present beneath the Byron Interbed. Pillow lavas and hyaloclastites are present in the lower two-thirds of the flow, which apparently was deposited in a large shallow lake. The Rosalia flow makes a transition from pillow lavas formed in a shallow lake to an intracanyon flow near Mosier (Tolan and Beeson, 1984).

Cavity fillings are more abundant in the Rosalia than in either the overlying Lolo or the underlying Sentinel Gap flows. This suggests that the Rosalia flow cooled in water and that heated water circulated through the flow during cooling, leaching and then depositing calcite, opal, and clay minerals in vesicles.

The Rosalia flow can be divided into three subunits based on lithology. These units are, from top to bottom, the subaerial, transition, and subaqueous subunits. The subaerial part of the Rosalia is approximately 50-ft thick. The uppermost 15 ft contains abundant vesicles that are partially filled and grades downward to a less vesicular, denser, coarse-grained rock.

Below this dense, coarse-grained rock is the transition zone. The transition zone is up to 20-ft-thick and forms a gradational contact between the subaerial and subaqueous parts of the flow. The transition zone is finer grained, more vesicular, and often more altered than the overlying dense rock, but it does not contain glass.

The lowest part of the Rosalia flow is the subaqueous zone (80 to 100 ft thick), which is comprised of two pillow lava horizons locally separated by a lava lobe. The upper part of the subaqueous zone contains pillow lavas and some glass with abundant clay alteration products and authigenic clays. This upper subaqueous zone is 5-ft to 45-ft thick and is referred to as the A aquifer.

A lava lobe, which is up to 20-ft thick, locally separates the upper and lower pillow lava horizons of the subaqueous zone. This lobe conceivably represents a surge of lava that plunged over the terminal margin of the Roza Member and blanketed the hyaloclastic debris that had washed out in front of the flow. The lobe is not considered to be extensive laterally and is quite vesicular in places. However, locally, the lobe provides a degree of hydraulic separation between the A and B aquifers.

The lowest 30 to 50 ft of the subaqueous zone represents the B aquifer and is characterized by an abundance of hyaloclastite (glass and scoria) with scattered pillow lavas. The base of the subaqueous zone is characterized by an enriched zone of pyrite.

The Quincy/Squaw Creek Sedimentary Interbed is approximately 20-ft thick and consists of a basal 3-ft lignite layer overlain by white tuffaceous siltstone and sandstone of fluvial and/or lacustrine origin. The Rosa flow, which is normally present between the Quincy and Squaw Creek interbeds, is absent at the MMRF.

The Sentinel Gap flow is an open-textured basalt with zones of large vesicles, but in contrast to the Rosalia flow, cavities are predominantly unfilled. The vesicular flow top and intraflow vesicular zones within the Sentinel Gap flow are permeable and correspond to the top of the DGWR at the MMRF.

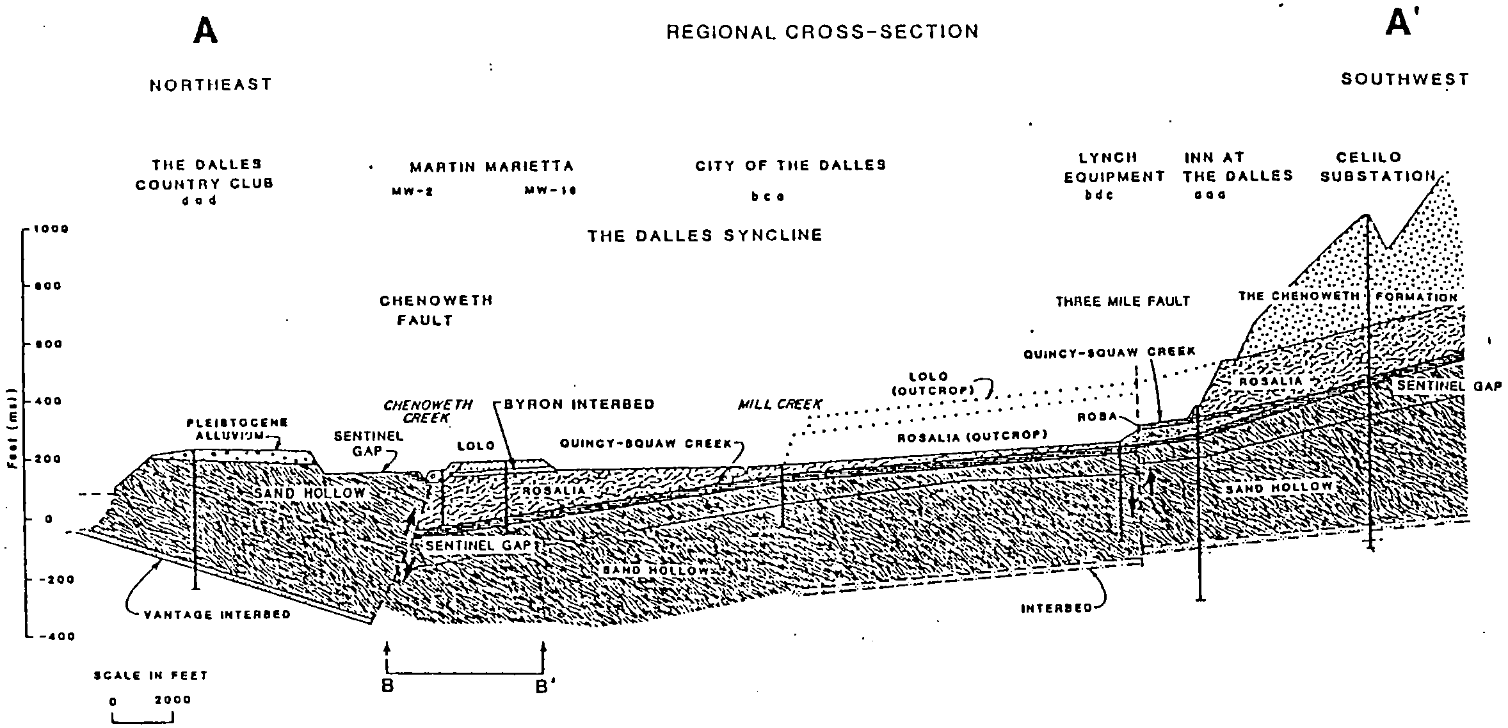
The Sand Hollow flow is an open-textured basalt with zones of larger vesicles and numerous fractures. The vesicular flow top of the Sand Hollow flow represents the primary water-yielding zone within the DGWR.

4.2.3 Site Geologic Structure

The MMRF is situated on the axis of the broad, northeast-trending The Dalles syncline. The Dalles basin is effectively bounded by the northwest-trending Threemile fault on the east, the south limb of The Dalles syncline on the south, the Cascade Upwarp on the west, and the Chenoweth fault on the north. A geologic cross section (Figure 4.5) from Threemile fault to the Chenoweth fault presents the structure at the site as related to the greater The Dalles area. Note that the CRBG flows that are aquifers beneath the MMRF are shallower to the south and that the A and B aquifers (Rosalia flow) are totally exposed; to the north these units are cut off by the Chenoweth fault.

Immediately beneath the site, very little structural complexity is evident. Drill hole and surface data show generally unfaulted, horizontal lava flows and interbeds (Figure 4.6). Only one drill hole (MW-8A) located at the old cathode waste pile shows greater than normal fracture density. This well also shows a zone of greater than normal alteration that may be related to tectonically produced high joint density. The manganese oxide coating on these joint surfaces, similar to that found in other tectonic zones where the CRBG is fractured, indicates that these joints predate the construction activity at the site.

North of the MMRF, the Chenoweth fault marks an abrupt change in orientation of the basalt layers from nearly flat-lying to southward-dipping at 5 to 10 degrees. The Rosalia, Sentinel Gap, and Sand Hollow flows emerge at the surface to the north of the fault.

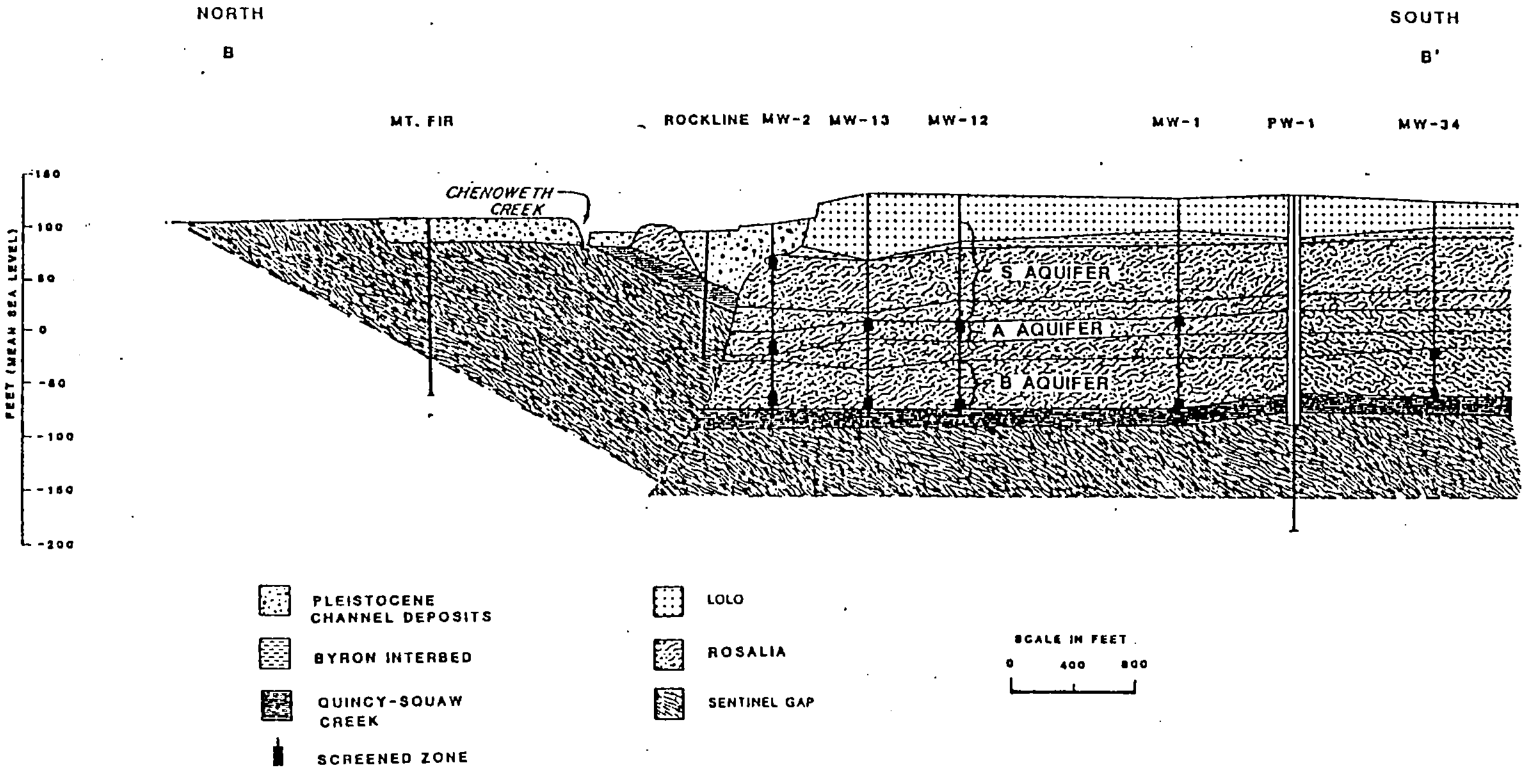


CROSS-SECTION LOCATION SHOWN ON FIGURE E. IN APPENDIX E.3

Figure 4.5 Regional Geologic Cross Section.

CLIENT NAME:

Martin Marietta Corporation



CROSS-SECTION LOCATION SHOWN ON FIGURE E. IN APPENDIX E.3

Figure 4.6 Cross Section B-B'.

CLIENT NAME:

Martin Marietta Corporation

The basalt flows that crop out to the north of the MMRF, near Chenoweth Creek, were analyzed for chemical constituents (see Appendix E). This information was utilized to evaluate the character of the Chenoweth fault and to estimate the magnitude of stratigraphic offset. The base of the Lolo flow is exposed along River Road south of Chenoweth Creek, and the top of the Sentinel Gap flow is exposed along the road to the north of the creek. Therefore, the amount of stratigraphic offset at this location is approximately the thickness of the missing Rosalia flow plus the Quincy/Squaw Creek interbed, or about 165 ft. The Rosalia flow (A & B aquifers), complete with pillow basalt, is exposed north of the fault toward the Columbia River (Figure 4.2), suggesting less offset nearer the river. The Chenoweth fault brings the Frenchman Springs flows to the surface and marks an abrupt change in the dip of the flows.

4.3 DESCRIPTION OF HYDROSTRATIGRAPHIC UNITS

The aquifer systems at the MMRF include a water-table aquifer (S-aquifer) overlying a series of confined aquifers (A aquifer, B aquifer, and DGWR). Perched water and an alluvial aquifer are present locally. The hydrostratigraphic nomenclature is consistent with previous investigations conducted at the site and is appropriate for the production facility vicinity. Further from the plant, this stratigraphic sequence may not persist. For instance, the A aquifer merges with the B aquifer to the north (near Chenoweth Fault), and with the S aquifer to the south (near the scrubber sludge ponds).

Major studies have been published on the ground-water resources of The Dalles area by Piper (1932), Newcomb (1969), and Grady (1983). Piper (1932) noted two water-bearing zones within the CRBG: one in the uppermost 100 ft of basalt and one 300 to 375 ft below the top of the basalt. Piper (1932) described the upper water-bearing zone (apparently corresponding to the A and B aquifer) as "perched," and the lower water-bearing zone (apparently corresponding to the DGWR) as the "main body of ground water." Newcomb (1969) identified the Rosalia flow (A and B aquifers) as his "highway pillow lava" and named the lower aquifer "The Dalles Ground Water Reservoir."

The S aquifer is present within the relatively low-permeability basalts of the Lolo flow and the subaerial portion of the Rosalia flow. The first confined aquifer (A aquifer) is within the upper lava horizon of the subaqueous portion of the Rosalia. The B aquifer is below the A aquifer, locally separated from it by a low permeability basalt (lava lobe). The lava lobe is apparently absent north of the site due to non-deposition. In areas where the lava lobe is absent, the A and B aquifers combine to form a single hydrogeologic unit. A thick clay-shale and siltstone unit is present below the B aquifer, forming the confining unit between the B aquifer and the underlying Dalles Ground-Water Reservoir (DGWR). The top of the DGWR occurs within the permeable zones of the Sentinel Gap flow. The most permeable portion of the DGWR is within the flow-breccia top of the Sand Hollow flow.

An alluvial aquifer, limited in areal extent but used as a water-supply source by the Animal Shelter, is present to the north of the study area. Perched water has been identified at the site in an area that was covered by permeable fill material.

4.3.1 Perched Water

The perched water occurs above competent basalt within the permeable fill material emplaced during construction and has been identified below the former cathode waste management area. The saturated thickness of the perched zone varies with available recharge, and was approximately 0 to 3 ft in test pits opened in August 1987.

One source of the perched water is precipitation. Infiltration from the landfill ditch and north ditch and leaks in below grade water distribution lines are other potential sources. A storm-water pipe was damaged during the RI which, prior to repair, likely contributed to the perched zone.

4.3.2 Alluvial Aquifer

The alluvial aquifer occurs north of the MMRF in the Plio-Pleistocene alluvial deposits. The alluvial aquifer is very limited in areal extent and only one well (Animal Shelter) produces water from this aquifer. The geometry of the alluvial aquifer is apparently controlled by the location of the trace of the Chenoweth fault (see Figures 4.1 and 4.2). The alluvial aquifer is approximately 400 ft wide and is at least 60 ft deep. The long axis of the aquifer is oriented east-northeast and extends approximately 3,000 ft from the Columbia River to the area where River Road crosses Chenoweth Creek. At its northeastern end, the alluvial aquifer merges with the flood plain deposits of Chenoweth Creek.

The materials in the aquifer, comprised of cobbles, gravel, sand, and clay, are poorly sorted. Ground-water yields from the alluvial aquifer are sufficient for domestic supply, but the limited extent and thickness of the aquifer restricts its water-supply potential.

4.3.3 The S Aquifer

The S-aquifer is under unconfined (water-table) conditions and occurs within the Lolo flow, the Byron Interbed, and the subaerial portion of the Rosalia flow (including the transition zone). The S aquifer averages about 100 ft in thickness. The flow base of the Lolo, the sediments of the Byron interbed, and the top of the Rosalia represent a zone of enhanced permeability within the S-aquifer.

The S aquifer is heterogeneous with a horizontal hydraulic conductivity that is greater than the vertical. Ground water in basalts of the S aquifer is present within the joints and fractures, predominantly cooling fractures, in the basalt and in the sediments of the Byron Interbed. Generally, the cooling fractures are oriented vertically, yet are vertically discontinuous. The fractures are more predominant at the top and bottom of the flows (e.g., sites of relatively rapid cooling) and less pronounced in the middle of the flows. Viewed from above, the cooling fractures form a series of polygons joined at their apex. The polygonal arrangement of the interconnected joints does not create a preferential lateral fracture orientation, but rather a fracture "net."

The hydraulic conductivity values calculated for the S aquifer primarily represent horizontal hydraulic conductivity resulting from lateral zones of enhanced permeability within specific portions of individual flows (Appendix G). The S aquifer is characterized by a steep vertical hydraulic gradient. Because the potential recharge at The Dalles is low, the vertical hydraulic conductivity of the S aquifer must also be low in order to support the observed steep vertical gradient under steady-state conditions.

The vertical hydraulic conductivity of the S aquifer is enhanced in places where secondary fractures are more pronounced. Enhanced fracturing of the Lolo and upper Rosalia flows was identified in samples from well MW-8A, located at the old cathode waste pile. Water-level data near the old cathode waste area indicate a potentiometric low in the lower part of the S aquifer (transition zone) and a potentiometric high in the A aquifer.

The S aquifer is bounded to the east by the Columbia River and to the north by the alluvial aquifer and the Chenoweth fault. Saturated conditions were not identified in the S-aquifer to the west (wells MW-1, MW-12, MW-13, and MW-34).

4.3.4 The A Aquifer

The A aquifer occurs within the upper pillow lava horizon of the Rosalia subaqueous zone. The pillow lava horizon has significant primary porosity due to rapid cooling of the lava which quenched in water while still mobile. The pillow lava horizon comprising the A aquifer is laterally continuous in the northern part of the MMRF, but the A aquifer thins and becomes less permeable to the south.

The A aquifer ranges from 5 to 45 ft thick. The thickness and water-bearing capacity of the A aquifer decreases significantly to the south (as observed at well clusters MW-18, MW-24, and MW-30), and it becomes hydraulically and lithologically indistinguishable from the S aquifer. The A aquifer is bounded by the Columbia River to the east and by the Chenoweth fault to the north. The A aquifer is the uppermost aquifer underlying the site which is capable of producing appreciable quantities of water. Yields of up to 20 gpm are possible from the A aquifer.

The lava lobe locally separates the A and B aquifers. This lobe represents a surge of lava into the rapidly filling paleo-basin, which cooled more slowly than the zones above or below. The lobe is thickest (about 20-ft thick) near the process buildings. Where present, the degree of confinement varies according to the thickness of the lobe and fracture density. The degree of confinement provided by the lava lobe is indicated by the relative hydraulic head differences between the A and B aquifers (Appendix G).

4.3.5 The B Aquifer

The B aquifer is the most prolific aquifer within the Rosalia flow. This aquifer occurs within the lower pillow lava horizon of the subaqueous zone of the Rosalia flow and is capable of producing water at over 500 gpm. The most permeable portion of this aquifer is the zone of hyaloclastite (debris flow material) immediately above the Quincy/Squaw Creek interbed.

The B aquifer is continuous beneath the MMRF and ranges in thickness from 30 to 50 ft. The channel of the Columbia River apparently extends to the base of the aquifer in places and bounds, at least partially, the aquifer to the east.

The B aquifer is bounded by the Chenoweth fault to the north. The altitude of the aquifer increases to the south of the MMRF, along the southern limb of the Dalles syncline (Figure 4.5). The southern boundary of the aquifer is located south of Mill Creek, where the Rosalia flow outcrops. The westward extent of the aquifer is controlled by the geometry of the basin in which it was deposited.

The Quincy/Squaw Creek Interbed separates the B-aquifer from the DGWR. The interbed consists of tuffaceous siltstone and sandstone with a lignite layer at the base. Laboratory testing of a sample of the Quincy/Squaw Creek interbed from well MW-16D indicates a vertical hydraulic conductivity of 1.25×10^{-6} cm/sec and a horizontal hydraulic conductivity of 9.02×10^{-7} cm/sec.

The lower Rosalia is not expected to be as productive in areas where the Rosa flow is present. The permeable nature of the lower Rosalia is related to its deposition in a shallow lake. The location of the lake is related to the absence of the Rosa. In areas where the Rosa is present, the permeability of the lower Rosalia is much less.

4.3.6 The Dalles Ground-Water Reservoir

The Dalles Ground Water Reservoir (DGWR) is the major water-supply aquifer in the area with reported yields of over 1,000 gpm. The aquifer ranges in thickness from 10 to 50 ft and covers an area of 25 to 30 mi^2 (Grady, 1983). Although the water-bearing zones within the Sentinel Gap flow are part of the DGWR, the primary water-bearing zone within the DGWR is the highly permeable flow top of the Sand Hollow flow.

Grady (1983) notes an abrupt change in potentiometric levels from 100 ft msl to 600 ft msl within the CRBG south of The Dalles. He speculates (as did Newcomb, 1969) that this may result from either a structural barrier or a relative increase in hydraulic conductivity within the rocks. These authors have suggested that the abrupt change in potentiometric level coincides with the southern and western extent of the DGWR. The Chenoweth fault bounds the DGWR to the north, and therefore, the MMRF is located near the northern extent of the DGWR. To the north of the fault, the rocks of the DGWR (Sentinel Gap and Sand Hollow flows) have been elevated to a position across from the B aquifer and form a separate aquifer system. The DGWR extends northward into

Washington where it is bounded by Threemile and Big Eddy faults (Figure 4.2).

4.4 GROUND-WATER USE

A review of well-completion records for Klickitat County, Washington, and Wasco County, Oregon, was conducted. These records were used in conjunction with information provided in "Ground-Water Resources of the Hood Basin, Oregon" (Grady, 1983) to identify water-supply wells in the area of The Dalles (locations shown on Figure 4.7 and depth, location, and ownership information summarized in Table 4.2). Well-completion records are available for wells numbered 1 through 88, except well 16, and are included in Appendix F.

Approximately 35 percent of the wells in The Dalles area at locations south and east of the MMRF are screened in the sediments of the Chenoweth formation. The well yields are generally 0.5 to 55 gpm with a few wells producing 150 to 250 gpm (Grady, 1983). All of these wells are in the uplands at elevations greater than 1,000 ft above mean sea level, and because the aquifer that they penetrate is above the elevation of the MMRF, they cannot be affected by activities on the plant site.

Approximately 65 percent of the supply wells in the area produce water from the CRBG, with most of these producing from the DGWR. Reported yields of wells in the DGWR range from 100 to 2,500 gpm, with an average yield of 1,000 gpm. Specific capacities range from 100 to 550 gpm/ft of drawdown with an average of 300 gpm/ft of drawdown (Grady, 1983).

The City of The Dalles operates six production wells, five of which produce from the DGWR. The sixth produces from the CRBG at a site approximately three miles south of the southernmost extent of the DGWR. These wells are used to

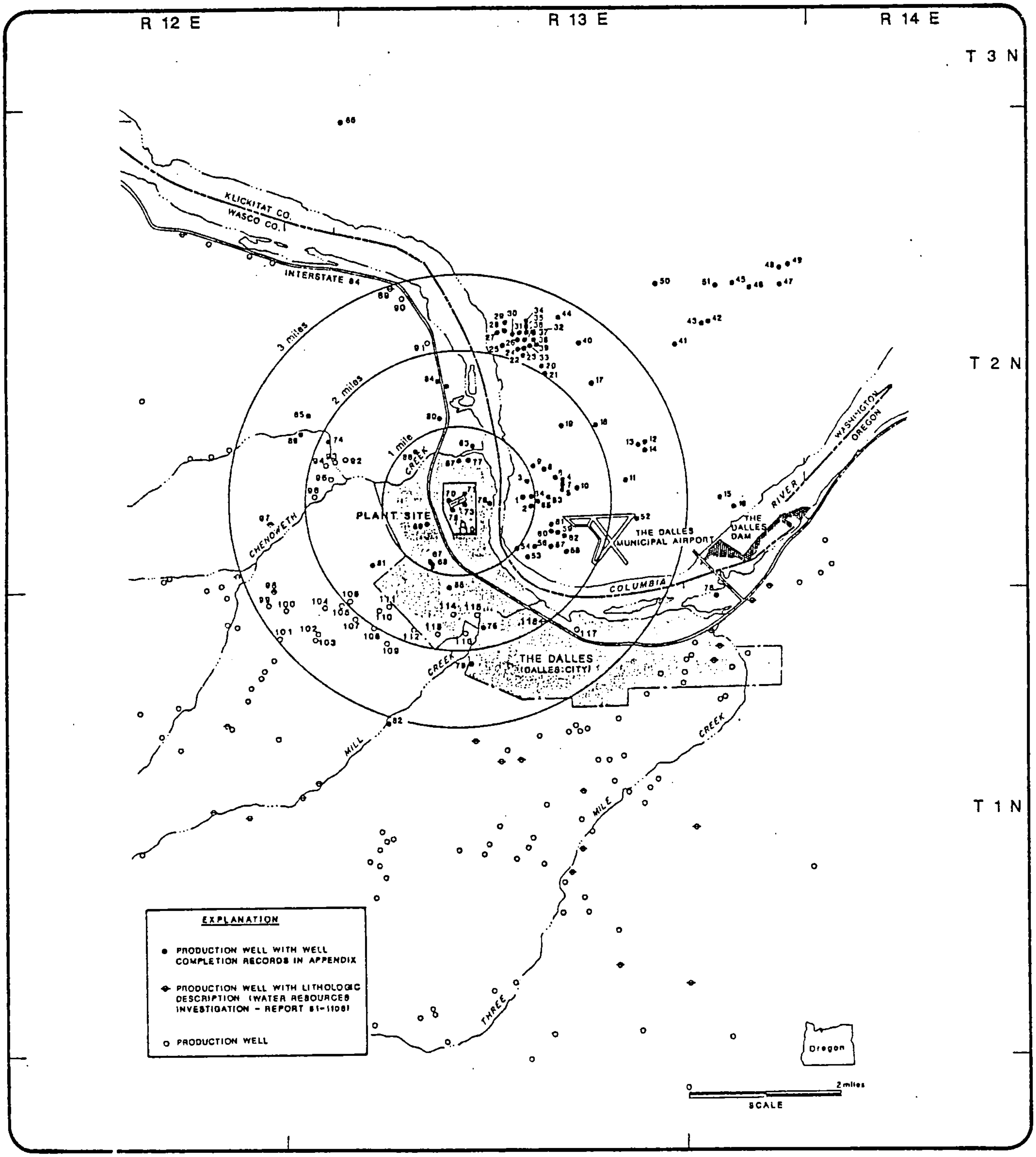


Figure 4.7 Location of Supply Wells in the Vicinity of The Dalles.

CLIENT NAME:

Martin Marietta Corporation

Table 4.2 List of Available Well-Construction Records of Supply Wells in The Dalles Area

Well Number	Owner	Depth (ft)	Location
	Klickitat County		
1	Marvin Harrison	200	SE-SW-28-2-13
2	Franke Leno	205	SE-SW-28-2-13
3	Hugh Bullock	220	NE-SW-28-2-13
4	Harold Shepler	120	NE-SE-28-2-13
5	Larry Holliday	140	NE-SE-28-2-13
6	Mt. Veiw Water Association	210	NE-SE-28-2-13
7	Harold Shepler	251	NE-SE-28-2-13
8	Jim Wise	155	SW-NE-28-2-13
9	Harry Toda	170	SE-NW-28-2-13
10	Leroy Showalter	110	NW-SW-27-2-13
11	Roger Cool	125	NE-SE-27-2-13
12	Jarl Construction	215	NE-NE-27-2-13
13	Vernie Jarl	150	NE-NE-27-2-13
14	Jarl Construction	595	NE-NE-27-2-13
15	Dallesport Industrial Park	292	SE-SE-26-2-13
16	Klickitat County Port #1	210	SW-SW-25-2-13
17	Fred Smith	500	SE-NW-22-2-13
18	W.H. Gregory	285	SE-SW-22-2-13
19	Don Graves	160	SE-SE-21-2-13
20	Larry Frazier, Inc.	150	NW-NE-21-2-13
21	Darrel King	170	NW-NE-21-2-13
22	Minor's Addition Water Supply	119	SE-SW-16-2-13
23	Murdock Tract Water Fund	200	SE-SW-16-2-13
24	Ivor T. Jones	205	SE-SW-16-2-13
25	Earl B. Cooper	280	SW-SW-16-2-13
26	George McKinnen	175	E-SW-16-2-13
27	E.B. Cooper	109	NW-SW-16-2-13
28	Phillip Hearron	109	NW-SW-16-2-13
29	Ken Zeilinski	88	NW-SW-16-2-13
30	Robert G. Knowles	250	NE-SW-16-2-13
31	Pearl Fehr	115	NE-SW-16-2-13
32	Earl Cooper (1)	325	NE-SW-16-2-13
	Earl Cooper (2)	280	NE-SW-16-2-13
33	Larry Odom	330	NW-SW-16-2-13
34	Earl Cooper	175	NE-SW-16-2-13
35	Earl Cooper	150	NE-SW-16-2-13
36	Earl Cooper	344	NE-SW-16-2-13
37(1)	Cecil Odom	170	NE-SW-16-2-13
37(2)	Cecil Odom	286	NE-SW-16-2-13
37(3)	Cecil Odom	220	NE-SW-16-2-13
38	Robert Knowles	125	NE-SW-16-2-13
39	Larry Frazier	100	NE-SE-16-2-13
40	Jerry Frazier	290	SW-SW-15-2-13

Table 4.2 (continued)

Well Number	Owner	Depth (ft)	Location
41	Martha Niblack	490	SE-SW-14-2-13
42	Frenche Vezina	550	NE-SE-14-2-13
43	Joseph H. Blanck	340	NE-SE-14-2-13
44	Jack Schreiner	285	NE-SE-16-2-13
45	Charles Sterrit	370	NW-NW-13-2-13
46	Ronald Johnson	340	NW-NE-13-2-13
47	Melvin Thornburg	200	NW-NE-13-2-13
48	Dennis Beeks	160	SW-SE-12-2-13
49	John Huteson, Jr.	390	SW-SE-12-2-13
50	Dan Gunkle	420	NW-NW-14-2-14
51	Yakima Indian Nation	445	NE-NE-14-2-14
52	Dallesport Water Association	334	NE-NE-34-2-13
53	Donald M. Dietz	163	SE-SW-33-2-13
54	Cliff Whitt	298	SW-SW-33-2-13
55	Cliff Whitt	298	SW-SW-33-2-13
56	Lyle School District	320	NW-SE-33-2-13
57	George Sheradella	230	NE-SE-33-2-13
58	Lyle School District	320	NE-SE-33-2-13
59	John Haggard	120	SE-NE-33-2-13
60	Foley	250	NE-NE-33-2-13
61	Mike Helyer	265	NE-NE-33-2-13
62	Dallesport Community	365	NE-NE-33-2-13
63	Bud Williams	205	SW-SE-28-2-13
64	Dallesport Domestic	182	SW-SE-28-2-13
65	Arthur Dahl	210	SW-SE-28-2-13
66	Dayton Henderson	160	NW-NW-06-2-13
	Wasco County		
67	Chenoweth Irrigation Co-op #1	258	NE-SE-32-2-13
68	Chenoweth Irrigation Co-op #2	260	NE-SE-32-2-13
69	Chenoweth Irrigation Co-op #3	275	NE-NE-32-2-13
70	Harvey Machine #1 (MMRF)	314	NW-SW-28-2-13
71	Harvey Machine #2A(A) (MMRF)	302	NE-SW-28-2-13
72	Harvey Machine #3A (MMRF)	319	SW-SW-28-2-13
73	Harvey Machine #4A (MMRF)	303	SE-SW-28-2-13
74	Jack Huffman	152	SW-SE-19-2-13
75	Jordon St. Well	291	SE-NW-04-1-13
76	Klindt	100	------21-2-13
77	Linebarger (Rockline)	98	NW-NE-28-2-13
78	Lone Pine Well	385	NE-NW-01-1-13
79	Marks Well	570	SE-SW-04-1-13
80	Floyd Marsh	350	NE-NE-20-2-13
81	George Moon	539	---SW-32-2-13

Table 4.2 (continued)

Well Number	Owner	Depth (ft)	Location
82	Mill Creek Well	371	NW-SW-08-1-13
83	Mt. Fir Lumber	145	SE-SW-21-2-13
84	Pine Wood Mobile	220	-------21-2-13
85	Richard J. Murray	118	NE-SW-19-2-13
86	Neil Pake	164	SW-SW-19-2-13
87	Wasco Animal Shelter	65	NE-NW-23-2-13
88	Fred Wetle	251	SW-NE-29-2-13
89	The Dalles Country Club	480	SE-SE-17-13-2
90	Tooley Water District	306	NE-NW-17-13-2
91	Tooley Water District	32	NE-NW-17-13-2
	D. Hill	78	NE-NW-17-13-2
92	W. Pullen	Spring	NE-NE-30-13-2
93	W. Pullen	605	NE-NE-30-13-2
94	R. Walters	665	NE-NW-30-13-2
95	Lower Chenoweth Water District	243	SE-NW-30-13-2
96	Lower Chenoweth Water District	222	NE-SW-30-13-2
97	E. Kuck	443	SE-SE-25-12-2
98	C. Buster	500	SE-SE-36-12-2
99	W. Goeckel	500	NE-NE-01-12-1
100	R. Krueger	700	NW-NW-06-13-1
101	R. Goolsby	160	SE-NW-01-12-1
102	E. Ayres	360	SE-NW-06-13-1
103	J. Ayres	365	SE-NW-06-13-1
104	L. Shoemaker	880	NE-NW-06-13-1
105	L. Shoemaker	790	NW-NE-06-13-1
106	C. Smith	360	NE-NE-06-13-1
	C. Smith	350	NE-NE-06-13-1
107	M. Malcolm	103	NE-NE-06-13-1
108	E. Hendricks	530	SW-NW-05-13-1
109	Foley	323	NW-SW-05-13-1
110	Martin Marieta	537	NW-NW-05-13-1
111	J. Miller	395	NW-NW-05-13-1
112	Cherry Heights Irrigation Co.	546	SW-NE-05-13-1
113	J. Fieck	470	SE-NE-05-13-1
114	Columbia Lodges	303	SW-NW-04-13-1
115	R. Bennett	320	NW-NW-04-13-1
116	Sisters of the Holy Name	210	NE-NW-04-13-1
117	Dalles Cherry Growers	114	SE-NW-03-13-1
118	City of The Dalles	200	NE-NE-03-13-1
119	Martin Marietta Recreation Well	---	NW-NW-33-13-2

Note: Lithologic descriptions available for all wells except 16.

567/3

augment surface water, the major source of water supply for the City of The Dalles.

The Lower Chenoweth Water District, located west of the MMRF, operates two wells, both of which are screened in the sediments of the Chenoweth formation. South and southwest of the plant, the Chenoweth Irrigation Cooperative operates three wells, all of which produce from the DGWR. Based on construction details of these wells, they also produce water from the Rosalia flow (A and B aquifers). On the Washington side of the Columbia River there are approximately 70 wells, most of which produce from the CRBG.

Five shallow supply wells are located in the immediate vicinity of the plant. To the north, two wells operated at Mt. Fir and Rockline produce from the Sentinel Gap flow of the CRBG. The Mt. Fir well also produces from the Sand Hollow flow. These formations comprise the DGWR south of the fault. Another well north of the plant (Animal Shelter) is screened in Pleistocene channel deposits (alluvial aquifer) associated with the trace of the Chenoweth Fault. To the east of the MMRF, one well (Klindt) produces from the S aquifer and the A aquifers.

Six supply wells originally were present at the plant site, four located around the main plant building, one in the recreation area, and one at the house near the recycle pond. Of the four wells near the plant, three are used to produce water for plant operations. All three of these wells are cased off below the Quincy/Squaw Creek interbed and produce water from the DGWR. The fourth production well (PW-2) was abandoned in 1985 by pulling the pump and backfilling the borehole with cement grout. The recreation area well produces water for irrigation purposes; no well-completion record is available for this well to indicate depth or production intervals. The "residence" well, located at the old farmhouse near the recycle pond is not currently used, but a submersible pump remains in the well. The well was completed to a depth of 120 ft and produced from the A and B aquifers.

4.5 AQUIFER CHARACTERISTICS

To characterize the hydraulic properties of various aquifers underlying the site, slug tests and constant-rate pumping tests were performed. Slug tests were conducted in the S, A, and B aquifers and constant-rate pumping tests in the A and B aquifers and the DGWR. Analysis and interpretation of test data are presented in Appendix G. The aquifer test results are summarized in Tables 4.3 and 4.4.

When water is withdrawn from a well, the water level or potentiometric surface of the surrounding aquifer is drawn down to form a cone of depression, the gradient and extent of which are determined by the aquifer characteristics of transmissivity and storativity. As pumping continues, the cone of depression continues to expand until a state of equilibrium is reached between the volume of water being pumped and the volume of recharge induced by the lowered water level.

In confined aquifers, such as the A and B aquifers, the cone of depression expands until the increased area of increased head difference is sufficient to induce leakage through the confining beds equal to the pumpage. Results of both the A and B aquifer tests indicated a limited amount of leakage occurred during pumping. Drawdown continued throughout the tests and recovery of water levels after the pumping ceased occurred slowly indicating that water had been withdrawn primarily from storage.

Table 4.3 Slug Test Results

Monitor Well No.	Aquifer	Hydraulic Conductivity Bouwer feet/day	Hydraulic Conductivity Hvorslev feet/day
		Open Well Packer Tests	
MW-15S	S	23.1	24.4
MW-20S	S	0.7	0.4
MW-16A	S	3.5	3.9
MW-13A	A	44.9	65.1
MW-14A	A	6.3	8.1
MW-15A	A	40.3	42.6
MW-20A	B	75.7	61.1
		Cased Well Tests	
MW-16A	S	0.2	---
MW-6A	A	87	135.5
MW-7A	A	0.042	---
MW-8A	A	14.3	17.8
MW-14A	A	6.0	7.3
MW-15A	A	7.6	10.9

569/2

Table 4.4 Results of Aquifer Test Analyses

Well Number	Transmissivity gpd/ft	Storativity	Distance from Pumping Wells ft
	A Aquifer (pumping well 8A)		
6AA	2,900	2.43×10^{-4}	345
9A	2,600	2.3×10^{-3}	76
15A	2,800	2.46×10^{-4}	193
	B Aquifer (pumping well 8B)		
6B[1]	222,000	5.67×10^{-4}	345
9B	254,000	6.83×10^{-3}	76
15B	326,000	1.07×10^{-3}	193
16B	194,000	3.43×10^{-4}	439
26B	181,000	2.16×10^{-4}	654
27B	258,000	1.83×10^{-4}	629

1/ Corrected for barometric efficiency

569/4

The mathematical concepts on which aquifer test analyses are based include the assumptions that the aquifer is isotropic, homogeneous, and of infinite areal extent. Clearly, the A and B aquifers in The Dalles area do not meet these criteria. Precise analytical solutions, therefore, have not been obtained. Interpretation of the data, however, do provide reasonable, internally consistent values for aquifer characteristics, and, in conjunction with knowledge of local geology, afford an understanding of the ground-water flow regime in the area.

The geologic setting of the A and B aquifers suggests that ground-water flow may be affected to the northeast by the Chenoweth fault and to the east by the Columbia River, whose channel is incised through both aquifers. Although faults commonly serve as ground-water conduits and rivers commonly are in hydraulic connection with adjacent aquifers, both serving as recharge lines, plots of drawdown data in the A and B tests suggest that this is not the case in The Dalles area and that the fault and river may form impermeable boundaries. Ground-water percolation through the fault zone may have resulted in precipitation of minerals that have effectively sealed the fracture zones. Clay minerals of the montmorillonite group are a common weathering product of the CRBG. These clays are noted for their capacity to swell when wet and may have formed an impermeable seal in the river bottom.

The linear increase of drawdown with time, as shown in the log-log graphs of Appendix G, strongly suggests impermeable boundaries and only slight recharge in response to pumping. The data from observation wells used in the tests of the A and B aquifers suggest that impermeable boundaries may exist at distances of about 2,400 and 13,000 ft from the pumped well. The idea that the fault and the river comprise impermeable boundaries to both aquifers, though strongly supported by aquifer-test analyses, must remain a hypothesis.

Pumping from the B aquifer (well MW-8B) appeared to have an effect on the water-level trend in the A aquifer as shown by the hydrograph of well MW-8A in Appendix G. No method is known for calculating leakage through a confining bed except by interpretation of the effects noted in the pumped aquifer. In the case of the B aquifer test, the strong indications of impermeable boundaries effectively masked any effects of leakage.

4.6 GROUND-WATER MOVEMENT

Ground-water flow through basalt is typically through fractures within the rock. Newcomb (1969) has documented the effect of geologic structure on the movement of water in basalt aquifers. According to these studies, folds and faults may isolate segments of aquifers, thus disrupting their hydraulic continuity. Tectonic structures lead to inclination of aquifers and formation of barriers to lateral percolation and paths for vertical movement.

The measured hydraulic conductivities associated with the A and B aquifers are predominantly due to primary porosity which is a result of the subaqueous deposition of basalt. The high hydraulic conductivity of the DGWR is associated with the flow breccia top of the Sand Hollow Flow. Fracturing (secondary porosity) of these water-bearing zones is not anticipated to significantly increase the hydraulic conductivity within the units and flow through these units should be as flow through porous media.

Ground-water flow within the S aquifer is primarily controlled by the presence and character of the Byron Interbed, a sedimentary unit. Cooling fractures within the S aquifer create a fracture-net, lacking a preferential orientation.

Based on the above discussion, ground water and potential contaminant migration can be evaluated and described under porous media assumptions. Potentially, fracturing would have the greatest impact on vertical ground-water flow by enhancement of the permeability of the confining units which separate the aquifers. If present, fractures of this nature would impact the potentiometric distribution nearby and, in areas of shallow ground-water degradation, be reflected in the chemistry of ground water in lower hydrogeologic units. The old cathode waste management area is the only area where these characteristics are observed and significant fracturing is indicated.

Numerous potentiometric maps were made based on water-level measurements from monitor wells installed at the site in order to determine the direction of ground-water movement and the hydraulic relationship between the various aquifer systems (Appendix G). Movement is predominantly horizontal in the aquifers, although the potential for ground-water movement in basalts underlying the MMRF site is also vertically downward. In the aquifer systems underlying the MMRF, potentiometric levels are generally highest in the more shallow aquifers, becoming progressively lower in the deeper aquifers. Seasonally, ground-water levels are higher in the DGWR than in the B aquifer and ground-water flow potential is from the DGWR to the B aquifer.

The description of ground-water movement in each aquifer is based on available data; these data indicate that the general direction of ground-water flow is not likely to vary significantly. However, details presented in the description of ground-water flow are likely to vary due to temporal differences in ground-water conditions and differences in interpretation of existing data.

4.6.1 Recharge/Discharge

Recharge in The Dalles area is limited by low annual precipitation and high potential evapotranspiration. The OWRB (1965, p. 110) estimated about 1 inch per year (in/yr) of ground-water recharge in the Fifteenmile Creek watershed, which includes the more arid eastern part of the Wasco area. Newcomb (1969, p. 24) suggested that recharge in the more humid Mosier Creek watershed is between 1 and 3 in/yr. Consequently, the recharge rate in the Dalles area is estimated to be between 1 and 1.5 in/yr, a value characteristic of semi-arid regions.

Potential recharge is greatest in the winter months. During December and January, average monthly precipitation is highest, the average temperature is about 34°F, and evaporation potential is relatively low. Precipitation during these months is generally in the form of snow. Melting of the snow provides a source of water over a longer period of time, which enhances recharge potential in areas characterized by a low infiltration rate.

The cumulative moisture deficit for The Dalles (see Section 2.2) indicates very little available recharge for the local ground-water system. Recharge potential is greatest at locations where the substrate exhibits a high infiltration rate and where there is minimal vegetative cover such as in areas that have been filled.

Table 4.5 presents the recharge/discharge relationships based on evaluation of hydraulic head distributions among the various aquifers underlying the MMRF. In general, ground-water flow is primarily horizontal with potential downward

Table 4.5 Potential Recharge/Discharge Relationships

Aquifer	Potential Recharge From:	Potential Discharge To:
Perched Water	Precipitation Landfill ditch North ditch Underground pipes	S-aquifer Landfill ditch Alluvial aquifer Discharge channel Seeps Hardpitch sump
Alluvial Aquifer	Precipitation S-aquifer Perched water Runoff Columbia River	Wells A and B aquifers Columbia River
S Aquifer	Precipitation Perched water Recycle pond Discharge channel	Columbia River A aquifer
A Aquifer	Columbia River S aquifer Alluvial aquifer	Wells B aquifer
B Aquifer	Columbia River A aquifer DGWR (seasonally)	Wells DGWR A aquifer (seasonally)
DGWR	Columbia River B aquifer (seasonally)	Wells Lower aquifers B aquifer (seasonally)

569/13

movement of water from upper aquifers to lower aquifers. During the winter months when ground-water withdrawals from the DGWR are reduced, an upward ground-water flow potential from the DGWR to the B aquifer has been observed.

4.6.2 Perched Water

Movement of the perched water is controlled by topography of the bedrock underlying the fill, the degree of hydraulic loading, and the hydraulic properties of the fill material. The bedrock surface underlying the perched zone generally slopes to the east and northeast, and migration of perched water also should be in these directions.

A component of perched water is apparently intercepted by the hard-pitch sump. The numerous NPDES analytical results (Appendix A) from the hard-pitch sump water indicate chemistries similar to those of the perched water from the test pits.

The perched water would be expected to flow preferentially along underground utilities and ultimately discharge to the discharge channel. The sewers at the old cathode waste management area were laid in excavations blasted into the bedrock and filled with sand. The excavations slope toward and terminate at the discharge channel to accommodate the gravity-flow sewer lines.

Some of the perched water migrates downward and recharges the S aquifer. A zone of enhanced vertical fracturing near the old cathode waste pile area may be an area of preferential recharge of perched water to the S aquifer.

4.6.3 Alluvial Aquifer

Potentiometric data from the alluvial aquifer are not available. However, since the aquifer intersects Chenoweth Creek at a higher elevation than it does the Columbia River, potential ground-water flow is expected to be to the southeast from the creek toward the river. Potentiometric levels in the alluvial aquifer are anticipated to be between the creek and the river, or about 75 ft msl.

4.6.4 S Aquifer

In the S aquifer, ground water flows through joints and fractures within the rock matrix. The rock matrix consists of the Lolo Flow and the sub-aerial portion of the Rosalia Flow; columnar joints are most well developed within the base and top of these flows. Together with the intervening Byron Interbed, the flow top and bottom create a laterally continuous zone of enhanced permeability and preferential ground-water flow. Below this zone, fracture density within the S aquifer decreases, as does bulk hydraulic conductivity. The decrease in hydraulic conductivity impedes downward vertical movement except in areas of enhanced secondary fracturing.

In the S aquifer, ground-water flows to the east and northeast (Figure 4.8) to discharge to the Columbia River and the alluvial aquifer. Ground-water movement through the S aquifer is influenced by the geometry of the more permeable zone (flow top, interbed, flow bottom). As shown on the geologic map (Figure 4.2) the outcrop pattern of the Rosa/Rosalia contact, corresponding to the zone of enhanced permeability, does not extend to the Columbia River but terminates at the alluvial aquifer. In fact, the outcrop represents a local discharge point for the S aquifer, although flow continues eastward through less permeable

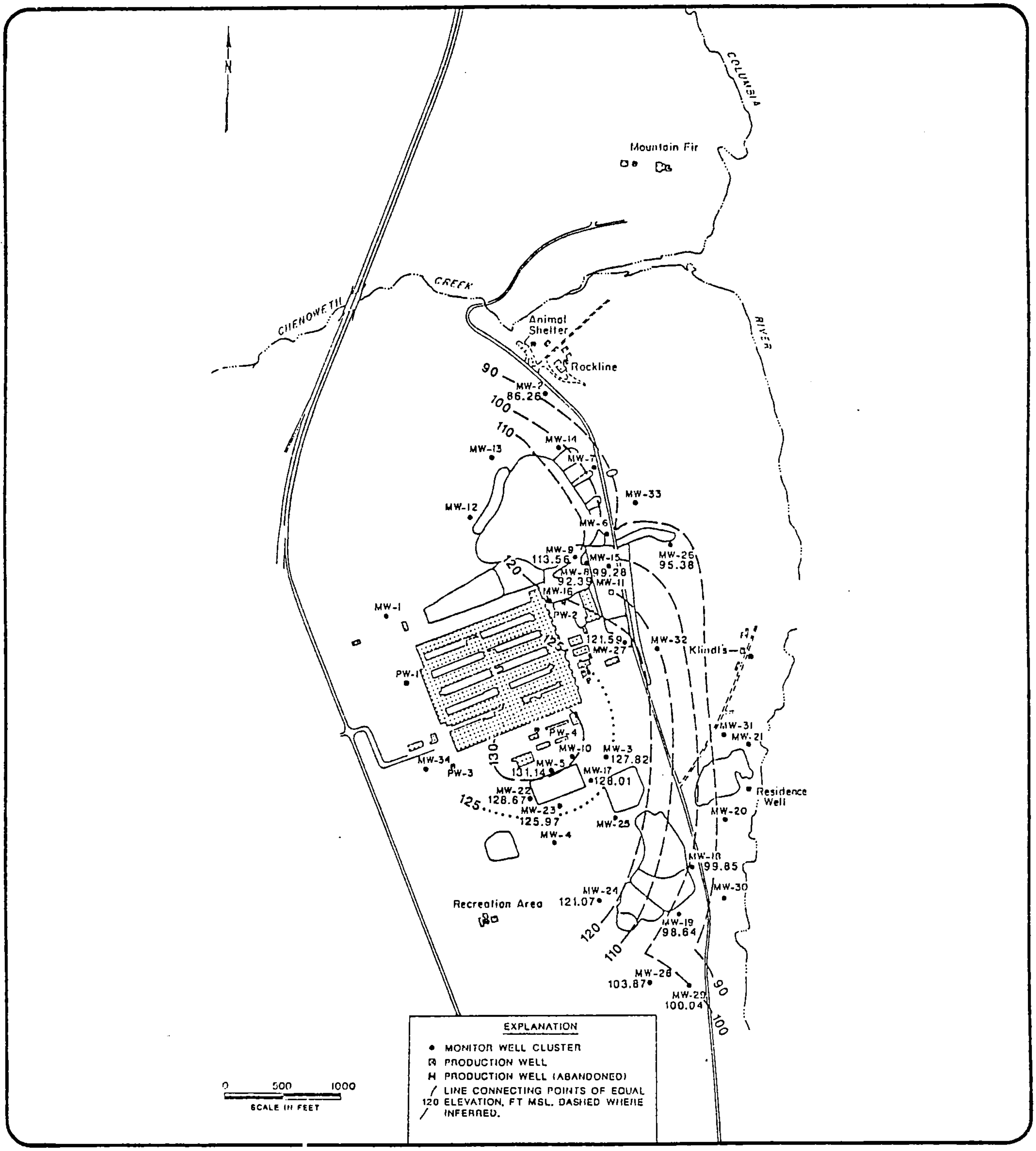


Figure 4.8 Water-Table Contour Map (S Aquifer), August 6, 1987.

CLIENT NAME:

Martin Marietta Corporation

rocks. Therefore, there is a zone of decreased hydraulic conductivity (i.e., lower permeability) within the S aquifer between the MMRF and the Columbia River. The rate of ground-water flow through this less permeable zone is calculated to be approximately 1 ft/day based on a hydraulic conductivity of 2.1 ft/day (average calculated at wells MW-16A and MW-20S), a hydraulic gradient of 0.05, and an effective porosity of 0.10. Assuming a saturated thickness of the S aquifer near the Columbia River of 50 ft, discharge from the S aquifer to the Columbia River is calculated to be less than 1 gpd/linear foot.

Lateral ground-water flow within the S aquifer may be preferentially along the zone of enhanced permeability, which extends to the alluvial aquifer. Based on a hydraulic conductivity of 23.7 ft/day (average calculated at well MW-15S), a hydraulic gradient of 0.05, and an effective porosity of 0.10, ground-water flow rates along this preferential direction are calculated to be about 12 ft/day. The value of 0.10 for effective porosity of the S aquifer was estimated based on published values for fractured basalt (Fetter, 1980, and Morris and Johnson, 1967) and considering the enhanced effective porosity associated with the Byron Interbed.

Some ground water within the S aquifer migrates vertically downward and provides recharge to the A aquifer, the relative amount of the recharge varies spatially, based on fracture density. A zone of enhanced recharge appears to be located beneath the salvage area and old cathode waste pile, where geologic samples from well MW-8A indicate some tectonic fracturing. In addition, potentiometric levels in the S aquifer are lower in this area and calculated hydraulic conductivities of the aquifer are higher.

4.6.5 A Aquifer

Ground-water flow in the A aquifer, as in the S aquifer, is controlled by the relative distribution of hydraulic conductivity throughout the aquifer. The permeability of the A aquifer is greatest in areas where the upper pillow lava horizon (glass zone) is best developed (e.g., beneath the landfill and former cathode waste management area). In this area, well yields on the order of 10 to 15 gpm are common. In contrast, yields of A aquifer wells to the south are less than one gpm and the A aquifer is generally indistinguishable both hydraulically and lithologically from the S aquifer.

The distribution of potentiometric head within the A aquifer also shows this hydraulic conductivity contrast (Figure 4.9). Water levels in the A aquifer beneath the old cathode waste pad are on the order of 25 to 35 ft mean sea level, whereas water levels in the A aquifer to the south are much higher, on the order of 75 to 85 ft msl.

The ground-water flow direction in the A aquifer is predominantly from east to west, but further to the south, the flow is to the northwest (Figure 4.9). This flow pattern may be influenced by recharge from the alluvial aquifer, and along the zone of preferential fracturing within the S aquifer (near the salvage area).

Based on a hydraulic conductivity of about 15 ft/day calculated from hydraulic test data, a hydraulic gradient of 0.005, and an assumed effective porosity of 0.20, ground-water flow rates within the A aquifer are calculated to be approximately 0.3 ft/day. The effective porosity of 0.20 is an estimate based on published data for vesicular basalt (Fetter, 1980, and Morris and Johnson, 1967).

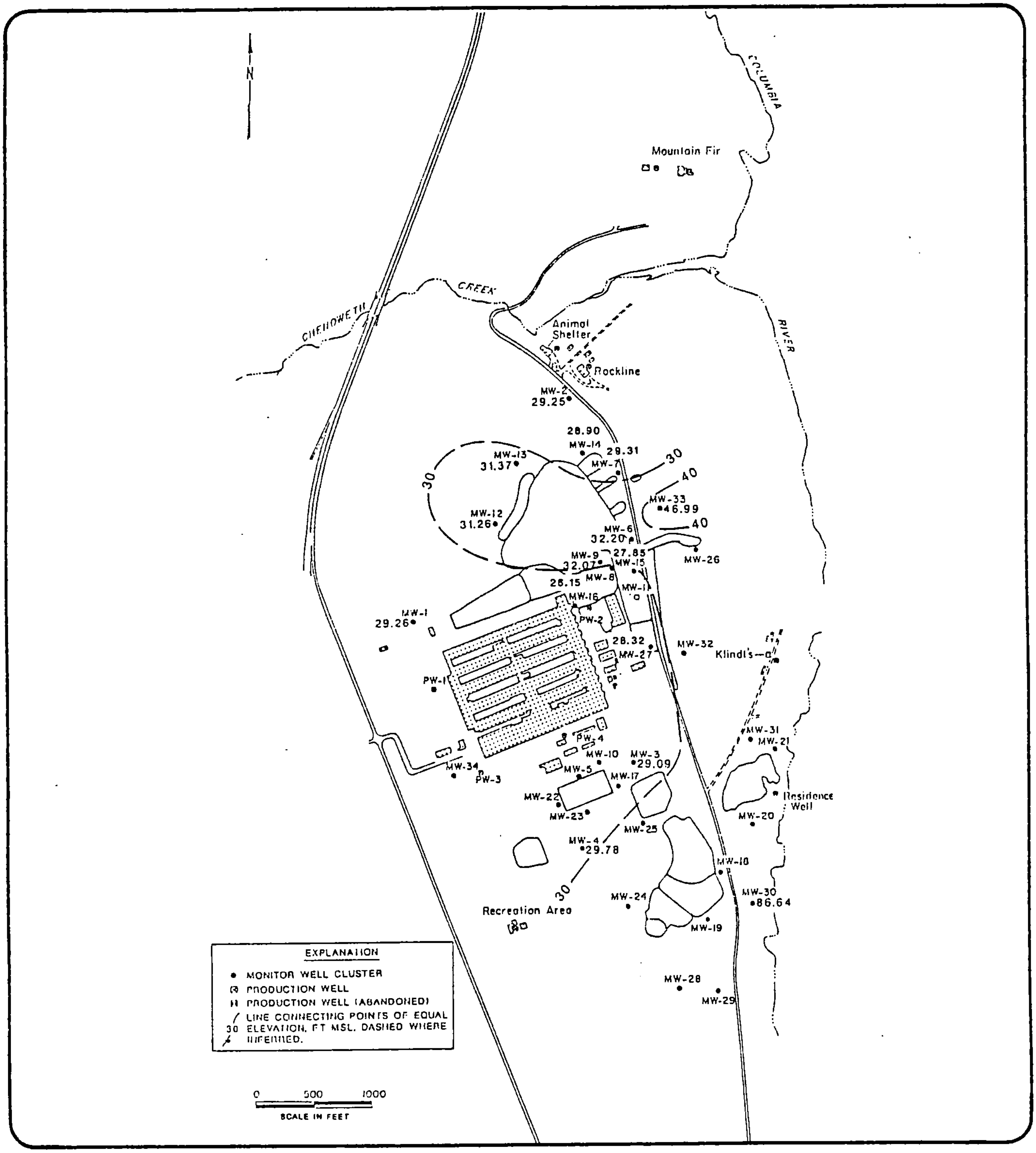


Figure 4.9 Potentiometric Surface of the A Aquifer, August 23, 1987.

CLIENT NAME:

Martin Marietta Corporation

4.6.6 B Aquifer

Ground-water flow within the B aquifer is generally to the west and south from the MMRF. However, hydraulic gradients across the site in the B aquifer are very low (Figure 4.10) and the measured potentiometric levels are subject to influences such as pumping for irrigation and public supply, changes in river stage, and changes in barometric pressure (Appendix G). Based on a hydraulic conductivity of about 1,300 ft/day, an effective porosity of 0.20, and a hydraulic gradient of 0.0002, ground-water flow rates within the B aquifer are calculated to be on the order of 1.3 ft/day. The effective porosity of 0.20 is an estimate based on published data for vesicular basalt (Fetter, 1980, and Morris and Johnson, 1967).

4.6.7 Dalles Ground Water Reservoir

No potentiometric maps of the DGWR have been prepared with the exception of the early work done by Grady (1983). Little information on potentiometric levels in the DGWR exists in the vicinity of the MMRF. The local ground-water flow direction in the DGWR is toward the on-site production wells, when they are operating. Pumping of the numerous irrigation wells located to the west of the MMRF would influence the ground-water movement in the DGWR and a component of flow in the DGWR would be toward these wells. The influence of these wells is also apparent in the long-term decline in water levels in the DGWR over the last 30 years.

4.7 GROUND-WATER QUALITY

The ground-water quality at the MMRF has been impacted near several potential source areas. The primary constituents associated with the observed ground-water

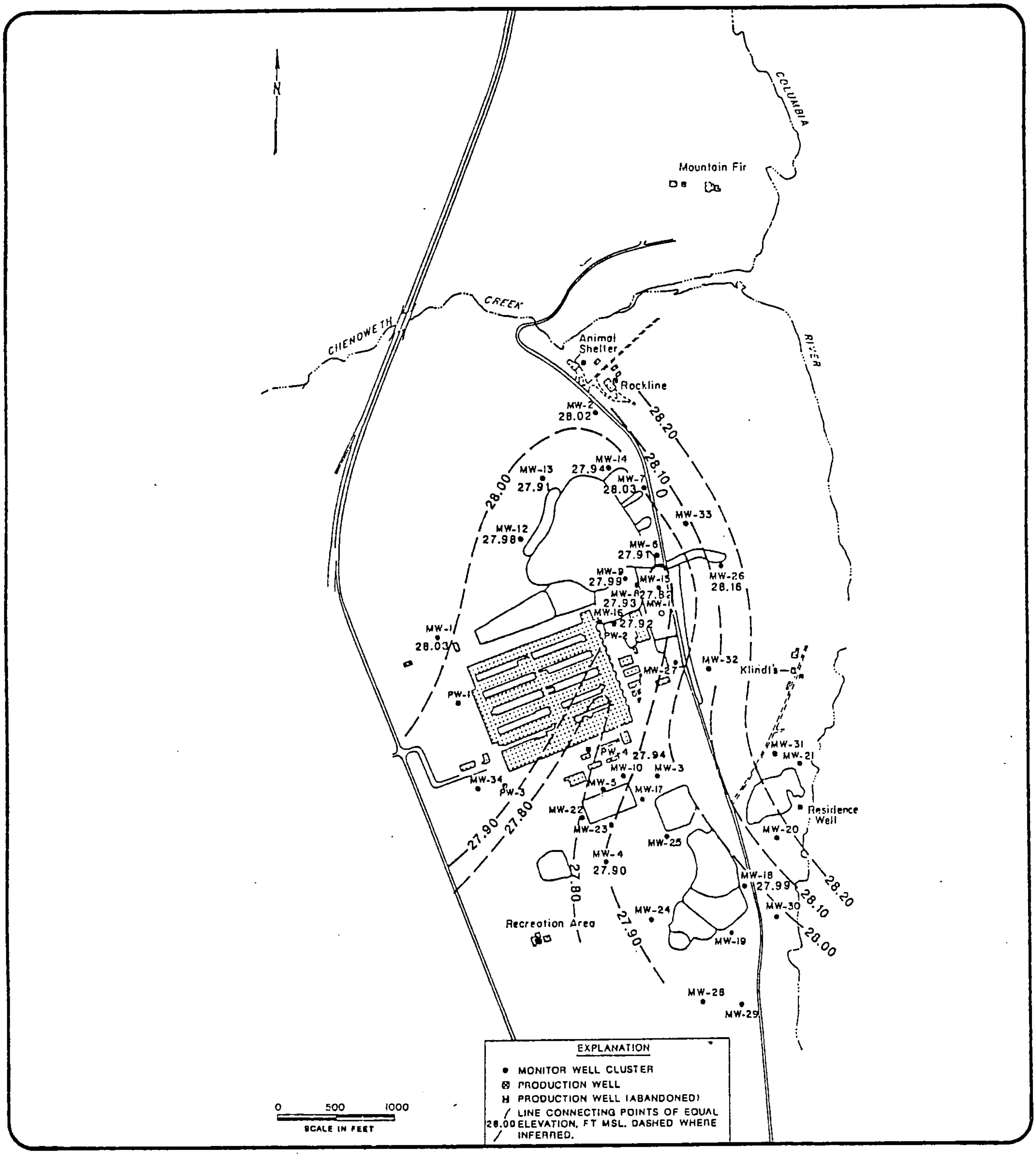


Figure 4.10 Potentiometric Surface of the B Aquifer, August 13, 1987.

CLIENT NAME:

Martin Marietta Corporation

quality degradation are total and free cyanide, fluoride, sodium, and sulfate. The observed impacts are greatest in the shallow aquifers and decrease with depth. The primary potential source areas which contribute to ground-water quality degradation at the site are the landfill, former cathode waste management area, scrubber sludge ponds, and the area near the alumina unloading building.

Ground-water quality impacts associated with the landfill are primarily related to overland flow of landfill leachate to the alluvial aquifer prior to construction of the leachate collector system. Landfill leachate flowed north and north-east, providing recharge to the alluvial aquifer. The associated wash constituents migrated from the alluvial aquifer to the A and B aquifers through which they began migrating southward, back under the landfill. Construction of the leachate collection system has eliminated this contaminant pathway.

Ground-water degradation at the former cathode waste management area (primarily the old cathode waste pile and the salvage area) is greatest in the perched water found in the fill material. Enhanced fracturing of the basalt in this area potential provides a pathway for downward migration of waste constituents to underlying aquifers. However, the degree of ground-water quality degradation in this area generally decreases and becomes less widespread with depth; ground-water quality of the DGWR (the deepest aquifer tested) is within ARARs.

Ground-water quality degradation associated with the scrubber sludge ponds is primarily restricted to the uppermost (S) aquifer. The potentiometric surface of the S aquifer is above the bottom of the onds and a portion of the scrubber sludge is saturated. Recharge of the S aquifer through the scrubber sludge contributes to transport of waste constituents (primarily fluoride and sulfate) to the S aquifer in this area.

The other area of identified ground-water quality impacts is near the alumina unloading building, hydraulically upgradient of the new cathode waste pad. Cathode waste material was used to fill topographic depressions near the alumina unloading building and is the apprarent source of the impacts identified. The observed impacts are generally restricted to the uppermost (S) aquifer, although some degradation of ground-water quality (primarily cyanide) in lower aquifers is observed.

4.7.1 Geochemical Evaluation of Native Ground Waters

Detailed studies have been conducted to assess the evolution of ground-water chemistry within the CRBG. A paper by the USGS (Newcomb, 1972), the most comprehensive work to date, indicates that two predominant changes occur in the ground water with time and depth. As the water gets older, there is a decrease in the concentration of calcium, magnesium, and bicarbonate and an increase in the concentration of sodium and potassium. Calcium, magnesium, and bicarbonate are dissolved in the water due to interaction with the soil environment. As the ground water enters the basalt aquifer system, dissolution of basaltic glass introduces sodium and potassium, and calcium and magnesium are precipitated as carbonates or incorporated into clays. The result is a predominantly sodium-bicarbonate ground water.

Figure 4.11 presents a Piper diagram prepared from analytical results of the 10 monitor and 3 production wells believed to be unaffected by plant activities and includes a dashed line which incorporates the average values for data collected by Newcomb. Although all of the data fall within

MARTIN MARIETTA, THE DALLES
BACKGROUND GEOCHEMICAL DATA

1	MWR-1A
2	MW-20A
3	MW-24A
4	MW-2S
5	MW-20S
6	PW-3
7	PW-4
8	PW-1
9	MW-11D
A	MW-16D
B	MW-25S
C	MW-3S
D	MW-24S

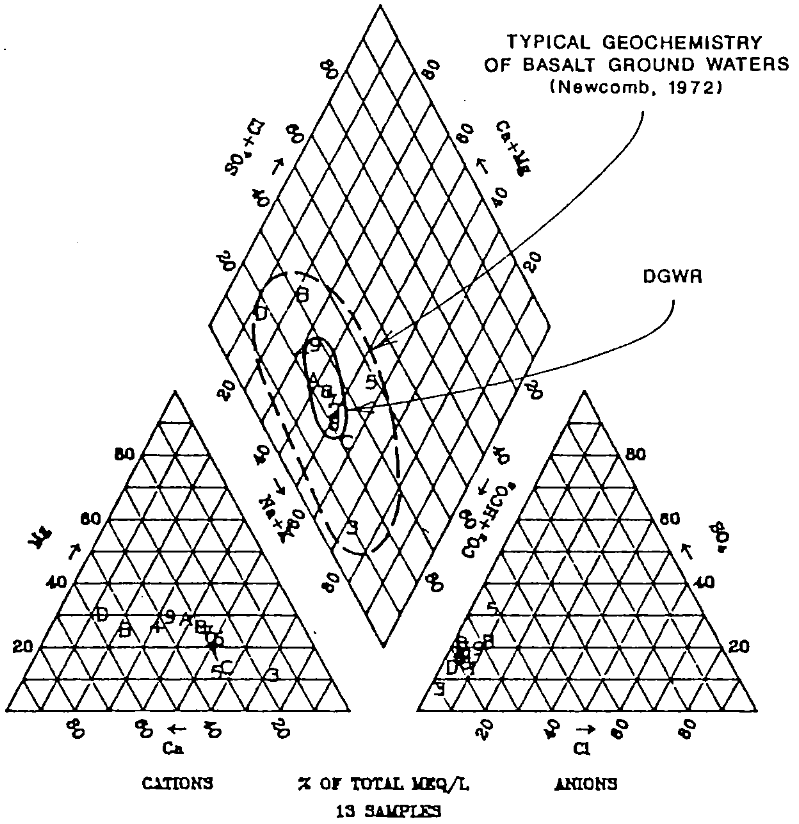


Figure 4.11 Piper Diagram.

CLIENT NAME:

Martin Marietta Corporation

the boundaries of the dashed line and are considered typical for basalt ground water, a geochemical evaluation of the ground water from all on-site monitor wells does not provide sufficient information to interpret the direction of ground-water movement or mixing between aquifers.

4.7.2 Distribution of Constituents

The distribution of constituents in the ground-water systems underlying the MMRF has been described from the analytical results of samples from the monitor-well network. Two sets of ground-water samples were collected during the RI, during the summers of 1986 and 1987. A total of 60 ground-water samples, 6 aqueous field blanks, and 46 aqueous trip blanks were collected from August 26 to September 4, 1986. The analyses performed included base/neutral acid extractable organics, volatile organic compounds, PCBs, total and free cyanide, fluoride, sodium, arsenic, EP toxicity metals and sulfate.

During the period from July 27 to September 2, 1987, 101 ground-water samples, 14 field blanks, and 2 trip blanks were collected in accordance with the sampling protocol presented in the RI/FS work plan. Samples were submitted to Versar, Inc., and Compuchem Laboratories. Samples submitted to both laboratories were analyzed for total and free cyanide, fluoride, sulfate, and sodium. Samples submitted to Versar were also analyzed for calcium, magnesium, potassium, chloride, bicarbonate, and carbonate.

The resulting analytical data (Table 4.6 and Appendix C) have been validated as described in the QA/QC summary (Appendix D). In addition, numerous ground-water analyses of samples from the monitor wells at the MMRF had been performed prior to implementation of the RI. These data, where utilized, were limited to qualitative interpretations and no

Table 4.6 Ground-Water Quality Analytical Results
(all results expressed in milligrams per liter)

Well No.	Date	Free Cyanide	Total Cyanide	Sodium Total	Fluoride	Sulfate
MW-2S	08/04/87	<0.01	<0.01	10.5	<1.0	33
MW-3S	08/09/87	<0.01	<0.01	28.3	<1.0	<5.0
MW-4S	08/28/86	<0.01	0.049	15	0.83	98
MW-4S	08/02/87	<0.01	0.024	12.9	<1.0	25J
MW-5S	08/09/87	0.215	34.10	1270	57	680
MW-8S	08/03/87	0.136	7.07	57.2	<1.0	103
MW-9S	08/04/87	0.060	16.7	82.2	1.9	41
MW-15S	08/26/86	0.049	0.67	59	7.4	136
MW-15S	08/03/87	0.095	0.312	59.7	4.7	74
MW-17S	08/26/86	0.024	0.78	22	1.3	143
MW-17S	07/30/87	0.027	0.549	31.4	<1.0	1130J
MW-18S	08/28/86	<0.01	0.05	16	12	617
MW-18S	08/08/87	<0.01	0.05	374	7.1	1810
MW-19S	08/26/86	<0.01	<0.01	184	8.9	573
MW-19S	07/30/87	<0.01	<0.01	246	4.8	117J
MW-20S	08/26/86	<0.01	<0.01	39	0.98	37
MW-20S	07/30/87	<0.01	<0.01UJ	49.9	<1.0	66J
MW-21S	08/27/86	<0.01	<0.01	45	12	74
MW-21S	08/05/87	<0.01	0.014	90.5	5.5	871
MW-22S	08/02/87	0.012	0.112	32.0	<1.0	46J
MW-23S	07/31/87	0.015	0.18J	18.8	<1.0	16J
MW-24S	08/03/87	<0.01	<0.01	3.93	<1.0	10
MW-25S	08/08/87	<0.01	<0.01	11.3	<1.0	33
MW-26S	07/31/87	<0.01	<0.01UJ	32.3	<1.0	22J
MW-27S	08/03/87	0.077	0.795	15.7	<1.0	32

Table 4.6 (continued)

Well No.	Date	Free Cyanide	Total Cyanide	Sodium Total	Fluoride	Sulfate
MW-28S	08/07/87	<0.01	<0.01	82.6	<1.0	123
MW-29S	08/08/87	<0.01	<0.01	658.0	<1.0	3020
MW-30S	08/24/87	<0.01	<0.01	84.8	<1.0	924
MW-31S	08/27/87	<0.01	0.041	58.5	1.0	153
MW-32S	08/24/87	0.052	1.02	24.5	2.5	45
MW-1A	08/29/86	<0.01	<0.01	49	0.93	48
MWR-1A	08/16/87	<0.01	<0.01J	56.4	<1.0	36
MW-2A	08/29/86	<0.01	0.13	23	0.65	20
MWR-2A	08/15/87	0.038	0.608J	31.7	<1.0	91
MW-3A	08/27/86	<0.01	<0.01	24	0.97	30
MWR-3A	08/09/87	<0.01	0.016	23.0	<1.0	38
MW-4A	08/28/86	<0.01	0.059	15	0.86	135
MWR-4A	08/09/87	<0.01	0.213	29.1	<1.0	64
MW-5A	08/28/86	<0.01	<0.01	17	0.51	37
MW-5A	08/07/87	<0.01	0.041	17.1	<1.0	59
MW-6A	09/03/86	0.23	0.38	23	1.1	9.1
MW-6AA	09/01/86	0.036	0.32	24	0.97	8.3
MW-6AA	08/12/87	0.062	0.557	34.9	1.0	22
MW-7A	08/28/86	0.086	0.46	19	1.2	18
MWR-7A	08/05/87	0.099	0.803	29.0	<1.0	28
MW-8A	09/03/86	0.48	1.1	38	1.0	44
MWR-8A	07/28/87	0.030J	1.78	42.7	<1.0	76
MW-9A	09/03/86	0.053	1.8	42	1.4	40
MWR-9A	08/04/87	0.132	12.6	167	10	100
MW-10A	08/28/86	<0.01	<0.01	24	0.58	22
MW-10A	08/06/87	<0.01	0.020	26.8	<1.0	21
MW-12A	08/27/86	0.013	0.084	25	0.90	13
MW-12A	07/28/87	<0.01	0.096J	29.5	<1.0	<5.0
MW-13A	08/27/86	<0.01	0.13	20	0.85	20
MW-13A	07/29/87	0.037	0.241	20.9	<1.0	21J

Table 4.6 (continued)

Well No.	Date	Free Cyanide	Total Cyanide	Sodium Total	Fluoride	Sulfate
MW-14A	08/26/86	<0.01	0.026	29	1.3	14
MW-14A	07/29/87	<0.01	0.023	31.8	1.0	77
MW-15A	08/26/86	0.049	2.4	33	1.1	52
MW-15A	08/11/87	0.052	0.270	37.0	<1.0	44
MW-16A	08/28/86	<0.01	0.033	43	1.2	22
MW-16A	08/11/87	0.012	0.040J	41.2	<1.0	25
MW-18A	08/29/87	<0.01	<0.01J	46.7	<1.0	81
MW-20A	08/27/86	<0.01	<0.01	34	1.0	35
MW-20A	08/05/87	<0.01	<0.01	38.4	<1.0	27
MW-24A	08/12/87	<0.01	<0.01	44.7	1.0	23
MW-26A	08/10/87	0.025	0.312J	61.2	<1.0	75
MW-27A	08/10/87	0.016	0.200J	28.1	1.0	29
MW-33A	08/24/87	0.085	1.50	43.2	<1.0	71
MW-34A	08/27/87	<0.01	<0.01	61.4	<1.0	27
MW-1B	08/28/86	<0.01	<0.01	30	1.3	22
MWR-1B	08/17/87	<0.01	<0.01	41.1	<1.0	17
MW-2B	08/28/86	0.093	0.57	35	0.9	80
MWR-2B	08/16/87	0.034	1.180J	48.3	<1.0	100
MW-3B	08/28/86	<0.01	0.026	26	1.3	24
MWR-3B	08/13/87	<0.01	0.024J	31.3	<1.0	22
MW-4B	08/13/87	<0.01	<0.01J	33.9	<1.0	54
MW-6B	09/03/86	0.47	1.2	26	0.93	83
MWR-6B	07/28/87	0.051	1.12J	25.1	<1.0	73
MW-7B	09/01/86	0.042	0.77	22	0.71	78
MWR-7B	08/16/87	0.035	0.953J	27.7	<1.0	99
MW-8B	09/03/86	0.19	0.48	25	1.8	67
MWR-8B	07/27/87	0.062J	1.22	43.7	2.9	61
MW-9B	09/04/86	0.54	1.0	32	1.4	50
MWR-9B	08/15/87	0.057	10.00J	195.0	20	92

Table 4.6 (continued)

Well No.	Date	Free Cyanide	Total Cyanide	Sodium Total	Fluoride	Sulfate
MW-12B	08/27/86	0.01	0.08	16	0.65	22
MW-12B	07/29/87	0.02	0.099J	17.4	<1.0	9.4
MW-13B	08/27/86	0.025	0.15	13	0.82	24
MW-13B	07/29/87	0.022	0.138	14.8	<1.0	20J
MW-14B	08/26/86	0.058	0.30	24	0.86	73
MW-14B	07/29/87	0.041	0.641	24.8	<1.0	72J
MW-15B	08/26/86	0.052	1.5	22	1.1	97
MW-15B	08/11/87	0.095	0.802	23.8	<1.0	88
MW-16B	08/28/86	0.030	1.1	34	4.2	31
MW-16B	08/23/87	0.015	0.260	25.1	1.4	21
MW-18B	08/17/87	<0.01	<0.01J	67.0	<1.0	271
MW-26B	08/20/87	0.047	1.28	32.5	<1.0	83
MW-27B	08/26/87	0.033	0.716	27.0	<1.0	34
MW-33B	08/24/87	0.10	0.955	21.7	<1.0	145
MW-34B	08/25/87	<0.01	0.013	37.2	<1.0	12
MW-1C	08/28/86	<0.01	<0.01	27	1.0	22
MW-3C	09/02/86	<0.01	0.036	28	0.9	24
MW-11D	08/28/86	<0.01	<0.01	17	0.77	24
MW-11D	08/09/87	<0.01	<0.01UJ	16.4	<1.0	22
MW-16D	08/27/86	<0.01	<0.01	17	0.68	24
MW-16D	08/11/87	<0.01	<0.01UJ	17.9	<1.0	21
PW-1	09/02/86	<0.01	<0.01	29	1.2	34
PW-1	08/11/87	<0.01	<0.01UJ	29.3	<1.0	29
PW-3	09/01/86	<0.01	<0.01	33	1.1	29
PW-3	08/11/87	<0.01	<0.01UJ	38.9	<1.0	20
PW-4	09/02/86	<0.01	0.01	23	0.72	21
PW-4	08/11/87	<0.01	<0.01UJ	23.8	<1.0	16
Animal Shelter						
	09/03/86	<0.01	0.036	7.4	0.38	26
	08/11/87	<0.01	0.023	6.23	<1.0	15

Table 4.6 (continued)

Well No.	Date	Free Cyanide	Total Cyanide	Sodium Total	Fluoride	Sulfate
Chenoweth No. 1	09/04/86	<0.01	<0.01	43	1.1	42
	08/13/87	<0.01	<0.01	47.4	<1.0	40
Chenoweth No. 3	09/04/86	<0.01	<0.01	39	1.0	32
	08/13/87	<0.01	<0.01	44.8	1.0	30
Klindt	09/02/86	0.013	0.46	10	0.63	49.5
	08/11/87	0.037	0.177	14.0	<1.0	55
Mt. Fir Lumber	09/02/86	<0.01	0.013	19	1.1	194
	08/11/87	<0.01	<0.01	20.5	<1.0	125
Recreation Well	08/29/86	<0.01	<0.01	36	1.3	22
	08/06/87	<0.01	0.01	40.0	<1.0	33
Rockline	09/03/86	<0.01	0.29	35	2.8	121
	08/11/87	0.023	0.336	4.16	2.2	105
CRSWG-1	08/25/87	<0.01	<0.01	5.23	<1.0	11
CCSWG-1	08/02/87	<0.01	<0.01	18.4	<1.0	22
CCSWG-2	08/24/87	<0.01	<0.01	6.0	<1.0	9.0
Residence Well	08/19/87	<0.01	0.055	95.1	6.6	429
8B Pump Test Start	08/27/87	0.057	0.608	28.5	1.0	60
8B Pump Test Middle	08/29/87	0.026	0.402	18.5	<1.0	41
8B Pump Test End	08/30/87	0.038	0.457	18.9	<1.0	38
O CWP (Test Pit B)	06/26/87	3.010	294.0	10500	3730 3000	—

Notes: J = value estimated because did not meet QC criteria
U = value estimated because did not meet QC criteria and was below the detection limit

569/8

data validation has been performed on previously collected test results.

Several inorganic constituents have been identified within the perched water, the alluvial, S, A, and B aquifers, but not in the DGWR. The identified waste constituents included total and free cyanide, fluoride, sodium, and sulfate. With few exceptions, the concentrations of these constituents in the potential water-supply aquifers (A and B) are below ARARs. Highest constituent concentrations were identified in perched water with progressively lower concentrations generally identified within the S, A, and B aquifers.

Sodium, sulfate, fluoride, total and free cyanide were identified in samples of perched water. Four separate areas containing concentrations of constituents above background were identified in the S aquifer: one near the landfill and former cathode waste management areas; one near the alumina unloading building area and the new cathode waste pad; one from the scrubber sludge ponds; and one from the recycle pond. The area containing constituent concentrations associated with the landfill and former cathode waste management areas extends vertically from the S to the B aquifer, including the alluvial aquifer, and is characterized primarily by total cyanide; fluoride, sulfate, sodium, and free cyanide are also present but more localized in distribution. The area containing constituent concentrations associated with the scrubber sludge ponds contains sulfate, sodium, and fluoride with cyanides essentially absent and is generally restricted to the S aquifer. Sulfate and fluoride, below ARARs, were detected in the B aquifer near the ponds. The constituents associated with the area near the alumina unloading building and the new cathode waste pad are total cyanide and some free cyanide, which are apparently restricted to the S and A aquifers. The area containing constituent concentrations associated with the recycle pond is apparently very localized and contains fluoride, sodium, and sulfate. The ground-water quality associated with the various aquifers is described below. The discussions reference the analytical data from the summer of 1987, which represent the data from the reconstructed monitor wells.

4.7.2.1 Perched Water

The perched water contains concentrations of total cyanide (294 mg/L), free cyanide (3.01 mg/L), fluoride (3000 mg/L), sodium (10,500 mg/L), and PAHs in one of the unfiltered samples (summed at 0.255 mg/L) (Tables 3.2 and 3.3). PAHs were not identified in subsequent samples of perched water, whether filtered or unfiltered.

4.7.2.2 Alluvial Aquifer

Only the Animal Shelter well uses the alluvial aquifer as a source of supply. Analytical results of samples taken from the Animal Shelter well in August 1987 provide an indication of ground-water quality in the northwestern part of the alluvial aquifer (Figure 4.12). Total cyanide concentration was reported at 0.023 mg/L; no free cyanide or fluoride was detected. Water samples from the quarry adjacent to the MMRF and located within the alluvial aquifer were collected prior to the RI. Although these analyses are not supported by sufficient quality assurance documentation, levels of total and free cyanide and fluoride were reported as present. These samples were collected prior to construction of the leachate-collection system and probably represent a component of landfill runoff. The Rockline well is cased through the alluvial aquifer and screened in the underlying Sentinel Gap flow. The cyanide concentrations identified at Rockline are apparently related to the plume within the

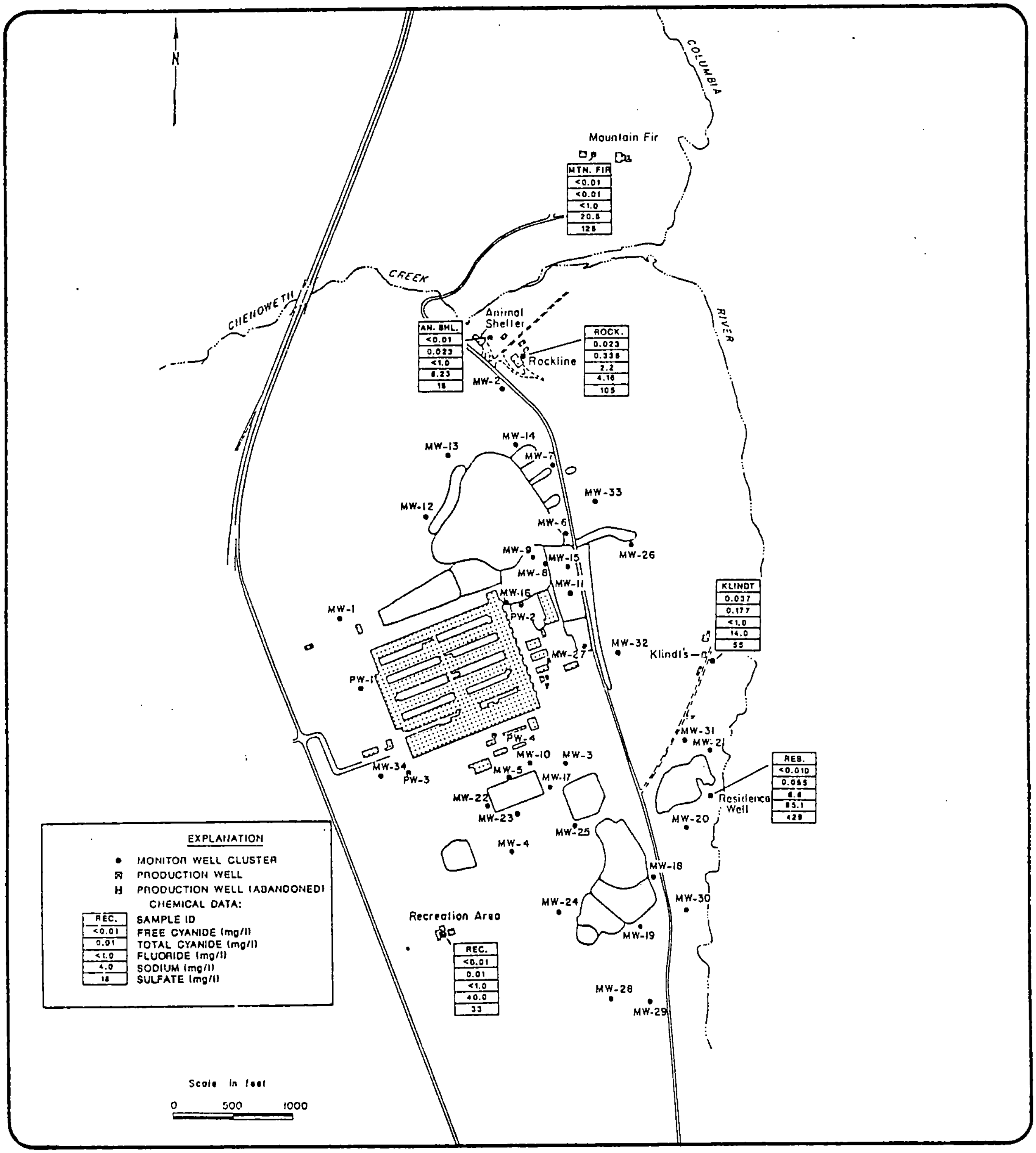


Figure 4.12 Water-Supply Well Water Quality.

CLIENT NAME:

Martin Marietta Corporation

alluvial aquifer, possibly resulting from leakage down the casing or downward ground-water flow.

4.7.2.3 S Aquifer

Four relatively distinct areas of elevated constituent concentrations with differing chemical characteristics, can be identified in the S aquifer (Figures 4.13, 4.14, 4.15, and 4.16). These are situated near the landfill and former cathode waste management area, recycle pond, scrubber sludge ponds, and in the vicinity of the aluminum unloading building and the new cathode waste pad area.

The largest of these areas is associated with the landfill area and the former cathode waste management area. The highest concentrations within the area are located beneath the former cathode waste management area. This corresponds to the area of the S aquifer overlain by perched water. This area is characterized by total cyanide (up to 16.7 mg/L) and sulfate (up to 103 mg/L); fluoride concentrations were identified below the salvage area and at well MW-32S (1.9 to 4.7 mg/L), but otherwise are reported at less than laboratory detection limits (1.0 mg/L). Free cyanide concentrations range from <0.010 to 0.136 mg/L. Maximum sodium concentrations were identified below the old cathode waste pad and salvage area ranged from 57.2 to 82.2 mg/L. The area containing elevated concentrations of total cyanide extends from the landfill area eastward to the Columbia River, northward to the alluvial aquifer, and south to the area of fluoride concentrations above background associated with the recycle pond.

Another distinct area of elevated constituent concentrations in the S aquifer is related to the scrubber sludge ponds. That area contains fluoride (4.8 to 7.1 mg/L), sodium (246 to 658 mg/L), and sulfate (117 to 3,020 mg/L). Free

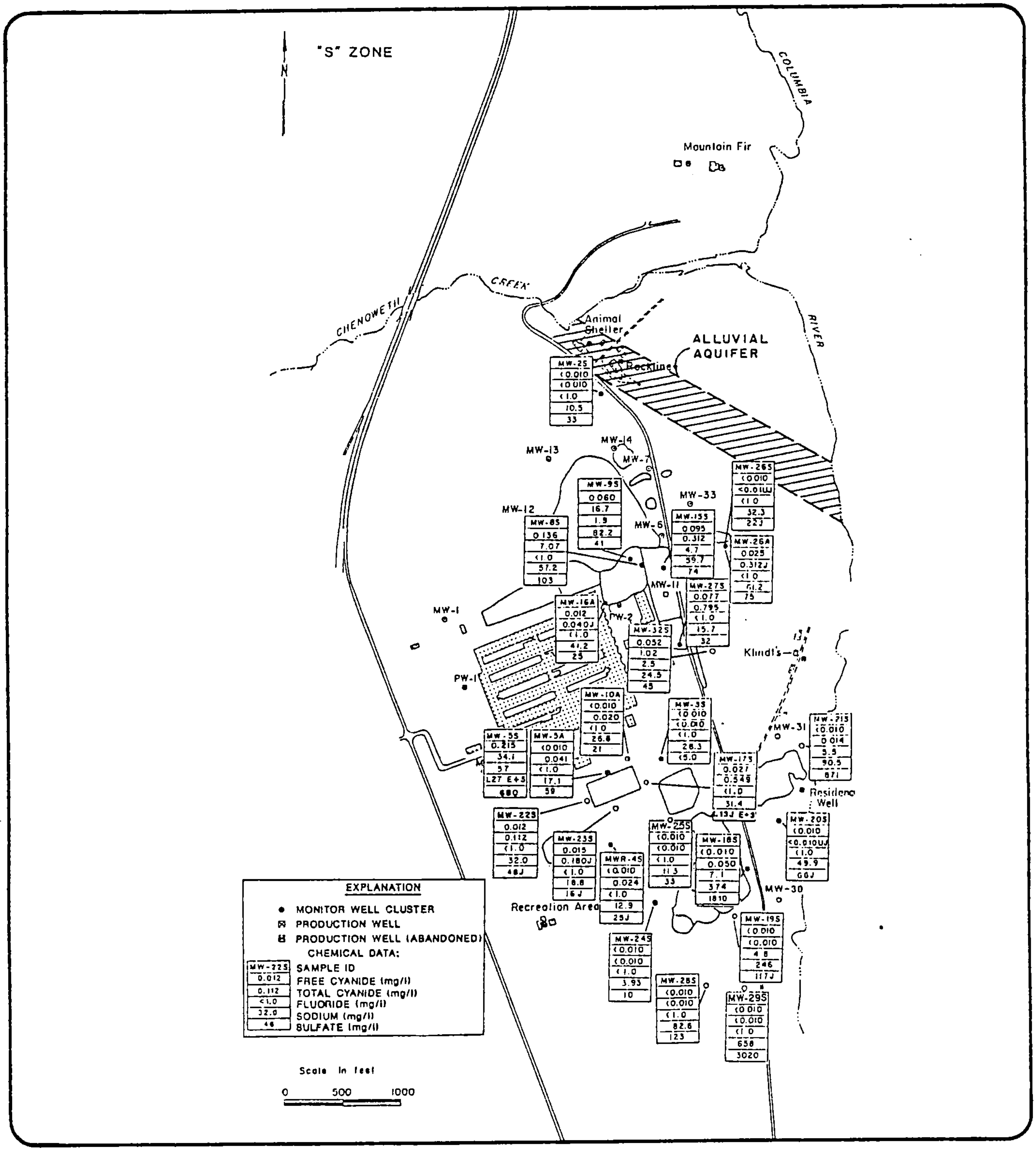


Figure 4.13 S Aquifer Water Quality.

CLIENT NAME:

Martin Marietta Corporation

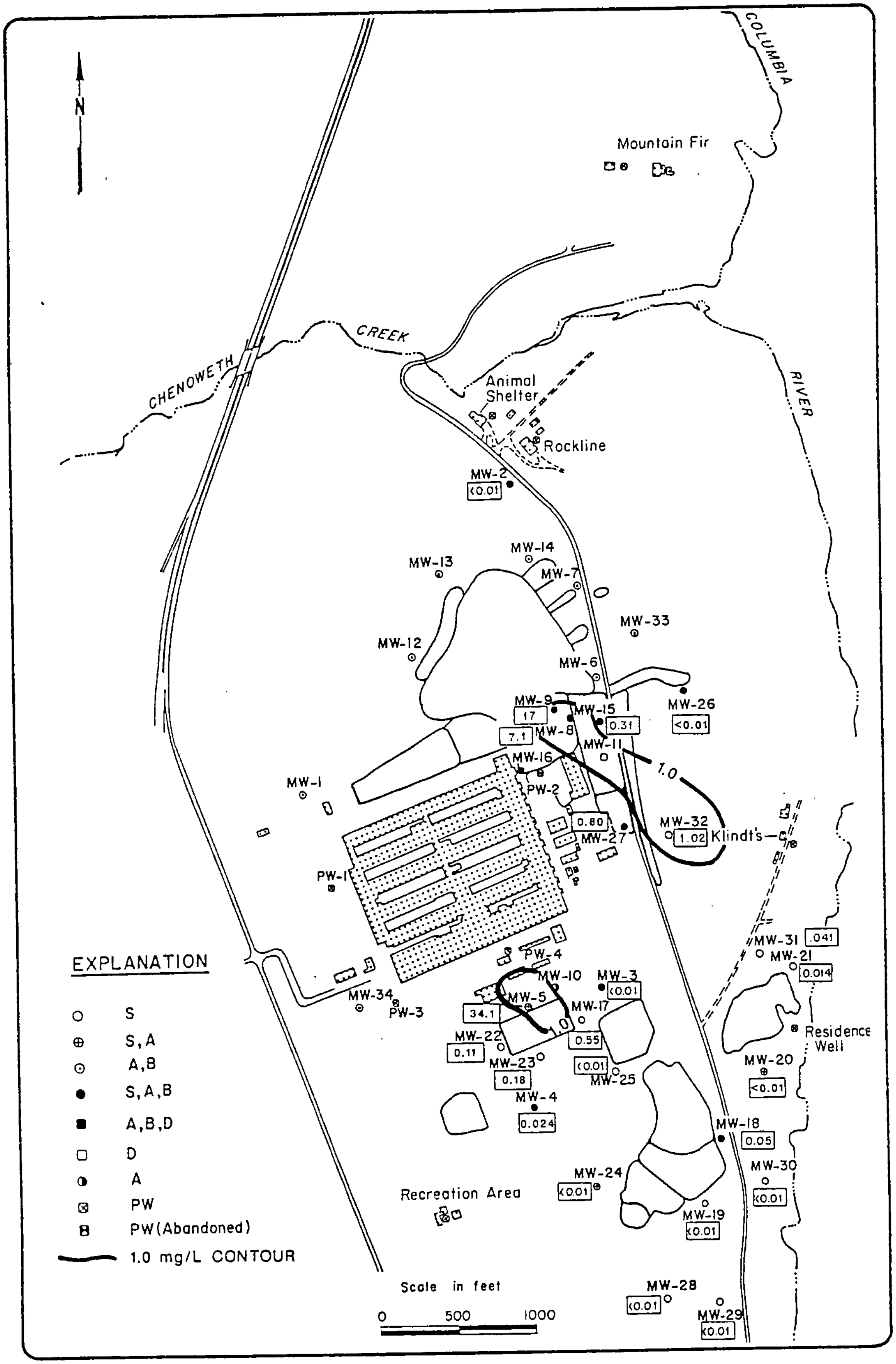


Figure 4.14 Total Cyanide Concentration, S Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation

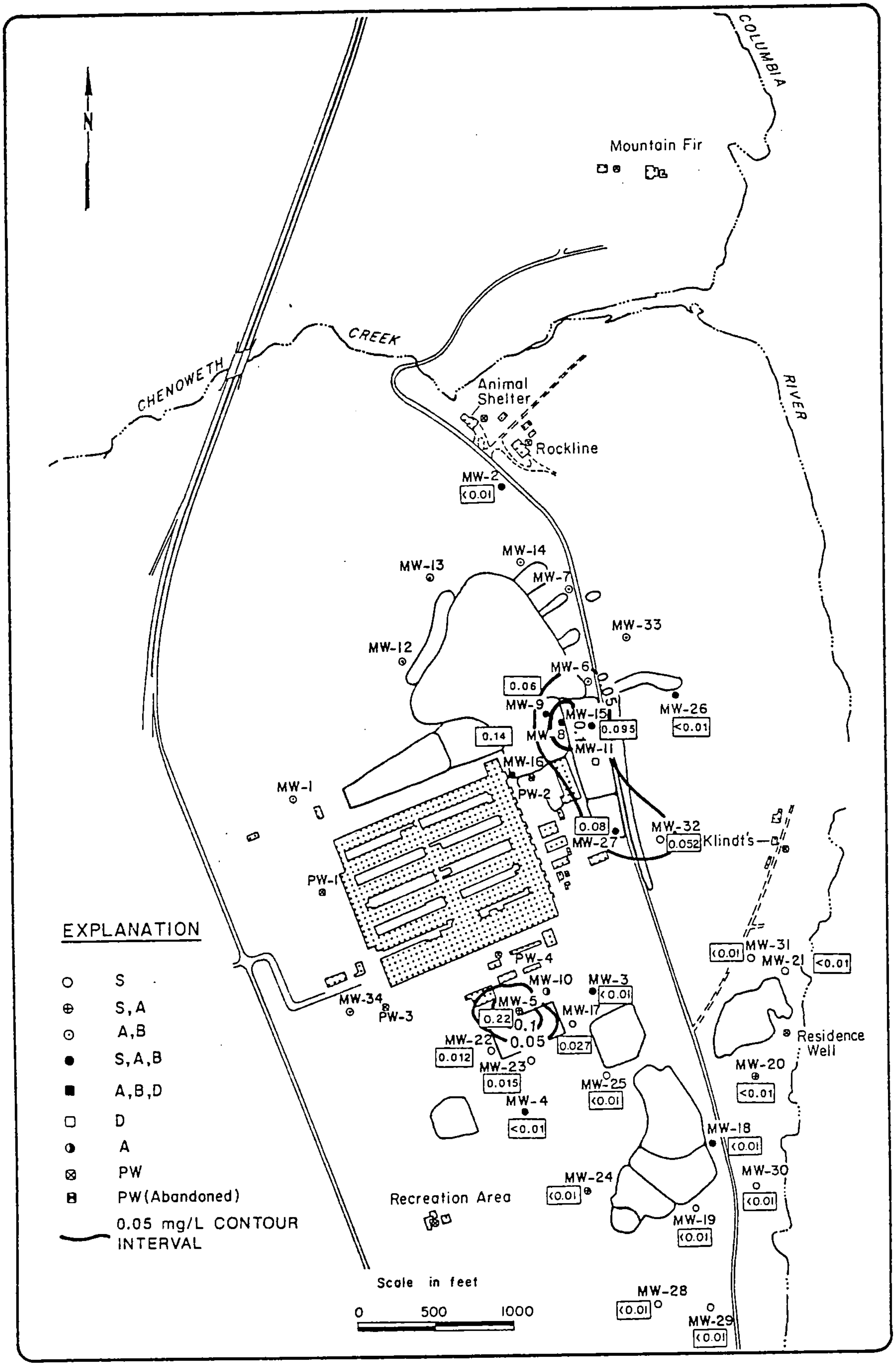


Figure 4.15 Free Cyanide Concentration, S Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation

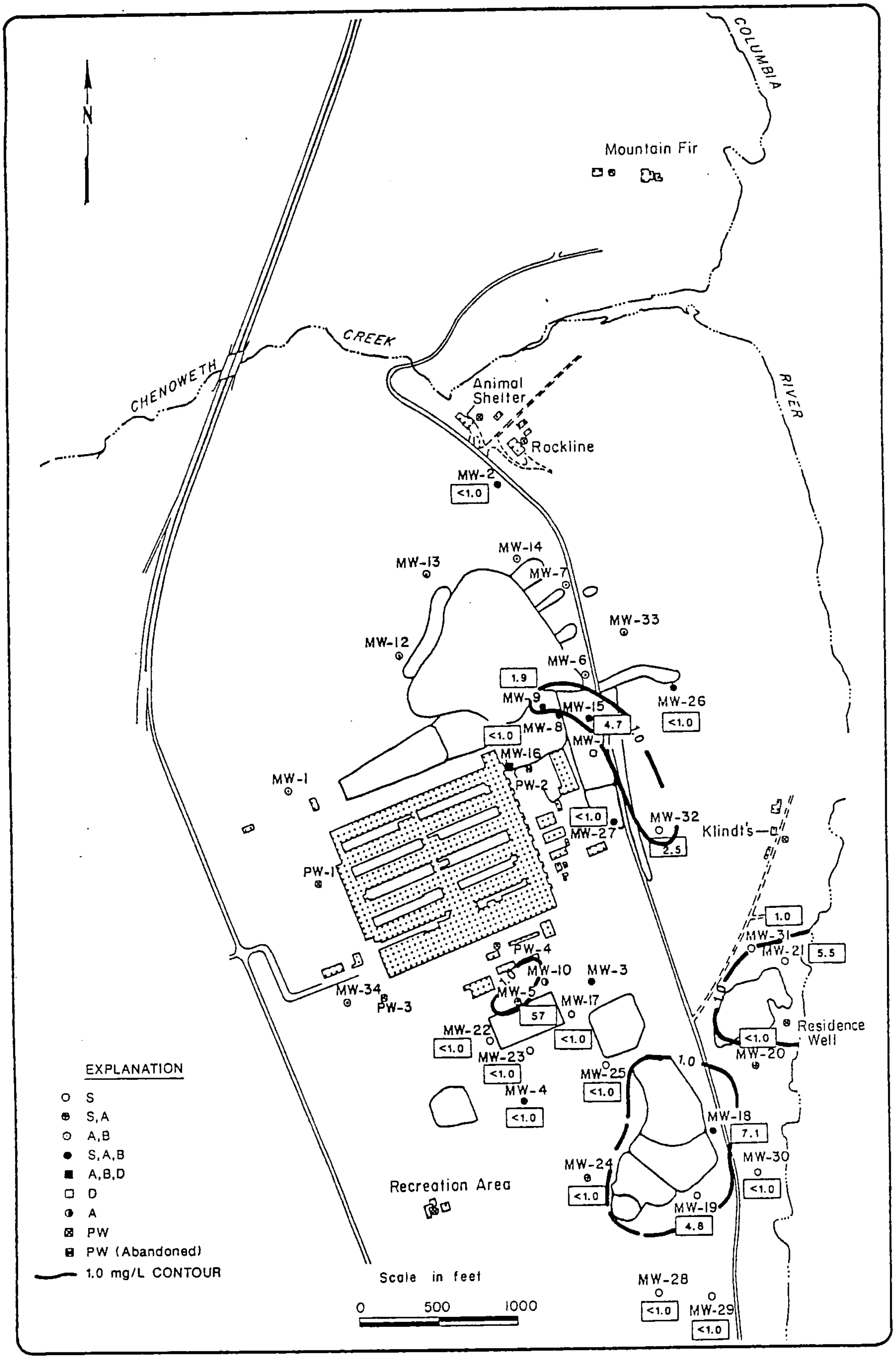


Figure 4.16 Fluoride Concentration, S Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation

cyanide was below detection limits and total cyanide was reported in only one well (MW-18S) at 0.05 mg/L. This area extends from the northwestern boundary of the scrubber sludge ponds southeastward to the Columbia River.

In the S aquifer, the highest concentrations of constituents are reported at well MW-5S, located upgradient of the new cathode waste pad. These concentrations suggest a potential source area, not investigated during the RI, near the alumina unloading building. A preliminary evaluation of potential sources has identified cathode waste in this area. The distribution of the cathode waste material will be evaluated as part of the FS. Ground water in the S aquifer near this area contains total cyanide; concentrations of fluoride, sodium, and sulfate are found at well MW-5S but were below detection limits in samples from downgradient wells collected in July and August 1987. Total cyanide concentration at well 5S was 34.1 mg/L but ranged from 0.112 to 0.549 mg/L in the wells immediately downgradient. The sample from well 17S, collected in August 1986, contained 0.78 mg/L total cyanide and 1.3 mg/L fluoride. Total cyanide and other constituents decrease laterally (total cyanide concentration at well 4S was 0.024 mg/L), and vertically (total cyanide concentrations at wells 5A and 10A, screened at the base of the S aquifer, were 0.041 and 0.020 mg/L, respectively). Sulfate concentrations were 1,270 mg/L at well MW-5S and 1,130 mg/L at well MW-17S.

The fourth area identified in the S aquifer containing elevated constituent concentrations is associated with the recycle pond. This area contains concentrations of fluoride, sodium, and sulfate, is localized near the pond and extends eastward to the Columbia River. Concentrations of 5.5 mg/L of fluoride and 871 mg/L of sulfate were noted in MW-21S.

4.7.2.4 A Aquifer

Ground-water quality impacts in the A aquifer are less widespread and at lower concentrations than those identified in the S aquifer (Figures 4.17, 4.18, 4.19, and 4.20). The highest concentrations of constituents in the A aquifer are reported east of the landfill and the former cathode waste management area. Ground water in this area contains total cyanide in concentrations ranging from 0.023 to 1.78 mg/L. Concentrations of total cyanide were 1.5 mg/L at well MW-33A, 0.312 mg/L at well MW-26A, and 0.200 mg/L at well MW-27A. A value of 12.6 mg/L total cyanide reported at well MW-9A is felt to be an artifact of well construction and not representative of ambient water quality in this area. Well MW-9A was constructed in an area underlain by perched water and the borehole was open for several days until installation of the well casing and annular seal. Perched water, characterized by concentrations of total cyanide of about 300 mg/L and fluoride of about 3,500 mg/L, flowed down the borehole and entered the A aquifer. Assuming a flow rate of 1 gpm for three days, over 4,000 gallons may have been introduced. Although additional analyses are required to confirm this hypothesis, the decline in reported fluoride concentrations at well MW-16B (also installed through the perched water) from 1986 to 1987 provides supporting data.

Sodium concentrations were 167 mg/L beneath the old cathode waste pile (well MW-9A) but are less than 60 mg/L elsewhere. Free cyanide concentrations range from 0.016 to 0.132 mg/L and are highest below the old cathode waste pile. The area containing elevated constituent concentrations extends from the landfill southeast to the Columbia River and northeast to the Chenoweth fault. Cyanide at well MW-31S (0.041 mg/L) may represent the extent of total cyanide concentrations derived from the former cathode waste management area.

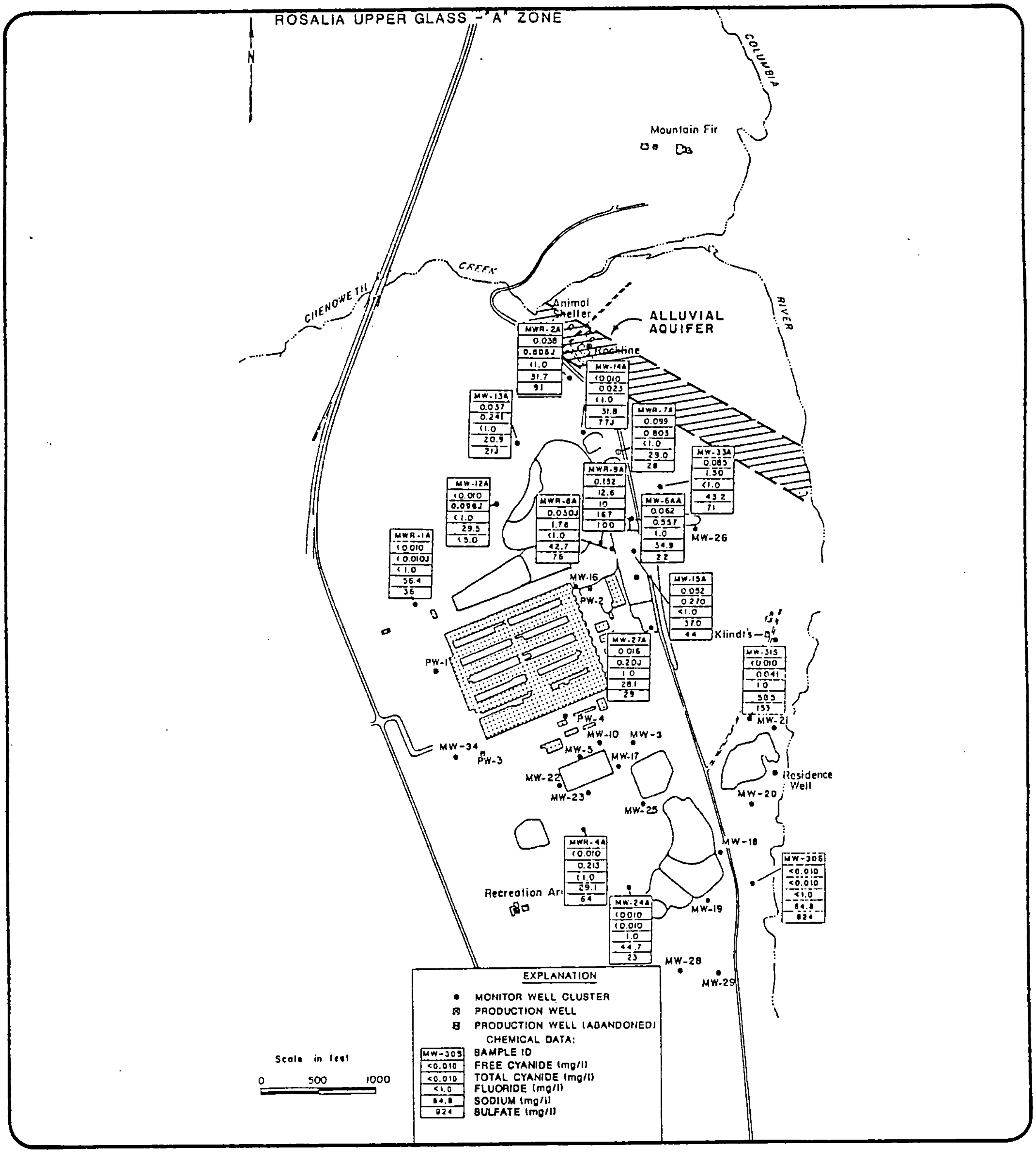


Figure 4.17 A Aquifer Water Quality.

CLIENT NAME:

Martin Marietta Corporation

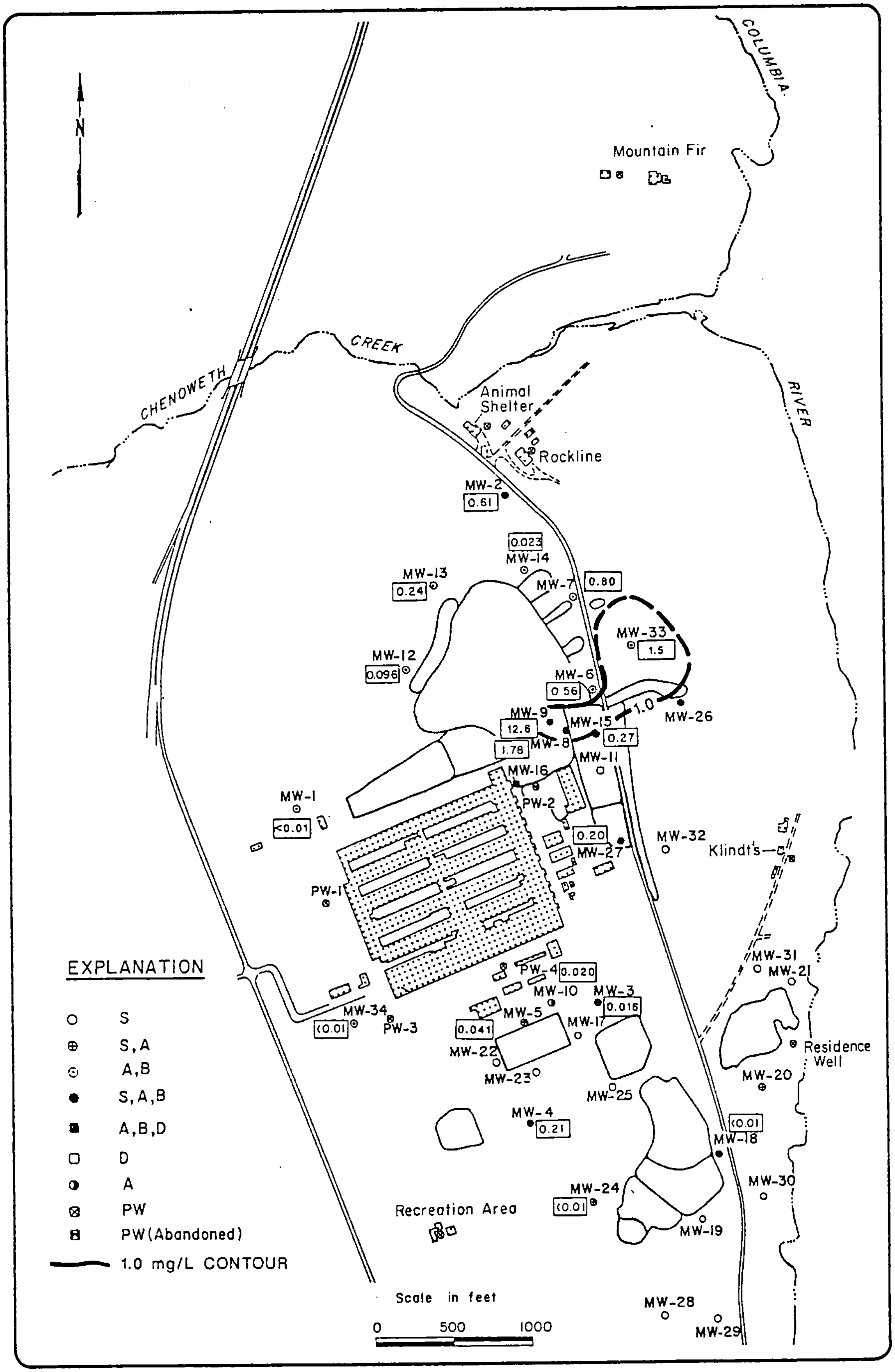


Figure 4.18 Total Cyanide Concentration, A Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation

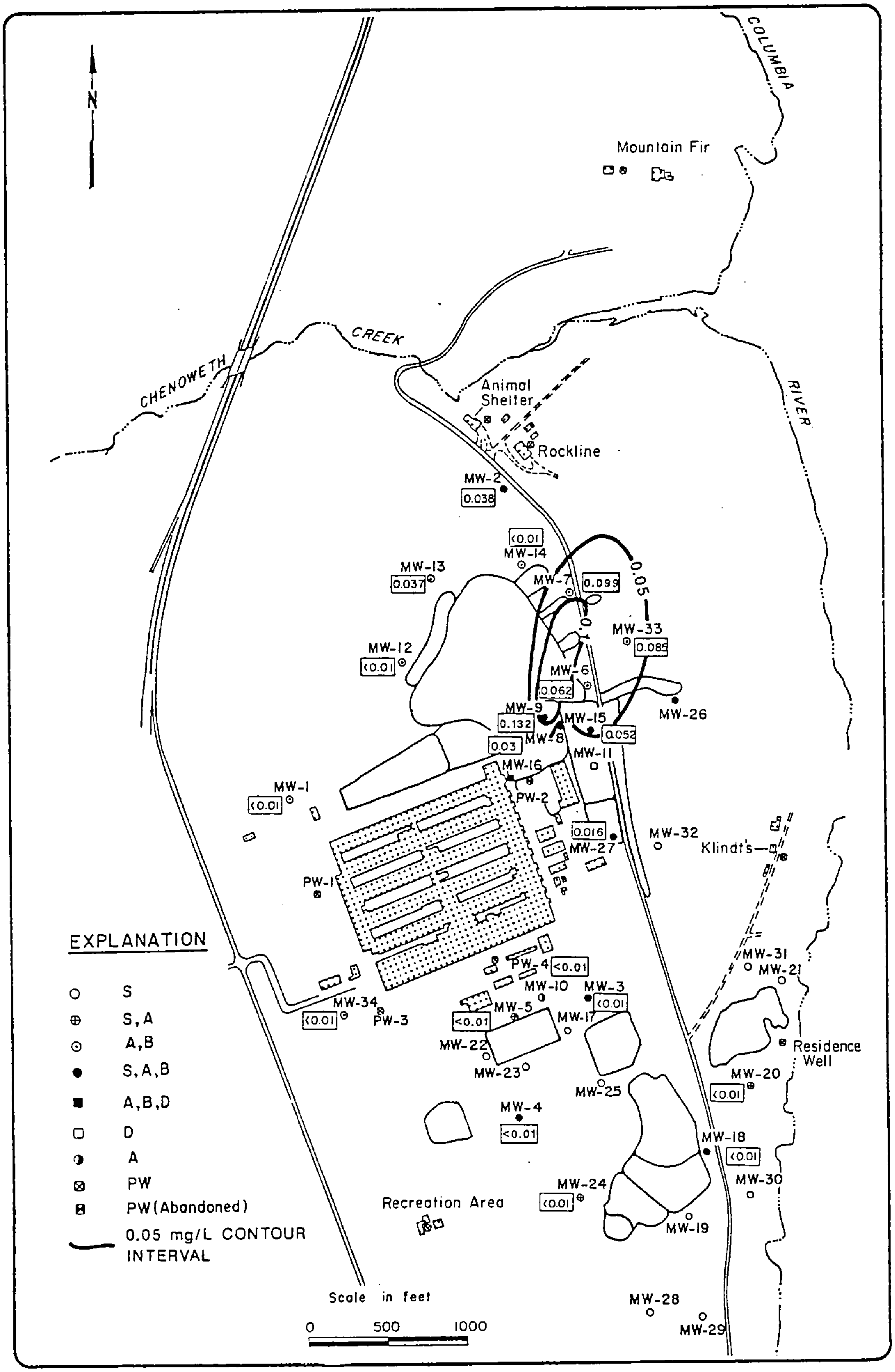


Figure 4.19 Free Cyanide Concentration, A Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation

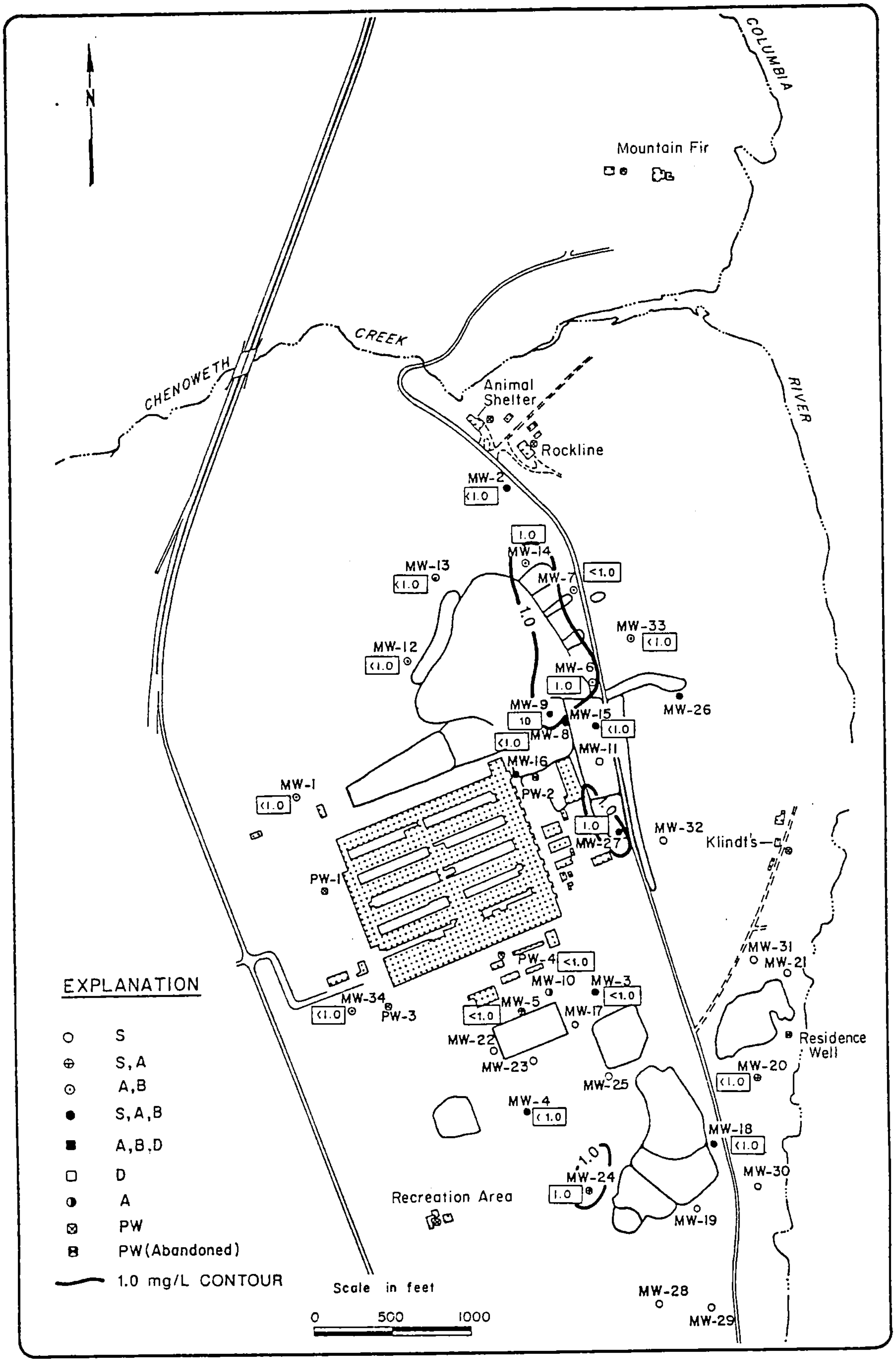


Figure 4.20 Fluoride Concentration, A Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation

In the A aquifer near the scrubber sludge ponds, sodium was reported at 44.7 and 84.8 mg/L, sulfate at 23 and 924 mg/L, and fluoride at 1.0 and <1.0 mg/L. In the A aquifer near the recycle pond, the ground water contains low levels of sulfate (153 mg/L) presumably related to operation of the pond.

4.7.2.5 B Aquifer

Ground-water quality impacts in the B aquifer are primarily confined to the landfill and old cathode waste management areas (Figures 4.21, 4.22, 4.23, and 4.24). The impacted area extends from west of the landfill eastward to the Chenoweth fault, and southeastward through the cathode wash area toward the Columbia River. The area is characterized by levels of total cyanide generally ranging up to 1.5 mg/L. Total cyanide concentrations at well MW-9B were reported at 10.0 mg/L. Free cyanide concentrations are 0.10 mg/L or less. Fluoride concentrations were 20.0 mg/L at well MW-9B and 2.9 at well MW-8B, but are otherwise less than 1.4 mg/L. As described previously, the elevated concentrations of total and free cyanide and other constituents at wells installed in the perched water (clusters MW-8 and MW-9) are believed to be an artifact of well construction. These data are considerably higher than historically reported in this area. Well MW-8B was sampled three times during the pump test of the well and the total cyanide results ranged from 0.402 to 0.608 mg/L, about half the original result. Fluoride analyses were below detection limits for the pump test samples versus 2.4 mg/L for the original sample.

No other major areas on constituent concentrations above background are evident in the B aquifer. Total cyanide concentrations in the B aquifer near the new cathode waste pad are 0.024 mg/L. Sulfate concentrations in the B aquifer near the scrubber sludge ponds are slightly elevated (271

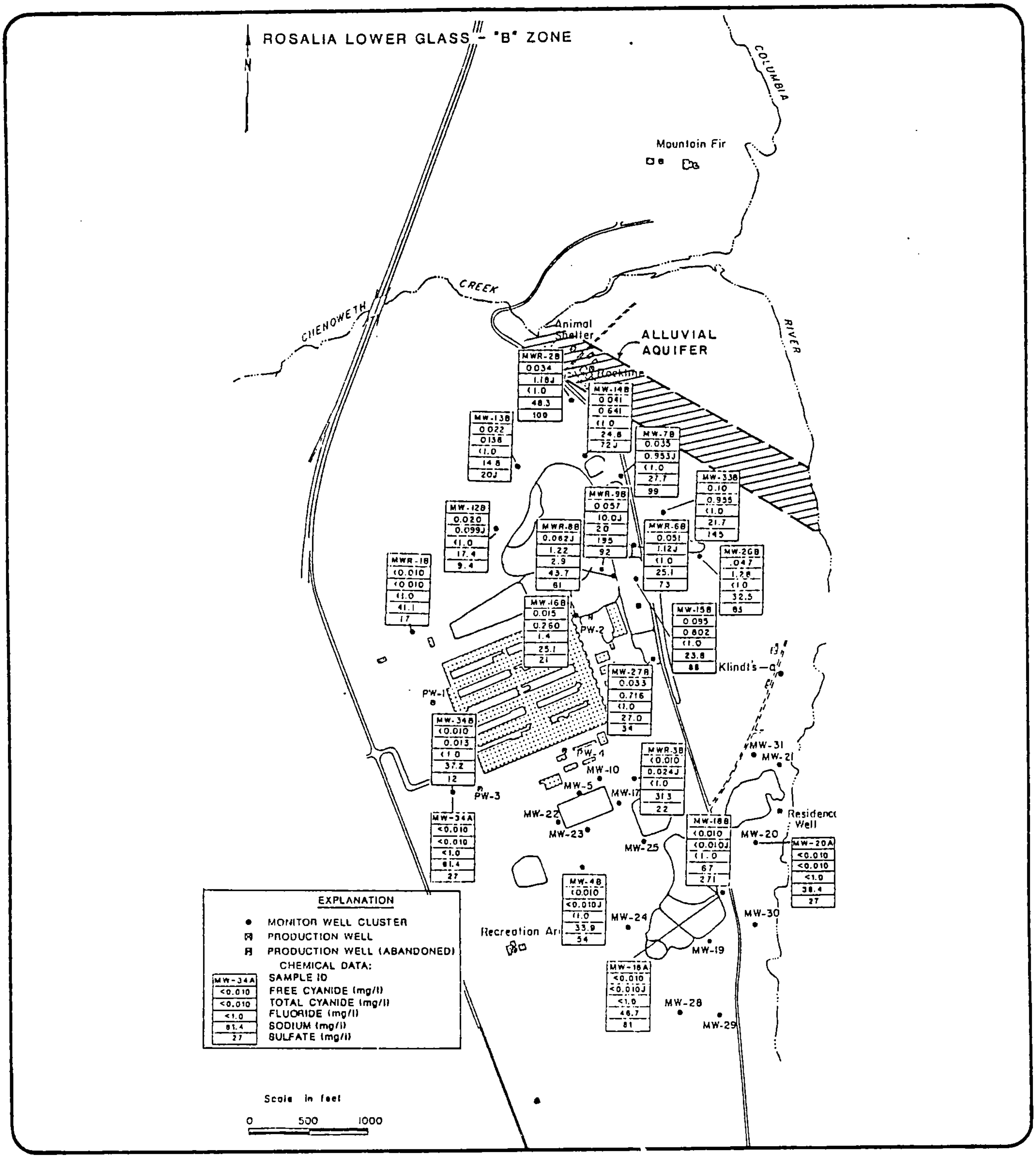


Figure 4.21 B Aquifer Water Quality.

CLIENT NAME:

Martin Marietta Corporation

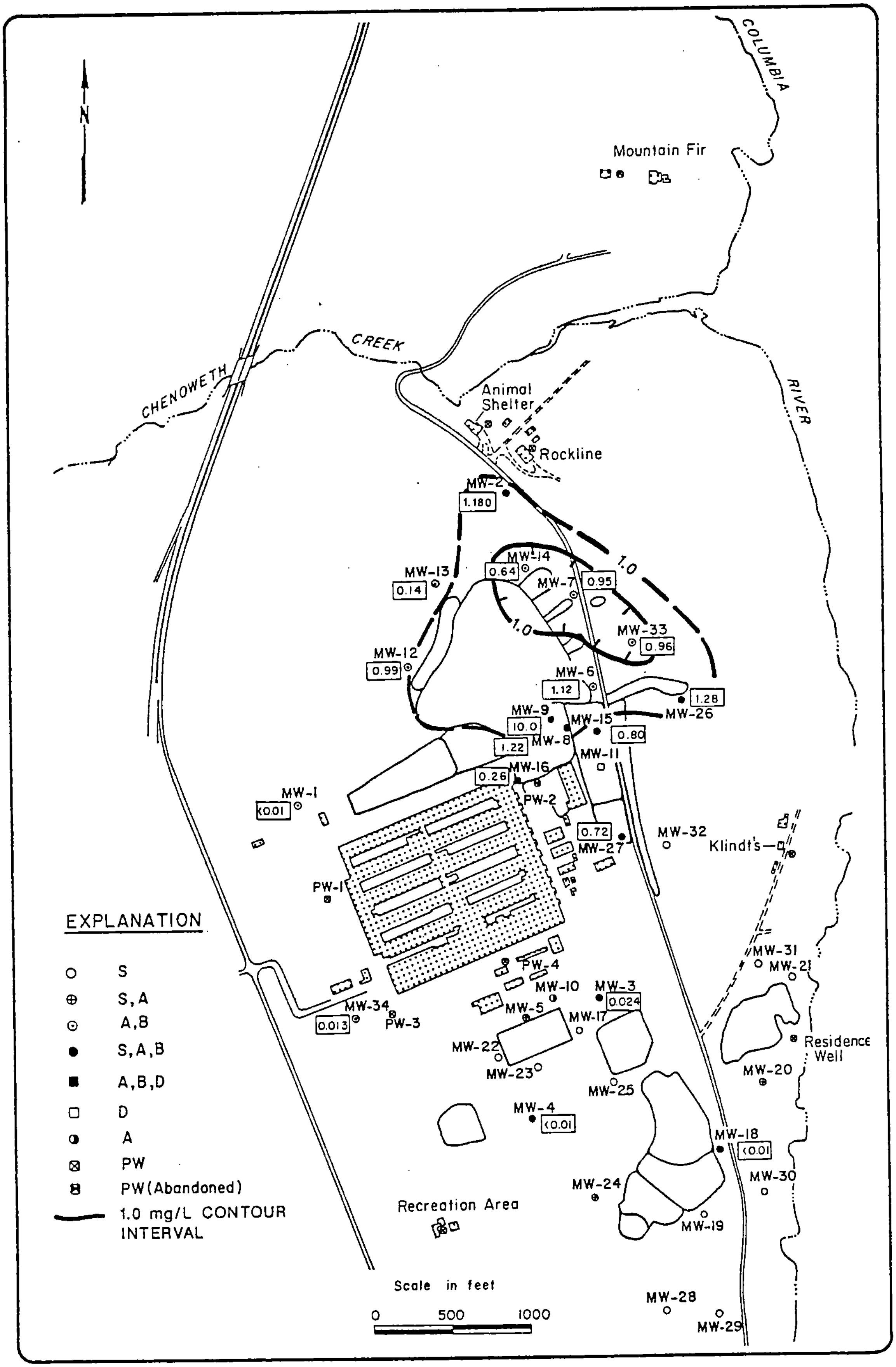


Figure 4.22 Total Cyanide Concentration, B Aquifer, August 1987.

CLIENT NAME:
Martin Marietta Corporation

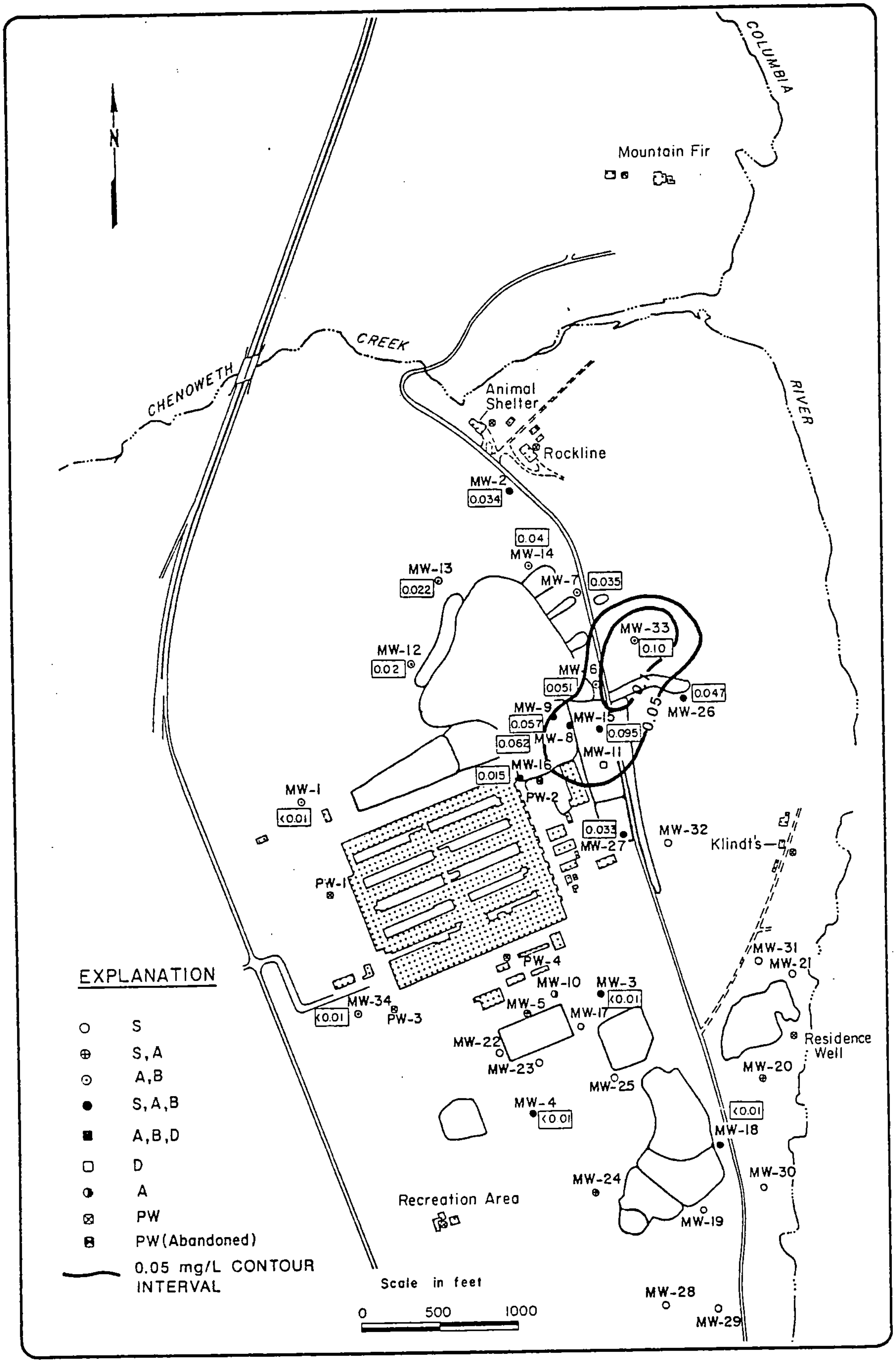


Figure 4.23 Free Cyanide Concentration, B Aquifer, August 1987.

CLIENT NAME:
Martin Marietta Corporation

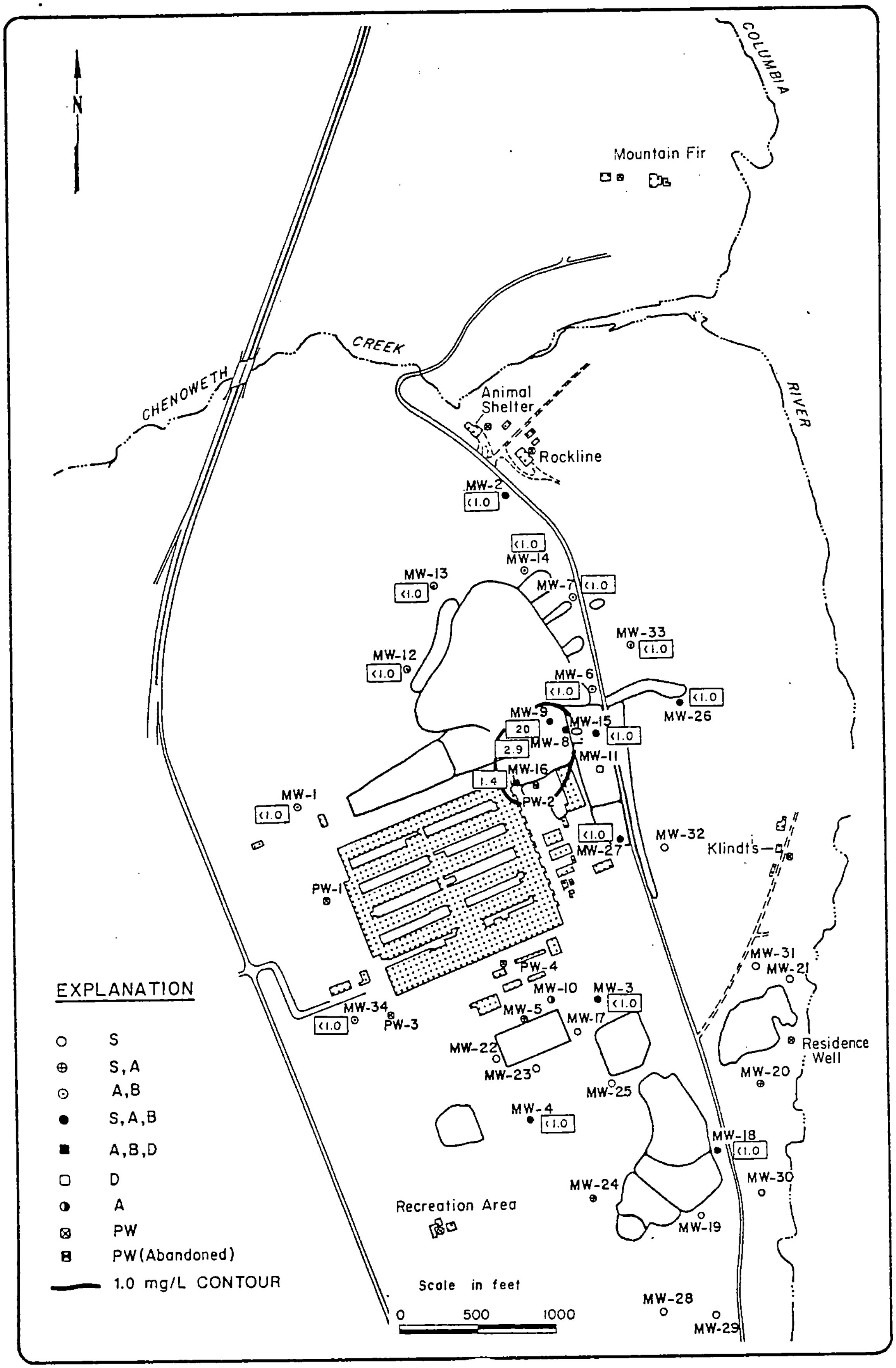


Figure 4.24 Fluoride Concentration, B Aquifer, August 1987.

CLIENT NAME:

Martin Marietta Corporation,

mg/L). The ground-water quality in the B aquifer near the recycle pond has not been defined but presumably is better than in the overlying A aquifer.

4.7.2.6 The Dalles Ground-Water Reservoir

Ground-water quality impacts to the DGWR were not identified (Figure 4.25). Concentrations of constituents in water samples from on-site production wells and monitor wells and off-site production wells in the DGWR were low and within the range expected for background.

4.7.3 Transport and Attenuation Mechanisms

Waste constituents dissolved by infiltrating precipitation from process, storage, and disposal activities have become part of and move with the surrounding ground water. Also, waste constituents may have been transported by overland runoff to recharge aquifers in areas some distance away.

Once in the ground-water system, the dissolved constituents will move from areas of higher fluid potential to areas of lower fluid potential. This movement may be laterally and/or vertically away from the source. The specific direction of movement will depend on the aquifer system under consideration, as described in earlier sections.

The principal constituents of interest at the MMRF are cyanides, fluorides, sulfates, and sodium. The mechanism of attenuation for the fluorides, sulfates, and sodium is principally dilution. Attenuation mechanisms for cyanides include: volatilization, dilution, anion exchange, dispersion, and chemical complexation. A detailed discussion of the chemical characteristics of these constituents, including attenuation mechanisms, was provided in Section 3.3.

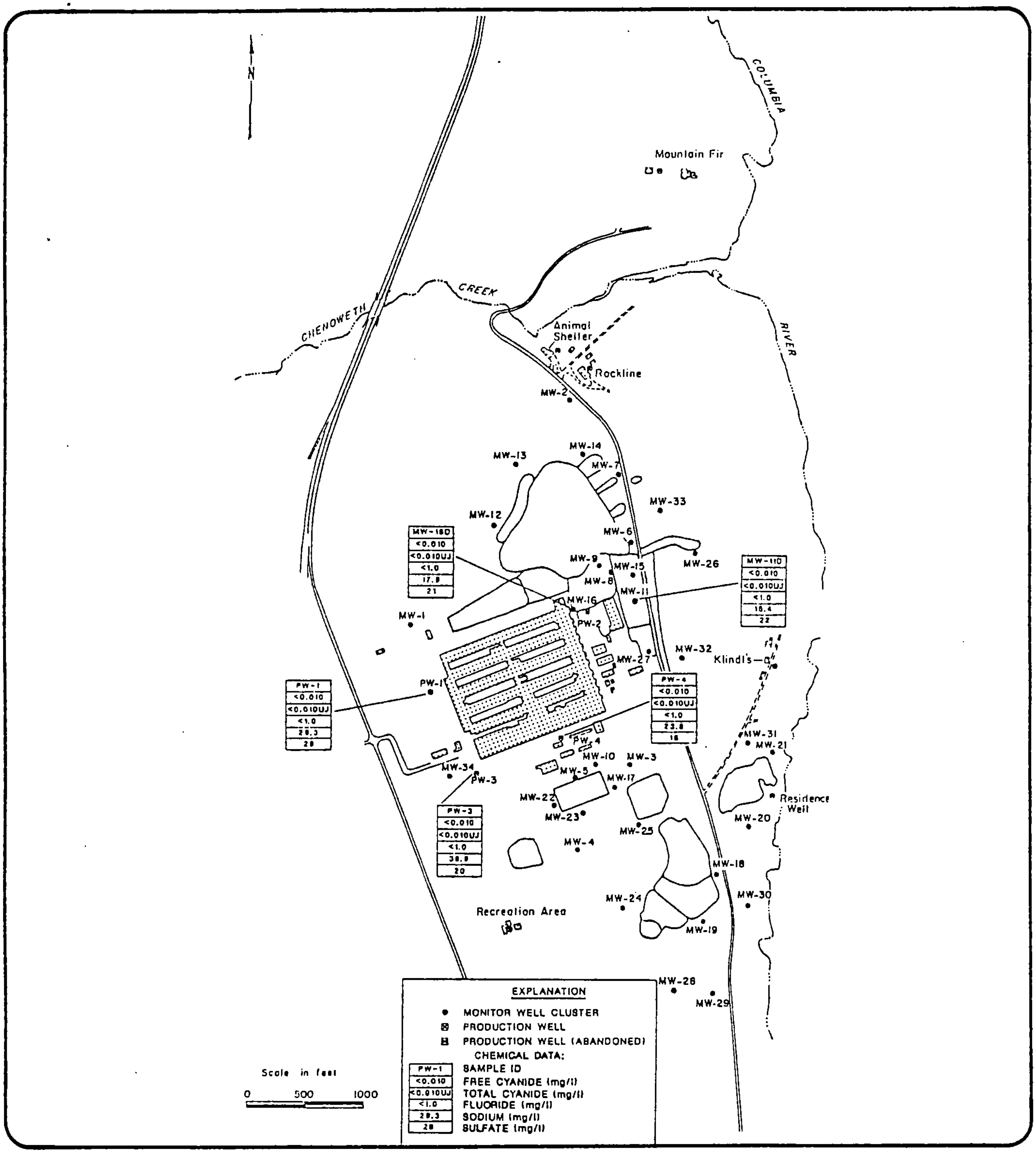


Figure 4.25 DGWR Water Quality.

CLIENT NAME:

Martin Marietta Corporation

Based on the hydrostratigraphy of the site, there are three primary routes for contaminant migration through the ground-water system. These routes are:

- o Vertical migration of constituents of concern from the perched water and/or shallow aquifer to deeper water-producing aquifers.
- o Horizontal migration of constituents of concern from the landfill to the alluvial aquifer with subsequent downward migration to the B aquifer.
- o Horizontal migration of constituents of concern through the S aquifer to the Columbia River.

The hydraulic properties of the various hydrostratigraphic units are highly variable; the B aquifer and the DGWR are by far the most productive units. Based on the completion and distribution of production wells in the area, the B and the DGWR are the primary aquifers of concern. Although the alluvial aquifer is utilized, the only existing production well is upgradient of the area of concern. Because of the vast dilution effects of the Columbia River, this transport pathway is anticipated to be of minor concern.

To evaluate the potential impact of site-derived constituents on ground-water users in the area, a preliminary assessment of contaminant migration was carried out. The focus of this assessment was the Chenoweth production wells located downgradient (based on measured gradients in the B aquifer) of the site; these wells draw water from all zones, but primarily from the B aquifer and the DGWR (based on the transmissivity of the various units). The well of particular concern is Chenoweth Irrigation Well #3 located approximately one mile southwest of the MMRF.

The most direct pathway for contaminant migration to the Chenoweth wells is via the second pathway described above; that is, constituents of concern migrate horizontally to the alluvial aquifer with subsequent vertical migration along the Chenoweth fault to the B aquifer. Although direct vertical migration is a potential route at the site, the low vertical hydraulic conductivity of geologic units inhibit migration via this pathway.

To evaluate future concentrations of site-derived constituents at the Chenoweth well, a well-documented analytical solution of the two-dimensional, advection-dispersion equation was used (Appendix G). The solution was published by Cleary and Ungs (1978). The major assumptions of the assessment performed include:

- Site-derived chemical constituents may reach production wells pumping from the aquifers in The Dalles Basin; the most likely route of transport is from shallow zones via the Chenoweth fault to the B aquifer. The well of particular concern is Chenoweth Irrigation Well #3.

- The major source of the constituents of concern is from the on-site landfill. This source was virtually cutoff in 1983 after the installation of the leachate-collection system.

- The concentrations of free cyanide, total cyanide, fluoride, sodium, and sulfate observed in monitor wells near the landfill and open to the B aquifer will decay over time as water of background quality replaces/-

displaces existing water. The concentrations will drop to half very quickly (less than two years based on measured aquifer characteristics); however, as a conservative estimate, it is assumed that concentrations will drop to half the measured values in approximately 16 years.

- The distance from the source (Chenoweth fault) to the potential receptor (Chenoweth well #3) is several thousand feet; on this scale the B aquifer acts as a porous media.

- It is assumed that no "clean" water vertically migrating from overlying units reaches the B aquifer between the source and potential receptor. This assumption is conservative; that is, any recharge reaching the B aquifer would dilute the concentration of constituents of concern.

- It is conservatively assumed that constituents are neither retarded by chemical action or degraded by biological action.

- It is conservatively assumed that the source is assumed to be directly upgradient of the potential receptor.

- The average ground-water velocity in the B aquifer is 1.3 ft/day.

- The lateral and transverse dispersivity of the B aquifer is assumed to be 100 and 60 ft/day, respectively. These values are based on those values used in a comparable study of basalt formations (Ahlstrom, 1977).

- The dimension of the source area is assumed to be 2,000 ft (the approximate length of the fault which is likely to be in contact with site-derived constituents) by 500 ft (estimated width of fault zone).
- The initial source concentrations were calculated by averaging values measured in August 1987 for the B aquifer wells nearest the fault (wells 26B, 33B, 7B, 14B, and 2B).

Because there is not a continuous source of constituents present, the peak concentrations reaching the receptor will be for a short duration only. The table below presents three sets of values; the average initial concentration, the concentration in the B aquifer at the receptor (average peak value over a 70-year period), and the diluted concentration within the production well (based on a transmissivity ratio of 5:2 for the DGWR to the B aquifer and assuming the DGWR contains negligible concentrations of the constituents of concern).

CONSTITUENT CONCENTRATION (mg/L)

	Initial	B Aquifer	Production Well
Free CN	0.051	0.012	0.003
Total Cn	1.00	0.24	0.07
Na	31	7.5	2.1
F	1.12	0.27	0.08
SO_4	84	20	5.7

As shown above, even using very conservative assumptions, the concentrations of constituents reaching the nearest downgradient receptor are expected to many times lower than those concentrations reported on site. If additional assumptions are made regarding the degradation and retardation of the constituents of concern, the calculated values would likely be much lower. The ground-water pathway evaluated above is anticipated to be the most direct and important pathway; other pathways are more difficult to assess, but are likely to be longer and slower pathways to potential receptors with correspondingly lower concentrations.

569/3

Section Five

5.0 DRAINAGE AND SURFACE WATER

The City of The Dalles is located in the Wasco drainage basin, which covers an area of approximately 540 square miles (346,000 acres). The Wasco area contains 226 miles of perennial and 818 miles of intermittent streams, which generally run northeasterly through narrow, deep canyons, discharging to the Columbia River. Intermittent streams in the Wasco basin generally originate at lower elevations or on the easterly slopes of the Cascade Range. Natural stream flow is quite low in most perennial streams during the summer (OWRB, 1965).

Estimated average annual runoff ranges from about 13,000 Ac-ft (acre feet) for Eightmile Creek near Boyd to almost 40,000 Ac-ft for Fifteenmile Creek near Wrentham. Average annual outflow from the Wasco area is about 130,000 Ac-ft (4.6 inches per acre). Seasonal distribution of runoff for streams in the Wasco area is typical of semi-arid regions, with over 70 percent of the runoff occurring during the December through April non-growing season.

5.1 COLUMBIA RIVER

The Columbia River is the largest Pacific Coast drainage system in North America, with a drainage basin of 259,000 square miles in the United States and Canada. The river originates at Columbia Lake, Canada, and flows for more than 1,000 miles before reaching its mouth west of Portland, Oregon. The section of the river adjacent to the study area is part of the Bonneville Reservoir.

Two impoundments directly affect the discharge of water from and the level of the water in the Columbia River near the study area. The Dalles Dam, located approximately one river mile east and upstream of the study area, is used primarily for electric power generation and to improve navigation on the river. There is little storage reserve in The Dalles Reservoir for flood control or seasonal water storage (Stanford Research Institute [SRI], 1971).

The Bonneville Dam, located downstream approximately 45 river miles west of the study area, is used to improve navigation on the lower Columbia River and to produce electric power. The water-level elevation of the Bonneville Reservoir can fluctuate from 70 to 82.5 ft msl as a result of releases at the Bonneville Dam (SRI, 1971). The normal water-level elevation in the Columbia River near the site is about 70 ft msl.

A surface-water sample was collected from the Columbia River as part of the water-quality investigation. Calcium was the predominant cation at 17.8 mg/L, with almost equal amounts of magnesium (4.89 mg/L) and sodium (5.28 mg/L). Bicarbonate was the dominant anion at 63 mg/L (as calcium carbonate) with minor sulfate (8.2 mg/L) and chloride (5.0 mg/L). Total cyanide, free cyanide, and fluoride concentrations were below detection limits.

5.2 CHENOWETH CREEK

Chenoweth Creek, an intermittent stream that discharges to the Columbia River, is located at the northern boundary of the study area. Most of the water in this creek originates as snow melt from the Cascade Mountains and runoff from local precipitation events. The highest discharge occurs during the spring thaw, and in the summer the creek alternates between low flow and dry stream bed conditions. No data are available on annual discharge.

Water-quality samples were collected from Chenoweth Creek on August 2 and 24, 1987, as part of the surface-water investigation. Total cyanide, free cyanide, and fluoride concentrations were reported below laboratory detection limits (Appendix C). The water is predominantly a calcium-bicarbonate solution. An increase in the concentrations of all cations and anions was reported between the August 2 and August 24 sampling events. The increase is apparently a reflection of low-flow conditions in which evaporation of water from the creek concentrated the inorganic constituents. The August 24 sampling event is an example of water quality during increased flow associated with local rainfall.

5.3 LOCAL DRAINAGE FEATURES

The topography at the MMRF largely controls the direction of surface-water flow, except where man-made structures have been built to alter flow patterns. Local drainage systems and surface drainage features are shown in Figure 5.1. In general, surface-water runoff from active portions of the site is routed to the recycle pond.

North-northwest of the production buildings is a stand of trees maintained by irrigation, with the excess irrigation water flowing to the north-northeast to discharge to Chenoweth Creek. To the south of the production buildings, the golf course at the recreation area is irrigated, with the excess irrigation waters flowing southward to discharge to an unnamed intermittent stream, which in turn discharges to the Columbia River.

Runoff from the landfill area is currently intercepted by the leachate collection system and the landfill ditch and then routed to the recycle pond via the discharge channel. Prior to the construction of this interception network, runoff from the landfill followed three primary drainage pathways, all of which discharged to the alluvial aquifer. The northernmost drainage system is associated with landfill

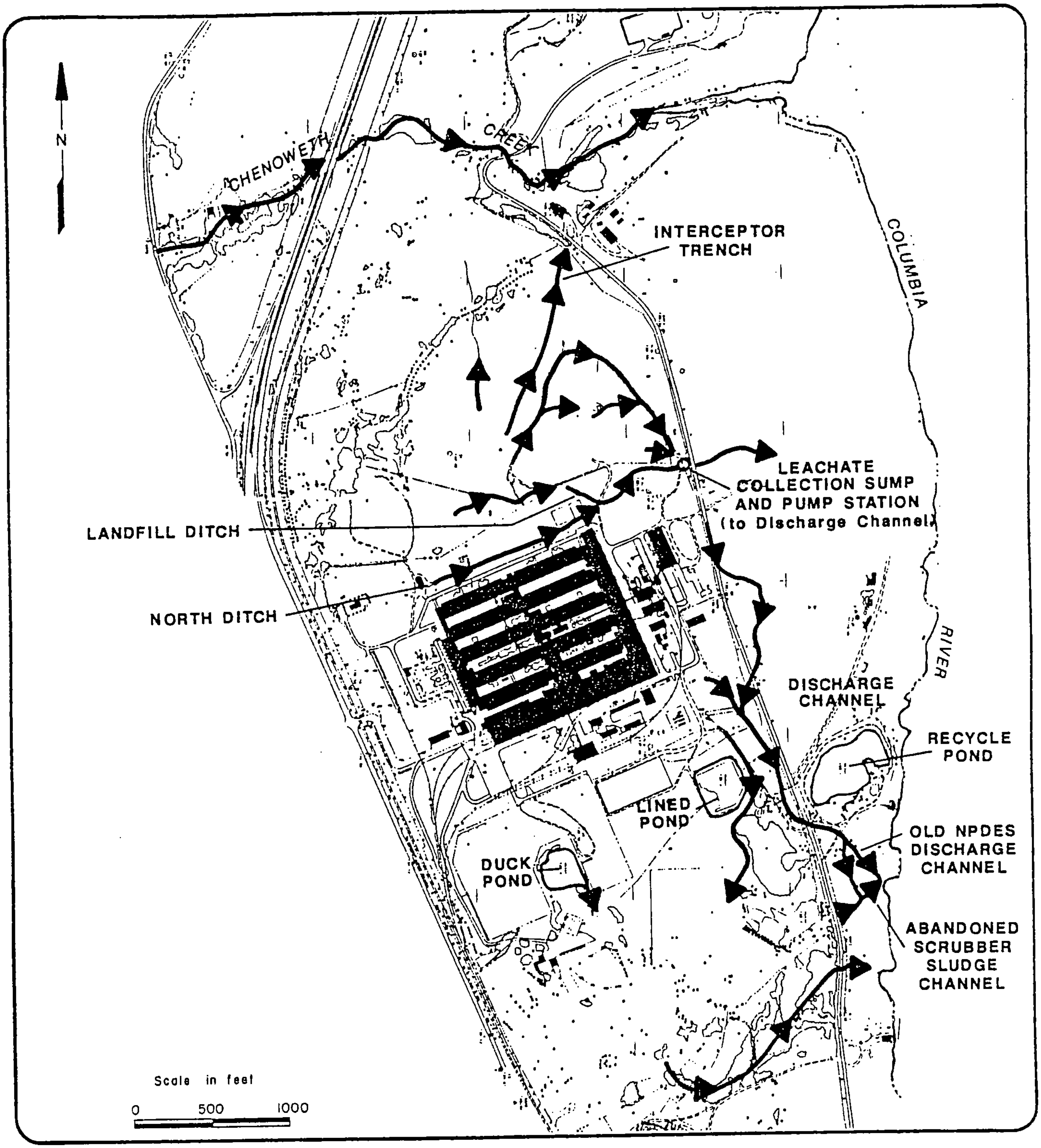


Figure 5.1 Site Drainage Features.

CLIENT NAME:

Martin Marietta Corporation

runoff areas B and D (Figure 3.1), continuing to the northeast to the alluvial aquifer. The middle drainage system is associated with landfill runoff area C, extending to the quarry within the alluvial aquifer. The southernmost drainage system associated with the landfill is the north ditch/landfill ditch/River Road ditch drainage system. Surface-water flow through this system was from the southern part of the landfill to the north-northeast, ultimately discharging to the southeastern end of the alluvial aquifer.

The ponds at the MMRF are the four scrubber sludge ponds, recycle pond, duck pond, and lined pond. The recycle pond, which serves as a collection point for runoff from the landfill, the former cathode waste management area, and areas to the immediate south and west of the plant, discharges to the Columbia River in accordance with a National Pollutant Discharge Elimination System (NPDES) permit. The recycle and lined ponds are currently in use. The scrubber sludge ponds are no longer in use but intersect the water table and are indurated in proportion to the relative ground-water elevation.

570/2

Section Six

6.0 AIR INVESTIGATION

During the site investigation, several air-quality evaluations were conducted as proposed in the work plan and its addendum (Table 6.1). In addition, several other studies were performed that extended and enhanced the data-collection activities specified in the work plan. These studies included ambient air-quality monitoring, health and safety air-quality monitoring, and collection of sediment samples at several locations to be used in fugitive particulate modeling calculations.

6.1 AMBIENT AIR-QUALITY MONITORING

6.1.1 1986 Sampling Results

An ambient air-monitoring study in the area was conducted from May 29 through July 23, 1986, during which 128 air-impinger solutions were collected and analyzed for gaseous hydrogen cyanide (HCN) and gaseous hydrogen fluoride (HF). Samples were collected upwind and downwind of active drilling sites for approximately a one-hour period twice each day from each of four stations.

The results of that study (Appendix H) show that the reported concentrations of cyanide at the four stations (Figure 6.1) were consistently below both the method detection limit (MDL) and the OSHA Permissible Exposure Limit (PEL). The reported concentrations of fluoride varied slightly above and below the MDL but remained well below the OSHA PEL.

In addition to the ambient air monitoring, 34 samples (plus 5 blanks) were collected in the period between during June 10 and June 18, 1986, at locations upwind and downwind

Table 6.1 Air Data Summary

Sample Dates	Parameter	Number of Analyses	Type 1/	Max	Min	Units
5/29-7/23/86	HCN gas	128	Area	<0.26	<0.26	mg/L
	HF gas	128	Area	0.24	<0.2	mg/L
6/10-6/18/86	Dust, Total	7	Personnel/16, 21	11.52	0.24	mg/m^3
	CN part	14	Area/15, 16, 20, 21	<2.5	<2.5	ug/ml
	HCN gas	14	Area/5, 15, 16, 20, 21	<2.5	<2.5	ug/ml
	F part	18	Personnel/15, 16, 20, 21	0.017	0.002	mg/m^3
	F part	2	Area/16	0.007	0.002	mg/m^3
	F gas	17	Personnel/15, 16, 20, 21	<0.010	<0.003	mg/m^3
	F gas	3	Area/16, 20	<0.007	<0.003	mg/m^3
	CPT Volatiles	7	Personnel/16, 20	0.476	0.02	mg/m^3
6/16-6/18/87	CN part	9	Area/8A, 9S	<0.01	<0.01	TWA/PEL
	HCN gas	9	Area/8A, 9S	0.01	<0.01	TWA/PEL
	HF gas	6	Area/8A, 9S	<0.01	<0.01	TWA/PEL
	HF gas	3	Personnel/8A, 9S	<0.01	<0.01	TWA/PEL
	F part	6	Area/8A, 9S	<0.01	<0.01	TWA/PEL
	F part	3	Personnel/8A, 9S	<0.01	<0.01	TWA/PEL
	Dust, Total	6	Area/8A, 9S	<0.01	<0.01	
	Dust, Total	3	Personnel/8A, 9S	0.07	0.03	TWA/PEL
	CPT Volatiles	6	Area/8A, 9S	0.31	<0.01	TWA/PEL
	CPT Volatiles	3	Personnel/8A, 9S	0.18	<0.01	TWA/PEL
6/25-6/27/87	F part	9	Area/Test Pit	<0.01	<0.01	TWA/PEL
	HF gas	9	Area/Test Pit	<0.01	<0.01	TWA/PEL
	CN part	9	Area/Test Pit	<0.02	<0.02	TWA/PEL
	HCN gas	9	Area/Test Pit	<0.02	<0.02	TWA/PEL
	Dust, Total	6	Area/Test Pit	0.07	<0.01	
	Dust, Total	3	Personnel/Test Pit	0.04	0.01	TWA/PEL
	CPT Volatiles	6	Area/Test Pit	1.20	<0.01	
	CPT Volatiles	3	Personnel/Test Pit	0.39	<0.01	TWA/PEL

NOTE: Details of the air studies are provided in Appendix H.

1/ Indicates sample type (area or personnel/sample sites)

CPT = Coal Tar Pitch
Part = Particulate
gas = gaseous
TWA = Total Weighted Average
PEL = Permissible Exposure Limit

571/3

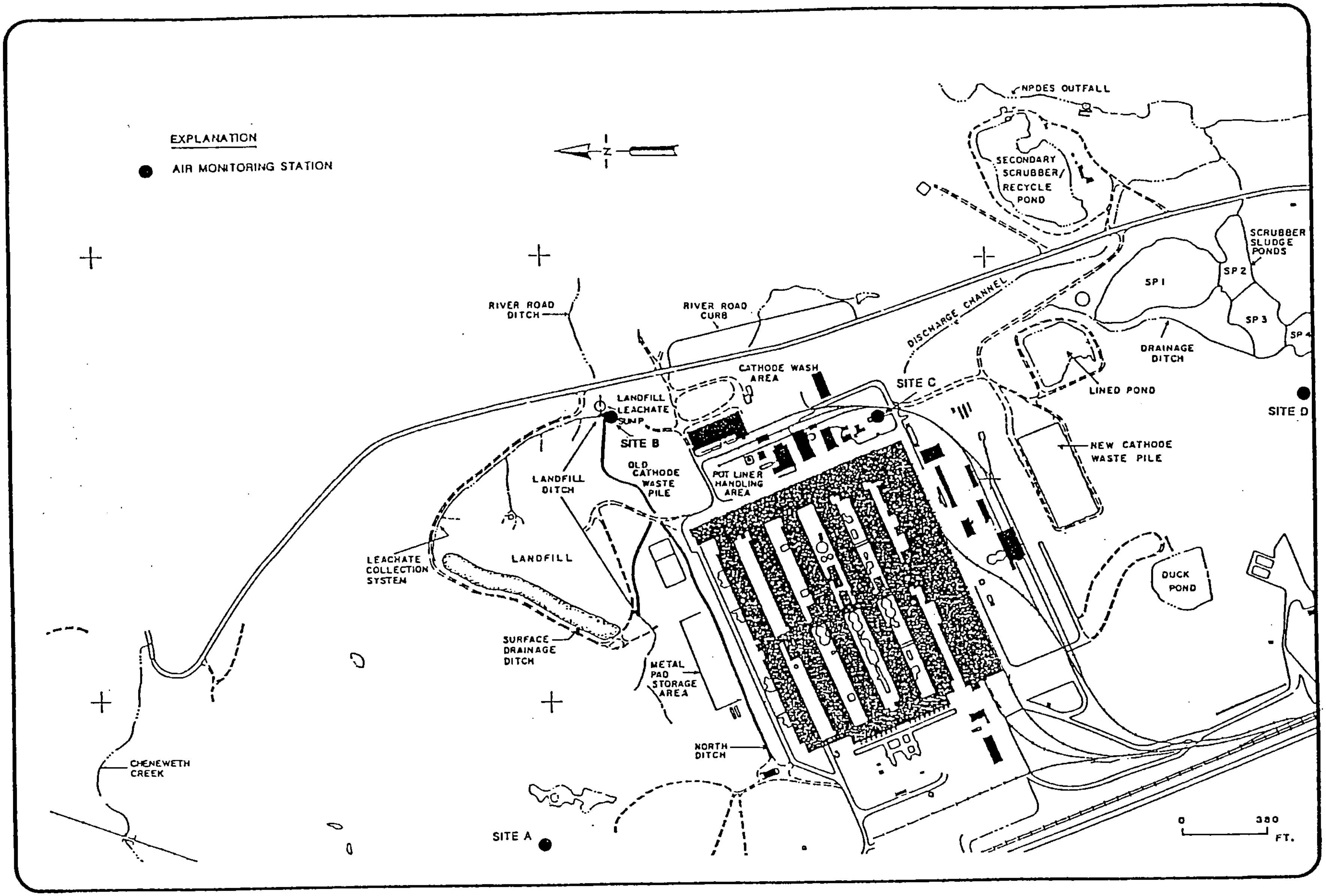


Figure 6.1 Ambient Air-Monitoring Stations.

CLIENT NAME:

Martin Marietta Corporation

of selected drilling sites. These samples were analyzed for the following parameters.

- Particulate cyanide (14 samples)
- Gaseous cyanide (14 samples)
- Particulate fluoride (3 samples)
- Gaseous fluoride (3 samples)

All reported values were below OSHA PELs. The results of the analyses are contained in Appendix H.

6.1.2 1987 Sampling Results

During implementation of the RI addendum, a total of 78 airborne samples (plus 9 field blanks) were collected upwind and downwind of areas (i.e., drilling and test pit sites) in which field activities were occurring. These samples were collected during the periods from June 16 to 18, 1987, and from June 25 to 27, 1987. The samples were analyzed for:

- Gaseous cyanide (18 samples)
- Particulate cyanide (18 samples)
- Gaseous fluoride (15 samples)
- Particulate fluoride (15 samples)
- Coal tar pitch volatiles/total dust (12 samples)

The sampling results are contained in Appendix H. None of the reported results for the 1987 ambient air-quality monitoring program exceeded OSHA PELs with the exception of coal tar pitch volatiles in one sample collected on June 26, 1987. This sample, taken at a location upwind of the backhoe being used to excavate test pits, was slightly above the PEL. All other samples were generally below MDLs or well below the PEL.

6.2 PERSONNEL/HEALTH AND SAFETY AIR-QUALITY MONITORING

6.2.1 1986 Sampling Results

Health and safety air monitoring, as described in the Project Safety and Health Plan, was performed during the RI work in 1986. The following parameters were monitored during the various field activities:

- Total ionizable pollutants using a Photovac TIP^{TM} (215 measurements) at 30- and 60-minute intervals.
- Gaseous cyanide using Draeger tubes (115 measurements) at 30- and 60-minute intervals.
- Gaseous fluoride using Draeger tubes (111 measurements) at 30- and 60-minute intervals.

The results of this monitoring reported no concentrations of ionizable pollutants above the threshold requiring Level C protection. No concentrations of gaseous cyanide or fluoride were detected with the Draeger tubes during the 1986 field investigation.

In addition to health and safety monitoring with the TIP^{TM} and Draeger tubes, personnel samples were collected during the period June 10 to 18, 1986 and analyzed for the following constituents:

- Particulate fluoride (17 samples)
- Gaseous fluoride (17 samples)
- Coal tar pitch volatiles/total dust (6 samples)

The results of these analyses, which are contained in Appendix H, showed all values to be below the OSHA PEL with the exception of three coal tar pitch volatile results for samples collected on June 13, 1986, at drill site MW-21. All other results were either below the MDL or well below the PELs.

6.2.2 1987 Sampling Results

In order to document full-shift personnel exposure during field activities, 12 personnel samples were collected during the periods from June 16 to 18, 1987, and June 24 to 27, 1987. The samples were analyzed for the following parameters:

- Gaseous fluoride (3 samples)
- Particulate fluoride (3 samples)
- Coal tar pitch volatiles/total dust (6 samples)

The results of these analyses are contained in Appendix H. None of the analytical results was found to exceed OSHA PELs, with most results reported below the MDL.

Routine health and safety monitoring was also performed during implementation of the work plan addendum. The monitoring conducted during 1987 was similar to that performed in 1986 with the following parameters analyzed during the various field activities:

- Total ionizable pollutants using a Photovac TIP^{TM} (175 measurements) at 30- and 60-minute intervals.
- Gaseous cyanide using Draeger tubes (127 measurements) at one- to three-hour intervals.
- Gaseous fluoride using Draeger tubes (127 measurements) at one- to three-hour intervals.

The results of the health and safety monitoring reported no concentrations of ionizable pollutants above the threshold requiring Level C protection. No concentrations of gaseous cyanide or fluoride were detected with the Draeger tubes during the 1987 field investigation.

6.3 FUGITIVE PARTICULATE MODELING

Wind erosion could lead to entrainment of contaminated dust particles reported in the surface materials of three unvegetated areas at the MMRF site: the landfill, the old cathode waste pile, and scrubber sludge ponds 2 and 3. Scrubber sludge ponds 1 and 4 are not expected to contribute contaminants to the air since both ponds have been covered with a layer of soil and are vegetated. Mechanical (e.g., vehicular) erosion of the three study areas (another mechanism by which significant quantities of dust can be generated) is not expected to be significant inasmuch as these areas are currently inactive and fenced. Additionally, none of the constituents of interest reported in the soils are volatile, and therefore, no significant air concentrations due to volatilization of contaminants from the surface materials are expected at the MMRF.

During the week of June 15, 1987, soil samples were collected from the old cathode waste pile area, landfill, scrubber sludge pond 3, and the berm around scrubber sludge pond 3. These samples were sieved and analyzed for grain size in order to determine the threshold function velocity for use in particulate modeling calculations. The results of the sieve-size analyses are contained in Appendix H.

The emissions of respirable dust (i.e., those particles with an aerodynamic diameter equal to or less than 10 um) from each of the study areas have been estimated using a model (Versar, 1986) identified by EPA in its draft Superfund Exposure Assessment Manual. The results of the modeling are combined with an appropriate air dispersion model to assess potential impacts to exposed populations. A detailed discussion of the fugitive particulate model, air dispersion model, and associated calculations is presented in the Risk Assessment in Appendix B.

571/2

Section Seven

7.0 RISK ASSESSMENT SUMMARY

As part of the RI performed for the MMRF site, the potential impacts of past operations at the site on human health or the environment were assessed. This baseline risk assessment is equivalent to an evaluation of the no-action alternative and therefore enables a determination to be made of whether remedial actions are indicated for any areas of the site.

Tables 7.1 and 7.2, which are explained briefly below, summarize the main features and results of the risk assessment. The complete risk assessment (presented in Appendix B) should be consulted for details concerning the information summarized in these tables.

In the summary tables, the main features and results of the risk assessment are organized by study area and exposure medium (water, soil, etc.) in a particular study area. After this, chemicals of potential concern (defined as those chemicals present in environmental media in a particular study area at above naturally-occurring levels) are identified.

Subject to the availability of adequate toxicity information, those chemicals of potential concern were evaluated in the risk assessment by first identifying the exposure pathways by which human and environmental populations could be exposed under either current or hypothetical future land use of the MMRF and surrounding areas. All exposure pathways involving ground water and surface water were evaluated. Many pathways involving human exposure to contaminated soils and dust were possible; therefore, for each category of exposure to soils (i.e., industrial or general population exposures, with and without

Table 7.1

Summary of Potential Human Health and Environmental Risk Assessment

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization Carcinogenic Risks[a] Average Exposure	 Maximum Exposure	 Hazard Index[b] Average Exposure	 Maximum Exposure
Landfill - soils	PAHs, Cyanide, Fluoride, Sodium	a) Future onsite Construction Workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-5} (cPAHs)	10^{-4} (cPAHs)	0.004 (<1)	0.02 (<1)
		- Inhalation of particulates	10^{-6} (cPAHs)	10^{-5} (cPAHs)	0.0004 (<1)	0.001 (<1)
		TOTAL RISK:	10^{-5}	10^{-4}	0.004 (<1)	0.02 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-2} (cPAHs)	0.003 (<1)	0.02 (<1)
		- Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-4}	10^{-2}	0.003 (<1)	0.02 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-2} (cPAHs)	0.003 (<1)	0.02 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.003 (<1)	0.02 (<1)
Landfill Runoff Area - soils	Arsenic, Cyanide, Fluoride, Sulfate	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-8} (As)	10^{-6} (As)	0.004 (<1)	0.02 (<1)
		- Inhalation of particulates	10^{-10} (As)	10^{-10} (As)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-6}	0.004 (<1)	0.02 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-7} (As)	10^{-5} (As)	0.003 (<1)	0.01 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-5}	0.003 (<1)	0.01 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-6} (As)	10^{-5} (As)	0.003 (<1)	0.02 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-6}	10^{-5}	0.003 (<1)	0.02 (<1)
Leachate Collection Ditch - surface water	Arsenic, Cyanide, Fluoride, Sodium Sulfate	a) Birds and animals drinking ponded leachate	Birds and animals are at risk of adverse effects due to fluoride.			

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization: Carcinogenic Risks[a] Average Exposure	Risk Characterization: Carcinogenic Risks[a] Maximum Exposure	Risk Characterization: Hazard Index[b] Average Exposure	Risk Characterization: Hazard Index[b] Maximum Exposure
Landfill Ditch						
- surface water	PAHs, Arsenic, Cyanide, Fluoride, Sodium, Sulfate	a) Birds and animals drinking water	Birds and animals are at risk of adverse effects due to cyanide and fluoride.			
- sediments	Cyanide	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	<0.0001 (<1)	0.0002 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)[c]	<0.0001 (<1)[c]
		TOTAL RISK:	NR	NR	<0.0001 (<1)	0.0003 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	<0.0001 (<1)	0.0001 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	<0.0001 (<1)	0.0001 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	<0.0001 (<1)	0.0002 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	<0.0001 (<1)	0.0002 (<1)
North Drainage Ditch						
- surface water	Arsenic, Cyanide, Sodium, Fluoride Sulfate	a) Birds and animals drinking water	Birds and animals are unlikely to be at risk of adverse effects since concentrations are below the no-effect level.			
- sediment	none detected above background					

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization: Carcinogenic Risks[a] Average Exposure	Carcinogenic Risks[a] Maximum Exposure	Hazard Index[b] Average Exposure	Hazard Index[b] Maximum Exposure
Metal Pad Storage Area - soils	Cyanide, Fluoride	a) Current site maintenance workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		b) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.003 (<1)	0.007 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	NR	NR	0.003 (<1)	0.007 (<1)
		c) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.002 (<1)	0.005 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.002 (<1)	0.005 (<1)
		d) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.002 (<1)	0.007 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.002 (<1)	0.007 (<1)
Bath Recovery Pad Area - soils	Cyanide, Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.003 (<1)	0.009 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	NR	NR	0.003 (<1)	0.009 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption	NR	NR	0.002 (<1)	0.006 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.002 (<1)	0.006 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.003 (<1)	0.008 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.003 (<1)	0.008 (<1)

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization: Carcinogenic Risks[a] Average Exposure	Maximum Exposure	Hazard Index[b] Average Exposure	Maximum Exposure
Old Cathode Waste Pile - soils	Cyanide, Fluoride	a) Current site maintenance workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		b) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.002 (<1)	0.006 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	NR	NR	0.002 (<1)	0.006 (<1)
		c) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.001 (<1)	0.004 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.001 (<1)	0.004 (<1)
		d) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.001 (<1)	0.006 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.001 (<1)	0.006 (<1)
Potliner Handling Area - soils	PAHs, Cyanide, Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-3} (cPAHs)	0.003 (<1)	0.006 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-4}	10^{-3}	0.003 (<1)	0.006 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-2} (cPAHs)	0.002 (<1)	0.004 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-1}	0.002 (<1)	0.004 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs)	10^{-1} (cPAHs)	0.002 (<1)	0.007 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-1}	0.002 (<1)	0.007 (<1)

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization			
			Carcinogenic Risks[a]		Hazard Index[b]	
			Average Exposure	Maximum Exposure	Average Exposure	Maximum Exposure
Salvage Area - soils	Cyanide	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.0006 (<1)	0.009 (<1)
		- Inhalation of particulates	NR	NR	NQ	<0.0001 (<1)
		TOTAL RISK:	NR	NR	0.0006 (<1)	0.009 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.0004 (<1)	0.007 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.0004 (<1)	0.007 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.002 (<1)	0.004 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.002 (<1)	0.004 (<1)
Cathode Wash Area - soils	Cyanide, Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.004 (<1)	0.01 (<1)
		- Inhalation of particulates	NR	NR	NQ	NQ
		TOTAL RISK:	NR	NR	0.004 (<1)	0.01 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.003 (<1)	0.009 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.003 (<1)	0.009 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.003 (<1)	0.01 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.003 (<1)	0.01 (<1)

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization: Carcinogenic Risks[a] Average Exposure	Carcinogenic Risks[a] Maximum Exposure	Hazard Index[b] Average Exposure	Hazard Index[b] Maximum Exposure
Scrubber Sludge Pond 1 - sediments	PAHs, Fluoride, Arsenic	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-4} (cPAHs)	0.001 (<1)	0.003 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-4}	10^{-4}	0.001 (<1)	0.003 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs, As)	10^{-2} (cPAHs, As)	0.0008 (<1)	0.002 (<1)
		- Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.0008 (<1)	0.002 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs, As)	10^{-2} (cPAHs, As)	0.0009 (<1)	0.003 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-2}	0.0009 (<1)	0.003 (<1)
Scrubber Sludge Pond 2 - sediments	PAHs, Fluoride, Arsenic	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-4} (cPAHs)	0.001 (<1)	0.002 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-4}	10^{-4}	0.001 (<1)	0.002 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs, As)	10^{-2} (cPAHs, As)	0.0008 (<1)	0.002 (<1)
		- Inhalation of particulates	10^{-8} (cPAHs)	10^{-8} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.0008 (<1)	0.002 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs, As)	10^{-2} (cPAHs, As)	0.002 (<1)	0.005 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-2}	0.002 (<1)	0.005 (<1)

Table 7.1, continued

			Risk Characterization			
			Carcinogenic Risks[a]		Hazard Index[b]	
Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Average Exposure	Maximum Exposure	Average Exposure	Maximum Exposure
Scrubber Sludge Pond 3 - sediments	PAHs, Fluoride, Arsenic	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-4} (cPAHs)	0.002 (<1)	0.005 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-4}	10^{-4}	0.002 (<1)	0.005 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs, As)	10^{-2} (cPAHs, As)	0.001 (<1)	0.004 (<1)
		- Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.001 (<1)	0.004 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs, As)	10^{-2} (cPAHs, As)	0.002 (<1)	0.005 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-2}	0.002 (<1)	0.005 (<1)
		d) Current individuals:				
		- Ingestion of beef from cows grazing on land adjacent to scrubber sludge pond 3	Risks via this pathway were qualitatively evaluated due to lack of data on uptake of the chemicals of concern into edible flesh. Ingested fluoride is expected to accumulate in bones rather than in edible tissue. PAHs are readily metabolized by mammals.			
Scrubber Sludge Pond 4 - sediments	PAHs, Fluoride, Arsenic	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-4} (cPAHs)	NQ	NQ
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-7} (cPAHs)	NQ	NQ
		TOTAL RISK:	10^{-4}	10^{-4}	NQ	NQ
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-2} (cPAHs, As)	NQ	NQ
		- Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	<0.0001 (<1)	<0.0001 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs, As)	10^{-2} (cPAHs, As)	NQ	NQ
		- Inhalation of particulates	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	<0.0001 (<1)	<0.0001 (<1)

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization			
			Carcinogenic Risks[a]		Hazard Index[b]	
			Average Exposure	Maximum Exposure	Average Exposure	Maximum Exposure
Surface Drainage Ditch - sediments	PAHs, Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-3} (cPAHs)	0.002 (<1)	0.004 (<1)
		- Inhalation of particulates	10^{-4} (cPAHs)[c]	10^{-4} (cPAHs)[c]	0.002 (<1)[c]	0.003 (<1)[c]
		TOTAL RISK:	10^{-4}	10^{-4}	0.004 (<1)	0.007 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-1} (cPAHs)	0.002 (<1)	0.003 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.002 (<1)	0.003 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs)	10^{-1} (cPAHs)	0.002 (<1)	0.004 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-2}	0.002 (<1)	0.004 (<1)
Drainage Ditch - sediments	Cyanide, Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.002 (<1)	0.007 (<1)
		- Inhalation of particulates	NR	NR	0.001 (<1)[c]	0.005 (<1)[c]
		TOTAL RISK:	NR	NR	0.003 (<1)	0.012 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.001 (<1)	0.005 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.001 (<1)	0.005 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.001 (<1)	0.008 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.001 (<1)	0.008 (<1)

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization Carcinogenic Risks[a] Average Exposure	 Maximum Exposure	 Hazard Index[b] Average Exposure	 Maximum Exposure
Discharge Channel - surface water	Cyanide, Fluoride, Sodium	a) Birds and animals drinking water	Birds and animals are unlikely to be at risk of adverse effects since concentrations are below the no-effect level.			
- sediments	Cyanide, Fluoride, PAHs	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-4} (cPAHs)	0.003 (<1)	0.008 (<1)
		- Inhalation of particulates	10^{-7} (cPAHs)[c]	10^{-7} (cPAHs)[c]	0.002 (<1)[c]	0.006 (<1)[c]
		TOTAL RISK:	10^{-4}	10^{-4}	0.005 (<1)	0.014 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-2} (cPAHs)	0.002 (<1)	0.006 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.002 (<1)	0.006 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs)[c]	10^{-2} (cPAHs)	0.002 (<1)	0.009 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-2}	0.002 (<1)	0.009 (<1)
Lined Pond - surface water	Fluoride, Arsenic, Sodium, Sulfate	a) Birds and animals drinking water	Birds and animals are unlikely to be at risk of adverse effects since concentrations are below the no-effect level.			
- sediments	PAHs, Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-3} (cPAHs)	0.01 (<1)	0.03 (<1)
		- Inhalation of particulates	10^{-6} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-4}	10^{-3}	0.01 (<1)	0.03 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-2} (cPAHs)	0.01 (<1)	0.02 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.01 (<1)	0.02 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingostion & dermal absorption)	10^{-2} (cPAHs)	10^{-1} (cPAHs)	0.01 (<1)	0.03 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)	10^{-6} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-1}	0.01 (<1)	0.03 (<1)

Table 7.1, continued

Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Risk Characterization			
			Carcinogenic Risks[a]		Hazard Index[b]	
			Average Exposure	Maximum Exposure	Average Exposure	Maximum Exposure
Recycle Pond - surface water	Cyanide, Fluoride, Sodium	a) Birds and animals drinking water	Birds and animals are unlikely to be at risk of adverse effects since concentrations are below the no-effect level.			
- sediments	Fluoride, PAHs	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-4} (cPAHs)	10^{-4} (cPAHs)	0.004 (<1)	0.02 (<1)
		- Inhalation of particulates	10^{-6} (cPAHs)[c]	10^{-6} (cPAHs)[c]	0.003 (<1)[c]	0.008 (<1)[c]
		TOTAL RISK:	10^{-4}	10^{-4}	0.007 (<1)	0.03 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-3} (cPAHs)	10^{-2} (cPAHs)	0.003 (<1)	0.008 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-3}	10^{-2}	0.003 (<1)	0.008 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	10^{-2} (cPAHs)	10^{-2} (cPAHs)	0.003 (<1)	0.01 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-2}	10^{-2}	0.003 (<1)	0.01 (<1)
Duck Pond - surface water	Fluoride, Sodium, Sulfate	a) Birds and animals drinking water	Birds and animals are unlikely to be at risk of adverse effects since concentrations are below the no-effect level.			
- sediments	Fluoride	a) Future onsite construction workers:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.0006 (<1)	0.005 (<1)
		- Inhalation of particulates	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	NR	NR	0.0006 (<1)	0.005 (<1)
		b) Future onsite employees:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.0004 (<1)	0.004 (<1)
		- Inhalation of particulates from whole site	10^{-8} (cPAHs)[e]	10^{-7} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-8}	10^{-7}	0.0004 (<1)	0.004 (<1)
		c) Future onsite residents:				
		- Direct contact (incidental ingestion & dermal absorption)	NR	NR	0.0005 (<1)	0.005 (<1)
		- Inhalation of particulates from whole site	10^{-7} (cPAHs)[e]	10^{-6} (cPAHs)[e]	<0.0001 (<1)	<0.0001 (<1)
		TOTAL RISK:	10^{-7}	10^{-6}	0.0005 (<1)	0.005 (<1)

Table 7.1, continued

			Risk Characterization			
			Carcinogenic Risks[a]		Hazard Index[b]	
Study Area/ Exposure Medium	Chemicals of Potential Concern[d]	Exposure Scenarios Evaluated	Average Exposure	Maximum Exposure	Average Exposure	Maximum Exposure
Columbia River - surface water	Fluoride, Zinc	a) Current individuals: - ingestion of freshwater fish	NR	NR	<0.0001 (<1)	<0.0001 (<1)
		b) Exposure of aquatic life	Estimated concentrations of chemicals resulting from site groundwater discharge are well below concentrations associated with adverse effects in fish.			
Chenoweth Creek - surface water	None detected	a) Exposure of aquatic life	Although no chemicals were detected, the quantification limit for cyanide (0.01 mg/liter) is above the Ambient Water Quality Criteria for the protection of aquatic life (AWQC) of 0.005 mg/L and the quantification limit for fluoride (1 mg/liter) is above the concentration associated with avoidance behavior (0.2 mg/liter). The creek is being resampled using quantification limits below the chronic AWQC values for cyanide and the avoidance behavior level for fluoride.			
Whole Site - soils	Arsenic, Cyanide, Fluoride, PAHs	a) Future offsite employees: - Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		b) Future offsite local residents of the City of the Dalles: - Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)
		c) Future offsite local residents at trailer park: - Inhalation of particulates	10^{-8} (cPAHs)	10^{-7} (cPAHs)	<0.0001 (<1)	<0.0001 (<1)

Table 7.1, continued

[a] Carcinogenic risks has been rounded to the nearest 10. In determining remedial actions at Superfund sites, EPA has recommended a target risk range of 10^{-4} to 10^{-7} for total excess carcinogenic risk; an excess cancer risk of 10^{-6} (i.e. one excess cancer per million persons exposed for a lifetime) is typically used in risk assessments as a benchmark against which to evaluate the magnitude of exposures. The chemical(s) listed in parentheses after the risk estimates is (are) the most significant chemical(s) with respect to the excess cancer risk in this exposure scenario.

[b] The overall hazard index is defined as the sum of the ratios of the daily intakes of noncarcinogenic substances to their corresponding relevant health-based guidelines. Hazard indices less than 1 indicate endangerment of human health is unlikely to result from given exposures; hazard indices greater than 1 suggest possible cause for concern. Hazard indices less than 0.0001 were listed as "<0.0001".

[c] Potential exposure to chemicals in these areas (ditches and discharge channel) has been evaluated by analogy to study areas which were quantitatively evaluated.

[d] Chemicals are of potential concern based on their presence at or near the site at above background concentrations.

[e] Because future residents or employees may potentially be exposed to dust emissions from all areas equally, the whole site was considered as a source for exposure via inhalation. Risks calculated for onsite employees or onsite residents who inhale particulates were assessed on a whole-site basis; therefore, although no potential carcinogens were detected in a particular study area, the carcinogenic risks calculated for this exposure scenario were contributed from a different site area.

NR = not relevant, chemicals of potential concern have not been associated with carcinogenic effects.
NQ = not quantified

Table 7.2

Summary of Comparison of Groundwater and Estimated Air Concentrations with ARARs or other criteria

Exposure Medium/Area	Chemicals of Potential Concern	Results of Comparison with ARARs or other criteria
Groundwater: S Aquifer	Bicarbonate, Calcium, Carbonate, Cyanide, Fluoride, Magnesium, Potassium, Sodium, Sulfate, Zinc	Fluoride in 6/26 wells exceeds Federal drinking water standard (MCL) of 4 mg/liter; fluoride in 8/26 wells exceeds or is within the range of the Oregon temperature-dependent drinking water standard of 1.4-2.4 mg/liter. Sulfate in 5/26 wells exceeds health-based standard of 400 mg/liter. Sulfate in 6/26 wells exceeds Oregon MCL of 250 mg/L. Wells exceeding standards are located primarily in areas near scrubber sludge ponds, recycle pond, former cathode waste management areas, and alumina unloading area. Cyanide and zinc concentrations in all wells are below ARARs (770 ug/L or 220 ug/L for free cyanide; 5 mg/L for zinc); no ARARs or adequate toxicity criteria are available for the other chemicals of potential concern.
A Aquifer	Bicarbonate, Carbonate, Cyanide, Fluoride, Sodium	Fluoride in 1/19 wells exceeded the Federal standard (4 mg/liter); Fluoride in 1/19 wells exceeded the Oregon (1.4-2.4 mg/liter) standard. No ARARs or adequate toxicity driteria are available for the other chemicals of potential concern.
B Aquifer	Bicarbonate, Calcium, Carbonate, Cyanide, Fluoride, Magnesium, Sodium, Sulfate, Zinc	Fluoride in 1/18 wells exceeds Federal MCL of 4 mg/liter; fluoride in 2/18 wells exceeds Oregon standard of 1.4-2.4 mg/liter. Cyanide and zinc levels in all wells are below ARARs (770 ug/L or 220 ug/L for cyanide; 5 mg/L for zinc). No ARARs or adequate toxicity criteria are available for the other chemicals of potential concern.
Klindt Well	Cyanide, Zinc	No concentrations exceed ARARs (770 ug/liter or 220 ug/liter for free cyanide, 5 mg/liter for zinc).
Mountain Fir Well	Cyanide, Magnesium, Calcium, Bicarbonate, Zinc	No concentrations exceed ARARs (770 ug/liter or 220 ug/liter for free cyanide, 5 mg/liter for zinc); no ARARs or adequate toxicity criteria are available for the other chemicals).
Rockline Well	Cyanide, Fluoride, Calcium, Bicarbonate, Zinc	Fluoride level less than Federal MCL of 4 mg/liter but within Oregon standard range of 1.4-2.4 mg/liter. Cyanide and zinc concentrations below ARARs (770 ug/L or 220 ug/L for cyanide; 5 mg/L for zinc); no ARARs or adequate toxicity criteria are available for the other chemicals.
Animal Shelter Well	Total Cyanide	Free cyanide was not analyzed for in the Animal Shelter well. Total cyanide levels are below ARARs of 770 ug/liter or 220 ug/liter for free cyanide.

Table 7.2, continued.

Exposure Medium/Area	Chemicals of Potential Concern	Results of Comparison with ARARs or other criteria
Recreation Area Production Well	No chemicals except lead detected at above background conc.	Lead level is approximately equal to the proposed federal drinking water Maximum Contaminant Level Goal (MCLG) of 20 ug/liter and is below Oregon drinking water standard (MCL) of 50 ug/liter.
Chenoweth Irrigation Company Wells	No chemicals currently above background conc. Predicted future conc. of cyanide and fluoride	-- Predicted future conc. of cyanide and fluoride below ARAR values.
Onsite Production Wells	No chemicals detected at above background conc.	--
Air: Onsite Dust (short-term exposure of onsite workers)	Arsenic, Cyanide, Fluoride, PAHs	Estimated short-term maximum concentrations of chemicals due to airborne dust are below OSHA PEL values.
Offsite Dust (short-term exposure of offsite residents)	Arsenic, Cyanide, Fluoride, PAHs	Estimated short-term maximum concentrations of chemicals due to airborne dust are below OSHA PEL values which have been adjusted for general populations.

-- = Not applicable

soil disturbance at the site), the exposure scenario selected for evaluation was that which would result in the highest exposure and risk. For each exposure pathway evaluated, an average case and a maximum exposure case are evaluated. For the average exposure case, populations are assumed to be exposed to mean concentrations of contaminants in the exposure medium at average exposure frequencies, etc. Under the maximum exposure case, the maximum reported concentration is used together with upper-bound exposure parameters.

In reviewing the risks that may result from these exposures, the probability or improbability of these exposures occurring should be kept in mind. For instance, one of the future exposure scenarios evaluated assumes that houses will be built at the MMRF site and that an individual living in one of these homes for a 70-year lifetime will frequently be exposed to contaminated soils by direct contact. The risks predicted for this scenario are likely to provide an upper bound on potential risks from the site.

As can be seen from the risk characterization column of Tables 7.1 and 7.2, risks from these exposures were characterized in several ways. Preferentially, potential risk was assessed by comparing concentrations of chemicals in the contaminated exposure medium (e.g., ground water) at points of potential exposure to state or frederal environmental standards, criteria, or guidance that were identified as ARARs or other relevant guidance. When such comparison values were not available for all chemicals in a particular exposure medium, exposures of humans to that contaminated medium were evaluated by quantitative risk assessment. Ground water was the only exposure medium for which ARARs were available for all chemicals. Hence, exposures to chemicals in surface water, soil, and air were evaluated by quantitative risk assessment.

Quantitative risk assessment involves estimating intakes (doses) by potentially exposed populations based on the assumed exposure scenario. These intakes are then combined with reference doses (Rfds, defined as acceptable daily doses for noncarcinogens) or cancer potency factors (for carcinogens) to derive estimates of noncarcinogenic hazard or excess lifetime cancer risks of the potentially exposed populations. For carcinogens (in the case of the MMRF site, these are arsenic and cPAHs), the excess lifetime cancer risk is expressed as a probability. A 10^{-6} risk indicates that, as a result of the exposure being considered, an exposed individual has a probability of one in a million of getting cancer.

When considering the carcinogenic risks presented in the table, it should be noted that there is uncertainty in the scientific community regarding the cancer potency factor used to evaluate carcinogenic PAHs. This could potentially result in overestimation of the actual cancer risks associated with these compounds.

For noncarcinogens (which in the case of the MMRF site includes all of the chemicals of potential concern except arsenic and cPAHs) results are presented as a hazard index, which is defined as the sum of the ratios of the intake of each chemical to its RfD. Hazard indices exceeding unity indicate that health hazards might result from such exposures.

Pathways by which environmental receptors at and near the MMRF could potentially be exposed to contaminants originating at the site were generally qualitatively evaluated due to the general paucity of data with which to evaluate such exposures. When sufficient data were available, estimates of risks to biota were made based on exposure and toxicity estimates. With respect to the potential risks to environmental receptors shown in Table 7.1, it should be noted that proposed or existing ecological risk assessment methodology used by EPA generally assumes that, except in the case of an individual belonging to a threatened or endangered species, adverse effects to individual organisms may be acceptable for most species if the integrity of the population of that species is not affected. Several site-specific factors are expected to reduce the risk at the population level at the MMRF site:

(1) Because the ditches and puddles of concern at the site are smaller than other sources of fresh water nearby, the impacts of the on-site study areas on entire environmental populations are expected to be small; and

(2) Because much of the area around the site is undeveloped, a population of organisms probably exists to replace ailing individuals.

Finally, it should be noted that these summary risk tables do not capture all aspects of the uncertainty associated with this risk assessment and risk assessment in general. A discussion of these uncertainties is contained in Appendix B. The estimates of risk presented in the risk assessment or this summary are not precise and are presented solely to guide the decision of whether to take remedial action at the MMRF site. In general, the exposure assumptions and models used to estimate these human health risks are conservative, i.e., tend to overestimate exposure and risk, and the health effects criteria incorporate margins of uncertainty. Hence, final estimates of exposure and risk will be near to or higher (often much higher) than the upper end of the actual range of exposure and risk.
591/3

Section Eight

8.0 SUMMARY OF FINDINGS

8.1 PURPOSE

This report describes the RI performed by G&M at the MMRF in The Dalles, Wasco County, Oregon. The investigation, conducted on behalf of Martin Marietta Corporation (MMC), was overseen by Region X of the U.S. Environmental Protection Agency under a Consent Order (No. 1085-04-02-106) dated September 1985. Implemented in accordance with the RI Work Plan dated December 1985, as modified in May 1987, the investigation is consistent with the requirements of the National Contingency Plan and CERCLA guidance documents.

This report summarizes the results of data collected during RI activities and includes an RA prepared by ICF/Clement Associates. A separate FS report, scheduled for completion in the first half of 1988, is to be prepared based on the findings of the RI and the RA.

8.2 SITE BACKGROUND

8.2.1 Site Location

The MMRF site is located in The Dalles, Wasco County, Oregon, west of the Columbia River and east of the Union Pacific Railroad Road. The site occupies approximately 350 acres within an 800-acre area zoned for heavy industry and manufacturing. The area of the site used for industrial purposes encompasses approximately 110 acres. The MMRF is bounded near the Mountain Fir wood hauling and chip mill on the north, Webber Street to the south, the Columbia River on the east, and the Union Pacific Railroad line and West Second Street to the west.

8.2.2 Site History

The MMRF is an aluminum processing facility designed to produce approximately 90,000 tons per year of aluminum from alumina. Operations were begun at the site by Harvey Aluminum, Inc., in 1958. That company became a wholly owned subsidiary of MMC in 1970. The MMRF continued operations under the name of Martin Marietta Aluminum, Inc., until 1984, when the plant was shut down and MMC acquired legal title to the property. In 1986, MMC leased the plant and portions of property adjacent to the plant to Northwest Aluminum Company, which resumed primary aluminum operations in 1987. A chronological history of events and actions related to the aluminum plant operations is provided in Table 8.1.

During facility operation, waste constituents derived from alumina reduction were stored, treated, and disposed of at the MMRF. Although waste management techniques such as installation of wet and dry scrubbers were employed and all necessary environmental operating permits were obtained, waste constituents, principally fluoride, sodium, sulfates, cyanide, and polynuclear aromatic hydrocarbons (PAHs), were released to the environment. As a result of such releases, MMC entered into a Consent Order with Region X of the EPA in September 1985 that directed MMC to perform an RI/FS for specific areas at the site that might have been impacted during plant operations.

Prior to initiating the RI, a number of interim remedial actions were performed at the MMRF to mitigate the environmental effects of plant activities. These include: construction of the lined pond; relocation of the old cathode waste pile to the new cathode waste pad containing a leachate collection system; fencing of the landfill to restrict access (performed as an interim remedial measure); and construction

Table 8.1 Chronological History of MMRF Operations

Dates	Event
1957 and through 1960	Plant construction debris placed in the Landfill. Paper and wood burned in the Landfill.
1958	Process operations initiated by Harvey Aluminum, Inc. Plant emissions collected in a wet primary fluoride scrubber system (known as the "Old Tower" system) and discharged to Scrubber Sludge Ponds 2 and 3.
1960	Paper and wood waste were crushed and shipped to Wasco County Landfill.
1960's	Old Tower system replaced with electrostatic precipitators. Collected emissions sent to Scrubber Sludge Ponds 2 and 3.
1960	Old Cathode Waste Pile started at northeast corner of the plant. Old Cathode Wash Area constructed east of plant and next to River Road.
1961-1971	Bricks separated from cathodes taken out of service and placed in the Landfill. Other cathode waste shipped off-site for processing at Reynolds Aluminum.
1968	Berm and settling basin added to Old Cathode Wash Area.
1969	Secondary scrubber added to existing scrubber system to enhance air emission controls.
1970	Harvey Aluminum, Inc., becomes a wholly-owned subsidiary of Martin Marietta Corporation.
1972	Clarifier placed on-line. Use of Scrubber Sludge Pond 1 began. Scrubber Sludge Ponds 2 and 3 use discontinued except for use as a backup when clarifier was off-line.
1974	Recycle Pond constructed for use as settling basin for solids separation from secondary scrubber water. Old NPDES Discharge Channel taken out of service.
1974-1984	Waste from the Casthouse, Paste Plant, and plant operations deposited in the Landfill.
1976	Scrubber Sludge Pond 4 constructed and used to store dredged materials from Scrubber Sludge Ponds 2 and 3 and the Recycle Pond.
1977	Scrubber Sludge Pond 2 dredged and dredged material placed in Scrubber Sludge Pond 4.

Table 8.1 (Continued)

Dates	Event
1978	Dry Scrubber system installed to replace electrostatic precipitators. Wet scrubber added downstream of the dry system as a backup and to collect sulfur dioxide emissions. Fluoride in the dry scrubber adsorbed by alumina and recycled to the pots. Solids from the wet system were pumped to the Scrubber Sludge Ponds.
1979	Old Cathode Wash Area extended to the east.
1980	Lined pond constructed to reduce volume placed in the Scrubber Sludge Ponds.
July 1980	Piping from the Landfill to the Landfill leachate collection sump installed. Sump pump installed to mitigate discharges from the Landfill.
1981	Use of Scrubber Sludge Ponds 1 and 4 discontinued; ponds capped.
1982	Scrubber Sludge Pond 2 receives runoff from Scrubber Sludge Pond 3. Dredged bottoms of Lined Pond and Recycle Pond placed in Scrubber Sludge Pond 3.
1983	Cyanide levels above detection limits detected during routine sampling of Production Well #2. Well subsequently properly abandoned.
Spring 1983	Century West Engineering investigates Landfill as a result of detected leachate migration. Surface cover added to Landfill to control surface drainage towards the east and drainage ditches were constructed to control runoff and runon. A diversion berm was constructed on west side of ditch to eliminate surface runoff.
Spring 1983	EPA performs hazardous waste ranking of MMRF.
Spring 1983	State of Oregon Department of Environmental Quality lists potliner waste as hazardous. Permitted waste pad built to store waste potliner; potliner waste previously stored at the Old Cathode Waste Pile relocated to the permitted storage area.
1984	Martin Marietta Corporation acquires legal title to property from Martin Marietta Aluminum, Inc. Martin Marietta Corporation constructs leachate collection system for the Landfill and new Cathode Waste Pad. Remaining Old Cathode Waste Pile waste and six inches of soil relocated to the new Cathode Waste Pad.
December 1984	Martin Marietta Aluminum, Inc., ceases production.

Table 8.1 (Continued)

Dates	Event
September 1985	Martin Marietta Corporation enters into a consent order with EPA Region X. Requirements of the consent order include the performance of a Remedial Investigation and Feasibility Study (RI/FS) for the MMRF.
December 1985	Work plan for the RI/FS prepared by Geraghty & Miller, Inc. for Martin Marietta Corporation submitted to the EPA. Camp, Dresser & McKee, Inc. submits a community relations plan for the MMRF to the EPA.
February 1986	RI/FS Work Plan modified.
March 1986	RI/FS Work Plan implemented by Geraghty & Miller, Inc.
April 1986	Fencing installed to secure Landfill.
September 1986	Martin Marietta Corporation leases the MMRF to Northwest Aluminum Company under a five-year lease/sale agreement. Lined Pond, Discharge Channel, and Recycle Pond are reactivated for plant operations.
November 1986	Results of initial RI data collection activities summarized by Geraghty & Miller, Inc. in "Interim Report - Remedial Investigation, MMRF, The Dalles, Oregon," submitted to EPA.
November 1986	Northwest Aluminum Company resumes primary aluminum operations.
1987	Flows to the Duck Pond are diverted to the discharge channel.
January 1987	MMRF designated as a Superfund site.
March 1987	RI/FS Work Plan Addendum submitted to EPA.
May 1987	RI/FS Work Plan Addendum modified.
June 1987	EPA approves RI/FS Work Plan Addendum. Field activities specified in the addendum initiated.
November 1987	Preliminary Remedial Investigation Report submitted to EPA.

566/5

the landfill of a leachate collection system consisting of perimeter ditches and a collection sump.

8.2.3 Summary of the Remedial Investigation

The RI for the site was initiated by G&M in March 1986. The areas investigated during the RI are the:

- o Landfill and Adjacent Areas
- o Former Cathode Waste Management Area
- o New Cathode Waste Pad
- o Duck Pond
- o Lined Pond
- o Recycle Pond
- o Scrubber Sludge Ponds
- o Wastewater and Surface-Water Transport Ditches.

Table 8.2 summarizes the volumes of soil, sediment, waste, or liquid estimated to be contained within these areas. In addition, ground-water systems located beneath the facility were investigated for impact from plant operations. Four aquifer systems, labeled the S, A, and B aquifers and the DGWR, have been identified at the MMRF. Perched water at the old cathode waste pile, salvage area, potliner handling area, cathode wash area, and an alluvial aquifer of limited areal extent were also evaluated during the RI.

The RI consisted of waste characterization at the landfill and sampling of sediment, soil, air, surface water, and ground water throughout the site to: characterize site conditions and the extent and nature of constituents released to the environment; gather site data necessary to evaluate potential remedial responses; and determine the nature and extent of the risk posed to public health, welfare, or the environment by the release of constituents at the MMRF. During this work, monitor wells were installed, several

Table 8.2 Summary of Volume Estimates

	Estimated Volume	
Area of Investigation	cubic yards	gallons
Landfill	200,000	-
Landfill Runoff Areas		
Area A	510	-
Area B	150	-
Area C	230	-
Area D	138	-
Metal Pad Storage Area	1,690	-
Bath Recovery Pad Area	1,660	-
Old Cathode Waste Pile Area	24,200	-
Salvage Area	28,700	-
Potliner Handling Area	9,910	-
Cathode Wash Area	4,530	-
Duck Pond	2,430	-
Lined Pond	7,570	4,000,000
Lined Pond (Wind Blown)	130	-
Recycle Pond	8,915	8,000,000
Scrubber Sludge Ponds		
SSP1	71,700	-
SSP2	9,580	-[1]
SSP3	58,100	-
SSP4	28,500	-
Wind Blown	538	-
Ditches		
Surface Drainage Ditch	1,240	-
Leachate Collection Ditch[2]/	-	-
Landfill Ditch	2,050	-
North Ditch	610	-
River Road Ditch	200	-
River Road Curb	-	-
Discharge Channel	1,100	-
Drainage Ditch	920	-
Old NPDES Discharge Channel	-	-
Abandoned Scrubber Sludge Channel	-	-

---

[1] Seasonally affected

[2] Lined with concrete; unable to probe soils underneath.

\- Not relevant

566/7

previously constructed wells were replaced, aquifer tests were conducted, and water-level measurements were made. New monitor wells were installed on-site and off-site to enhance delineation of the direction of ground-water movement and hydraulic relationships among the aquifer systems.

RI data-collection activities included the following:

- Abandonment of 3 wells;
- Reconstruction of 16 pre-existing monitor wells;
- Installation of 41 new monitor wells;
- Completion of 66 borings;
- Completion of 15 test pits;
- Collection of 272 ft of rock core;
- Completion of 13 slug tests;
- Completion of 6 aquifer pumping tests;
- X-ray diffraction analysis of 29 rock samples;
- Collection and analysis of 133 ground-water samples;
- Collection and analysis of 38 surface-water samples;
- Collection and analysis of 19 soil samples;
- Collection and analysis of 60 sediment samples;
- Collection and analysis of 22 waste samples;
- Collection and analysis of 446 air samples.

The types of constituents detected in source areas and ground-water systems at the MMRF were consistent with the types of materials treated, stored, or disposed of at the site. Table 8.3 is a summary of the analytical data obtained for soil, sediment, waste, and surface-water samples.

Table 8.3 Constituents Measured Above Detection Limits

Area of Investigation	Media	Total CN	Free CN	F	Na	As	SO_4	Ba	Hg	Cd	Cr	PAHs	Bis-(2-Ethylhexyl) Phthalate	TCE	Chloro-form	1,1,1 TCA
Bath Recovery Pad	Soil	X	X	X	X											
Cathode Wash Area	Soil	X	X	X	X											
Discharge Channel	Surface Water	X	X	X	X		X									
	Sediment		X	X	X			X	X			X				
Drainage Ditch	Sediment		X	X	X											
Duck Pond	Surface Water			X	X		X		X				X			
	Sediment			X	X											
Landfill	Soil	X	X	X	X			X				X				
Landfill Ditch	Surface Water	X	X	X	X	X	X		X			X	X			
	Sediment		X	X	X			X								
Landfill Leachate	Surface Water	X	X	X	X	X	X		X		X	X		X		
Landfill Runoff																
Area A	Soil	X	X	X	X											
Area B	Soil	X	X	X	X		X									
Area C	Soil	X	X	X	X	X	X	X								
Area D	Soil	X	X	X	X											
Lined Pond	Surface Water			X	X	X	X					X			X	X
	Sediment			X		X				X		X				
Metal Pad Storage Area	Soil	X		X	X											
North Ditch	Surface Water	X		X	X	X	X		X							
	Sediment			X	X			X								

Table 8.3 (Continued)

Area of Investigation	Media	Total CN	Free CN	Fl	Na	As	SO_4	Ba	Hg	Cd	Cr	PAHs	Bis-(2-Ethylhexyl) Phthalate	TCE	Chloro-form	1,1,1 TCA
Old Cathode Waste Pile	Soil	X	X	X	X							X				
	Surface Water	X	X	X	X											
Potliner Handling Area	Soil	X	X	X	X							X				
Recycle Pond	Surface Water				X											
	Sediment			X	X							X				
River Road Ditch	Soil			X	X											
Salvage Area	Soil	X	X	X	X											
Scrubber Sludge																
Pond 1	Sediment			X	X	X						X				
Pond 2	Sediment			X	X	X						X				
Pond 3	Sediment			X	X	X						X				
Pond 4	Sediment			X	X	X						X				
Surface Drainage Ditch	Sediment			X	X							X				
S Aquifer	Water	X	X	X	X		X									
A Aquifer	Water	X	X	X	X		X									
B Aquifer	Water	X	X	X	X		X									
DGWR	Water	X		X	X		X									
Alluvial	Water	X	X	X	X		X									
Rockline Well	Water	X	X	X	X		X									

Explanation:
Total CN = Total Cyanide
Free CN = Free Cyanide
F = Fluoride
Na = Sodium
As = Arsenic
SO_4 = Sulfate
Ba = Barium
Hg = Mercury
Cd = Cadmium
Cr = Chromium

PAHs = Polynuclear Aromatic Hydrocarbons
TCE = Trichloroethene
1,1,1 TCA = 1,1,1-Trichloroethane

566/16

8.3 PHYSICAL CHARACTERISTICS OF THE SITE

8.3.1 Climate

The MMRF is located within the semi-arid region of eastern Oregon where the climate is characterized by warm, dry summers and cold, relatively wet winters. At The Dalles, the mean annual temperature is about 54°F. July is generally the warmest month with a mean maximum temperature of 86°F. The mean minimum temperature is 34°F in January.

The area receives from 10 to 15 inches of precipitation annually with a mean annual precipitation at The Dalles of 13.7 inches. Average annual evaporation from shallow lakes in the area is approximately 40 inches. Records from The Dalles indicate a cumulative moisture deficit of about 15 inches per year; that is, evaporation exceeds precipitation.

Wind velocity measured at an on-site meteorological station during the months of June and July 1987 showed maximum wind speeds of up to 60 miles per hour (mph); gusts of up to 30 mph were common. The highest wind speeds are associated with northwest winds. Typical wind speeds range from 5 to 20 mph and the predominant wind direction is from the northwest.

8.3.2 Topography

Land-surface elevations at the MMRF range from about 100 ft msl at the Columbia River to more than 155 ft msl at the Landfill. The topography of the site has changed over time due to filling of low areas; in general, the site is level with the exception of distinct man-made and natural features. These features include: man-made ponds, the landfill, drainage ditches, stream channels, and road beds.

8.3.3 Surface-Water Drainage

The topography at the MMRF largely controls the direction of surface-water flow, except where man-made structures have been built to alter flow patterns. In general, surface-water runoff from active portions of the site is routed to the recycle pond.

Runoff from the landfill area is currently intercepted by the leachate collection system and the landfill ditch and then routed to the recycle pond via the discharge channel. Prior to the construction of this interception network, landfill runoff followed three primary drainage pathways, all of which discharged to the alluvial aquifer.

The ponds at the MMRF are the four scrubber sludge ponds, recycle pond, duck pond, and lined pond. The recycle pond, which serves as a collection point for runoff from the landfill, the former cathode waste management area, and areas to the immediate south and west of the plant, discharges to the Columbia River in accordance with a National Pollutant Discharge Elimination System (NPDES) permit. The recycle and lined ponds are currently in use. The scrubber sludge ponds are no longer in use but intersect the water table and are indurated in proportion to the relative ground-water elevation.

Surface-water runoff from the southwest part of the site flows to the south and east through a natural drainage channel prior to discharging to the Columbia River. Surface-water drainage from the non-active part of the MMRF (northwest of the landfill) discharges directly to Chenoweth Creek.

8.3.4 Lithology/Geology

The surface soils at The Dalles are poorly developed and in most places are non-existent. The four native soil groups known to be present, are, in order of decreasing areal extent: (1) the Rock Outcrop-Xeropsamments Complex, (2) the Hesslan-Skyline Complex, (3) the Van Horn Loam, and (4) the Quincy Loam Fine Sand. During construction and operation of the MMRF, a large part of the native soils at the site were covered with fill material.

Underlying the soils/fill at the site is rock of the Columbia River Basalt Group (CRBG). The rock formations evaluated consist of the following stratigraphic horizons (in order of increasing depth):

- Lolo flow of Priest Rapids Member;
- Sedimentary (Byron) Interbed;
- Rosalia flow of Priest Rapids Member;
- Sedimentary (Quincy/Squaw Creek) Interbed; and
- Sentinel Gap flow of Frenchman Springs Member.

The rock strata at the site are generally flat lying except in the north where the Chenoweth Fault transects the site. The CRBG is overlain by Pleistocene Age alluvial deposits in the northern parts of the site.

8.3.5 Hydrogeology

The ground-water flow system at the MMRF includes a water-table aquifer (S aquifer) overlying a series of confined aquifers (A and B aquifers and DGWR). Zones of perched water and an alluvial aquifer are present locally.

The unconfined S aquifer is present within the relatively low permeability basalts of the Lolo flow and the subaerial portion of the Rosalia flow and the Byron Interbed. The first confined aquifer (A aquifer) is within the upper pillow lava horizon of the subaqueous portion of the Rosalia flow. The A aquifer ranges from 5 to 45 ft in thickness. The B aquifer is below the A aquifer and is locally separated from it by a low permeability basalt (lava lobe). The lava lobe is apparently absent north of the site due to non-deposition. The B aquifer ranges from 30 to 50 ft in thickness. In areas where the lava lobe is absent, the A and B aquifers combine to form a single hydrogeologic unit. A thick, low permeability siltstone and sandstone unit forms the confining unit between the B aquifer and the underlying DGWR. The top of the DGWR occurs within the permeable zones of the Sentinel Gap flow, and the most permeable portion of the DGWR is within the flow-breccia top of the Sand Hollow flow.

Ground-water flow in the S aquifer is generally to the east and northeast; discharge from the S aquifer is believed to be into the alluvial aquifer and the Columbia River. Ground-water flow in the A aquifer is predominantly east to west. The A aquifer may be recharged by the alluvial aquifer, the Columbia River, and the S aquifer; discharge appears to be to the B aquifer and regional water-supply wells. Ground-water flow in the B aquifer is generally to the west and south; hydraulic gradients vary, however, depending on the hydrologic and pumping conditions.

An alluvial aquifer, approximately 400 ft wide and at least 60 ft deep, is present in the area north of the plant within Pleistocene age sand deposits. The geometry of the alluvial aquifer is apparently controlled by the location of the trace of the Chenoweth Fault. Flow in the alluvial aquifer is expected to be east, toward the Columbia River.

Perched water has been identified at the old cathode waste pile, salvage area, and potliner handling areas within the permeable fill material emplaced above competent basalt during plant construction. The saturated thickness of the perched zone varies with rates of natural recharge, and was approximately 0 to 3 ft in test pits opened in August 1987. One source of the perched water is precipitation; other potential sources include infiltration from the landfill ditch and north ditch and leaks in below-grade water distribution lines.

8.3.6 Existing and Future Land and Ground-Water Use

The MMRF, as noted previously, is located within 800 acres zoned for heavy industry and manufacturing. Northwest Aluminum is currently the largest industry in this zoning area, employing 250 to 300 persons.

A small trucking facility, the MMRF recreation area, and the rodeo grounds are located near the southern boundary of the industrial area. The northern part of the area contains the Mountain Fir facility and two small areas zoned as community facilities. Located within these community facilities are the Wasco County Animal Shelter, Rockline (which consists primarily of a machine shop employing about four people), and an electric power substation. A gravel pit owned by Munson Paving is also located in the northern part of this zoning area.

Currently, there is little development along the Columbia River waterfront in the vicinity of the MMRF, although there are plans to use a tract between the site and the river for industrial development. The area has been leveled, graded, and landscaped. A small barge company is located on the waterfront approximately 0.5 mile southeast of the MMRF.

The remainder of the zoning area is lightly vegetated or wooded; MMRF land that is not used for industrial processes is leased for agricultural uses such as cattle grazing. Cattle grazing takes place primarily in the vegetated areas northeast of the facility and in the area near the rodeo grounds.

A strip of land zoned for light industrial and manufacturing development is located between the railroad tracks and Interstate 84 directly west of the MMRF main building. In addition to several small businesses, this area currently includes a few residential homes. These homes were in place prior to zoning, and upon new ownership or destruction of the homes, the area will be used strictly for light industrial and manufacturing development. Based on recent aerial photographs, less than 20 homes and businesses are in the area west of the site.

Interstate 84 separates the light and heavy industrial/manufacturing area from residential areas. Directly west of the interstate and approximately one-third of a mile from the MMRF site are several areas zoned for residential development. General commercial sites, such as a drive-in theater, are located in and around these residential areas, approximately two-thirds of a mile west of the MMRF. Additional residential areas zoned for single-family, multi-family, and mobile home dwellings are located southwest of the site.

Ground water is an important source of water supply in The Dalles area for domestic, industrial, and agricultural uses. The primary aquifer in the area is the DGWR; the alluvial aquifer located in the Chenoweth Creek area is used by the Animal Shelter.

The Columbia River and its tributaries represent the major surface-water resources in the area, with an impoundment on Mill Creek used as the principal source of water supply for the City of The Dalles. The Columbia River and its tributaries provide habitat for important commercial and sport fisheries, with salmon, trout, steel head, walleye, and bass being among the many game fish common to the river. Many of the tributaries serve as hatcheries for the salmonoids.

A gravel pit is operated within the quaternary gravels of the alluvial aquifer northeast of the MMRF. This operation is relatively small, and probably could not be expanded significantly owing to the limited extent of the alluvium.

8.4 NATURE AND EXTENT OF SITE-DERIVED CONSTITUENTS

The nature and extent of the site-derived constituents can be defined from the RI results, including the RA conclusions and the characteristics of the site and waste materials. Analytical data obtained during the RI are used to ascertain the lateral and vertical extent of the released constituents. Conditions are further defined based on waste and site characteristics for the areas of concern in order to evaluate potential exposure, transport, and remediation of site materials. Finally, in the RA, potentially impacted areas are assessed for points of exposure and associated risks to human health, welfare, and the environment. In order to perform the RA, chemical-specific standards for constituents detected at the site are established.

8.4.1 Site and Waste Characterization for Areas of Concern

8.4.1.1 Landfill

The landfill occupies approximately 15 acres just north of the alumina reduction building. Former drainage pathways from the landfill area correspond to the landfill runoff areas. The installation of the leachate collection ditch, which was later gunite lined, was intended to cut off migration of the leachate. The leachate collection ditch is effective in preventing surface runoff but is apparently less effective in capturing leachate following the contact between surface soils/fill and the underlying basalt. MMRF installed an interceptor trench in an effort to minimize the impact of surface-water runoff from the area to the west of the landfill.

Wastes at the landfill were placed randomly on the ground surface and piled to the current configuration; total waste volume is estimated to be about 200,000 cubic yards. Wastes present in the landfill as a result of the reduction process and construction operations consist of: construction debris (primarily basalt fragments); spent cathode waste materials; refractory bricks; off-specification carbon block, pitch, and coke; cryolite; metallic materials such as buss bars and collector studs; and pallets, cans, rags, and empty drums. Prior to the regulation of asbestos disposal and handling practices, asbestos and materials containing asbestos were disposed of in a random fashion within the landfill. Since regulation of these materials, MMRF disposed of asbestos in discrete areas of the landfill.

Waste materials within the landfill can be divided into four main categories:

- Basalt fragments;
- Asbestos;
- Metallic wastes; and
- Target wastes.

Most of the waste appears to be basalt from construction activities; particle sizes range from very fine silts to boulders several feet in diameter. Although written records do not exist, the volume of asbestos in the landfill is not anticipated to be a large quantity (less than 100 cubic yards). However, it is not possible to accurately estimate the volume of asbestos distributed throughout the landfill prior to controlled burial. Metallic wastes consist of buss bars, collector studs, and miscellaneous drums, cans, etc. However, there does not appear to be a significant quantity of metallic wastes. The target wastes consist of the remaining materials, including: spent cathode waste, refractory bricks, and off-specification carbon block, pitch, and coke . The following volumes have been estimated for the waste types in the landfill:

o Basalt Fragments	100,000 yds^3
o Asbestos	
- Buried	100 yds^3
- Distributed	200 yds^3
o Metallic Wastes	500 yds^3
o Target Wastes	99,200 yds^3

It is estimated that 5,000 tons of spent cathode waste materials are present in the landfill; these wastes contain high levels of carbon, sulfate, sodium, and fluoride in addition to minor amounts of cyanide. Cryolite, which is composed of fluoride, sodium, and aluminum, is also present in the landfill. Pitch and coke associated with the continuous anode in the reduction process are present in the landfill and contain elevated levels of PAHs and low levels of arsenic.

To confirm the composition of the landfill, five test pits were excavated. The materials observed ranged from fine dust to very large basalt boulders. Composite samples from the five test pits indicate the presence of the following constituents:

EP Toxicity Metals - Barium	0.234 mg/L (one sample)
Total cyanide	0.32 - 70 mg/kg
Free cyanide	<0.27 - 54 mg/kg
Sodium	3,400 - 82,200 mg/kg
Fluoride	204 - 2,880 mg/kg
PAHs	276 - 2,406 mg/kg

Leachate generated by the landfill is contained by a leachate collection system that consists of the following ditches:

- Surface Drainage Ditch;
- Leachate Collection Ditch; and
- Landfill Ditch.

The generation of leachate is seasonally dependent and its presence is directly related to precipitation or snow melt. Available records of leachate collected and pumped range from 0 to 50,000 gallons per day (gpd) with peak flows occurring generally in the early spring.

Analyses of leachate samples from the leachate collection ditch identified the presence of the following constituents:

Volatile Organic Compounds - Trichloroethylene	8 mg/L (one sample)

o Cyanide	
- Total	0.11 - 29 mg/L
- Free	0.01 - 4.7 mg/L
o Fluoride	1,490 - 2,440 mg/L
o Sodium	4,270 - 5,900 mg/L
o Sulfate	840 - 2,660 mg/L

Analyses of leachate samples from the landfill ditch identified the presence of the following constituents:

o PAHs (including Bis[2-ethylhexyl]Phthalate)	<0.01 - 206 ug/L
o Cyanide	
- Total	373 - 1,280 mg/L
- Free	34.2 - 77.2 mg/L
o Fluoride	5,400 - 8,000 mg/L
o Sodium	36,600 - 99,800 mg/L
o Sulfate	10,500 - 49,300 mg/L
o Chloride	1,210 - 3,430 mg/L

The surface drainage ditch was dry and leachate was not present for sampling. The leachate collection ditch was gunite lined and sediment samples were not available. Sediments from the surface drainage ditch and the landfill ditch were analyzed for the following constituents:

o Cyanide	
- Free	< 0.62 - 3.6 mg/kg
o Fluoride	189 - 519 mg/kg
o Sodium	2,720 - 5,600 mg/kg

The inorganics in the leachate and sediments are the result of precipitation and/or snow melt percolating through the wastes in the landfill and flowing to the ditches. A small section of the landfill ditch upstream of its intersection with the north ditch has exposed wastes in the adjacent banks of the landfill and bath recovery pad areas, which account for the high levels of constituents in the leachate samples taken from this area. The visual condition of the leachate suggests that it contains high levels of suspended particulates. Because of the low solubility of PAHs, the presence of the PAHs in the leachate can be attributed to suspended particles.

8.4.1.2 Landfill Runoff Areas

The landfill runoff areas (LRAs) consist of four separate areas (A through D) which are located north and northeast of the existing landfill. The locations of the LRAs correspond to the historical drainage features around the landfill. The size and estimated volume of material for each LRA consist of:

LRA	Size (Acres)	Volume (Cubic Yards)
A	0.22	510
B	0.10	150
C	0.14	230
D	0.09	140

LRA A, B, and D consist of soil that has been in contact with surface water or leachate emanating from the landfill. LRA C has both soils and large basalt fragments from MMRF construction activities with estimated volumes of 180 and 50 cubic yards, respectively.

The LRAs were formed when runoff and leachate generated by precipitation contacting the landfilled wastes flowed or migrated along the historical drainage pathways. Surface waters are present in the areas only in relation to significant precipitation events while leachate may migrate along the soil/fill and underlying basalt for a longer period. The LRAS are usually wet during the winter and early spring months and dry in the summer through fall when ponded water infiltrates or evaporates.

Soil samples from each LRA were collected and analyzed for the following constituents:

	Landfill Runoff Areas			
	A	B	C	D
Cyanide				
Total (mg/kg)	10	7.4	60	4
Free (mg/kg)	0.66	0.80	5.0	0.5
Fluoride (mg/kg)	2,300	1,830	604	347
Sodium (mg/kg)	10,500	12,400	12,900	5,030
Arsenic (mg/kg)	BDL	BDL	19	BDL
Sulfate (mg/kg)	BDL	3,440	3,440	BDL
EP Toxicity Metals				
Barium (mg/L)	BDL	BDL	0.314	BDL

Ponded water was absent during sampling of the LRAs and was not characterized.

8.4.1.3 Potliner Handling Areas

The potliner handling area (PHA) occupies approximately 0.9 acre, just east of the reduction building. The PHA was used during the period when waste cathode was crushed and loaded onto railroad cars for off-site recycling. As a result of the crushing process, cathodic dust, pitch, and coke residuals have accumulated on the surface of the PHA.

Test pits in the old cathode waste pile area immediately north of the PHA exposed fill thicknesses between 4.7 and 8.8 ft for the old cathode waste pile. Extrapolating this information to the PHA indicates that an estimated 9,910 cubic yards of fill and residuals may be present at the PHA. The 3-inch layer of residuals accounts for approximately 1,450 cubic yards of the total volume. The primary material crushed for off-site recycling was carbon block. Therefore, the majority of the residuals on the PHA surface will be cathode waste. The sample from the PHA surface residuals indicates the presence of the following constituents:

o Cyanide	
- Total	14 mg/kg
- Free	4 mg/kg
o Fluoride	673 mg/kg
o Sodium	29,600 mg/kg
o PAHs	9,041 mg/kg

These results are characteristic of cathode waste, coke, and pitch.

8.4.1.4 Scrubber Sludge Ponds

The scrubber sludge ponds (SSPs) consist of four surface impoundments (numbered 1 through 4) located south of the reduction buildings and west of River Road. The locations for the SSPs were selected because the air emission slurry produced in the aluminum reduction process could be discharged to the SSPs under gravity conditions. The large surface area and retention capacity of the SSPs allowed for particulate settlement and final discharge of accumulated water to the Columbia River.

SSP1 was diked and was used to receive chemical sludges resulting from the lime precipitation of the air emission control waters for fluoride removal. The primary salt formed during the precipitation was calcium fluoride. SSP4 received dredgings from SSP2 and SSP3 and the recycle pond. Both SSP1 and SSP4 were removed from service and covered in 1981.

Collectively, the lateral extent of the SSPs is approximately 14.8 acres. SSP1 and SSP4 have soil covers and established vegetation which currently precludes direct contact with the wastes. SSP2 and SSP3 are not covered. The material present in the SSPs can be divided into three categories: (1) soil cover, (2) sludges, and (3) contaminated subsoils. The volumes for each SSP by category are presented below:

Pond	Cover	Sludge	Subsoil	Subtotal
SSP1	7,970	63,730	-	71,700
SSP2	-	6,820	2,760	9,580
SSP3	-	43,600	14,500	58,100
SSP4	4,640	17,660	6,200	28,500
			TOTAL	167,880

In addition, prevalent winds have scattered approximately 538 cubic yards of sludge south of SSP2 and SSP3.

The elemental sludge produced at the MMRF was 9 percent fluoride. Of the fluoride present, only 4 percent was soluble. Therefore, approximately 0.36 percent of scrubber sludge is potentially leachable fluoride.

Samples were collected from each pond and analytical results indicate the presence of the following chemicals:

SSP1

o Cyanide - Free	BDL
o Fluoride	204 - 407 mg/kg
o Arsenic	BDL - 64 mg/kg

Sodium	15,400 - 20,700 mg/kg
VOCs	BDL
PAHs	2,760 - 8,570 mg/kg

SSP2

Cyanide - Free	BDL
Fluoride	263 - 317 mg/kg
Arsenic	34 - 71 mg/kg
Sodium	14,500 - 17,700 mg/kg
VOCs	BDL
PAHs	1,940 - 7,180 mg/kg

SSP3

Cyanide - Free	BDL
Fluoride	387 - 613 mg/kg
Arsenic	66 - 77 mg/kg
Sodium	18,400 - 45,000 mg/kg
VOCs	BDL
PAHs	3,950 - 8,360 mg/kg

SSP4

Cyanide - Free	BDL
Fluoride	212 - 258 mg/kg
Arsenic	BDL - 50 mg/kg
Sodium	6,250 - 13,600 mg/kg
VOCs	BDL
PAHs	2,670 - 3,979 mg/kg

Water was not present in SSP2 when samples were collected and therefore could not be analyzed.

8.4.1.5 Ground Water

The constituents of concern identified in the groundwater system include total and free cyanide, fluoride, sodium, and sulfate. The highest constituent concentrations are present in the perched water with progressively lower concentrations identified within the S, A, and B aquifers.

Concentrations of constituents in wells tapping the DGWR are low and within the range expected for background.

Perched water samples from the old cathode waste pile show elevated concentrations of total cyanide (294 mg/L), free cyanide (3.01 mg/L), fluoride (3,000 mg/L), and sodium (10,500 mg/L). Samples from the well in the alluvial aquifer at the Animal Shelter include a total cyanide concentration of 0.023 mg/L; no free cyanide or fluoride was detected.

Elevated constituent concentrations were identified in the S aquifer at several locations:

(1) Near the landfill and former cathode waste management area. Total cyanide is present in the ground water up to a concentration of 16.7 mg/L and sulfate up to 103 mg/L. Fluoride concentrations range from <1.0 mg/L to 4.7 mg/L. Free cyanide ranged from <0.90 to 0.136 mg/L, and sodium ranged from 57.2 to 82.2 mg/L.

(2) Scrubber sludge ponds. This area contains fluoride (4.8 to 7.1 mg/L), sodium (246 to 658 mg/L), and sulfate (117 to 3,020 mg/L). Free cyanide is below detection limits and total cyanide is reported in only one well (MW-8S) at 0.05 mg/L.

(3) The new cathode waste area near the alumina unloading building. Total cyanide is found at a concentration of 34.1 mg/L in well MW-5S, but ranges from 0.112 to 0.549 mg/L in the wells immediately downgradient. Sulfate is found at concentrations of up to 1,270 mg/L. Ground-water samples show detectable fluoride

and sodium at well MW-5S, but results are below detection elsewhere.

(4) Recycle pond. Samples from well MW-31 downgradient of the pond indicate fluoride concentrations of 5.5 mg/L, sodium concentrations of 90.5 mg/L, and sulfate concentrations of 871 mg/L.

Ground-water quality impacts in the A aquifer are less widespread and at lower concentrations than those identified in the S aquifer. The highest concentrations in the A aquifer exist east of the landfill and the former cathode waste management area. In this area, total cyanide concentrations range from 0.023 to 1.78 mg/L; sodium is found at 167 mg/L. In parts of the area, fluoride and free cyanide concentrations exceed 1 mg/L.

Site-derived constituents are also present in the A aquifer near the scrubber sludge ponds. Sodium ranges from 44.7 to 84.8 mg/L, sulfate from 23 to 924 mg/L, and fluoride from <0.1 to 1.0 mg/L.

In the B aquifer, elevated constituent concentrations are chiefly confined to a single location: the landfill and old cathode waste management area. The highest readings are reported for wells MW-9B and MW-8B, but they are suspected to be an artifact of well construction. In other wells, levels of total cyanide range up to 1.0 mg/L. Free cyanide concentrations are 0.10 mg/L or less and fluoride concentrations are less than 1.4 mg/L.

8.4.1.6 Air

Ambient air samples were collected upwind and downwind of active drilling and test pit sites during the investigation. Samples were analyzed for gaseous cyanide, particulate cyanide, gaseous fluoride, particulate fluoride, and coal tar pitch volatiles/total dust. All samples collected were below OSHA PELs with the exception of one upwind sample for coal tar pitch volatiles.

Personnel/Health and Safety air-quality monitoring was also carried out; no concentrations of ionizable pollutants were detected above the threshold requiring Level C protection and all samples were below OSHA PELs (except one sample for coal tar pitch volatiles).

In order to assess fugitive dust from the site, soil sieve analyses and fugitive particulate modeling was carried out. The results of this modeling is included in the Risk Assessment (Appendix B) for the site.

8.4.2 Identification of ARARs

Applicable or relevant and appropriate requirements (ARARs) are designated standards identified in accordance with SARA for the establishment of cleanup levels for remediation of CERCLA sites. There are basically three types of ARARs: ambient or chemical specific, performance or design criteria, and location standards. Ambient or chemical-specific ARARs are used to set health or risk based concentration limits in various media for specific substances. Chemical-specific ARARs include Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) promulgated under the Federal Safe Drinking Water Act, national ambient air quality standards under the Clean Air Act, and state standards if those standards are more stringent than federal regulations. Because of the limited number of ambient and chemical specific standards currently in effect, non-promulgated advisory levels, such as carcinogenic potency factors or reference doses, are often used as chemical-specific ARARs.

Tables 8.4 and 8.5 list ARARs for constituents detected in samples of ground water and surface water from the MMRF. ARARs for constituents detected in air are presented in Table 8.6. For constituents which do not have an ARAR for ground water, surface water, or air, a quantitative RA was performed.

ARARs for the constituents detected in soils and sediments at the site are not available. However, acceptable concentration levels for arsenic and PAHs in soil have been developed, based on a 10^{-4} excess lifetime cancer risk for arsenic and an urban background concentration for PAHs. The proposed values for these constituents are 65 mg/kg for arsenic and 175 mg/kg for PAHs.

Fluoride concentrations in the soils at the MMRF are a potential source of elevated ground-water concentrations at the site. Limited information is available on health based levels for regulating fluoride concentrations in soils.

Performance, design, or other action specific requirements control the site remediation methods. Examples of action specific requirements include Resource Conservation and Recovery Act (RCRA) rules governing hazardous waste disposal unit closure or incineration. Location ARARs are based on federal and state siting laws for hazardous waste facilities.

8.4.3 Risk Assessment Summary

As part of the RI performed for the MMRF site, the potential impacts of past operations at the site on human health or the environment were assessed. This baseline risk

Table 8.4 Chemical-Specific ARARs for Constituents of Concern Detected in Ground Water or Perched Water

	Federal MCL (SMCL) (mg/L)[a]	Federal MCLG (mg/L)[b]	Oregon MCL (SMCL) (mg/L)[c]	Other (mg/L)
Bicarbonate	—	—	—	—
Calcium	—	—	—	—
Carbonate	—	—	—	—
Cyanide (free)	—	—	—	.220 (child)[d] .770 (adult)[e]
Fluoride	4(2)[f]	—	1.4–2.4[g]	—
Lead	.050	.020	—	—
Magnesium	—	—	—	—
Sodium	—	—	—	—
Sulfate	(250)	—	250	400[h]
Zinc	(5)	—	5	—

(a) Maximum Contaminant Levels are enforceable drinking water standards from 40 CFR 141.11. These levels are based on health, technical feasibility, and cost benefit analysis. Secondary Maximum Contaminant Levels are shown in parentheses and are goals for drinking water quality based on aesthetic considerations such as taste, odor, or staining ability, 40 CFR 143.3.

(b) Final and proposed MCLGs (maximum contaminant level goals) are developed as part of the process for developing final drinking water standards, i.e., MCLs, under the Safe Drinking Water Act. MCLGs are entirely health-based and are always less than or equal to the proposed or final MCLs subsequently developed.

(c) Oregon Administration Rule 333-61.

(d) Health advisory by USEPA Office of Drinking Water for long-term exposure of children, March 1987; based on exposure to free cyanide.

(e) Health advisory by USEPA Office of Drinking Water for lifetime exposure for adults, March 1987; based on exposure to free cyanide.

(f) National Primary and Secondary Drinking Water Regulations. Federal Register 51: 11396-11412, April 1986.

(g) Temperature dependent.

(h) Guidance level proposed by USEPA Office of Drinking Water 50 FR 46936, 13 Nov. 1985.

566/9

Table 8.5 Chemical-Specific ARARs for Constituents of Concern in Surface Water

	Water-Quality Criteria (a)			Water-Quality Criteria for Protection of Aquatic Life (c)	
	Water & Fish Ingestion (mg/L)	Fish Consumption Only (mg/L)	Water-Quality Standard for the Hood Basin (b) (mg/L)	Acute (mg/L)	Chronic (mg/L)
Cyanide	0.200	--	0.005	0.022	0.0052
Fluoride	--	--	1.0	--	--
Zinc	5(d)	5(d)	0.01	0.12(e)	0.11(e)

(a) Oregon Water Quality Standards. Oregon Administrative Rule 340-41-525, August 28, 1987.
(b) Oregon Administrative Rule 340-41-525.
(c) Oregon criteria for water, USEPA, 1987 (EPA 1987c).
(d) Based on taste and odor effects.
(e) Assuming a hardness of 100 mg/L calcium carbonate in water.

566/10

Table 8.6 Chemical-Specific ARARs for Chemicals of Potential Concern in Air

Chemical	OSHA Permissible Exposure Limit (PEL)[a] (mg/m^3)
Arsenic	0.2[b]
Bicarbonate	--
Calcium	--
Carbonate	--
Cyanide (Free)	5.00
Fluoride	2.50[c]
Magnesium	--
Sodium	--
Sulfate	--
Zinc	--
Coal Tar Pitch Volatiles (particulate PAHs)	0.2

(a) NIOSH/OSHA Pocket Guide to Chemical Hazards, U.S. Department of Health, Education, & Welfare.
(b) OSHA Permissible Exposure Limit (PEL) for arsenic is based on levels of arsine.
(c) OSHA PEL for fluoride dust.

566/11

assessment is equivalent to an evaluation of the no-action aternative and therefore enables a determination to be made of whether remedial actions are indicated for any areas of the site.

Exposure media (e.g., soil or water) and chemicals of potential concern (defined as those chemicals present in environmental media in a particular study area at above naturally-occurring levels) were identified in each study area at the MMRF. Subject to the availability of adequate toxicity information, these chemicals of potential concern were evaluated in the risk assessment by first identifying the exposure pathways by which human and environmental populations could be exposed under either current land use or hypothetical future land use of the MMRF and surrounding areas. All exposure pathways involving ground and surface waters were evaluated. Many pathways involving human exposure to contaminated soils and dust were possible; therefore, for each category of exposure to soils (i.e., industrial or general population exposures, with and without soil disturbance at the site), the exposure scenario selected for evaluation was that which would result in the highest exposure, and therefore highest potential risk (worst case). This resulted in several exposure scenarios related to potential future uses of the site and surrounding areas, by both future industrial and residential populations, being evaluated. For each exposure scenario evaluated, an average case (populations exposed to average site chemical concentrations at average exposure frequencies, etc.) and a maximum exposure case (maximum reported concentration was used with upper-bound exposure scenarios) were evaluated.

Risk from these exposures were characterized in several ways. Because ground water was the only exposure medium for which ARARs were available for all chemicals of potential concern, potential concern risks associated with ground water were assessed by comparing concentrations of chemicals in ground water at points of potential exposure (both on and off site) to ARARs. Such comparison values were not available for all chemicals in other site exposure media (i.e., surface water, soil, and air); exposure of humans to these contaminated media were evaluated by quantitative risk assessment in which potential intakes calculated for each potentially exposed population were combined with critical toxicity values.

Pathways by which environmental receptors (flora and fauna) at and near the MMRF could potentially be exposed to site-derived chemical constituents were generally qualitatively evaluated due to the general paucity of data with which to evaluate such exposures. When sufficient data were available, estimates of risks to biota were made based on exposure and toxicity estimates. Because the ditches and puddles of concern at the MMRF are smaller than other sources of fresh water nearby, the potential impacts of the site study areas on entire environmental populations is expected to be small.

The noncarcinogenic chemicals of potential concern (e.g., fluoride and cyanide) are not expected to pose adverse health effects to humans under any of the soil-related exposure scenarios quantitatively evaluated; this conclusion is based on calculated hazard indices which were all several orders of magnitude less than 1 (the hazard index is defined as the sum of the ratios of the daily intakes of noncarcinogenic substances by potentially exposed individuals to their corresponding relevant reference dose or intake). It should be noted, however, that fluoride and sulfate concentrations in a few ground-water wells exceeded ARARs.

Certain areas of the MMRF were identified in the risk assessment as being associated with potentially unacceptable carcinogenic risk to humans under the exposure scenarios assumed and to potentially have adverse health impacts on environmental receptors. These areas are listed below with details of the exposures, media, and chemicals which have been associated with this risk. Included in this list are those areas which may also be potential sources of chemical constituents in ground water.

- Landfill and associated areas:
  - direct contact by humans with cPAHs in landfill soils;
  - direct contact by humans with arsenic in landfil runoff area soils;
  - ingestion by wildlife of fluoride in leachate collection ditch water;
  - ingestion by wildlife of cyanide and fluoride in landfill ditch water;
  - direct contact by humans with cPAHs in surface drainage ditch sediments.

- Potliner Handling Area:
  - direct contact by humans with cPAHs in soils.

- Discharge Channel:
  - direct contact by humans with cPAHs in sediments.

- Scrubber Sludge Ponds:
  - direct contact by humans with cPAHs in pond sediments;
  - sediments are potential source of fluoride in ground water.

- Lined Pond:
  - direct contact by humans with cPAHs in pond sediments.

- Recycle Pond:
  - direct contact by humans with cPAHs in pond sediments;
  - sediments are potential source of fluoride in ground water.

- Alumina Unloading Building Area (Upgradient of New Cathode Waste Pad):
  - buried cathodic waste material is a potential source of fluoride in ground water.

- Former Cathode Waste Management Areas:
  - soils are potential source of fluoride to ground water.
- Perched Water:
  - potential source of site-derived chemical constituents to ground water.

8.5 DISCUSSION OF MAJOR FINDINGS

The findings of the remedial investigation at the Martin Marietta Reduction Facility are summarized as follows:

- Numerous areas around the facility were used to support overall plant activities as well as to manage or store wastes generated as part of the alumina reduction process. During the investigation, 23 potential source areas were investigated. The types of constituents found in the source areas were consistent with the nature of materials treated, stored, or disposed of at the site. These constituents consist principally of fluoride, sodium, sulfate, cyanide, and polynuclear aromatic hydrocarbons.

- Samples of soil, sediment, and waste materials indicate the presence of cyanide above background in the landfill waste and leachate, soils, perched water associated with the cathode management area, and in the discharge channel sediments. Fluoride concentrations above background were reported in cathode wash area soils, landfill leachate, recycle pond and lined pond sediments, and in perched water underlying the old cathode management area. Concentrations of polynuclear aromatic hydrocarbons above background were reported in landfill waste materials, the cathode waste-management area soils, and scrubber sludge pond soils and sediments.

- During monitor-well installation, four aquifer systems were identified beneath the facility. Following historical nomenclature, from shallowest to deepest, these aquifers were labeled the S, A, B, and Dalles Ground Water Reservoir (DGWR). Perched water was encountered in locations that had been filled in the former cathode waste management areas. In addition, an alluvial aquifer of limited areal extent was identified north of the plant near Chenoweth Creek.

- Concentrations of constituents above background were reported as present in the various aquifer systems underlying the site. The concentrations were generally localized near the source areas, being highest in the perched water and at decreased concentrations with depth and distance from the source. The major sources of these constituents were the scrubber sludge ponds and runoff and leachate generated at the landfill and old cathode waste pile. Generation and migration of leachate has been remedied to a large extent by relocating the old cathode waste pile to the new concrete lined pad and by installing a leachate-collection system around the perimeter of the landfill.

- A degree of hydraulic connection exists between the upper aquifers underlying the site. The DGWR is separated from overlying units by low permeability sediments which effectively preclude the exchange of water between the DGWR and

B aquifer. No water-quality impacts were identified in the DGWR.

- No concentration of any constituents in the S, A, B, or DGWR exceeded ARARs (applicable, relevant, and appropriate requirements) with the exception of fluoride in the S aquifer near the scrubber sludge ponds, the recycle pond, and the alumina unloading building (well MW-5S), and in one sample each from the A and B aquifers at monitor-well cluster MW-9. As discussed in the text, the results at MW-9 appear to be an artifact of well construction and not to represent ambient water quality at this location.

- Six water-supply wells in the immediate vicinity (Klindt, Animal Shelter, Rockline, Mt. Fir, Residence Well, Recreation Area) and three Chenoweth Irrigation wells were sampled. No constituents were reported above detection or background in any of the Chenoweth wells. Although traces of selected constituents were reported as present in several of the water-supply wells, no constituents were reported to exceed ARARs with the exception of fluoride at the old Residence Well. This well is owned by Martin Marietta and is not used as a potable water-supply source.

- Samples collected from Chenoweth Creek showed no impacts from plant activities and in general, all constituents analyzed were below detection and/or below background for the area; additional samples of sediment and water from Chenoweth Creek are being collected and analyzed. Because of the effects of dilution, impacts to the

Columbia River due to the source areas investigated are expected to be below detection, if present.

- The risk assessment performed for the site evaluated the potential impacts of site-related constituents in ground water, surface water, soil, sediment, and air on human or environmental populations in the area under current land-use conditions as well as hypothetical future land-use conditions. Exposures evaluated were direct contact with soil and inhalation of dust, and exposures to ground water and surface water. Of the exposures evaluated in the risk assessment, only the following are of potential concern: (1) use of the S aquifer as a sole drinking-water resource may pose adverse health effects based on fluoride concentrations in several wells at the site that exceeded ARARs; (2) exposure of hypothetical future on-site construction workers, and future workers who work outdoors via direct contact with soils containing arsenic and PAHs in the following areas: landfill, landfill runoff areas, potliner handling area, and the scrubber sludge ponds. In addition, concentrations of constituents in the landfill leachate may result in adverse effects to wildlife drinking this water.

All of the potential risks identified can be remedied with currently available technologies; these remedial measures will be fully considered in the feasibility study. A number of control measures have already been implemented by Martin to diminish or eliminate the environmental effects of past plant activities. These include construction of the lined pond; relocation of the old cathode waste pile to a new lined cathode waste pad; fencing of the landfill to restrict access (interim remedial measure taken during the RI); construction of a leachate-collection system at the landfill; and, construction of a concrete lined pad in the cathode wash area.

566/15

Section Nine

9.0 REFERENCES

Ahlstrom, S.W., et al, 1977. Multicomponent Mass Transport Model: Prepared for Batelle, BNWL-2127, Hanford, Washington.

Alesii, B.A. and W.H. Fuller, 1976. The Mobility of Three Cyanide Forms in Soils. In Fuller, W.H., ed. Residual Management by Land Disposal, Proceedings of the Hazardous Waste Research Symposium. EPA 600/7-76-015, NTIS PB-256 768 (July).

American Cyanamid Company, 1953. Cyanamid's Nitrogen Chemicals Digest, Volume II. The Chemistry of the Ferrocyanides. New York.

American Public Health Association, 1985. Standard Methods for the Examination of Water and Wastes: 16th Edition, Washington, D.C., 1268 pp.

Beeson, M.H., K.R. Gecht, S.P. Reidel, and T.L. Tolan, 1985. Regional Correlations Within the Frenchman Springs Member of the Columbia River Basalt Group: New Insights into the Middle Miocene Tectonics of Northwestern Oregon: Oregon Geology, v. 47, no 8, pp. 87-96.

Bela, J.L., 1982. Geologic and Neotectonic Evaluation of North-Central Oregon: The Dalles 1° x 2° Quadrangle: GMS-27, Geological Map Series, issued by State of Oregon Department of Geology and Mineral Industries, Portland, OR.

Bolt, G., and B. Bruggenwert, 1976. Soil Chemistry A: Basic Elements: Elsevier Publishing Co., New York.

Bouwer, Herman, and R.C. Rice, 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells: Water Resources Res., v. 12, no. 3, pp. 423-428.

Callahan, M.A., M.W. Slimak, N.W. Gabel, C.P. May, G.F. Fowler, J.R. Freed, P. Jennings, R.L. Durfee, F.C. Whitmore, B. Maestri, W.R. Mahey, B.R. Holt, and C. Gould, 1979. Water-Related Environmental Fate of 129 Priority Pollutants, Volume 1: U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C., EPA 440/4-79-029a.

Century Testing Laboratories, Inc., 1985. Martin Marietta Corporation, Ground-Water Monitoring Quarterly 40 CFR 265 Subpart F, Analytical Results, The Dalles, Oregon Facility: Consultant's report prepared for Martin Marietta Corporation. May.

Century West Engineering Corporation, 1983. Martin Marietta Aluminum Company, The Dalles Reduction Plant Report on Solid Waste Disposal Site, Preliminary Investigation: Consultant's report prepared for Martin Marietta Aluminum Company. July.

Century West Engineering Corp., 1983. Martin Marietta Aluminum Company, The Dalles Reduction Plant, Report on Solid Waste Disposal Site, Phase II Investigation: Consultant's report prepared for Martin Marietta Aluminum Company. September.

Century West Engineering Corp., 1984. Martin Marietta Aluminum Company, The Dalles, Oregon, Reduction Plant, Report on Monitor Well Network Installation and Ground-Water Conditions: Consultant's report prepared for Martin Marietta Aluminum Company. July.

Century West Engineering Corp., 1985. Martin Marietta Corporation, The Dalles, Oregon, Facility, Monthly Ground Water Monitoring Results: Consultant's report prepared for Martin Marietta Corporation. June.

Cleary, R.W., and M.J. Ungs, 1978. Groundwater Pollution and Hydrology, Mathematical Models and Computer Programs: Princeton, New Jersey.

Cowherd, C., G.E. Muleski, P.J. Englehart, and D.A. Gillette, 1984. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites: U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, D.C. (September).

Ecological Analysts, Inc., 1979. Cyanide, An Overview and Analysis of the Literature on Chemistry, Fate, Toxicity, and Detection in Surface Waters: Prepared for the Inter-Industry Cyanide Group (June).

Farouqui, Saleem M., et.al., 1981. Neogene Formations Overlying the Columbia River Baslat Group in North-Central Oregon: Oregon Geology, vol. 43, no. 10, pp 131-140.

Fetter, C.W., 1980. Applied Hydrogeology: Charles E. Merrill Publishing Co., Columbus, OH.

Finlayson-Pitts, B.J., and J.N Pitts, Jr., 1986. Atmospheric Chemistry: Fundamentals and Experimental Techniques: John Wiley and Sons, New York.

Foxworthy, B.L., and C.T. Bryant, 1967. Artificial Recharge Through a Well Tapping Basalt Aquifer at The Dales, Oregon: U.S. Geological Survey Water-Supply Paper 1594-E, 55 pp.

Fuller, W.H., 1977. Movement of Selected Metals, Asbestos, and Cyanide in Soil: Applications to Waste Disposal Problems. Prepared for the Municipal Research Laboratory, EPA 600/2-77-020, NTIS PB-266 905 (April).

Geraghty & Miller, Inc., 1985. Work Plan, Remedial Investigation and Feasibility Study, Martin Marietta Reduction Facility, The Dalles, Oregon: Consultant's report prepared for Martin Marietta Corporation, Bethesda, Maryland (December).

Geraghty & Miller, Inc., 1986. Interim Report, Remedial Investigation, Martin Marietta Reduction Facility, The Dalles, Oregon: Consultant's report prepared for Martin Marietta Corporation, Bethesda, Maryland (November).

Geraghty & Miller, Inc., 1987. RI/FS Work Plan Addendum, Martin Marietta Reduction Facility, The Dalles, Oregon: Consultant's report prepared for Martin Marietta Corporation, Bethesda, Maryland (March).

Grady, S.J., 1983. Ground-Water Resources in the Hood Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 81-1108, 68 p.

Green, George L., 1982. Soil Survey of Wasco County Oregon, Northern Part: U.S. Department of Agriculture, Soil Conservation Service, 125 p.

Griffin, R.A., N.F. Shimp, J.D. Steel, R.R. Ruch, W.A. White, and G.M. Hughes, 1976. Attenuation of Pollutants in Municipal Landfill Leachate by Passage Through Clay: In Environ. Sci. Technol. 10:1262-1268.

Hagood, M.C., 1986. Structure and Evolution of the Horse Heaven Hills in South-Central Washington: RHO-BW-SA-344P, 99 p.

Horizons, Inc., 1986. Martin Marietta The Dalles, Oregon: Site Survey and Topographic Map.

Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Groundwater Observations: U.S. Army Corps of Engineers, Waterways Exp. Sta. Bull. 36, Vicksburg, MS.

Hurt, R.E., 1981. North American Primary Aluminum Companies. Report of Spent Potliner Compositions and Generation Rates: Prepared for presentation at Workshop on Storage, Disposal, and Recovery of Spent Potlining (December 3-4).

Johnsgard, G.A., 1963. Temperature and the Water Balance for Oregon Weather Stations: Oregon State University Agricultural Experiment Station Special Report 150, Corvallis, Oregon, 127 p.

Kabata-Pendias, A., and H. Pendias, 1984. Trace Elements in Soils and Plants: CRC Press, Boca Raton, Florida.

Karasaki, Kenzi, 1986. Well Test Analysis in Fractured Media: Doctoral thesis, University of California, Berkeley, 239 p.

Lemmo, N.V., S.P. Faust, T. Belton, and R. Tucker, 1983. Assessment of the Chemical and Biological Significance of Arenical Compounds in a Heavily Contaminated Watershed. Part 1. The Fate and Speciation of Arsenical Compounds in Aquatic Environments: A Literature Review: J. Environ. Sci. Health 18:335-387.

McWhorter, D.B., and D.K. Sunada, 1977. Ground-Water Hydrology and Hydraulics: Water Resources Publications, Fort Collins, CO, 290 p.

Morris, D.A., and A.I. Johnson, 1967. Summary of Hydrologic and Physical Properties of Rock and Soil Materials, As Analyzed by the Hydrologic Laboratory of the U.S. Geological Survey 1948-1960: U.S. Geological Survey Water-Supply Paper 1899-K, 44 p.

National Archives and Records Administration, 1986. 40 Code of Federal Regulations (Parts 100 to 149): Office of Federal Register, Washington, D.C., 830 pp. (July 1).

National Research Council, 1977. Drinking Water and Health: National Academy of Sciences, Washington, D.C.

National Research Council, 1971. Fluorides: National Academy of Sciences, Washington, D.C., pp. 29-42.

Newcomb, R.C., 1972. Quality of the Ground Water in Basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Supply Paper 1999-N.

Newcomb, R.C., 1969. Effect of Tectonic Structure on the Occurrence of Ground Water in the Basalt of the Columbia River Group of The Dalles Area, Oregon and Washington: U.S. Geological Survey Professional Paper 383-C, 33 p.

Newcomb, R.C., 1961. Storage of Ground Water Behind Subsurface Dams in the Columbia River Basalt: U.S. Geological Survey Professional Paper 383-A, 15 p.

Oregon Water Resources Board, 1965. Hood Basin: 113 p.

Piper, A.M., 1932. Geology and Ground-Water Resources of The Dalles Region: U.S. Geological Survey Water-Supply Paper 659-B, 189 p.

Radding, S.B., T. Mill, C.W. Gould, D.H. Liv, H.L. Johnson, D.C. Bomberger, and C.V. Fojo, 1976. The Environmental Fate of Selected Polynuclear Aromatic Hydrocarbons: U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C., EPA 560/5-75-009.

Raef, S.F., W.G. Charackles, M.A. Kessick, and C.H. Ward, 1977a. Fate of Cyanide and Related Compounds in Aerobic Microbial Systems-I. Chemical Reaction with Substrate and Physical Removal. <u>In</u> Water Res. 11:477-483.

Raef, S.F., W.G. Charackles, M.A. Kessick, and C.H. Ward, 1977b. Fate of Cyanide and Related Compounds in Aerobic Microbial Systems-II. Microbial Degradation. <u>In</u> Water Res. 11:485-492.

Reidel, S.P., 1983. Stratigraphy and Petrogenesis of the Grande Ronde Basalt from the Deep Canyon Country of Washington, Oregon, and Idaho: Geological Society of America Bulletin, v. 94, pp. 519-542.

Sargent, S.C., 1956. The Dalles Dam: Geologic Map Dam Site and Vicinity: Geologic Map Services DD-20-23/1, Portland District, U.S. Army Corps of Engineers.

Stanford Research Institute, 1971. Bonneville Environmental Impact Study: Consultant's Report prepared for Portland District U.s. Army Corps of Engineers, Contract DACW 57-71-C-0058, Menlo Park, CA.

Strobel, G.A., 1967. Cyanide Utilization in Soil. <u>In</u> Soil Sci. 103:299-302.

Swanson, D.A., T.L. Wright, P.R. Hooper, and R.D. Bentley, 1979. Revisions in Stratigraphic Nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p.

Theis, C.V., 1935. The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage: Trans. Amer. Geophys. Union, v. 16, pp. 519-524.

Tolan, T.L., and M.H. Beeson, 1984. Intracanyon Flows of the Columbia River Basalt Group in the Lower Columbia River Gorge and Their Relationship to the Troutdale Formation: Geological Society of America Bulletin, v. 95, no. 4, pp. 463-477.

Tolan, T.L., M.H. Beeson, and B.F. Vogt, 19__. Exploring the Neogene History of the Columbia River: Discussion and Geologic Field Trip Guide to the Columbia River Gorge, Part I, Discussion: Oregon Dept. of Geology and Mineral Industries, Oregon Geology, v. 46, no. 8, pp. 87-97.

Towill, L.E., J.S. Drury, B.L. Whitfield, E.G. Lewis, E.L. Galyan, and A.S. Hammons, 1978. Review of the Environmental Effects of Pollutants: V. Cyanide: Oak Ridge National Laboratory, Oak Ridge, Tennessee, EPA 600/1-78-027.

U.S. Environmental Protection Agency, 1979. Handbook for Analytical Quality Control in Water and Wastewater Laboratories: Environmental Monitoring and Support Laboratory, Cincinnati, OH, EPA 600/4-79-019 (March).

U.S. Environmental Protection Agency, 1982. An Exposure and Risk Assessment for Benzo(a)pyrene and Other Polycyclic Aromatic Hydrocarbons: Volume I. Summary. Office of Water Regulations and Standards, Washington, D.C. EPA 440/4-85-020-V1.

U.S. Environmental Protection Agency, 1982. An Exposure and Risk Assessment for Benzo(a)pyrene and Other Polycyclic Aromatic Hydrocarbons: Volume II. Naphthalene. Office of Water Regulations and Standards, Washington, D.C. EPA 440/4-85-020-V2.

U.S. Environmental Protection Agency, 1982. An Exposure and Risk Assessment for Benzo(a)pyrene and Other Polycyclic Aromatic Hydrocarbons: Volume III. Anthracene, Acenaphthene, Fluoranthene, Fluorene, Phenanthrene, and Pyrene. Office of Water Regulations and Standards, Washington, D.C. EPA 440/4-85-020-V3.

U.S. Environmental Protection Agency, 1982. An Exposure and Risk Assessment for Benzo(a)pyrene and Other Polycyclic Aromatic Hydrocarbons: Volume IV. Benzo(a)pyrene, Acenaphthylene, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h.i)perylene, Chrysene, Dibenz(a,h)anthracene, and Indeno(1,2,3-c,d)-pyrene. Office of Water Regulations and Standards, Washington, D.C. EPA 440/4-85-020-V4.

U.S. Environmental Protection Agency, 1982. Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater: Environmental Monitoring and Support Laboratory, Cincinnati, OH, EPA 600/4-82-057 (July).

U.S. Environmental Protection Agency, 1983. Methods for Chemical Analyses of Water and Wastes: Environmental Monitoring and Support Laboratory, Cincinnati, OH, EPA 600/4-79-020.

U.S. Environmental Protection Agency, 1985a. Ambient Water Quality Criteria for Cyanide-1984: Washington, D.C., EPA 440/5-84-028; NTIS PB 85-227 460 (January).

U.S. Environmental Protection Agency, 1985b. Drinking Water Criteria Document for Sulfate. Final Draft: Office of Drinking Water, Washington, D.C., NTIS PB86-118286.

U.S. Environmental Protection Agency, 1985. Evaluation Criteria for Existing Data from CERCLA Study Areas: Region VIII, Denver, CO (January).

U.S. Environmental Protection Agency, 1985. Functional Guidelines for the Validation of Laboratory Data for Organics and Inorganics Analyses: Technical Directive Document No. HQ-8410-01, prepared by the Data Validation Work Group for the Hazardous Site Control Division, Washington, D.C. (May 28).

U.S. Environmental Protection Agency, 1985. Guidance on Remedial Investigations Under CERCLA: Office of Research and Development, Cincinnati, OH, and Office of Emergency & Remedial Response and Office of Waste Programs Enforcement, Washington, D.C., EPA/540/G-85/002 (June).

U.S. Environmental Protection Agency, 1985. Guidance on Feasibility Studies Under CERCLA: Office of Research and Development, Cincinnati, OH, and Office of Emergency & Remedial Response and Office of Waste Programs Enforcement, Washington, D.C., EPA/540/G-85/003 (June).

U.S. Environmental Protection Agency, 1986. Test Methods for Evaluating Solid Waste: Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency, 1986. Industrial Source Complex Dispersion Model User's Guide - 2nd Edition, Volume 1: Office of Air Quality Planning and Standards, Research Triangle Park, N.C., EPA-450/4-86-005a.

U.S. Environmental Protection Agency. U.S. EPA Contract Laboratory Program Statement of Work: Office of Emergency and Remedial Response, CLP Sample Management Office, Washington, D.C. (most recent version).

U.S. Geological Survey, 1975. Background Geochemistry f Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States: Washington, D.C., Professional Paper 574-F.

VanZyl, Dirk, 1985. Cyanide and the Environment: Proceedings for a conference held in Tucson, AZ (December 11-14).

Versar, Inc., 1986. Draft Superfund Exposure Assessment Manual: Consultant's report prepared for the U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. (January).

Verschuren, K., 1983. Handbook of Environmental Data for Organic Chemicals, Second Edition: VanNostrand, Reinhold Co., New York.

Walsh, L.M., M.E. Sumnher, and D.R. Keeney, 1977. Occurrence and Distribution of Arsenic in Soils and Plants. Environ. Health Perspect. 19:67-71.

Ware, G.C., and H.A. Painter, 1955. Bacterial Utilization of Cyanide: In Nature 171:900.

Weast, R.C., 1978. CRC Handbook of Chemistry and Physics. CRC Press, West Palm Beach, FL.

Wenzel, L.K., 1942. Methods for Determining Permeability of Water Bearing Materials with Special Reference to Discharging Well Methods: U.S. Geological Survey Water-Supply Paper 887, 192 p.

Woolson, E.A., 1977. Fate of Arsenicals in Different Environmental Substrates. Environ. Health Perspec. 19:73-81.

544/22