INSTALLATION RESTORATION PROGRAM

2

REMEDIAL INVESTIGATION REPORT

MINNESOTA AIR NATIONAL GUARD BASE
DULUTH INTERNATIONAL AIRPORT
DULUTH, MINNESOTA

VOLUME 1

HAZWRAP SUPPORT CONTRACTOR OFFICE
Oak Ridge, Tennessee 37831
Operated by MARTIN MARIETTA ENERGY SYSTEMS, INC.
For the U.S. DEPARTMENT OF ENERGY under contract DE-AC05-840R21400

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The report describes the remedial actions performed on sites confirmed to contain hazardous waste contamination which endangers the human health. The actions performed are described and the potential for future problems. The study was conducted under the Air National Guard's Installation Restoration Program.

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REMEDIAL INVESTIGATION REPORT

MINNESOTA AIR NATIONAL GUARD BASE
DULUTH INTERATIONAL AIRPORT
Duluth, Minnesota

VOLUME 1

JANUARY 1990

Prepared By
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Prepared For
HAZARDOUS WASTE
REMEDIAL ACTIONS PROGRAM
Oak Ridge, Tennessee

Submitted To
MINNESOTA AIR NATIONAL GUARD
Duluth International Airport
Duluth, Minnesota

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PREFACE

Engineering-Science (ES) entered into an agreement with the HAZWRAP Support Contractor office operated by Martin Marietta Energy Systems, Inc. for the U.S. Department of Energy (DOE) to perform a Remedial Investigation at the Minnesota Air National Guard Base, Duluth International Airport, Duluth, Minnesota, to be submitted to the National Guard Bureau, Andrews Air Force Base, Maryland. This investigation was initiated in July, 1988 under Task Order Y02, General Order 18B-97387C, which is under DOE contract DE-AC05-84OR21400, with Martin Marietta Energy Systems under Interagency Agreement 1489-1489-A1. The overall objectives of this effort were to define the magnitude, extent, direction, and rate of movement of identified contaminants and to summarize the need for remedial actions based on an assessment of risks to human health and the environment.

This investigation was performed by Engineering-Science personnel from the Oak Ridge, Tennessee office with oversight provided by Martin Marietta Energy Systems. Mr. Larry Janssen, of Martin Marietta Energy Systems was the Technical Monitor for Lt. Col. Michael Washeleski of the National Guard Bureau. Major Joel D. Manns, Minnesota Air National Guard Base, Duluth, Minnesota, provided field support. Engineering-Science personnel included Mr. Robert S. McLeod, P.E., P.G., who served as Project Manager and Mr. John D. Hardeman, P.G., who served as the Field Team Leader. Mr. Robert L. Thoem, P.E. was the ES Technical Director for the project.

Engineering-Science wishes to acknowledge North Star Drilling, Little Falls, Minnesota as the drilling and well installation subcontractor. Salo Engineering, Duluth, Minnesota, provided professional surveying services. ES Berkeley Laboratory, Berkeley, California; ES Atlanta Laboratory, Atlanta, Georgia; MetaTrace, Inc., St. Louis, Missouri; NUS Corporation, Pittsburgh, Pennsylvania; and IT Radiological Sciences Laboratory, Oak Ridge, TN provided analytical laboratory services for sample analyses.

This work was accomplished between July 1988 and March 1989.

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EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

This report presents the results of the Remedial Investigation (RI) of five sites on the Duluth International Airport which are under the jurisdiction of the Minnesota Air National Guard. The purpose of the RI was to define the character and extent of contamination at the five sites and to assess the risk to human health resulting from contamination determined to be significant.

The character and extent of contamination was investigated at Sites 2, 3, 4, 8, and 10 by field investigations which include drilling boreholes and sampling soils; installing monitoring wells and well points; trenching; aquifer testing; measuring stream flow; surface water, sediment and ground-water sampling; and the laboratory analysis of the sediment, surface water, soil, and ground-water samples. Background and airport area conditions were established. A total of 19 well points and 26 monitoring wells were constructed, 7 aquifer slug tests were conducted, 3 stream flows were measured, and 153 soil samples, 55 ground-water samples, 18 surface water samples, and 19 sediment samples were collected and analyzed for selected chemical parameters and physical properties. Also, 75 test pits were excavated and one soil gas survey was conducted.

The word, "contamination", as used in this report, is any substance introduced into the environment as a result of man's activities and does not necessarily imply a health risk. Contamination, as defined here, was found at each site. No contaminants were found to migrate off the airport property. The ground water at each site discharges to the surface water either at the site itself or in close proximity to it. The surface water in the airport area was found to be of good quality.

Three criteria are used to judge the significance of a contaminant in ground water and surface water. First, contamination is considered to be significant if its concentration in the water exceeds a Safe Drinking Water Act (SDWA) maximum concentration limit (MCL) as promulgated by the United States Environmental Protection Agency (USEPA). Second, contamination is considered to be significant if its concentration in the water exceeds a State of Minnesota recommended allowable limit (RAL). Third, background criteria are used to judge significance of the contamination when neither an MCL or RAL exists.

The medium in which contamination was detected affected which criteria were applicable. The presence of metals in soil and sediment was judged to be significant if maximum background levels for these parameters, as determined from airport area and background samples were exceeded. The significance of volatile and semi-volatile organic compounds in soil and sediment was judged on a health risk basis and on their continued impact as a source for ground-water contamination.

Ground water and soil at Site 2, which includes Fire Training Areas 1 and 2 are contaminated with significant levels of volatile organic compounds. The compounds trichloroethene, trans-1,2-dichloroethene, and vinyl chloride were found in ground water downgradient from Fire Training Area 2 at levels above MCLs. Ground water at the site where Fire Training Area 1 is believed to have been located contained trichloroethene at a concentration in excess of the MCL.

Site 2 is an area of ground-water recharge with flow radially away from the area. Flow and contaminant migration from Fire Training Area 1 is to the southeast with ground-water discharge to the drainage ditch about 100 feet southeast of that fire training area. Flow and contaminant migration from Fire Training Area 2 is to the northeast with ground-water discharge to the unnamed stream about 600 feet northeast of this fire training area.

The soil at the fire training areas may be a continuing source of organic compounds leaching to the ground water. Significant levels of organic compounds were found in soil samples taken from two boreholes within Fire Training Area 2.

Several test pits dug in and around the presumed location of Fire Training Area 1 failed to uncover any obviously contaminated soils. The surface water at Site 2 was not found to be contaminated.

Ground water and surface water at Site 3, a formerly used storage pad behind the Defense Reutilization and Marketing Office (DRMO) (DPDO Storage Area "C"), are contaminated with significant levels of volatile organic compounds. Several halogenated volatile organic compounds were detected in the ground water at levels above MCLs for the respective compounds. The compound 1,1,1-trichlorethane was found most often in the ground water and at the highest concentrations followed by trichloroethene and tetrachloroethene. Trichloroethene was also detected in two water samples from the drainage ditch that adjoins Site 3 at levels above the MCL for that compound. The compounds, 1,1,1-trichlorethane and tetrachloroethene were detected at the most downstream surface water sampling location, but were below the MCLs.

Other contamination was also noted at Site 3. Two sediment samples contained significant levels of lead and each of the three sediment sampling sites had significant levels of petroleum hydrocarbons. Significant levels of one or more trace metals were identified in three soil samples. One soil sample had significant levels of several aromatic volatile organic compounds.

Ground-water flow at Site 3 is predominantly to the north and northeast. There is some smaller amount of local ground-water flow to the northwest. Ground water flows from a ground-water high area southwest of the site with some discharge to the drainage ditch that adjoins the site and the remaining discharge either to the drainage ditch about 500 feet north of the site or to the drainage ditch located to the north of the storage tanks at Site 4. The compounds trichloroethene and 1,1,1-trichlorethane are found in the ground water at Site 3 and also in the drainage ditch that adjoins the site indicating that at least some of the contaminated ground water at Site 3 is discharging to this ditch. The presence of these compounds about 750 feet northeast of the site suggests that contaminants from Site 3 may be migrating northeast to the drainage ditch located at Site 4.

Ground-water flow and contaminant migration at Site 4, the fuel storage area, is generally toward the drainage ditch located immediately north of the fuel storage tanks. The drainage ditch is deeply cut into the water table in that area causing the ditch to act as a sump for ground-water discharge. The surface water in the ditch is due to discharge of ground water at the site to the surface. Correspondingly, the surface water contamination is because it became contaminated during the time it was ground water. Some ground-water flow and contamination migration at Site 4 is also toward the drainage ditch located near the southwest corner of the Tank Farm. All the surface drainage from Site 4 is directed into buried culverts which conduct the surface water to the north side of the main east-west runway where it joins a north flowing drainage ditch.

Samples of surface water, sediment, soil and ground water at Site 4 all contained significant levels of contaminants. Benzene was detected in water from one well at a concentration above the MCL limit for that compound and petroleum hydrocarbons were detected in water from another well at levels considered to be significant. The benzene concentration in surface water at four locations also exceeded the MCL for benzene in surface water. Xylenes in the surface water at one location exceeded the MCL. Benzene was detected in the sediment at one surface water sampling site at a significant level and the compounds ethyl benzene, toluene, and xylenes were detected in the sediments at significant levels at two surface water sampling sites. Some trace metal levels in the sediment were also considered to be significant. Lead was the dominant trace metal occurring in the sediment at significant levels. Three soil samples and the sediment samples from all six surface water sampling locations had petroleum hydrocarbons concentrations at significant levels.

Contamination in general at Site 8, the former DPDO Storage Area, is not significant. Petroleum hydrocarbons were found in significant concentrations in one sediment sample and two soil samples. A significant level of pesticides was found in one soil sample and PCBs at a trace level were found in another soil sample. The data base for these results included 15 soil samples from 5 boreholes, 24 surface soil samples, and 3 sediment samples.

Significant ground-water contamination by radiological parameters exists at Site 10, low level radioactive waste disposal area. Gross alpha radiation and gross beta radiation in water from all three wells sampled exceeded the MCLs for these parameters.

A summary of significant contamination by site is given in Table 1.

Surface water transportation is the most probable route for the migration of contaminants off the airport. This is because the ground water at each site is intercepted by drainage ditches located at the sites. There is no deep regional ground-water flow system in the area and, therefore, no extended ground-water flow paths.

No contaminants present at any of the sites investigated were found to be migrating off the airport property. Analyses of surface waters and sediments samples on three streams at points where they approximately leave the airport boundaries failed to detect any of the contaminants found at any of the sites.

Risk assessments were performed for Sites 2, 3, 4 and 8 in accordance with the method described in the Superfund Public Health Evaluation Manual (USEPA, 1986a). No risk assessment was done for Site 10 because of insufficient data. This methodology uses conservative estimates throughout. No risk to human health either present or future was determined to exist at Site 8.

TABLE 1
SUMMARY OF FINDINGS BY SITE

Site Number	Site Descriptor	Significant Results
2	Fire Training Areas 1 and 2	Ground water and soils contaminated with significant levels of organic compounds. A trace level of organics in one sediment sample.
3	Storage Pad Behind the DRMO (DPDO Storage Area "C")	Ground water and surface water contaminated with significant levels of organic compounds. Three soil samples and sediments at two locations also contained significant levels of one or more trace metals. Total petroleum hydrocarbons were at significant levels in sediments at all three sampling locations. Significant soils contamination by aromatic volatile organic compounds noted in one soil sample.
4	Fuel Storage Area	Ground water, surface water, sediments, and soils contaminated with significant levels of organic compounds. Sediments also contained significant levels of barium and lead.
8	Old DPDO Storage Area	Sediments at one location and soils at two locations contaminated with petroleum hydrocarbons. Significant level of pesticides found in one soil sample. Trace levels of PCBs found in one soil sample.
10	Low Level Radioactive Waste Disposal Site	Ground water contaminated with significant levels of radiation.

No present risk to human health from the contamination was found at Sites 2, 3 and 4, but a risk to human health in the future does exist at these sites.

Sufficient data exists to proceed with Focused Feasibility Studies for Sites 2, 3 and 4, and we recommend that these studies be done.

Insufficient data exists with respect to Site 10. In particular the exact location of the burial trench is not known; the type and quantity of the radiation source is not fully known; whether the cover material, which reportedly consisted of local refuse, is contributing hazardous waste contaminants is not known, the geologic and hydrogeologic regimes are not fully understood; and finally, the amount and extent of contamination is not known. We recommend that a Site 10 Remedial Investigation be performed to provide the data required to fully understand the contamination at this site.

SECTION 1
INTRODUCTION

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SECTION 1
INTRODUCTION

The United States Air Force responds to releases or potential releases of hazardous substances under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Section 104 establishes the authority of the President to respond to such releases and mandates that any such response must be consistent with the National Contingency Plan (NCP) as outlined in 40 Code of Federal Regulations (CFR) Part 300. In Section 120 of the Superfund Amendments and Reauthorization Act (SARA), Congress required federal facilities to respond to hazardous substance releases in the same manner and to the same extent as non-governmental entities. Section 120(a)(4) of SARA requires federal facilities which are not on the National Priorities List (NPL) to comply with state laws concerning remedial and removal actions as long as these laws are not discriminatory towards the federal facility.

The Department of Defense (DOD) has devised a comprehensive Installation Restoration Program (IRP) to identify, report, and correct potential environmental deficiencies that could result in ground-water contamination and probable migration of contaminants beyond DOD installation boundaries. The IRP was established by DOD to identify the locations and contamination levels of past disposal sites at their installations and to eliminate the hazards to public health in an environmentally responsible manner. The IRP is implemented in accordance with the National Contingency Plan as set forth in 40 CFR Part 300. Specific requirements for the investigation of hazardous substance release are contained in Subpart F of that document. The IRP program originally consisted of four parts: Phase I - Problem Identification/Records Search; Phase II - Problem Confirmation and Quantification; Phase III - Technology Base Development; and Phase IV - Corrective Action.

The IRP underwent significant changes in terminology and methodology after the Superfund Amendments and Reauthorization Act (SARA) was passed in 1986. This Act required that federal facilities, including DOD installations, adhere to guidelines and procedures set forth by the United States Environmental Protection Agency (USEPA) for the investigation and cleanup of former disposal and spill sites. This Act further stated that federal agencies shall negotiate interagency agreements with the USEPA regarding oversight of all remedial actions on federal property. The IRP now consists of six primary efforts referred to as: Preliminary Assessment, Site Inspection, Remedial Investigation, Feasibility Study, Remedial Design, and Remedial Action.

The Remedial Investigation (RI) emphasizes data collection and site characterization and is conducted concurrently with the Feasibility Study (FS) which identifies specific alternatives for remediation of each site as necessary. The RI then is the data collection mechanism for the FS effort.

As part of the Department of Defense remediation program, the National Guard Bureau (NGB), through the Air Force Engineering and Services Center, has entered into an interagency agreement (IAG No. 1489-1489-A1) with the U.S. Department of Energy (DOE) under which DOE will provide technical assistance for the implementation of the NGB's Installation Restoration Program (IRP) and related activities. Martin Marietta Energy Systems, Inc., (Energy Systems) has been assigned responsibility for managing this effort under the interagency agreement.

The NGB has specifically requested the support of DOE in assessing the extent of contamination including a Remedial Investigation at five sites at the Minnesota Air National Guard Base at Duluth International Airport, Duluth Minnesota (Duluth Air National Guard Base). This work was conducted by Engineering-Science, Inc. (ES) as a subcontractor to Energy Systems.

1.1 PURPOSE OF REPORT

This report is concerned with five sites located at the Minnesota Air National Guard Base, Duluth, Minnesota. It summarizes previous work at these sites done under the IRP four-phase process, describes the work and results from the current study which is a Remedial Investigation, presents a baseline risk assessment, and summarizes the status at the five sites. The RI was conducted as part of the Department of Defense's Installation Restoration Program.

1.1.1 Description of Installation Restoration Program

A brief description of the IRP four-phase program is presented in order to understand the context in which previous work was done.

The four phases of the early IRP program were:

> <u>Phase I - Problem Identification/Records Search</u> - The purpose of Phase I was to identify past disposal sites that may pose a hazard to public health or the environment as

a result of contaminant migration to surface or ground waters, or that may have an adverse effect by the persistence of contaminants in the environment. The need for further action to confirm an environmental hazard at a site is also determined in this phase, and the Phase I report is the principal background document for the Phase II study. If a site required immediate remedial action, such as removal of abandoned drums, the recommended site activity would have been to proceed directly to Phase IV.

Phase II - Problem Confirmation and Quantification - The objectives of Phase II included defining and quantifying the presence or absence of contamination, the extent of contamination and waste characteristics. An additional objective was to identify sites or locations where remedial action would be required in Phase IV.

Phase III - Technology Base Development - The purpose of Phase III was to develop a sound technological data base for use in preparing a comprehensive remedial action plan, including the development of new technology for waste treatment and site remediation.

Phase IV - Corrective Action - The primary purpose of Phase IV was to prepare and implement remedial action plans for contaminated sites identified in Phases I and II.

The six phases of the current IRP program are:

Preliminary Assessment - The purpose of the Preliminary Assessment is to identify past disposal sites that may pose a hazard to public health or the environment as a result of contaminant migration to the surface or ground waters, or that may have an adverse effect by the persistence of contaminants in the environment.

Site Inspection - A site inspection is conducted to confirm or deny the presence of environmental contamination and to assess the risks to potential receptors; either human or environmental.

Remedial Investigation - A Remedial Investigation (RI) is performed for each site requiring continuing investigation to confirm and augment prior findings and to provide a basis for the Feasibility Study. The RI will include a work plan, field investigation, risk assessment, and a final report. A RI is often an iterative process. Further investigation beyond that currently planned may be required to adequately support a choice of action alternatives or provide sufficient information for a Feasibility Study.

Feasibility Study: The Feasibility Study (FS) is performed to choose the most advantageous remediation method from among practical alternatives. Selection of remediation methods is based on engineering feasibility, protectiveness of public health and the environment, regulatory requirements, and cost. The feasibility study includes development of alternative remediation techniques, screening of these alternatives, a detailed analysis of plausible alternatives, an environmental assessment of these alternatives, selection of the preferred alternative and preparation of a report documenting these selections and the selection rationale. In addition, a record of decision is prepared that records the recommended action required.

<u>Remedial Design</u>: If remediation is required, the remediation response will be either Immediate or Developed. The Immediate Remedial Response requires minimal evaluation of remediation alternatives to obtain prompt remediation. The Developed Remedial Response is used for those situations where remediation is required but within a time frame that permits a FS.

<u>Remedial Action</u>: Either immediate or developed remedial design will be implemented towards the remedial action of each site. The extent of remedial action will depend on the results of all previous investigations.

1.1.2 Report Organization

This report is organized into an executive summary, eight sections and 24 appendices.

The executive summary summarizes the work that was done, the significant findings and the recommendations.

Section 1, Introduction, provides the context for this report and the setting of the Duluth International Airport. The context for the Remedial Investigation includes the Department of Defense's Installation Restoration Program (IRP). The setting of the Duluth International Airport includes its physiography, climate, demography, geology, hydrology, water quality and water use; and the history of its use by the Minnesota Air National Guard. The Duluth International Airport and each of the sites is described, its history given, and previous investigations and their results are summarized. This material lays the ground work for understanding the types and amounts of work which were done during the remedial investigation which is described in Section 2, Remedial Investigation Description and presents ancillary data and information used in Section 6, Risk Assessment.

Section 2, Remedial Investigation Description, describes the investigations that were done on each site. First, the investigations performed at locations to obtain baseline and background data are described. Then the investigations performed at Sites 2, 3, 4, 8 and 10 are then described.

Section 3, Investigation Results, presents the results of the non-chemical analysis investigations. The results of the surface feature, surface water hydrology, geology and geohydrology investigations are presented. The results of these investigations are used in Section 5, Contaminant Fate and Transport and Section 6, Risk Analysis.

Section 4, Nature and Extent of Contamination, presents the results of the chemical analysis investigation. These results define whether or not contaminants are present at the site and, if present, what the areal extent of the contamination is.

Section 5, Contaminant Fate and Transport, uses the results presented in Sections 3 and 4 to evaluate the future extent both areally and temporally of the contamination.

Section 6, Risk Assessment, uses the information from all preceding sections to present formal risk assessments for Sites 2, 3, 4 and 8.

Section 7 presents the Summary and Recommendations.

Section 8 contains the References.

The appendices contain details of the field protocols, field investigations, field data analysis and interpretation, chemical analyses, risk analysis, quality assurance report and quality assurance data.

1.2 BACKGROUND OF DULUTH AIR NATIONAL GUARD BASE

A brief description of the regional environmental setting is given in Section 1.2.1 followed by a brief history of the Air National Guard Base in Section 1.2.2 and a summary of the previous investigations in Section 1.2.3. Detailed descriptions of the site specific environmental setting, history, and previous investigations for each of the five sites is given in Section 1.2.4 through Section 1.2.8.

1.2.1 Description of Duluth Air National Guard Base

The Duluth Air National Guard Base is located at the Duluth International Airport. The airport is located in St. Louis County in northeastern Minnesota, approximately seven miles northwest of the city of Duluth as shown on Figures 1-1 and 1-2. The airport is operated by the city.

The airport encompasses about 2,000 acres. Its configuration is shown on Figure 1-3. The City of Duluth owns the main east-west runway and supporting taxiways. Ownership of the rest of the land comprising the airport

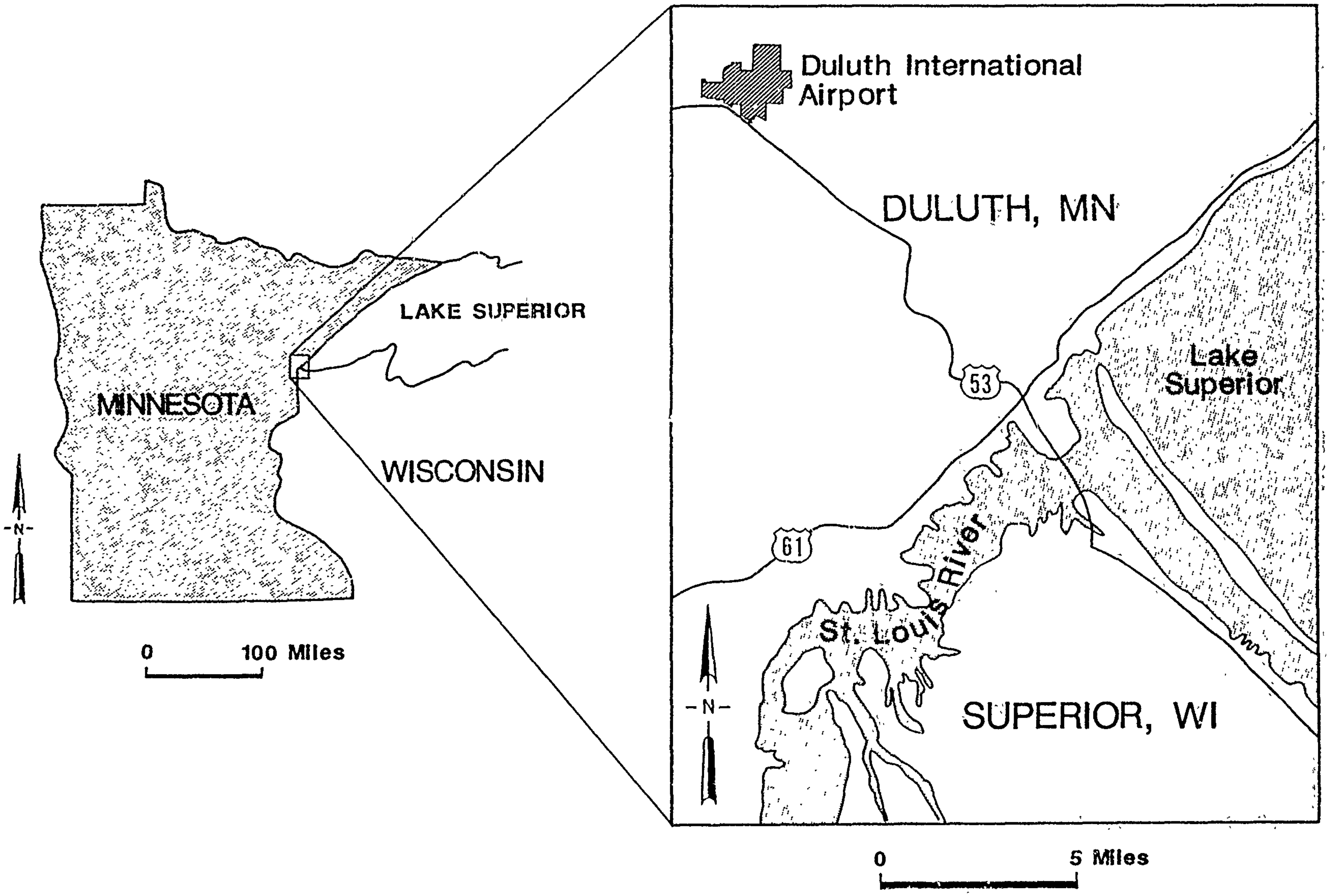

Figure 1-1 Location Map.

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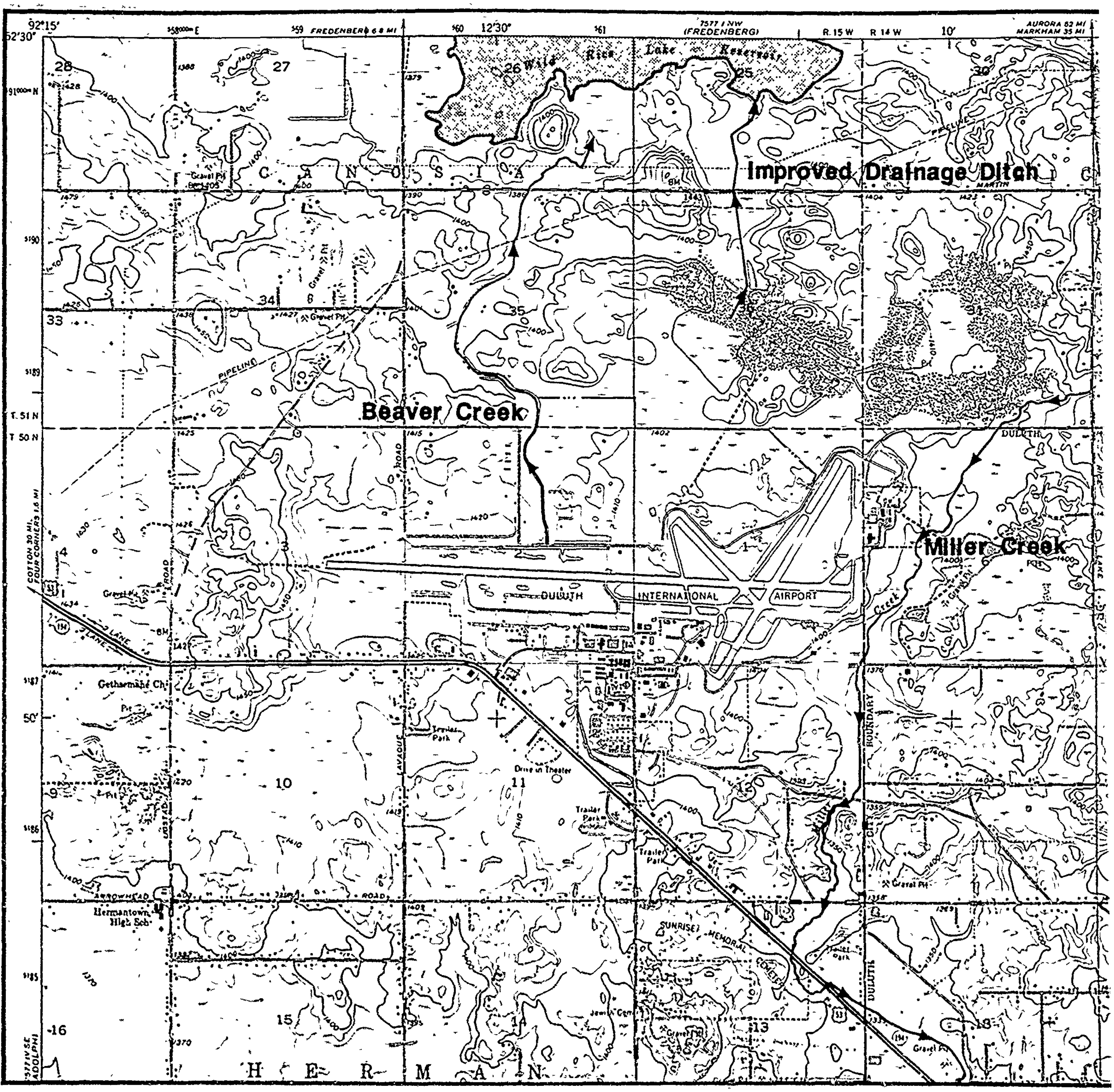

Base from USGS Duluth Heights, MN
1:24,000 quadrangle

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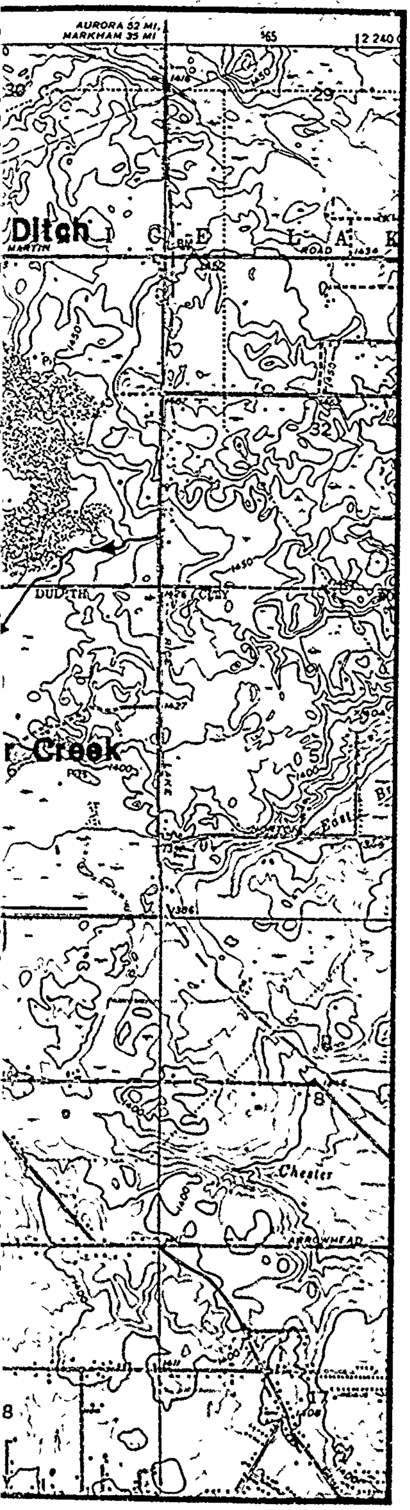
Figure 1-2 Site Vicinity Map.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is divided among the Federal Government, the State of Minnesota, and the City of Duluth.

The Guard is located on the east side of the airport but also leases land at other locations on the airport. The Guard sublets some of its space to other entities, including the Defense Reutilization and Marketing Office (DRMO) of the Department of Defense (DOD).

The Air Force no longer owns or leases any facilities at the airport.

1.2.1.1 Physiography, Climate and Drainage.

The airport lies within the North Shore Highland Section of the Superior Upland Physiographic Province which is a dissected plateau with varied relief and prominent escarpments. Regional elevations of the North Shore Highland generally range from 900 feet above the National Geodetic Vertical Datum of 1929 (NGVD), overlooking Lake Superior west of Duluth, to 1500 feet above the NGVD at the Canadian border about 150 miles north of Duluth. Area relief is the result of glacial activity during the last, or Wisconsin, period of major glaciation which has covered the area bedrock with a relatively thin veneer of glacial drift. Locally, relief may be very distinct due to the presence of deposits of unconsolidated materials in the form of such glacial landforms as kames which are irregular, rounded, sometimes dome-like hillocks of stratified drift; kettles, which are depressions caused by melting pockets of glacial ice which may fill with water forming marshes, swampy areas, and ponds; and moraines, which are accumulations of glacial till dropped, and sometimes pushed up, by a glacier at its sides, along its interfaces with other glaciers, or at its front. At the airport, the surface elevation ranges from approximately 1,400 to 1,430 feet above NGVD as shown on Figure 1-2. To the east, the land surface drops abruptly across the City of Duluth to Lake Superior, the surface of which is about 602 feet above NGVD.

The area near the airport is a typically glaciated terrain with resultant poor, deranged drainage, irregular low relief, and numerous shallow lakes and bogs occupying the low areas. Deranged drainage is typified by short stream segments, swampy lands, and numerous ponds.

As is typical of airfields, the Duluth International Airport has been subject to much earth moving which has affected topography and drainage. Pre-existing boggy areas have been filled in, small knobs have been lowered or removed, and drainage channels have been created. Each of the sites investigated here is located on structural fill or otherwise disturbed ground.

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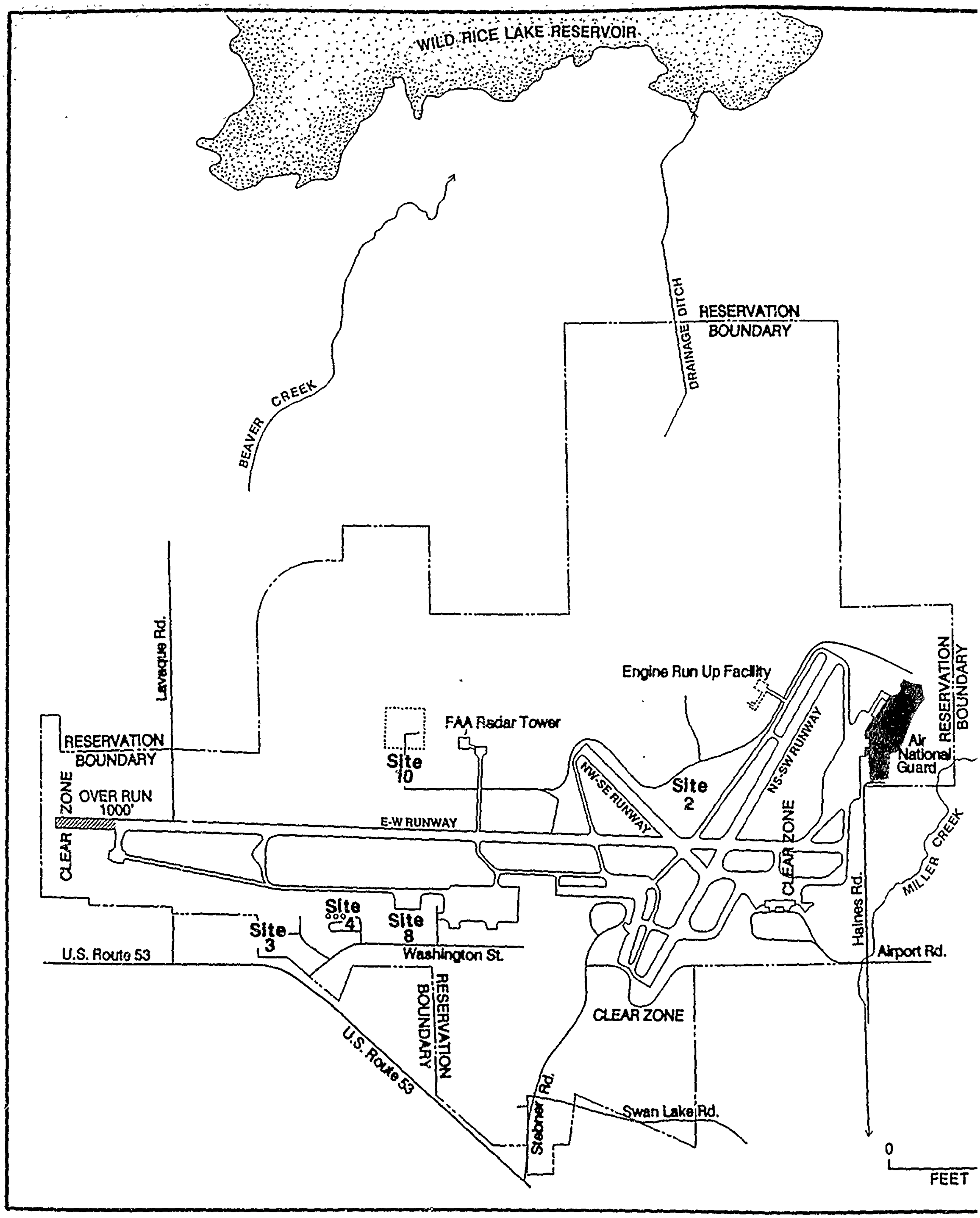
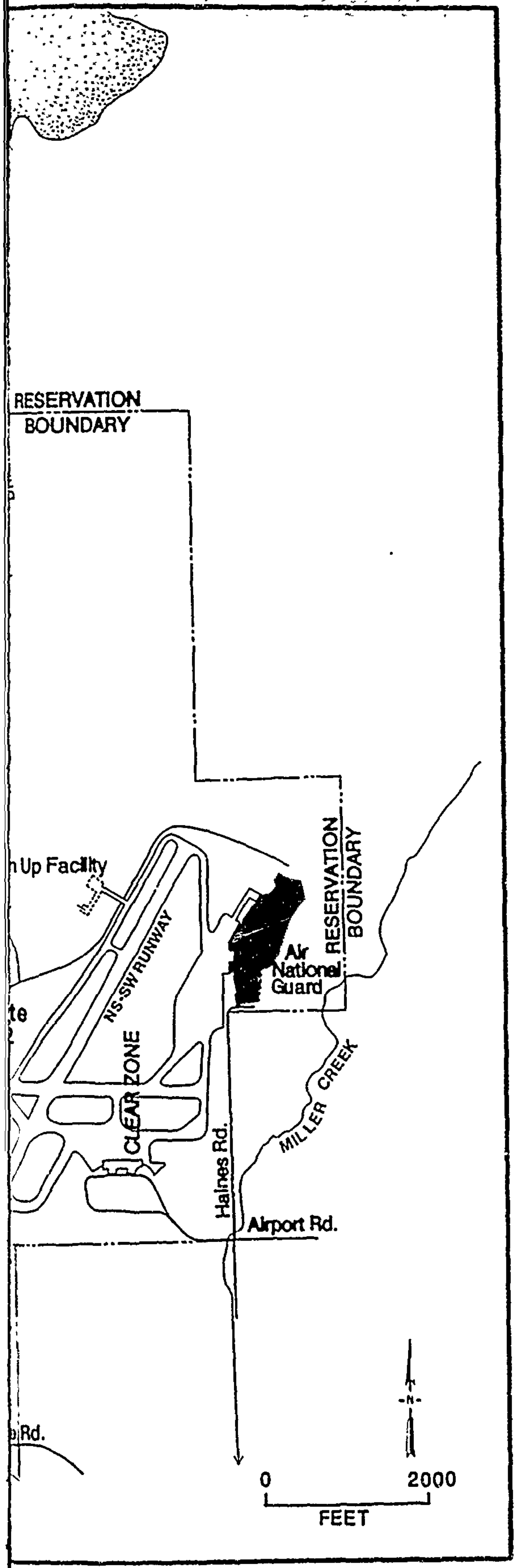


Figure 1-3 Airport Configuration.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The climate of the region is predominantly continental with significant local Lake Superior effects. Duluth averages 143 days between the last occurrence of freezing in mid-May and the first in early October. At the airport, the average first and last occurrences of freezing are late May and late September, giving a freeze-free period of 123 days. Summers are mild with the normal daily maximum for June, July, and August around 72°F. The winters are cold with the maximum daily temperature below freezing an average of 108 days a year.

Annual precipitation at the airport is 28.49 inches and consists of rain in the summer and snow in the winter (NOAA, 1988). Maximum precipitation generally occurs in the summer months of May through September (see Table 1-1).

The Duluth International Airport belongs to the St. Louis River Watershed of the Great Lakes Basin as shown on Figure 1-4. The southeastern corner of this watershed north of the St. Louis River is drained by several small creeks which flow southeast and join the St. Louis River near its mouth. The rest of the watershed north of the river drains to the southwest and the smaller streams and tributaries join the St. Louis River along its upper reaches. The St. Louis River is the largest river that flows into Lake Superior from Minnesota. Along its lower reach, the St. Louis River forms the boundary between Minnesota and Wisconsin.

The airport lies on a drainage divide between the Midway River, Wild Rice Lake and Miller Creek (see Figures 1-2 and 1-4). Drainage from the eastern and southern part of the airport drains east and south to Miller Creek which flows into the St. Louis River at St. Louis Bay (see Figures 1-1, 1-2 and 1-4). (Miller Creek more or less parallels U.S. Rt. 53.) Drainage from the northern and western areas of the airfield drain north to Beaver Creek and an improved drainage ditch both of which discharge into Wild Rice Lake. Wild Rice Lake is drained by the Beaver River and then the Cloquet River which joins the St. Louis River about 19 miles west of the airport. The Midway River drains much of the region southwest of the airport, but does not appear to drain the airport itself.

1.2.1.2 Demography and Land Use

The area of the airport, with the exception of the Route 53 corridor was formerly sparsely settled and rural. It is currently in the process of becoming part of suburban Duluth. Additional retail stores and light industry is

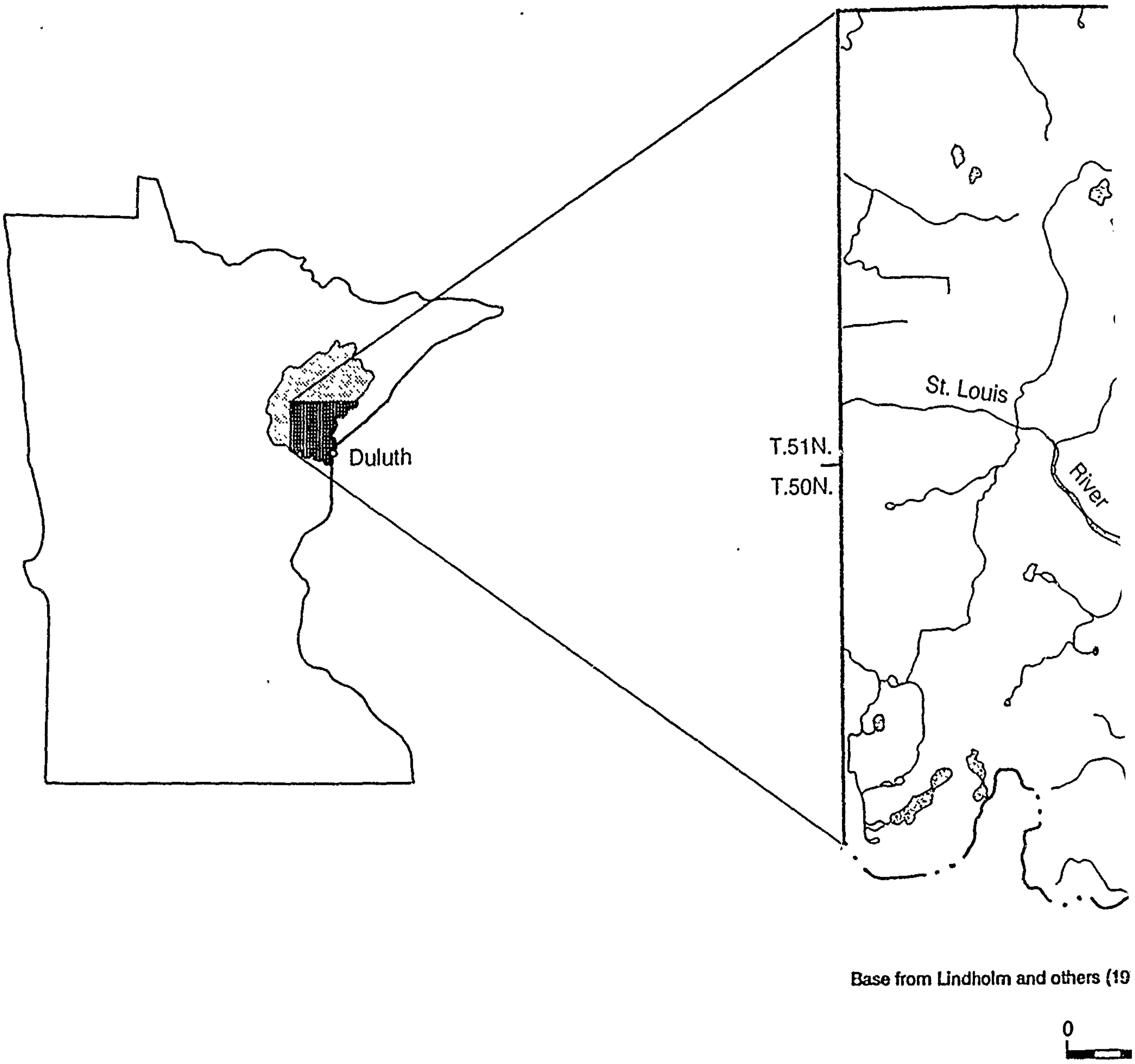
TABLE 1-1

CLIMATIC DATA FOR DULUTH INTERNATIONAL AIRPORT

Month	Temperature Mean Max (°F)	Temperature Mean Min (°F)	Rainfall (1) Mean (in)	Rainfall (1) Max (in)	Snowfall(2) Mean (in)	Snowfall(2) Max (in)	Wind Mean Speed(3) (mph)	Wind Quadrant(4)
Jan	17.0	-0.5	1.11	4.70	16.8	46.8	11.7	NW
Feb	21.5	3.5	0.93	2.37	11.5	31.5	11.3	NW
Mar	32.5	15.8	1.64	5.12	13.7	45.5	11.9	WNW
Apr	47.1	29.4	2.17	5.84	6.4	31.5	12.7	NW
May	59.4	39.2	3.09	7.67	0.8	8.1	11.8	E
June	69.0	48.0	3.95	8.04	T(5)	T	10.6	E
July	75.5	54.9	3.76	8.48	0.0	0.0	9.6	WNW
Aug	73.3	54.0	3.47	10.31	T	T	9.5	E
Sept	64.0	46.0	3.31	6.61	T	0.7	10.5	WNW
Oct	52.6	36.1	2.24	7.53	1.3	8.1	11.3	WNW
Nov	35.6	21.9	1.68	5.01	10.9	37.7	11.8	WNW
Dec	22.3	6.9	1.13	3.70	15.4	44.3	11.3	NW
Annual	47.5	29.6	28.49	39.61	76.9	121.0	11.2	WNW

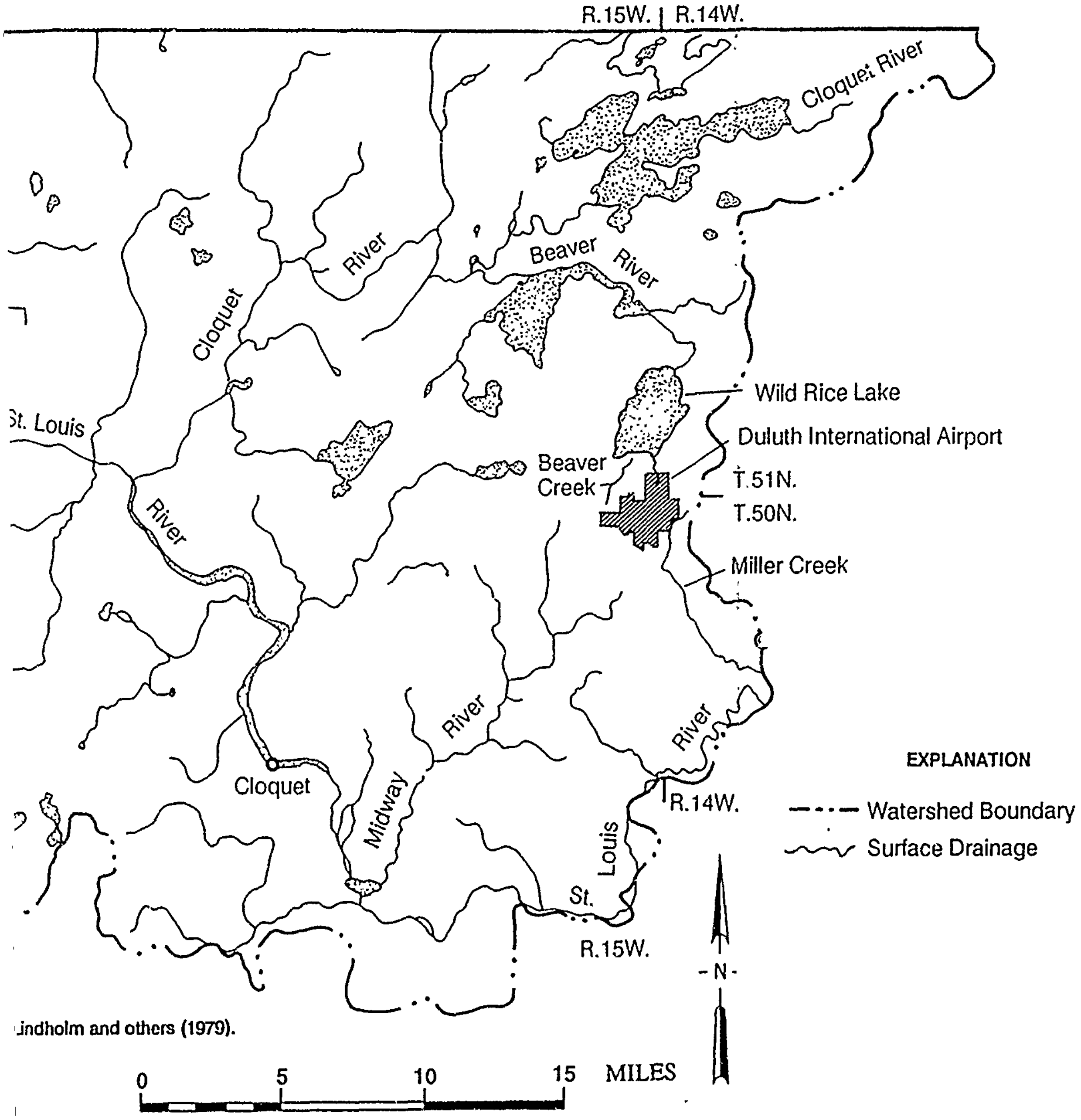
1. Period of record of means 1904-1987.
2. Period of record of means 1944-1987.
3. Length of record is 38 years.
4. Quadrant data through 1963.
5. Trace.

Data from National Oceanic and Atmospheric Administration, 1988.



Base from Lindholm and others (19

Figure 1-4 St. Louis River Watershed.



indholm and others (1979).

developing along Route 53 and Haines Road. Residential areas are growing along existing roads in all directions. No new development has occurred immediately adjacent to the airport within the last ten or so years.

Facilities formerly utilized by the Air Force are currently being used in a variety of ways. Some hangars are leased to private groups such as the Experimental Aircraft Association, others are used for special maintenance projects by the Air National Guard. A federal prison occupies buildings formerly used for Base housing when the U.S. Air Force was present at the airport. The demography and land use of each site is included in the individual site descriptions, Sections 1.2.4.1, 1.2.5.1, 1.2.6.1, 1.2.7.1 and 1.2.8.1.

A general aviation facility occupies the old commercial air terminal, while the air terminal currently in use lies to the south of the east end of the east-west runway. The Air National Guard Base is situated on the northeast side of the airport.

1.2.1.3 Geology

Duluth lies on the southern margin of the Superior Province of the Canadian Shield. This is a region of Precambrian sedimentary and igneous rocks that have been metamorphosed and deformed.

The area is underlain by crystalline bedrock belonging to the Duluth Complex. The bedrock is composed of various intrusive igneous rocks made of minerals which contain a large proportion of the heavier elements such as calcium, iron, and magnesium. These igneous rocks have been categorized on the basis of whether they are layered or massive, contain intrusions of other material, or contain predominant amounts of particular minerals.

At the airport, the Duluth Complex rocks consist of dark gray, medium- to coarse-grained, olivine gabbro which is called the Duluth Gabbro. Olivine is a rock-forming silicate mineral which contains iron and magnesium. Gabbro is a dark-colored intrusive rock which contains silicate minerals consisting of calcium, magnesium, and iron, as well as other rock forming silicate minerals.

The Duluth Gabbro is a heavy, dense, crystalline rock. It has few to no pore spaces but contains zones which are fractured. These zones can be closely spaced, but frequently can be miles or tens of miles apart.

Structurally, the Duluth Complex is located on the western limb of the Superior Syncline the axis of which corresponds roughly to the axis of Lake Superior (Sims and Morey, 1972). At the airport, the base of the syncline dips irregularly toward Lake Superior.

The Precambrian bedrock of the Duluth area, and northern Minnesota in general, has been scoured by glaciers of Pleistocene age which removed any younger rocks overlying the Precambrian surface. The last glacial period, the Wisconsin, removed any evidence of prior glaciation and left behind a thin veneer of glacial till known as red-sandy till overlying the bedrock.

The glacial till in the area of the airport forms a relatively flat surface and is composed of low to moderately permeable unstratified sands, silts and clays with boulders and cobbles. Locally occurring peats are found within the till. The till is unconsolidated and ranges in thickness from 10 to 60 feet.

1.2.1.4 Hydrogeology

Two hydrogeologic units underlie the airport. One unit is the Duluth Gabbro within which ground water is found in limited quantities in fracture zones. The other unit is the overlying glacial drift consisting of unsorted, non-stratified till, 10 to 60 feet thick within which ground water generally occurs in limited quantities.

Because of their limited capacity to produce water and the availability of abundant surface water, the bedrock and glacial drift have not been developed extensively as aquifers in the Duluth area. The glacial drift, however, is used in rural areas for farm and domestic use by low production hand-dug or shallow-drilled wells.

The hydraulic head in the gabbro near the airport is similar to that in the overlying glacial drift while the bedrock permeability is generally much lower than the overlying sediments (ES, 1982). This means that while the two units are hydraulically interconnected, most flow occurs in the glacial drift. The principal flow path of ground water in the area is thus direct recharge from ground surface to the shallow water table in the glacial drift, then horizontal flow in the water table to discharge in local streams and ponds.

Streamflow varies during the year. High flows, caused by snowmelt and spring rains, normally occur in April and May. Streamflow then recedes through summer, reacting only temporarily to occasional periods of storm runoff. Flow increases slightly as evapotranspiration losses diminish in the fall. During winter, flow is sustained by ground-water discharge and recedes slowly until March, when accumulated snow begins to melt.

Throughout the area of the airport, the shallow ground-water table provides discharge to streams and their tributaries. The water table is also continuous with marsh and bog areas which are essentially areas where the water table is at or above the ground surface.

1.2.1.5 Water Quality

According to Lindholm (1979), the quality of ground water in the St. Louis River watershed is generally good and among the best in the state. Dissolved-solids concentration in water from drift and bedrock aquifers in the eastern part of the watershed is commonly less than 250 milligrams per liter (mg/L). Water in bedrock aquifers is mostly of the calcium bicarbonate type. The median value of dissolved solids in streams draining the red-sandy till is 142 mg/L.

1.2.1.6 Water Use

As reported by Lindholm (1979), the glacial till is not usually considered an aquifer. Its water yielding capability is dependent upon the predominant grain size. Clay-rich till yields little water; sandy till may yield minimal supply for domestic or stock purposes.

The consolidated bedrock in the area, the Duluth Gabbro, is massive and a poor source of water. The gabbro may yield domestic or stock supply from fractures.

Lindholm (1979) reports that yields are generally less than 25 gallons per minute (gal/min) for the glacial till and less than 5 gal/min for the Duluth Gabbro. Where the till is used as a source of water, the wells are dug open-end, and where the gabbro is used as a source, the wells are completed as open hole. In both cases, the lower parts of the wells themselves are used as reservoirs.

A list of wells installed within a mile of the outer boundary of the airport was compiled for the Phase II, Stage 2 study (Dames & Moore, 1987, pps. 37-40). The information on the wells was obtained from the State of Minnesota, Department of Health, Water Well Records. These wells are listed in Table 1-2 and the index to their locations are shown on Figure 1-5. It is possible that there are additional wells which either existed and were not on record with the Minnesota Department of Health or have been installed since the time the list was compiled.

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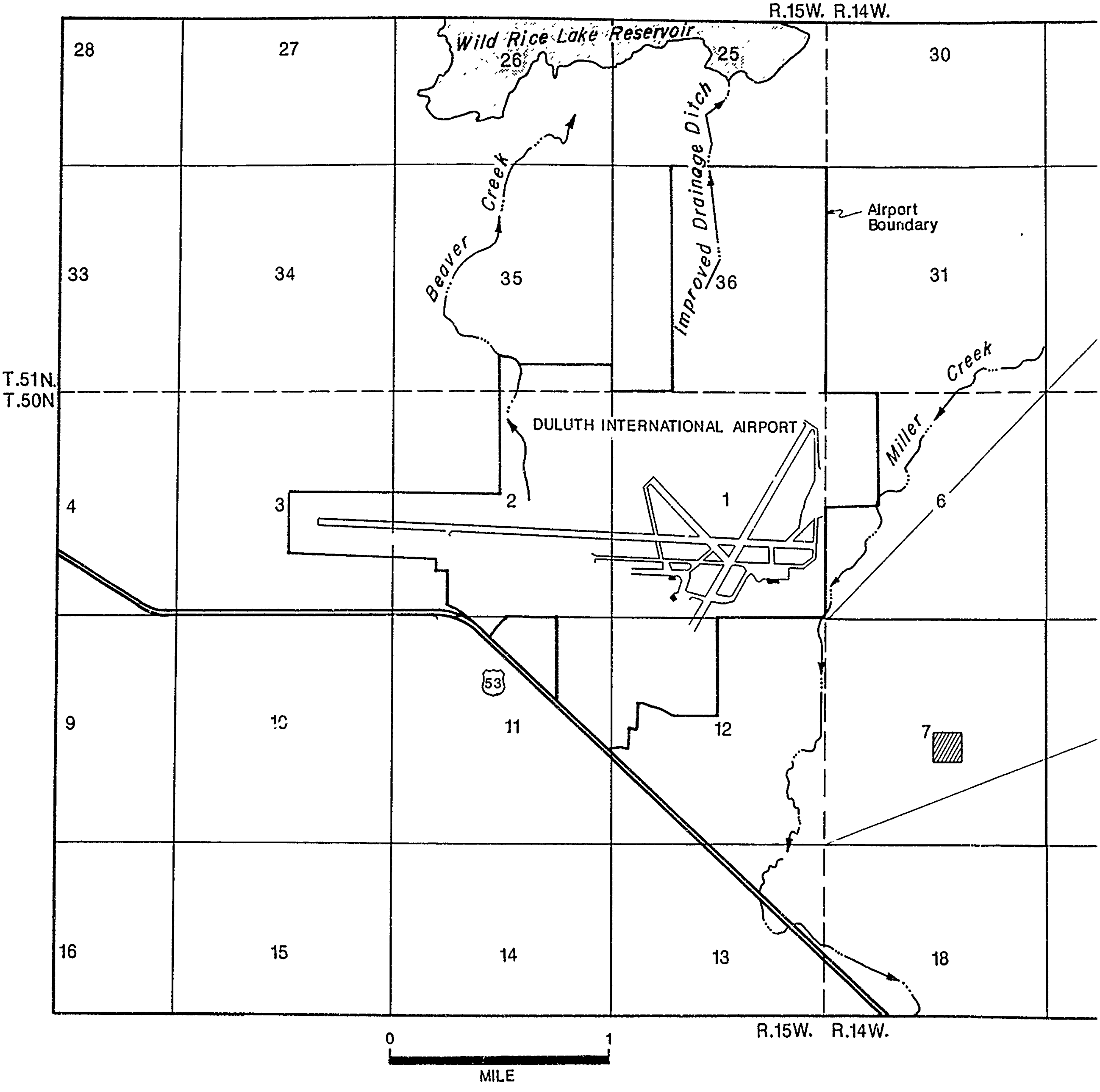
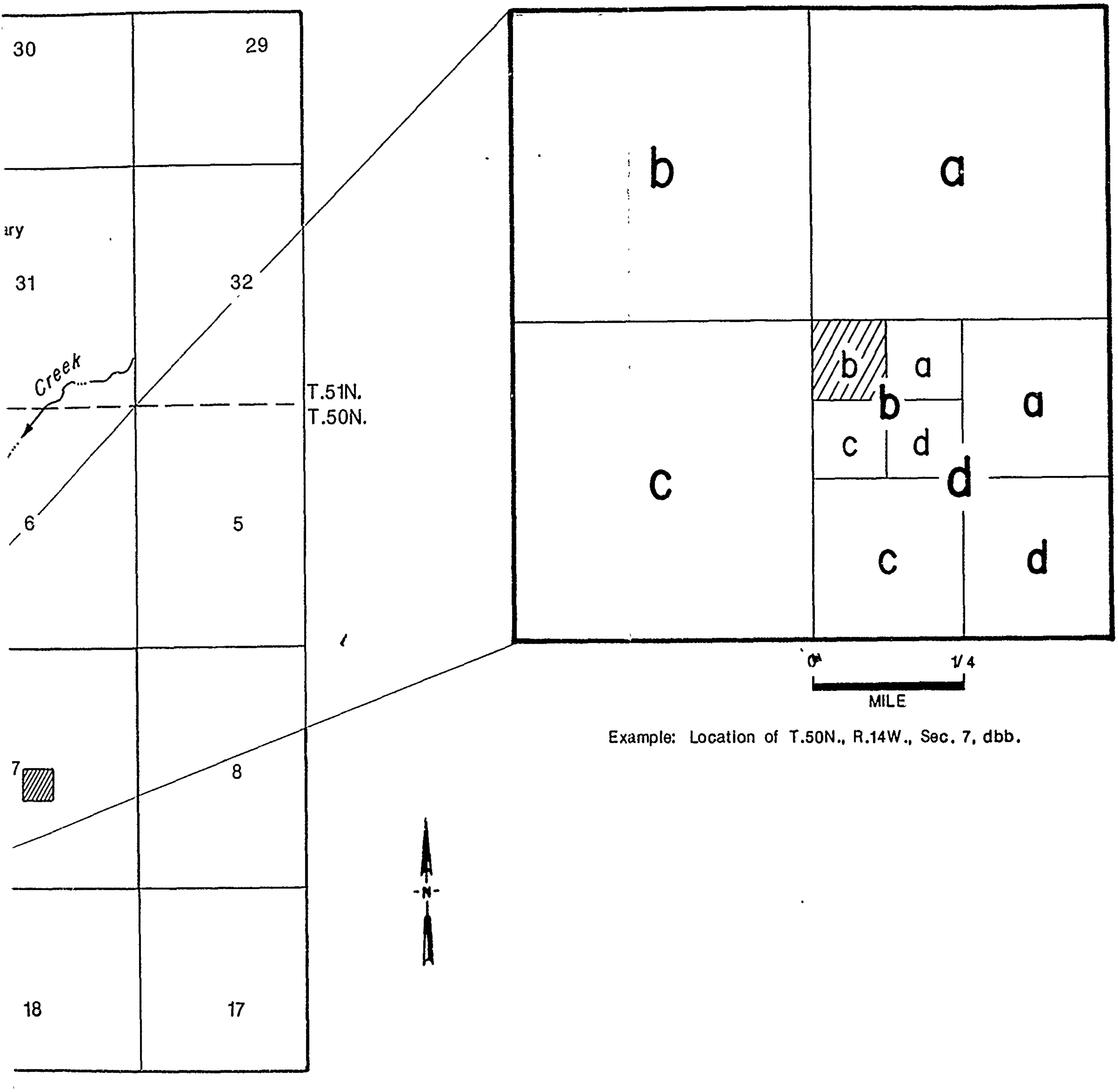


Figure 1-5 Location scheme for water wells in the State of Minnesota.



Example: Location of T.50N., R.14W., Sec. 7, dbb.

ES
ENGINEERING-SCIENCE, INC.

TABLE 1-2

WELL DATA, 1-MILE RADIUS OF SITE
DULUTH IAP, DULUTH, MINNESOTA

Location(1)		Well Depth (ft)	Well Diameter (in)	Well Type	Static Water Level (ft)	Yield	Water Quality	Water Use	Problems	Other
150N, R14W, Sec. 7	dbb	17	20	dug	13	--	mediun	domestic	goes dry	Aquifer: quicksand
	ccc	12	12	dug	7	--	soft	domestic	pumps dry	Aquifer: sand and a "boulder"
	cab	40.0	--	dug	15	--	soft	domestic	can pump dry	Hit ledge at bottom
	bac	21.7	36	dug	17.15	--	hard	domestic	pumped dry	Bedrock at T.D.
	bdd	23	24	dug	15	never dry	medium	domestic	--	Aquifer: sand, no bedrock at T.D.
	aaa	24	--	--	--	--	--	--	--	Bedrock at 24 ft?
	acd	--	--	--	--	--	--	--	--	
	bbcc	33	--	--	--	--	--	--	--	Bedrock at 22.8 ft?
	bbc	102	6	--	--	--	--	domestic	--	No rock
	acc	25	37	dug	14.2	--	medium	domestic	went dry	Bedrock at T.D.
150N, R14W, Sec. 6	abb	55	6	--	--	--	--	domestic	--	Gravel pit
	bbc	--	--	--	--	--	--	--	--	Gravel pit
	ddd	--	--	--	1	--	hard-mildew	domestic	can pump dry	
	caa	--	--	--	--	--	--	--	--	Gravel pit
	cac	--	--	--	--	--	--	--	--	Gravel pit
	cca	--	--	--	--	--	--	--	--	Gravel pit
	ccd	37	--	open hole	--	--	--	unused test	--	USGS well, boulder or bedrock at 37 ft.
	ada	27	--	dug	20	--	soft	domestic	went dry once	
150N, R15W, Sec. 2	abb	22	--	--	--	--	--	unused test	--	USGS well, boulder at 22 ft.
	ccd	20	36	dug	12	--	medium	domestic	will pump dry	
	bcb	20	--	dug	--	--	hard and soft	domestic	will pump dry	Also has "spring well" 7 ft. deep

TABLE 1-2
(Continued)

Location(1)		Well Depth (ft)	Well Diameter (in)	Well Type	Static Water Level (ft)	Yield	Water Quality	Water Use	Problems	Other
	bbc	20	36	dug	--	--	soft	domestic	can pump down	
	bbb	22	36	dug	3	never dry	medium	domestic	--	40 ft. well on property
	baa	18	30	dug	--	--	soft	domestic	will pump dry	
T150N, R15W, Sec. 3	ddd	40	4	drilled	15	--	soft	domestic	will pump dry	Has 25- to 30-ft. dug well also
	ddd	160	6	drilled	2	--	soft	domestic	will pump dry	
	ddc	23	--	dug	--	never dry	hard	domestic	--	Hit bedrock?
	dcd	18	30	dug	10	never dry	hard	domestic	--	
	dcd	22	30	dug	17	--	hard	domestic	will pump dry	
	dcc	31	4	drilled	--	--	medium	domestic	--	Hit bedrock 31 ft.
	?dbb	15.8	--	open hole	15.5	--	--	unused test	--	USGS well, boulder or bedrock 15.8 ft.
	cdd	15	--	dug	--	never dry	hard	domestic	--	
	cdd	34	--	dug	23	--	hard	domestic	pumps dry	
	cdc	32	30	dug	24	never dry	soft	domestic	--	
	cdc	20.2	12	dug	19.10	never dry	medium	domestic	--	
	aaa	18	--	dug	--	--	hard	domestic/stock	pumps dry	On bedrock or boulder at 18 ft.
	bb	208	6	drilled	11	--	--	domestic	--	Bedrock at 27 ft.
	cca	22	6	dug	15	never dry	soft	--	--	
	ccc	45	36	--	35	never dry	medium	--	--	No bedrock
	ccc	102	--	drilled	--	5 gpm	--	domestic	--	6 ft. to bedrock
	ccc	30	30	dug	8	never dry	medium	domestic	--	
	ccb	10	30	dug	8	--	soft	domestic	can pump dry	

TABLE 1-2
(Continued)

Location(1)		Well Depth (ft)	Well Diameter (in)	Well Type	Static Water Level (ft)	Yield	Water Quality	Water Use	Problems	Other
150N, R15W, Sec. 11	bbc	30	36	dug	15	never dry	hard	domestic	--	
	bbc	27	--	dug	17	never dry	soft	--	--	
	bbc	21	30	dug	--	never dry	soft	domestic	--	Bedrock at 21 ft.
	bbb	24	30	dug	--	--	hard	domestic	went dry once	
	bbb	30	24	dug	17	never dry	hard	domestic	--	
	bbb	30	48	dug	20	--	hard	domestic	will go dry	
	bba	NL	36	dug	9.30	never dry	soft	domestic	--	
	bba	22	18	dug	10	never dry	medium	domestic	--	
	bab	13	9	dug	9.1	never dry	soft	domestic	--	
	dad	17	--	drilled	±9.0	--	--	--	--	Bedrock at 17 ft?
	dad	26.5	--	drilled	±9.0	--	--	--	--	
	abc	22	--	open hole	--	--	--	unused test	--	USGS well, boulder or bedrock at 22 ft.
	abc	17	24	dug	7	--	hard	domestic	went dry once	
	abb	22	18	dug	1	--	hard	domestic	will pump dry	Recovers in 12 hours
	adcd	42	--	drilled	1?	--	--	--	--	MN Hwy. Dept., bedrock at 42.0 ft.
	add	43	--	drilled	NL	--	--	--	--	MN Hwy. Dept.
	bda	16	30,36,50	dug	5-6	--	soft, iron	domestic	will pump dry	
	cbb	20	--	--	--	--	--	--	--	Bedrock at 20.0 ft.
	cbb	20	--	--	--	--	--	--	--	Bedrock at 20.0 ft.
	cbb	20	--	open hole	--	--	--	unused test	--	USGS well
	dcc	36	NL	dug	26	--	NL, iron	domestic	NL	
	dcc	36	--	dug	--	--	very hard	domestic	pumps dry	Bottom 12 ft. solid rock, water gets oily film.

TABLE 1-2
(Continued)

Location(1)		Well Depth (ft)	Well Diameter (in)	Well Type	Static Water Level (ft)	Yield	Water Quality	Water Use	Problems	Other
	ddc	22	30	dug	5	never dry	medium	domestic	--	
	dcc	18	--	dug	--	never dry	medium	domestic	--	
	ddc	24	--	--	--	never dry	medium	domestic	--	
	ddc	25	--	dug	--	never dry	hard	domestic	--	
	aca	17	2-4	dug	10	NL	soft	domestic	NL	NL
150N, R15W, Sec. 12	bcb	16	16	dug	5-6	never dry	soft	domestic	--	
	bccc	47	--	drilled	7.1	--	--	--	--	
	bccc	34.5	--	drilled	NL	--	--	--	--	
	bdd	18	30	dug	8	never dry	medium	domestic	--	
	cca	16	30	dug	--	--	medium	domestic	dry once	
	cbb	123?	--	drilled	80	never dry	hard	domestic	--	
	cbb	30	8	dug	--	--	hard, iron	domestic	will go dry	Oily, swamp taste
	cbb	159	6	drilled	--	never dry	soft	domestic	--	
	cbd	35	6	dug	2	never dry	soft	domestic	--	
	cca	12,21	--	dug	8	never dry	soft	domestic	--	
	cca	23,19	--	dug	11	--	--	--	can pump dry	
	cbd	SAME AS ABOVE		--	--	--	--	--	--	
	ccc	20	24	dug	16-17	--	hard	domestic	pumped dry	
	ccd	15	24	dug	7	--	soft, iron?	domestic	pumps dry	Gets oily in spring
	dcd	20	30	dug	10-12	--	soft	domestic	--	
	dcc	25	30	dug	6	--	soft	domestic	--	
	dbd	21	48	dug	10	never dry	soft	domestic	--	

TABLE 1-2
(Continued)

Location(1)	Well Depth (ft)	Well Diameter (in)	Well Type	Static Water Level (ft)	Yield	Water Quality	Water Use	Problems	Other
dbd	15	24	dug	--	--	soft, iron	domestic	will go dry	
cdd	21	30	dug	10	never dry	soft	domestic	--	
cdd	20	30	dug	12	--	hard	domestic	goes dry	
cdd?	20	36	dug	15	never dry	hard	domestic	--	
cdb	30	30	dug	--	never dry	soft	--	--	
cdb	30	24	dug	10	--	hard	domestic	will pump dry	
bc	155	6	drilled	20	--	--	commercial	--	Bedrock, 48 ft.

Modified from Dames and Moore (1987).

NL - Not legible.

TD - Total depth.

1 - For location scheme see Figure 1-4.

1.2.2 History of Duluth Air National Guard Base

The airport has undergone three name changes. It was originally known as Williamson-Johnson Airport. In 1952, the name was changed to Duluth Municipal Airport. In 1963, the name was changed to its current name of Duluth International Airport.

The airport has been used for military operations since 1948. From 1948 to 1961, the airport was used by the 179th Squadron, which was attached to the 133rd Fighter Group of the Minnesota Air National Guard (ANG) as an active unit of the U.S. Air Force. In 1961, the 148th Group of the Minnesota ANG was activated at Duluth and ties with the 133rd Group were broken. This unit has remained at the airport since that time as an active unit of the Minnesota ANG.

The Duluth Air Defense sector became operational at the airport on November 15, 1959 and the 4787th Air Base Group of the U.S. Air Force Air Tactical Command began operations. The 4787th remained on the airport until December 1981 when Air Force operational missions were discontinued.

At the present time, the Minnesota ANG continues operations and both commercial and private civilian entities use the airport.

1.2.3 Previous Investigations

There have been three previous investigations of the sites covered by this report. An IRP Phase I study was conducted in 1982 (ES, 1982). An IRP Phase II, Stage I study was conducted in 1983 (Weston, 1984) and an IRP Phase II, Stage 2 study was conducted in 1986 and 1987 (Dames & Moore, 1987).

In early 1982, a Phase I IRP study was performed. This phase determined the hazardous materials which had been used; waste management practices; the adequacy of waste management procedures to immobilize, contain, treat, destroy, or detoxify the waste; potential pathways of waste migration; and potential effects of discharge or release of the wastes.

The work performed during Phase I consisted of: site records review; interviews with personnel familiar with past waste generation and disposal; inventory of wastes; determination of quantities and locations of past hazardous waste storage, treatment, and disposal; evaluation of disposal practices and methods; field inspection; compilation of pertinent information from federal, state, and local agencies; assessment of potential for contamination; and determination of potential for hazardous contaminants to migrate.

As a result of this study, 11 Sites were identified and were ranked according to the Hazardous Assessment Rating Methodology (HARM). A list of these sites and their priority ranking is given in Table 1-3. Their reported locations are shown in Figure 1-6.

In 1983, an IRP Phase II, Stage 1 Problem Confirmation and Quantification Study was undertaken at four of the ten sites identified during Phase I (Weston, 1984). These four sites were: Site 1, Goose Missile Site Disposal Area (Site D-1, Goose Missile Site Dump); Site 2, Fire Training Areas (Sites FT-1 and FT-2); Site 3, DPDO Storage Area "C" (Site S-2); and Site 4, Fuel Storage Area (Site SP-1, Tank Farm Area).

The field work at Site 2 consisted of construction of seven ground-water monitoring wells and analyzing ground-water samples. The field work at Site 3 consisted of drilling ten soil sample boreholes to a depth of five feet with continuous soil sampling and collecting sediment samples at two locations. The field work at Site 4 consisted of constructing four ground-water monitoring wells, installing twenty temporary well points, analyzing ground-water samples and digging two test pits. Details and results of this previous work are summarized in Sections 1.2.4 through 1.2.6.

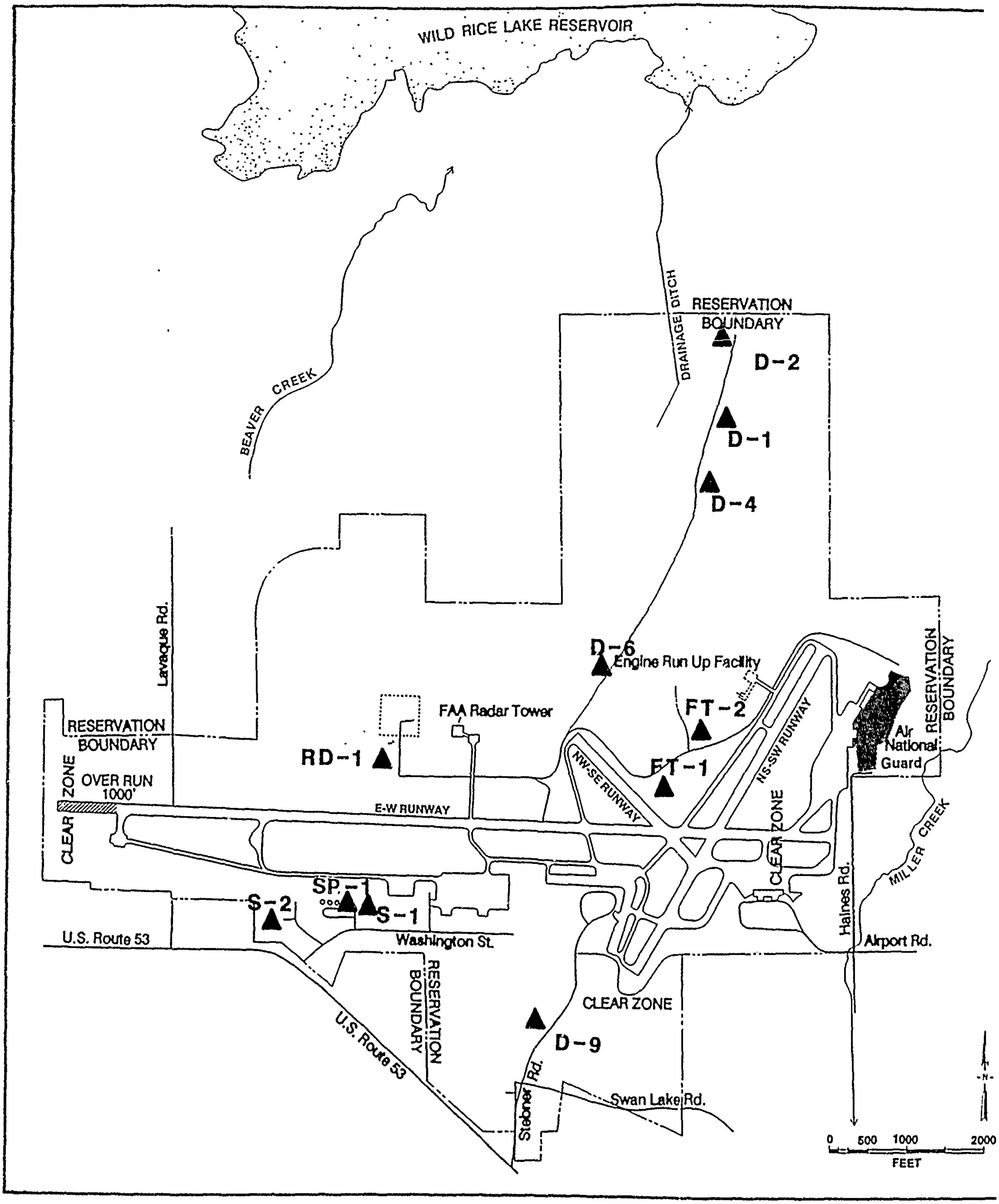
In 1986, an IRP Phase II, Stage 2 investigation was performed at five sites including Sites 2, 3, and 4, which had been investigated in the Phase II, Stage 1 study, and two other sites: Site 8, Old DPDO Storage Area (S-1) and Site 10, Low-level Radioactive Waste Disposal (RD-1), which had been identified in Phase I but which were not investigated in the Phase II, Stage 1 study. These 5 sites are the same as those addressed in this report. The field work at Site 2 consisted of constructing five monitoring wells, drilling and sampling two soil borings, analyzing ground-water samples and sampling three surface soil surface and water locations. The field work at Site 3 consisted of constructing four monitoring wells, drilling and sampling three soil borings, analyzing ground-water samples and sampling three surface soil and surface water locations. The field work at Site 4 consisted of constructing four monitoring wells, drilling and sampling five soil borings, analyzing ground-water samples, sampling at four surface soil and surface water locations, and a geophysical survey. The field work at Site 8 consisted of constructing three monitoring wells, drilling and sampling two soil borings, analyzing ground-water

TABLE 1-3

PHASE I PRIORITY RANKING OF POTENTIAL CONTAMINATION SOURCES[1]

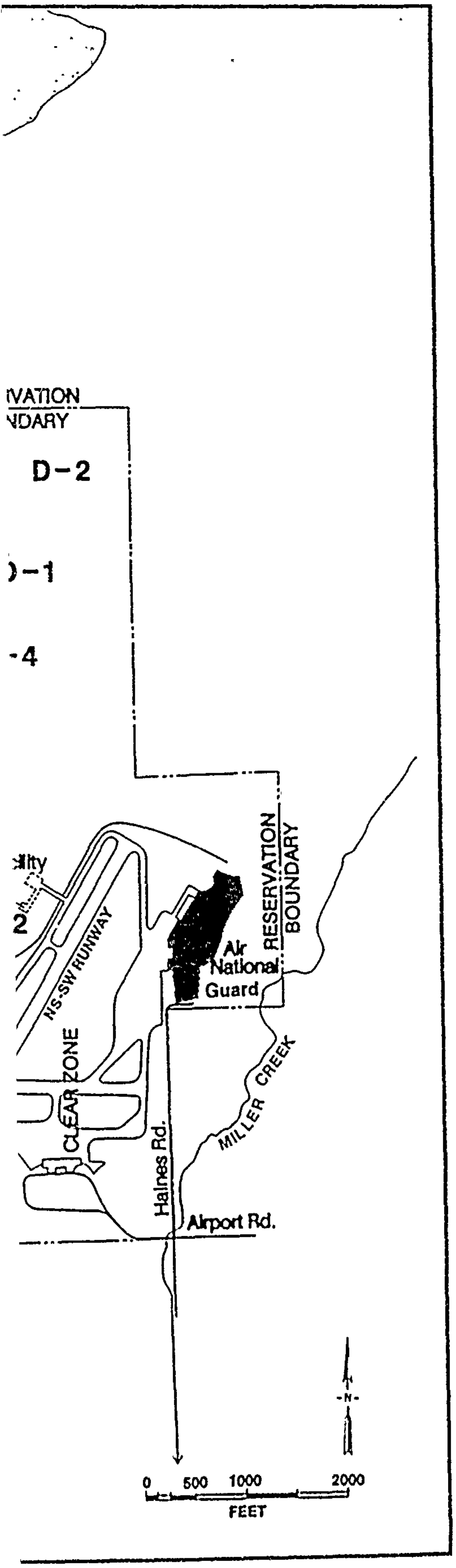
Rank		Site Name	Score	Site Number
1	D-1	Goose Missile Site Dump	64	1
2	FT-2	Fire Training Area	63	2
3	FT-1	Fire Training Area	56	2
4	S-2	DPDO Storage Area "C"	55	3
5	SP-1	Tank Farm Area	53	4
6	D-4	South Goose Missile Site Dump	50	5
7	D-2	Goose Missile Site Dump	49	6
8	D-6	Runway 13 NE Disposal	48	7
9	S-1	Old DPDO Storage Area	48	8
10	D-9	Disposal Pit	44	9
11	RD-1	Low-Level Radioactive Waste Disposal	44	10

1. This ranking was performed according to the Hazardous Assessment Rating Evaluation Methodology (HARM), (ES, 1982).



Data from ES, 1982.

Figure 1-6 Sites Defined and Ranked during IRP Phase I Study.



EXPLANATION

▲ **D-1** Site identified during Phase I study.

samples and sampling at two surface soil and surface water locations. The field work at Site 10 consisted of constructing three monitoring wells, analyzing ground-water samples and performing a geophysical survey.

Details and results of this previous work are summarized in Sections 1.2.4 through 1.2.8. The same terminology used in the reports of previous work is used here in the summaries of that work.

1.2.4 Description and History of Site 2

In this section, Site 2 is described, its history given, and previous investigations and their results are summarized.

1.2.4.1 Description

Site 2 has the highest elevations of the airport ranging from just under 1,420 to just over 1,440 feet above the National Geodetic Vertical Datum of 1929 (NGVD). Actual elevations and contours of the site have changed with time as grading and regrading of the site have occurred.

The Site 2 area contains two fire training areas which are located north of the main east-west runway and in the V-shaped piece of land between two smaller runways which run northeast-southwest and northwest-southeast (Figure 1-7). The site covers about 50 acres and is bounded to the north by a poorly drained area and to the south by taxiways that service the runways.

The airport perimeter road cuts through the site in a roughly east-west direction. Fire Training Area 1 (FTA-1) lies to the south of this road, and Fire Training Area 2 (FTA-2) lies to the north.

The FTA-1 was used prior to the 1960s. It consists of about 20 acres of fairly level land which slopes gently southward from the perimeter road toward the runways where the land drops off abruptly. The size of the area actually used for fire training was much smaller in extent, and is described as being two pits approximately 40 feet wide, 50 feet long, and 3 to 4 feet in depth (ES, 1982). The land is presently in meadow and shows some areas of stressed vegetation where the meadow grasses and flowers are not as thick and lush as in seemingly similar adjacent areas. No associated surface contamination is evident.

The FTA-2 consists of about 30 acres which slopes gently to the north. The fire training area itself is a circular area, approximately 100 feet in diameter currently containing a pile of burned and partially burned materials at its center. Various pieces of metal including pipe and barrels are located around the outside perimeter of the circular area. The remains of an incomplete berm or dike are also located around this perimeter. While the present investigation was in progress, up to several dozen barrels leaking a black viscous substance were deposited between the road and the center of FTA-2 and roped off.

Surface drainage is poor and non-integrated, with water accumulating and standing in shallow surface depressions caused by either regrading or tire ruts. Some of these have an oily film at times. Surface runoff occurs in a radial direction.

The geology and hydrogeology of Site 2 are the same as that of the airport area in general. The geology of the Duluth International Airport is described in Section 1.2.1.3; hydrogeology is described in Section 1.2.1.4; water quality is described in Section 1.2.1.5.

This site has no facilities which are occupied on a daily basis. A skeet shooting club has its shooting range just north of FTA-2 and access to it is gained by driving through FTA-2. The range is used on almost a daily basis in the summer by the club which has a membership of 20 to 25 adults and children. A small arms firing range is to the northwest of FTA-2, to which access is gained by driving past the west side of FTA-2 on a dirt road. It is used by up to 10 people on an almost daily basis during the summer. A radar facility is located just west of FTA-2. It is maintained on a periodic basis by one worker. These facilities are shown on Figure 1-7.

The airport perimeter road to the south of FTA-2 is used by about 10 to 15 workers who travel to the vicinity of Site 10 on a daily basis. In addition, Air National Guard personnel commonly jog and walk on the road during the summer months.

Site 2 is not near an airport boundary. It is isolated from the area south of the east-west runway and is not easily accessible to any but Air National Guard personnel.

1.2.4.2 History

Prior to the early 1960s, fire training activities were conducted in two excavated pits (FTA-1) located on high ground between the perimeter road and the main runway. The pits were approximately 40 feet wide, 50 feet long, and 3 to 4 feet deep, and contained about 2 feet of standing water. For fire training exercises, from 300 to 1,000 gallons of flammable materials were placed in the pits, ignited, and extinguished with a protein-based foam, aqueous film forming foam (AFFF), or chlorobromomethane (CB). Carbon

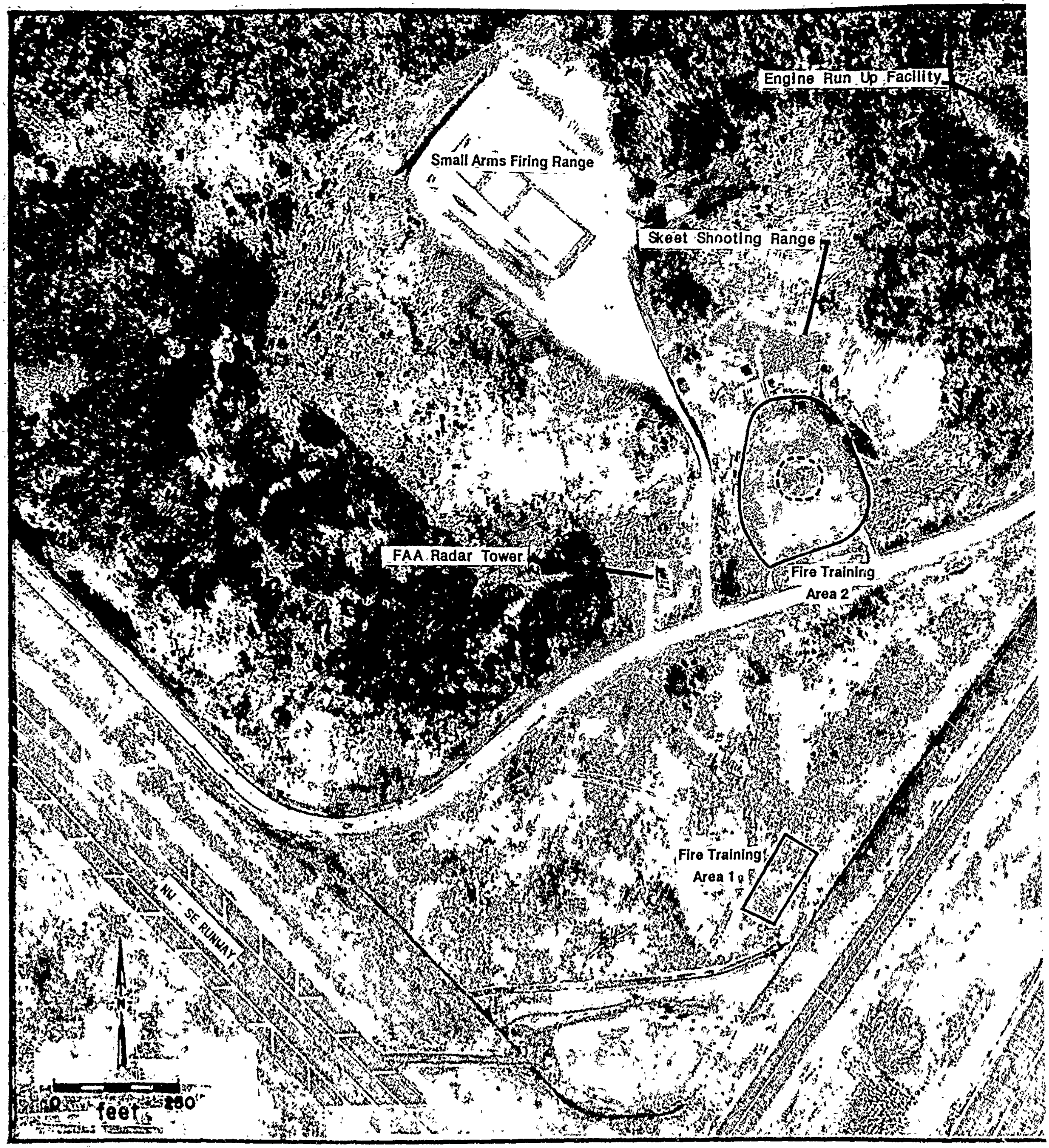


Figure 1-7 Aerial Photograph of Site 2, April 1988.

EXPLANATION

◯ Approximate boundary for fire training area.

◌ Burn pit.

tetrachloride may have been used as an extinguishing agent during the early years of pit operation. Materials burned in the pit during training exercises consisted of JP-4 fuel brought in by tank truck as well as drummed materials such as waste oils, thinners, and solvents, which were not accepted by the Defense Property Disposal Office (DPDO) which is now known as the Defense Reutilization and Marketing Office (DRMO).

After completion of a fire training exercise, waste materials and residue were allowed to remain in the pit and percolate into the ground. Fire training activities during this early period were conducted as frequently as once per week, although once a month was more typical.

The pits at FTA-1 were abandoned after construction of FTA-2 north of the perimeter road in the early 1960s. The area around FTA-1 was leveled and the pits filled in at this time.

From the early 1960s to 1987, fire training activities were conducted in the area designated as FTA-2. Training exercises were originally conducted in an excavated area of the site; however, a perimeter berm was removed and the area graded in the early 1970s. The present burn area is approximately 100 feet in diameter with a partial berm about 200 feet in diameter. Runoff from the site is not contained.

Two training exercises were conducted each month. The ground was saturated with water to minimize infiltration and up to 500 gallons of JP-4 fuel were burned during a typical training exercise. Contaminated fuels and drummed waste materials such as oils, paint thinners, and solvents were also burned in the pit. The fire was extinguished with approximately 30 gallons of AFFF or CB. Residual materials from the training exercises either infiltrate into the ground or contributed to surface runoff.

The site is not currently being used for fire training exercises.

Several drums of soil contaminated with waste oil were removed from Site 3 in 1980 and the material was spread within FTA-2.

Part of the work done during this remedial investigation was a study of photographs of the airport from 1950 to present. The results of this study, including the historical changes in the topography of FTA-1, are given in Section 3.2.1.

1.2.4.3 Previous Investigations

This site was defined during the Phase I Investigation (ES, 1982).

A Phase II, Stage 1 investigation was conducted in 1983 (Weston, 1984). Seven ground-water monitoring wells numbered MW 1 through MW 7 were installed. They were located around the presumed perimeter of the two FTAs with monitoring well MW 4 located between the areas, as shown on Figure 1-8. Wells MW 1 through MW 3 were located along the known northern perimeter of FTA-2, approximately 75 feet from the fire pit at the center of the site. Wells MW 5 through MW 7 were located along the then estimated southern border of FTA-1. Because of site regrading, there were no indications in the field of the boundaries of FTA-1 or the exact location of the fire pit. Monitoring wells ranged in depth from 15 to 25 feet below land surface, and ground-water was encountered between one and twelve feet below land surface.

All the borings encountered fill soils overlying glacial drift. None of the borings penetrated bedrock. A one and one-half foot diameter boulder was cored at MW 5.

Six of the wells were constructed with the top of casing at least two feet above the ground surface. One well, MW 3, was constructed with the top of casing 0.1 foot above the ground surface.

The relative altitudes of the monitoring well casing tops were surveyed. The horizontal coordinates of the wells were not established.

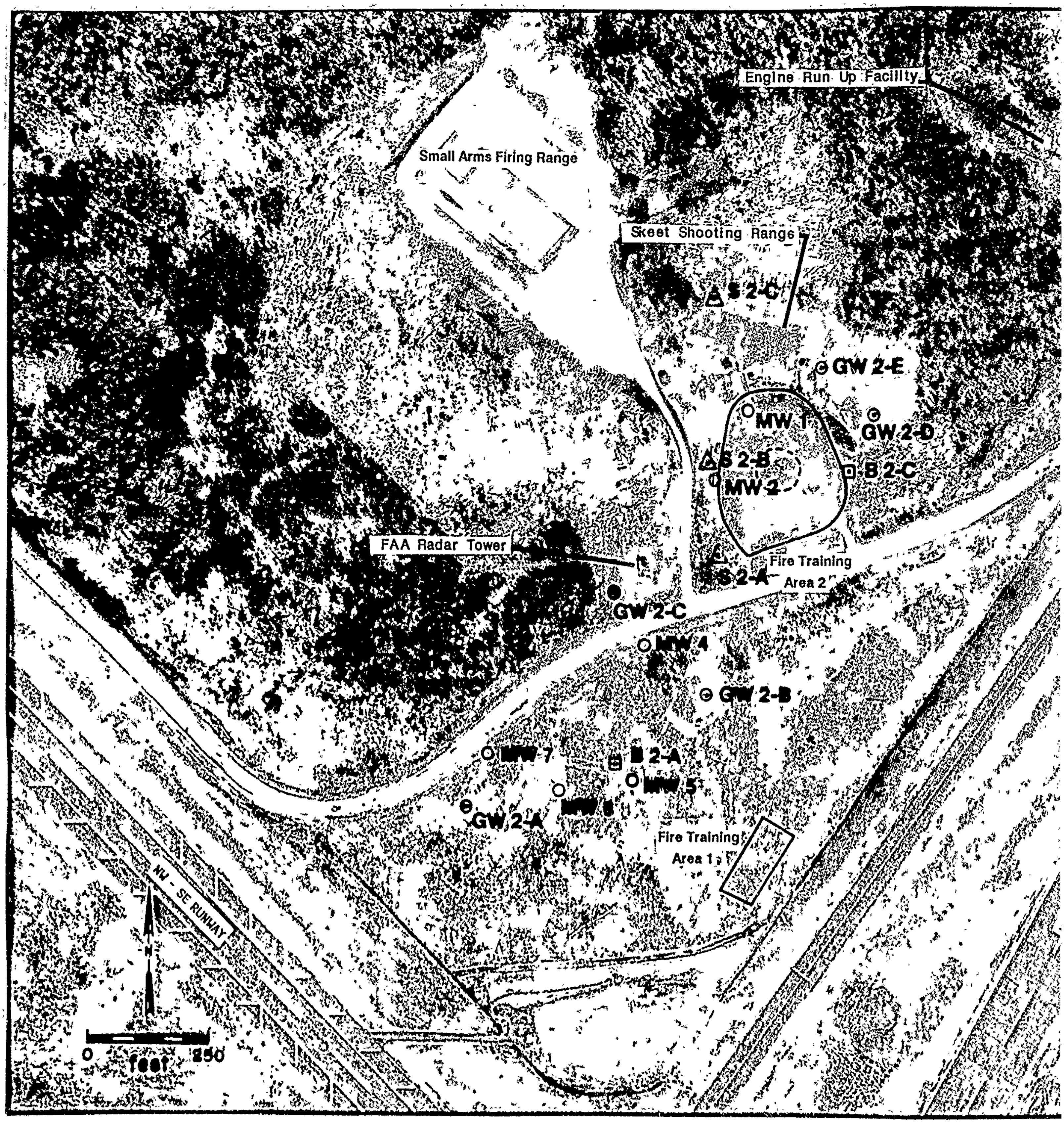
One round of water level measurements was made in November 1983.

Ground-water samples from the seven monitoring wells were analyzed for oil and grease, total organic halides (TOX), total organic carbon (TOC), and nitrates. Field measurements were taken for temperature, pH and specific conductance.

The results of the analyses are summarized in Table 1-4.

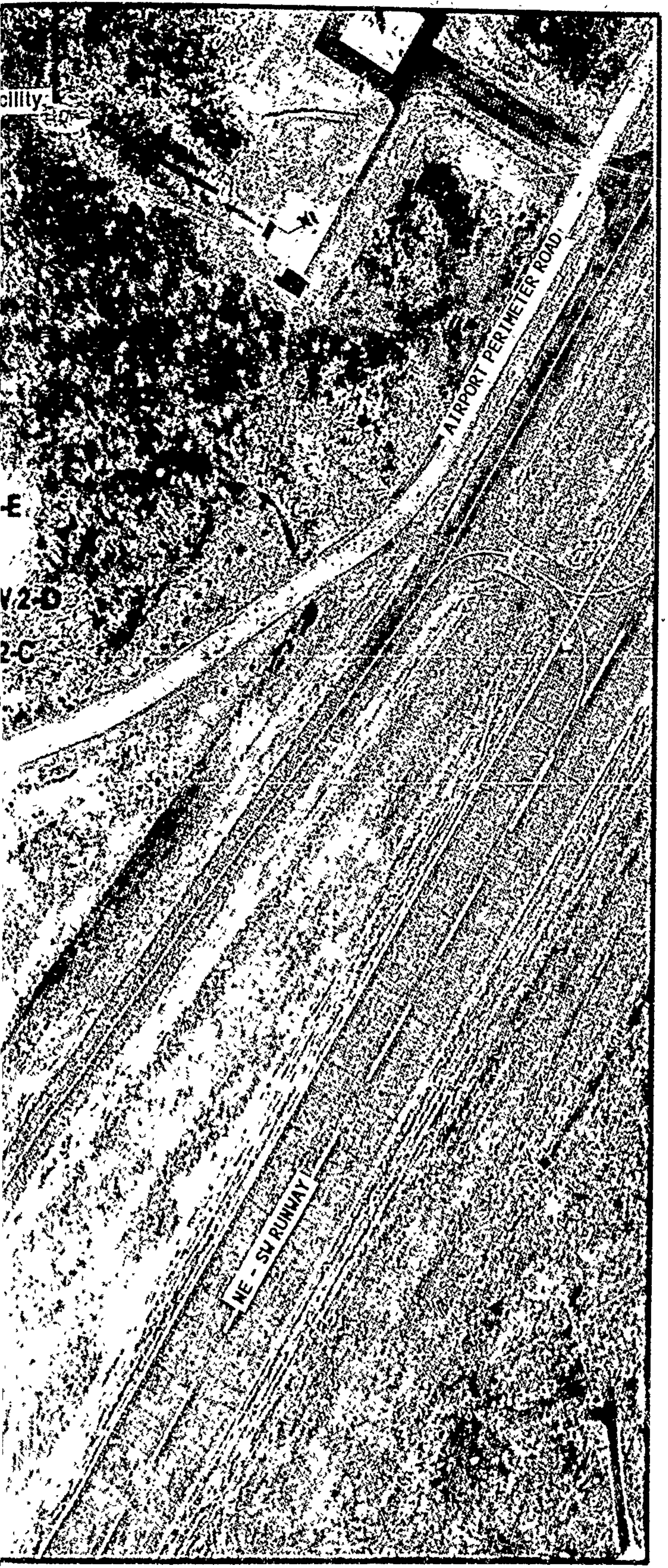
A Phase II, Stage 2 investigation was conducted in the fall of 1986 (Dames & Moore, 1987). Seven boreholes were drilled using a rotary rig with hollow stem augers (see Figure 1-8). The boreholes were sampled at five-foot intervals using a split-spoon sampler. One soil sample from each of the boreholes was retained for analysis.

Monitoring wells were constructed in five of the boreholes. Two of the monitoring wells were constructed at the presumed location of FTA-1 with one to the west and one to the east of the Phase II, Stage 1 monitoring wells. Two other monitoring wells were constructed at FTA-2, both to the northeast of the Phase II, Stage I wells. One monitoring well was constructed between



Data from Weston, 1984 and Dames & Moore, 1987.

Figure 1-8 Site 2 Sampling Locations Utilized during Phase II Investigations.



EXPLANATION

SURFACE LOCATIONS

△ S 2-C Phase II, Stage 2

BOREHOLES

⊡ B 2-C Phase II, Stage 2

MONITORING WELLS

⊙ GW 2-C Phase II, Stage 2

○ MW 2 Phase II, Stage 1

MW 3 was not located.

○ Approximate boundary for fire training area.

◌ Burn pit.

TABLE 1-4

PARAMETERS ANALYZED AND DETECTED IN SITE 2 GROUND WATER SAMPLES

DURING THE PHASE II, STAGE 1 INVESTIGATION

(Results in milligrams per liter unless specified otherwise.)

Parameter	Method Used	Location						
		MW 1	MW 2	MW 3	MW 4	MW 5	MW 6	MW 7
Total Organic Halogens (TOX) (micrograms per liter)	EPA 9020	44.3	602.6	81.7	15.9	28.0	15.4	126.3
Total Organic Carbon (TOC)	EPA 415.1	35.0	67.5	66.2	5.6	44.6	24.6	17.0
Oil and Grease	IR (Weston 1984) EPA 412.3	0.19	0.53	0.86	0.42	0.75	0.27	0.38
Nitrates	Not specified	0.48	0.55	0.93	0.39	0.35	0.38	0.47
pH (standard units)	Field measurement	7.08	7.10	6.91	7.10	7.40	7.30	7.50
Specific Conductivity (umhos/cm)	Field measurement	816	820	1107	574	360	636	657

Data from Weston, 1984.

the two fire training areas. Two of the boreholes were drilled for soil sampling only: one at FTA-1, where two soil samples were retained, the other at FTA-2, where three soil samples were retained for analysis.

The soil samples were analyzed for the parameters listed in Table 1-5.

Oil and grease and phenolics were detected in soil samples from both FTA-1 and FTA-2. No other parameters were detected in the soil samples from FTA-1. The parameters detected at FTA-2 are listed in Table 1-6.

Ground-water samples were obtained from each of the monitoring wells. Surface water samples were collected from the three locations shown on Figure 1-6.

These water samples were analyzed for the parameters listed in Table 1-7. The analysis method used is also listed.

Contaminants were detected in the ground water in what was thought to be the vicinity of FTA-1. Oil and grease were detected in the ground water from Well GW 2-B. The compound dichloromethane (methylene chloride) and trichlorofluoromethane were detected in water from monitoring well MW 7. Contaminants were also detected in the ground water and surface water in the vicinity of FTA-2. The compound trans-1,2-dichloroethene was detected in water from monitoring wells GW 2-D, GW 2-E, and MW 1 and from surface water at location SW 2-C. Monitoring well GW 2-E also had detectable amounts of trichloroethane. These results are listed in Table 1-8.

1.2.5 Description and History of Site 3

In this section, Site 3 is described, its history given, and previous investigations and their results are summarized. The site is shown on Figure 1-9.

1.2.5.1 Description

The Site 3 area is about 5 acres in extent and lies at about 1,420 feet above the NGVD. Some regrading of the area has taken place with low spots filled in to create level storage areas and drainage ditches constructed to aid drainage of the area. A drainage ditch borders the storage area to the east and north. A spring occurs at the southeast corner of the storage area.

The area is located south of the western end of the east-west taxiway and lies mostly west of the northwest-southeast access road near the western end of Washington Street (see Figure 1-6). The area is wooded in part, but also has buildings, paved storage areas, roadways and grassy areas. Site 3 abuts and is continuous with Site 4 to the east.

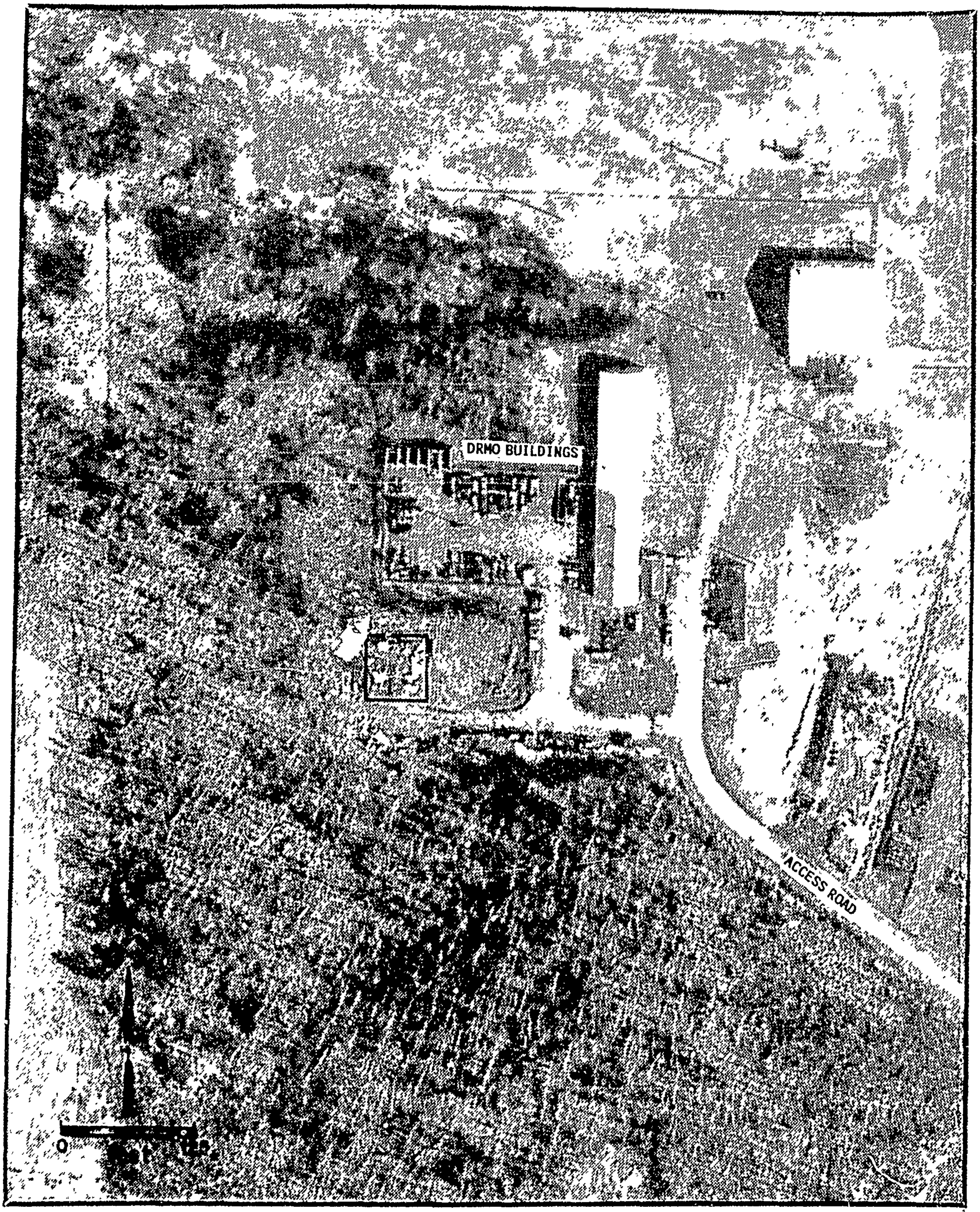


Figure 1-9 Aerial Photograph of Site 3, April, 1988.

EXPLANATION

☐ Approximate location of Storage Area "C".

TABLE 1-5

PARAMETERS ANALYZED IN SITE 2 SOIL SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

Parameter Analyzed	Method Used
Purgeable Halocarbons	SW 8010
Purgeable Aromatics	SW 8020
Moisture	EPA 160.3
Oil and Grease	EPA 413.2
Phenolics	EPA 420.2

Data from Dames & Moore, 1987.

TABLE 1-6

PARAMETERS DETECTED IN SITE 2 SOIL SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in milligrams per kilogram.)

Parameter	Location (depth in feet)												
	Borings					Monitoring Well Boreholes					Surface Samples		
	B 2-B		B 2-C			GW 2-A	GW 2-B	GW 2-C	GW 2-D	GW 2-E	SS 2-A	SS 2-B	SS 2-C
	2.5 - 4	5 - 6.5	0 - 1.5	2.5 - 4	5 - 6.5	5 - 6.5	5 - 6.5	15 - 16.5	15 - 16.5	15 - 16.5			
Purgeable Aromatics													
Benzene			0.014										
Ethylbenzene			0.35		0.011								
Toluene			0.54		0.0088								
o-Xylene			1.8		0.076							0.018	
Oil and Grease		21	9,400	2,000	1,700	6	410	6	46	7	1,200	220	560
Phenolics	0.5	5.5	0.6			30		90					

Data from Dames & Moore, 1987.

TABLE 1-7

PARAMETERS ANALYZED IN SITE 2 WATER SAMPLES DURING THE PHASE II STAGE 2 STUDY

Analytic Parameter	Method
Purgeable Halocarbons	EPA 601
Purgeable Aromatics	EPA 602
Oil and Grease	EPA 413.2
Phenolics	EPA 420.2

Data from Dames & Moore, 1987.

TABLE 1-8

PARAMETERS DETECTED IN SITE 2 WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in micrograms per liter unless otherwise noted.)

	Location					
	Monitoring Well					Surface
Parameter	MW-1	MW 7	GW 2-B	GW 2-D	GW 2-E	SW 2-C
Purgeable Hydrocarbons						
Dichloromethane		4.4				
Trichlorofluoromethane		0.88				
trans-1,2-Dichloroethene	2.3			13	66	2.6
Trichloroethene					20	
Oil and Grease (mg/L)						2.0
pH (standard units)	6.4	6.5	6.5	6.0	6.2	6.0
Specific Conductivity (umhos/cm)	1000	590	660	760	1400	900

Data from Dames & Moore, 1987.

The source area of concern within Site 3 is referred to in previous reports as Defense Property Disposal Office (DPDO) Storage area "C". The DPDO has been renamed, and is now called the Defense Reutilization and Marketing Office (DRMO) Building. The area is approximately 90 feet long and 75 feet wide and lies about 150 feet behind the DRMO building. This formerly utilized storage is unfenced, unlined and borders a drainage ditch. It is flat with a pea gravel surface.

Eight employees work at the DRMO facility on a daily basis. Other workers and the public visit this facility to drop off or pick up excess equipment and supplies. Road access to the site is controlled by a locked gate during non-business hours. Storage Area "C" is not fenced and is accessible on foot from its western or wooded side. The side abuts the southwest boundary of the airport, and commercial property lies directly to the west of the site.

1.2.5.2 History

From 1965 to 1980, waste petroleum, oils and lubricants (POL), waste solvents, and chemicals were stored in Area "C" of the DPDO storage area. The maximum number of containers stored at any time at this site was 80 to 100 55-gallon drums.

No major spills in this area have been recorded, but minor drum leaks are known to have occurred. Several drums of waste oil contaminated soil were removed from this site in 1980. This material was spread within FTA-2 at Site 2. Storage area "C" is no longer used for storage.

1.2.5.3 Previous Investigations

This site was defined during the Phase I records search (ES, 1982).

A Phase II, Stage 1 investigation was conducted in the fall of 1983 (Weston, 1984). Soil samples were obtained from ten five-foot deep soil borings on the storage pad. Five samples were taken at one-foot intervals from each borehole. The method used was hollow stem augering with split-spoon sampling. Grab samples of surface soil were taken at two locations along the drainage ditch. These locations are shown on Figure 1-10. A total of 22 soil samples were analyzed for the USEPA Priority Pollutant List of Volatile Organic Compounds (VOA) and for oil and grease. The results are given in Table 1-9.

Volatile organic compounds were found in the two drainageway soil samples and in all but two of the exploratory boring samples. A total of 11

TABLE 1-9

PARAMETERS DETECTED IN SITE 3 SOIL SAMPLES DURING THE PHASE II, STAGE 1 INVESTIGATION

(Results in milligrams per kilogram.)

		Parameter										
Location	Depth (feet)	Bromodichlormethane	Chloroform	Dibromochloromethane	1,1 Dichloroethane	1,2 Dichloroethane	1,1 Dichloroethylene	Tetrachloroethylene	Trans-1,2-Dichloroethylene	1,1,1 Trichloroethane	Trichloroethylene	Oil and Grease
C-1	0 - 1		0.025							0.011		0.025
	1 - 2											
C-2	0 - 1	0.001	0.12									0.12
	1 - 2											
C-3	0 - 1						0.006					
	1 - 2		0.047					0.002				0.047
C-4	0 - 1	0.008	0.315					0.001		0.003	0.005	0.315
	1 - 2		0.066									0.006
C-5	0 - 1		0.076								0.21	0.076
	1 - 2		0.048								0.94	0.048
C-6	0 - 1		0.061					0.3		0.011	0.002	0.061
	1 - 2		0.073					0.22		0.21		0.073
C-7	0 - 1		0.055						0.006			0.055
	1 - 2		0.018									0.018
C-8	0 - 1			0.003			0.014					
	1 - 2						0.015					
C-9	0 - 1				0.012	0.003	0.032	0.001				
	1 - 2				0.013	0.018	0.037					
C-10	0 - 1				0.022	0.003	0.015					
	1 - 2				0.007	0.003	0.012		0.014			
S-1	0 - 0	0.016	0.24						0.5	0.001	0.14	0.24
S-2	0 - 0	0.006	0.22							0.001	0.02	0.22

Data from Weston, 1984.

compounds were found in the samples. The most common organic compound was chloroform which was found in 13 of the samples. The most concentrated compound detected was trichloroethene at 0.940 ug/g in the one- to two-foot sample of boring C 5. Five volatile organic compounds were found in the drainageway sediments. It was concluded that the variety of compounds throughout the site indicated the local occurrence of leaks associated with the storage of drums of diverse materials at the site.

Oil and grease were found in most of the samples. Concentrations decreased rapidly with depth but were still high in the deeper samples. The results confirmed the field observation that oily products had seeped onto a large portion of the ground surface.

A Phase II, Stage 2 investigation was conducted in the fall of 1986 (Dames & Moore, 1987). Three exploratory borings were drilled and soil samples were collected from each boring at depths of 0 to 1.5 feet, 2.5 to 4.0 feet, and 5.0 to 6.5 feet. Four borings were drilled for construction of monitoring wells and soil samples were obtained from each of these borings at a depth of 5.0 to 6.5 feet. Sediment and water samples were taken at three surface water locations. The three exploratory boreholes were drilled along the eastern edge of the storage pad; the monitoring wells form a semi-circle around the north, west and southern edges of the storage pad; and the surface sample locations are along the drainage ditch which drains the area to the north. All locations are shown on Figure 1-10. The locations of the monitoring wells were surveyed. Water levels were taken at the three monitoring wells. Ground-water samples were obtained from the monitoring wells.

Soil and sediment samples were analyzed for the parameters listed in Table 1-10. The soil results are given in Table 1-11 and the sediment results are given in Table 1-12. The water samples were analyzed for the parameters listed in Table 1-13 and the results are given in Table 1-14.

Some contamination was detected at the site. Halogenated volatile organic compounds were detected in sediments taken from the drainage ditch and in borehole B 3-A. Pesticides, oil and grease, and metals were detected in both sediment and soil samples from all locations.

1.2.6 Description and History of Site 4

In this section, Site 4 is described, its history given and previous

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Data from Weston, 1984 and Dames & Moore, 1987.

Figure 1-10 Site 3 Sampling Locations Utilized during Phase II Investigations.

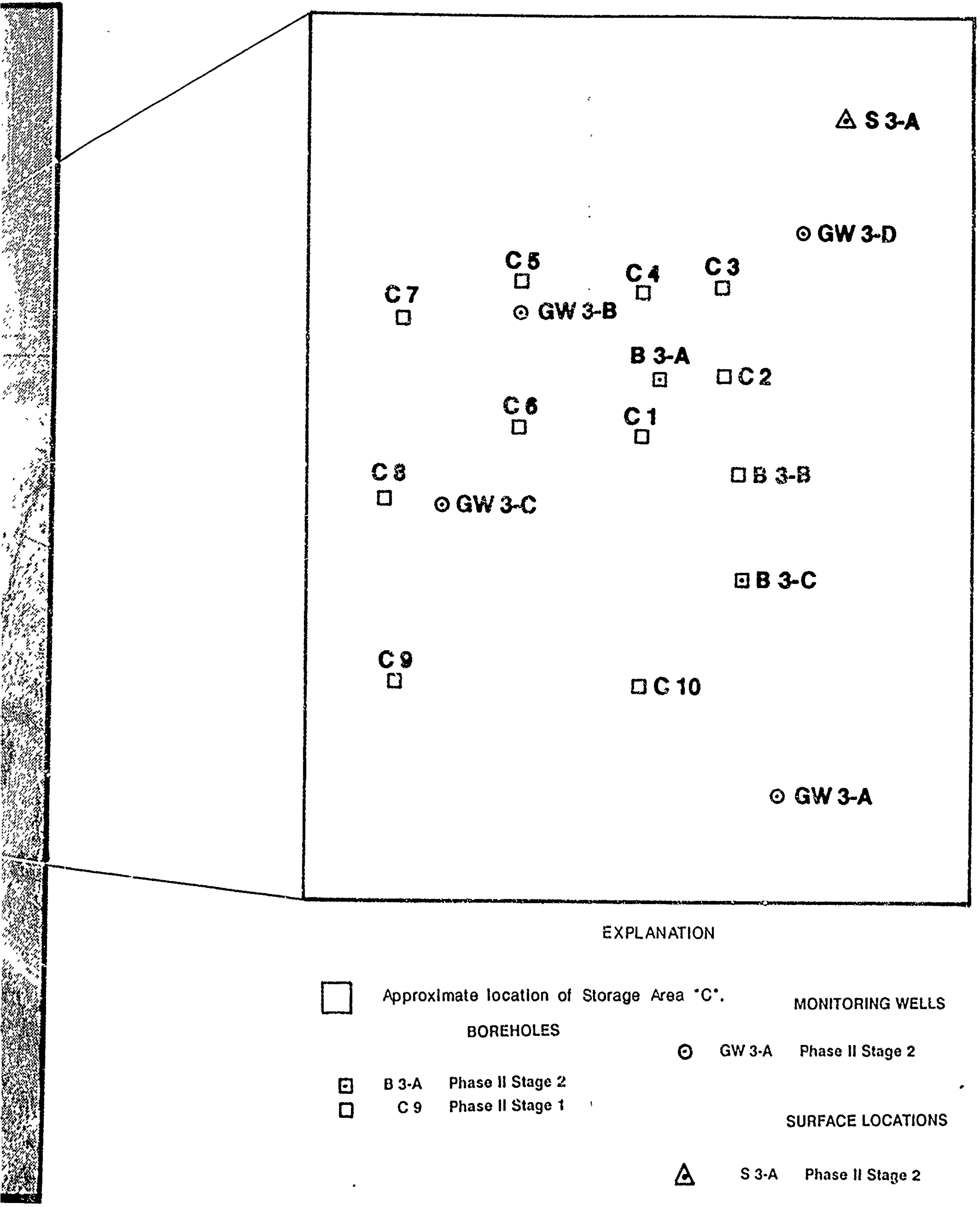

S 3-A
GW 3-D
C 5
C 4
C 3
C 7
GW 3-B
B 3-A
C 2
C 6
C 1
C 8
B 3-B
GW 3-C
B 3-C
C 9
C 10
GW 3-A
EXPLANATION
Approximate location of Storage Area "C".
BOREHOLES
B 3-A Phase II Stage 2
C 9 Phase II Stage 1
MONITORING WELLS
GW 3-A Phase II Stage 2
SURFACE LOCATIONS
S 3-A Phase II Stage 2

TABLE 1-10

PARAMETERS ANALYZED IN SITE 3 SOIL AND SEDIMENT SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

Parameter Analyzed	Method Used
Purgeable Halocarbons	SW 8010
Purgeable Aromatics	SW 8020
Pesticides	EPA 3550/8080
Herbicides	EPA 8150
Moisture	EPA 160.3
Oil and Grease	EPA 413.2
Phenolics	EPA 420.2
Arsenic	EPA 3050/7060
Barium	EPA 200.7
Cadmium	EPA 200.7
Chromium	EPA 200.7
Lead	EPA 200.7
Mercury	EPA 7471
Selenium	EPA 3050/7740
Silver	EPA 200.7

Data from Dames & Moore, 1987.

TABLE 1-11

PARAMETERS DETECTED IN SITE 3 SOIL SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in milligrams per kilogram.)

Parameter	Location (depth in feet)											
	Borings									Monitoring Well Boreholes		
	B 3-A			B 3-B			B 3-C			GW 3-A	GW 3-B	GW 3-D
	0 - 1.5	2.5 - 4	5 - 6.5	0 - 1.5	2.5 - 4	5 - 6.5	0 - 1.5	2.5 - 4	5 - 6.5	5 - 6.5	5 - 6.5	5 - 6.5
Purgeable Halocarbons												
1,1,1-Trichloroethane		0.017	0.083									
Purgeable Aromatics												
Toluene	0.018											
o-Xylene	0.057	0.73	0.47									
Pesticides and PCBs												
delta-BHC									0.002	0.002		
4,4'-DDD				0.41	2.1				0.003			
4,4'-DDE								0.09	0.008	0.02		
4,4'-DDT	0.01			0.08			0.10	0.11	0.06	0.04		0.007
Oil and Grease	8800	7200	1600	190	90	50	1100				90	1700
Barium	39	45	45	54	49	34	48	39	29	35	50	65
Cadmium												
Chromium	22	20	20	20	25	26	17	23	15	24	17	20
Lead							17					

Data from Dames & Moore, 1987.

TABLE 1-12

PARAMETERS DETECTED IN SITE 3 SEDIMENT SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in milligrams per kilogram.)

	Surface Sample Location		
	SS-3A	SS-3B	SS-3C
Purgeable Halocarbons			
Chloroform			0.0053
1,1-Dichloroethane	0.016	0.033	
1,1-Dichloroethene	0.0075	0.018	
Trans-1,2-Dichloroethene	0.14	0.0029	
Tetrachloroethene		0.0019	
1,1,1-Trichloroethane	0.0042	1.5	0.013
Trichloroethene (TCE)	0.010	0.026	0.0053
Vinyl Chloride	0.027		
Purgeable Armoatics			
Toluene	0.014		
Pesticides			
Endosulfan Sulfate	0.31	0.06	
Arochlor	1.1	0.17	0.04
Oil and Grease	1,200	270	30
Arsenic	19	14	16
Barium	100	51	37
Cadmium	7	3	1
Chromium	25	20	16
Lead	77	5.7	
Mercury	0.1		

Data from Dames & Moore, 1987.

TABLE 1-13

PARAMETERS ANALYZED IN SITE 3 WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

Parameter Analyzed	Method Used
Purgeable Halocarbons	EPA 601
Purgeable Aromatics	EPA 602
Pesticides	EPA 608
Herbicides	EPA 615
Oil and Grease	EPA 413.2
Phenolics	EPA 420.2
Arsenic	EPA 206.2
Barium	EPA 208.1
Cadmium	EPA 213.1
Chromium	EPA 218.1
Lead	EPA 239.2
Mercury	EPA 245.1
Selenium	EPA 270.2
Silver	EPA 272.1

Data from Dames & Moore, 1987.

TABLE 1-14
PARAMETERS DETECTED IN SITE 3 WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in micrograms per liter unless otherwise specified.)

Parameter	Location						
	Surface Samples			Monitoring Wells			
	SW 3-A	SW 3-B	SW 3-C	GW 3-A	GW 3-B	GW 3-C	GW 3-D
Purgeable Halocarbons							
Bromodichloromethane	0.87						
Chloroethane							0.7
Chloroform		1.6	1.4		3.6		2.3
1,1 Dichloroethane	6.8	36	37		310	83	97
1,2 Dichloroethane		3	2.8		4.7		1.9
1,1 Dichloroethene	5.7	35	26		30	0.69	47
Tetrachloroethene	10	10	8.1		490	430	1,000
Trans-1,2-Dichloroethene	82	70	55		35	260	68
1,1,1 Trichloroethane	25	1,400	970		1,900	83	1,400
Trichloroethene	740	570	350		4.4	31	4.4
Vinyl Chloride	6	4.8	3				9.1
Purgeable Aromatics							
Toluene					36		
Phenolics					16	12	
Oil and Grease (mg/L)	1						
Arsenic (mg/L)		0.02					
Barium (mg/L)		0.6	0.1	0.4	1		0.5
Cadmium (mg/L)		0.014	0.06				
Chromium (mg/L)		0.2		0.3	0.71	0.01	0.2
Lead (mg/L)	0.04	0.76	0.14		0.03		

Data from Dames & Moore, 1987.

investigations and their results are summarized. Figure 1-11 is an aerial photograph of Site 4.

1.2.6.1 Description

The area is about 15 acres in size, lies at an altitude of between 1,410 and 1,420 feet NGVD, and is comprised of grassy areas, roadways, and some marshy areas. It is south of the east-west taxiway, and abuts Site 3 to the west and Site 8 to the east.

There are three above ground storage tanks for the storage of JP-4 jet fuel with ancillary piping, pumps, loading and unloading facilities, and several small buildings. Two of the storage tanks have a capacity of 420,000 gallons (10,000 barrels) and one has a capacity of 210,000 gallons (5,000 barrels). Each above ground tank has a berm around it designed to contain 110 percent of the tank's capacity.

No workers are present on this site on a full-time daily basis. Workers are present to transfer jet fuel from delivery trucks to the storage tanks and from the storage tanks to fueling trucks. Maintenance of pumps and facilities is required, and workers also maintain the grounds and keep the grass mowed. The site is reached from Washington Street which is open to the public. The facility itself is entirely fenced and access is controlled by locked gates.

1.2.6.2 History

The storage tanks were built in the 1950s. A suspected leak was detected in 1980 approximately 150 feet from Tank No. 3. Diesel Fuel No. 2 oil was observed during repair of a waterline at a depth of 6 to 7 feet. This leak was observed about 100 feet outside the bermed area. The 210,000-gallon tank was taken out of service in 1982. The two larger capacity tanks are still in use.

1.2.6.3 Previous Investigations

This site was defined during the Phase I Records Search (ES, 1982).

A Phase II, Stage 1 Investigation was conducted in the fall of 1983 (Weston, 1984). Twenty soil borings ranging in depth from 6 to 16 feet were drilled into the water table. All borings were drilled by hollow stem auger with sample collection by split-spoon. Temporary well points were installed in the boreholes. Each well point and the water surface in the drainage ways around the site were surveyed to an arbitrary datum on site to obtain relative altitudes. After ground-water flow patterns were established, four permanent monitoring wells, MW 8 through MW 11 were installed in four of the temporary

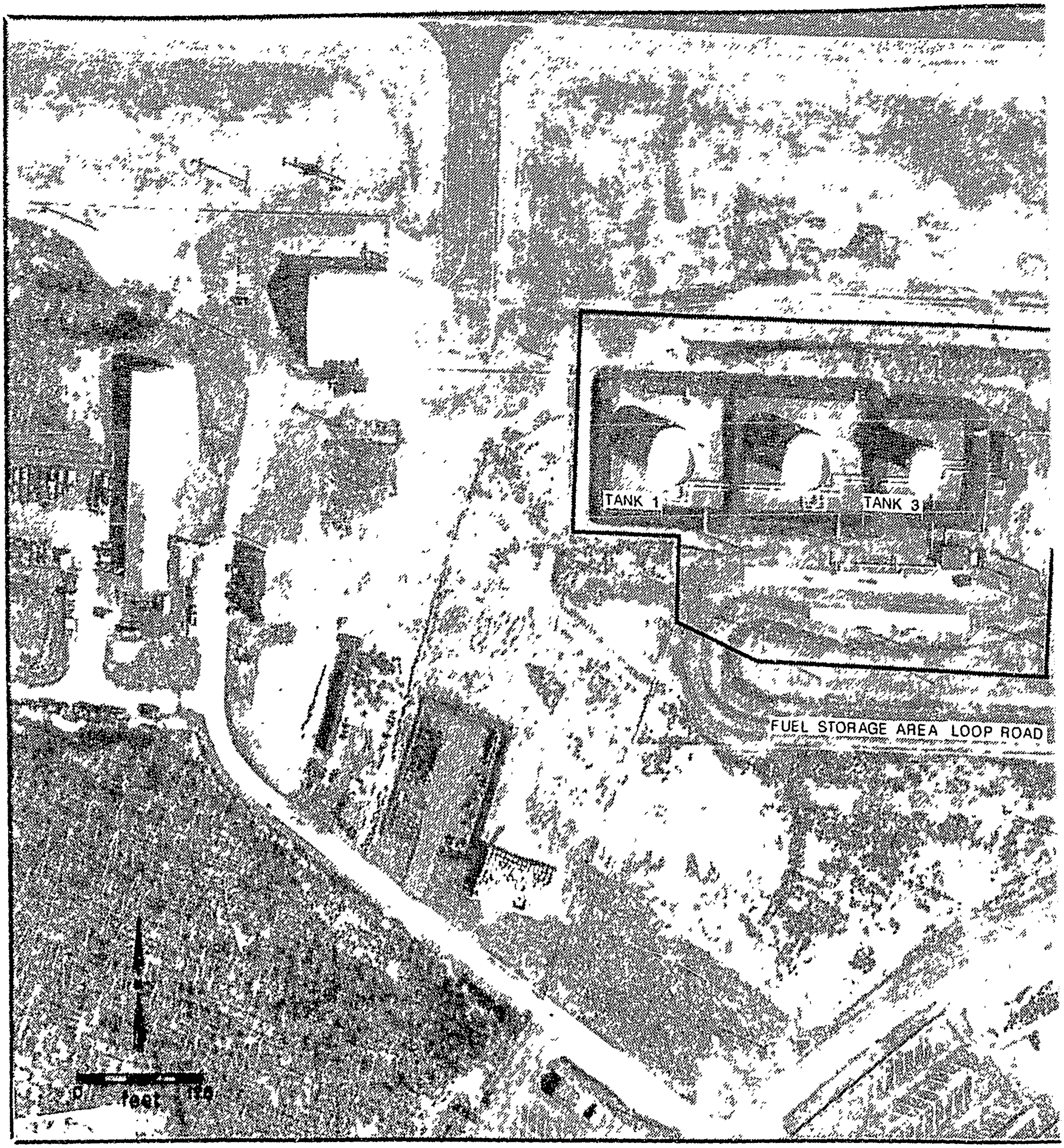
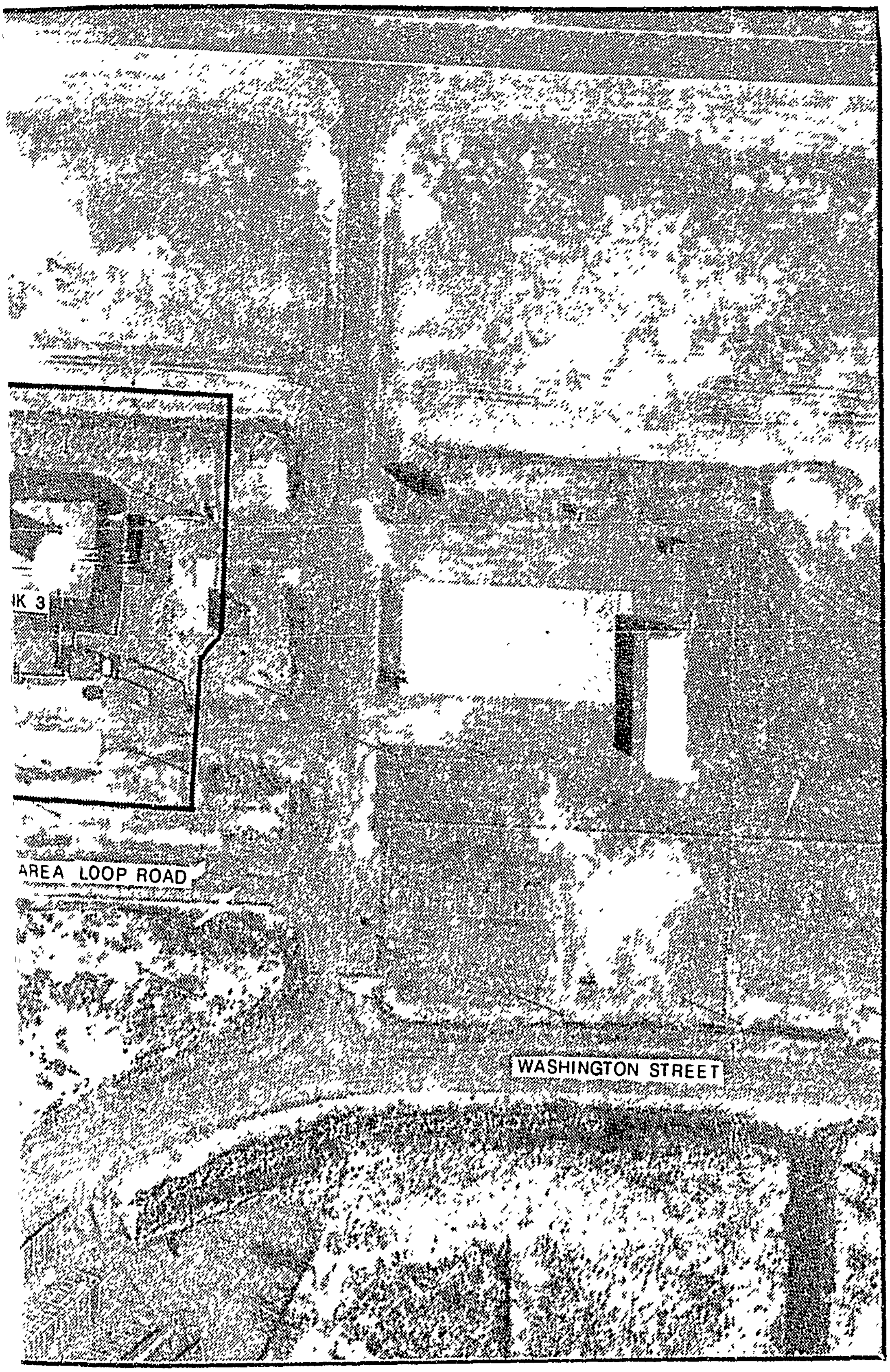


Figure 1-11 Aerial Photograph of Site 4, April, 1988.



EXPLANATION

☐ Approximate boundary for Fuel Storage Area (Fenced Area).

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well points. All sampling locations are shown on Figure 1-12. Two test pits were dug with a backhoe in areas suspected to be discrete avenues of contaminant migration.

Ground-water samples from the four monitoring wells, one water sample from Test Pit 2 (Test Pit 1 was dry) and two surface water samples from the drainage ditch were analyzed for total organic carbon (TOC), oil and grease and lead. Field measurements were taken for temperature, pH and specific conductance. The results of the analyses are given in Table 1-15.

Total organic carbon and oil and grease were found in all samples, but evidence of specific leak was not detected nor was an area of contamination defined. It concluded that the water levels in wells drilled indicated an overall ground-water flow to the northwest and that surface water was controlled by man-made drainageways.

A Phase II, Stage 2 Investigation was conducted in the fall of 1986 (Dames & Moore, 1987). Site 4 was surveyed using a metal locator and electromagnetics (EM) in order to determine the locations of buried pipes and to identify possible places where the pipes might be leaking. The survey extended 50 feet to the west, north, and east of the fence surrounding the storage tanks and southward to the Site 3 access drive and to Washington Street.

Nine boreholes were drilled and monitoring wells constructed in four of them. Three samples were obtained from each borehole at depths of from 2.5 to 4 feet, from 5 to 6.5 feet and from 7.5 to 9 feet. Four surface soil samples were collected. The sampling locations are shown on Figure 1-11. The soil samples were analyzed for the parameters listed in Table 1-16. The analyses results are shown on Table 1-17.

Twelve water samples were obtained. Ground-water samples were taken from each of the Phase I and Phase II, Stage 2 monitoring wells and at four surface sampling sites. Their locations are shown on Figure 1-12. These samples were analyzed for the same parameters as the soil samples, see Table 1-16.

No analytes were found in the water samples from the newly constructed monitoring wells and very few at low levels were found in the Phase II Stage 1 Wells. Some analytes were found in the surface water samples. The results are given in Table 1-18.

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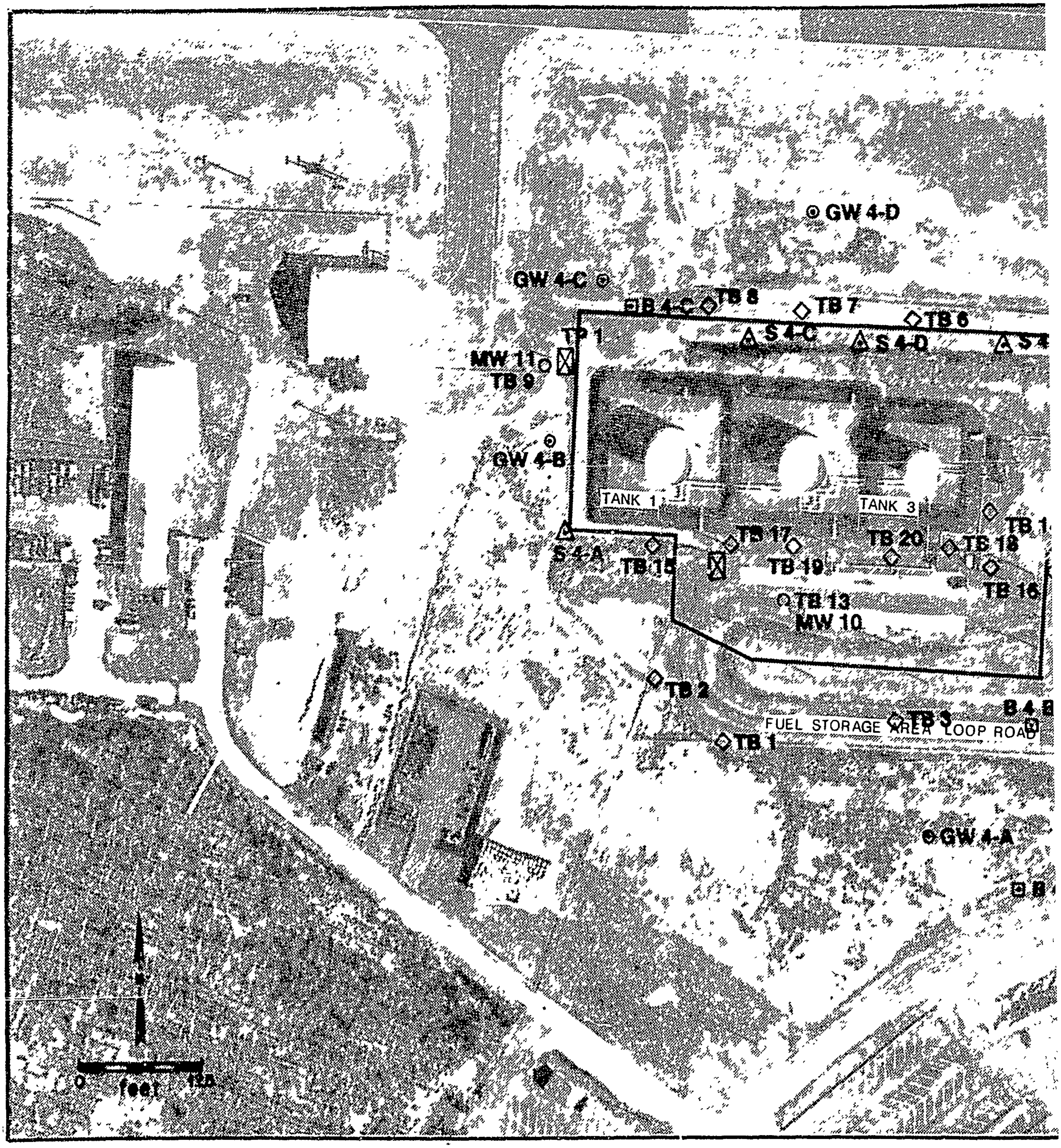
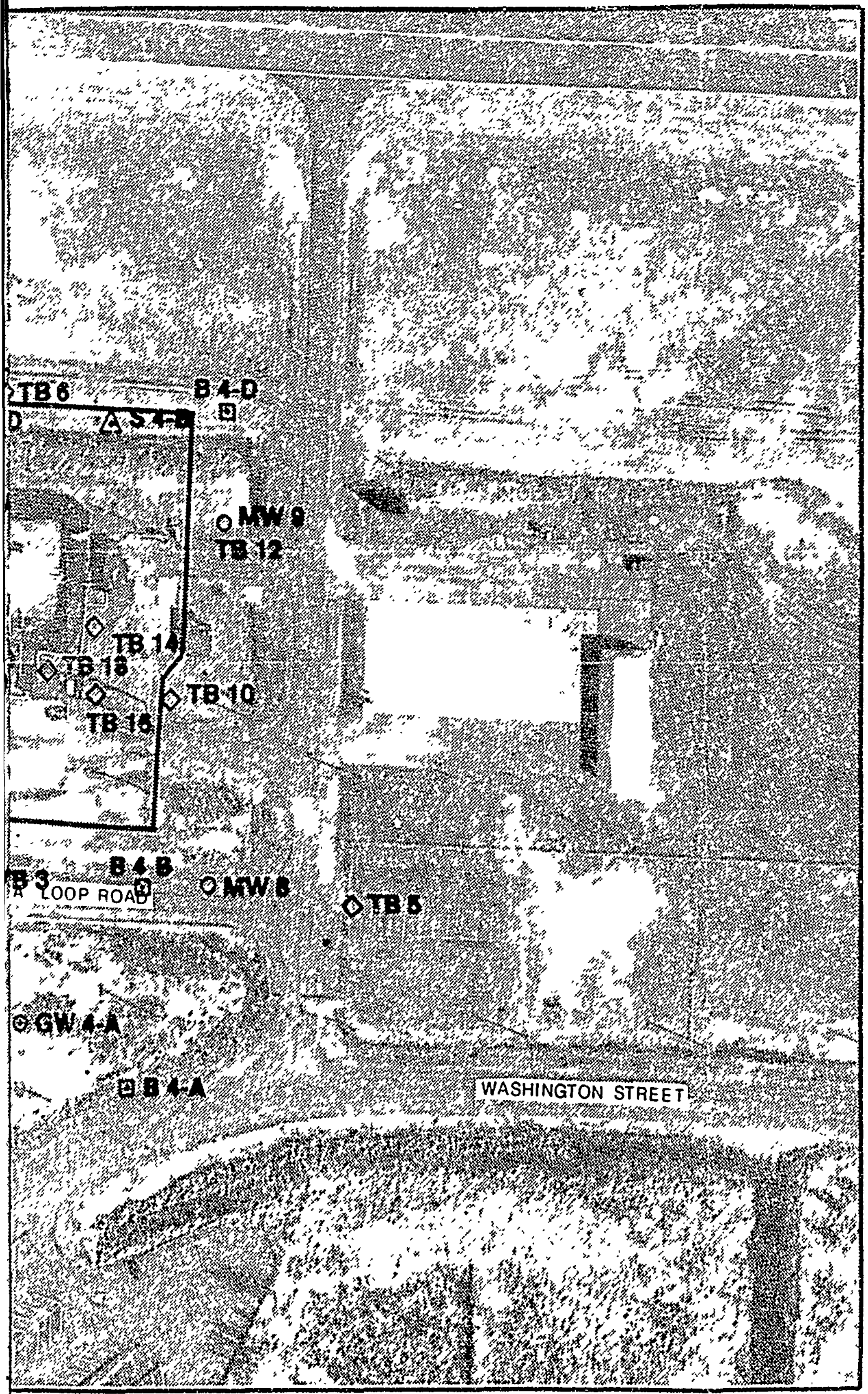


Data from Weston, 1984 and Dames & Moore, 1987.

Figure 1-12 Site 4 Sampling Locations Utilized during Phase II Investigations.



EXPLANATION

⊡	B 4A	Soil Boring Phase II Stage 2.
⊙	GW 4-D	Monitoring Well Phase II Stage 2
◇	TB 6	Temporary Well Point Phase II Stage 1.
○	MW 9	Monitoring Well Phase II Stage 1.
☒	TP1	Test Pit Phase II Stage 1.
△	S 2 C	Surface location Phase II Stage 2
☐		Approximate boundary for Fuel Storage Area (Fenced Area).

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TABLE 1-15

PARAMETERS ANALYZED AND DETECTED IN SITE 4 WATER SAMPLES DURING THE PHASE II, STAGE 1 INVESTIGATION

(Results in milligrams per liter unless otherwise specified.)

Parameter	Method Used	Location						
		Monitoring Wells				Test Pit	Drainage	
		MW 8	MW 9	MW 10	MW 11	TP 2	S 1	S 2
Total Organic Carbon (TOC)	EPA 450.1	49.3	70.0	49.0	17.0	140	<1.0	20.5
Oil and Grease	EPA 413.2	0.36	1.46	49.80	<0.10	3240	47.20	48.00
Lead	EPA 239.2	<0.020	<0.020	<0.020	<0.020	0.031	<0.020	<0.020
pH (standard units)	Field measurement	6.9	7.25	7.18	6.55			
Specific Conductance (umhos/cm)	Field measurement	578	782	608	716			

Data from Weston, 1984.

TABLE 1-16

PARAMETERS ANALYZED IN SITE 4 SOIL SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

Parameter Analyzed	Method Used
Halogenated Volatile Organics	EPA 8010
Aromatic Volatile Organics	EPA 8020
Oil and Grease	EPA 413.2

Data from Dames & Moore, 1987.

TABLE 1-17

PARAMETERS DETECTED IN SITE 4 SOIL SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in milligrams per kilogram.)

Location	Depth (Feet)	Halogenated Volatile Organics		Aromatic Volatile Organics				
		Methylene Chloride	Tetrachloroethene	Benzene	Ethyl Benzene	Toluene	O-Xylene	Oil and Grease
SS 4-A								1200
SS 4-B				16	400	49	35	2800
SS 4-C					2.8		5.8	2500
SS 4-D				2.3		9.2	29	
B 4-A	2.5 - 4							6500
	5 - 6.5							2000
	7.5 - 9					0.028	0.58	830
B 4-B	2.5 - 4			6.2	12	25	315	6500
	5 - 6.5					8.1	70	1300
	7.5 - 11.5					0.013	0.1	28
B 4-C	2.5 - 4							540
	5 - 6.5							48
	7.5 - 9							
B 4-D	2.5 - 4							100
	5 - 6.5							540
	7.5 - 9							110
B 4-E	2.4 - 4							
	5 - 6.5							
GW 4-A	10 - 11.5							740
GW 4-B	5 - 6.5		0.023					240
GW 4-C	10 - 12							96
GW 4-D	5 - 6.5	0.29						3500

Data from Dames & Moore, 1987.

TABLE 1-18
PARAMETERS DETECTED IN SITE 4 WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in micrograms per liter unless otherwise specified.)

	Location							
	Monitoring Well				Surface Water			
Parameter	MW 8	MW 9	MW 10	MW 11	SW 4-A	SW 4-B	SW 4-C	SW 4-D
Purgeable Halocarbons								
Chlorobenzene						0.98	2.2	
Methylene Chloride					2.1	2.3	2.8	3.5
Trans-1,2-Dichloroethene			5.8			4	4.4	2.2
1,1,1 Trichloroethane							19	10
Trichloroethene						22	16	9.6
Trichlorofluoromethane	5.5							
Purgeable Aromatics								
Benzene						15	89	6.8
Chlorobenzene						1.6	2.8	
Toluene							2	
m-Xylene							73	
Oil and Grease (mg/L)		2				1	2	

Data from Dames & Moore, 1987.

1.2.7 Description and History of Site 8

In this section, Site 8 is described, its history given, previous investigations are described and their results are summarized. Figure 1-13 is an aerial photograph of Site 8.

1.2.7.1 Description

Site 8 consists of about 15 acres. It is a nearly level grassy area of about 1,410 feet altitude above NGVD with some scrub bushes and trees along the surface drainage. It is just east of Site 4, south of the east-west taxiway, and extends south to a drainage ditch running along the southern boundary of the airport. The northeast corner of the site includes an unused apron. An unused quonset hut and unused paved parking lot occupy part of the western side and a building now used for metal plating is on the southeast side.

About five workers occupy the plating facility on a full-time, daily basis. Grass at the site is kept mowed. Washington Street forms the south boundary of the site and about five hundred feet south of it is a residential trailer park which abuts the airport boundary. The northern half of the site is fenced while the southern half of the site is unfenced and open.

1.2.7.2 History

The central part of the Site 8 area was the base salvage yard and Defense Procurement Disposal Office (DPDO) storage yard from 1950 to 1964. Materials handled through this area included DDT drums, waste fuel oil and solvents, and PCB transformers (ES, 1982). The exact boundaries of the storage area are unknown. It is suspected that at least minor leakage of drums did occur.

1.2.7.3 Previous Investigations

The site was identified during the Phase I records search (ES, 1982).

No work was done on this site during Phase II, Stage 1 investigations.

A Phase II, Stage 2 investigation was conducted in 1986 (Dames & Moore, 1987). Two soil sampling boreholes and three monitoring well boreholes were drilled. Two surface sampling locations were established. All locations are shown on Figure 1-14.

Three samples were collected from each of the soil sampling boreholes, at depths of from 0 to 1.5 feet, from 2.5 to 4 feet and from 5 to 6.5 feet. One soil sample was collected from each of the monitoring well boreholes. The soil samples were analyzed for the parameters given in Table 1-19. The sample depths and analysis results are given on Table 1-20.

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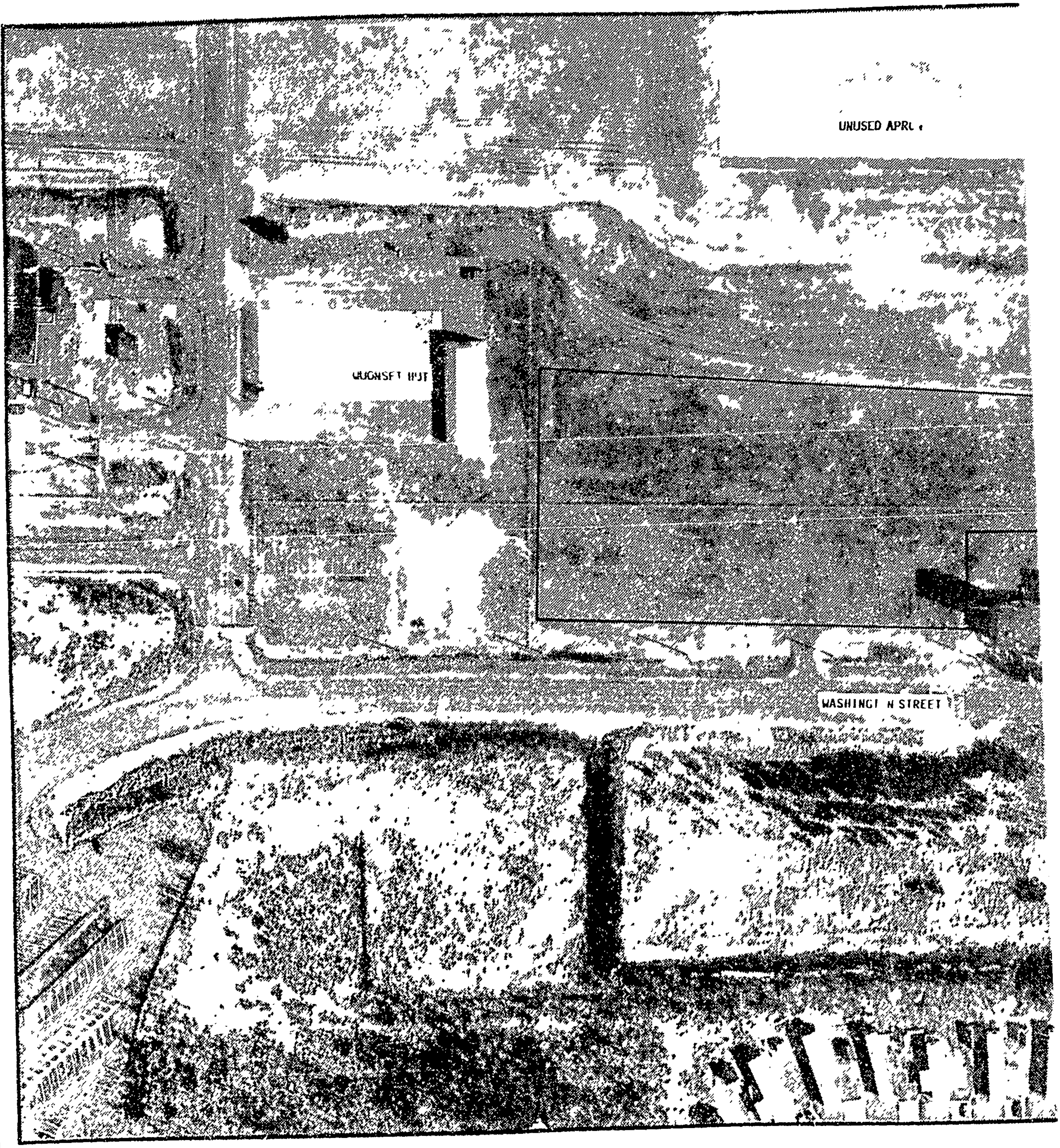
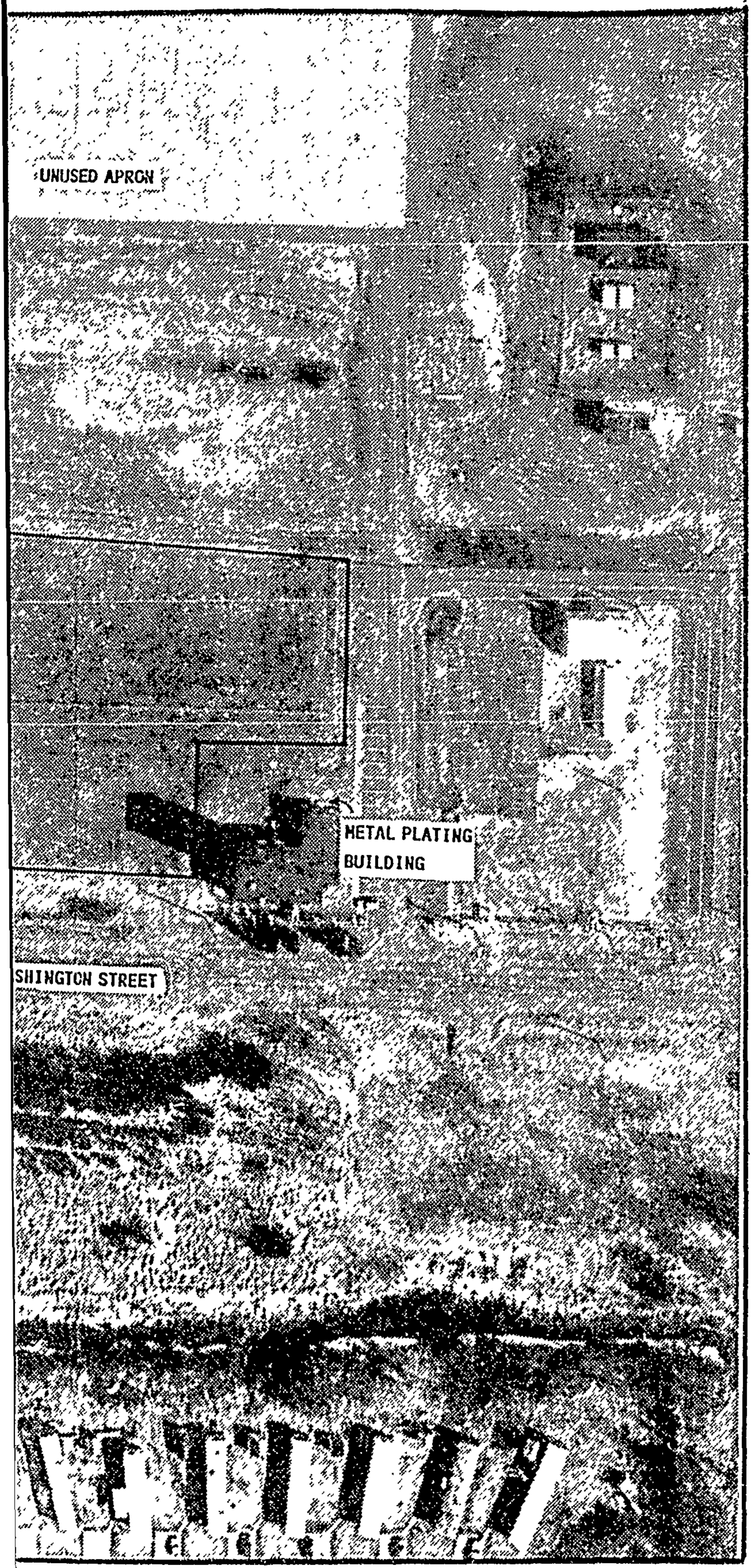


Figure 1-13 Aerial Photograph of Site 8, April, 1988.



EXPLANATION

☐ Approximate boundary of Storage Area (old DPDO office).

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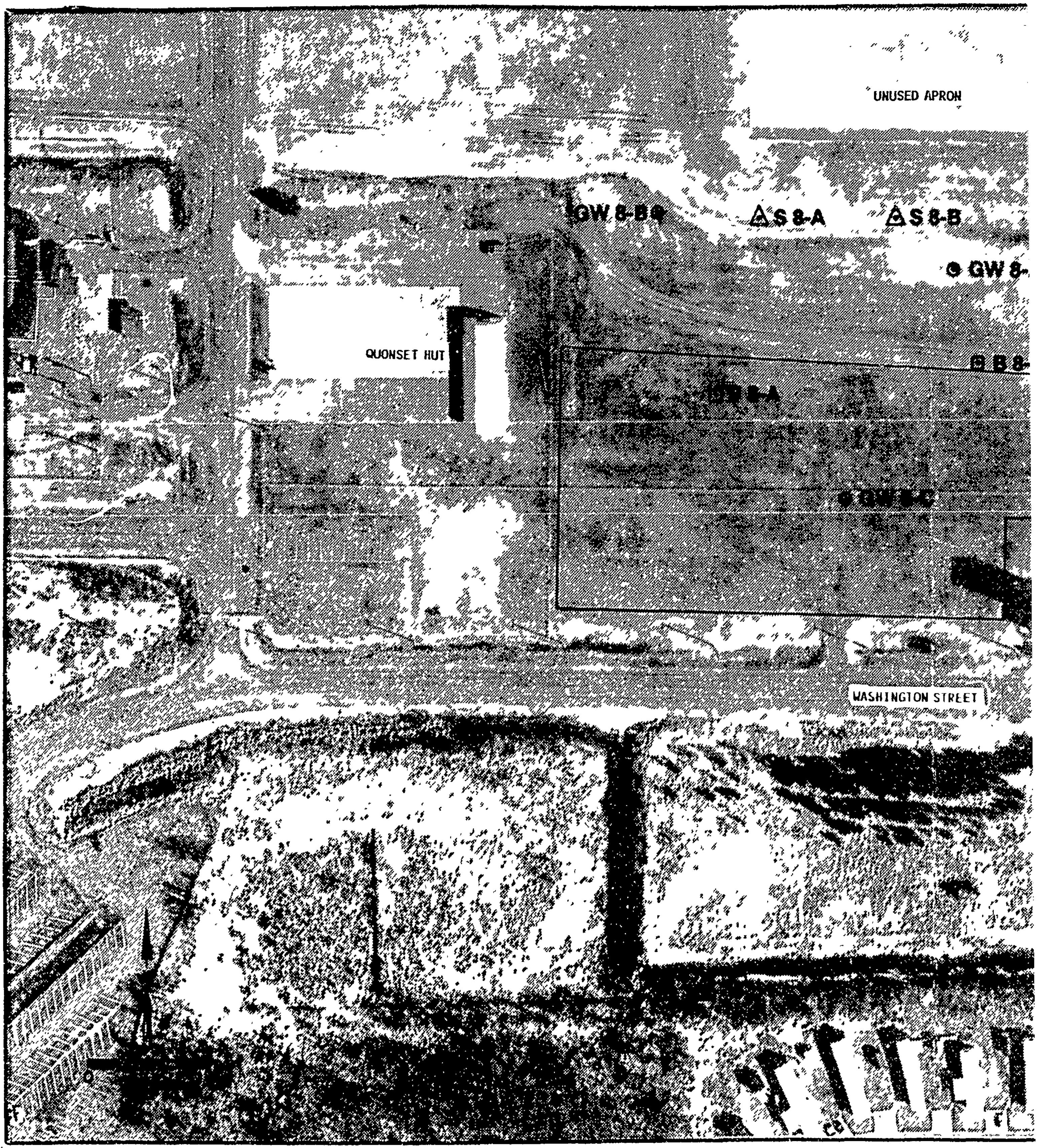
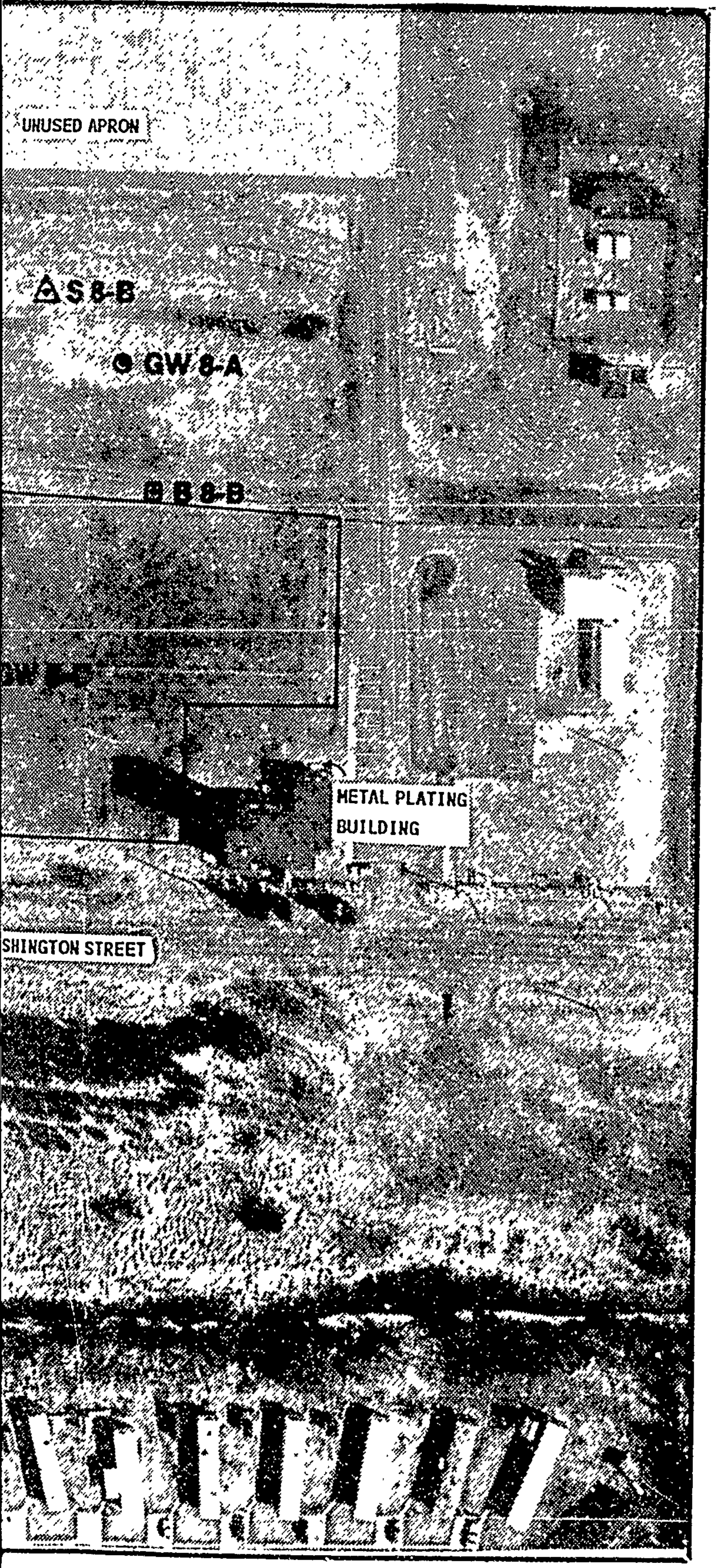


Data from Dames & Moore, 1987.

Figure 1-14 Site 8 Sampling Locations Utilized During Phase II, Stage 2 Investigations.



EXPLANATION

⊡ B 8-A
Soil Boring, Phase II Stage 2.

◎ GW 8-A
Well, Phase II Stage 2.

△ S 8-A
Surface Location
Phase II Stage 2.

▭ Approximate boundary of Storage Area (old DPDO office).

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TABLE 1-19

PARAMETERS ANALYZED IN SITE 8 SOIL AND WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

Parameter Analyzed	Method Used
Halogenated Volatile Organics	SW 8010
Aromatic Volatile Organics	SW 8020
Pesticides and PCBs	EPA 3550/8080
Herbicides	EPA 8150
Oil and Grease	EPA 413.2
Phenolics	EPA 420.2
Arsenic	EPA 3050/7060
Barium	EPA 200.7
Cadmium	EPA 200.7
Chromium	EPA 200.7
Lead	EPA 200.7
Mercury	EPA 7471
Selenium	EPA 3050/7740
Silver	EPA 200.7

Data from Dames & Moore, 1987.

TABLE 1-20

PARAMETERS DETECTED IN SITE 8 SOIL SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in milligrams per kilogram.)

Parameter	Location (depth in feet)										
	Borehole Samples						Monitoring Well Borehole Samples			Sediment Samples	
	B 8-A			B 8-B			GW 8-A	GW 8-B	GW 8-C	SS 8-A	SS 8-B
	0 - 1.5	2.5 - 4	5 - 6.5	0 - 1.5	2.5 - 4	5 - 6.5	5 - 6.5	10 - 11.5	10 - 11.5		
Purgeable Aromatics											
Toluene											41
Pesticides											
Arochlor 1254											2.30
delta-BHC										0.001	
4,4'-DDD				0.007							
4,4'-DDE				0.008							
Endosulfan 1											0.04
Oil and Grease	350			94	44	160			180	100	3200
Barium	200	73	85	48	25	51	71	32	63	70	100
Chromium	21	35	40	20	7.7	24	33	13	13	27	48
Lead				18							190

Data from Dames & Moore, 1987.

Some contamination was detected in the soil samples (Table 1-20). Toluene was detected in one surface soil sample. Arochlor 1254 was found in one surface sample and the pesticides, 4,4'-DDD and 4,4'-DDE, were detected at low levels near the surface in another sample. Oil and grease were detected in the surface and near surface samples, but in only one out of five deep samples. Barium and chromium were found in all samples at all depths. Lead was detected in two surface and near-surface samples.

Five water samples were obtained. One water sample was taken from each of the monitoring wells, and one from each of the two surface sampling sites. The water samples were analyzed for the parameters given in Table 1-19. The analysis results are given in Table 1-21. Some contamination was detected. Two halogenated volatile organics, dichloromethane and trichlorofluromethane, were found in one ground water sample. One aromatic volatile organic, toluene, was found in one surface water sample. The pesticide 4,4'-DDD was found in both surface water samples. Lead was found in the two surface water samples and both barium and chromium were detected in all three ground-water samples.

1.2.8 Description and History of Site 10

In this section, Site 10 is described, its history given, previous investigations are described and their results given. An aerial photograph is shown in Figure 1-15.

1.2.8.1 Description

This site is about 15 acres in size and is about 1,410 feet in altitude above NGVD. It lies north of the airport perimeter road, north of the main east-west runway, east of a drainage ditch which flows into Beaver Creek and west of a Federal Aviation Administration (FAA) radar facility. It lies south and southeast of the fenced area containing Buildings 511 and 513. Building 513 has been used to store hazardous materials since 1981. Building 511 is a PCB storage facility (ES, 1982).

This site was known to be located near Building 511. As identified in Phase I and studied in Phase II, Stage 1, it was thought to occupy the area south of the fence around Building 511, and lie between the drainage ditch and the Building 511 access road. In this study, the area is enlarged to include the area east of the access road lying to the south and southeast of

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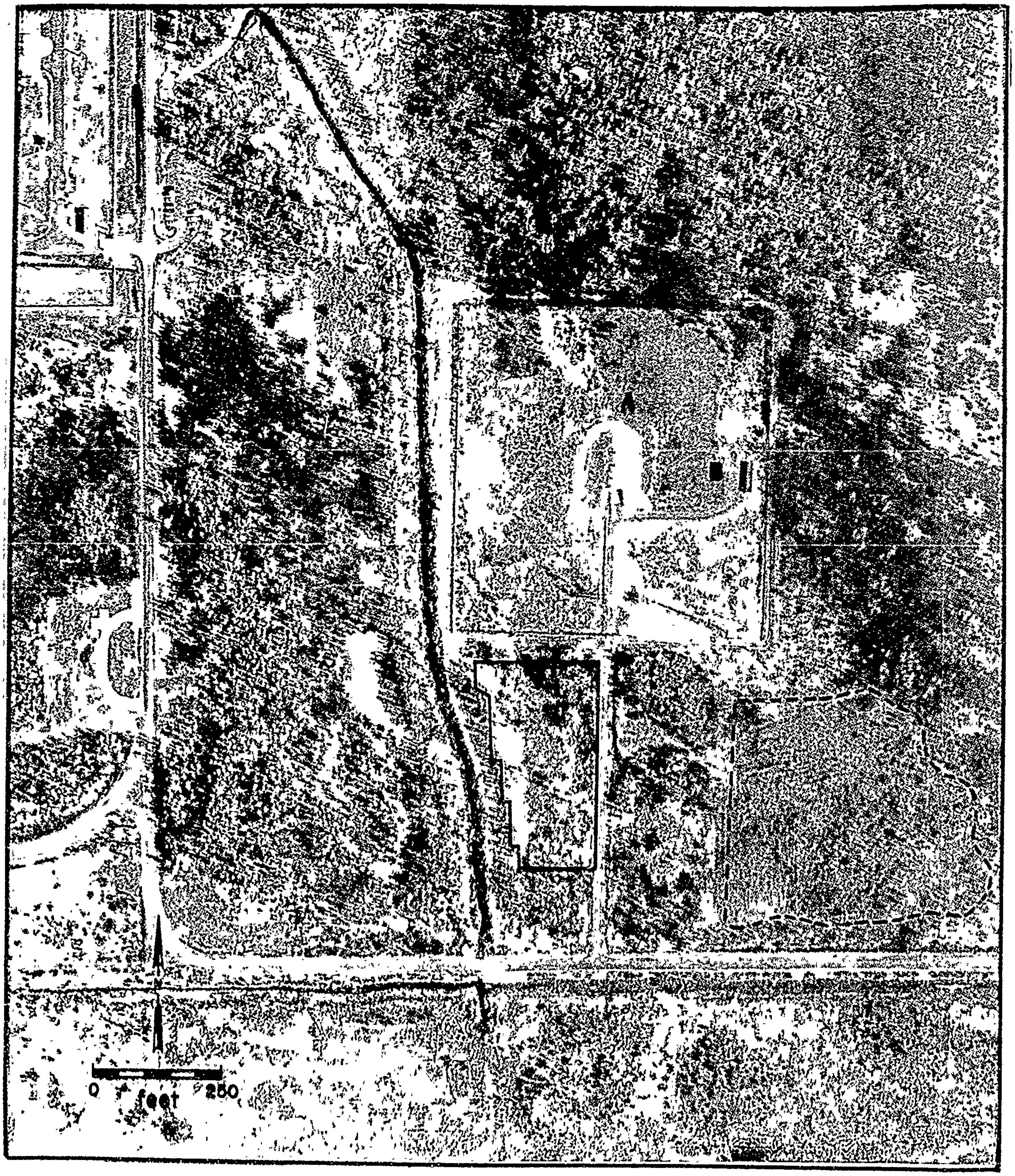

Figure 1-15 Site 10 Aerial Photograph, April 1988.

EXPLANATION

▭	General location of Phase II, Stage 2 geophysical survey.
⬚	Suspected new location of Site 10.
A	Building 511.
B	Building 513.

TABLE 1-21

PARAMETERS DETECTED IN SITE 8 WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in micrograms per liter unless otherwise specified.)

Parameter	Location				
	SW 8-A	SW 8-B	GW 8-A	GW 8-B	GW 8-C
Purgeable Halocarbons					
Methylene Chloride				2.8	
Trichlorofluoromethane				1.2	
Purgeable Aromatics					
Toluene		6.5			
Pesticides					
4,4'-DDD	0.009	0.003			
4,4'-DDT		0.01			
Oil and Grease (mg/L)		7			
Barium (mg/L)			0.3	0.5	1.0
Chromium (mg/L)			0.10	0.30	0.52
Lead (mg/L)	0.04	0.03			

Data from Dames & Moore, 1987.

Building 511. The original area is about four acres in size and contains trees with some slightly marshy areas. The area to the east of the access road is about 15 acres. The area just east of the access road also contains trees and some marshy areas, and further to the east is an area which has disturbed ground with only low vegetative growth.

There are no facilities on this site. About 10 to 15 workers use the perimeter road to drive past this site on a daily basis. Workers also use the Building 511 access road on an irregular basis. Site 10 is not near an airport boundary and is not easily accessible to any but Air National Guard personnel.

1.2.8.2 History

In the 1950s, low level radioactive materials such as cathode ray tubes, scopes and watch dials were disposed of in a 15-foot deep trench which was approximately forty feet long. These waste materials were covered with general refuse and local soil material.

1.2.8.3 Previous Investigations

The existence but not the exact location of this site was identified during the Phase I records search (ES, 1982).

No work was done on this site during Phase II, Stage 1 investigations.

A Phase II, Stage 2 investigation was conducted in 1986 (Dames & Moore, 1987). A geophysical field survey was conducted in the area shown on Figure 1-16 and three monitoring wells were installed.

The geophysical magnetic survey was done on the area originally described as Site 10. Total magnetic field intensity values were obtained for each survey grid location. The intent was to determine the location of the radioactive waste dump by locating the iron and steel associated with the radioactive sources. The results of the survey indicated that perhaps only 100 pounds or so of ferrous material is present if it is very near the surface. None of the anomalies are very broad, which would be a sign of larger mass at greater depth.

Three boreholes were drilled and monitoring wells were constructed in them. Water level measurements were obtained and the well locations were surveyed.

One water sample was taken from each monitoring well. The monitoring well locations are shown on Figure 1-16. The results of the water sample analyses are given in Table 1-22.

Data from Dames & Moore, 1987.

Figure 1-16 Site 10 Sampling Locations Utilized during the Phase II, Stage 2 Investigation.

EXPLANATION

GW 10-C	Phase II, Stage 2 monitoring well.
▭	General location of Phase II, Stage 2 geophysical survey.
⬚	Suspected new location of Site 10.
A	Building 511.
B	Building 513.

TABLE 1-22

PARAMETERS ANALYZED AND DETECTED IN SITE 10 GROUND-WATER SAMPLES DURING THE PHASE II, STAGE 2 INVESTIGATION

(Results in picocuries per liter.)

Parameter	Method	GW10-A	GW10-B	GW10-C
Gross Alpha	SM 703	8 ± 6	18 ± 8	8 ± 5
Gross Beta	SM 703	6 ± 3	12 ± 3	9 ± 3
Radium 226	SM 706	3.4 ± 2.0	5.0 ± 2.8	N.D.
Radium 228	SM 708	N.D.	N.D.	N.D.

N.D. = None Detected.
Data from Dames & Moore, 1987.

The ground-water sample from one location exceeded the National Primary Drinking Water Standard of 15 picocuries per liter for gross alpha. Samples from two locations exceeded the standard of 5 picocuries per liter for total radium. The upper range of radium 226 was above the limit, while radium 228 was not detected.

The report suggested that the location of the radioactive waste burial pit was not between the drainage ditch and the access road, but rather lay to the east of the road.

SECTION 2
REMEDIAL INVESTIGATION DESCRIPTION

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SECTION 2
REMEDIAL INVESTIGATION DESCRIPTION

This section gives a brief overview of the total work performed and then describes the work performed at each site. The site locations are shown on Figure 1-6.

The Remedial Investigation consisted of the following: discussions with base personnel on details of site locations; acquisition and examination of aerial photographs; pace and compass surveying; soil gas surveying; trenching; lithologic descriptions; soil sampling; grain size analysis; construction of monitoring wells; installation of well points; ground-water sampling; surface water sampling; aquifer slug tests; water level measurements; streamflow measurements; and surveying. A summary of the type of work done at each site is given in Table 2-1.

A total of 52 boreholes were drilled and a total of 330 soil, water, sediment and quality control samples taken for analysis. The number of types of both boreholes and samples is given in Table 2-2.

The field investigation was performed in three segments. The first segment occurred July 5 to July 15, 1988 and consisted of initial mobilization, soil gas sampling at Site 3 and shallow soil sampling at Site 8. The second segment occurred from July 25 to September 23, 1988 and included all drilling, all other field work and all other first round sampling. The third segment occurred from February 25 to March 1, 1989 and consisted of a second round of ground-water sampling at Site 10 and water level measurements at all wells.

2.1 AREA LOCATIONS

Area data were obtained to establish background and airport baseline information against which site specific information could be compared. The work consisted of surface water and sediment investigations, a geological investigation, a soil investigation and a ground-water investigation. Five surface locations consisting of one background and four airport locations were sampled. Three monitoring wells were constructed and sampled at background locations. The locations are shown on Figure 2-1. A summary of the work performed at each location is given in Table 2-3.

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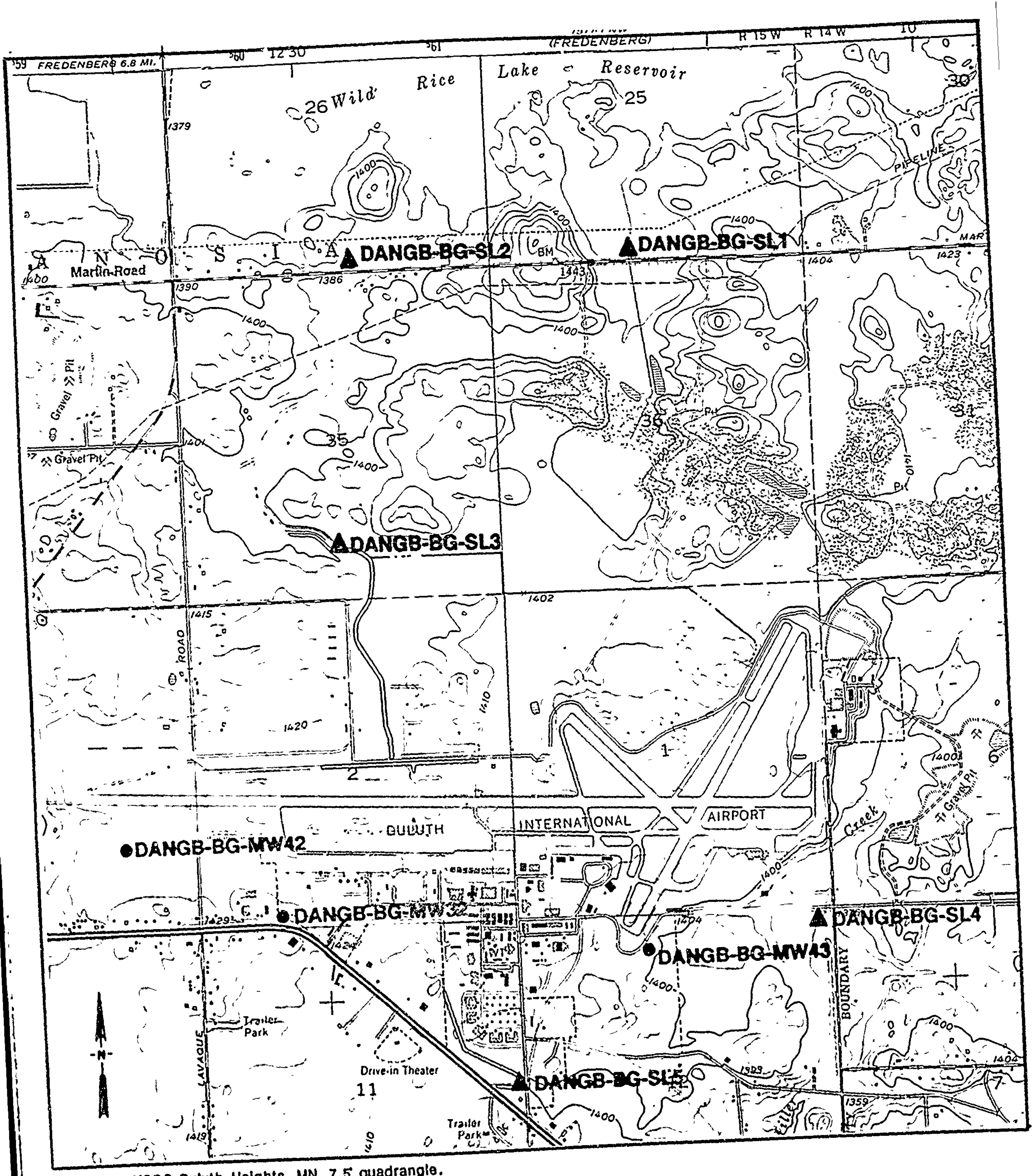


Base from USGS Duluth Heights, MN, 7.5' quadrangle.

Figure 2-1 Airport Area Sampling locations utilized during Remedial Investigations.

EXPLANATION

● DANGB-BG-MW42
Monitoring Well Remedial Investigation

▲ DANGB-BG-SL4
Surface water and sediment sampling location

0 2000
FEET

TABLE 2-1

SUMMARY OF REMEDIAL INVESTIGATION WORK BY SITE

Name of Report Section	Type of Work	Site 2	Site 3	Site 4	Site 8	Site 10	Area
Surface Investigation	Discussions with Base personnel on site locations	X					
	Examination of historical aerial photographs	X				X	
	Pace and compass surveying	X					
	Surveying	X	X	X	X	X	X
Surface water and Sediment Investigations	Surface water sampling	X	X	X	X		X
	Streamflow measurements			X			X
	Sediment sampling	X	X	X	X		X
Geological Investigations	Lithologic descriptions	X	X	X	X		X
	Grain size analyses	X	X	X	X		X
Soil Investigations	Soil gas survey		X				
	Trenching	X					
	Shallow soil sampling		X		X		
	Deep soil sampling	X	X	X	X		X
Ground-Water Investigations	Monitoring well construction	X	X	X	X		X
	Well point construction	X		X	X		
	Ground-water sampling	X	X	X	X	X	X
	Aquifer slug tests	X	X	X	X		X
	Water level measurements	X	X	X	X	X	X

TABLE 2-2

DRILLING AND SAMPLING SUMMARY

Item	Number
Boreholes Drilled	
Soil Sample	7
Monitoring Wells	26
Well Points	19
Total	52
Samples Taken for Chemical Analysis	
Deep Soil	101
Shallow Soil	55
Surface Water	18
Sediment	19
Ground-Water	55[b]
Quality Control[a]	82[c]
Total	330

a. Includes duplicate, field blank, trip blank, and bailer rinseate samples.
b. Includes 3 second sampling round samples from Site 10.
c. Includes 1 duplicate second sampling round sample from Site 10.

TABLE 2-3

SUMMARY OF WORK PERFORMED AT AREA LOCATIONS

Location Identification	Monitoring Well Construction	Well Point Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
DANGB-BG-MW32	X		X		X	X						X	X			X
DANGB-BG-MW42	X		X		X	X						X	X			X
DANGB-BG-MW43	X		X		X	X						X	X			X
DANGB-BG-SL1										X	X		X	X		X
DANGB-BG-SL2										X	X		X	X		X
DANGB-BG-SL3										X	X		X			X
DANGB-BG-SL4										X	X		X	X		X
DANGB-BG-SL5										X	X		X			X

2.1.1 Surface Feature Investigation

Aerial photographs from 1951 to present were examined. The photographs were taken in 1951, 1952, 1960, 1961, 1965, 1979 and 1988.

2.1.2 Surface Water and Sediment Investigations

Both background and airport drainage locations were investigated to establish contaminant distribution patterns. The background drainage location, DANGB-BG-SL-4, was established to gain information on background surface water and sediment conditions in the airport vicinity. The airport drainage locations, DANGB-BG-SL1, DANGB-BG-SL2, DANGB-BG-SL3 and DANGB-BG-SL5, were established to measure any contaminant migration that may be occurring in surface waters that drain the airport.

The samples from these locations were analyzed for all the compounds, metals and radiological parameters which were targeted for analysis at any of the sites. A summary of the kinds and numbers of analyses performed on surface water samples is given in Table 2-4 and on the sediment samples is given in Table 2-5. Analysis results are given in Appendix L.

2.1.2.1 Background Surface Drainage Location

Surface water and sediments were sampled at location DANGB-BG-SL4. This location is about 1/3 mile south of the east end of the main east-west runway on Miller Creek (Figure 2-1).

The samples from this location were analyzed for all the compounds, metals and radiological parameters which were targeted for analysis on any of the sites.

Streamflow was measured at the time of sampling. The measurement was made using a pygmy current meter during baseflow conditions. A general description of this streamflow measuring technique is given in Appendix D. A detailed description is given in Appendix J.

2.1.2.2 Airport Surface Drainage Locations

Three surface drainage locations were picked to obtain samples of surface water draining the airport as a whole (see Figure 2-1) Two of these locations are north of the main east-west runway and one location is south of it. The two northern locations are on Martin Road about a mile and a half north of the east-west runway: location DANGB-BG-SL1 is on an Unnamed Drainage Ditch and location DANGB-BG-SL2 is on Beaver Creek. The location south of the airport is DANGB-BG-SL5 and is about one mile south of the main runway on a drainage ditch which is tributary to Miller Creek.

TABLE 2-4

CHEMICAL ANALYSES PERFORMED ON BACKGROUND AND AIRPORT AREA SURFACE WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	5	3[a]
Aromatic Volatile Organics	SW 8020	5	3
Semi-Volatile Organics	EPA 625	5	1[b]
Pesticides and PCBs	EPA 608	5	1
Metals			
Arsenic	SW 7060	5	1
Barium	SW 6010	5	1
Cadmium	SW 7131	5	1
Chromium	SW 7191	5	1
Lead	SW 7421	5	1
Mercury	SW 7470	5	1
Nitrates	EPA 353.2	5	1
Radiological			
Gross alpha	SW 9310	5	1
Gross beta	SW 9310	5	1
Radium 226	SW 9315	5	1
Tritium	EPA 906.0	5	1
Specific Conductance	EPA 120.1	5	1
Temperature	EPA 170.1	5	1
pH	EPA 150.1	5	1

a. Includes 1 duplicate, 1 field blank and 1 trip blank sample.
b. Duplicate sample.

TABLE 2-5

CHEMICAL ANALYSES PERFORMED ON BACKGROUND AND AIRPORT AREA SEDIMENT SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	5	1[a]
Aromatic Volatile Organics	SW 8020	5	1
Semi-Volatile Organics	SW 8270	5	1
Pesticides and PCBs	SW 8080	5	1
Total Petroleum Hydrocarbons	EPA 418.1	5	1
Metals			
Arsenic	SW 7060	5	1
Barium	SW 6010	5	1
Cadmium	SW 7131	5	1
Chromium	SW 7191	5	1
Lead	SW 7421	5	1
Mercury	SW 7471	5	1

a. Duplicate sample.

A fourth location, DANGB-BG-SL3 (Figure 2-1) is about 3/4 mile north of the main runway and is just downstream from a spillway from a small detention pond. Drainage ditches from Sites 10 and 2 drain into this pond. Other areas may also drain into the pond.

Streamflow was measured at the time of sampling at locations DANGB-BG-SL1 and DANGB-BG-SL2. The measurements were made using a pygmy current meter during baseflow conditions. A general description of this streamflow measuring technique is given in Appendix D. A detailed description of the technique is given in Appendix J.

2.1.3 Geological Investigation

The airport area geological investigation consisted of determining lithologic descriptions. These were done from the continuous cores obtained during drilling of the three background monitoring wells DANGB-BG-MW32, DANGB-BG-MW42 and DANGB-BG-MW43. None of these holes was drilled to bedrock. Their locations are shown on Figure 2-1.

Lithologic descriptions from the boreholes for background wells were used to aid in defining the aquifer system in the airport vicinity.

2.1.4 Soil Investigation

Three samples from each of the three area boreholes were chosen for chemical analysis. One sample was taken near the surface, one at the water table and one just above total borehole depth. The surface portion of one borehole was resampled for a total of ten samples. The analyses performed are listed in Table 2-6.

Results of this investigation were used to establish background soil conditions in the airport vicinity.

2.1.5 Ground-Water Investigation

This investigation consisted of water level measurements, surveying of the water level measuring points on all monitoring wells, and chemical analyses of ground-water samples.

2.1.5.1 Water Level Investigation

Water level measurements were taken at monthly intervals as field work proceeded. Wells were included in the water level measurements at the next sampling round after their completion. The number of measurements taken at each monitoring well is summarized in Table 2-7.

TABLE 2-6

CHEMICAL ANALYSES PERFORMED ON AREA BACKGROUND SOIL SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	10	1[a]
Aromatic Volatile Organics	SW 8020	10	1
Semi-Volatile Organics	SW 8270	10	1
Pesticides and PCBs	SW 8080	10	1
Total Petroleum Hydrocarbons	EPA 418.1	10	1
Metals			
Arsenic	SW 7060	10	1
Barium	SW 6010	10	1
Cadmium	SW 7131	10	1
Chromium	SW 7191	10	1
Lead	SW 7421	10	1
Mercury	SW 7470	10	1

a. Duplicate sample.

TABLE 2-7

SUMMARY OF WATER LEVEL MEASUREMENT ROUNDS AT AREA BACKGROUND MONITORING WELLS

Well Number	Number of Rounds
DANGB-BG-MW32	2
DANGB-BG-MW42	3
DANGB-BG-MW43	3

The locations and altitudes of the three monitoring wells and the five surface sampling locations were surveyed for use in constructing water table maps.

The water level data were used to aid in defining ground-water flow directions in the airport vicinity.

2.1.5.2 Ground-Water Sampling Investigation

Samples were obtained from the three background monitoring wells (Figure 2-1) and analyzed for all the compounds, metals and radiological parameters which were targeted for analysis on any of the sites with the exception of Radium 228. A summary of the kinds and numbers of analyses performed on the ground-water samples is given in Table 2-8.

Results of these analyses were used to establish background ground-water quality in the airport vicinity.

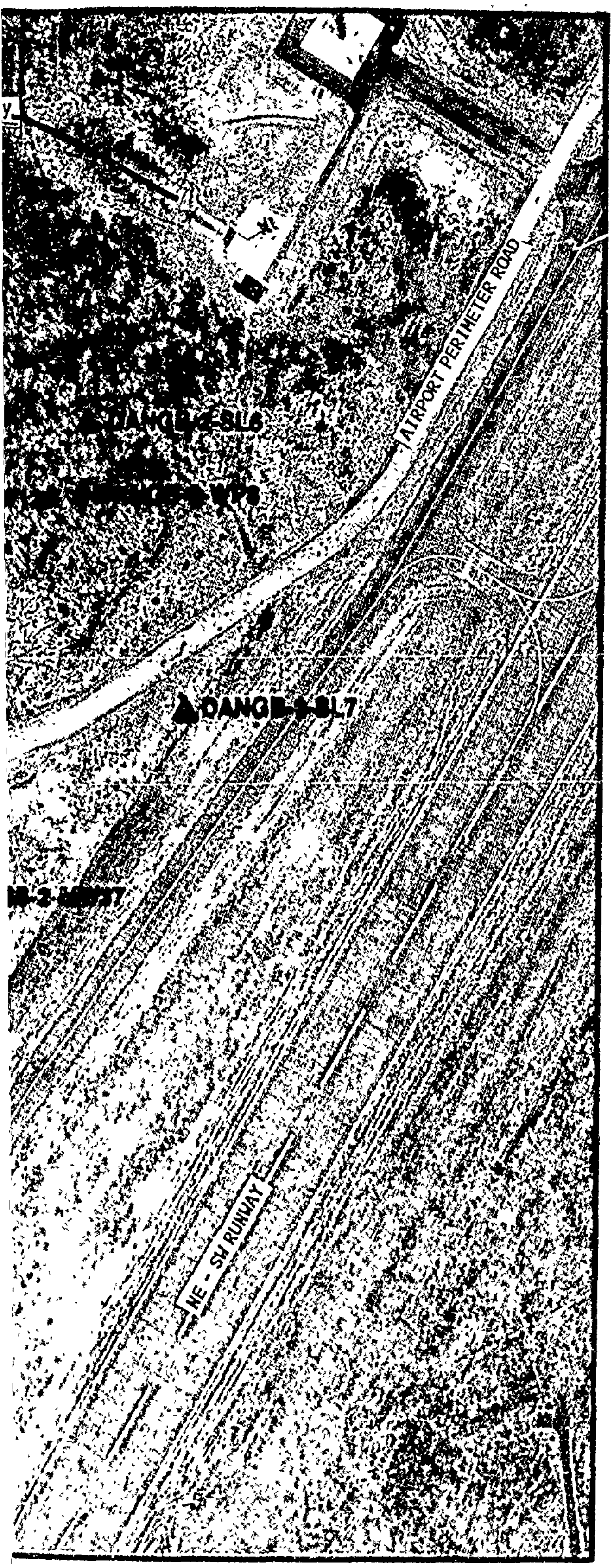
2.2 SITE 2

The Site 2 work consisted of a surface feature investigation, surface water and sediment investigations, a geological investigation, soil investigation and a ground-water investigation. A summary of the work performed at each location is given in Table 2-9. The sampling locations established during the Remedial Investigation are shown on Figure 2-2. All Site 2 sampling locations, both those newly established and those existing from Phase II studies, which were utilized during the Remedial Investigation are shown on Figure 2-3.

Thirteen deep boreholes were drilled. Two holes were drilled for soil sampling to address the vertical extent of the contamination at FTA-2. These holes were plugged and abandoned when completed. Two holes which were drilled as deep twins to existing monitoring wells reached bedrock at the same depth as the total depth of the existing wells. These holes were plugged and abandoned after soil samples were obtained. Five holes were drilled for monitoring well construction along the eastern, southern and western perimeters of the site in order to both define the extent of contamination from FTA-1 and to define its location. Four well points were installed in the remaining four boreholes along the northern perimeter to obtain additional water level data since sufficient ground-water and soil sampling locations already existed. Two of the well points were paired to obtain ground-water vertical gradient data.

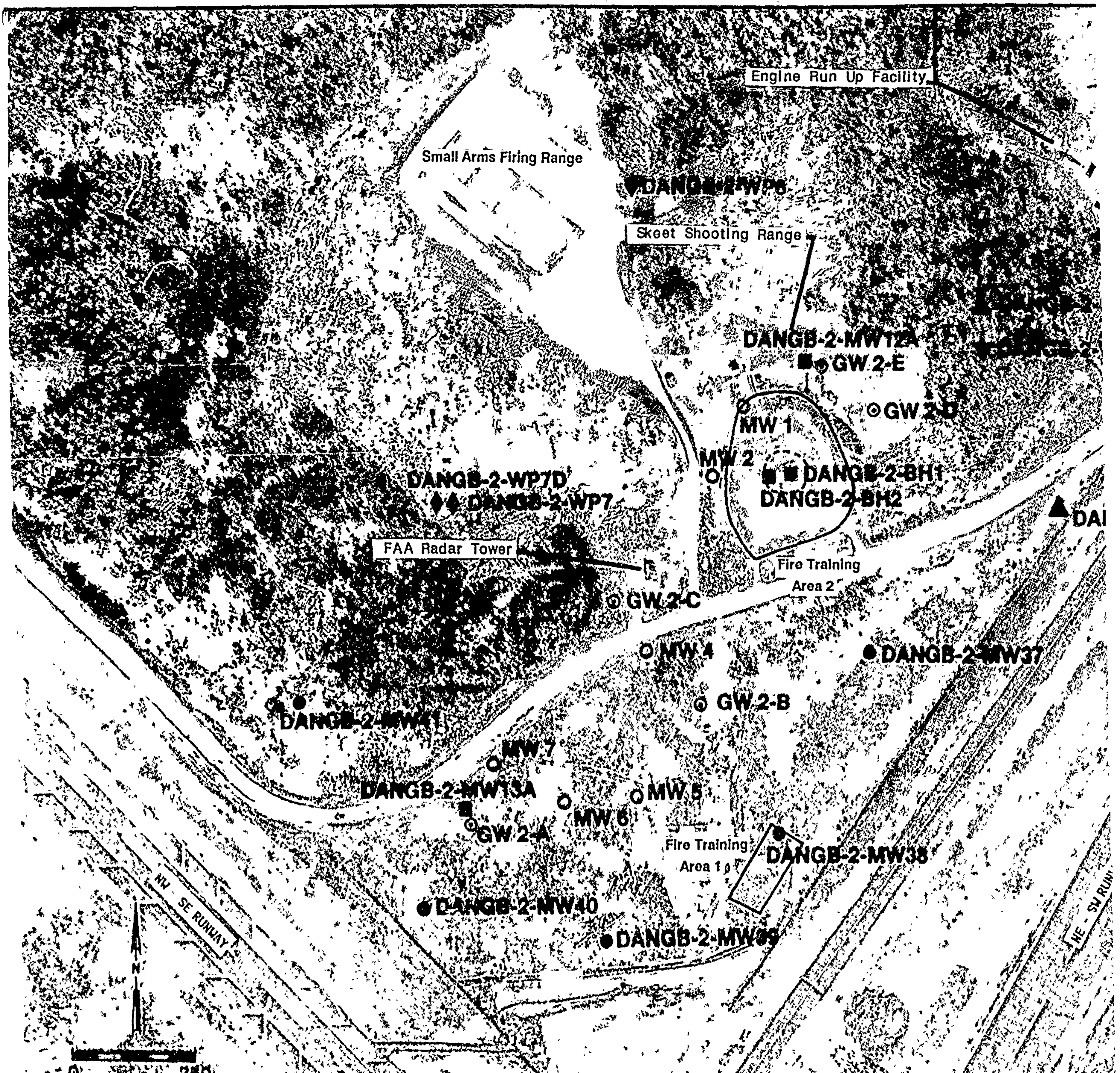
Two surface water locations were sampled.

Figure 2-2 Site 2 Boreholes, Surface Locations and Trenched Area of Remedial Investigation.

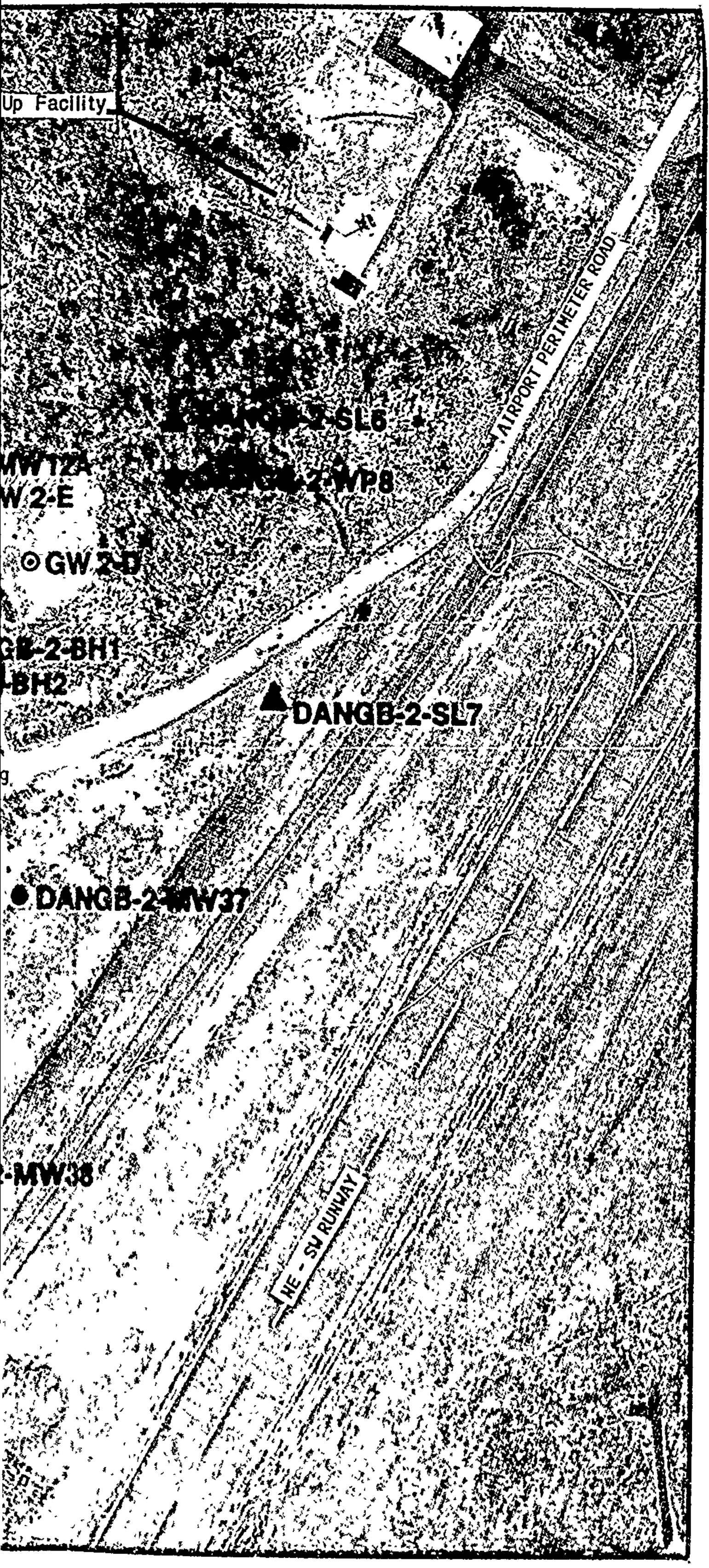


EXPLANATION

■ DANGB-2-BH1	Borehole, Remedial Investigation.
◆ DANGB-2-WP7	Well point, Remedial Investigation.
● DANGB-2-MW40	Monitoring well, Remedial Investigation.
▲ DANGB-2-SL6	Surface location, Remedial Investigation.
	Outline of area trenched on approximately 30 foot centers.
	Approximate boundary for fire training area.
	Burn pit.



ure 2-3 Site 2 Sampling Locations Utilized during Remedial Investigation.



EXPLANATION

■ DANGB-2-BH1	Borehole, Remedial Investigation.
◆ DANGB 2-WP7	Well point, Remedial Investigation.
● DANGB-2-MW40	Monitoring well, Remedial Investigation.
⊙ GW 2-A	Monitoring well, Phase II Stage 2.
○ MW 6	Monitoring well, Phase II, Stage 1.
▲ DANGB-2-SL6	Surface location, Remedial Investigation.
◯	Approximate boundary for fire training area.
◌	Burn pit.

TABLE 2-8

CHEMICAL ANALYSIS PERFORMED ON AREA BACKGROUND GROUND-WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	3	5[a]
Aromatic Volatile Organics	SW 8020	3	5
Semi-Volatile Organics	EPA 625	3	2[b]
Pesticides and PCBs	EPA 608	3	2
Total Petroleum Hydrocarbons	EPA 418.1	3	2
Metals			
Arsenic	SW 7060	3	2
Barium	SW 6010	3	2
Cadmium	SW 7131	3	2
Chromium	SW 7191	3	2
Lead	SW 7421	3	2
Mercury	SW 7470	3	2
Nitrates	EPA 353.2	3	2
Radiological			2
Gross Alpha	SW 9310	3	2
Gross Beta	SW 9310	3	2
Radium 226	SW 9313	3	2
Tritium	EPA 906.0	3	2
Specific Conductance	EPA 120.1	3	2
Temperature	EPA 170.1	3	2
pH	EPA 150.1	3	2

a. Includes 1 duplicate, 2 field blank, 1 trip blank and 1 bailer rinseate sample.
b. Includes 1 duplicate and 1 bailer rinseate sample.

Table 2-9
Summary of Work Performed at Site 2 Locations

Location Identification	Monitoring Well Construction	Well Point Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
DANGB-2-BH1			X		X	X										X
DANGB-2-BH2			X		X	X										X
DANGB-2-BH1R						X										
DANGB-2-BH2R						X										
DANGB-2-MW12A			X	X	X	X										X
DANGB-2-MW13A			X		X	X										X
DANGB-2-MW37	X		X		X	X						X				X
DANGB-2-MW38	X		X		X	X						X				X
DANGB-2-MW39	X		X		X	X						X				X
DANGB-2-MW40	X		X		X	X						X				X
DANGB-2-MW41	X		X		X	X						X				X
DANGB-2-WP6		X	X									X				X
DANGB-2-WP7		X	X									X				X
DANGB-2-WP7D		X	X									X				X
DANGB-2-WP8		X	X									X				X
DANGB-2-SL6									X	X		X				X
DANGB-2-SL7									X	X		X				X
MW-1											X	X			X	X
MW-2											X	X			X	X
MW-4											X	X			X	X
MW-5											X	X			X	X
MW-6											X	X			X	X
MW-7											X	X			X	X
GW-2A											X	X			X	X
GW-2B											X	X			X	X
GW-2C											X	X			X	X
GW-2D											X	X			X	X
GW-2E											X	X		X	X	X
TI-1 to 60								X							X	

Trenching was performed in an effort to locate FTA-1.

All locations were surveyed.

2.2.1 Surface Feature Investigation

Aerial photographs from 1951 to the present were examined. The photographs were taken in 1951, 1952, 1960, 1961, 1965, 1979 and 1988.

The particular purpose in examining photographs of this site was to locate FTA-1 and to further define the area of FTA-2.

2.2.2 Surface Water and Sediment Investigations

Surface water and sediments were sampled at two locations. Location DANGB-2-SL7 is on the drainage ditch which drains Site 2 south of the perimeter road. This is the area on which FTA-1 was located. Location DANGB-2-SL6 is east of FTA-2 and north of the perimeter road on a small tributary to the drainage ditch which drains Site 2 to the north.

A summary of the kinds and numbers of analyses performed on the surface water samples is given in Table 2-10 and on the sediment samples in Table 2-11.

Surface water and sediment were investigated to aid in defining the relationship between surface water and ground water at the site.

2.2.3 Geologic Investigation

The geologic investigation consisted of lithologic descriptions and grain size analyses.

The lithologic descriptions were done from the continuous cores obtained from the thirteen deep boreholes. Table 2-9 lists the boreholes from which cores were obtained and Figure 2-2 shows the borehole locations.

The lithologic descriptions were used to define the aquifer system underlying the site.

Grain size analyses were run on four soil samples obtained from the borehole drilled at location DANGB-2-MW12A. These samples were selected as representative of intervals of distinct lithology. These data were used to aid in defining the hydraulic properties of the water table aquifer.

2.2.4 Soil Investigation

Soil samples were obtained from nine boreholes. These were comprised of the two boreholes drilled for soil sampling, the two boreholes drilled for monitoring well construction which were plugged and abandoned, and the five boreholes in which monitoring wells were constructed.

TABLE 2-10

CHEMICAL ANALYSES PERFORMED ON SITE 2 SURFACE WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	2	3[a]
Aromatic Volatile Organics	SW 8020	2	3
Semi-Volatile Organics	EPA 625	2	1[b]
Total Petroleum Hydrocarbons	EPA 418.1	2	1
Metals			
Barium	SW 6010	2	1
Cadmium	SW 7131	2	1
Chromium	SW 7191	2	1
Lead	SW 7421	2	1
Nitrates	EPA 353.2	2	1
Specific Conductance	EPA 120.1	2	1
Temperature	EPA 170.1	2	1
pH	EPA 150.1	2	

a. Includes 1 duplicate, 1 field blank and 1 trip blank sample.
b. Duplicate sample.

TABLE 2-11

CHEMICAL ANALYSES PERFORMED ON SITE 2 SEDIMENT SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	2	1[a]
Aromatic Volatile Organics	SW 8020	2	1
Semi-Volatile Organics	SW 8270	2	1
Total Petroleum Hydrocarbons	EPA 418.1	2	1
Metals			
Arsenic	SW 7060	2	1
Barium	SW 6010	2	1
Cadmium	SW 7131	2	1
Chromium	SW 7191	2	1
Lead	SW 7421	2	1
Mercury	SW 7471	2	1

a. Duplicate sample.

Two soil sample boreholes were drilled using an auger drill rig and were sampled continuously with a two foot split-spoon sampler. Borehole DANGB-2-BH1 reached a total depth of 16 feet. Five samples were picked for analysis from the interval 0 to 12 feet based on high HNu readings, and representativeness of lithology. Borehole DANGB-2-BH2 reached a total depth of 21.5 feet. Four samples were picked for analysis from the interval 0 to 18 feet. During the course of field work it was determined that some samples had been lost from both holes after some analyses had been performed. Both holes were redrilled using the "Rotasonic" drill rig. Borehole DANGB-2-BH1 R reached a total depth of 24 feet and seven samples were selected for analysis from the entire drilled interval. Borehole DANGB-2-BH2 R reached a total depth of 25 feet. Six samples were selected for analysis from the entire drilled interval. Thus a total of 22 samples were obtained from two borehole locations. The samples from the first set of holes could be considered duplicate samples for those parameters for which samples from both sets of holes were analyzed.

Three soil samples were obtained from the boreholes drilled for construction of monitoring wells, whether or not they were completed as such. These samples were collected from near the surface, from at the water table and from either just above bedrock or from just above total depth at those locations where the borehole was not drilled to bedrock. Four samples were obtained from one monitoring well borehole (DANGB-2-MW37). In this hole, the lithology just above bedrock consisted of two distinct layers, and samples were taken from both. A summary of the kinds and numbers of analyses performed on the soil samples is given in Table 2-12. Analysis results for all samples taken is given in Appendix L.

Results of the soil investigation were used in defining any continuing sources for ground-water contamination and the extent to which soil aids in retarding migration of contaminants with the ground water.

2.2.5 Ground-Water Investigation

This investigation consisted of water level measurements, surveying of all water level measuring points and locations, an aquifer slug test, and chemical analyses of ground-water samples.

2.2.5.1 Aquifer Investigation

Water level measurements were taken at monthly intervals as field work proceeded. Wells were included in the water level measurements at the next

TABLE 2-12

CHEMICAL ANALYSES PERFORMED ON SITE 2 SOIL SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	35[a]	4[b]
Aromatic Volatile Organics	SW 8020	35	4
Semi-Volatile Organics	SW 8270	36[c]	4
Pesticides and PCBs	SW 8080	9[d]	0
Total Petroleum Hydrocarbons	EPA 418.1	36	4
Metals			
Arsenic	SW 7060	9	0
Barium	SW 6010	36	4
Cadmium	SW 7131	36	4
Chromium	SW 7191	27[e]	4
Lead	SW 7421	36	4
Mercury	SW 7470	9	0

a. Includes 22 samples from boreholes drilled for monitoring wells, and 13 samples from the redrilling of the two soil sampling boreholes.
b. Duplicate samples.
c. Includes 22 samples from boreholes drilled for monitoring wells, 9 samples from two soil sampling boreholes and 5 samples from redrilling of the two soil sampling boreholes. Either the 9 or the 5 could be considered duplicate quality control samples for those parameters where analyses were performed on both samples.
d. Samples from two soil sampling boreholes.
e. Includes 22 samples from boreholes drilled for monitoring wells and 5 samples from redrilling of the two soil sampling boreholes.

sampling round after their completion. The number of rounds at each monitoring well is summarized in Table 2-13.

Two surface water locations were also used as water level control points.

All these locations were surveyed.

The water level data were used to aid in determining horizontal and vertical ground-water flow directions in the aquifer system at the site.

An aquifer slug test was conducted using well GW 2-E. This information was used to aid in determining the ability of the water table aquifer to transmit water in the site vicinity.

2.2.5.2 Ground-Water Sampling Investigation

Samples were obtained from the five monitoring wells constructed during this study and from the eleven monitoring wells previously constructed for a total of 16 sampling locations.

Previous work indicated that the five previously constructed monitoring wells north of the airport perimeter road are sufficient to establish the ground-water quality in that area.

The additional five wells south of the perimeter road were constructed to establish the effect, if any, of FTA-1 on ground-water quality. At the time they were located and drilled, aerial photographs showing the probable location of FTA-1 were not available.

The samples were analyzed for the targeted compounds as determined by previous work. In addition, a complete semi-volatile organic analysis was run. A summary of the kinds and numbers of ground-water analyses performed is given in Table 2-14.

Results of ground-water sampling were used to aid in defining the extent to which contaminants have migrated away from the site.

2.3 SITE 3

The Site 3 work consisted of a surface feature investigation, surface water and sediment investigations, a geological investigation, soil investigations and a ground-water investigation. The sampling locations established during the Remedial Investigation are shown on Figures 2-4 and 2-5. Other sampling locations utilized were the Phase II Stage 2 monitoring wells. All Site 3 monitoring wells are shown on Figure 2-6. In addition, baseline monitoring well DANGB-BG-MW32 which is located just south of Site 3 is also shown on Figure 2-6.

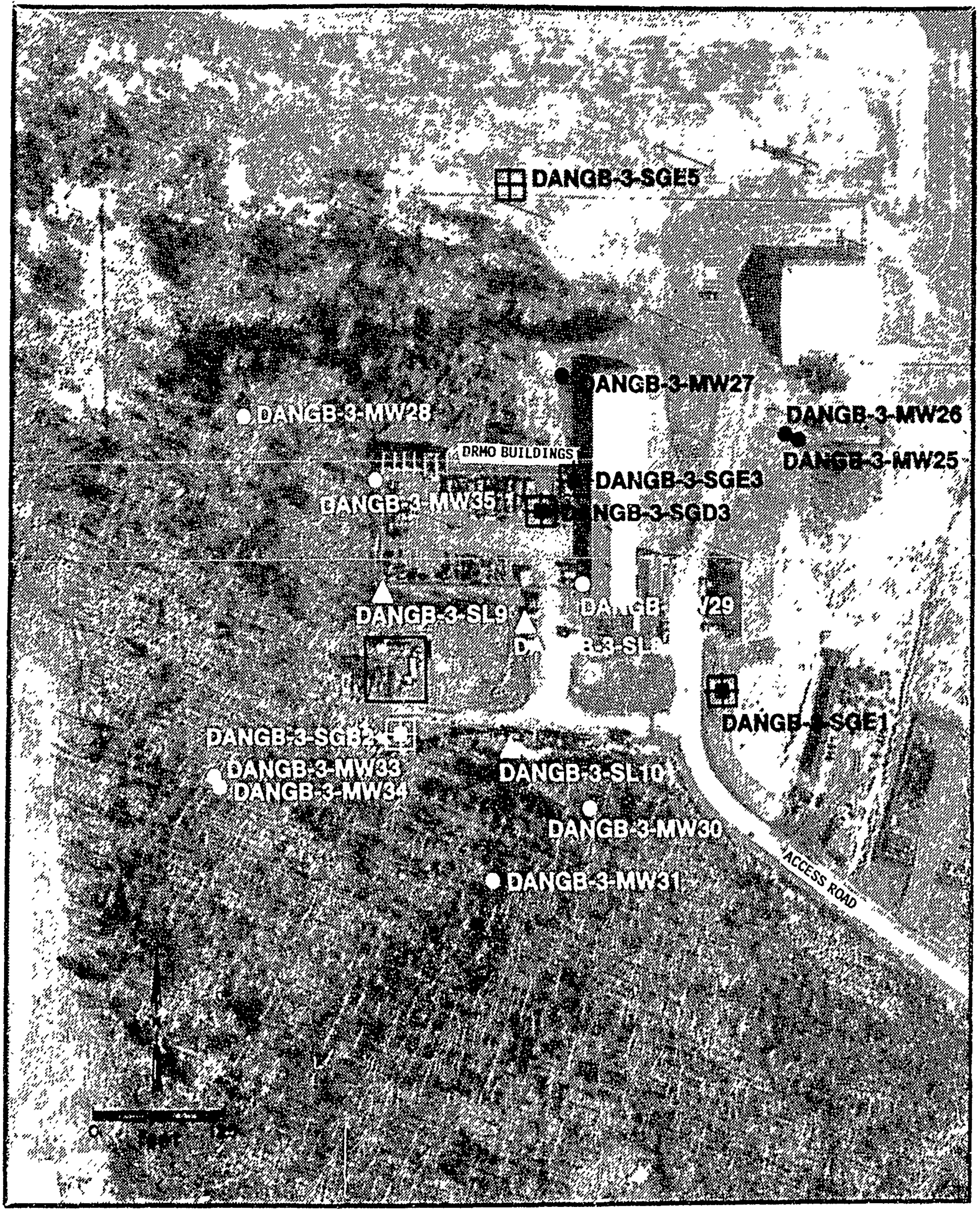


Figure 2-4 Site 3 Boreholes, Surface Locations, and Surveyed Soil Gas Grid Points of Remedial Investigation.

EXPLANATION

⊞	DANGB-3-SGE5	Surveyed soil gas grid point.
⧈	DANGB-3-SGE3	Survyed soil gas grid point and soil sample location.
●	DANGB-3-MW28	Monitoring well, Remedial Investigation.
▲	DANGB-3-SL10	Surface location, Remedial Investigation.
□		Approximate location of Storage Area "C".

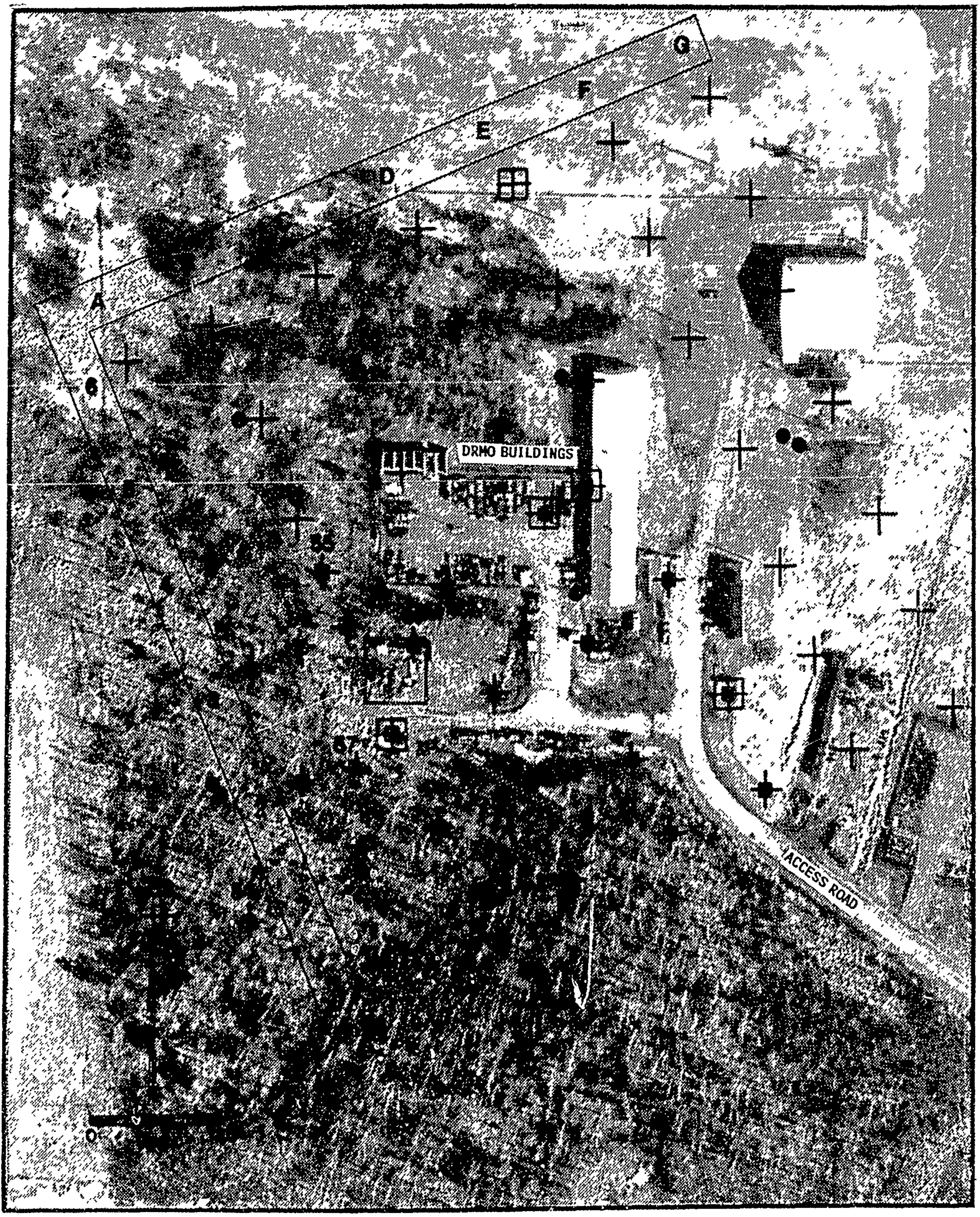


Figure 2-5 Site 3 Soil Gas and Shallow Soil Sample Locations.

EXPLANATION

┼	DANGB-3-SGA2	Soil Gas Grid Location.
✚	DANGB-3-SGB3	Soil Gas Grid and Soil Sample Location.
55 ┼	DANGB-3-SG59	Location outside of or immediate to grid.
⊞		Surveyed soil gas location.
▣		Surveyed soil gas and Soil sample location.
●		RI Monitoring Well.
▲		RI Surface Location.
□		Approximate location of Storage Area "C".

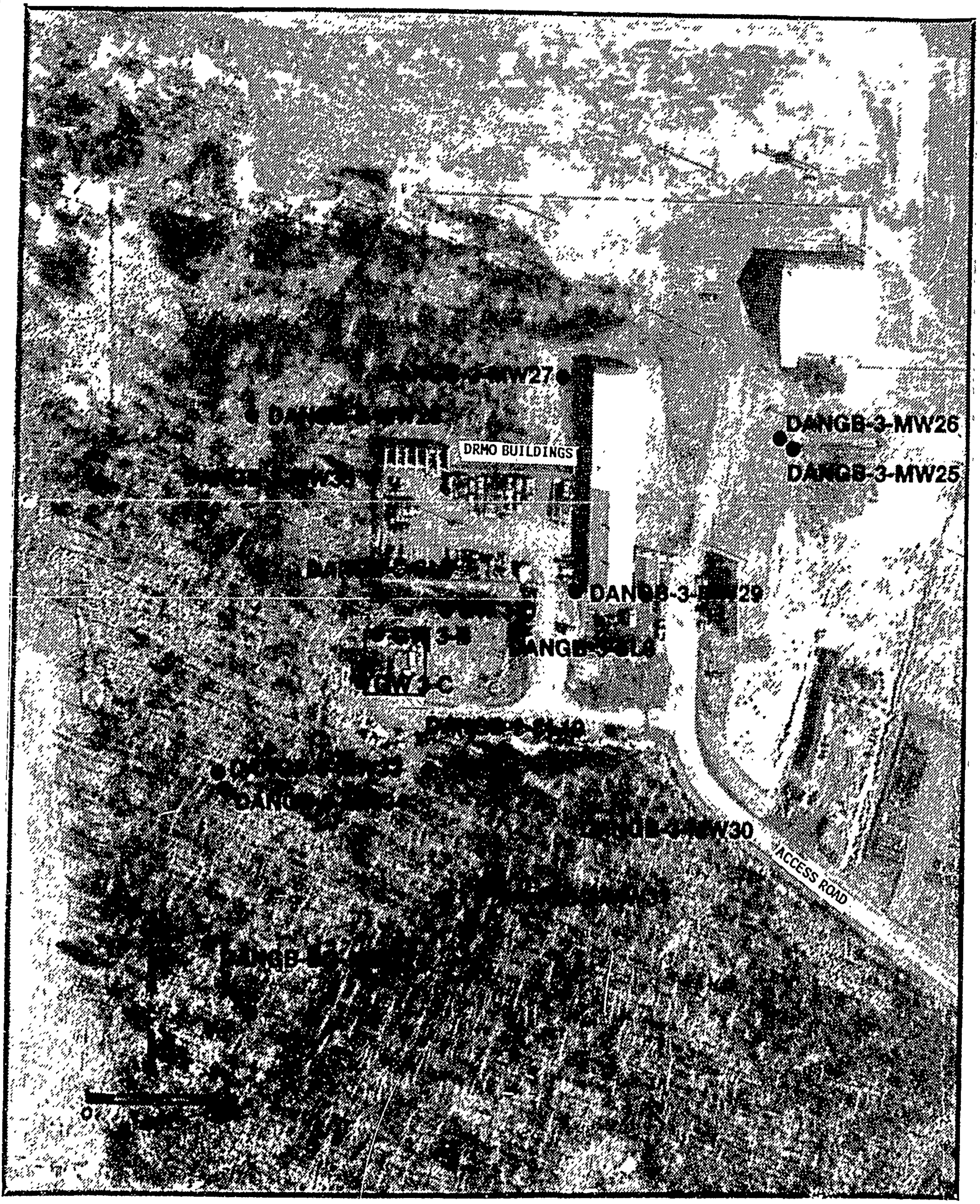
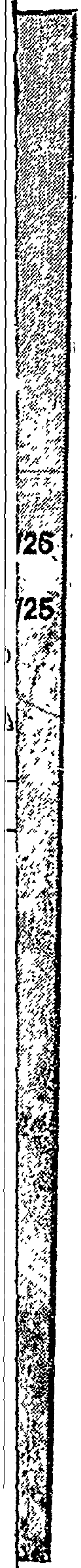


Figure 2-6 Site 3 Monitoring Wells Utilized during Remedial Investigation.



EXPLANATION

●	DANGB-3-MW25	Monitoring well, Remedial Investigation.
⊙	GW 3-A	Monitoring well, Phase II, Stage 2.
▲	DANGB-3-SL8	Surface water and sediment sampling location, Remedial Investigation.
☐		Approximate location of Storage Area "C".

TABLE 2-13

SUMMARY OF SITE 2 WATER LEVEL MEASUREMENT ROUNDS

Well Number	Number of Rounds
MW 1	4
MW 2	4
MW 3	4
MW 4	4
MW 5	4
MW 6	4
MW 7	4
GW 2-A	4
GW 2-B	4
GW 2-C	4
GW 2-D	4
GW 2-E	4
DANGB-2-MW37	3
DANGB-2-MW38	3
DANGB-2-MW39	3
DANGB-2-MW40	3
DANGB-2-MW41	3
DANGB-2-WP6	3
DANGB-2-WP7D	3
DANGB-2-WP7	3
DANGB-2-WP8	3

TABLE 2-14

CHEMICAL ANALYSES PERFORMED ON SITE 2 GROUND-WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	16	9[a]
Aromatic Volatile Organics	SW 8020	16	9
Semi-Volatile Organics	EPA 625	16	4[b]
Total Petroleum Hydrocarbons	EPA 418.1	16	4
Metals			
Barium	SW 6010	16	4
Cadmium	SW 7131	16	4
Chromium	SW 7191	16	4
Lead	SW 7421	16	4
Nitrates	EPA 353.2	16	2[c]
Specific Conductance	EPA 120.1	16	2
Temperature	EPA 170.1	16	2
pH	EPA 150.1	16	2

a. Includes 2 duplicate, 3 field blank, 2 trip blanks and 2 bailer rinseate samples.
b. Includes 2 duplicate and 2 bailer rinseate samples.
c. Duplicate samples.

A summary of the work performed for each location is given in Table 2-15.

Ten deep boreholes were drilled and monitoring wells were constructed in them.

A soil gas survey was conducted at the beginning of the field program. Fifty-seven points were sampled using a soil gas probe on a seven row by seven column grid with four additional interior points and four additional exterior points. Four locations were surveyed as shown on Figure 2-4.

The soil gas survey results were used to select locations for soil sampling.

Thirty one shallow soil samples were collected from one and one half to two feet deep holes dug with a fence-post digger.

Ground water and surface water were sampled. The monitoring wells installed during this and previous work were used to obtain ground-water samples and water level measurements. Three drainage ditch locations were sampled. All monitoring well drainage ditch locations were surveyed.

The work performed at each location is summarized on Table 2-15.

2.3.1 Surface Feature Investigation

Aerial photographs from 1951 to the present were examined. The photographs were taken in 1951, 1952, 1960, 1961, 1965, 1979, and 1988.

The particular purpose in examining photographs of this site was to corroborate the period of use and to determine modification of surface drainage.

2.3.2 Surface Water and Sediment Investigations

Surface water and sediment were sampled at three locations which are shown on Figure 2-4. Two of the locations are on a ditch which drains the storage pad on the east and north. The ditch drains to the north to an east draining ditch which flows to a culvert. The third location is on a drainage ditch which flows to the southeast and then joins a northward draining ditch.

A summary of the kinds and numbers of analyses performed on the surface water samples is given in Table 2-16 and on the sediment samples in Table 2-17.

Surface water and sediment were investigated [illegible] aid in defining the relationship between surface water and ground water at the site.

Table 2-15
Summary of Work Performed at Site 3 Locations

Location Identification	Monitoring Well Construction	Wellpoint Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
SG-A0					X		X								X	
SG-A1					X		X								X	
SG-A2					X		X								X	
SG-A3					X		X								X	
SG-A4					X		X								X	
SG-A5					X		X								X	
SG-A6							X								X	
SG-B0					X		X								X	
SG-B1					X		X								X	
SG-B2					X		X								X	X
SG-B3							X								X	
SG-B4							X								X	
SG-B5							X								X	
SG-B6							X								X	
SG-C0					X		X								X	
SG-C1					X		X								X	
SG-C2					X		X								X	
SG-C3					X		X								X	
SG-C4							X								X	
SG-C5					X		X								X	
SG-C6							X								X	
SG-D0					X		X								X	
SG-D1					X		X								X	
SG-D2					X		X								X	
SG-D3					X		X								X	
SG-D4					X		X								X	X
SG-D5					X		X								X	
SG-D6							X								X	
SG-E0					X		X								X	
SG-E1					X		X								X	X
SG-E2					X		X								X	
SG-E3					X		X								X	X
SG-E4							X								X	
SG-E5					X		X								X	X
SG-E6							X								X	

Table 2-15 (Continued)

Location Identification	Monitoring Well Construction	Wellpoint Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
SG-F0							X								X	
SG-F1							X								X	
SG-F2							X								X	
SG-F3							X								X	
SG-F4							X								X	
SG-F5							X								X	
SG-F6							X								X	
SG-49					X		X								X	
SG-53							X								X	
SG-54					X		X								X	
SG-55					X		X								X	
SG-56					X		X								X	
SG-57					X		X								X	
SG-58					X		X								X	
SG-59							X								X	
DANGB-3-MW25	X		X	X	X	X					X	X		X		X
DANGB-3-MW26	X		X								X	X		X		X
DANGB-3-MW27	X		X		X	X					X	X				X
DANGB-3-MW28	X		X		X	X					X	X				X
DANGB-3-MW29	X		X		X	X					X	X				X
DANGB-3-MW30	X		X		X	X					X	X				X
DANGB-3-MW31	X		X		X	X					X	X				X
DANGB-3-MW33	X		X		X	X					X	X		X		X
DANGB-3-MW34	X		X								X	X				X
DANGB-3-MW35	X		X		X	X					X	X				X
DANGB-3-SL8									X	X		X				X
DANGB-3-SL9									X	X		X				X
DANGB-3-SL10									X	X		X				X
GW3-A											X	X				X
GW3-B											X	X				X
GW3-C											X	X				X
GW3-D											X	X				X

TABLE 2-16

CHEMICAL ANALYSES PERFORMED ON SITE 3 SURFACE WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	3	2[a]
Aromatic Volatile Organics	SW 8020	3	2
Semi-Volatile Organics	EPA 625	3	1[b]
Pesticides and PCBs	EPA 608	3	1
Total Petroleum Hydrocarbons	EPA 418.1	3	1
Metals			
Barium	SW 6010	3	1
Cadmium	SW 7131	3	1
Chromium	SW 7191	3	1
Lead	SW 7421	3	1
Mercury	SW 7470	3	1
Arsenic	SW 7060	3	1
Specific Conductance	EPA 120.1	3	1
Temperature	EPA 170.1	3	1
pH	EPA 150.1	3	1

a. Includes 1 duplicate and 1 field blank sample.
b. Duplicate sample.

TABLE 2-17

CHEMICAL ANALYSES PERFORMED ON SITE 3 SEDIMENT SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	3	1[a]
Aromatic Volatile Organics	SW 8020	3	1
Semi-Volatile Organics	SW 8270	3	1
Pesticides and PCBs	SW 8080	3	1
Total Petroleum Hydrocarbons	EPA 418.1	3	1
Metals			
Arsenic	SW 7060	3	1
Barium	SW 6010	3	1
Cadmium	SW 7131	3	1
Chromium	SW 7191	3	1
Lead	SW 7421	3	1
Mercury	SW 7471	3	1

a. Duplicate sample.

2.3.3 Geologic Investigation

The geologic investigation consisted of lithologic descriptions and grain size analyses.

The lithologic descriptions were done from the continuous cores obtained in drilling the ten boreholes in which monitoring wells were constructed. See Table 2-15 for a listing of these locations. They are shown on Figure 2-6. Three holes were drilled to bedrock. Two of these were the deep holes in the two pairs of monitoring wells. The third hole reached bedrock at its previously estimated total depth of 17.5 feet. The other five boreholes were drilled to depths between 15 and 18 feet.

The lithologic descriptions were used to define the aquifer system underlying the site.

Grain size analyses were run on three soil samples obtained from the borehole drilled for monitoring well DANGB-3-MW25. The samples were selected as representative of intervals of distinct lithology. These data were used to aid in defining the hydraulic properties of the water table aquifer.

2.3.4 Soil Investigations

A soil gas survey was performed at the beginning of the field work. The objectives of the survey included locating contaminant sources, defining the approximate lateral extent of contamination and determining the migration direction of the contamination in subsurface soil and ground water.

A seven row by seven column grid was established over the approximately 600- by 600-foot area (Figure 2-5). The northwest-southeast oriented lines were numbered A through G and the northeast-southwest oriented lines were numbered 0 through 6. These points were designated A0, A1, A2, G4, G5, G6 (49 points). Four additional interior points and four additional exterior points are numbered 49, and 53 through 59 for a total of 57 points. The grid was established using a surveyor's tape and a hand held compass.

Sampling depths were determined by conducting depth profiles at two initial points (Points B2 and C2). The profiles were conducted by collecting and analyzing samples at depths ranging from one to eight feet. The purpose of the depth profiling was to identify the contact between the aerobic and anaerobic soil zones.

The compounds which were suspected to occur and which were targeted for detection are listed in Table 2-18.

TABLE 2-18

TARGETED COMPOUNDS FOR SOIL GAS ANALYSIS AT SITE 3

Targeted Compounds
Halogenated Volatile Organics
1,1-Dichloroethene
cis-1,2-Dichlorothene
Tetrachloroethene
1,1,1-Trichloroethane
Trichloroethene
Vinyl Chloride
Aromatic Volatile Organics
Benzene
Chlorobenzene
Toluene
Xylenes

The results of the soil gas survey were used to select 35 locations coincident with the soil gas grid for shallow soil sampling. Samples were collected at 31 of these locations. Three sampling locations were close to deep borings from which the near surface soil sample was collected when drilling the borehole. In one instance, DANGB-3-SGB4, the sampling location was in the midst of a boulder field, and the nearest location which could be sampled was coincident with a previously sampled location.

Five soil gas grid locations from which soil gas samples had been obtained were plugged with cement and a surveyor's pin was inserted in the cement with the location number and the location was surveyed. They are listed in Table 2-15.

Three soil samples were obtained for chemical analyses from each of eight boreholes drilled for construction of monitoring wells. Ten boreholes were drilled; four of these form two pairs of monitoring wells. Soil samples were taken only from the deeper of the paired boreholes. Samples were obtained from near the surface, from at the water table and from just above the bedrock surface or total depth if the well was not drilled to bedrock. The analyses that were done on these samples is given in Table 2-19.

Results of the soil investigations were used to define continuing sources of ground-water contamination and to determine the extent to which soil aids in retarding migration of contaminants with the ground water.

2.3.5 Ground-Water Investigation

This investigation consisted of water level measurements, surveying of all water level measuring points and locations, three aquifer slug tests and chemical analyses of ground-water samples.

2.3.5.1 Aquifer Investigation

Water level measurements were taken at monthly intervals as field work proceeded. Wells were included in the water level measurements at the next sampling round after completion. The number of rounds at each monitoring well is summarized in Table 2-20.

The three surface water locations were also used as water level control points for aquifer investigations. All these locations were surveyed and are shown on Figure 2-4.

The water level data were used to aid in determining horizontal and vertical ground-water flow directions in the aquifer system at the site.

TABLE 2-19

CHEMICAL ANALYSES PERFORMED ON SITE 3 SOIL SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	54[a]	7[b]
Aromatic Volatile Organics	SW 8020	54	7
Semi-Volatile Organics	SW 8270	54	7
Pesticides and PCBs	SW 8080	54	7
Total Petroleum Hydrocarbons	EPA 418.1	54	7
Metals			
Arsenic	SW 7060	54	7
Barium	SW 6010	54	7
Cadmium	SW 7131	54	7
Chromium	SW 7191	54	7
Lead	SW 7421	54	7
Mercury	SW 7471	54	7
Percent Moisture		54	7

a. Includes 31 samples from shallow auger holes and 23 samples from deep boreholes.

b. Includes 4 duplicate samples from shallow auger holes and 3 duplicate samples from deep boreholes.

TABLE 2-20

SUMMARY OF SITE 3

WATER LEVEL MEASUREMENT ROUNDS

Well Number	Number of Rounds
GW 3-A	4
GW 3-B	4
GW 3-C	4
GW 3-D	4
DANGB-3-MW25	2
DANGB-3-MW26	2
DANGB-3-MW27	2
DANGB-3-MW28	2
DANGB-3-MW29	2
DANGB-3-MW30	2
DANGB-3-MW31	2
DANGB-3-MW32	2
DANGB-3-MW33	2
DANGB-3-MW34	2
DANGB-3-MW35	2

Aquifer slug tests were conducted using wells DANGB-3-MW25, DANGB-3-MW33, and DANGB-3-MW34. These data were used to aid in determining the ability of the water table aquifer to transmit water in the site vicinity.

2.3.5.2 Ground-Water Sampling Investigation

Ground-water samples were obtained from the ten monitoring wells constructed during this study and from the four monitoring wells previously constructed for a total of 14 sampling locations. These are shown on Figure 2-6. These wells encircle the storage pad and extend downgradient to Site 4.

The samples were analyzed for the targeted compounds as determined from previous work. A summary of the kinds and numbers of analyses performed is given in Table 2-21.

Results of ground-water sampling and analysis were used to aid in defining the extent to which contaminants have migrated away from the site.

2.4 SITE 4

The Site 4 work consisted of a surface feature investigation, surface water and sediment investigations, a geological investigation, soil investigation and a ground-water investigation. The sampling locations established during the Remedial Investigation are shown on Figure 2-7. All Site 4 sampling locations, both those newly established and those existing from Phase II studies, which were utilized during the Remedial Investigation are shown on Figure 2-8. A summary of the work performed at each location is given in Table 2-22.

Fourteen deep boreholes were drilled. Four of the boreholes were drilled and completed as deep wells paired to four of the eight existing monitoring wells.

Four sets of paired well points were constructed along the northern boundary of the site and two single well points were constructed along the southern border of the site.

The distribution of boreholes was intended to completely encircle the fuel oil tanks with ground-water quality sampling locations and to establish a large scale network of locations for water level measurements to address ground-water flow directions.

The monitoring wells installed during this investigation and the monitoring wells installed during previous work were used to obtain ground-

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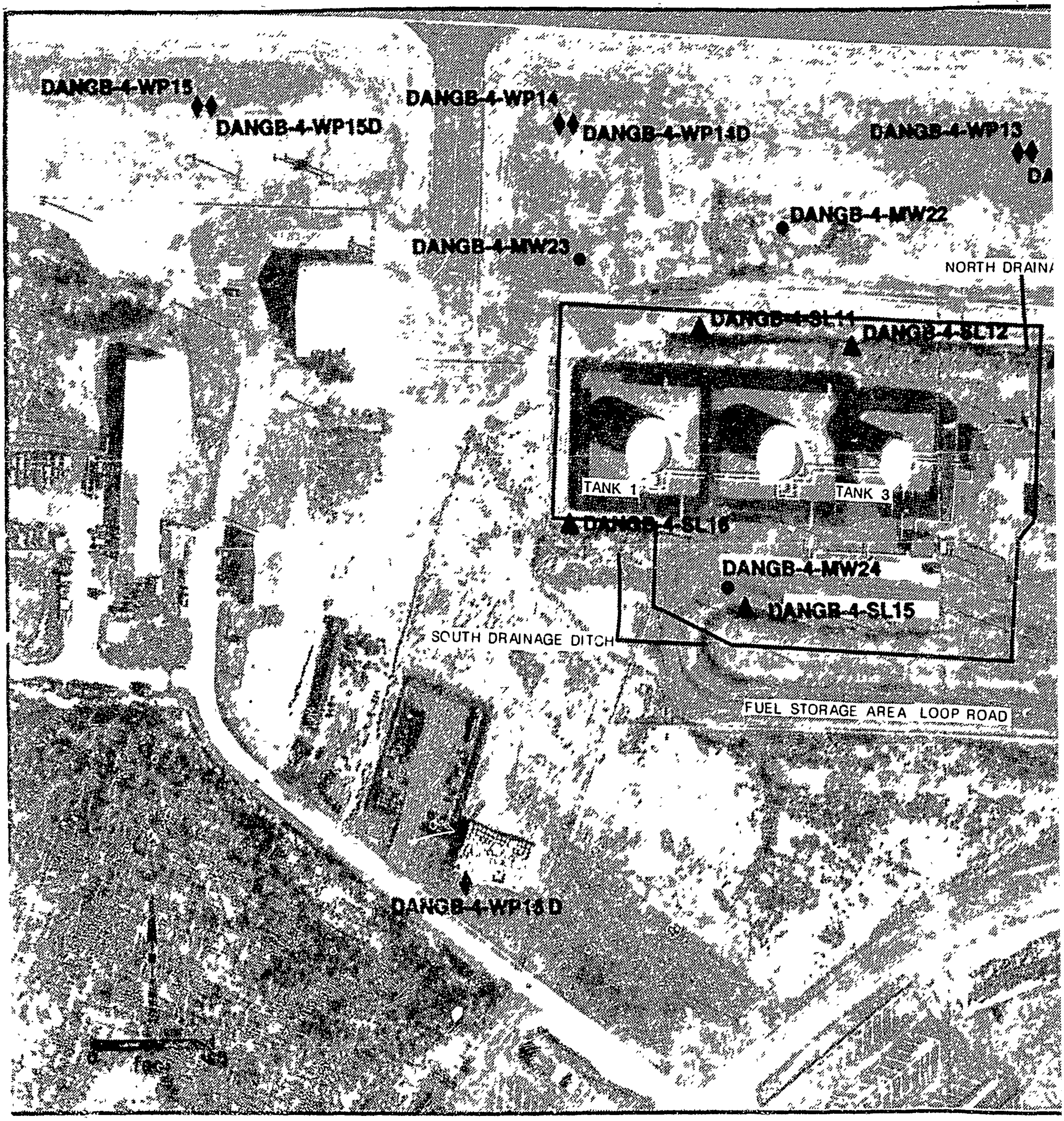
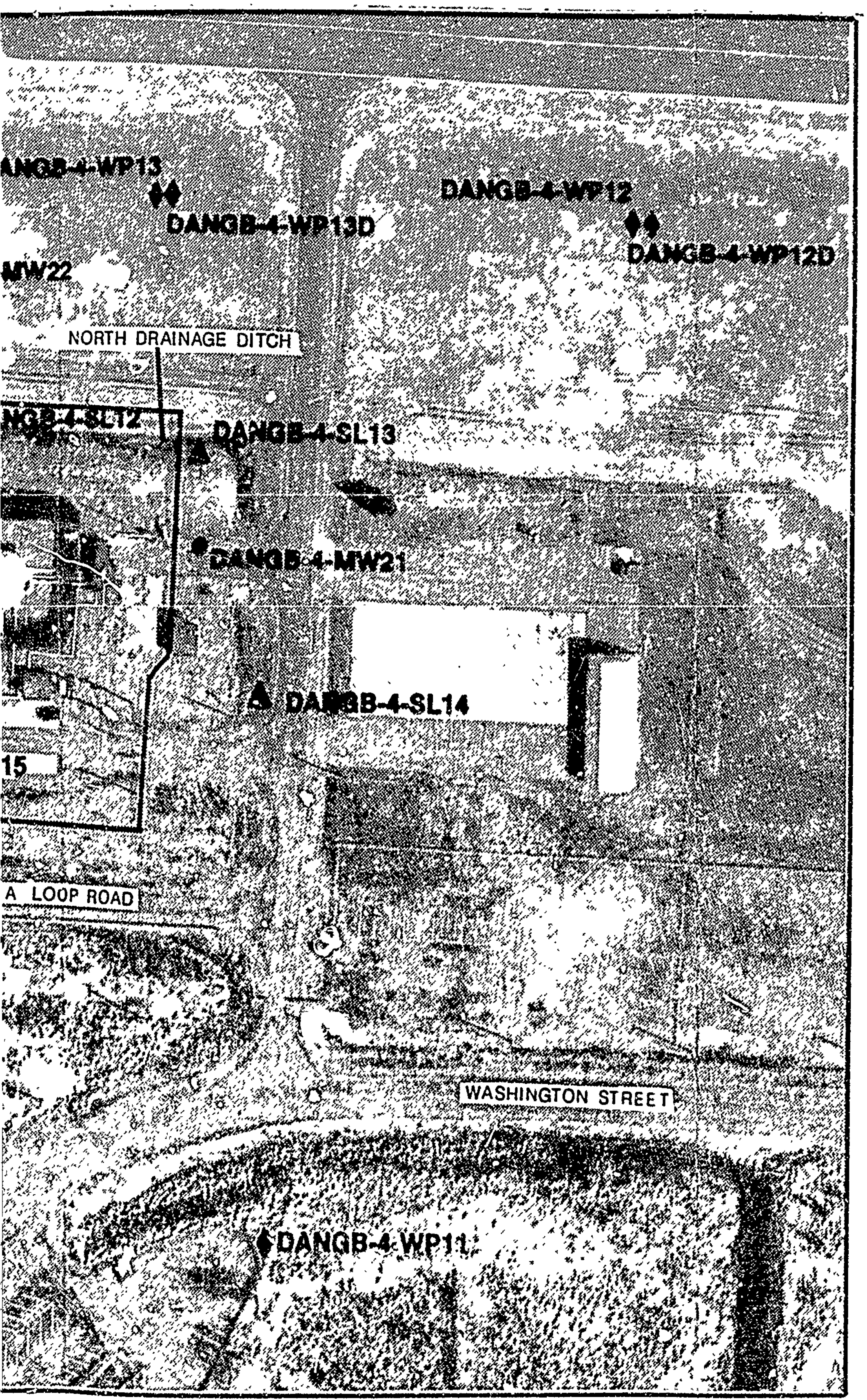


Figure 2-7 Site 4 Sampling Locations Established during Remedial Investigation.



EXPLANATION

◆ DANGB-4-WP14D	Well point Remedial Investigation.
● DANGB 4 MW23	Monitoring well Remedial Investigation
▲ DANGB-4-SL15	Surface location Remedial Investigation.
☐	Approximate boundary for Fuel Storage Area (Fenced Area).

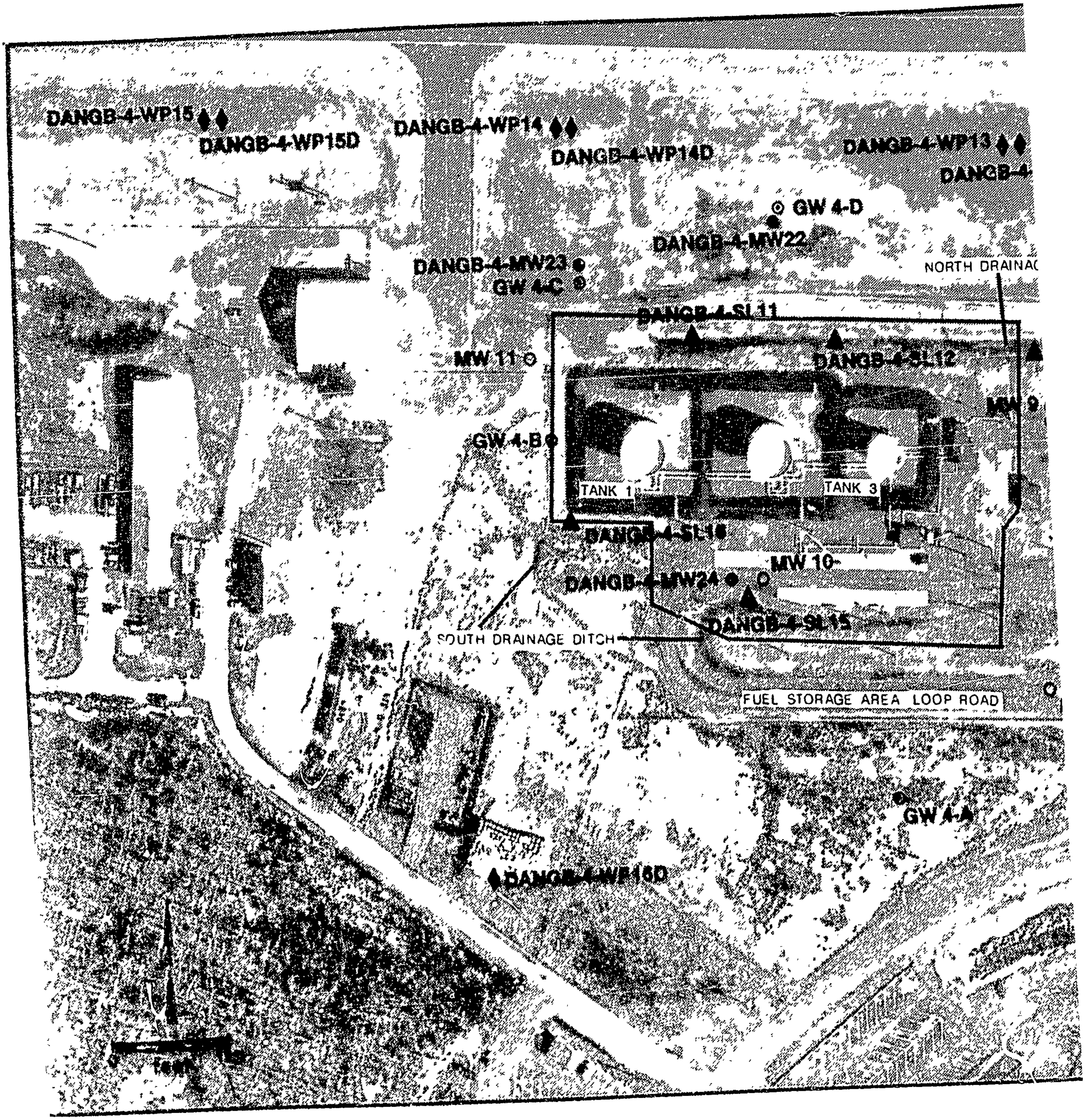
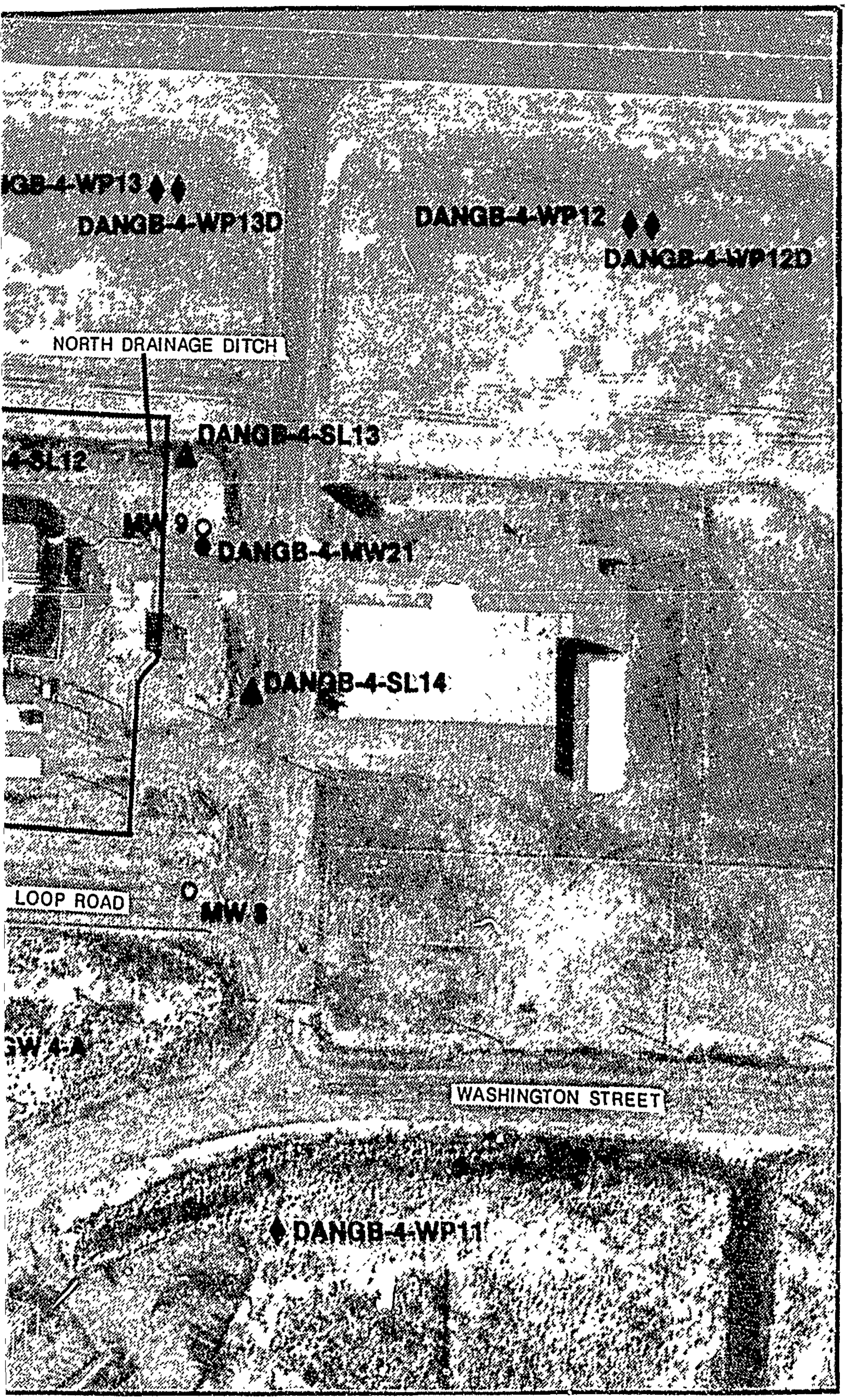


Figure 2-8 Site 4 Sampling Locations Utilized during Remedial Investigation.



EXPLANATION

◎ GW 4-A	Monitoring Well Phase II, Stage 2.
○ MW 8	Monitoring Well Phase II, Stage 1.
● DANGB 4 MW21	Monitoring Well Remedial Investigation.
◆ DANGB-4-WP12	Well Point Remedial Investigation.
▲ DANGB 4 SL11	Surface Location.
☐	Approximate boundary of Fuel Storage Area (fenced Area).

TABLE 2-21

CHEMICAL ANALYSIS PERFORMED ON SITE 3 GROUND-WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	14	12[a]
Aromatic Volatile Organics	SW 8020	14	12
Semi-Volatile Organics	EPA 625	14	5[b]
Pesticides and PCBs	EPA 608	14	5
Total Petroleum Hydrocarbons	EPA 418.1	14	5
Metals			
Arsenic	SW 7060	14	5
Barium	SW 6010	14	5
Cadmium	SW 7131	14	5
Chromium	SW 7191	14	5
Lead	SW 7421	14	5
Mercury	SW 7060	14	5
Specific Conductance	EPA 120.1	14	2[c]
Temperature	EPA 170.1	14	2
pH	EPA 150.1	14	2

a. Includes 2 duplicate, 3 field blank, 4 trip blank and 3 bailer rinseate samples.
b. Includes 2 duplicate and 3 bailer rinseate samples.
c. Duplicate samples.

Table 2-22
Summary of Work Performed at Site 4 Locations

Location Identification	Monitoring Well Construction	Wellpoint Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
DANGB-4-MW21	X		X		X	X					X	X				X
DANGB-4-MW22	X		X		X	X					X	X		X		X
DANGB-4-MW23	X		X		X	X					X	X				X
DANGB-4-MW24	X		X		X	X					X	X				X
DANGB-4-WP11		X	X									X				X
DANGB-4-WP12		X	X									X				X
DANGB-4-WP12D		X	X									X				X
DANGB-4-WP13		X	X									X				X
DANGB-4-WP13D		X	X									X				X
DANGB-4-WP14		X	X									X				X
DANGB-4-WP14D		X	X									X				X
DANGB-4-WP15		X	X									X				X
DANGB-4-WP15D		X	X									X				X
DANGB-4-16D		X	X									X				X
DANGB-4-SL11									X	X			X			X
DANGB-4-SL12									X	X						X
DANGB-4-SL13									X	X						X
DANGB-4-SL14									X	X						X
DANGB-4-SL15									X	X						X
DANGB-4-SL16									X	X						X
GW 4-A											X	X				X
GW 4-B											X	X				X
GW 4-C											X	X				X
GW 4-D											X	X				X
MW 8											X	X				X
MW 9											X	X				X
MW 10											X	X				X
MW 11											X	X				X

water samples and water level measurements. These wells are shown on Figure 2-8.

Five surface locations were sampled and streamflow was measured at one surface location.

All locations were surveyed.

2.4.1 Surface Feature Investigation

Aerial photographs from 1951 to the present were examined. The photographs were taken in 1951, 1952, 1960, 1961, 1965, 1979 and 1988. The purpose in examining these photos was to compare changes in topography and surface drainage and to identify additional sources of on-site contamination.

2.4.2 Surface Water and Sediment Investigations

Surface water and sediments were sampled at six locations (Figure 2-8). Locations DANGB-4-SL14, -SL13, -SL12 and -SL11 are on the same drainage ditch which drains the east and north sides of the site just outside of the bermed fuel storage area. At DANGB-4-SL11, the drainage enters a culvert which runs north and appears to discharge into the grassy strip which separates the east-west taxiway from the east-west runway. Locations DANGB-4-SL15 and DANGB-4-SL16 are to the south of the bermed fuel storage area on the drainage ditch which drains westward.

A streamflow measurement was taken at DANG-4-SL11. This location is just before the drainage enters the culvert.

A summary of the kinds and numbers of analyses performed on the surface water samples is given in Table 2-23 and on the sediment samples in Table 2-24.

Surface waters and sediments were investigated to aid in defining the relationship between surface water and ground water at the site.

2.4.3 Geologic Investigation

The geologic investigation consisted of lithologic descriptions and grain size analyses.

The lithologic descriptions were done from the continuous cores obtained from the boreholes drilled for the four monitoring wells which were constructed and the ten well points which were installed. All monitoring well boreholes and five of the well point boreholes were drilled into the bedrock, for a total of nine complete descriptions of the unconsolidated sediments. They are shown on Figure 2-7.

TABLE 2-23

CHEMICAL ANALYSES PERFORMED ON SITE 4 SURFACE WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	6	3[a]
Aromatic Volatile Organics	SW 8020	6	3
Total Petroleum Hydrocarbons	EPA 418.1	6	1[b]
Metals			
Barium	SW 6010	6	1
Cadmium	SW 7131	6	1
Chromium	SW 7191	6	1
Lead	SW 7421	6	1
Specific Conductance	EPA 120.1	6	1
Temperature	EPA 170.1	6	1
pH	EPA 150.1	6	1

a. Includes 1 duplicate, 1 field blank and 1 trip blank samples.
b. Duplicate sample.

TABLE 2-24

CHEMICAL ANALYSES PERFORMED ON SITE 4 SEDIMENT SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	6	1[a]
Aromatic Volatile Organics	SW 8020	6	1
Total Petroleum Hydrocarbons	EPA 418.1	6	1
Metals			
Barium	SW 6010	6	1
Cadmium	SW 7131	6	1
Chromium	SW 7191	6	1
Lead	SW 7421	6	1

a. Duplicate sample.

The lithologic descriptions were used to define the aquifer system underlying the site.

Grain size analysis was run on four soil samples obtained from the borehole drilled for monitoring well DANGB-4-MW22. The samples were selected as representative of intervals of distinct lithology. These data were used to aid in defining the hydraulic properties of the water table aquifer.

2.4.4 Soil Investigation

Soil samples were obtained from the boreholes drilled for the four monitoring wells which were constructed. Each borehole was drilled to bedrock, and soil samples were taken at the surface, at the water table and just above the bedrock surface. Table 2-25 summarizes the soil analyses that were performed.

Results of the soil investigation were used to aid in defining the extent to which soils at the site and in retarding migration of contaminants with the ground water.

2.4.5 Ground-Water Investigation

This investigation consisted of water level measurements, surveying of all water level measuring points and locations (Figure 2-8), an aquifer slug test and chemical analyses of ground-water samples.

2.4.5.1 Aquifer Investigation

Water level measurements were taken at monthly intervals as field work proceeded. Wells constructed during the current investigation were included in the water level measurements at the next sampling round after their completion. It was not possible to locate and take measurements at three wells during the sampling round of February 1989 due to depth of snow cover. The number of rounds at each location is summarized in Table 2-26.

The five surface water locations were also used as water level control points.

The water level data were used to aid in determining horizontal and vertical ground-water flow directions in the aquifer system at the site.

An aquifer test was conducted using well DANGB-4-MW22. This information was used to aid in determining the ability of the water table aquifer to transmit water in the site vicinity.

2.4.5.2 Ground-Water Sampling Investigation

Samples were obtained from the four monitoring wells constructed during this study and from the eight monitoring wells previously constructed for a

TABLE 2-25

CHEMICAL ANALYSES PERFORMED ON SITE 4 SOIL SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	13	2[a]
Aromatic Volatile Organics	SW 8020	13	2
Total Petroleum Hydrocarbons	EPA 418.1	13	2
Pesticides and PCBs	SW 8080	7	1
Metals			
Barium	SW 6010	13	2
Cadmium	SW 7131	13	2
Chromium	SW 7191	13	2
Lead	SW 7421	13	2
Percent Moisture		13	2

a. Duplicate samples.

TABLE 2-26

SUMMARY OF SITE 4 WATER LEVEL MEASUREMENT ROUNDS

Well Number	Number of Rounds
MW8	4
MW9	4
MW10	4
MW11	3
GW 4-A	4
GW 4-B	4
GW 4-C	4
GW 4-D	4
DANGB-4-MW21	3
DANGB-4-MW22	3
DANGB-4-MW23	3
DANGB-4-MW24	2
DANGB-4-WP11	2
DANGB-4-WP12	2
DANGB-4-WP12D	2
DANGB-4-WP13	2
DANGB-4-WP13D	2
DANGB-4-WP14	1
DANGB-4-WP14D	1
DANGB-4-WP15	2
DANGB-4-WP15D	2
DANGB-4-WP16	2

total of 12 individual sampling locations. These are shown on Figure 2-8. Eight of the 12 wells are paired, so that there are four paired well locations and four single well locations. Two of the paired well locations are to the north of the bermed area. One paired well location is to the east and the last paired well location is to the south. Of the single monitoring well locations, two are to the west of the bermed area. These two wells plus the eight paired wells encircle the fuel oil storage site and are located no further than 125 feet from the enclosing berm. The remaining two monitoring wells are located further to the south. The ground-water samples were analyzed for the targeted compounds as determined from previous work. A summary of the kinds and numbers of analyses performed is given in Table 2-27.

Results of the ground-water sampling and analysis were used to aid in defining the extent to which contaminants have migrated from the site.

2.5 SITE 8

The Site 8 work consisted of a surface feature investigation, surface water and sediment investigations, a geological investigation, soil investigations and a ground-water investigation. The sampling locations established during the Remedial Investigation are shown on Figure 2-9. All Site 8 sampling locations, both those newly established and those existing from Phase II studies, which were utilized during the Remedial Investigation are shown on Figure 2-10. A summary of the work performed at each location is given in Table 2-28.

Eleven deep boreholes were drilled during this study. Three holes which were drilled as deep pairs to the three existing monitoring wells reached bedrock at the same depth as the total depth of the existing wells. These holes were plugged and abandoned after soil samples were obtained. Four holes were drilled for construction of two monitoring well pairs south of the site. Four holes were drilled for installation of two well point pairs. One pair is to the west of the site and the other is to the south of the western part of the site. The paired holes were drilled to investigate vertical variations in hydraulic gradients and ground-water contamination.

Three surface water locations were sampled.

Twenty four two-feet deep boreholes were drilled using a hand held powered auger to collect shallow depth soil samples. These boreholes were located on a four row by six column grid as shown on Figure 2-9. The

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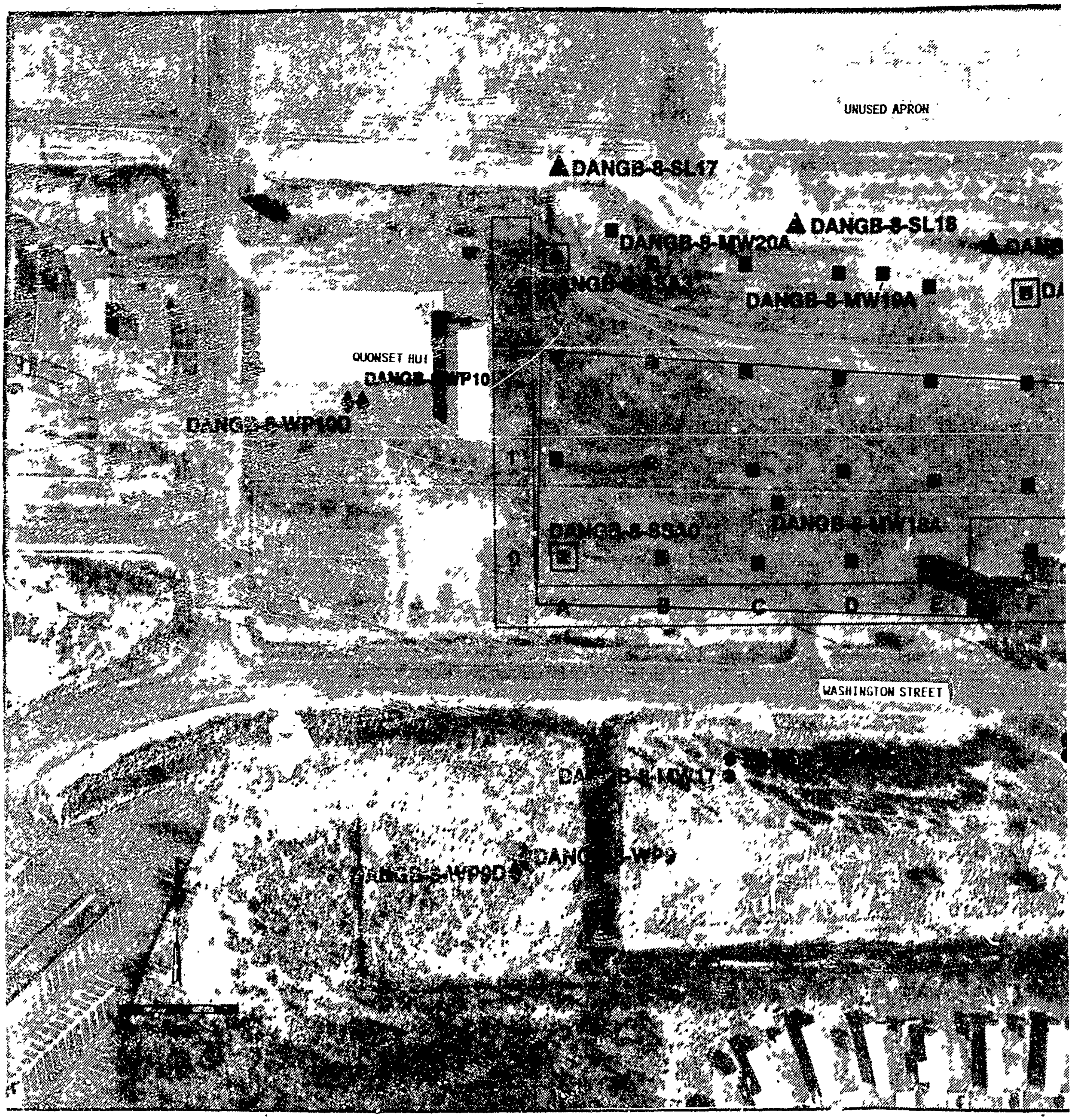
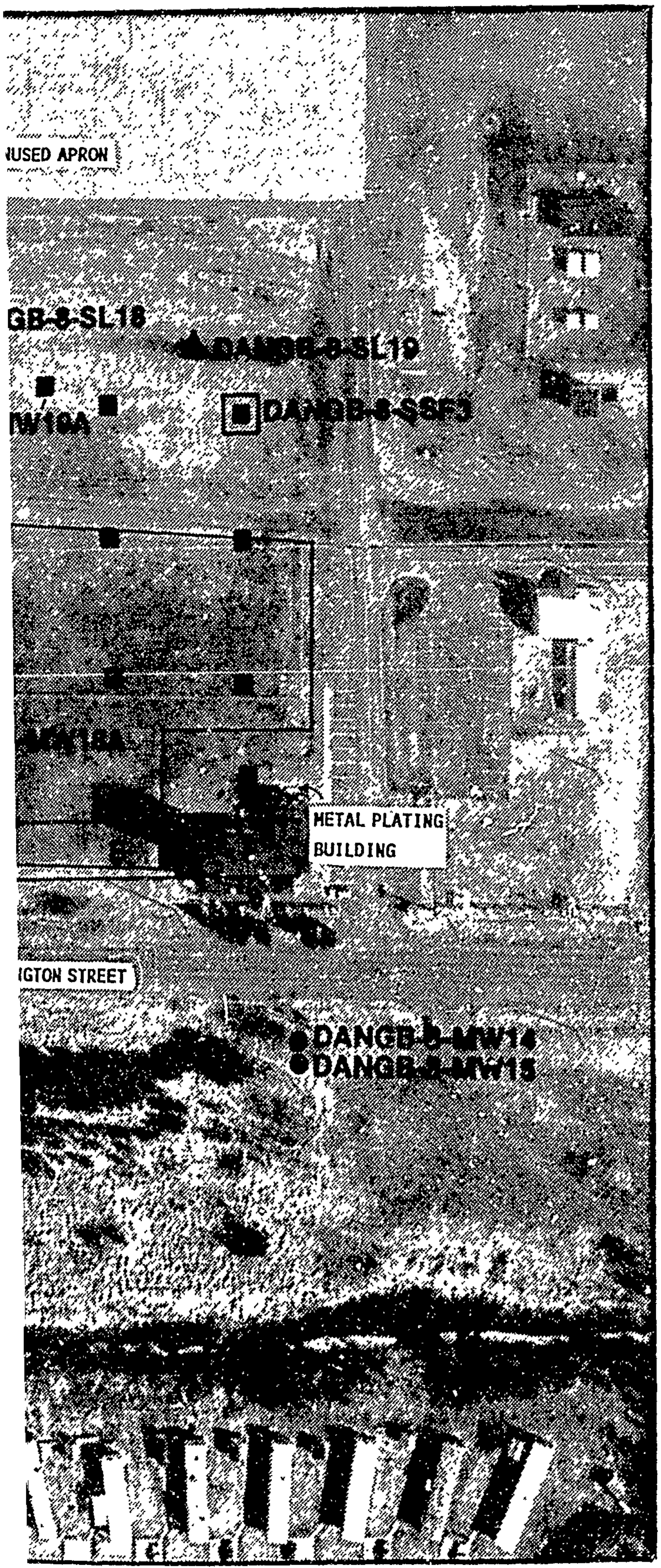


Figure 2-9 Site 8 Sampling Locations Established during Remedial Investigation.



EXPLANATION

◆ DANGB-8-WP10
Well Point installed this study.

● DANGB-8-MW16
Monitoring well constructed this study.

◒ DANGB-8-MW16
Monitoring well borehole drilled, plugged and abandoned this study.

■ DANGB-8-SGB3
Location on soil sample grid.

▣ DANGB-8-SGAD
Surveyed location on soil sample grid.

□ Approximate boundary of Storage Area (old DPDO office).

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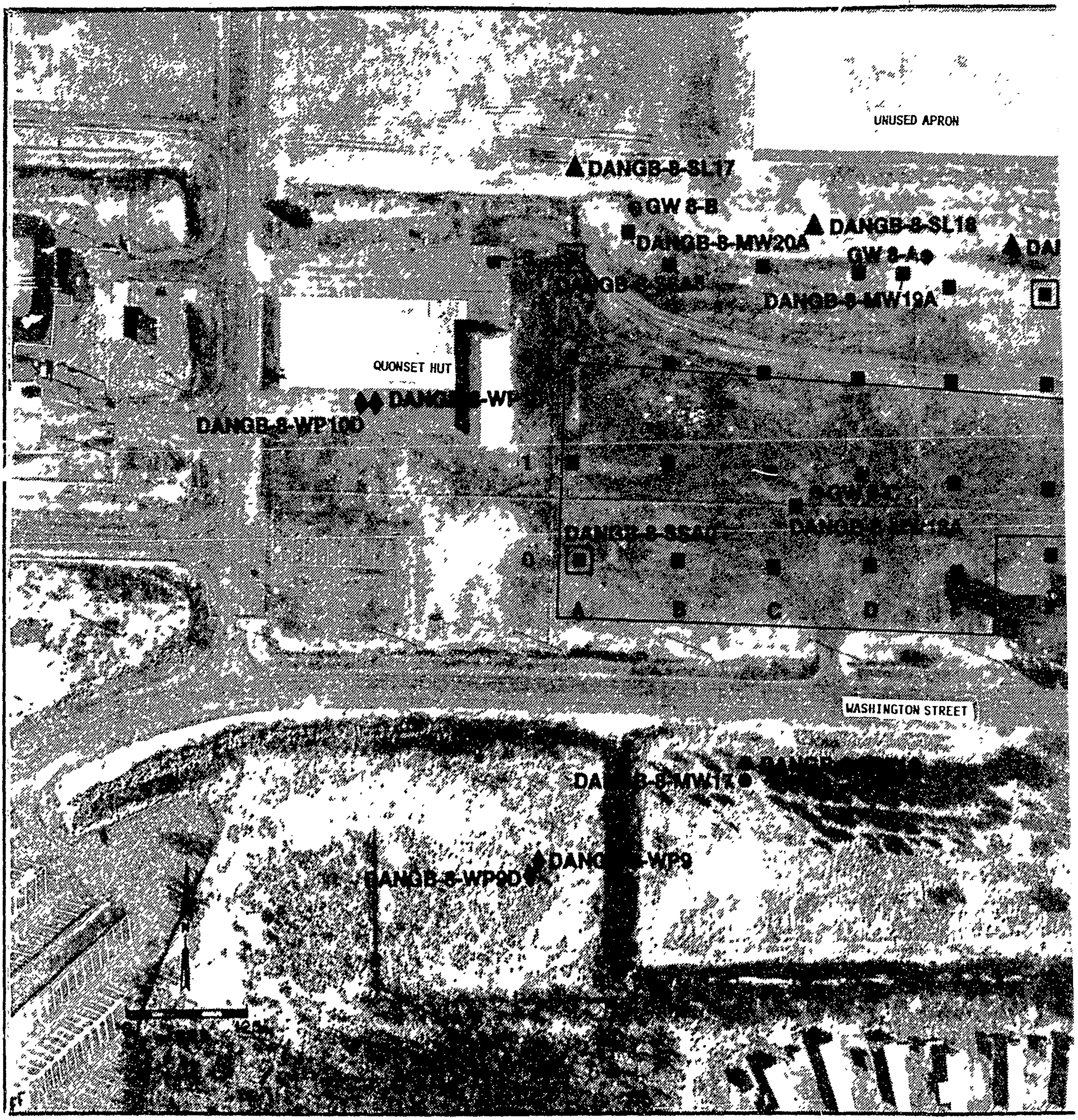
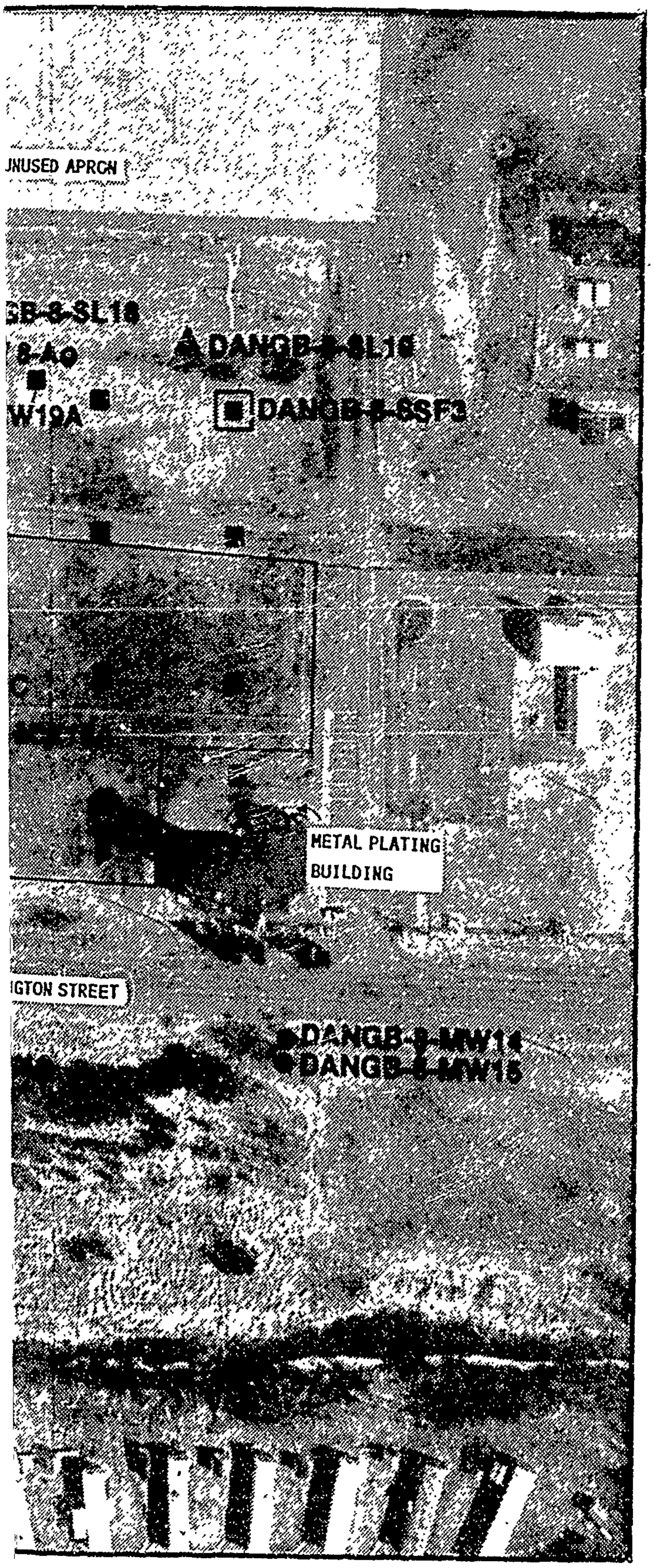


Figure 2-10 Site 8 Sampling Locations Utilized during Remedial Investigation.



EXPLANATION

◆	DANGB-8-WP10 Well point installed Remedial Investigation.
●	DANGB-8-MW16 Monitoring well constructed Remedial Investigation.
■	DANGB-8-MW18A Monitoring well borehole drilled, sampled, plugged and abandoned Remedial Investigation.
■	DANGB-8-SGB3 Location on soil sample grid.
▣	DANGB-8-SGA0 Surveyed location on soil sample grid.
⊙	GW 8-C Monitoring Well, Phase II Stage 2.
▲	DANGB-8-SL18 Surface water and sediment sampling location, Remedial Investigation.
☐	Approximate Boundary of the Storage Area (old DPDO office).

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TABLE 2-27

CHEMICAL ANAYSES PERFORMED ON SITE 4 GROUND-WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	12	8[a]
Aromatic Volatile Organics	SW 8020	12	8
Total Petroleum Hydrocarbons	EPA 418.1	12	3[b]
Metals			
Barium	SW 6010	12	3
Cadmium	SW 7131	12	3
Chromium	SW 7191	12	3
Lead	SW 7421	12	3
Specific Conductance	EPA 120.1	12	1[c]
Temperature	EPA 170.1	12	1
pH	EPA 150.1	12	1

a. Includes 1 duplicate, 3 field blank, 2 trip blank, and 2 bailer rinseate samples.
b. Includes 1 duplicate and 2 bailer rinseate samples.
c. Duplicate sample.

Table 2-28
Summary of Work Performed at Site 8 Locations

Location Identification	Monitoring Well Construction	Wellpoint Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
DANGB-8-SSA0					X										X	
DANGB-8-SSA1					X										X	
DANGB-8-SSA2					X										X	
DANGB-8-SSA3					X										X	
DANGB-8-SSB0					X										X	X
DANGB-8-SSB1					X										X	
DANGB-8-SSB2					X										X	
DANGB-8-SSB3					X										X	
DANGB-8-SSC0					X										X	
DANGB-8-SSC1					X										X	
DANGB-8-SSC2					X										X	
DANGB-8-SSC3					X										X	
DANGB-8-SSD0					X										X	
DANGB-8-SSD1					X										X	
DANGB-8-SSD2					X										X	
DANGB-8-SSD3					X											
DANGB-8-SSE0					X										X	
DANGB-8-SSE1					X										X	
DANGB-8-SSE2					X										X	
DANGB-8-SSE3					X										X	
DANGB-8-SSF0					X										X	
DANGB-8-SSF1					X										X	
DANGB-8-SSF2					X										X	
DANGB-8-SSF3					X										X	X
DANGB-8-MW14	X		X		X	X					X	X				X
DANGB-8-MW15	X		X		X	X					X	X				X
DANGB-8-MW16	X		X		X	X					X	X		X		X
DANGB-8-MW17	X		X		X	X					X	X				X

Table 2-28 (Continued)

Location Identification	Monitoring Well Construction	Wellpoint Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-Water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
DANGB-8-MW18A			X		X	X										X
DANGB-8-MW19A			X		X	X										X
DANGB-8-MW20A			X		X	X										X
DANGB-8-WP9		X	X									X				X
DANGB-8-WP9D		X	X									X				X
DANGB-8-WP10		X	X									X				X
DANGB-8-WP10D		X	X									X				X
DANGB-8-SL 17									X	X						X
DANGB-8-SL 18									X	X						
DANGB-8-SL 19									X	X						
GW 8-A											X	X		X		X
GW 8-B											X	X				X
GW 8-C											X	X				X

locations of northwest, northeast and southwest corners of this grid were surveyed.

2.5.1 Surface Feature Investigation

Aerial photographs from 1951 to the present were examined. The photographs were taken in 1951, 1952, 1960, 1961, 1965, 1979 and 1988.

2.5.2 Surface Water and Sediment Investigations

Surface water and sediment were sampled at three locations. All three locations are on the shallow drainage ditch which runs along the north side of the site and drains to the west.

A summary of the kinds and numbers of analyses performed on the surface water samples is given in Table 2-29 and on the sediment samples in Table 2-30.

Surface water and sediment were investigated to aid in defining the relationship between surface water and ground water at the site.

2.5.3 Geologic Investigation

The geologic investigation consisted of lithologic descriptions and grain size analyses.

The lithologic descriptions were done from the continuous cores obtained from the three monitoring well boreholes which were drilled, plugged and abandoned, the boreholes drilled for the four monitoring wells which were constructed and the boreholes drilled for the four well points which were installed. Of the eleven boreholes, seven were drilled into bedrock. To determine that bedrock and not just a large boulder was reached, the bedrock was cored for three to five feet. The second, shallow hole of both the paired monitoring wells and the paired well points was not drilled to bedrock. The borehole locations are shown on Figure 2-9.

The lithologic descriptions were used to define the aquifer system underlying the site.

The grain size analyses were done on 5 samples obtained from the borehole drilled for monitoring well DANGB-8-MW20A and on 5 samples obtained from the borehole drilled for monitoring well DANGB-8-MW16. The samples were selected as representative of intervals of distinct lithology. These data were used to aid in defining the hydraulic properties of the water table aquifer.

TABLE 2-29

CHEMICAL ANALYSES PERFORMED ON SITE 8 SURFACE WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	2	3[a]
Aromatic Volatile Organics	SW 8020	2	3
Pesticides and PCBs	EPA 608	2	1[b]
Total Petroleum Hydrocarbons	EPA 418.1	2	1
Metals			
Barium	SW 6010	1	0
Cadmium	SW 7131	1	0
Chromium	SW 7191	1	0
Lead	SW 7421	1	0
Specific Conductance	EPA 120.1	2	1
Temperature	EPA 170.1	2	1
pH	EPA 150.1	2	1

a. Includes 1 duplicate, 1 field blank and 1 trip blank sample.
b. Duplicate sample.

TABLE 2-30

CHEMICAL ANALYSES PERFORMED ON SITE 8 SEDIMENT SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	3	1[a]
Aromatic Volatile Organics	SW 8020	3	1
Pesticides and PCBs	SW 8080	3	1
Total Petroleum Hydrocarbons	EPA 418.1	3	1
Metals			
Barium	SW 6010	3	1
Cadmium	SW 7131	3	1
Chromium	SW 7191	3	1
Lead	SW 7421	3	1

a. Duplicate sample.

2.5.4 Soil Investigations

Soil investigations were done on samples from shallow, augered holes and on samples from deep boreholes.

The shallow augered holes were laid out in a grid (see Figure 2-9) with four rows running east-west and labeled 0 to 3 starting with the southernmost row and six columns running north-south and labeled A to F starting with the westernmost column. The location of individual holes was determined using a surveyor's tape and hand-held compass. Locations DANGB-8-SSA0, DANGB-8-SSA3 and DANGB-8-SSF3 were surveyed. Location DANGB-8-SSF0 is displaced slightly to the north from its theoretical grid location due to the presence of a building at that precise point.

The shallow soil sample holes at this site were drilled with a hand-held power auger. They ranged in depth from 1.4 to 2.1 feet, with most being about 1.8 feet deep.

The deep soil samples were obtained from the three monitoring well boreholes which were drilled, plugged and abandoned and from the deep boreholes of the two pairs of monitoring wells which were constructed. The samples were obtained from near the surface, from at the water table, and from just above the bedrock surface.

A summary of the kinds and numbers of analyses performed on the soil samples is given in Table 2-31.

Results of the soil investigations were used in defining any continuing sources for ground-water contamination and the extent to which soil aids in retarding migration of contaminants with the ground water.

2.5.5 Ground-Water Investigation

This investigation consisted of water level measurements, surveying of all water level measuring points and locations, an aquifer slug test and chemical analyses of ground-water samples.

2.5.5.1 Aquifer Investigation

Water level measurements were taken at monthly intervals as field work proceeded. Wells were included in the water level measurements at the next sampling round after their completion. The number of rounds at particular locations is summarized in Table 2-32. Two surface water locations were also used as water level control points.

The water level data were used to aid in determining horizontal and vertical ground-water flow directions in the aquifer system at the site.

TABLE 2-31

CHEMICAL ANALYSES PERFORMED ON SITE 8 SOIL SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	17[a]	3[b]
Aromatic Volatile Organics	SW 8020	17	3
Semi-Volatile Organics	SW 8270	2[c]	2[d]
Pesticides and PCBs	SW 8080	41[e]	6[f]
Total Petroleum Hydrocarbons	EPA 418.1	39[g]	6
Metals			
Barium	SW 6010	16[h]	3[i]
Cadmium	SW 7131	16	3
Chromium	SW 7191	16	3
Lead	SW 7471	16	3
Percent Moisture			

a. Samples from deep boreholes.
b. Duplicate samples from deep boreholes.
c. Samples from deep boreholes.
d. Duplicate samples from deep boreholes.
e. Includes 24 samples from shallow auger holes and 17 samples from deep boreholes.
f. Includes 3 duplicate samples from shallow auger holes and 3 from deep boreholes.
g. Includes 24 samples from shallow auger holes and 15 samples from deep boreholes.
h. Samples from deep boreholes.
i. Duplicate samples from deep boreholes.

TABLE 2-32

SUMMARY OF SITE 8 WATER LEVEL MEASUREMENT ROUNDS

Well Number	Number of Rounds
GW 8-A	4
GW 8-B	4
GW 8-C	4
DANGB-8-MW14	3
DANGB-8-MW15	3
DANGB-8-MW16	3
DANGB-8-MW17	3
DANGB-8-WP9	3
DANGB-8-WP9D	3
DANGB-8-WP10	3
DANGB-8-WP10D	3

Aquifer slug tests were conducted using wells DANGB-8-MW16, and GW 8-A. This information was used to aid in determining the ability of the water table aquifer to transmit water in the site vicinity.

2.5.5.2 Ground-Water Sampling Investigation

Samples were obtained from the four monitoring wells constructed during this study and from the three monitoring wells previously constructed for a total of seven sampling locations. Locations of these wells are shown on Figure 2-10.

The intent was to obtain ground-water samples from both shallow and deep levels from five separate locations at this site. Thus it was proposed that the three existing monitoring wells would be paired and two additional pairs would be constructed down gradient from the location of the old storage area itself. It was found when drilling the proposed deep boreholes at the existing shallow monitoring well locations that these existing wells had in fact reached bedrock which was at shallow depths at these locations, Thus the newly drilled boreholes were plugged and abandoned after soil samples were obtained. Bedrock was sufficiently deep at the two downgradient locations to construct the two downgradient pairs of monitoring wells.

The samples were analyzed for the targeted compounds as determined from previous work. A summary of the numbers and kinds of analyses performed is given in Table 2-33.

Results of the ground-water sampling and analysis were used to aid in defining the extent to which contaminants have migrated from the site.

2.6 SITE 10

The Site 10 work consisted of a surface feature and ground-water investigations. This work is summarized on Table 2-34.

2.6.1 Surface Feature Investigation

Aerial photographs from 1951 to the present were examined. The photographs were taken in 1951, 1952, 1960, 1961, 1979 and 1988.

In particular these photographs were examined in order to better define the precise location of the site.

2.6.2 Ground-Water Investigation

These investigations consisted of water level measurements, surveying of all water level measuring points and chemical analyses of ground-water samples.

TABLE 2-33

CHEMICAL ANALYSES PERFORMED ON SITE 8 GROUND-WATER SAMPLES

Analytic Parameter	Method Used	Number of Samples	Number of Quality Control Samples
Halogenated Volatile Organics	SW 8010	7	7[a]
Aromatic Volatile Organics	SW 8020	7	7
Pesticides and PCBs	EPA 608	7	3[b]
Total Petroleum Hydrocarbons	EPA 418.1	7	3
Metals			
Barium	SW 6010	7	3
Cadmium	SW 7131	7	3
Chromium	SW 7191	7	3
Lead	SW 7421	7	3
Specific Conductance	EPA 120.1	7	1[c]
Temperature	EPA 170.1	7	1
pH	EPA 150.1	7	1

a. Includes 1 duplicate, 3 field blank, 1 trip blank, and 2 bailer rinseate samples.
b. Includes 1 duplicate and 2 bailer rinseate samples.
c. Duplicate sample.

Table 2-34
Summary of Work Performed at Site 10 Locations

Location Identification	Monitoring Well Construction	Wellpoint Construction	Lithologic Descriptions	Grain Size Analysis	Shallow Soil Samples	Deep Soil Samples	Soil Gas Survey	Trenching	Sediment Sampling	Surface Water Sampling	Ground-water Samples	Water Level Measurements	Streamflow Measurements	Slug Tests	Pace and Compass Surveying	Surveying
GW 10-A											X	X				X
GW 10-B											X	X				X
GW 10-C											X	X				X

2.6.2.1 Aquifer Investigation

Two rounds of water level measurements were obtained from the three existing monitoring wells. This information is summarized in Table 2-35.

2.6.2.2 Ground-Water Sampling Investigation

Two rounds of ground-water sampling were performed. Samples were obtained from the three monitoring wells constructed during the Phase II, Stage 2 study. The samples from the first sampling round were obtained in September 1988. The samples from the second sampling round were obtained in February, 1989. They were analyzed for the targeted compounds as determined from previous work. A summary of the kinds and numbers of analyses performed is given in Table 2-36.

Results of the ground-water sampling and analysis were used to determine the existence and level of radiological contamination at the sampling locations.

TABLE 2-35

SUMMARY OF SITE 10 WATER LEVEL MEASUREMENT ROUNDS

Well Number	Number of Rounds
GW 10-A	2
GW 10-B	2
GW 10-C	2

TABLE 2-36

CHEMICAL ANALYSES PERFORMED ON SITE 10 GROUND-WATER SAMPLES

Analytic Parameter	Method Used	Round 1 Samples		Round 2 Samples	
		Number of Samples	Number of Quality Control Samples	Number of Samples	Number of Quality Control Samples
Radiological					
Gross Alpha	SW 9310	3	1[a]	3	1[a]
Gross Beta	SW 9310	3	1	3	1
Radium 226	SW 9315	3	1	3	1
Radium 228	SW 9320	0	0	3	1
Tritium	EPA 906.0	3	1	0	0
Specific Conductance	EPA 120.1	3	1	3	1
Temperature	EPA 170.1	3	1	3	1
pH	EPA 150.1	3	1	3	1

a. Duplicate sample.

End of Section 2.

SECTION 3
INVESTIGATION RESULTS

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SECTION 3
INVESTIGATION RESULTS

The non-chemical results of the Remedial Investigation are presented in this section. The results of the chemical analyses are presented in Section 4. In addition to the five sites studied (2, 3, 4, 8 and 10) there are sections for the airport area as a whole and for the zone formed by Sites 3, 4 and 8 which are adjacent to each other.

3.1 AREA LOCATIONS

The airport general area investigation locations consist of five surface locations and three boreholes in which monitoring wells were constructed. The surface locations consist of one background and four airport drainage locations. The three ground-water monitoring wells are background locations. The locations are shown on Figure 2-1 and the work performed is summarized on Table 2-3.

3.1.1 Surface Features

The aerial photographs from 1951 to 1988 show a gradual increase in urbanization in the vicinity of the airport. The growth of the airport itself appears to be the major change over the years. No other large scale construction or development appears to have taken place during these years.

A major expansion of the airport took place in 1951 and 1952 as seen in Figure 3-1, an aerial photograph taken in August 1952. This photograph was taken from an oblique angle and right angles on the ground do not appear to be right angles in the photograph.

Additional construction occurred on the north side of the airport in the 1960s and in 1970 a new commercial terminal was constructed on the southeast side of the airport.

3.1.2 Surface Water Hydrology

Streamflow measurements were taken at the one background and two of the airport drainage locations. The background location, DANGB-BG-SL4, is on Miller Creek south of the airport. The two airport drainage locations, DANGB-BG-SL1 and DANGB-BG-SL2 are both on small streams north of the airport. Measurement methodology, raw field data, and computation of the stream discharge is given in Appendix J. The results are shown in Table 3-1.

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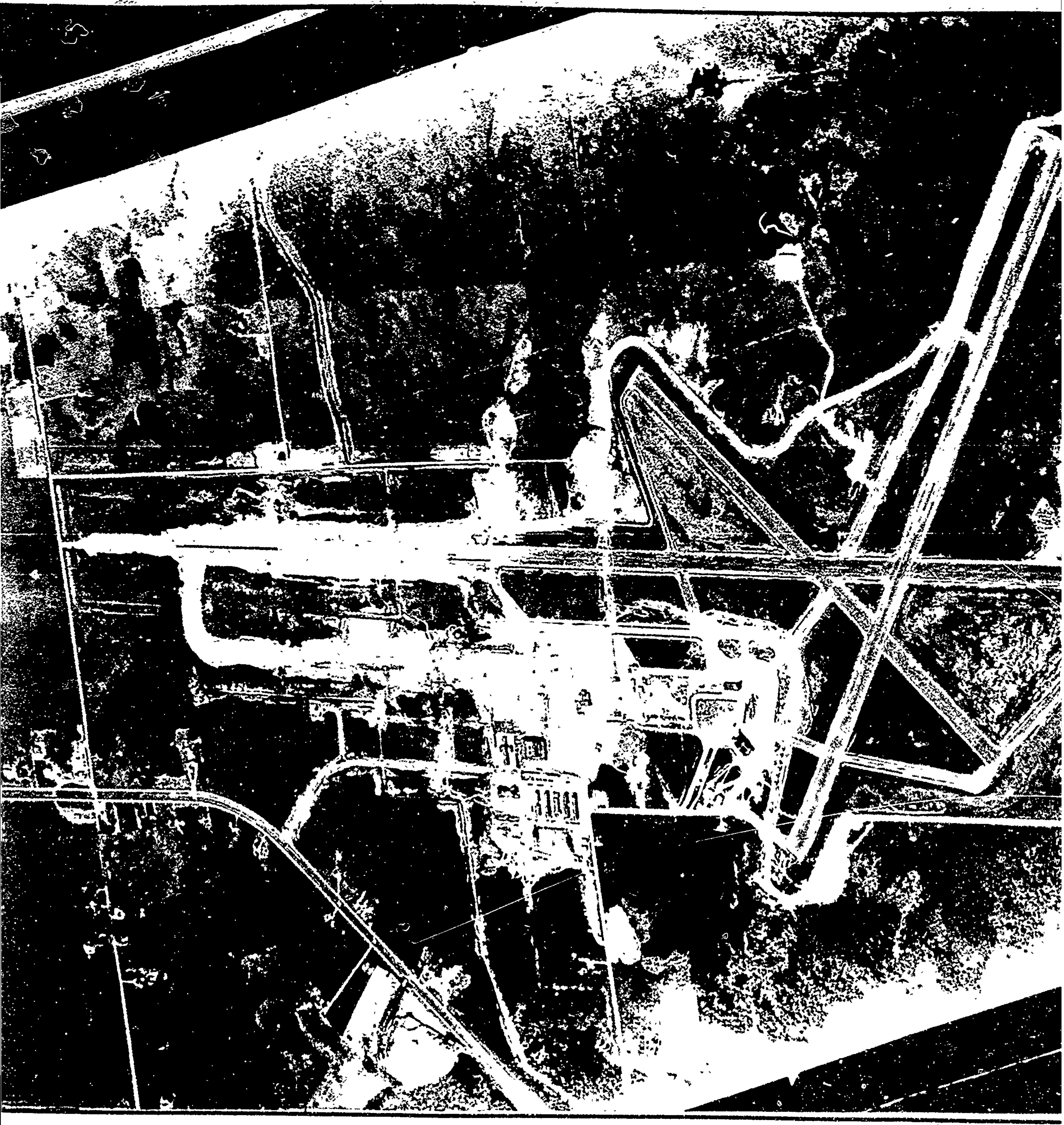
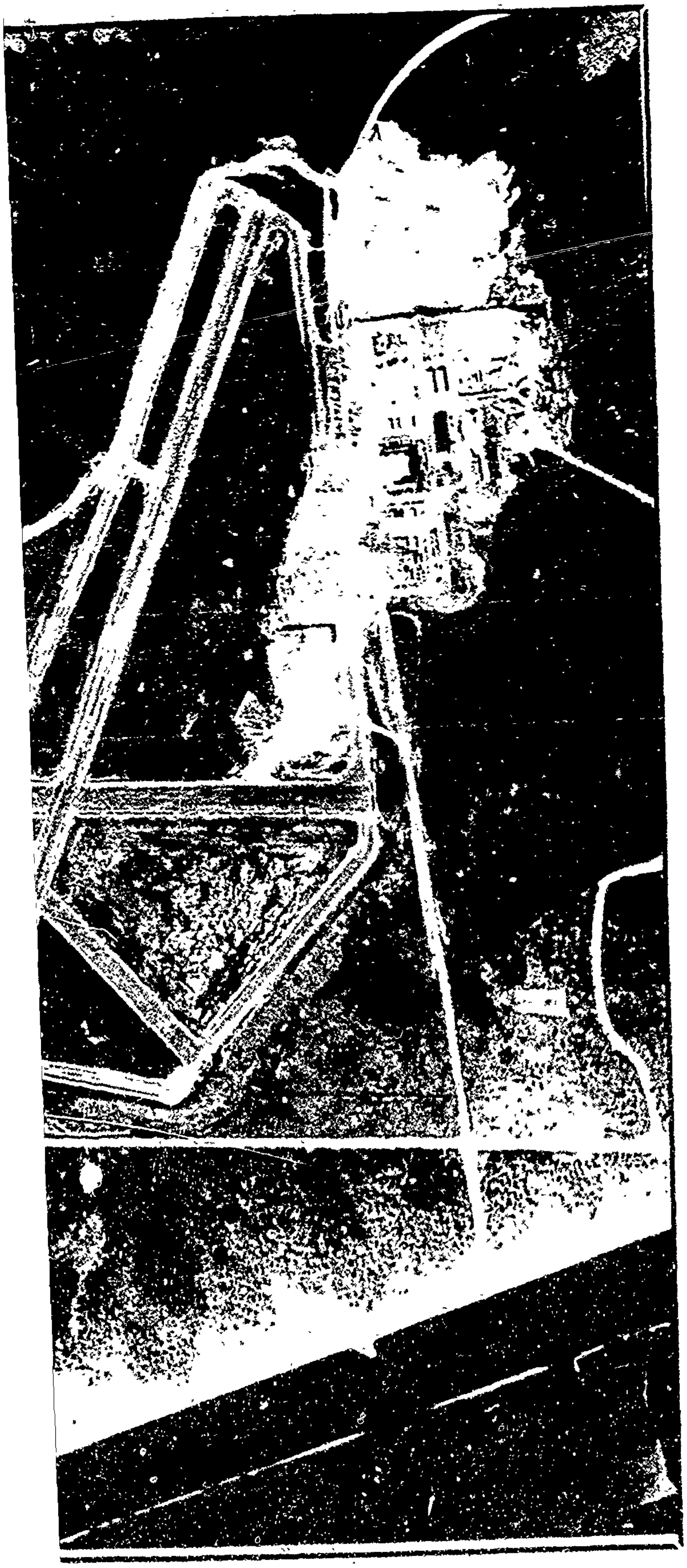


igure 3-1 Aerial Photograph of the Airport Area, August 1952.



Approximate North

Scale Approximate

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TABLE 3-1

STREAMFLOW AT THREE AREA LOCATIONS

Stream Name	Measurement Location	Discharge (gallons per minute)
<u>Airport Drainage Locations</u>		
Beaver Creek	DANGB-BG-SL1	129
Unnamed Drainage Ditch	DANGB-BG-SL2	120
<u>Background Location</u>		
Miller Creek	DANGB-BG-SL4	1,170

The discharge values for the two streams which drain the airport to the north into Wild Rice Lake are each about 10 percent of the discharge of Miller Creek at the place its streamflow was measured (see Figures 1-1, 1-2, and 2-1 for locations). This relationship correlates with the apparent relative size of the drainage areas at the measurement locations.

3.1.3 Geology

The airport is underlain by unconsolidated glacial till which overlies bedrock consisting of gabbro belonging to the Duluth Complex. The glacial till consists of clay, silt, sand, pebbles, gravel and mixtures of these components in layers and lenses of varying sizes. The layers appear to be lenses in the sense that they grade laterally into layers with different proportions of the same constituents. For example, a silty clay with some sand may grade into a silt with some clay and little sand. The proportion of pebbles and cobbles appears to increase downward. Large glacial boulders can be found at almost any depth. These relationships are shown in Figures 3-2 and 3-3, each of which shows a pair of paired boreholes. Well points DANGB-2-WP7 and DANGB-2-WP7D are at Site 2 on the north side of the airport, and monitoring wells DANGB-8-MW14 and DANGB-8-MW15 are at Site 8 on the south side of the airport. The gradation of one lithologic into another over a distance of as little as four feet makes it clear that individual strata cannot be correlated across the airport, and no attempt was made to do so. South of the main east-west runway, a layer of sand or sand and gravel, but sometimes silt or silty clay, appears to immediately overlie bedrock. North of the main east-west runway, a layer of clay or silty clay was found immediately overlying bedrock. Sometimes the uppermost foot to foot and one-half of the gabbro appears to be fractured.

The predominant bedrock feature in the airport area is a buried pre-glacial channel as indicated by the bedrock altitude contours on Figure 3-4. The channel is a north-south trending feature which deepens to the south from the vicinity of Sites 3 and 4 and to the north from the vicinity of Site 10.

Three monitoring wells were constructed at peripheral sites on the airport (see Figure 2-1). The continuous drill core from those boreholes was comprised of unconsolidated glacial till deposits consisting of poorly sorted mixture of clay, silt, sand, pebbles, and locally occurring boulders.

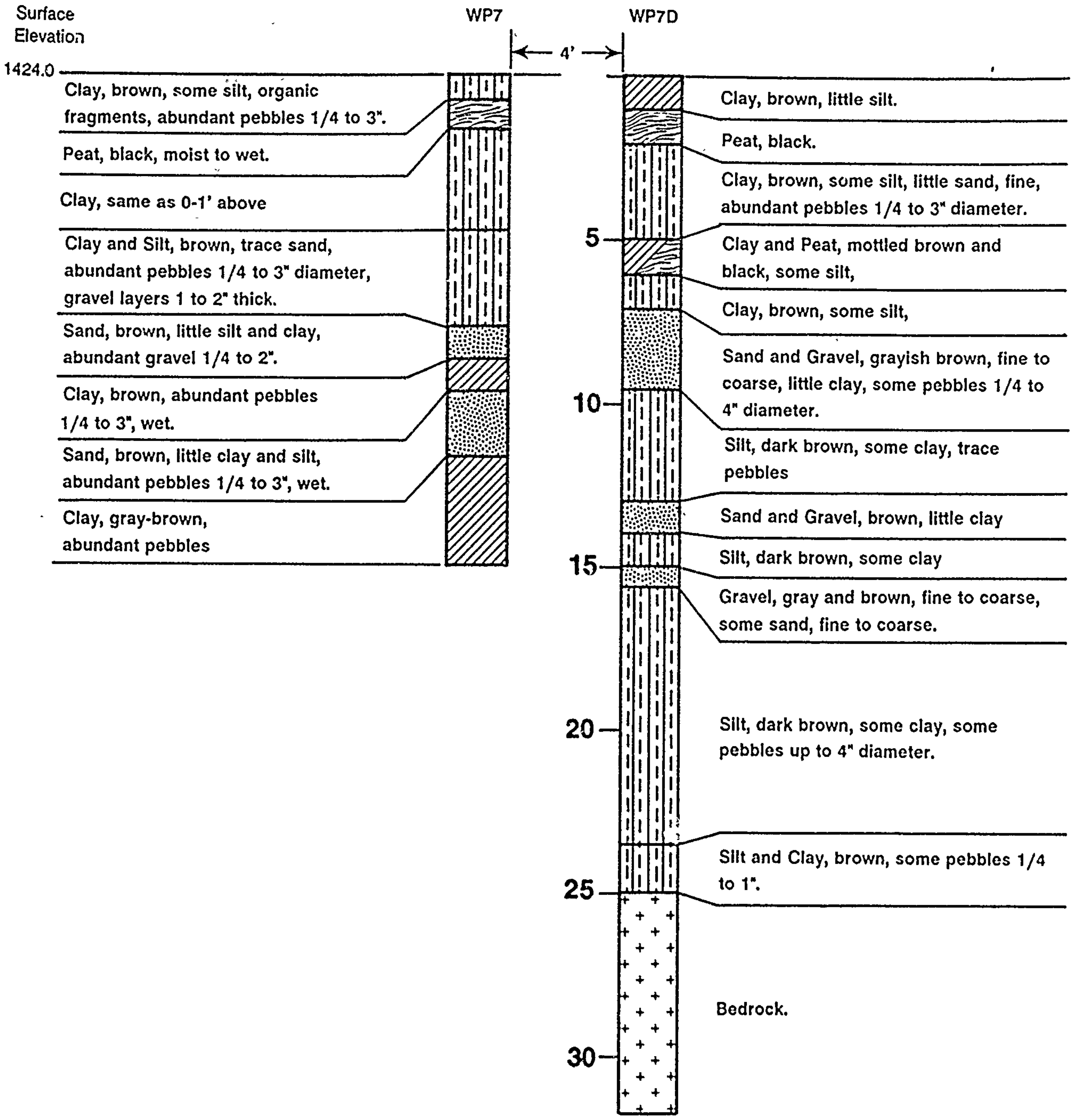

Figure 3-2 Lithologic Logs From Paired Well Points at Site 2.

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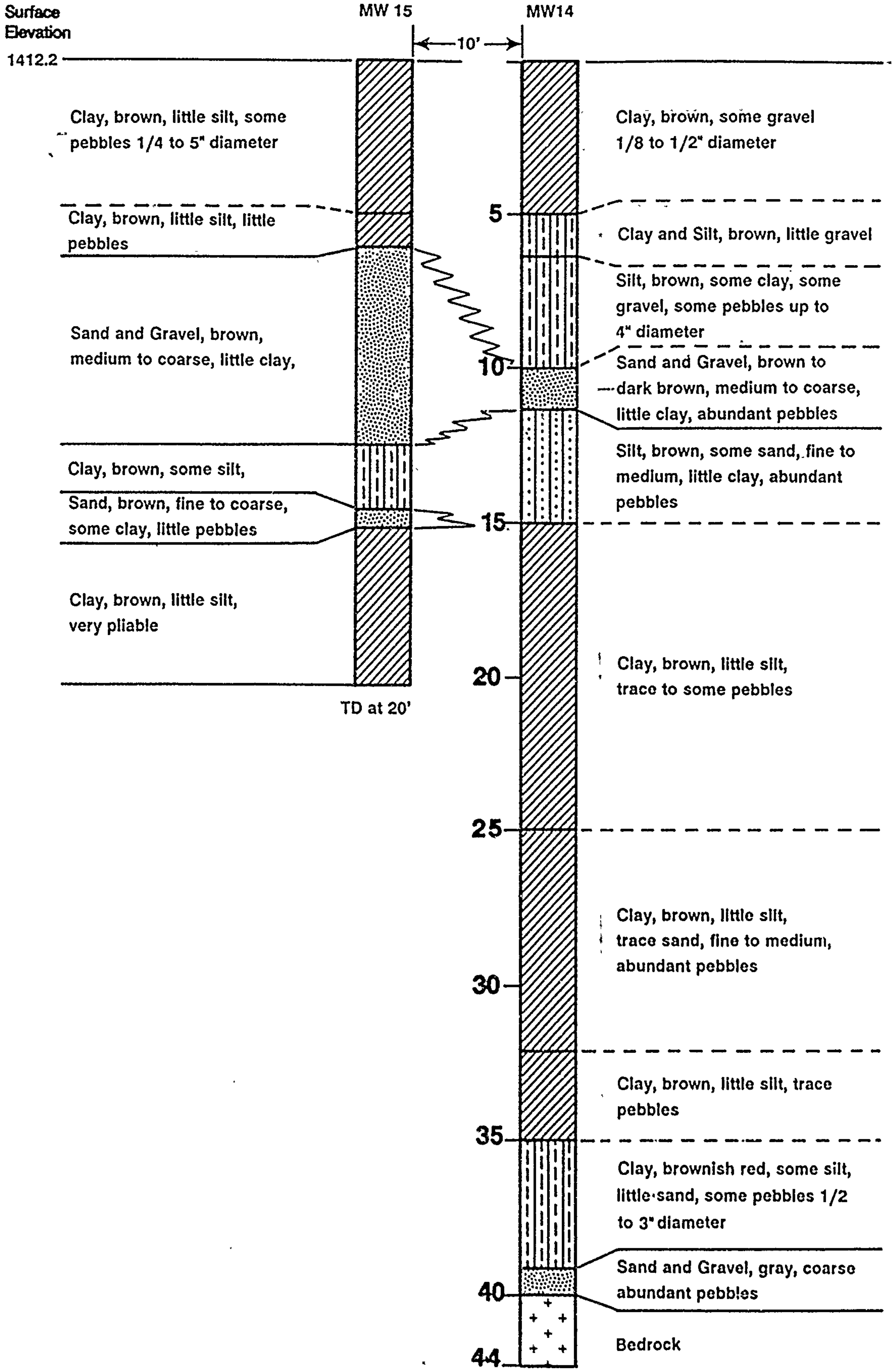

Figure 3-3 Lithologic Logs From Paired Well Points at Site 8.

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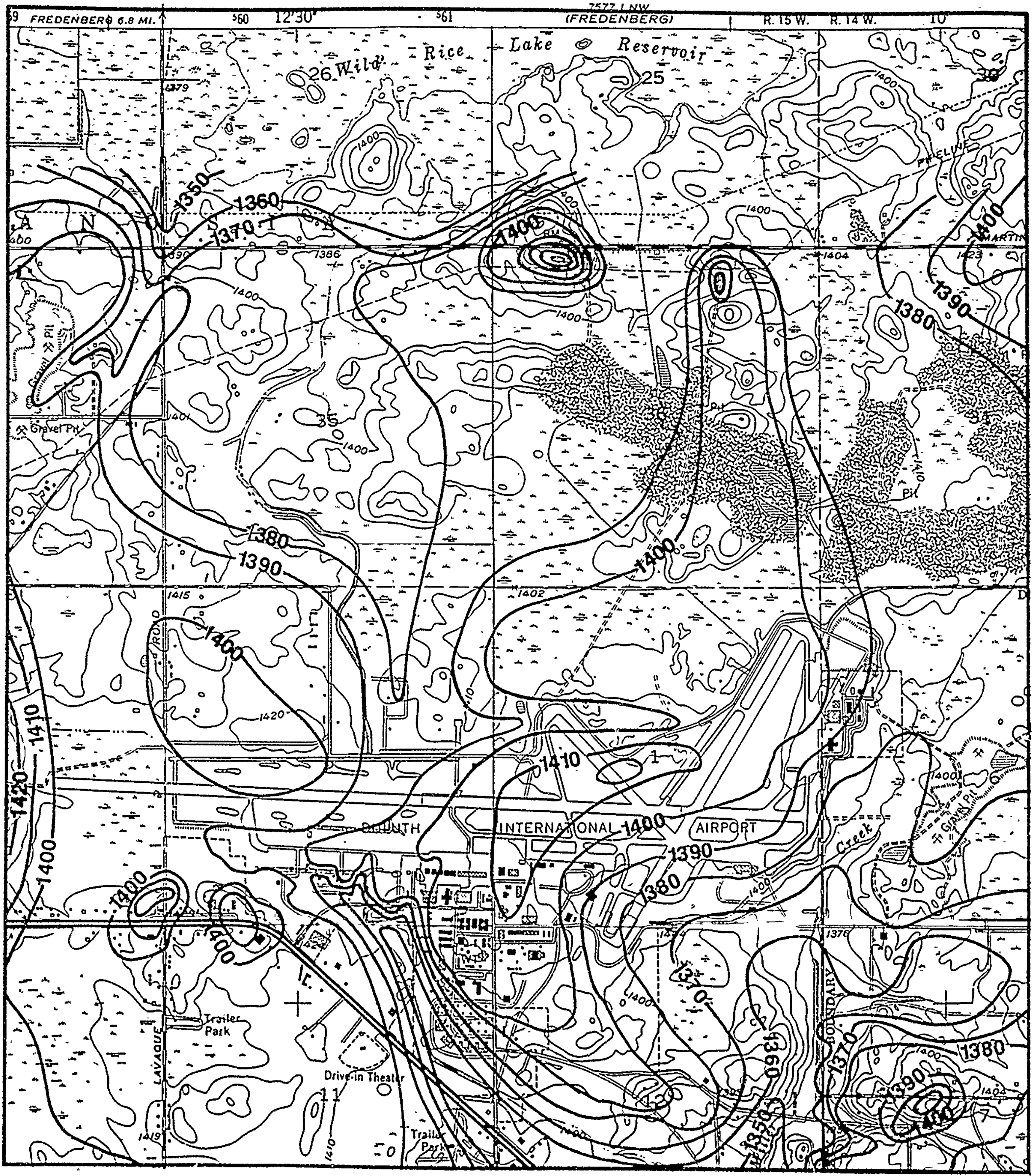
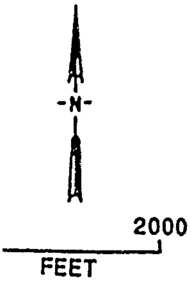


Geology modified from Rodgers (1962)
Base from USGS Duluth Heights, MN
1 : 24,000 quadrangle

Figure 3-4 Bedrock Contour Map fo the Airport Area.

EXPLANATION

——1410—Lines of equal bedrock altitude above NGVD. Contour interval is 10 feet.



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The ground does not appear to have been disturbed by construction activities at the two western locations DANGB-BG-MW32 and DANGB-BG-MW42, while there is a possibility that some surface disturbance took place at location DANGB-BG-MW43 during construction of the northeast-southwest runway. This runway was constructed prior to 1950.

3.1.4 Hydrogeology

The hydrogeology of the airport appears to be controlled predominantly by the topography of the bedrock. Drilling done during this study added detail to the bedrock surface as constructed by Rogers, 1962, but did not change the major features or their locations as delineated by him.

The data collected in this study also confirm that unconsolidated glacial deposits are the predominant aquifer in the airport area and that ground-water flow is also controlled by the amount of clay in the sediments at any particular location. Cross-sections shown on Figure 3-5 from DANGB-BG-42 on the west side of the airport and from DANGB-2-WP7D on the north, to DANGB-BG-43 on the east and south show drainage toward Sites 4 and 8, and additional ground-water flow southeastward toward Miller Creek. The index to cross-sections is shown on Figure 3-6. Water table altitude data are presented in Appendix I, Table I-1.

3.2 SITE 2

Site 2 consists of two fire training areas; Fire Training Area 1 (FTA-1) south of the airport perimeter road; and Fire Training Area 2 (FTA-2) north of the airport perimeter road (see Figures 1-6, 1-7, 2-2, and 2-3). The site is described and previous work is summarized in Section 1.2.4. The work done during this study is described in Section 2.3 and summarized in Table 2-9.

3.2.1 Surface Features

The location of FTA-1 was determined through the examination of aerial photographs. It is visible on Figure 3-7 which was taken in August 1952. This photograph is at the same scale (approximately 1" = 250') as the other photographs of this site. The two fire-training pits, one of which is "L"-shaped and the other rectangular, appear at the end of an access road to the east of the northwest-southwest access road in this photograph. A 1961 photograph shows that FTA-1 was being filled in and FTA-2 was being developed. A 1965 photograph, Figure 3-8, shows FTA-2 fully developed, and a small rectangular pit remaining at FTA-1. A 1979 photograph, Figure 3-9, shows no trace of FTA-1 and only faint traces of the access roads across the

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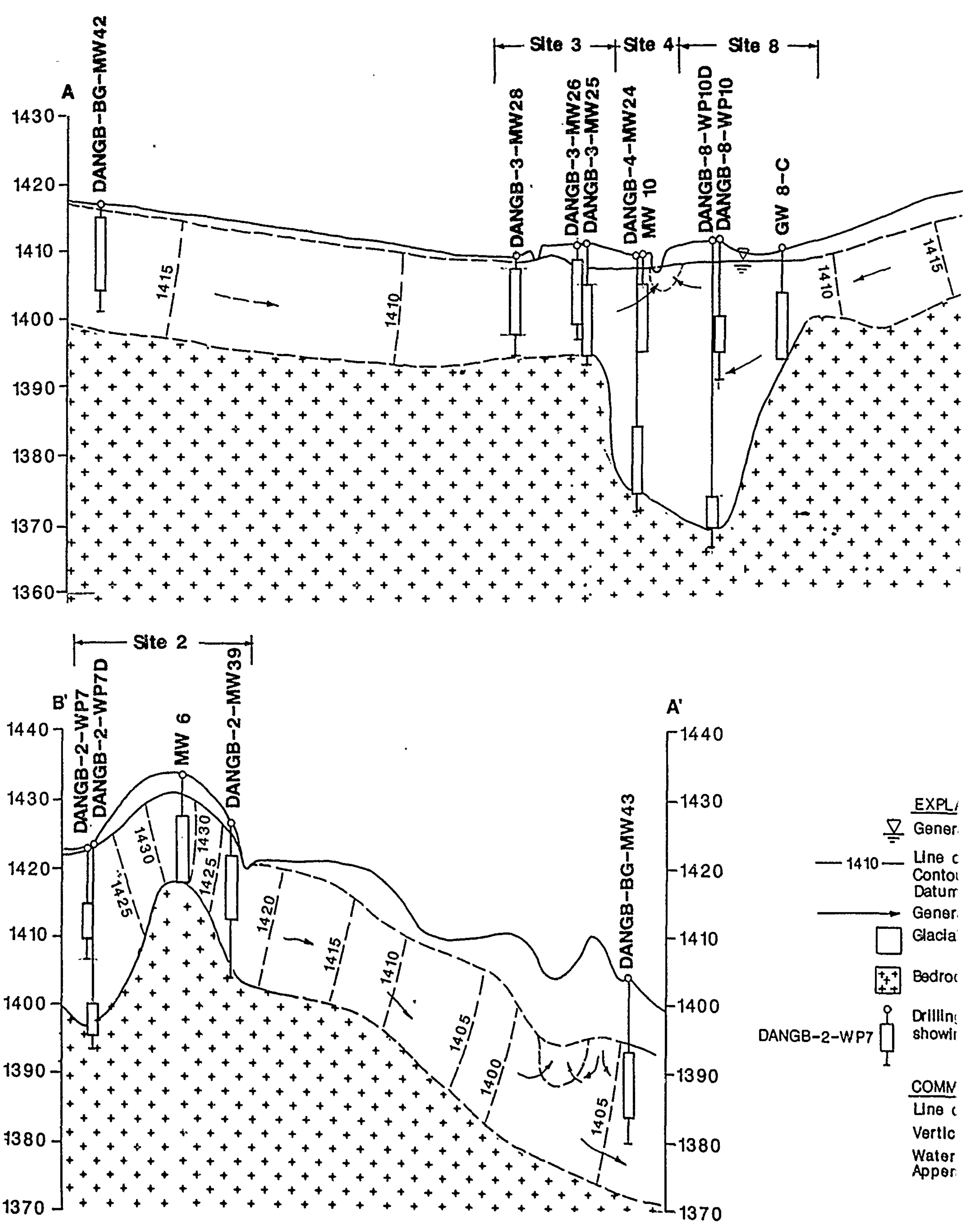
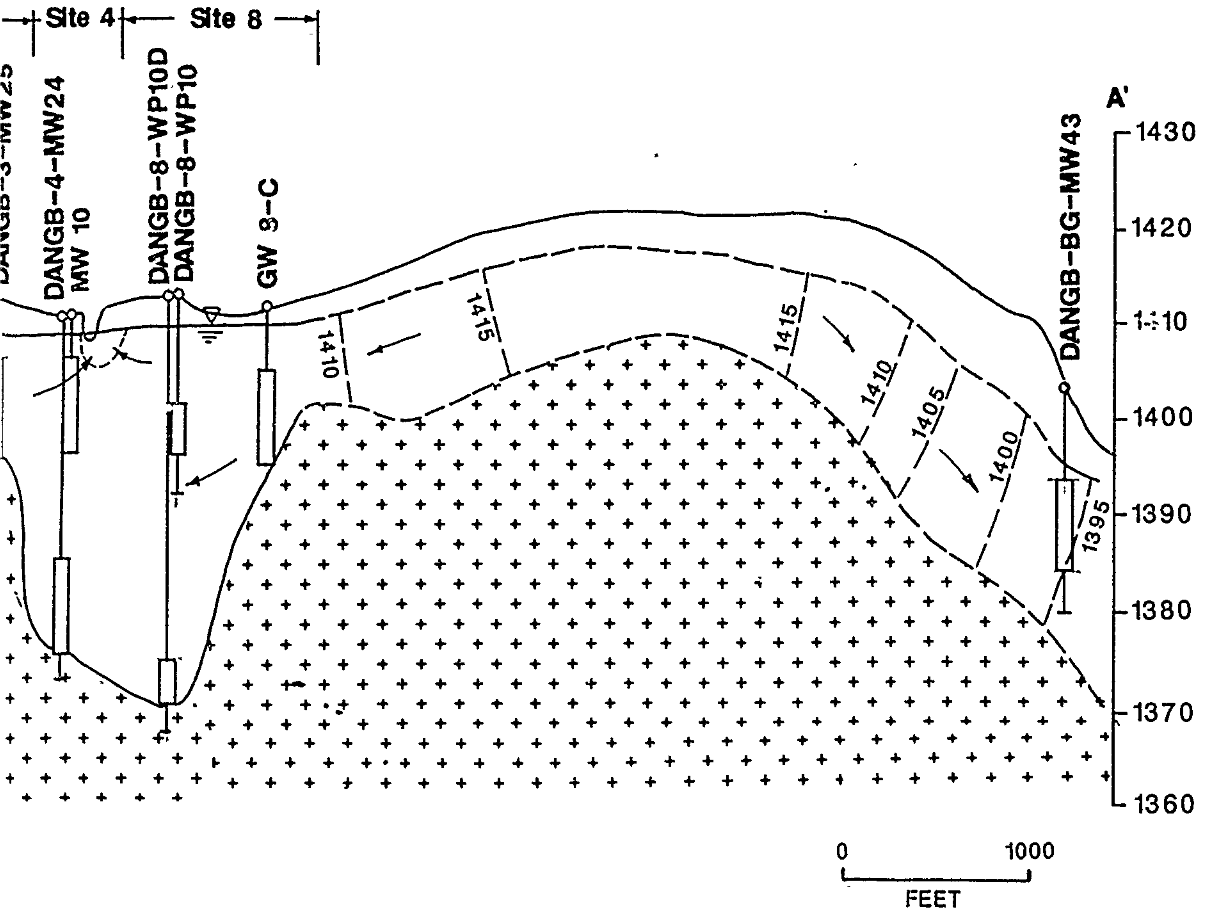
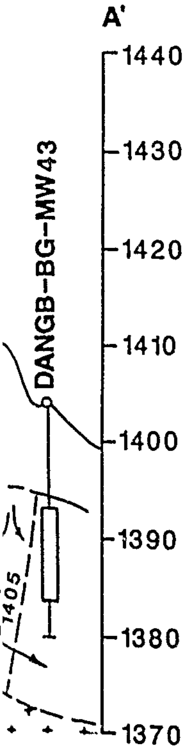


Figure 3-5 Geologic Cross-Sections of the Airport Area.





EXPLANATION

▽ Generalized water table.

—1410— Line of equal head on 27 September, 1988. Contour interval variable. Dashed where inferred. Datum is NGVD of 1929.

→ Generalized direction of ground-water flow.

☐ Glacial deposits.

⊞ Bedrock.

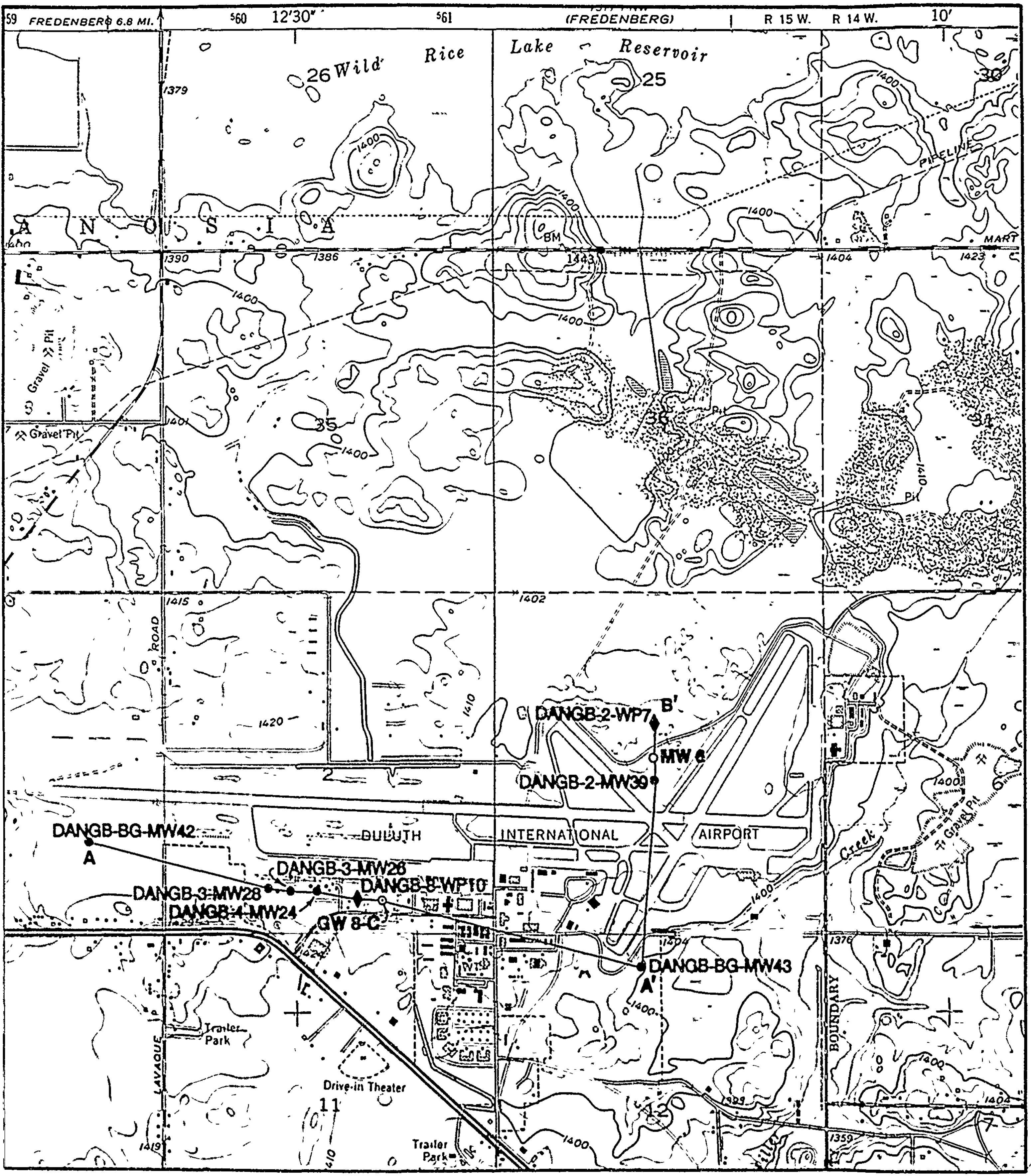
DANGB-2-WP7 Drilling location and well identification showing screened interval.

COMMENTS

Line of Sections shown on Figure 3-6.

Vertical exaggeration x 50.

Water table altitude data are given in Appendix I, Table I-1.



Base from USGS Duluth Heights, MN
1: 24,000 quadrangle

Figure 3-6 Index to Cross-Sections of the Airport Area.

EXPLANATION

● **DANGB-BG-MW42**
Monitoring Well, Remedial Investigation.

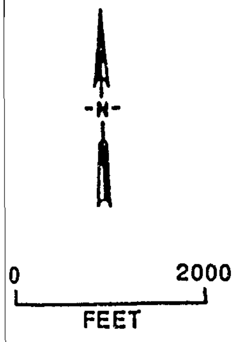
◊ **DANGB-8-WP10**
Well Point, Remedial Investigation,

⊙ **GW 8-C**
Monitoring Well, Phase II, Stage 2 Investigation.

○ **MW 6**
Monitoring Well, Phase II, Stage 2 Investigation,

Contour Interval 10.0'.

COMMENT: Water table altitude data are given in Appendix I, Table I-1.



igure 3-7 Aerial Photograph of Site 2, August 1952.

EXPLANATION

◯ Approximate boundary of Fire Training Area 1.

△ Future Location of Fire Training Area 2.

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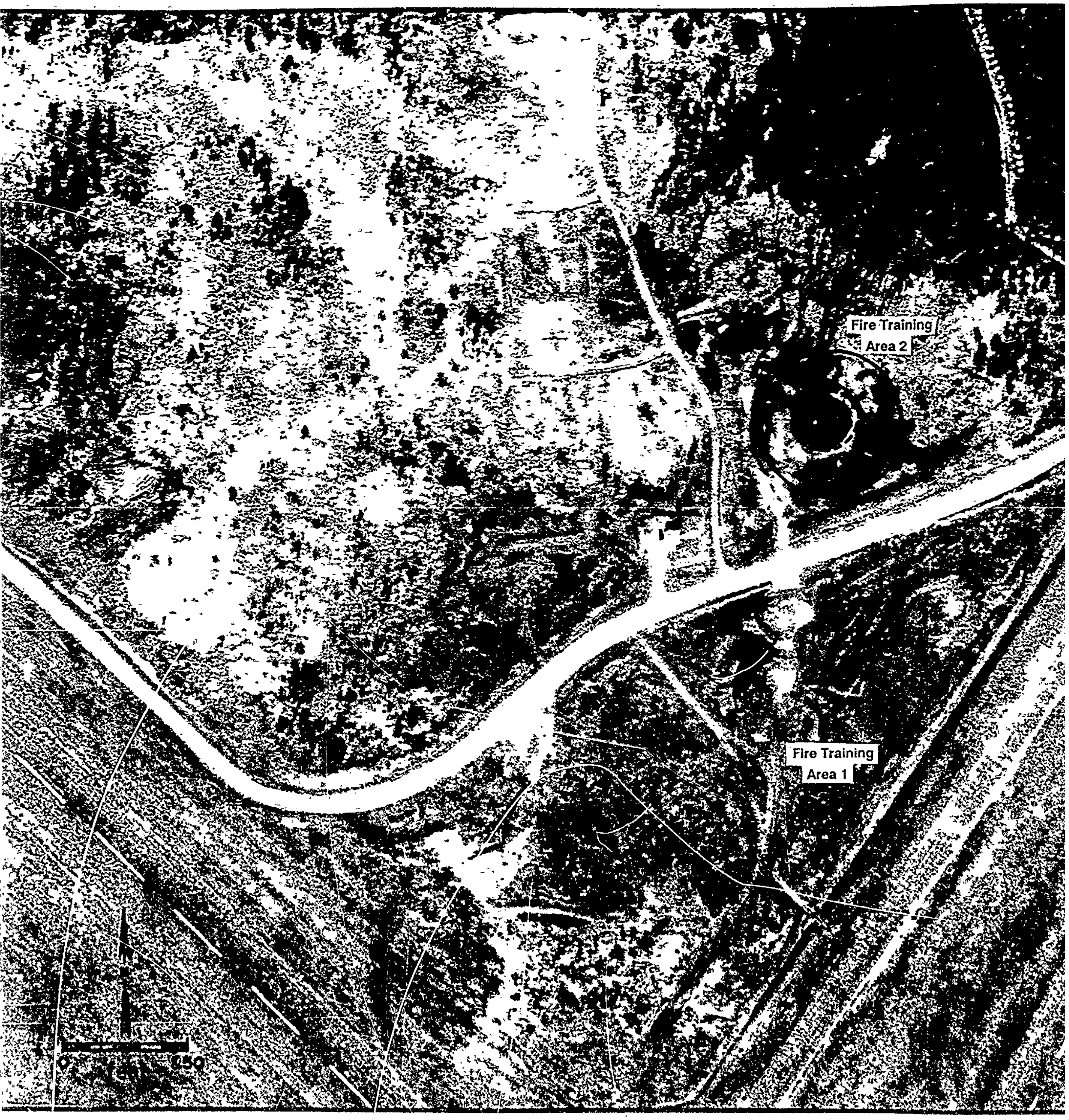
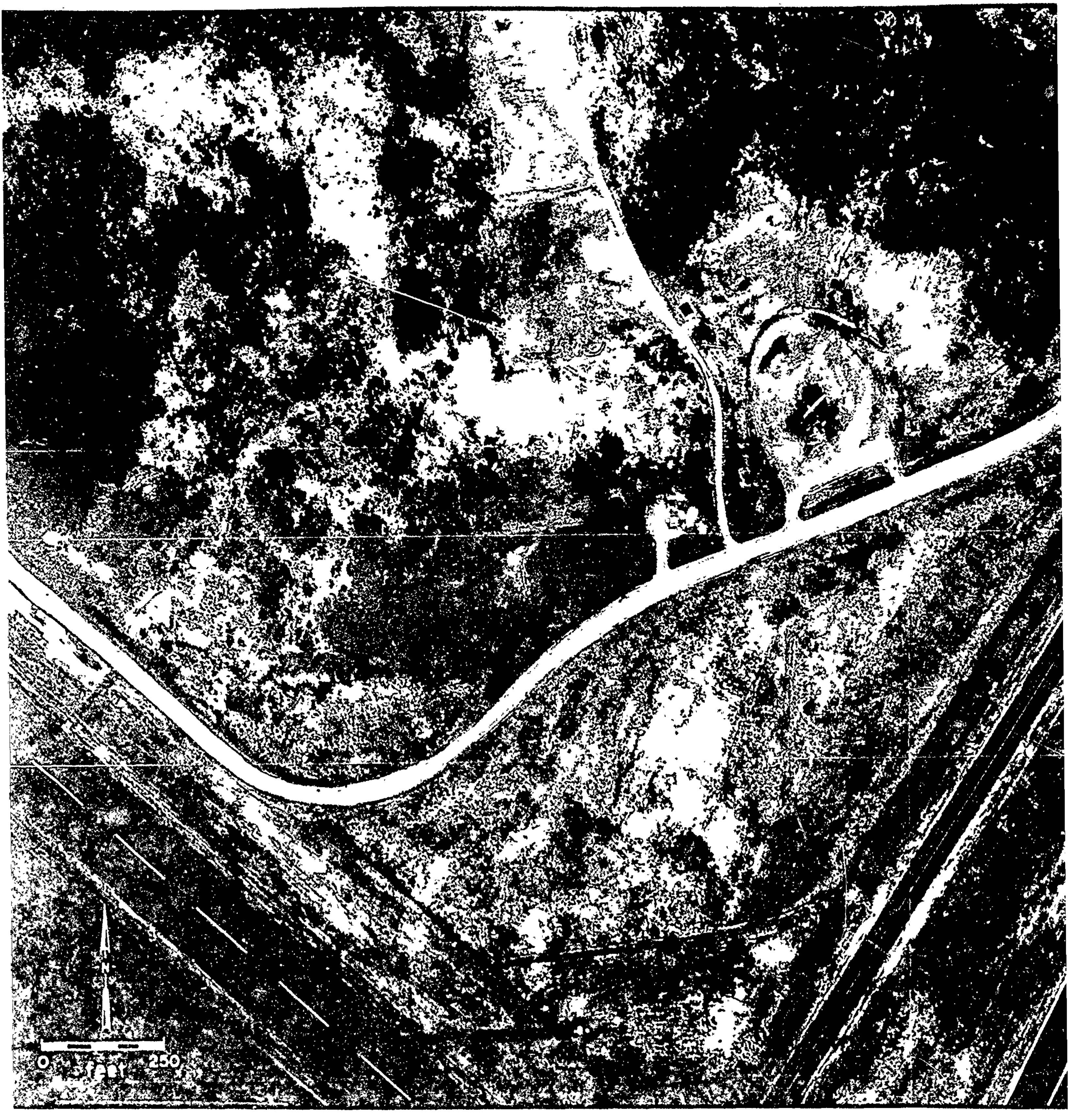


Figure 3-8 Aerial Photograph of Site 2, Ocotber 1965.

EXPLANATION

○ Approximate boundry of fire training area.

◌ Burn pit



igure 3-9 Aerial Photograph of Site 2, May 1979.

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area south of the airport perimeter road can be seen.

The location for well DANGB-3-MW38 was picked on the basis of all known information including the suspicion that the pit observed on the 1965 aerial photograph was the remains of FTA-1 and discussions with base personnel who had previously done some regrading on the site. This proved to be the correct location of FTA-1.

Monitoring well MW 3, constructed during the Phase II, Stage 1 investigation could not be located during this study. The well completion record for the well shows that it extended only 0.1 foot above ground. It is located in FTA-2, and it probably has been covered over.

The area south of the perimeter road was trenched in an attempt to locate physical evidence of FTA-1. The trenches were from three to five feet deep. They were located on thirty-foot or less centers throughout the area shown on Figure 2-2. The materials in the trenches consisted of brown till with sand, silt, clay, cobbles, boulders, and pebbles. Occasional pieces of asphalt were dug up indicating either a former road surface or a fill area. In a few trenches, small lenses composed almost entirely of sand-sized rock fragments were observed. The lenses ranged in size from about six inches to two feet long and up to one foot thick and were observed in the walls of the trenches. There is no reason to think that the material dug up while trenching did not also contain such material. The lenses did not appear to consist of material weathered in place, but instead appeared to be of glacial-fluvial origin because of the angularity and well sorted nature of the rock fragments. The presence of the sandy lenses indicated that those particular locations had not been disturbed by fire training related activities. The materials in all the trenches had the same brown color and no odor. It was apparent that the material used to fill the pits was local fill.

3.2.2 Surface Water Hydrology

Since Site 2 is located on a topographic dome (see Section 1.2.4.1), the surface drainage is more or less radially outward toward a drainage ditch which encircles the southern half of the site. It starts at the southwest side of the site, then flows eastward along the site's southern perimeter and northward along the eastern perimeter, and eventually turns back westward and joins Beaver Creek (see Figures 3-10 and 1-2). This drainage ditch captures the surface drainage to the southwest, south, and east.

Surface water and sediment sample location DANGB-2-SL7 is on this ditch. During sampling, the ditch had standing water in it, but immediately up

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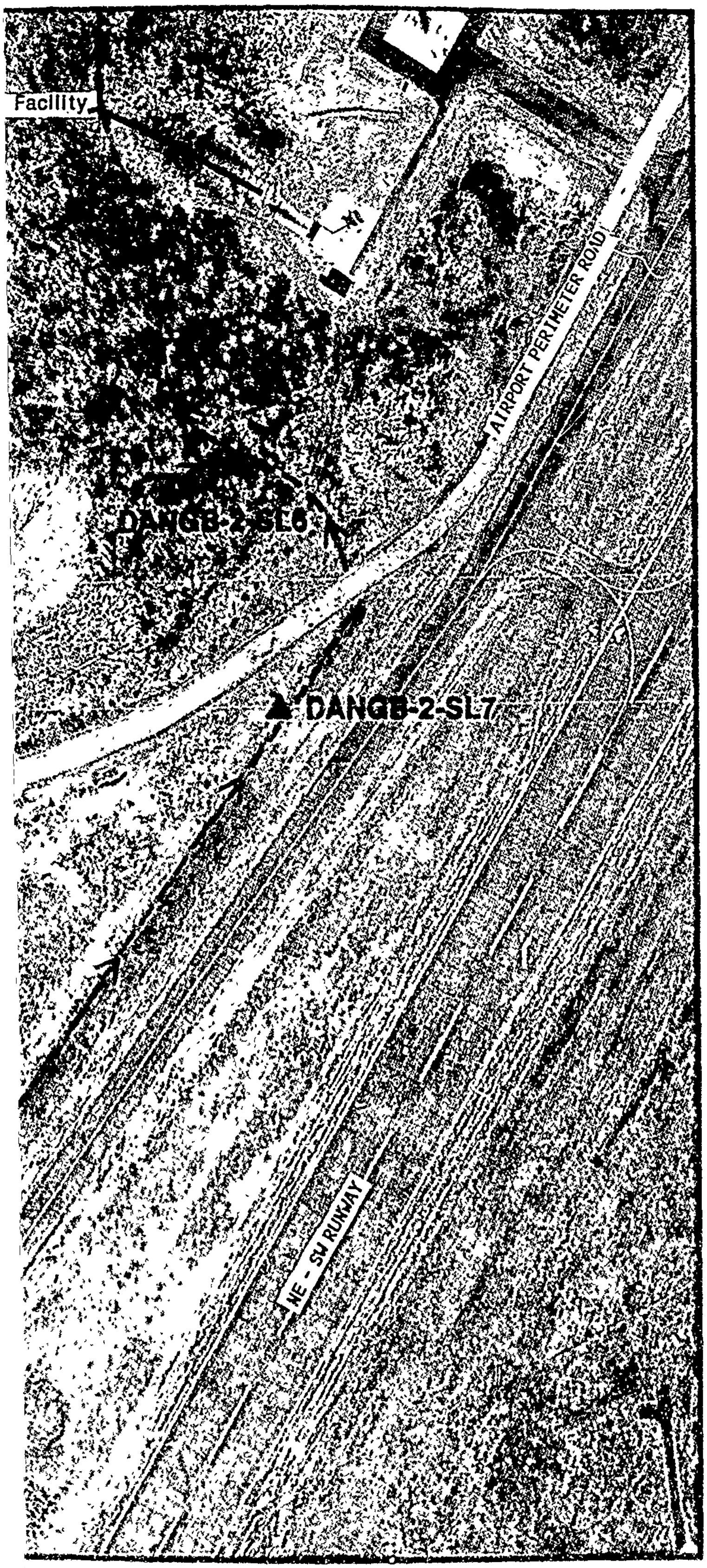
Figure 3-10 Surface Drainage of Site 2.



EXPLANATION

▲	Surface water and sediment sampling locations.
- - →	Surface drainage location and direction.
◯	Approximate boundary for fire training area.
◌	Burn pit.

drainage there was moist ground indicating that this location is the place where the ditch intersects the water table.

Sample location DANGB-2-SL6 is on a small tributary to this ditch. There was flowing water at the time of sampling but this ditch is usually a moist area.

Drainage from the north and northwest parts of the site drains to a boggy area to the north (see Figure 1-2).

3.2.3 Geology

Geologic information obtained from the continuous cores from thirteen boreholes was used to describe subsurface geology. The lithologic logs from the boreholes drilled during the Phase II, Stage 1 and Phase II, Stage 2 investigations were also available. Complete lithologic logs for the holes drilled during this investigation are presented in Appendix E.

Bedrock was reached at nine borehole locations and ranged from 14 feet to 25 feet below the surface and from 1420 to 1434 feet in altitude above NGVD. Bedrock consists of massive, gray, coarse-grained gabbro belonging to the Duluth Complex of rocks. Two boreholes, DANGB-2-12A and DANGB-2-13A had been planned as the wells which with existing shallow monitoring wells, GW 2-E and GW 2-A respectively would form two pairs of shallow and deep monitoring wells. Each of the deep boreholes reached bedrock at the same total depth as the existing well and was therefore plugged and abandoned. At each borehole drilled to bedrock, one and one half to three feet of gabbro were cored in order to verify that bedrock and not just a boulder was reached. In addition, the driller could identify from a different sense of vibration in the drill rig whether a boulder or the laterally confined bedrock was being drilled.

Unconsolidated glacial till overlies bedrock. The glacial till consists of clay, silt, sand, pebbles, gravel and mixtures of these components in layers and lenses of varying sizes. The layers appear to be lenses in the sense that they grade laterally into layers with different proportions of the same constituents. For example, a silty clay with some sand may grade into a silt with some clay and little sand. Figure 3-2 shows the change in lithology within four feet for paired well points DANGB-2-WP7 and DANGB-2-WP7D. Two geologic cross-sections, one from the northwest, DANGB-2-MW38, to the southeast, DANGB-2-MW38, and the other from the southwest, DANGB-2-MW40, to the northeast, DANGB-2-WP8, were constructed. The sections intersect near the center of the site at MW4. The index to cross-sections is shown on Figure 3-11 and the cross-sections themselves are shown on Figure 3-12. These sections show that for the most part the glacial materials consist of silty clays and clayey silts. Some general distinctions can be made. The upper part of the section has more clay than silt, sized material, a zone of sand and gravel beds and lenses occurs at intermediate depths, and the lower part of the section has more silt than clay sized material. The lithologic logs from the other wells (Appendix E) indicate that outside of the lines of the cross-sections, the upper part remains predominantly clayey, some sand is observed at intermediate depths, but the lower part becomes predominantly clay with some silt.

The porosity values for the four soil samples obtained from borehole DANGB-2-12A ranged from 43.5 to 46 percent. The effective porosity which is a measure of the interconnected-porespace through which flow can occur is estimated to average 20 percent (Morris and Johnson, 1967).

3.2.4 Hydrogeology

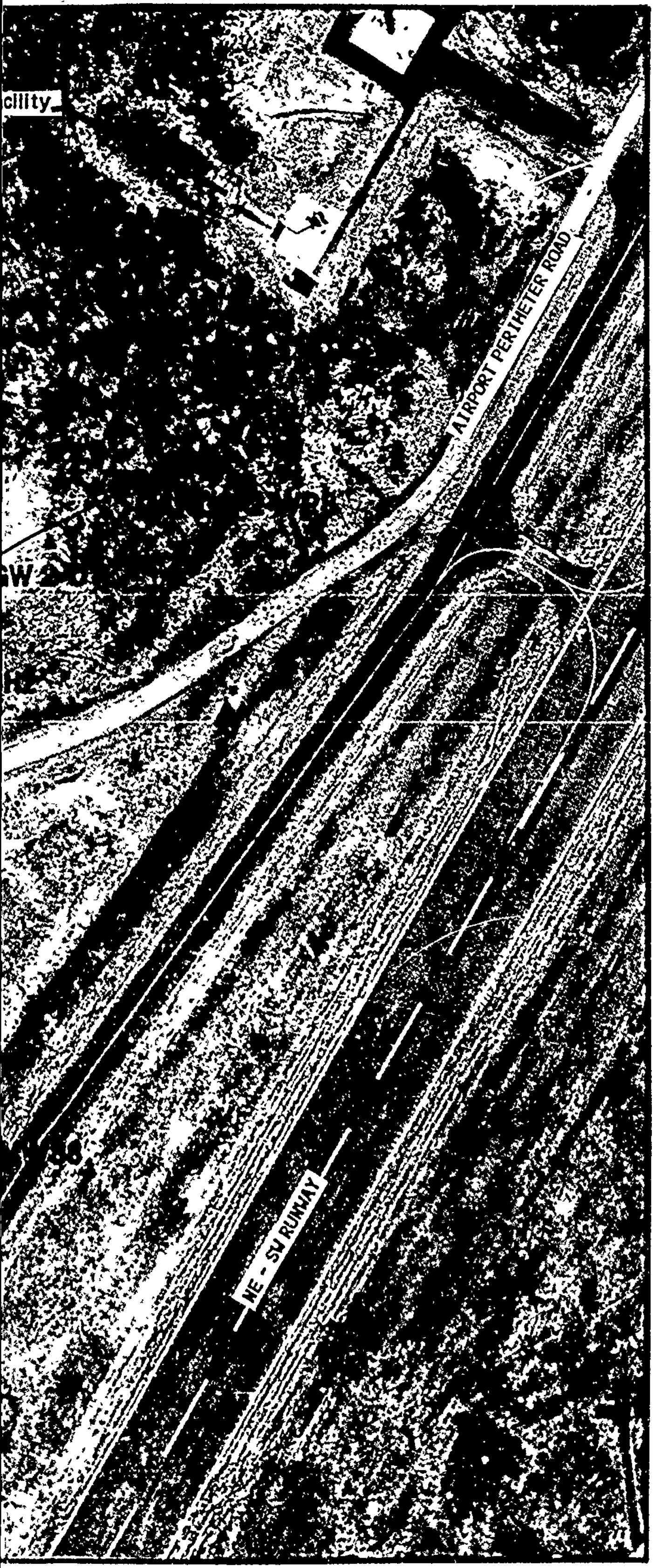
Ground water occurs both in the unconsolidated glacial sediments and in the underlying bedrock. The glacial sediments form the principal aquifer and vary from about 15 feet to 25 feet in thickness. The water table usually occurs at depths less than 10 feet and is believed to be continuous with surface drainage. The thinness of the aquifer and the shallowness of the water table would appear to indicate that the aquifer is unconfined. However, the inhomogeneous nature of the lenticular stratigraphy which is composed of lenses and discontinuous layers of intermixed clays and silts as well as silty sands and gravels causes semi-confined to confined conditions to exist within a few feet of the surface.

A water table altitude contour map was constructed, Figure 3-13, from the data collected on September 27, 1988. Cross-sections showing the vertical variation in hydraulic head within the glacial deposits are shown on Figure 3-14. Water table altitude data are presented in Appendix I, Table I-1.

These figures show a ground-water mound located below the site. The center of the mound is about 750 feet southwest of FTA-2 and about 475 feet west-northwest of FTA-1. The ground-water mound is a recharge area, and the ground-water flow is radially outward so that at FTA-2 the ground-water flow is toward the northeast and at FTA-1 the ground-water flow is toward the east-southeast.

The ground-water discharge areas are the drainage ditch on the eastern side of the site, the unnamed tributary northwest of the site, the marshy area to the north of the site and the drainage ditch on the south and southwest

igure 3-11 Index to Cross-Section Locations for Site 2.



EXPLANATION

○ MW 6	Monitoring Well Phase II, Stage 1.
◐ GW 2-D	Monitoring Well Phase II, Stage 2.
● DANGB-2-MW40	Monitoring Well Remedial Investigation.
◆ DANGB-2-WP8	Well Point Remedial Investigation.
▲ DANGB-2-SL6	Surface location Remedial Investigation.
A —— A′	Line of geologic cross-section.
◯	Approximate boundary for fire training area.
◌	Burn pit.

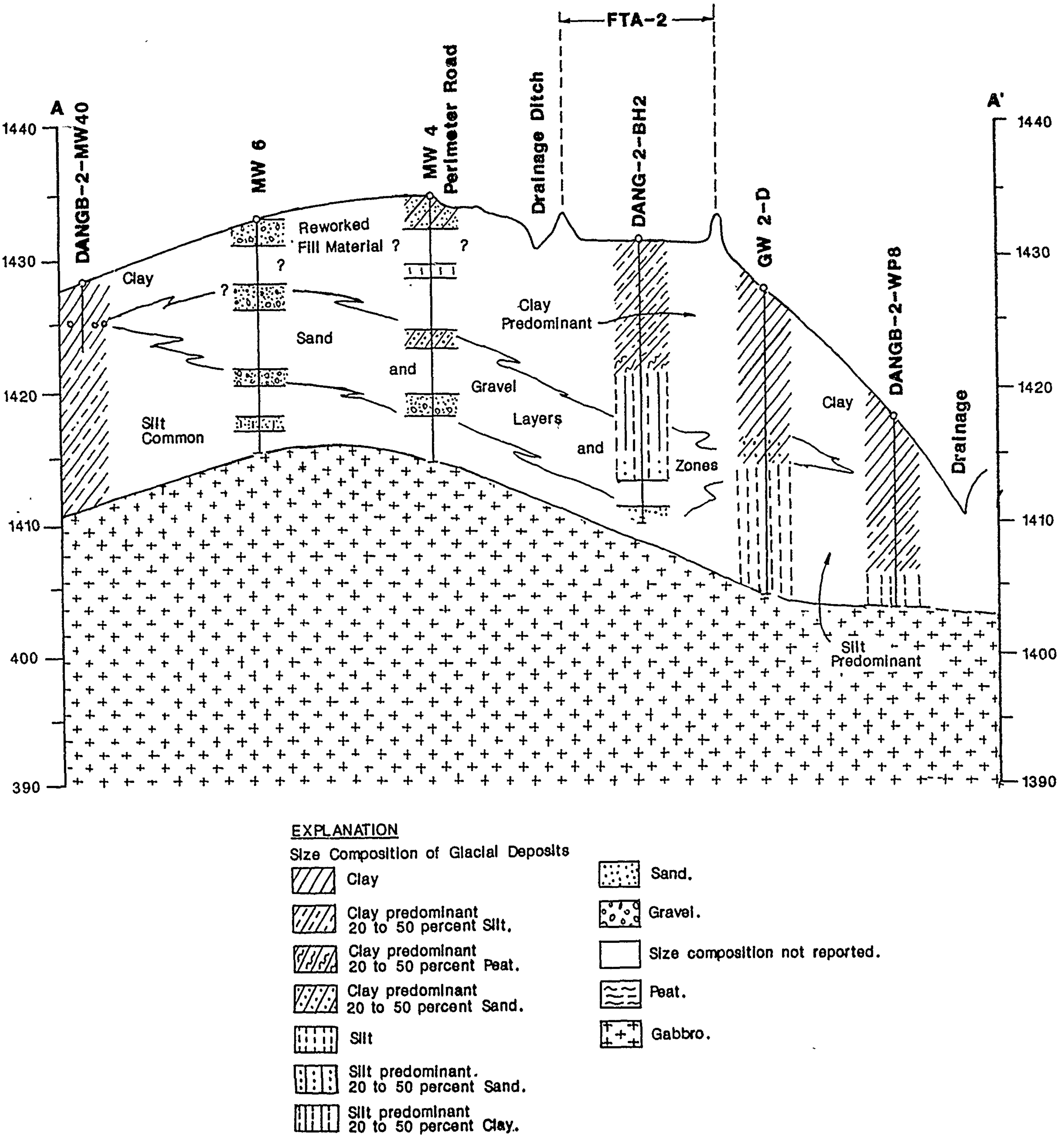
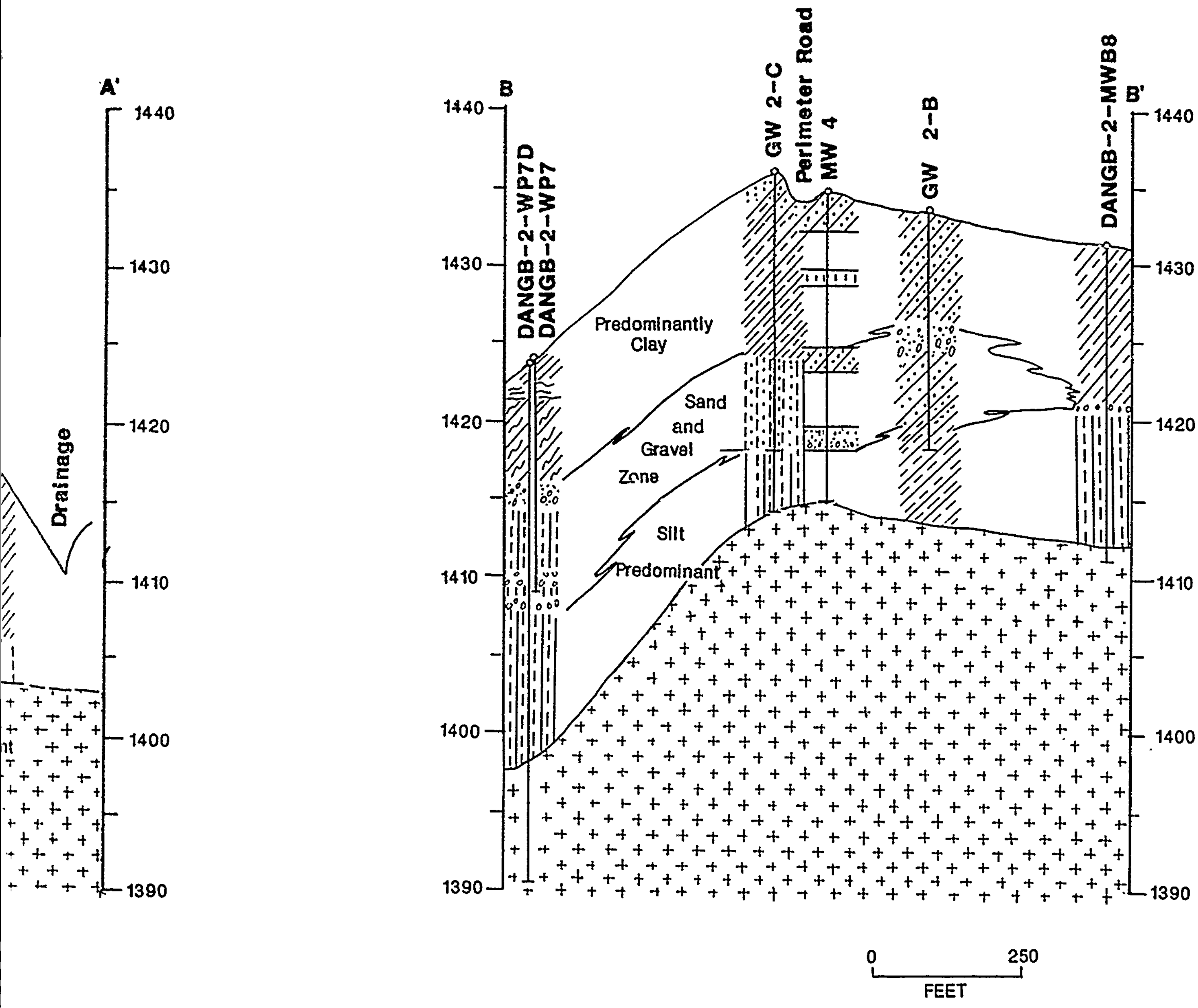


Figure 3-12 Geologic Cross-Sections for Site 2.



COMMENTS

Line of Sections shown on Figure 3-11.

Vertical exaggeration x 25.

Water table altitude data are given in Appendix I, Table I-1.

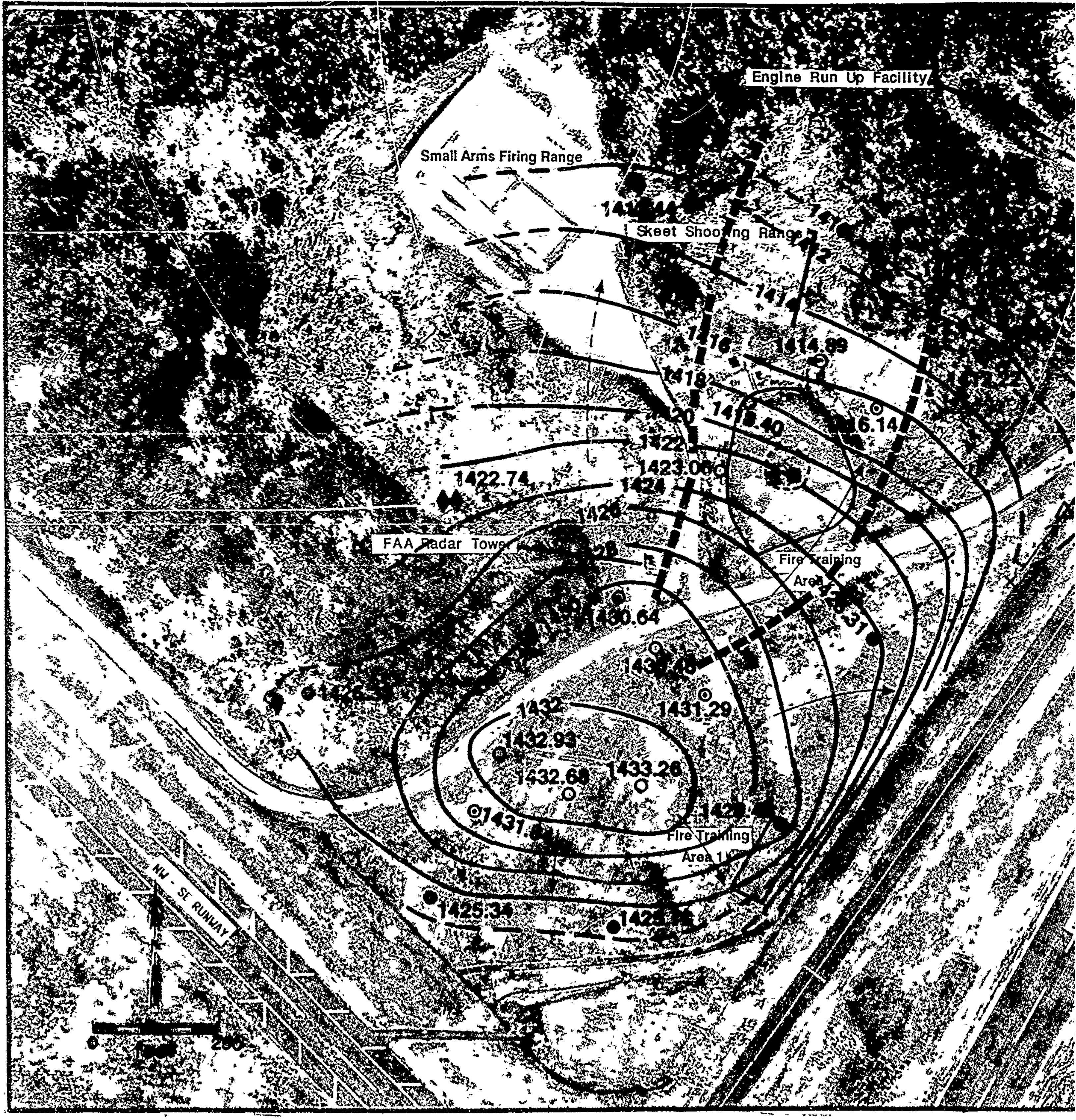


Figure 3-13 Water Table and Direction of Ground Water Movement at Site 2.

EXPLANATION

▬ ▬ ▬ ▬ ▬ Probable maximum lateral extent of ground-water contamination originating at FTA-2.

— 1420 — Water table contour. Shows altitude of water table on 27 September 1988. Contour interval is 2 feet. Datum is NGVD of 1929. Line is dashed where inferred.

←—— Generalized direction of ground-water flow.

× Spring

Monitoring wells and water level altitude.

○ 1423.06 Phase II; Stage 1.

⊙ 1431.84 Phase II; Stage 2.

● 1425.31 Remedial Investigation.

◆ 1412.22 Well point and water level altitude.

▲ 1413.52 Surface Water sampling location and water level altitude.

■ Borehole Locations.

←—< Surface drainage location and direction.

◯ Approximate boundry of fire training area.

◌ Burn pit .

COMMENT: Water table altitude data are given in Appendix I, Table I-1.

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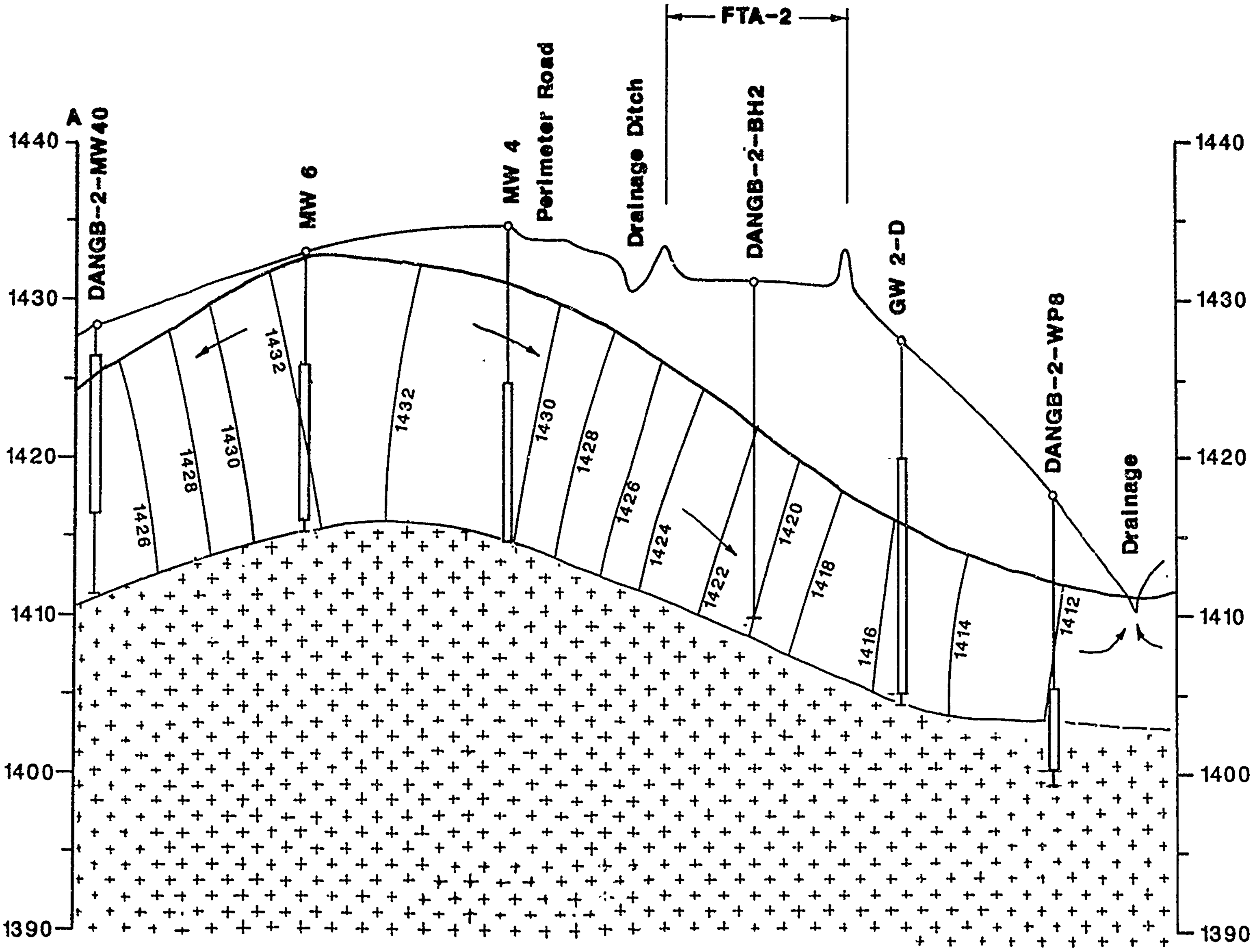


EXPLANATION

∇ Generalized water table.

—1426— Line of equal head on 27 September,1988. Interval 2 '. Dashed where inferred. Datum is NGVD of 1929.

——→ Generalized direction of ground-water flow.

☐ Glacial deposits.

▨ Bedrock.

2-MW38 Drilling location and well identification showing screened interval.

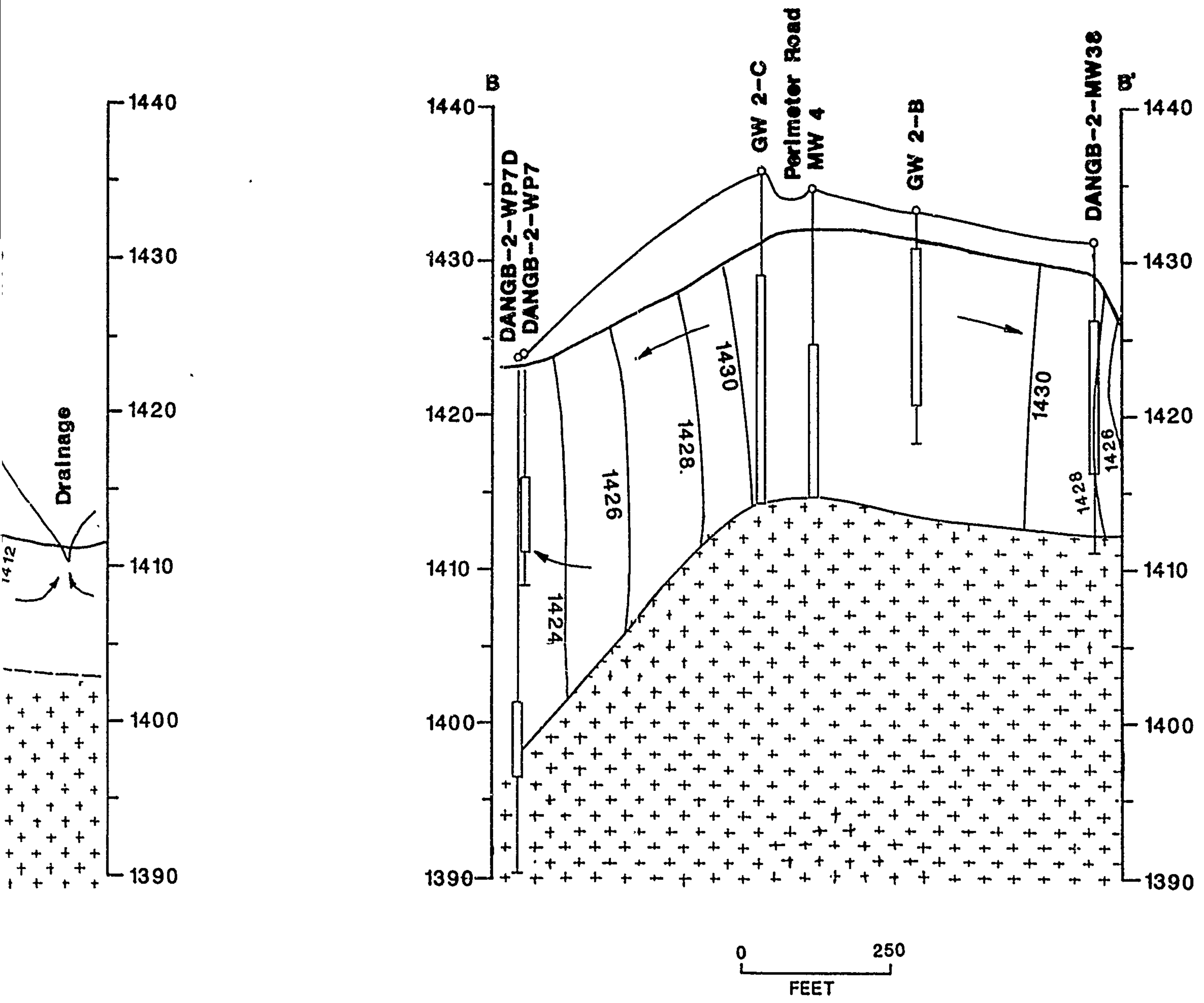
COMMENTS

Line of Section shown on Figure 3-11.

Vertical Exaggeration x 25.

Water table altitude data are given in Appendix I, Table I-1.

Figure 3-14 Variation in Vertical Hydraulic Head in the Glacial Till at Site 2 and Generalized Direction of Ground



ed Direction of Ground Water Movement.

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sides of the site. Water level measurements from the paired well points near the marshy area to the north indicate that there is an upward component to ground-water flow and that ground water discharges to the marsh. Although standing water was not present, the drainage ditch on the south side is a moist zone in which evapo-transpiration is likely taking place during the growing season and is a seepage area at other times of the year.

The hydraulic parameters which were calculated for this site are summarized in Table 3-2.

The transmissivity, T, in the vicinity of monitoring well GW 2-E was calculated to be 37.4 gallons per day per foot based on slug testing results at this well. The hydraulic conductivity, K, was calculated to be 5.2 gallons per day per square foot. The average hydraulic gradient, I, in the vicinity of this same Figure 3-12 monitoring well was calculated to be 0.02 feet from the water table map. The aquifer effective porosity, n, is estimated to be 0.20.

The average ground-water flow velocity, V, was calculated using these values to be about 25 feet per year. The velocity was computed from the equation:

$$V = .134 \frac{KI}{n}$$

Where:

V = velocity, in feet per day;

K = horizontal hydraulic conductivity, in gallons per day per square foot (gpd/ft^2);

I = average hydraulic gradient in feet per foot;

n = aquifer effective porosity, no dimensions; and

.134 = the conversion factor of gallons to cubic feet.

The average yearly infiltration rate, IF, needed to maintain the size of the ground-water mound was also calculated. This infiltration rate was calculated to be 4.6 inches per year for the area within the 1429 foot altitude as shown on Figure 3-13. It was calculated from the transmissivity obtained as before from the slug test results at monitoring well GW 2-E. The average mound was calculated to be 0.03. The rate of infiltration was determined from the equation:

TABLE 3-2

HYDRAULIC PARAMETERS FOR SITE 2

Parameter Symbol, Name	Units	Location	Value	Comments
T, transmissivity	gpd/ft	GW 2-E	37.4	Computed from slug injection data.
K, horizontal hydraulic conductivity	gpd/ft^2	vicinity of GW 2-E	5.2	
n, aquifer effective porosity	dimensionless	vicinity of GW 2-E	0.20	Grain size analysis of soils samples from DANGB-2-12A and other measurements of glacial till effective porosities.
I, average vertical hydraulic gradient	feet per foot	vicinity of GW 2-E	0.02	Computed from contours shown in Figure 3-13.
I, average vertical hydraulic gradient	feet per foot	vicinity of the 1429' ground water altitude contour	0.03	Computed from contours shown in Figure 3-13.
L, distance around a closed equal altitude contour	feet	the 1429' ground water altitude contour	2,175	Computed from contours shown in Figure 3-13.
A, area enclosed by an equal altitude contour	square feet	enclosed by the 1429' ground water altitude contour	309,375	Computed from contours shown in Figure 3-13.
V, average ground-water velocity	feet per year	vicinity of GW 2-E	25	See Text
IF, average infiltration rate	inches per year	ground water mound	4.6	See Text

$IF = 586\ Q/A$

Where:

IF = infiltration rate within a selected ground-water altitude contour, in inches per year;

Q = discharge through the cross-sectional area of the aquifer underlying the selected ground-water altitude contour, in gallons per day;

A = surface area of the aquifer bounded by the selected ground-water altitude contour in square feet; and

586 = conversion factor of gallons per day to inches per year.

The discharge, Q, was determined from the equation:

$Q = T \times I \times L$

Where:

T = transmissivity of the aquifer in gallons per day per foot;

I = average hydraulic gradient in the aquifer at the selected ground-water altitude contour in feet per foot; and

L = distance around the selected ground-water altitude contour in feet.

The values used to solve these equations are given in Table 3-2.

The calculated average yearly infiltration is about 16 percent of the average yearly precipitation at the airport of 28 inches and 47 percent of the average unadjusted runoff of 9.7 in/year for the St. Louis Watershed (Lindholm and others, 1979). These percentages appear to be reasonable and are independent verification that the value of the transmissivity as calculated from the slug test at GW 2-E is a good estimate.

3.3 SITE 3

Site 3 consists of a small pad, approximately 80 by 90 feet, on which drummed materials were stored from 1965 to 1988, and the surrounding area (Figures 1-6, 1-9, 2-4, 2-5 and 2-6). The site is described and previous work is summarized in Section 1.2.5. The work done during this study is described in Section 2.3 and summarized by location on Table 2-15.

3.3.1 Surface Features

The aerial photographs which were reviewed confirm that this site was not used as a storage area in 1961, but that it was being used as such in 1965.

A photograph taken in April 1988 (Figure 1-9) shows drums still stored on this site. The photographs were also examined with regard to surface drainage. In addition to the discussion of the surface drainage in Section 3.3.2 below, the results are discussed in Section 3.6.1, which discusses the surface drainage and ground-water hydrology of the zone formed by Sites 3, 4 and 8 together.

3.3.2 Surface Water Hydrology

The storage pad is level and elevated by a foot to several feet above the immediately surrounding ground (Figure 3-15), and surface water drains off the pad in all directions. To the west, the surface water drains northward to a main east-west drainage ditch. To the north, the surface water drains either to the north into the main east-west ditch or into an east-west ditch which lies very close to the pad. About half-way along the northern edge of the pad, this drainage ditch turns to the north and then joins the main east-west ditch. To the east, the surface water drains into the marshy area and ditch which lies to the east of the pad. There is a spring on this ditch just north of the pad access ramp. The water drains to the north and then to the west along the northern edge. To the south of the pad, the surface water is drained by a southeast flowing drainage ditch which lies south of the pad access ramp and access road. This ditch crosses under the road and flows to the northeast where it joins the drainage from Site 4.

The direction of surface drainage may have been changed from southward, and then to Miller Creek, to northward and to Wild Rice Lake during the development of the airport facilities. The description and timing of these possible changes is discussed in Section 3.6.2 where the surface water hydrology of the zone formed by Sites 3, 4, and 8 is described.

3.3.3 Geology

Geologic information obtained from the continuous cores from the ten boreholes was used to describe the subsurface geology. The lithologic logs from the boreholes drilled during Phase II, Stage 1 and Phase II, Stage 2 investigations were also available. Background data location DANGB-BG-MW32 is situated just south of this site, and the lithologic description was used for the Site 3 Geology. Complete lithologic logs for the holes drilled during this investigation are presented in Appendix E.

All of the boreholes drilled during this Remedial Investigation were drilled off the Site 3 storage pad itself.

Bedrock was reached at three borehole locations, and ranged from 1,394

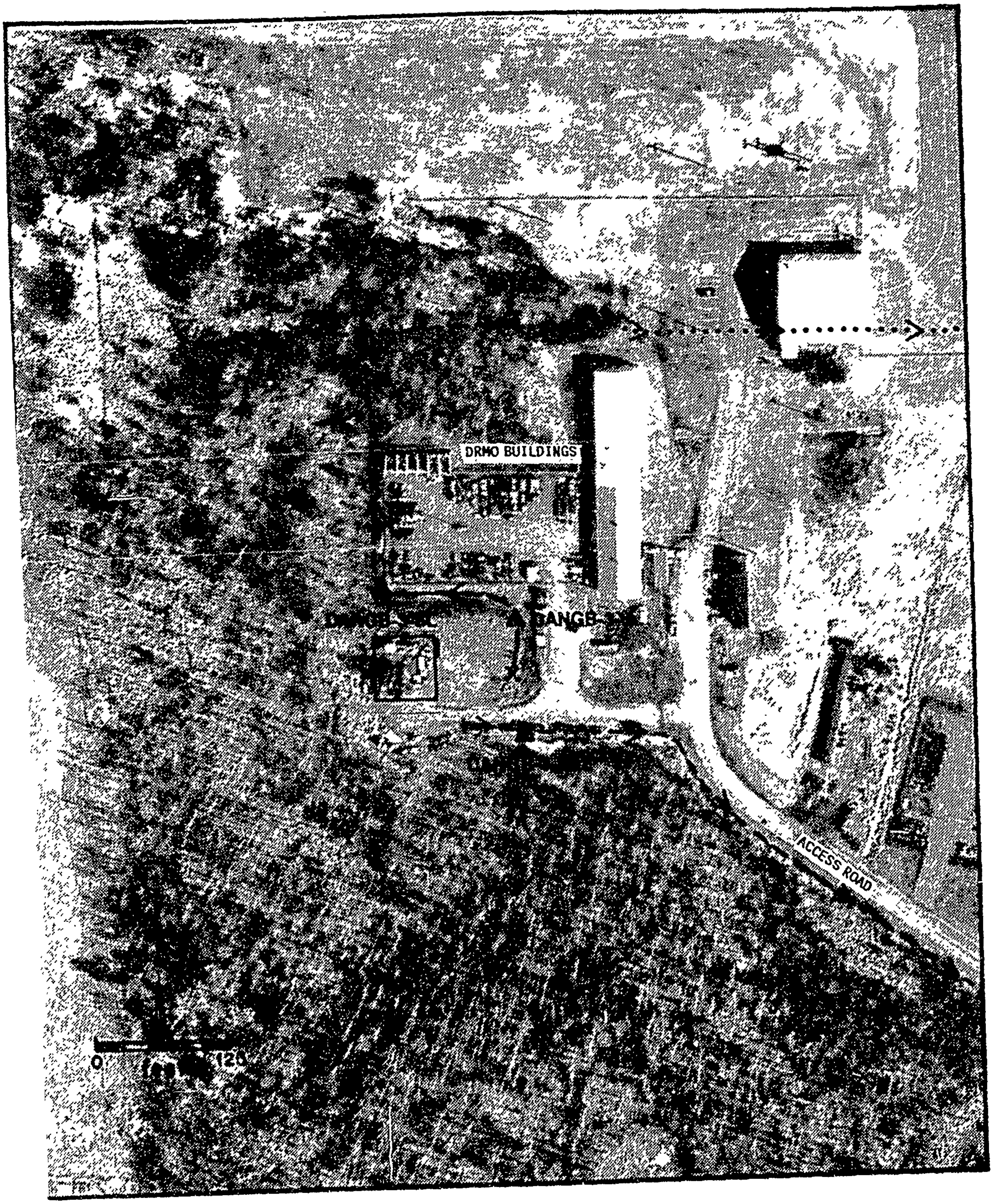

Figure 3-15 Surface Drainage of Site 3.

EXPLANATION

DANGB-3-SL ▲	Surface water and sediment sampling location and identification
×	Spring
— — →	Surface drainage location and direction
——→	Solid where perennial
- - - →	Dashed where ephemeral
• • • • • • >	Dotted where a culvert is inferred
☐	Approximate location of Storage Area "C".

feet to 1,396 feet in altitude above NGVD. Bedrock consists of massive, gray, coarse-grained gabbro belonging to the Duluth Complex of rocks. Bedrock topography for Site 3 is discussed in Section 3.6.3, along with that for Sites 4 and 8.

At each borehole drilled to bedrock, one and one-half to three feet of gabbro were cored in order to verify that bedrock and not just a boulder was reached. In addition, the driller could identify from a different sense of vibration in the drill rig whether a boulder or the laterally confined bedrock was being drilled.

Unconsolidated glacial till overlies the bedrock. The glacial till consists of clay, silt, sand, pebbles, gravel and mixtures of these components in layers and lenses of varying sizes. The layers appear to be lenses in the sense that they grade laterally into layers with different proportions of the same constituents (see Figures 3-2 and 3-3). A six-inch to one-foot thick layer of brown sand or gray brown sand and gravel was encountered immediately above the bedrock surface in boreholes drilled to bedrock at the site.

Clay, and clay and silt layers are more predominant in the upper part of the Site 3 boreholes. Pebbles, ranging in size from one-quarter inch to four inches, occur throughout the till and vary in abundance from trace amounts to abundant. Boulders, ranging in size from one foot to three and one-half feet thick were drilled through in five of the boreholes. In the three holes that were drilled to bedrock, sand and gravel was found just above the bedrock surface. In two holes which did not reach bedrock, sand, and sand and gravel occurred at the total depth of the hole. This was just above the depth at which bedrock could be expected to exist.

Cross-sections depicting the geology are indexed in Figure 3-16 and shown in Figure 3-17.

The porosity values for the three soil samples obtained from borehole DANGB-3-MW25 ranged from 42 to 43%. The effective porosity which is a measure of the pore space through which flow can occur is estimated to average 20 percent (Morris and Johnson, 1967).

3.3.4 Hydrogeology

Ground water occurs in both unconsolidated glacial sediments and in the underlying bedrock. The glacial sediments form the principal aquifer and vary from about 15 feet to about 20 feet in thickness. The water table occurs at depths of generally less than 10 feet and is believed to be continuous with surface drainage. The thinness of the aquifer and the shallowness of the

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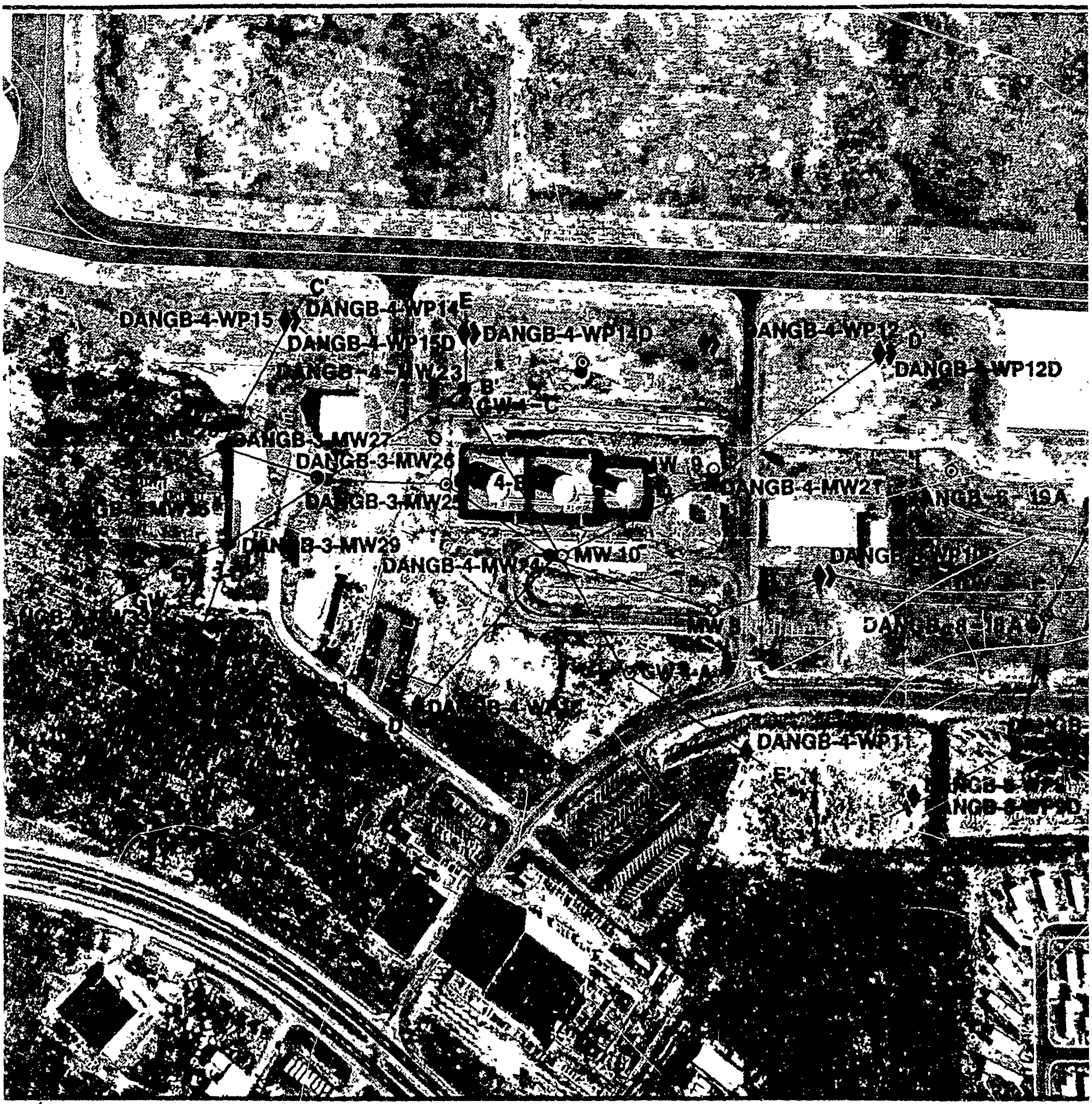
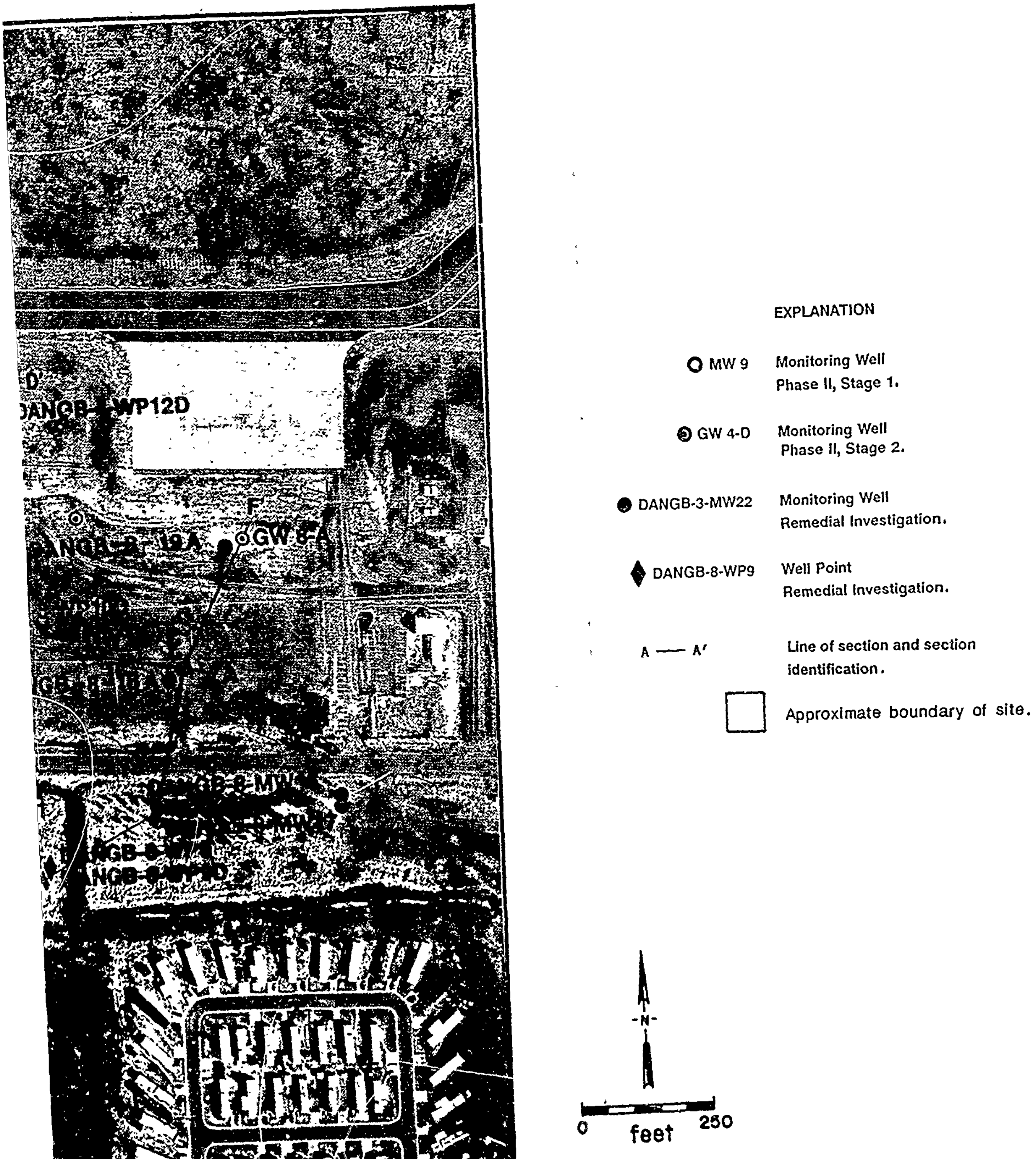


Figure 3-16 Index to Cross-Sections for Sites 3, 4, and 8.


D'
DANGB-8-WP12D
F
GW 8-A
EXPLANATION
MW 9 Monitoring Well Phase II, Stage 1.
GW 4-D Monitoring Well Phase II, Stage 2.
DANGB-3-MW22 Monitoring Well Remedial Investigation.
DANGB-8-WP9 Well Point Remedial Investigation.
A —— A' Line of section and section identification.
Approximate boundary of site.
N
0 feet 250

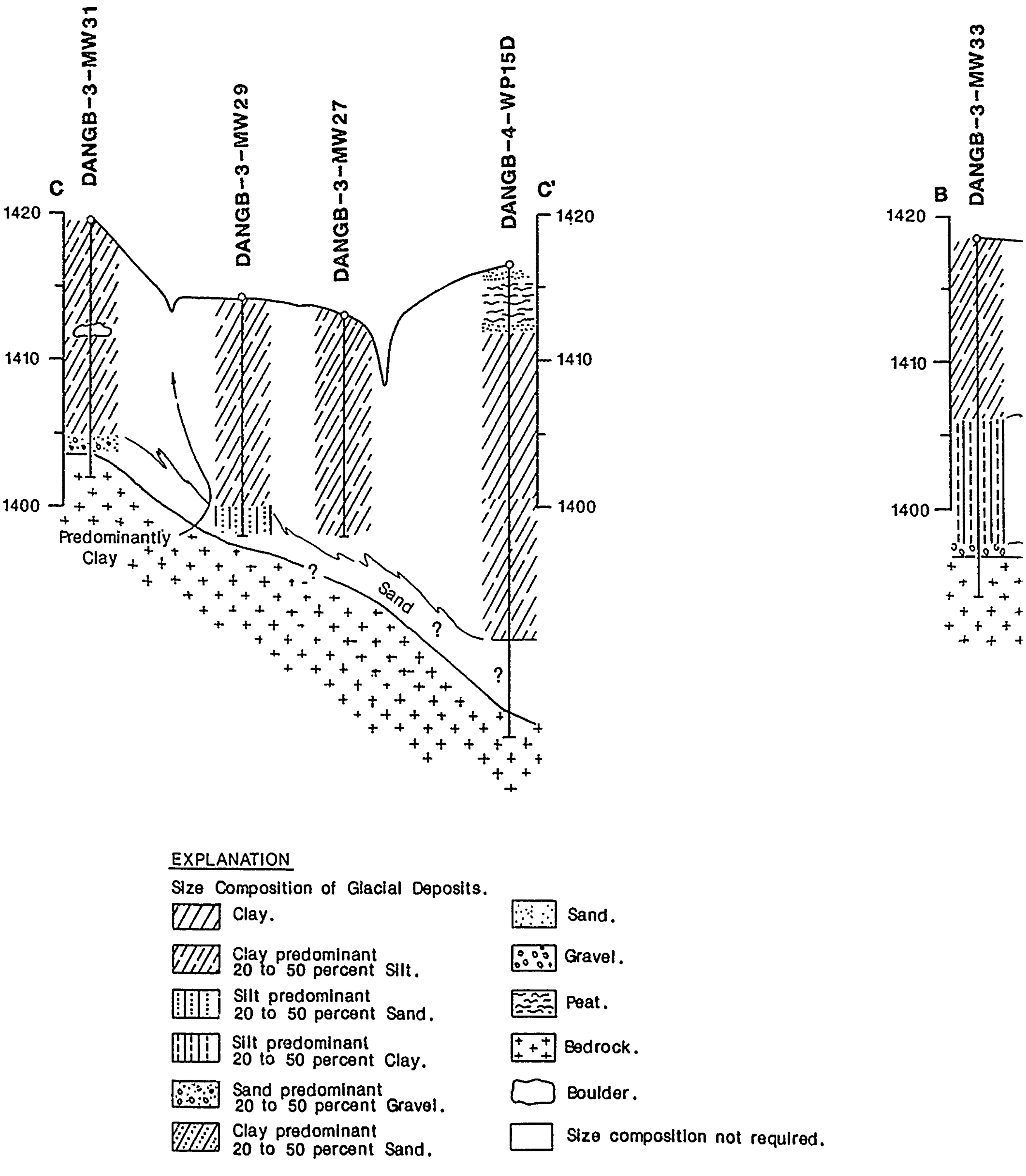
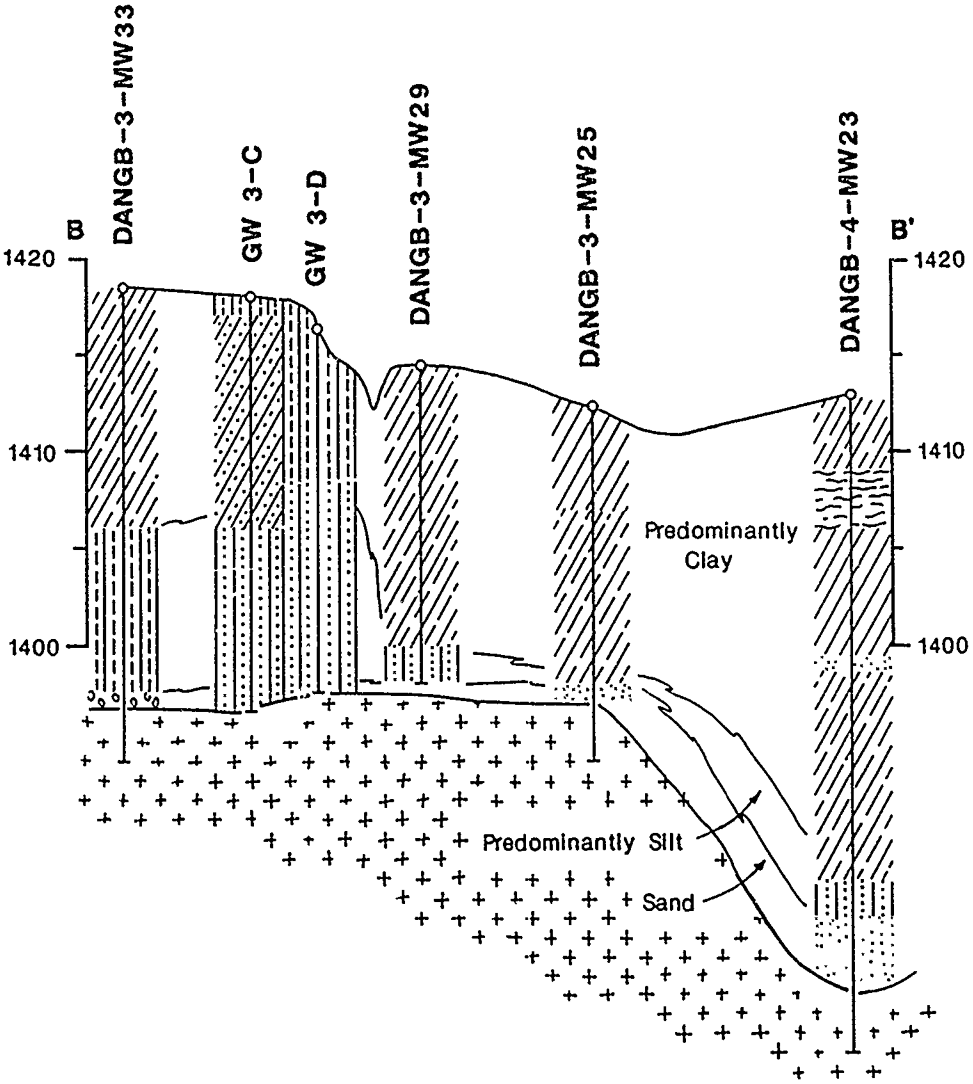


Figure 3-17 Geologic Cross-Sections for Site 3.



COMMENTS
Line of Sections shown on Figure 3-16.
Vertical exaggeration x 25.
Water table altitude data are given in Appendix I, Table I-1.

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water table would appear to indicate that the aquifer is unconfined. However, the inhomogeneous nature of the lenticular stratigraphy which is composed of lenses and discontinuous layers of intermixed clays and silts as well as silty sands and gravels causes semi-confined to confined conditions to exist within a few feet of the surface.

A water table altitude contour map was constructed from measurements taken on September 27, 1988 (Figure 3-18). The variation in vertical hydraulic head within the glacial deposits is shown on Figure 3-19. Water table altitude data are presented in Appendix I, Table I-1.

Ground-water flow at Site 3 is to the north and northeast with an average hydraulic gradient of about 0.01 feet per foot. Data from paired wells DANGB-3-MW33 and DANGB-3-MW34 on the southwest corner of the site identified a strong downward component to ground-water flow, indicating that this is an area of ground-water recharge. Ground-water recharge is by infiltration of precipitation through the glacial till to the water table. The flattening out of ground-water contours in the storage pad area correlates with ground-water discharge into a drainage ditch which partially penetrates the water table along the east and north side of the pad. Water levels in the paired wells on the northeast part of the site, DANGB-3-MW25 and DANGB-3-MW26 indicate a slight upward component of ground water which would indicate an area of ground-water discharge nearby. A marshy area east of the paired wells is a likely ground-water discharge area.

Three slug tests were performed at this site. The summary of the results is given in Table 3-3. The slug test data and their analyses are given in Appendix G.

Average ground-water flow velocities were calculated using the horizontal hydraulic conductivities calculated at locations DANGB-3-MW25 and DANGB-3-MW33 from both slug injection and slug withdrawal data and at location DANGB-3-MW34 from slug injection data, The velocities range in value from less than 0.5 foot per year to 9 feet per year. The average of the five values is 3.78 feet per year. These velocities were computed from the equation:

$$V = .134 \frac{KI}{n}$$

Where:

V = velocity, in feet per day;

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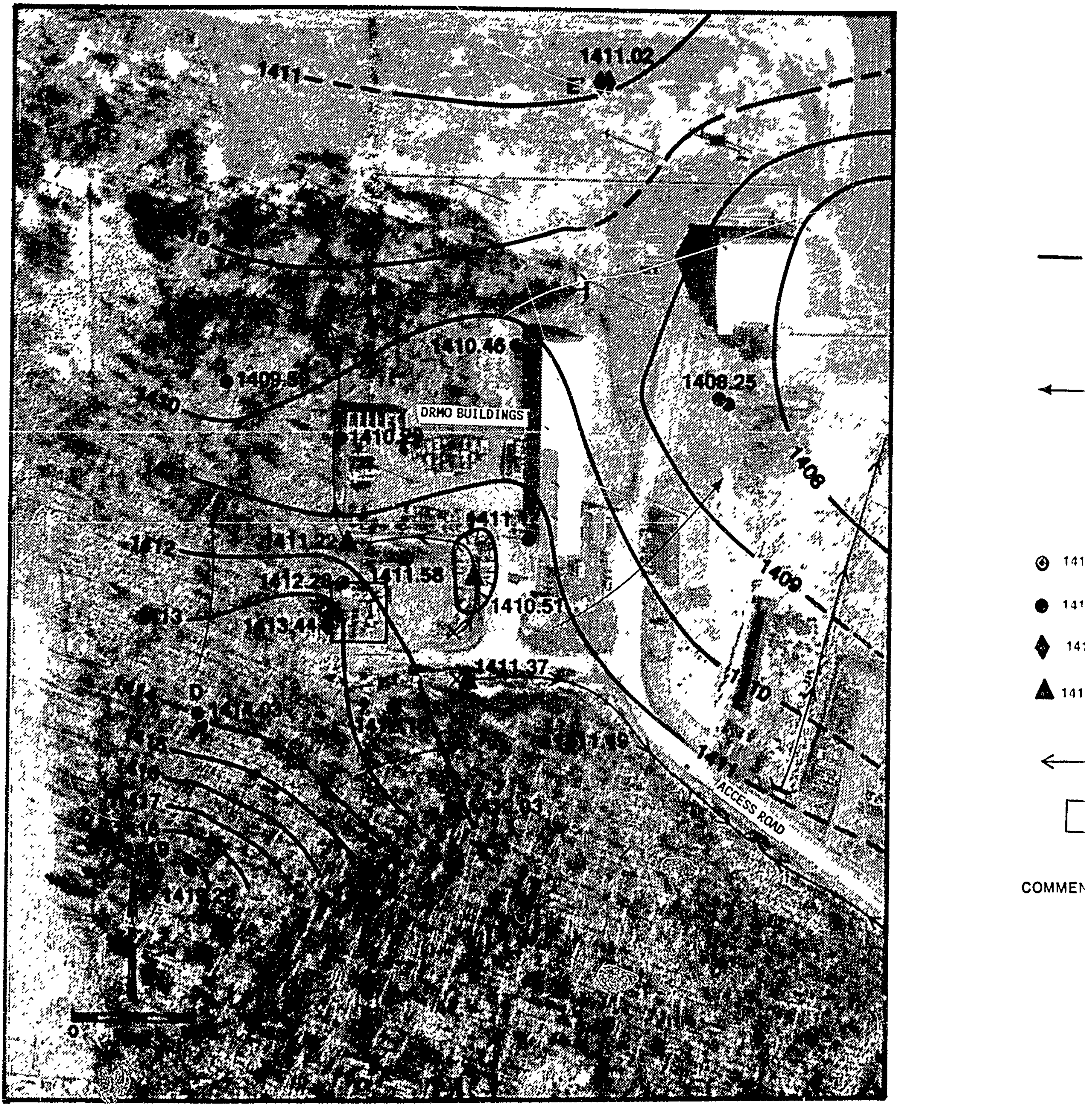


Figure 3-18 Water Table and Direction of Ground-Water Movement for Site 3.

EXPLANATION

—— 1410 —— Water table contour. Shows altitude of water table on 27 September 1988. Contour Interval is 1 foot. Datum is NGVD of 1929. Line is dashed where inferred.

←—— Generalized direction of ground-water flow.

X Spring

Monitoring wells and water level altitude.

⊙ 1411.58 Phase II; Stage 2.

● 1410.46 Remedial Investigation.

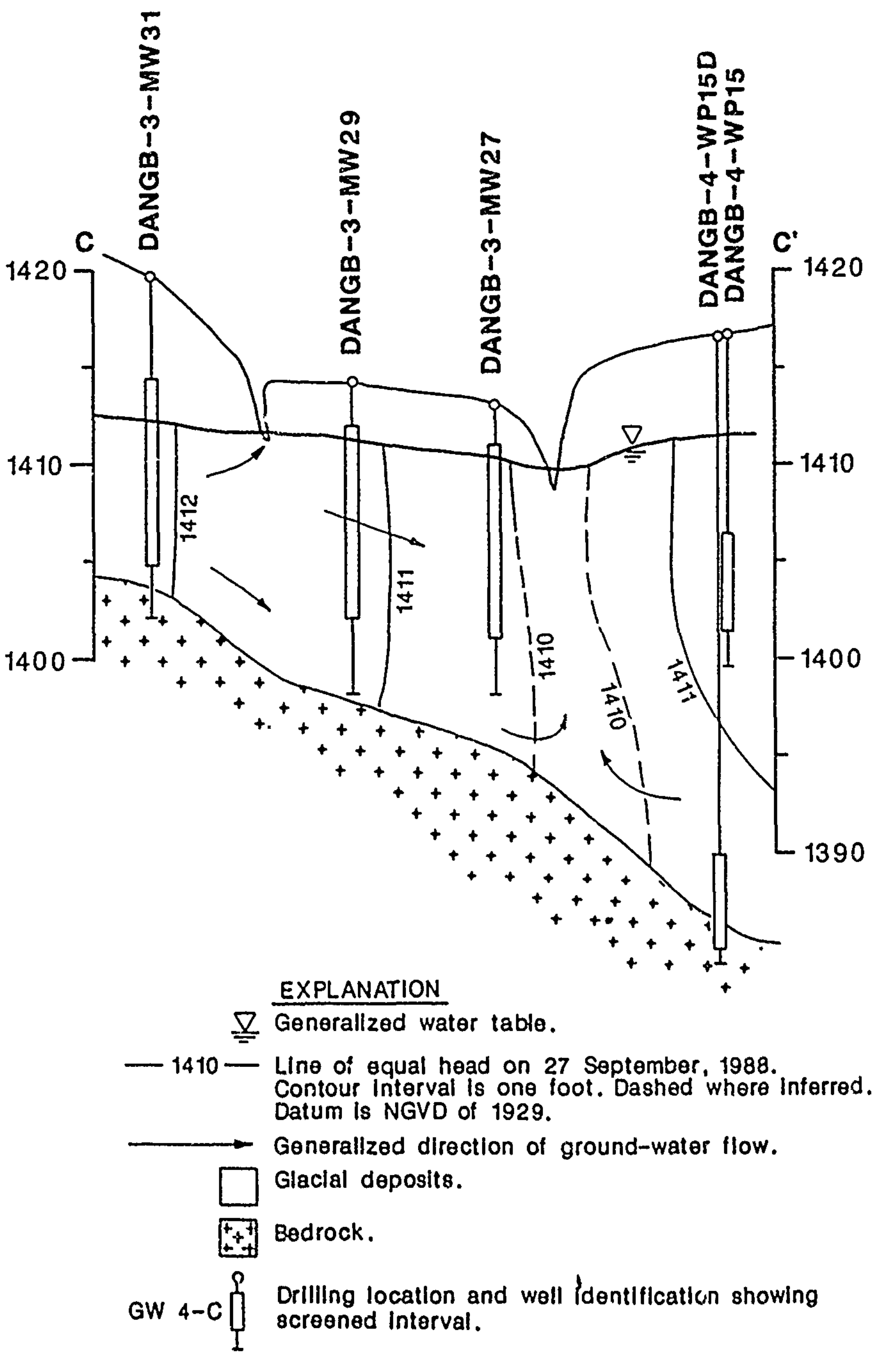
◆ 1411.02 Well point and water level altitude.

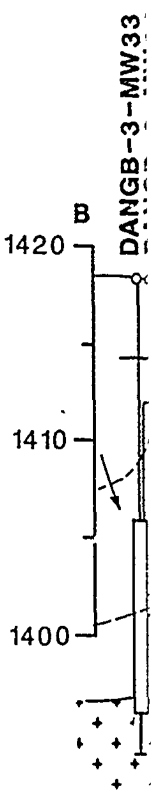
▲ 1410.51 Surface water and sediment sampling location and water level altitude.

←—< Surface drainage.

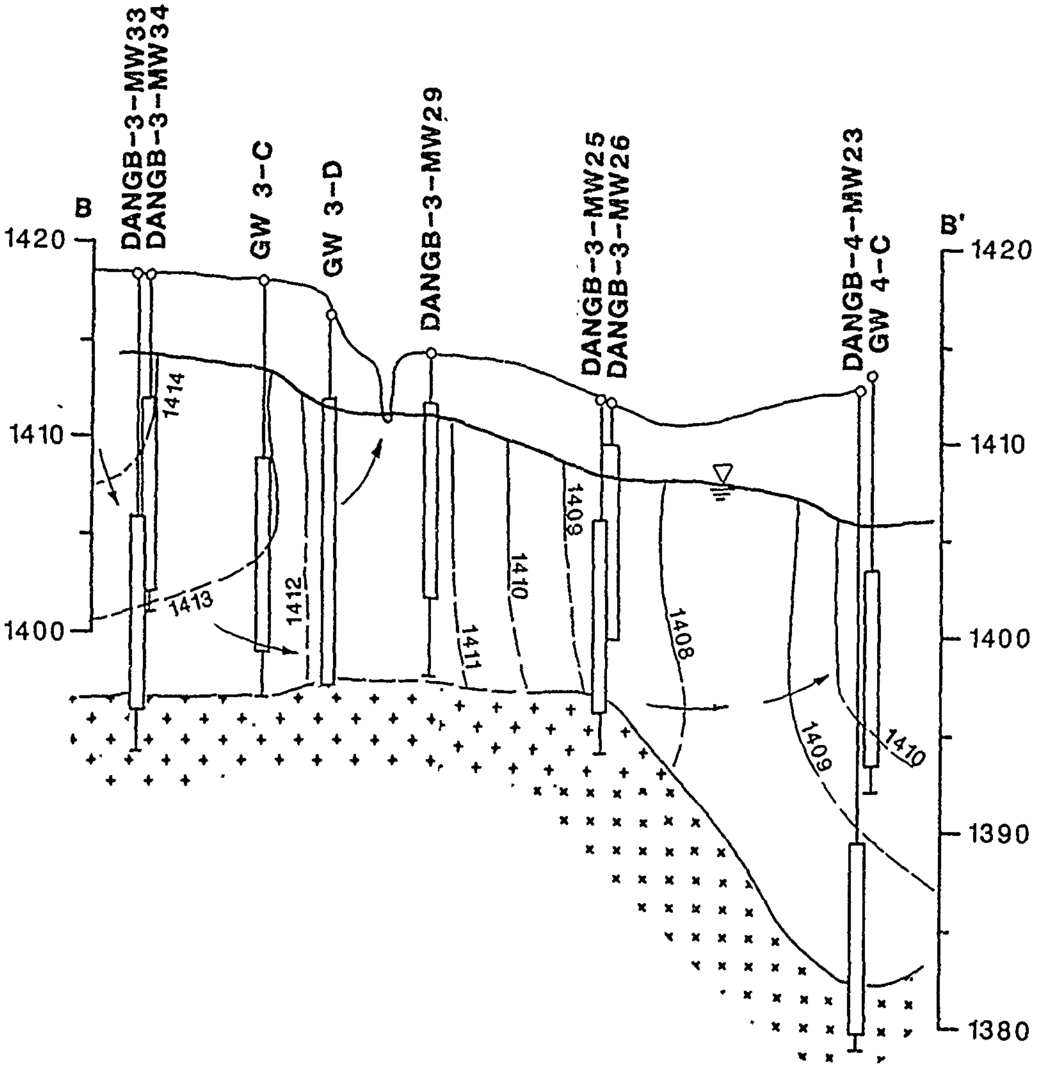
□ Approximate location of Storage Area "C".

COMMENT: Water table altitude data are given in Appendix I, Table I-1.





igure 3-19 Variation in Vertical Hydraulic Head in the Glacial Till at Site 3 and Generalized Direction of Ground-Wat



COMMENTS

Line of Sections shown on Figure 3-16.
Vertical exaggeration x 25.
Water table altitude data are given in Appendix I, Table I-1.

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zed Direction of Ground-Water Movement.

TABLE 3-3

SUMMARY OF SITE 3 SLUG TEST RESULTS

Monitoring Well Number	Transmissivity (gal/day/ft)		Horizontal Hydraulic Conductivity (gal/day/ft^2)	
	Injection	Withdrawal	Injection	Withdrawal
DANGB-3-MW25	20.4	37.4	2.0	3.7
DANGB-3-MW33	14.5	4.1	1.4	0.4
DANGB-3-MW34	1.2	64.1(1)	0.2	11.8(1)

1. These numbers are interpreted as not representative of aquifer properties. Only 6.21 feet of the 10 feet screened interval was saturated. The lack of 100 percent saturated screen thickness and dewatering of the sand pack around the well may have caused initial rapid rises in water level which distorted the withdrawal results.

K = horizontal hydraulic conductivity, in gpd/ft^2;

I = average hydraulic gradient, in feet per foot; and

n = aquifer effective porosity, no dimensions.

The following values were used:

K = 0.2 and 3.7 gpd/ft^2, based on the aquifer slug tests at the paired well location DANGB-3-MW33 and DANGB-3-MW34 and location DANGB-3-MW25 (see Appendix G);

I = 0.01, as measured from Figure 3-18; and

n = 0.20 based on the grain size analysis from location DANGB-3-MW25 (see Appendix K) and other measurements of glacial till porosities.

Actual localized ground-water flow velocities may vary substantially from the average value due to the inhomogeneous nature of the till. Within the till, ground-water flow velocities may be greater in sand lenses while less in clay lenses (see Figure 3-17).

No other hydrologic parameters were calculated for this site.

3.4 SITE 4

Site 4 consists of three bermed fuel oil storage tanks and the area around them as shown on Figures 3-20. The site is described and previous work is summarized in Section 1.2.6. The work done during this study is described in Section 2.4 and summarized by location on Table 2-22.

3.4.1 Surface Features

Photographs show that the appearance of this site has not changed very much since the fuel storage tanks were built in the mid-1950s. A fuel dock to the north of the eastern most tank has been removed, but otherwise the site appears to be the same.

3.4.2 Surface Water Hydrology

The direction of surface drainage may have been changed from southward, and then to Miller Creek, to northward and to Wild Rice Lake during the development of the airport facilities. The description and timing of this possible change is covered in Section 3.6.2 where the surface water hydrology of the zone formed by Sites 3, 4, and 8 is described.

The current surface drainage (see Figure 3-20) to the south and east of the storage tanks goes to a ditch which drains to the north along the east side of the site and then drains to the west just north of the bermed area. At the west side of the bermed area it flows into a north-south culvert at

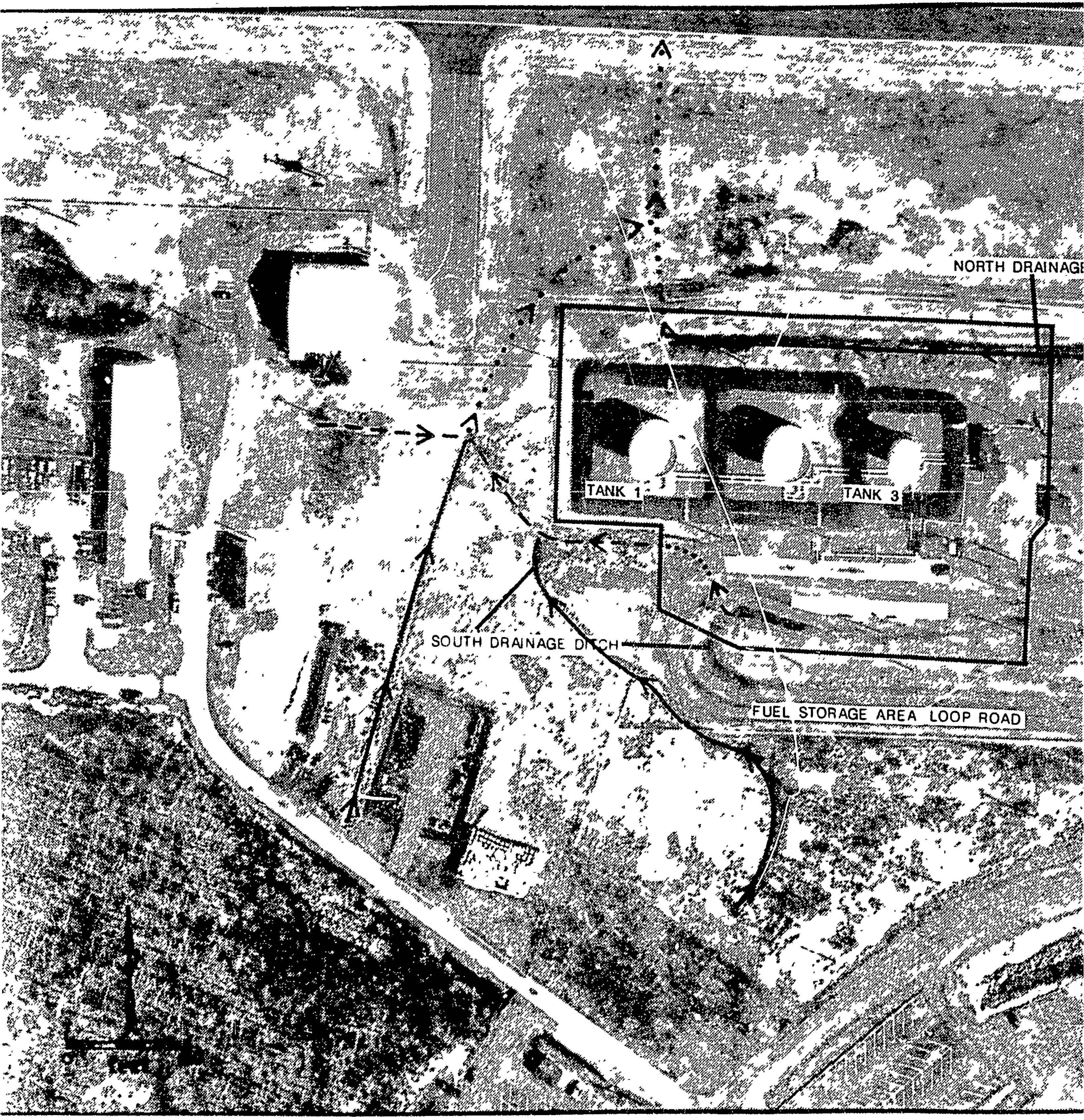
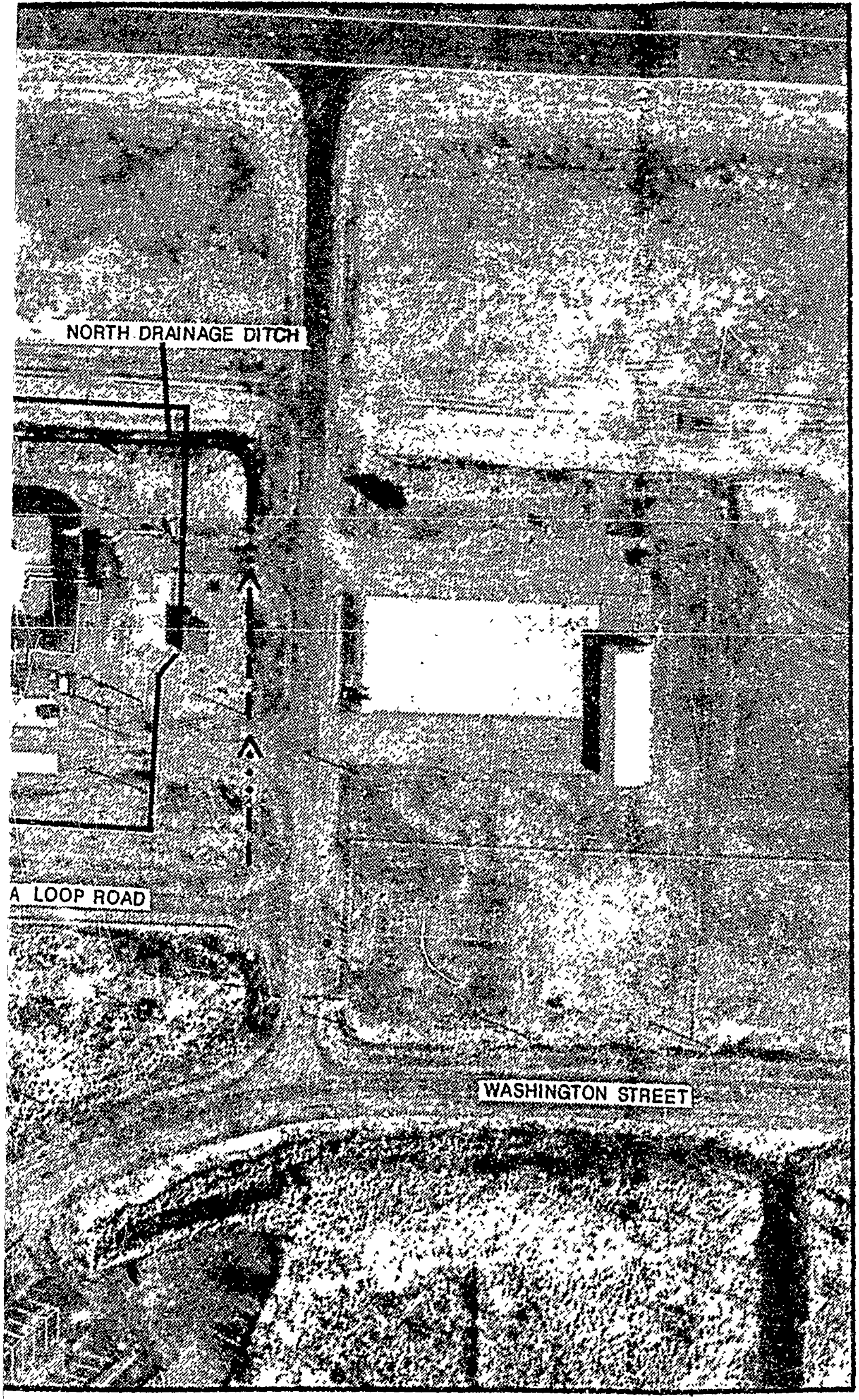


Figure 3-20 Surface Drainage at Site 4.



EXPLANATION

Surface drainage location and direction.

—→ Solid where perennial.

- - → Dashed where ephemeral.

· · · · → Dotted where a culvert is inferred.

☐ Approximate boundary for Fuel Storage Area (Fenced Area).

surface location DANGB-4-SL11.

Drainage to the south and west of the storage tanks drains westward and then northwestward around the tanks where it then flows into a culvert which then presumably drains the site to the north.

A streamflow measurement was taken at DANGB-4-SL11 using a portable weir. A discharge rate of 1,916 gallons per day was measured. This represents the volume of water discharging from the east side of Site 4, and possibly the north side of Site 8 during periods of base flow.

The surface water hydrology of Site 4 is also discussed in Section 3.6.4.

3.4.3 Geology

Geologic information obtained from the continuous cores from the fourteen boreholes was used to describe the subsurface geology. The lithologic logs from the boreholes drilled during Phase II, Stage 1 and Phase II, Stage 2 investigations were also available (see Figures 1-11 and 2-8). Complete lithologic logs for the holes drilled during this investigation are presented in Appendix E.

The site is underlain by unconsolidated glacial till which overlies the bedrock consisting of gabbro belonging to the Duluth Complex. The glacial till consists of clay, silt, sand, pebbles, gravel and mixtures of these components in layers and lenses of varying sizes. The layers appear to be lenses in the sense that they grade laterally into layers with different proportions of the same constituents (Figures 3-2 and 3-3).

Bedrock was reached in ten of the fourteen boreholes. This allowed the detailed modification of the bedrock surface contour map. A major bedrock channel which opens to the southeast underlies this site. The bedrock surface is discussed in Section 3.6.3 where the geology of the zone formed by Sites 3, 4, and 8 is presented.

All but three of the boreholes that reached bedrock had either a sand and gravel layer or a washed out zone indicative of a possible sand and gravel layer just above bedrock. That sand-sized particles rather than clay-sized particles washed out is indicated by the gumminess of the clay and its tendency to clump together in balls observed during the grain size analyses.

Two of the exceptions, locations DANGB-4-WP11 and DANGB-4-WP16, were at the southeast and southwest corners, respectively, of the site. They both had silt layers with some clay, pebbles, and gravel directly overlying bedrock, and both had sand layers overlying the silt.

The third exception, location DANGB-4-WP13D, is on the north side of the site. It also had a layer of silt with some clay and pebbles directly overlying bedrock. This bedrock also had a sand layer but it did not directly overlie the silt.

Cross-sections depicting geologic conditions at Site 4 are indexed in Figure 3-16 and shown in Figure 3-21.

The porosity values for the four soil samples obtained from borehole DANGB-4-MW22 ranged from 44.5 to 47 percent. The effective porosity which is a measure of the interconnected pore space through which flow can occur is estimated to average 20 percent but can be as low as 5 to 10 percent in the very clay rich layers (Morris and Johnson, 1967).

3.4.4 Hydrogeology

Ground water occurs in both the unconsolidated glacial sediments and in the underlying bedrock. The glacial sediments form the principal aquifer and vary from about 19 feet to about 34 feet in thickness. The water table occurs at depths generally less than 10 feet and is believed to be continuous with surface drainage. The thinness of the aquifer and the shallowness of the water table would appear to indicate that the aquifer is unconfined. However, the inhomogeneous nature of the lenticular stratigraphy which is composed of lenses and discontinuous layers of intermixed clays and silts as well as silty sands and gravels causes semi-confined to confined conditions to exist within a few feet of the surface.

A water table altitude contour map, Figure 3-22, was constructed from measurements taken on 27 September 1988. The variation in vertical hydraulic head is shown on Figure 3-23. Water table altitude data are presented in Appendix I, Table I-1.

Ground-water flow is predominantly toward the drainage ditch on the north side of Site 4 indicating that this drainage ditch is a discharge area. Water levels from two sets of paired monitoring wells north of the drainage ditch demonstrate an upward component of flow. Closed water table contours exist around the drainage ditch before it enters a culvert that flows to the north. Four sets of paired well points along the south side of the taxiway north of Site 4 indicate a downward component to flow. The downward component of flow present in the paired wells on the east side of the storage tanks correlates with a bedrock high located beneath the paired wells. There is also some ground-water flow toward the drainage ditch located near the southwest corner of the bermed area. The two wells south of the storage area are close together and are screened at different intervals. They indicate

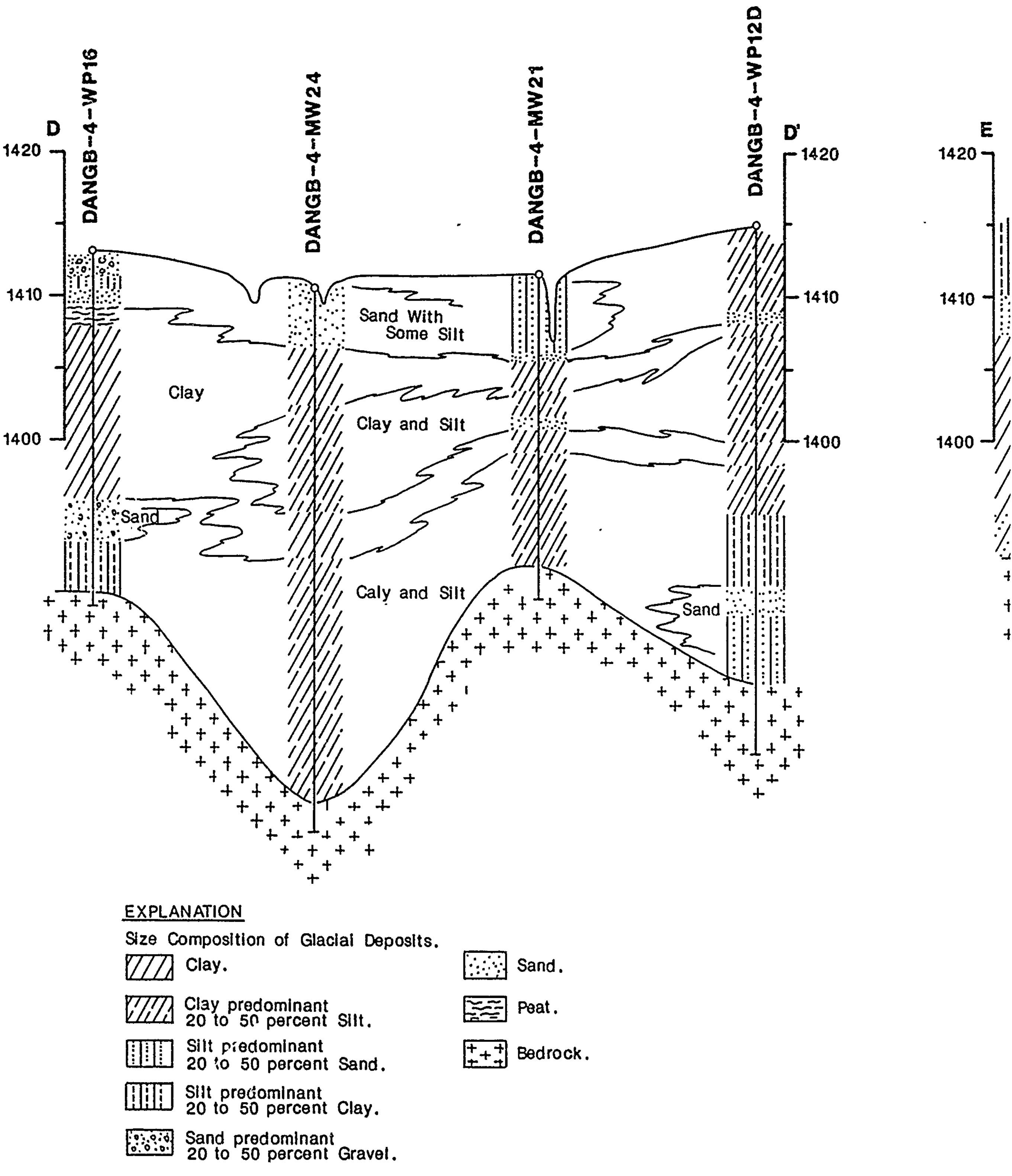
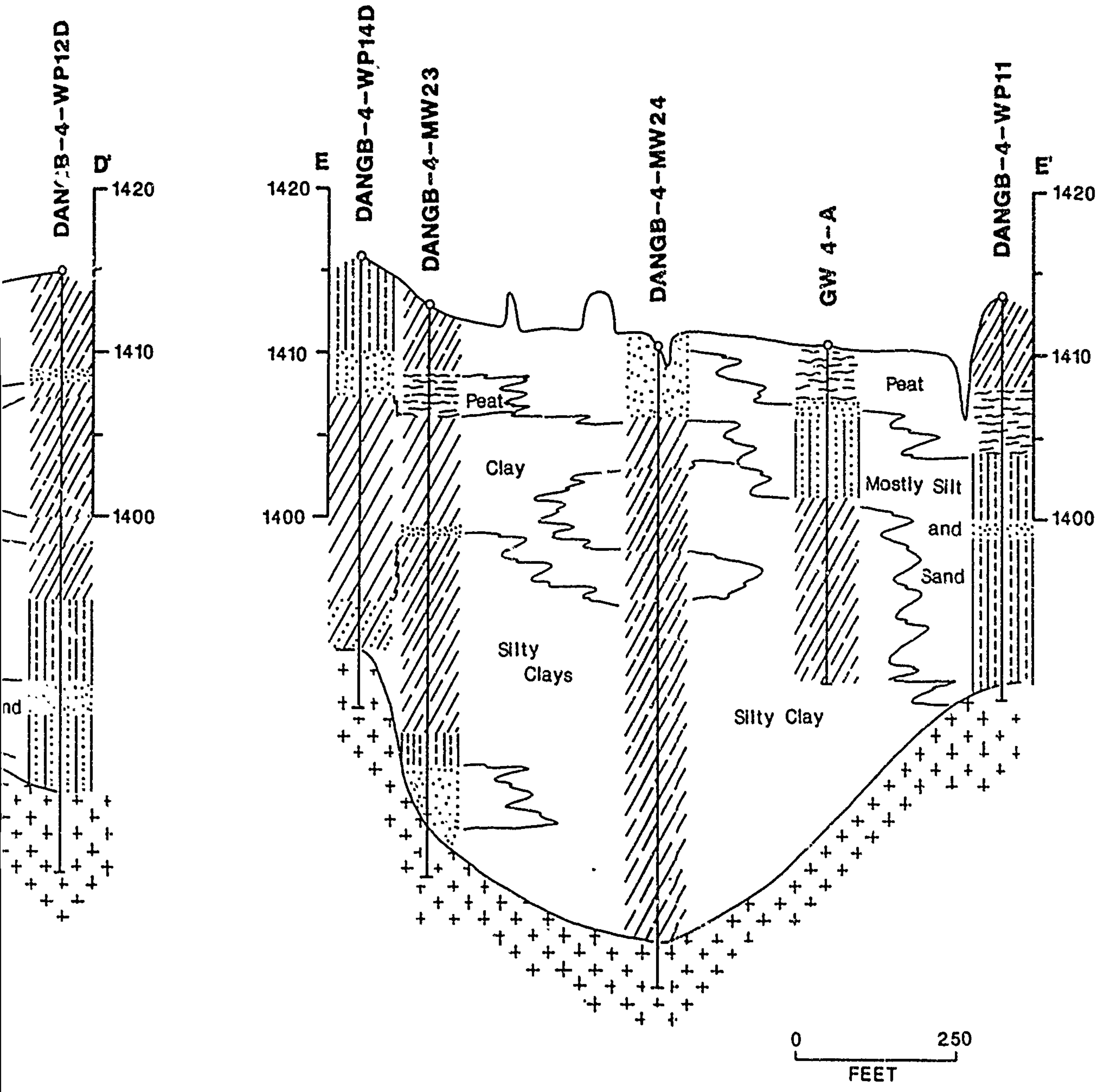


Figure 3-21 Geologic Cross-Sections for Site 4.



COMMENTS

Line of Sections shown on Figure 3-16.

Vertical exaggeration x 25.

Water table altitude data are given in Appendix I, Table I-1.

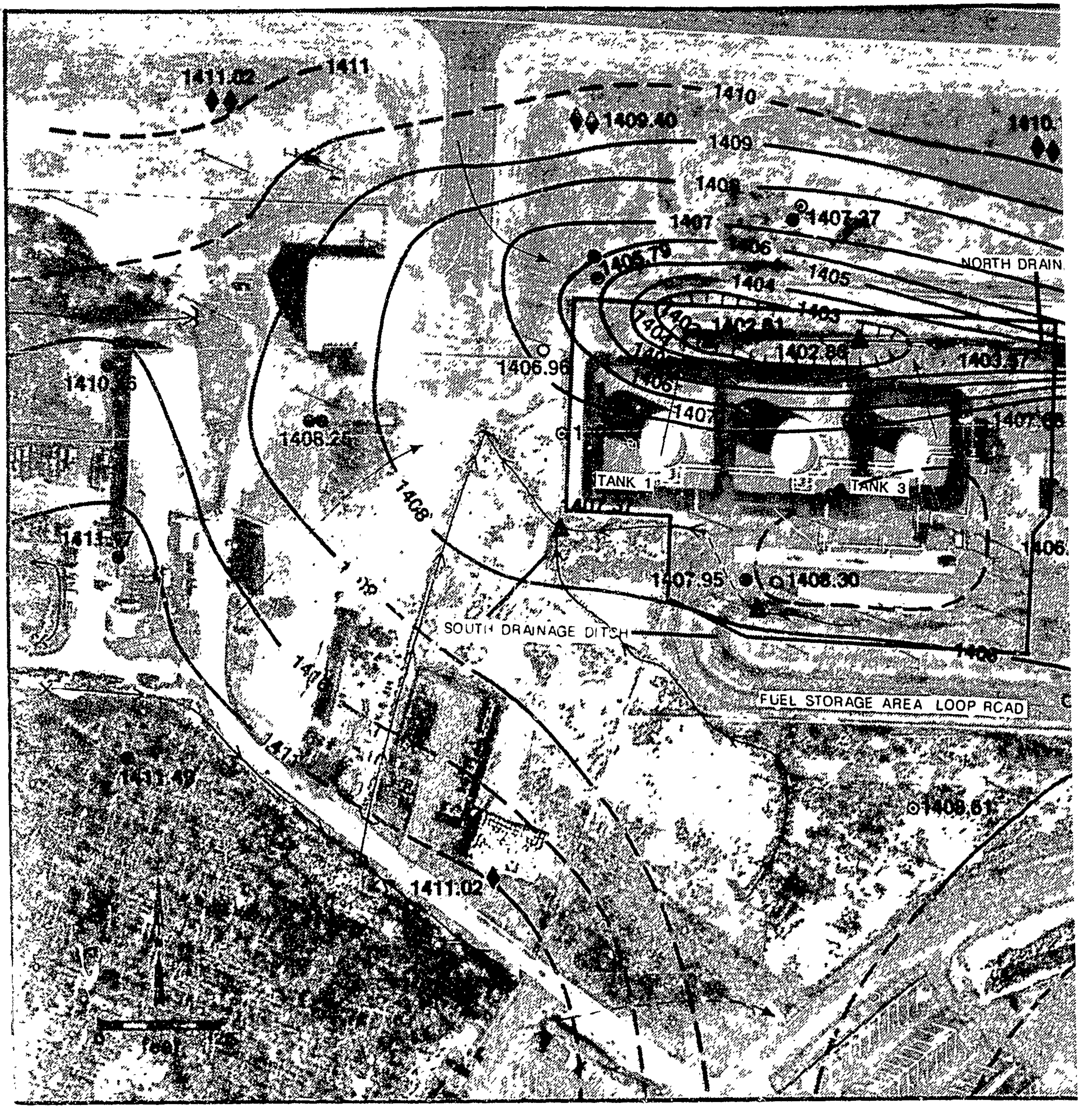
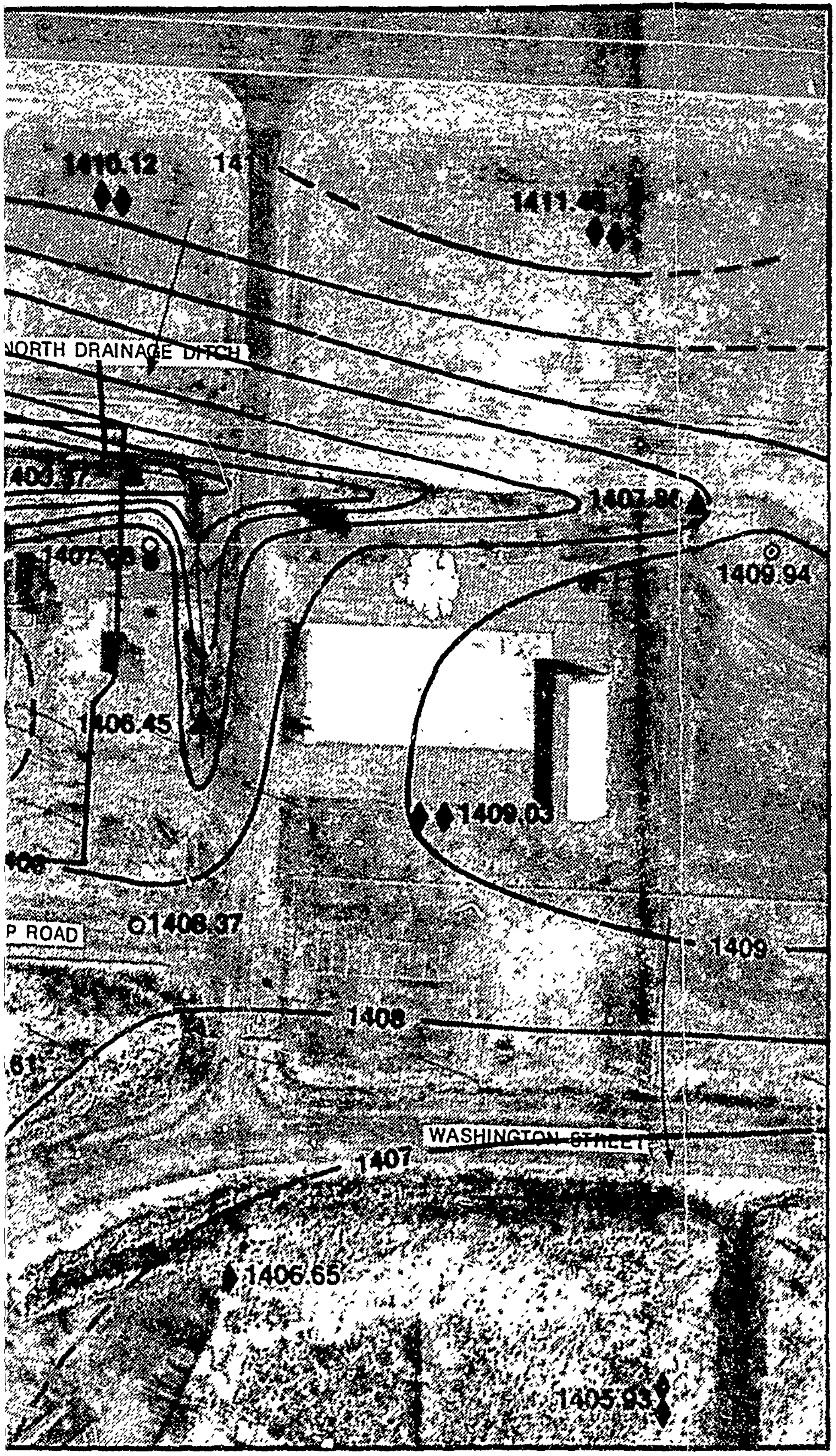


Figure 3-22 Water Table and Direction of Ground Water Movement for Site 4.



EXPLANATION

—1408— Water table contour. Shows altitude of water table on 27 September 1988. Contour Interval is 1 foot. Datum is NGVD of 1929. Line is dashed where inferred

←—— Generalized direction of ground-water flow.

X Spring

Monitoring wells and water level altitude.

○ 1408.30 Phase II; Stage 1.

● 1408.61 Phase II, Stage 2.

● 1408.25 Remedial Investigation.

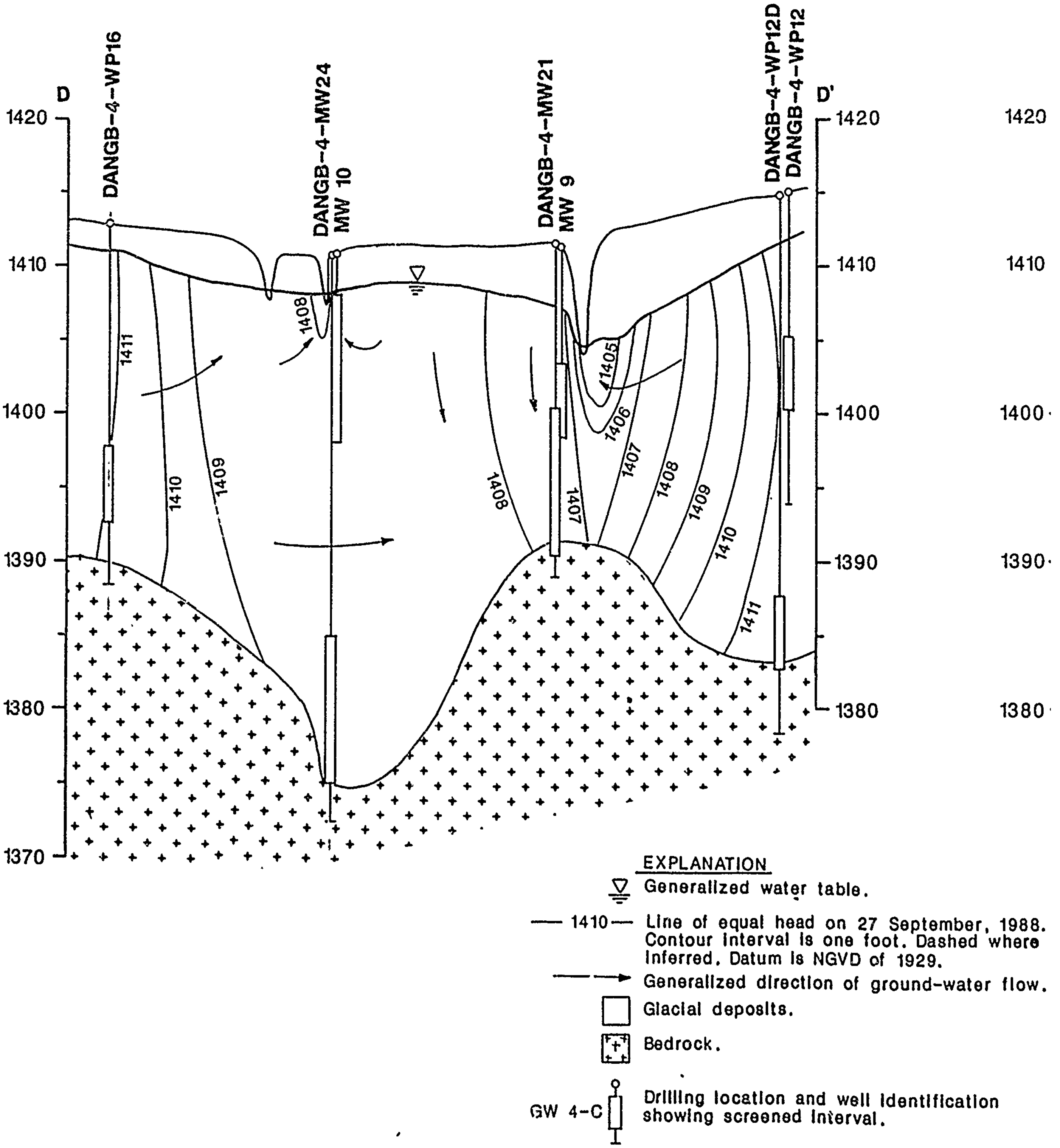
♦ 1411.02 Well point and water level altitude

▲ 1407.37 Surface water sampling location and water level altitude.

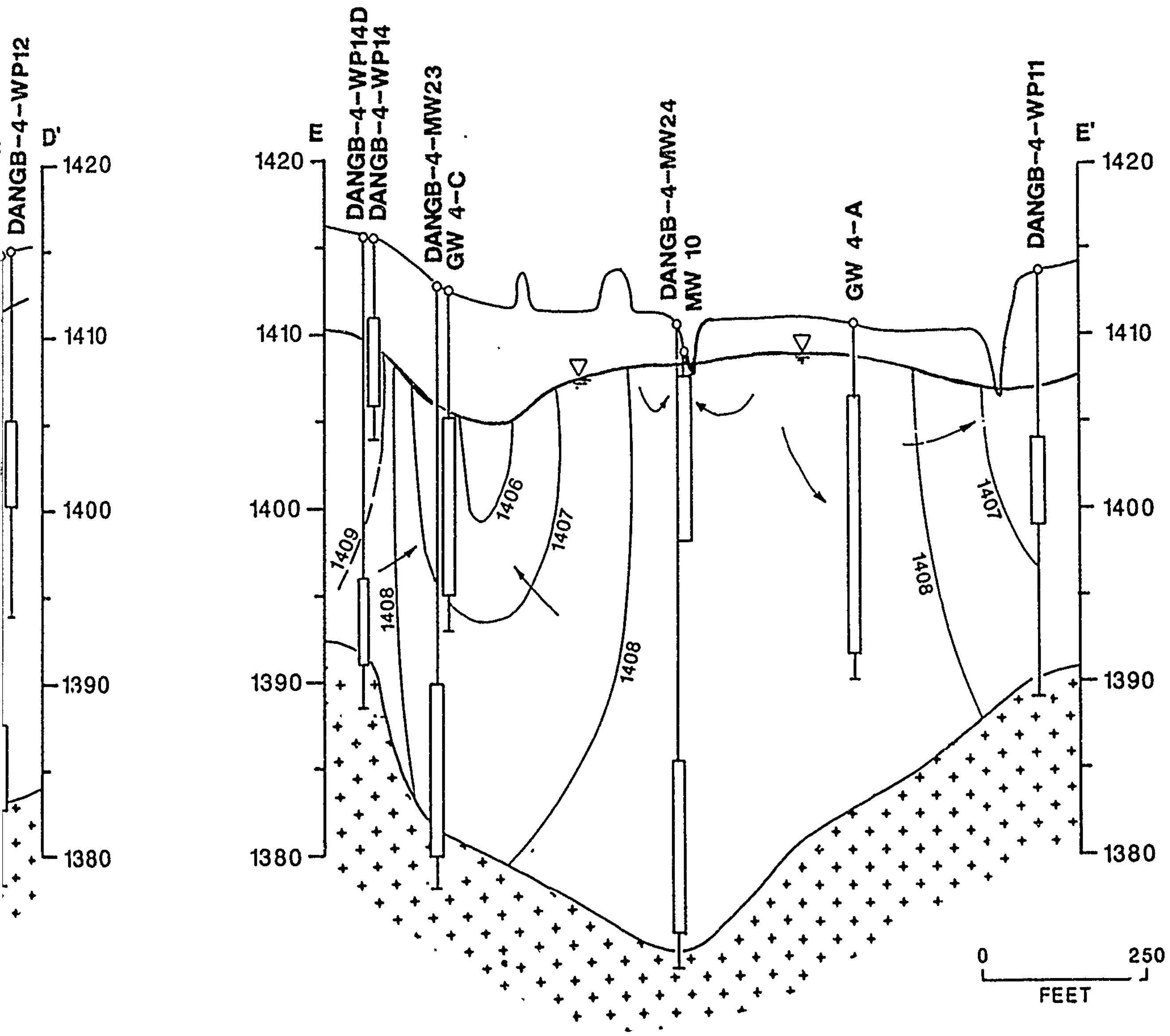
>——> Surface drainage location and direction.

☐ Approximate boundary for Fuel Storage Area (Fenced Area).

COMMENT. Water table altitude data are given in Appendix I, Table I-1.



igure 3-23 Variation in Vertical Hydraulic Head in the Glacial Till at Site 4 and Generalized Direction of Ground-Water



ter table.

ead on 27 September, 1988.
l is one foot. Dashed where
is NGVD of 1929.
ection of ground-water flow.
s.

COMMENTS
Line of Sections shown on Figure 3-16.
Vertical exaggeration x 25.
Water table altitude data are given in Appendix I, Table I-1.

n and well identification
ed interval.

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Direction of Ground-Water Movement.

there is likely an upward flow component to the drainage ditch at this location.

Transmissivity of the glacial deposits was calculated by two different methods and the results compared. In the first method, the transmissivity for the glacial till aquifer in the immediate vicinity of monitoring well DANGB-4-MW22 was calculated using slug test data. Calculating the transmissivity from both the slug injection and slug withdrawal data gave values of 10.9 and 22.4 gpd/ft. The corresponding values for the hydraulic conductivity were 1.1 and 2.2 gpd/ft^2. This data is summarized in Table 3-4 and the calculations are given in Appendix G.

In the second method, an average transmissivity for the glacial deposits at Site 4 was obtained by using the fact that the discharge from the drainage ditch north of the Tank Farm is approximately equal to flow through the cross-sectional area underlying the closed 1407 foot ground-water altitude contour. This relationship is expressed by the equation:

$$Q = T \times I \times L, \text{ or}$$

$$T = Q/(I \times L)$$

Where:

T = transmissivity of the aquifer, in gallons per day per foot;

Q = discharge through the cross-sectional area of the aquifer underlying the 1407 foot altitude contour, in gallons per day;

I = average hydraulic gradient in the aquifer within the 1407 foot contour, in feet per foot, and;

L = distance around the closed 1407 foot altitude contour, in feet.

Using the measured stream discharge at DANGB-4-SL11 and the closed 1407 foot contour, the following values were determined:

Q = 1,916 gallons per day;

I = 0.058 feet per foot; and

L = 2,160 feet.

Substitution of the values of Q, I, and L into the above equation yields a transmissivity value of 15.3 g/d/ft. This value lies about halfway between the two transmissivity values obtained from the slug test data at location DANGB-4-MW22, and is an independent verification of these values.

See also Section 3.6.4 for an additional discussion of Site 4 Hydrogeology.

3.5 SITE 8

Site 8 consists of a flat grassy area immediately to the east of Site 4

TABLE 3-4

SUMMARY OF SITE 4 SLUG TEST RESULTS

Monitoring Well Number	Transmissivity (gal/day/ft)		Horizontal Hydraulic Conductivity (gal/day/ft^2)	
	Injection	Withdrawal	Injection	Withdrawal
DANGB-4-MW22	22.4	10.9	2.2	1.1

and south of the main east-west taxiway. It was used to store drummed materials (Figures 1-5, 1-12, and 2-1).

3.5.1 Surface Features

The aerial photographs which were reviewed confirm that this area was used for storage of materials, including drummed materials, up to at least 1979. The photographs were also examined with regard to surface drainage. In addition to the discussion of the surface drainage in Section 3.3.2 below, the results are discussed in Section 3.6.1 which discusses the surface drainage and ground-water hydrology of the zone formed by Sites 3,4, and 8.

3.5.2 Surface Water Hydrology

A drainage ditch located on the north side of Site 8 flows west and joins with drainage from Site 4 and eventually flows north (see Figure 3-24). This drainage ditch is typically wet but with minor amounts of standing water in it. Drainage in the part of the site which is south of Washington Street is channeled into a man-made ditch that eventually flows southeast and empties into Miller Creek.

The direction of surface drainage may have been changed from southward, and then to Miller Creek, to northward and to Wild Rice Lake during the development of the airport facilities. The description and timing of this possible change is discussed in Section 3.6.2 where the surface water hydrology of the zone formed by Sites 3, 4, and 8 is described.

3.5.3 Geology

Geologic information obtained from the continuous cores from the eleven boreholes was used to describe the subsurface geology. The logs from the boreholes drilled during the Phase II, Stage 2 investigation were also available. Complete lithologic logs for the holes drilled during this investigation are presented in Appendix E. The site is underlain by unconsolidated glacial till which overlies the bedrock consisting of gabbro belonging to the Duluth Complex of rocks. The glacial till consists of clay, silt, sand, pebbles, gravel and mixtures of these components in layers and lenses of varying sizes. The layers appear to be lenses in the sense that they grade laterally into layers with different proportions of the same constituents. Although large glacial boulders can be found at almost any depth, the proportion of pebbles and cobbles appears to increase downward.

Bedrock was reached in seven of the eleven boreholes. This allowed for detailed modification of the bedrock surface contour map for this site originally constructed by Rogers (1962). A major bedrock channel lies on the

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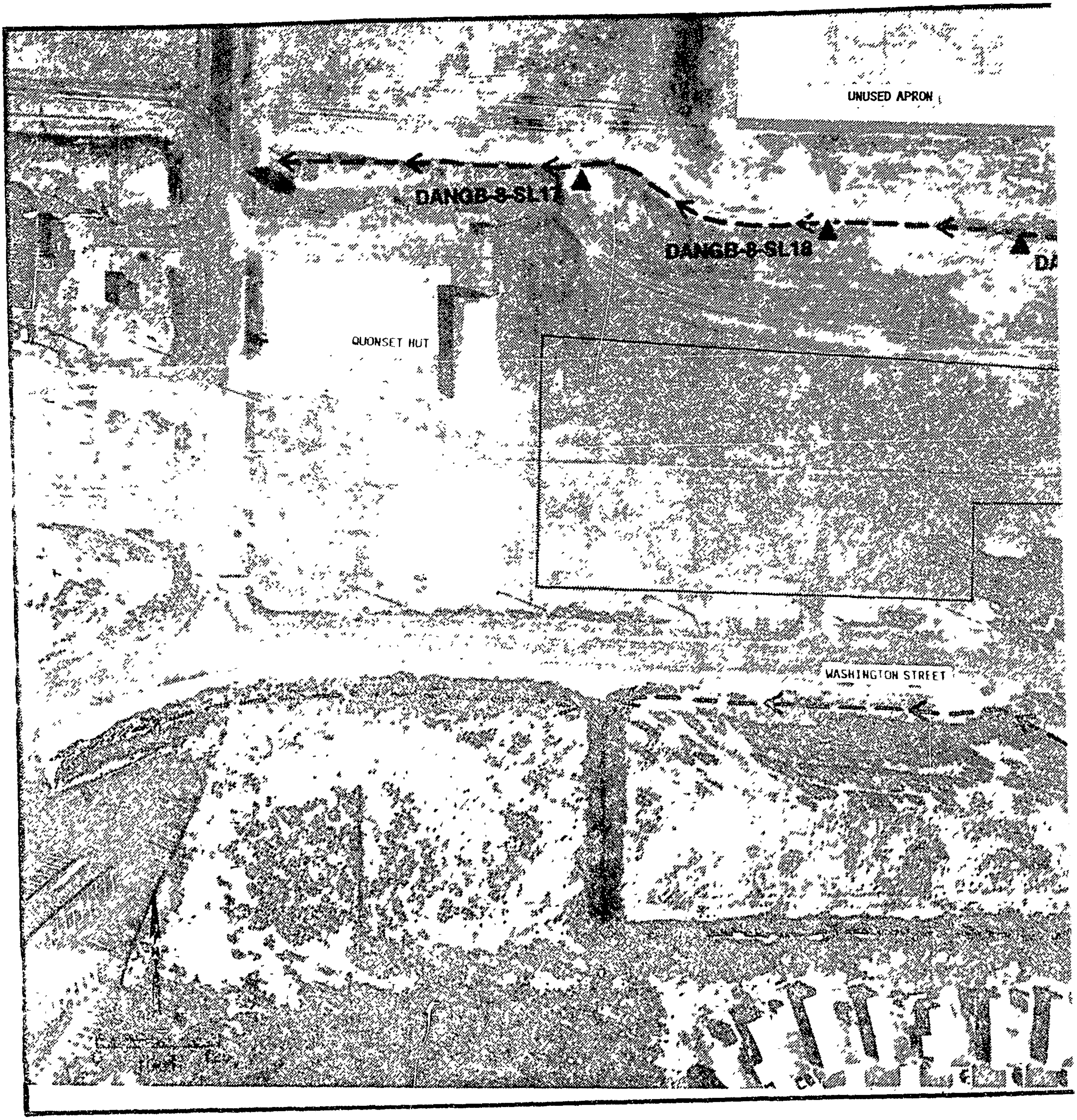
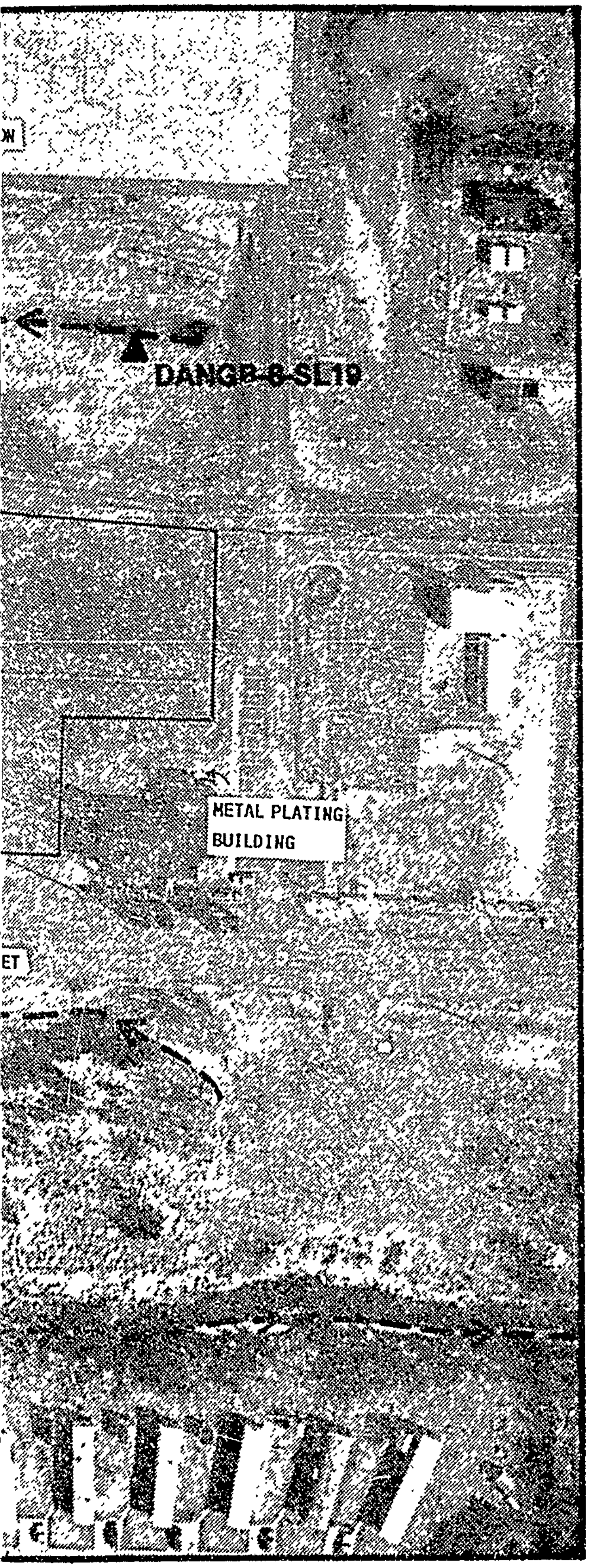


Figure 3-24 Surface Drainage at Site 8.



EXPLANATION

DANGB-8-SL18

▲ Surface water and sediment sampling location, Remedial Investigation

— — → Surface drainage location and direction

▭ Approximate boundary of Storage Area (old DPDO office).

western edge of this site. The bedrock surface is discussed in Section 3.6.3 where the geology of the zone comprised of Sites 3, 4, and 8 is presented.

Of the seven boreholes that reached bedrock, locations DANGB-8-MW14 and DANGB-8-MW16, which are south of Washington Street, had layers of sand and gravel overlying bedrock. At these locations the uppermost part of the bedrock appeared to be fractured. At location DANGB-8-WP9D, about a foot of clay immediately overlies bedrock, but above this is several feet of coarse sand and gravel. At the four locations north of Washington Street, at which depth to bedrock is shallower than those to the south, silt or silt and clay are immediately above bedrock. In one instance, clay is reported, but this sample had only 25 percent recovery indicating that either sand or gravel had been present but had washed out during coring. That sand-sized particles rather than clay-sized particles had washed out is indicated by the gumminess of the clay and its tendency to clump together in balls which was observed during the grain size analyses. At this location, the upper part of the bedrock was fractured. In one instance, the silt contained a sandy zone.

A one and one-half foot granite boulder was cored at location DANGB-8-WP9D just above bedrock. This location is on the sloping side of the bedrock channel and is the only boulder cored at locations at this site. The geologic material at Site 8 consists of finer grained materials than at other sites. Pebbles vary from a trace to common throughout.

Cross-sections depicting the geology at Site 8 are indexed in Figure 3-16 and shown in Figure 3-25.

The porosity values for the five soil samples from borehole DANGB-8-MW16 and the five soil samples from borehole DANGB-8-MW20A ranged from 41.5 to 46 percent. The effective porosity which is a measure of the interconnected pore space through which flow can occur is estimated to average 20 percent. It may vary from 5 to 20 percent for a silty clay to 25 to 35 percent for a fine sand (Morris and Johnson, 1967).

3.5.4 Hydrogeology

Ground water occurs in both the unconsolidated glacial sediments and in the underlying bedrock. The glacial sediments form the principal aquifer and vary from about 15 feet to about 50 feet in thickness. The water table occurs at depths generally less than 10 feet and is believed to be continuous with surface drainage. The thinness of the aquifer and the shallowness of the water table would appear to indicate that the aquifer is unconfined. However, the inhomogeneous nature of the lenticular stratigraphy which is composed of

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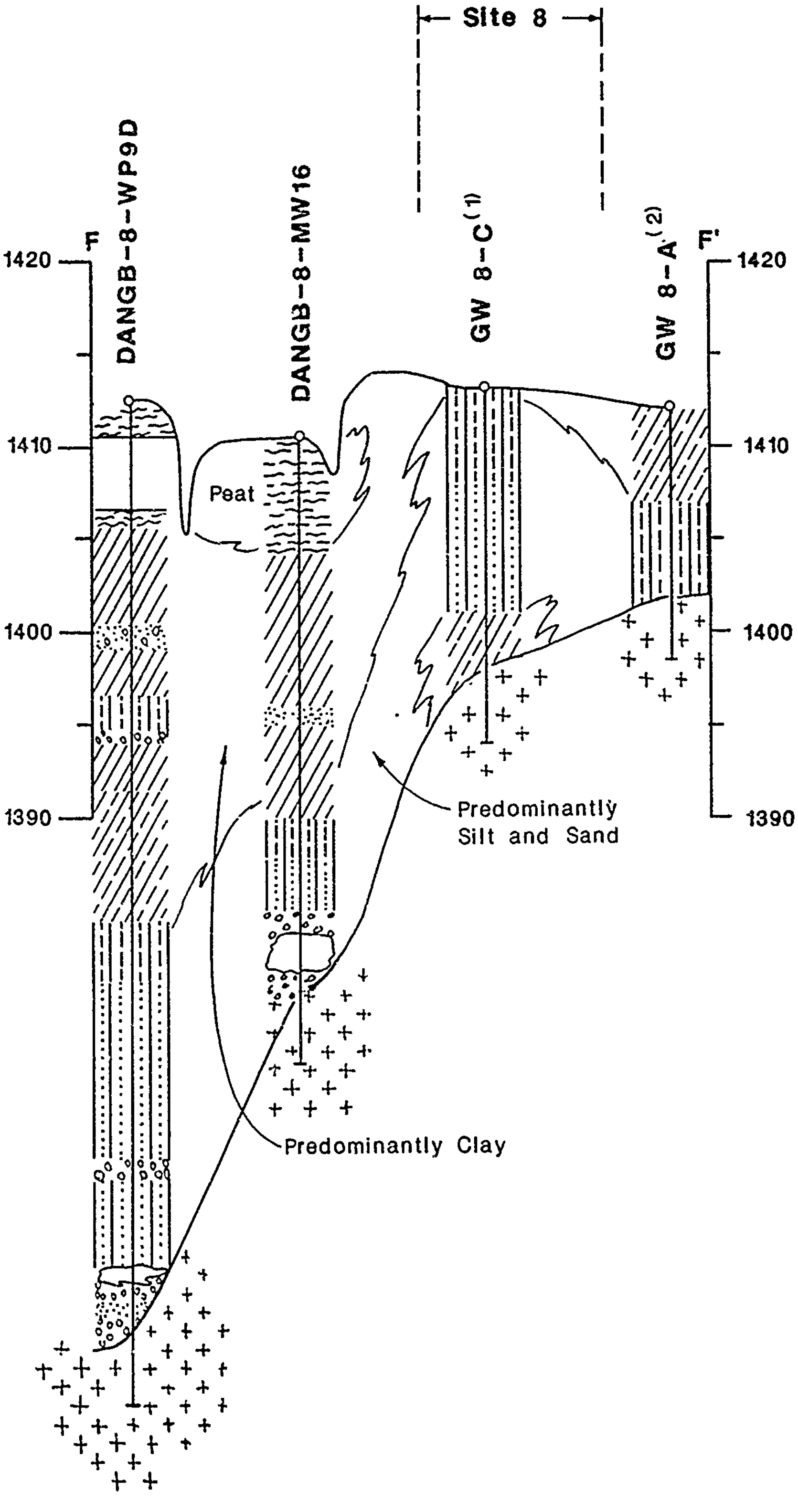

Figure 3-25 Geologic Cross-Sections at Site 8.

EXPLANATION

Size Composition of Glacial Deposits

- ▨ Clay
- ▨ Clay predominant 20 to 50 percent Silt.
- ▥ Silt predominant 20 to 50 percent Sand.
- ▥ Silt predominant 20 to 50 percent Clay.
- ▩ Silt predominant 20 to 50 percent Gravel.
- ▩ Sand predominant 20 to 50 percent Gravel.
- ▒ Sand.
- ▦ Gravel.
- ▤ Peat.
- ⊞ Bedrock.
- ☐ Size composition not reported.
- ▢ Boulder.

COMMENTS

Line of Sections shown on Figure 3-16.
Vertical exaggeration x 25.

(1) Lithologic log for boring DANGB-8-18 used to construct the Cross-Section.

(2) Lithologic log for boring DANGB-8-19A used to construct the Cross-Section.

Water table altitude data are given in Appendix I, Table I-1.

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lenses and discontinuous layers of intermixed clays and silts as well as silty sands and gravels causes semi-confined to confined conditions to exist within a few feet of the surface.

A water level contour map, Figure 3-26, was constructed from water level data collected on September 27, 1988. Water table altitude data are presented in Appendix I, Table I-1. The variation in the vertical hydraulic head is shown on Figure 3-27. Ground water from the western half of this site flows to the south and southeast and would appear to discharge into the drainage ditch which borders the southern boundary of the base at this locality. There may be some ground-water flow to the west toward Site 4 from the far western portion of the site and to the north from the northern portion of the site. The ground-water flow direction from the eastern half of the site is poorly defined but appears to be toward the east and southeast.

Two slug tests were performed at this site. Based on two data sets from slug injection and one data set from slug withdrawal, the transmissivity is computed to range from 8.6 to 15.0 gal/day/foot and the corresponding horizontal hydraulic conductivities were calculated to range from 1.1 to 1.5 gal/day/ft^2. These results are given in Table 3-5. The slug test data and their analyses are given in Appendix G.

3.6 SITES 3,4, AND 8

This section presents the surface features, surface water hydrology, geology, and hydrology of the zone formed by Sites 3, 4, and 8 together.

3.6.1 Surface Features

The present surface features of Sites 3, 4, and 8 are shown on the aerial photograph of these sites, Figure 3-28. Site 3 is to the left of the photograph. The storage pad of concern is the small, almost nondescript, area to the south and partly to the west of the fenced area which is behind the long building. Site 4 is the area around the fuel storage tanks. Site 8 is the flat grassy area east of the storage tanks.

3.6.2 Surface Water Hydrology

The surface water hydrology in this area has been altered over time as construction occurred at the airport. Photographs of Sites 3, 4 and 8 in 1952, 1965, and 1979 are shown in Figures 3-29, 3-30 and 3-31, respectively. The 1952 photograph shows the east-west taxiway under construction and the future locations of Sites 3, 4 and 8 which were not constructed. The point labeled B in the figure is the same as surface location DANGB-4-SL11 (see Figure 3-18). It is located on an east-west drainage ditch Figure 3-25 at the

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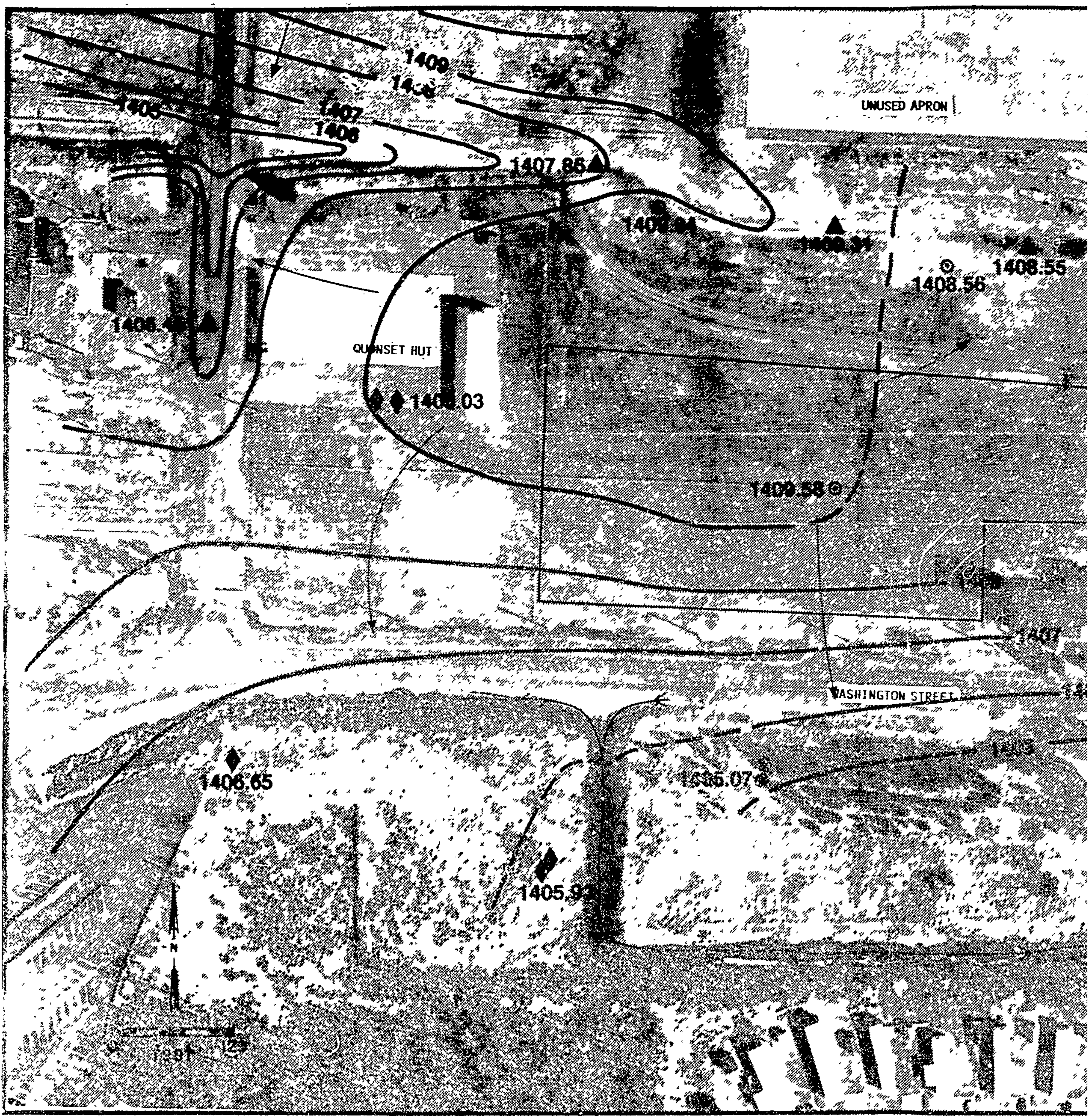
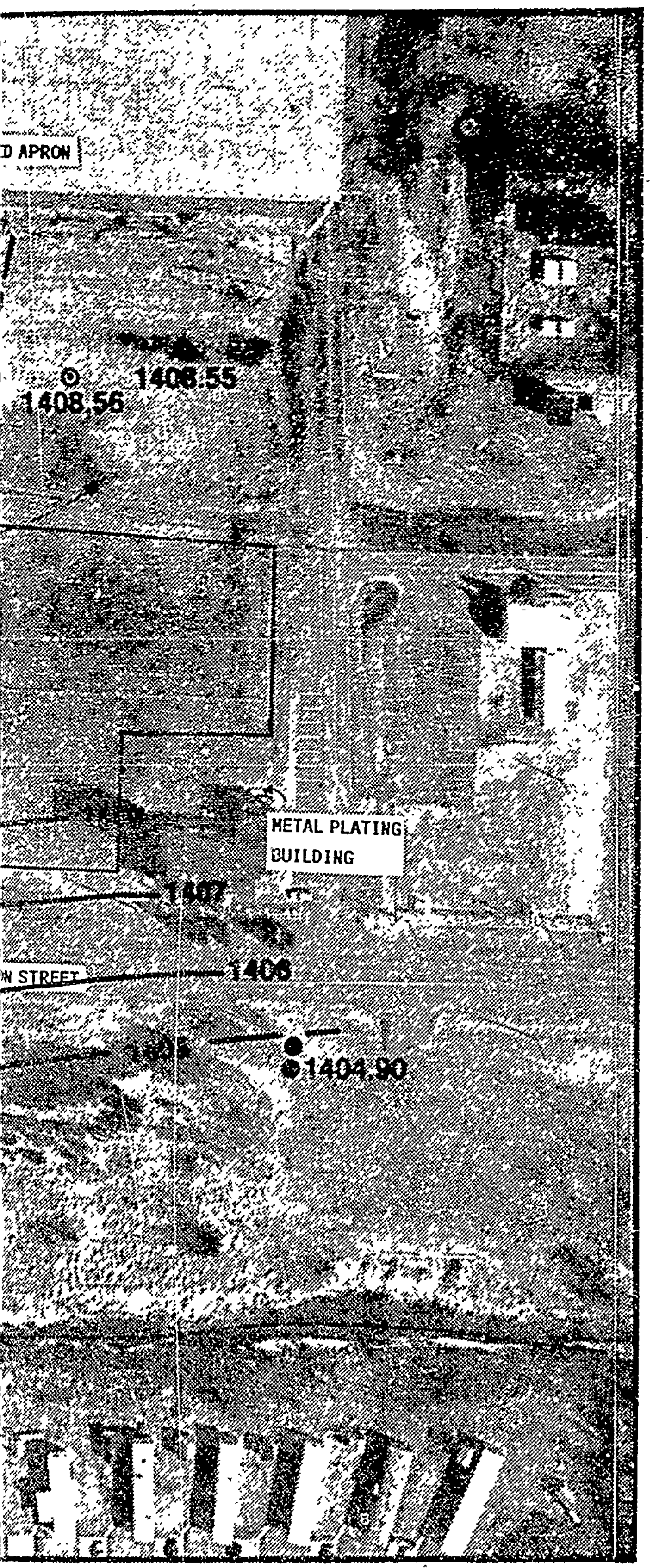


Figure 3-26 Water Table and Direction of Ground-Water Movement for Site 8.



EXPLANATION

— 1408 —	Water table contour. Shows altitude of water table on 27 September 1988. Contour Interval is 1 foot. Datum is NGVD of 1929. Line is dashed where inferred.
←	Generalized direction of ground-water flow.
	Monitoring wells and water level altitude.
⊙ 1409.58	Phase II; Stage 2.
● 1405.07	Remedial Investigation.
◆ 1405.93	Well point and water level altitude.
▲ 1406.45	Surface water sampling location and water level altitude.
←<	Surface drainage location and direction.
□	Approximate Boundary of the Storage Area (old DPDO office).

COMMENT: Water table altitude data are given in Appendix I, Table I-1.

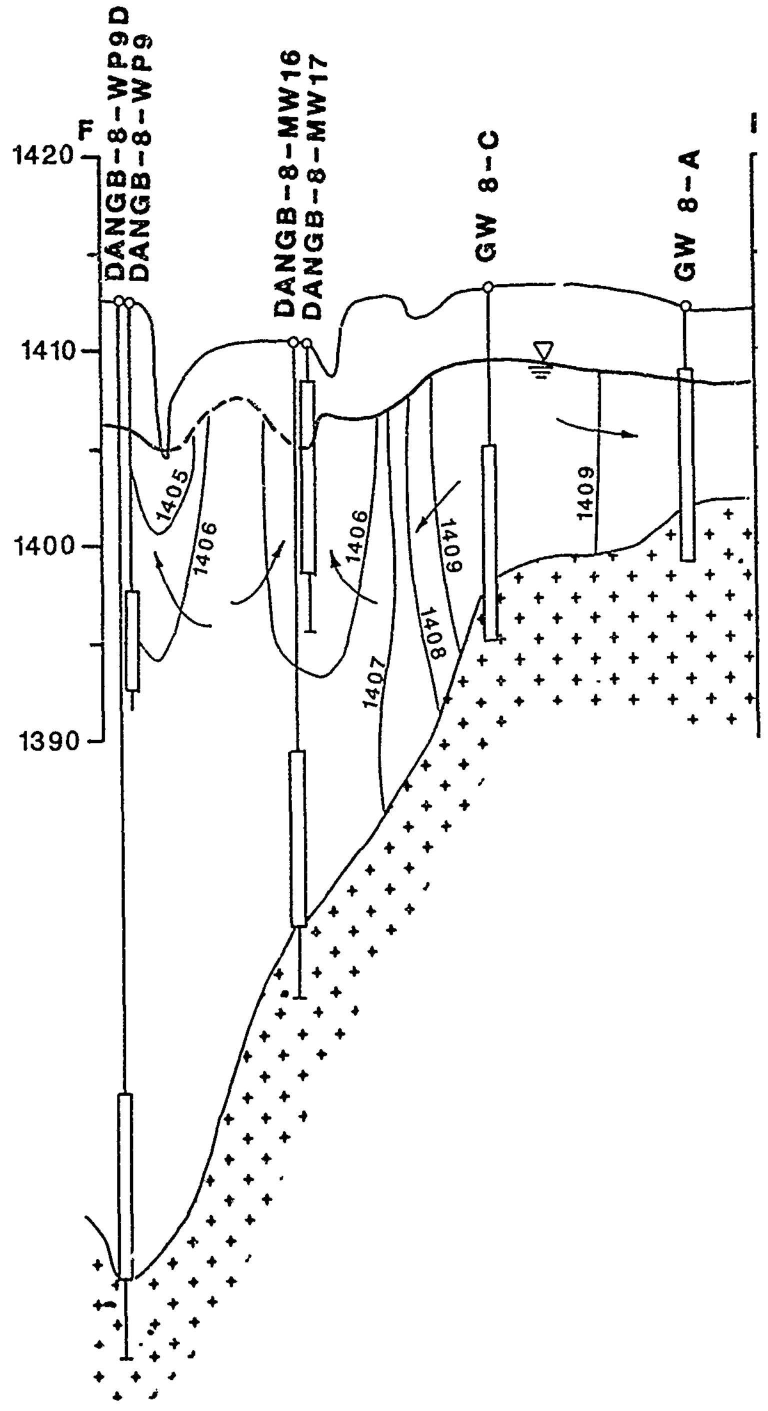
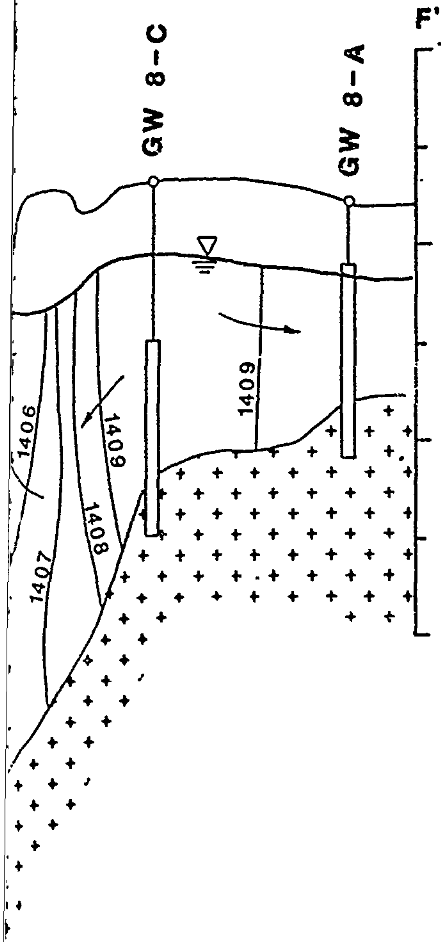


Figure 3-27 Variation in Vertical Hydraulic Head in the Glacial Till at Site 8 and Generalized Direction of Ground-



EXPLANATION

∇ Generalized water table.

—1410— Line of equal head on 27 September, 1988. Contour interval is one foot. Dashed where inferred. Datum is NGVD of 1929.

———→ Generalized direction of ground-water flow.

☐ Glacial deposits.

▨ Bedrock.

GW 8-C Drilling location and well identification showing screened interval.

COMMENTS

Line of Sections shown on Figure 3-16.
Vertical exaggeration x 25.
Water table altitude data are given in Appendix I, Table I-1.

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neralized Direction of Ground-Water Movement.

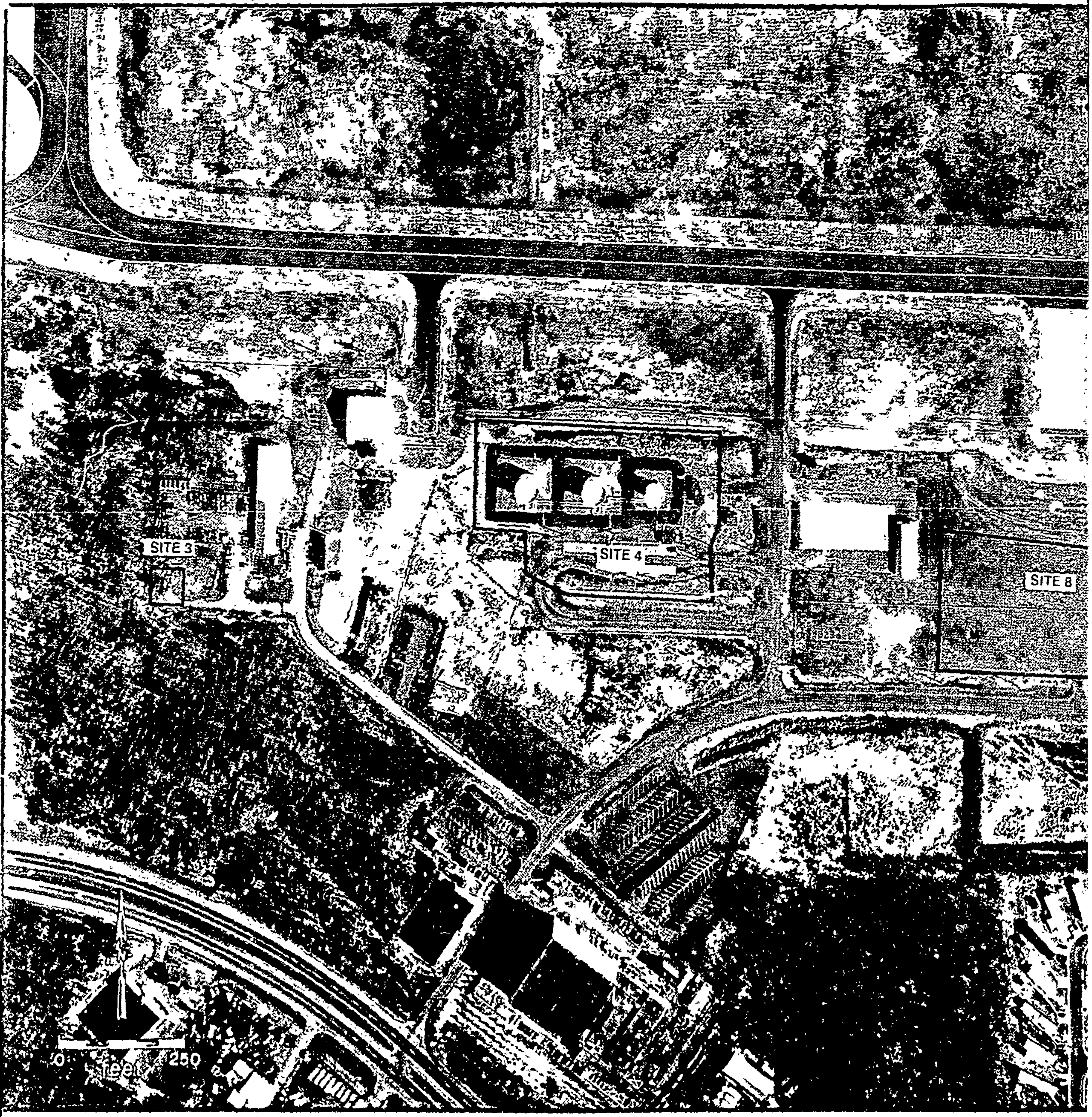
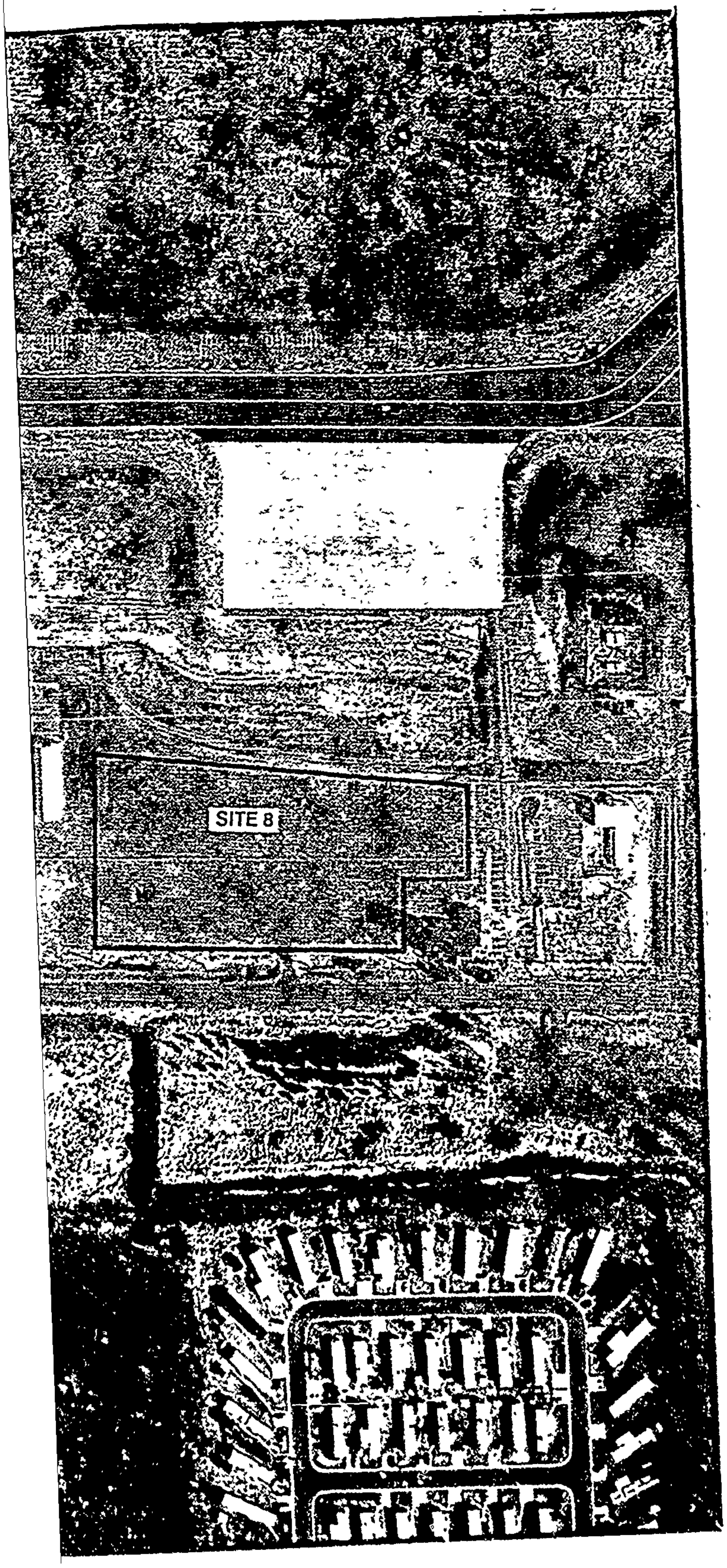


Figure 3-28 Aerial Photograph of Sites 3, 4, and 8, April 1988.



EXPLANATION

☐ Approximate boundary of site.

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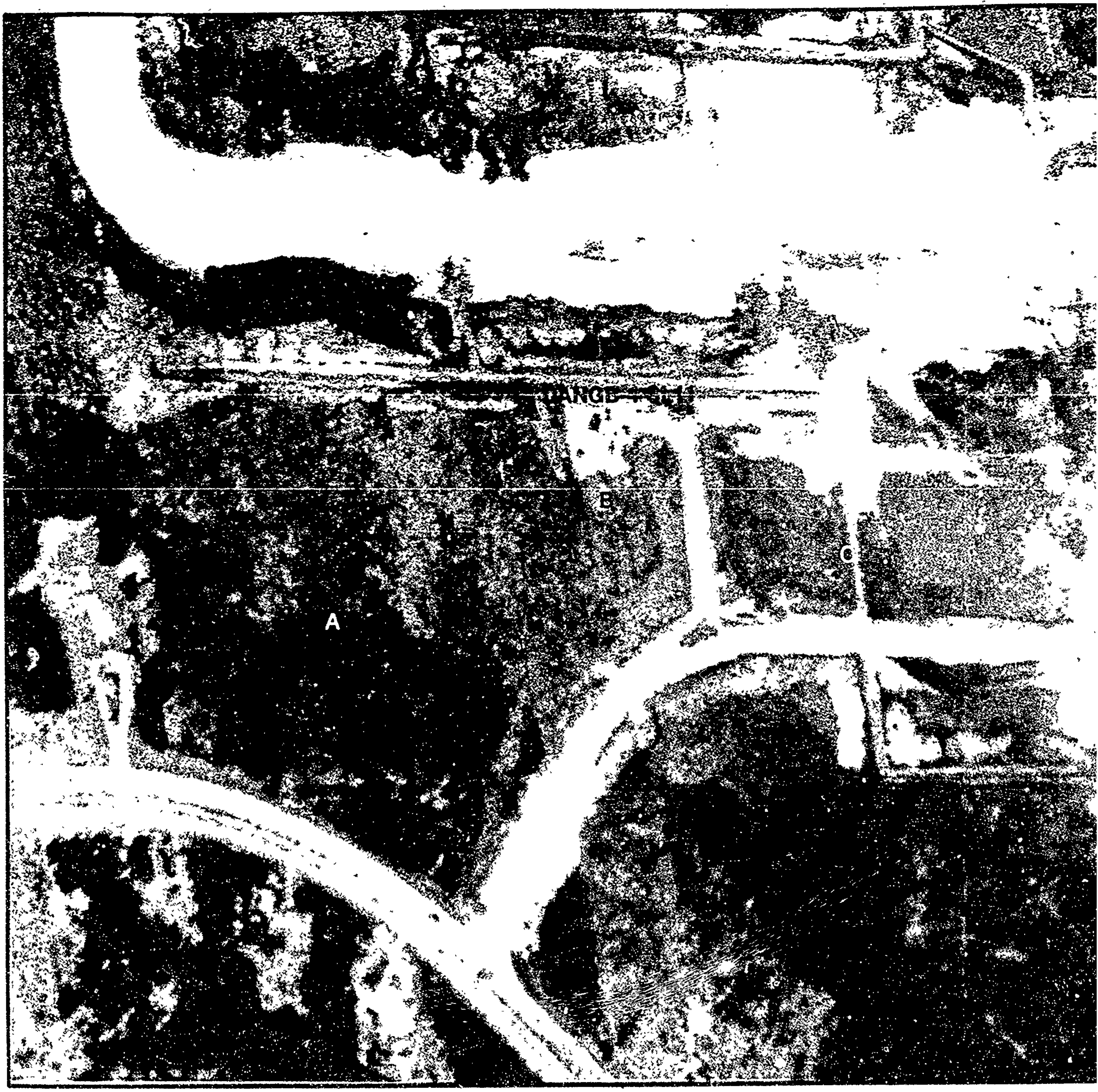
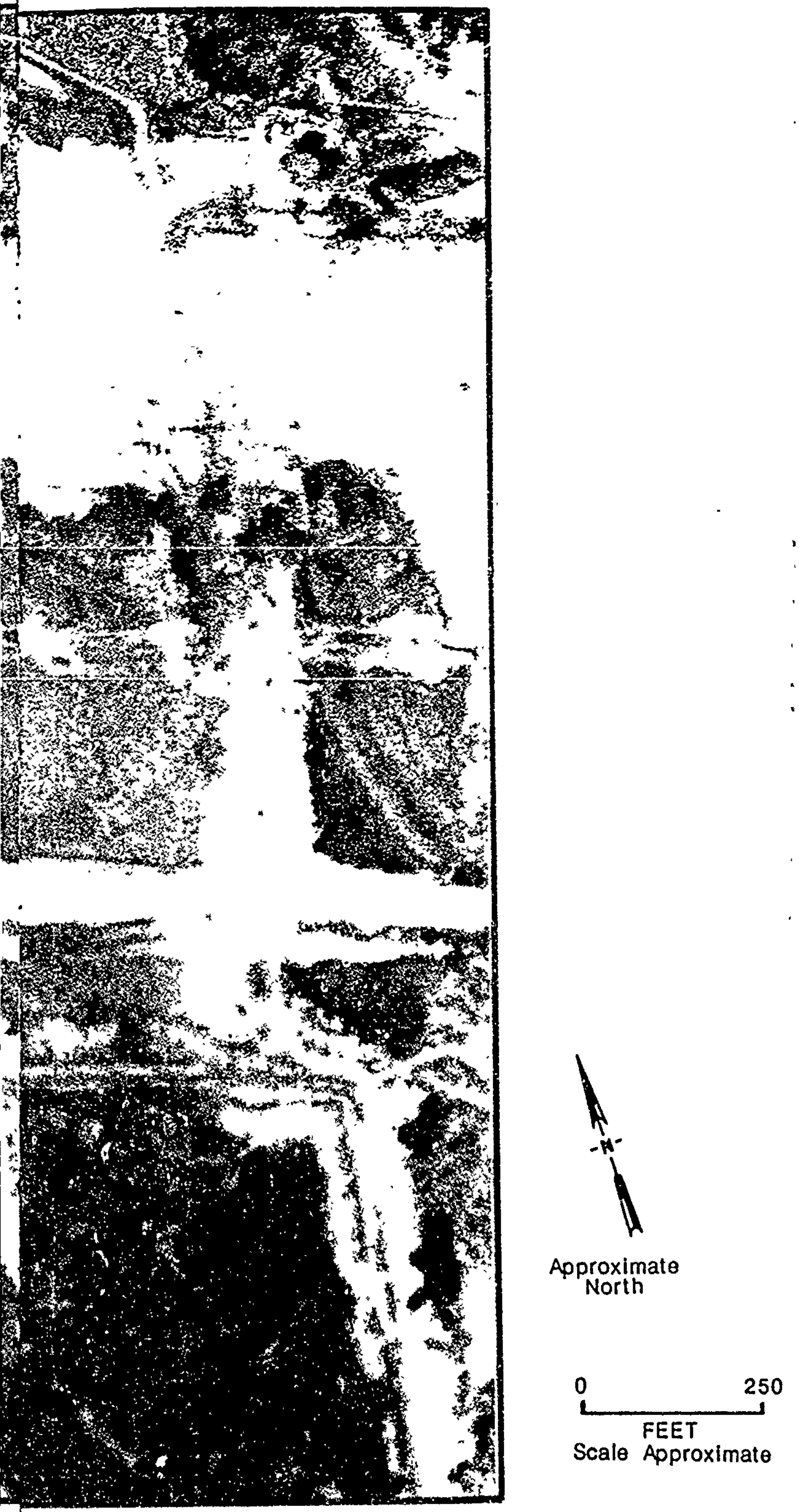


Figure 3-29 Aerial Photograph of Sites 3, 4, and 8, August, 1952.



EXPLANATION

A Future location of Site 3.
B Future location of Site 4.
C Future location of Site 8.
▲ DANGB-4-SL11 Surface Sampling point.

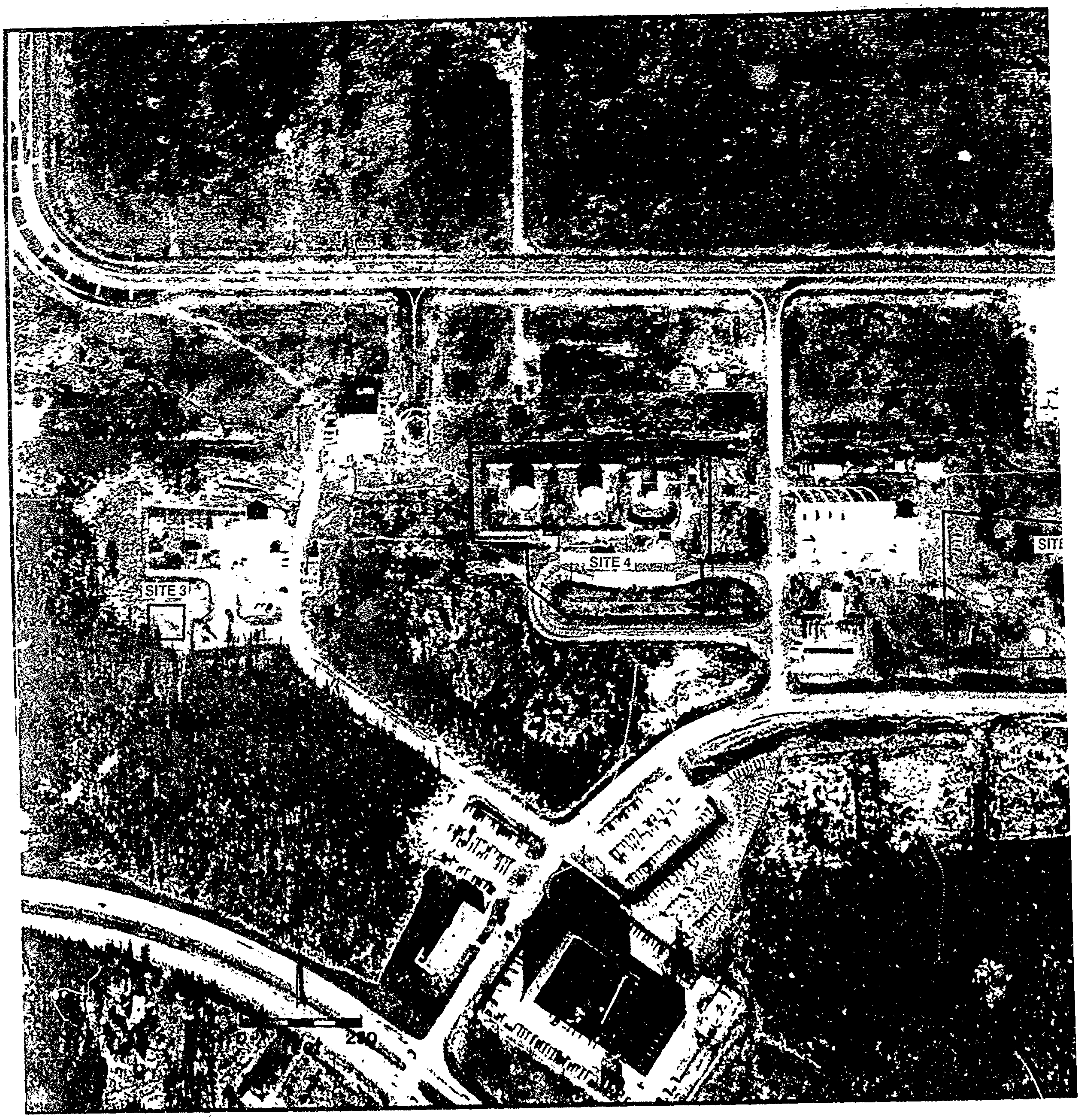
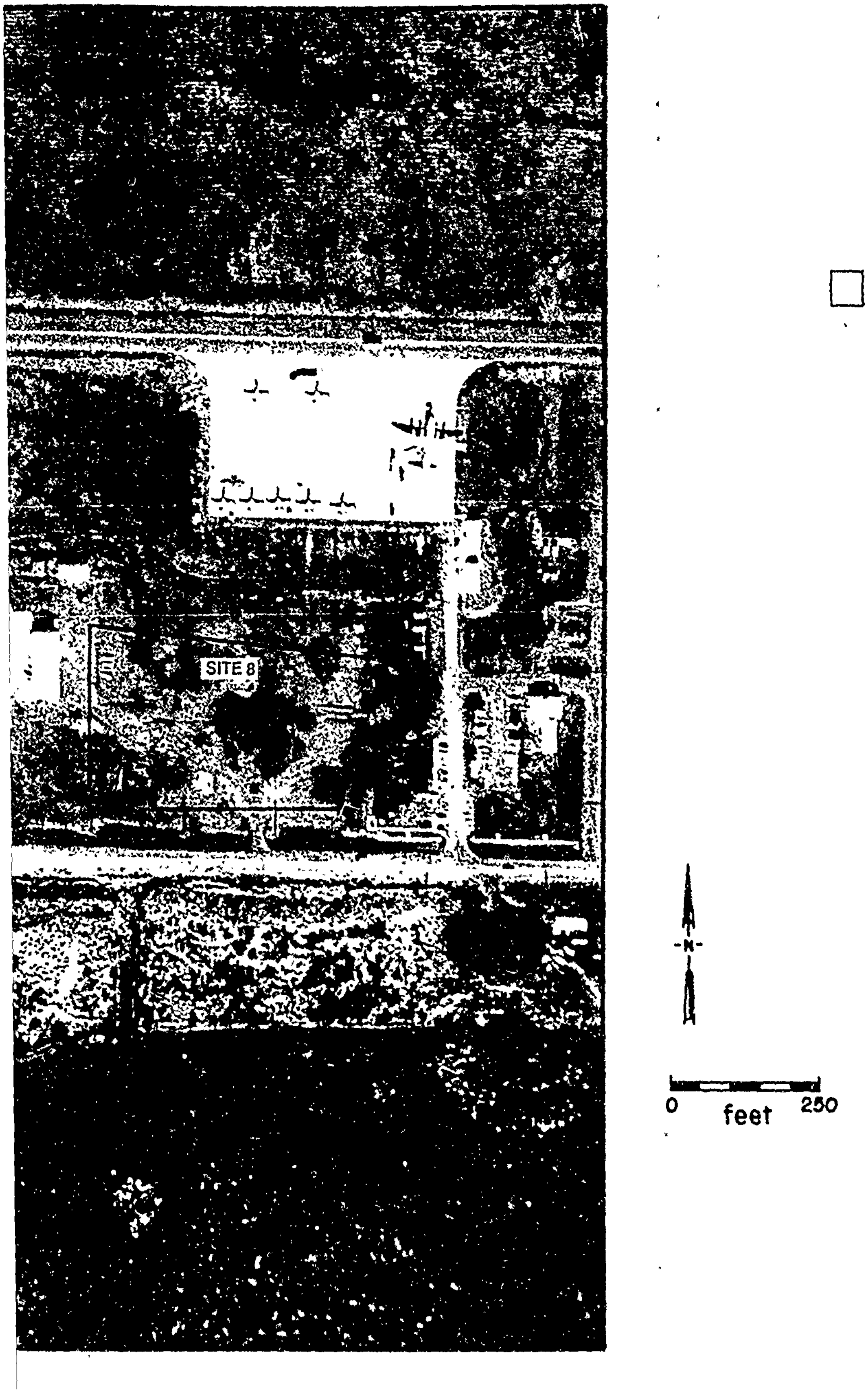


Figure 3-30 Aerial Photograph of Sites 3, 4, and 8, October, 1965.



EXPLANATION

☐ Approximate boundary of site.

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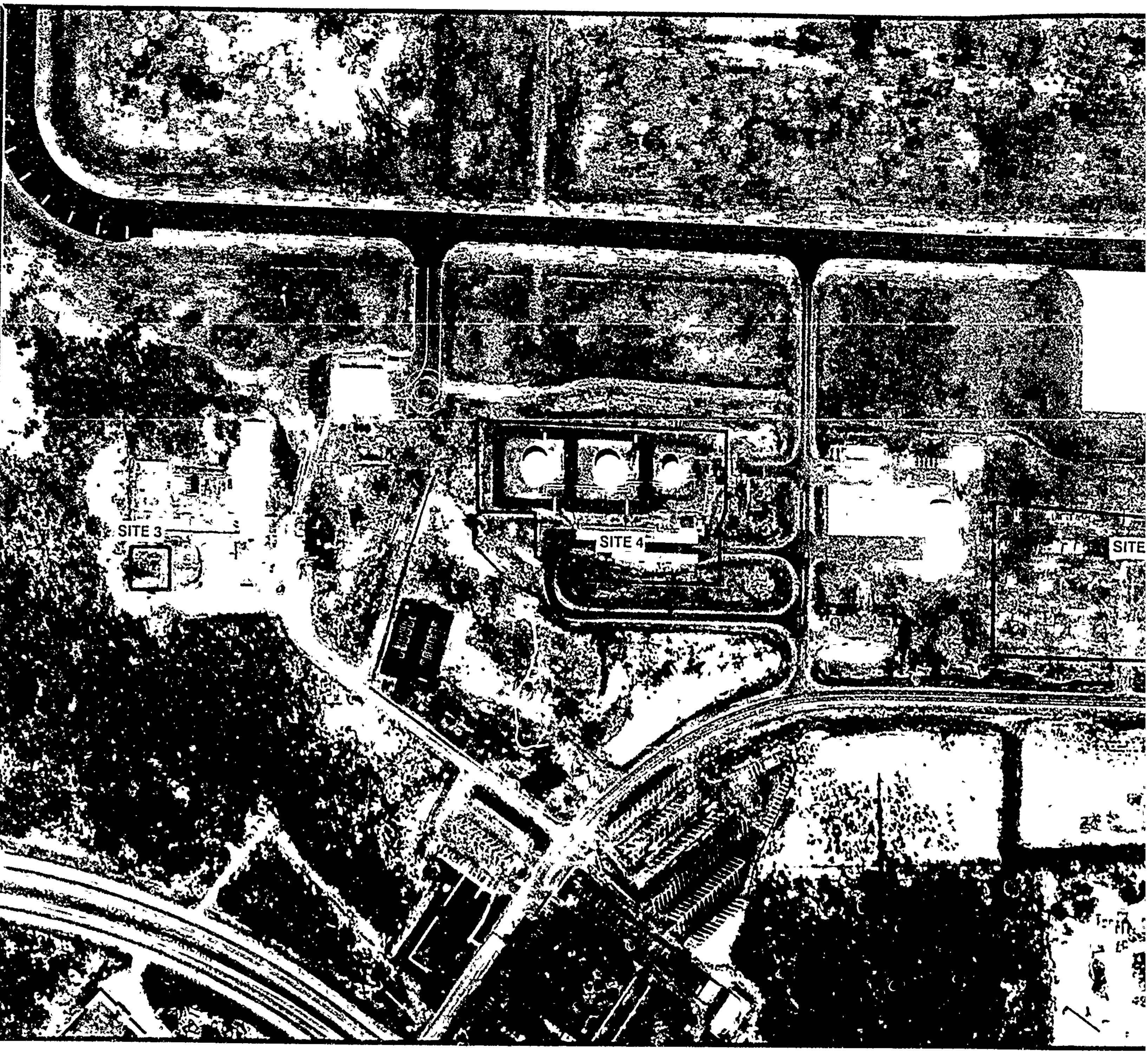

Figure 3-31 Aerial Photograph of Sites 3, 4, and 8, May 1979.

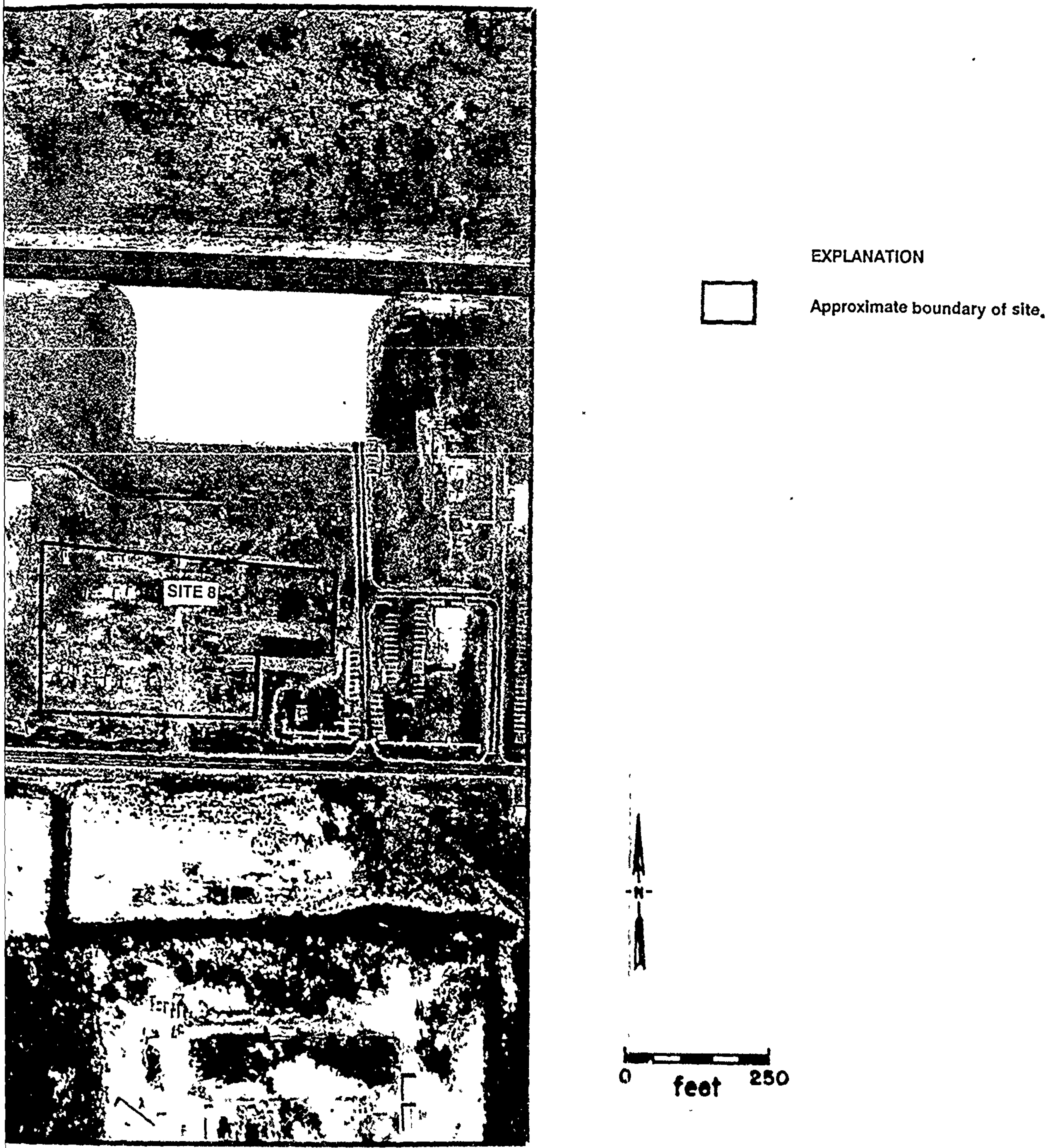

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TABLE 3-5

SUMMARY OF SITE 8 SLUG TEST RESULTS

Monitoring Well Number	Transmissivity (gal/day/ft)		Horizontal Hydraulic Conductivity (gal/day/ft^2)	
	Injection	Withdrawal	Injection	Withdrawal
DANGB-8-MW16	15.0	10.9	1.5	1.1
GW 8-A	8.6	321(1)	1.4	51.7(1)

1. These numbers are interpreted as not representative of aquifer properties. Only 6.21 feet of the 10 feet screened interval was saturated. The lack of 100 percent saturated screen thickness and dewatering of the sand pack around the well may have caused initial rapid rises in water level which distorted the withdrawal results.

point where the drainage from the east joins the drainage from the west, and they are diverted northward, under the taxiway. Before reaching the east-west runway, (just out of Figure 3-18 but visible in Figure 3-1) the ditch flows eastward for about 500 feet and then turns northward again. This ditch goes under the runway and joins the drainage ditch at Site 10. The east-west drainage ditch on which point B is located drains the future locations of Sites 3,4 and the northern part of 8. Most of the Site 8 location is drained by the drainage ditch (C on the Figure) which drains to the south, goes under Washington Street and joins the south and east flowing drainage system which drains to Miller Creek.

The 1965 Photograph, Figure 3-29, shows that the three sites have been constructed. In addition, a culvert has replaced part of the east-west drainage ditch west of location DANGB-4-SL11, and a building has been constructed on the former location of the ditch. The exact location of this culvert or how it joins the drainage ditch coming from the east is not known. At DANGB-4-SL11, the drainage from the east flows into a culvert which goes north, and presumably follows the path of the drainage ditch visible in the 1952 photograph. This culvert empties into an unnamed drainage ditch at Site 10. The south flowing drainage ditch at Site 8 is no longer clearly visible, but there does not appear to be a culvert under Washington Street.

In the 1979 photograph, Figure 3-31, the sites have not changed much from 1965. A drainage ditch has been constructed which drains the southern part of Site 3, goes east, southeast, then turns north under the access road and goes to just west of the fuel storage tanks where it goes into a culvert. At Site 8 there no longer appears to be a culvert under Washington Street, and all drainage seems to drain to the north.

3.6.3 Geology

The geology of this zone is presented in the individual site discussions: Sections 3.3.3, 3.4.3 and 3.5.3 for Sites 3,4 and 8 respectively.

A pre-glacial bedrock channel underlies sites 3, 4 and 8. The details of this northwest-southeast trending channel are shown in Figure 3-32. The buried bedrock channel is not reflected in the topography.

The channel trends northwest-southeast and deepens to the southeast. It appears to bifurcate at about the common boundary of Sites 4 and 8 with one arm continuing in a northwest direction while the other trends to the northeast. In the center and sides of the channel a layer of clay or clay and

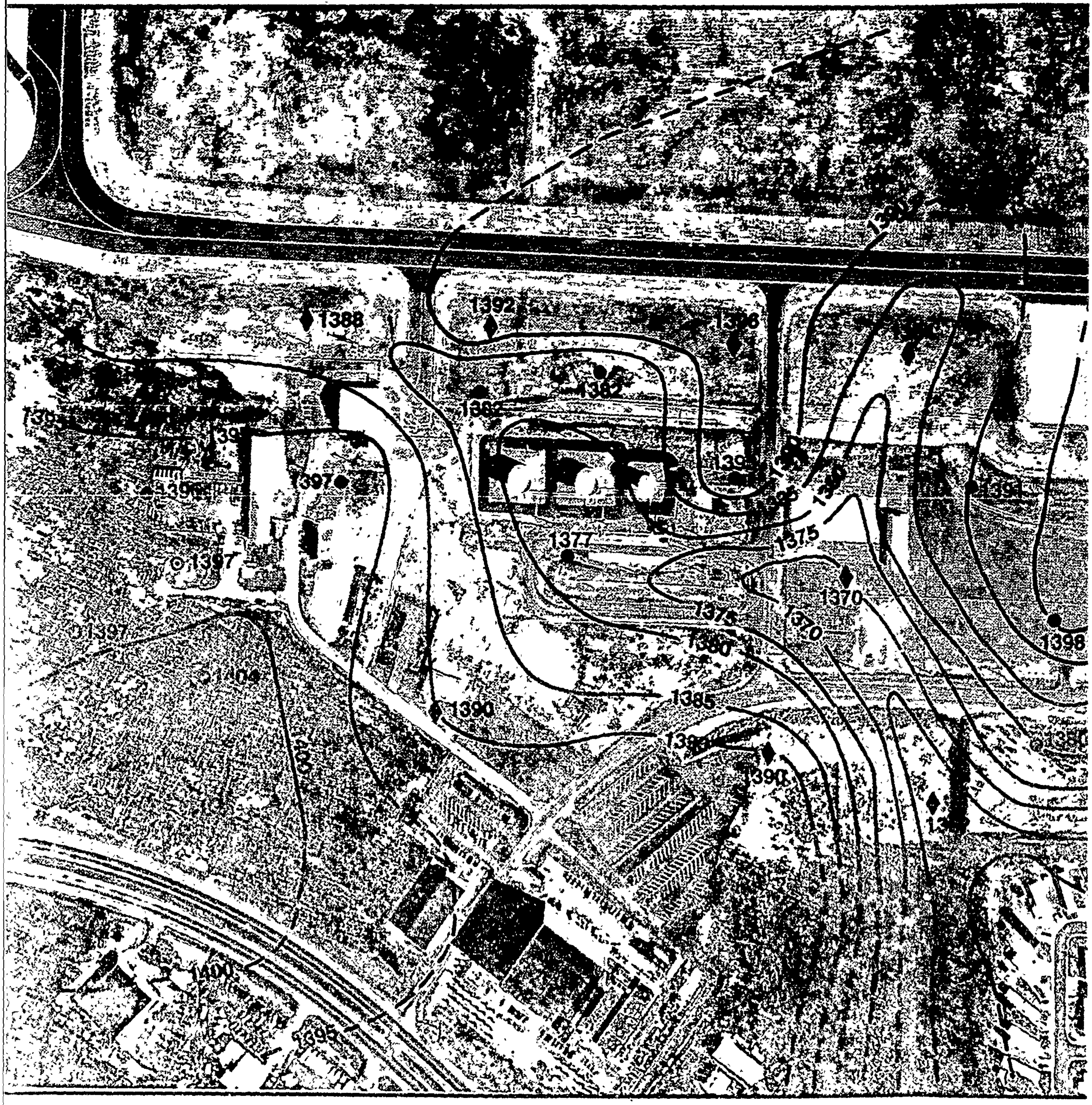
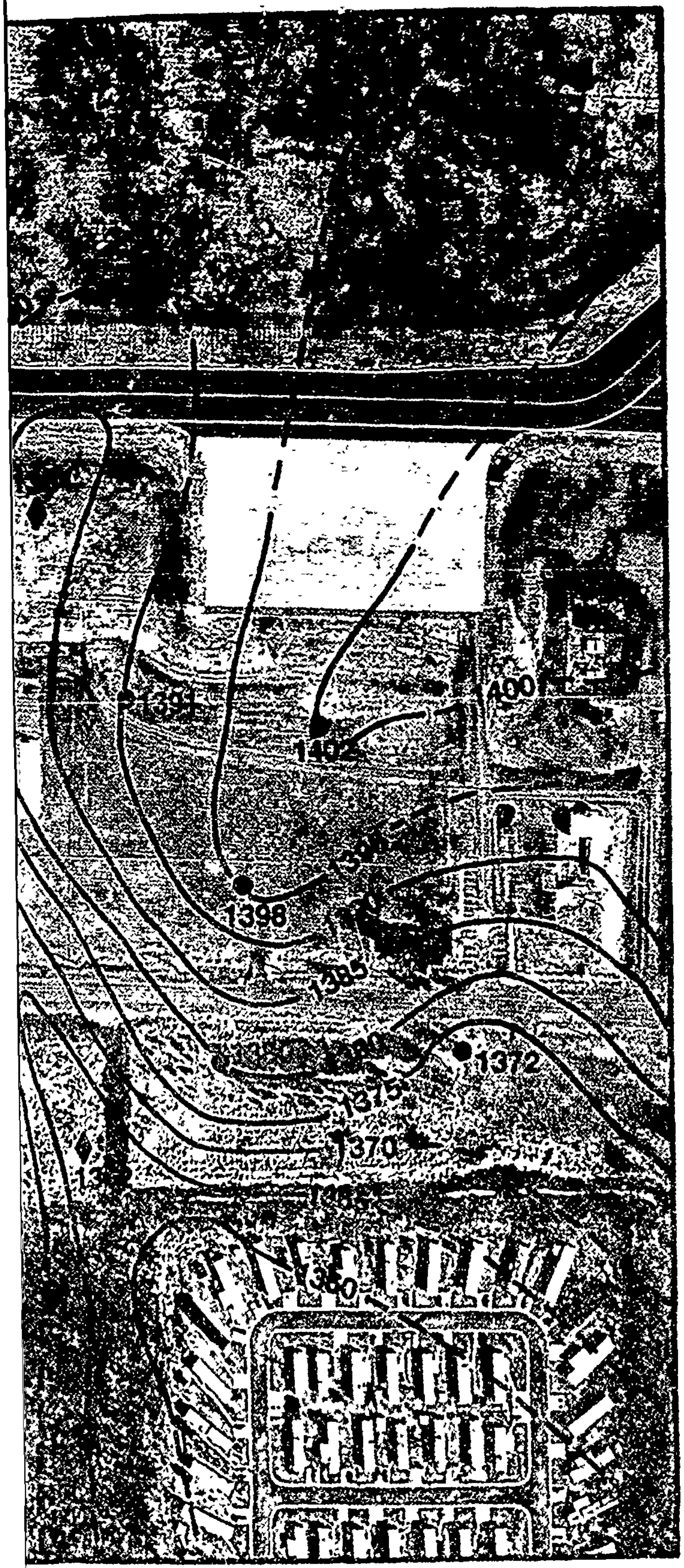


Figure 3-32 Bedrock Contour Map of Sites 3, 4, and 8.



EXPLANATION

— — — 1400	Bedrock contour line. Dashed where inferred. Datum is NGVD of 1929. Contour interval is 5 ft.

Bedrock altitude and Monitoring well location.

⊙ 1395	Phase II; Stage 2.
● 1397	Remedial Investigation.
◆ 1390	Well point, Remedial Investigation.
☐	Approximate boundary of site.

COMMENT: Water table altitude data are given in Appendix I, Table I-1.

N

0 feet 250

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silt directly overlies bedrock. A layer of sand and gravel is sometime occurs a few feet above bedrock in these locations as shown in the geologic cross-section shown in Figure 3-33.

3.6.4 Hydrogeology

The details of the hydrogeology are given in the individual site discussions: Sections 3.3.4, 3.4.4 and 3.4.5 for Sites 3,4 and 8 respectively.

There is no direct one-for-one correlation between bedrock topography, ground-water flow, surface topography and surface water flow. This is due in part to the non preferential deposition of glacial materials but is also due to the man-made surface drainage. When the surface drainage enters a culvert, as it does north of the Site 4 storage tanks (Figure 3-32), it becomes disconnected from the ground water-surface water system. This may be the explanation for the ground-water discharge area located just north of the fuel storage tanks and for the ground-water flow pattern of Site 4 as a whole.

The disconnection is not perfect since the culverts are most likely made out of concrete and there is some seepage of the ground water into them, but the culverts are thought not to be perforated such as drainage tiles. The water level in a culvert is not continuous with the ground-water level and it is normal to have an inch or two of water in a culvert which is entirely below ground saturated with water.

The water table contour map and direction of ground-water movement is shown on Figure 3-34. The variation in hydraulic head and generalized direction of ground-water movement is shown on Figure 3-35. Water table altitude data are presented in Appendix I, Table I-1.

The entire ground-water flow from Sites 3 and 4 and from the northern and western parts of Site 8 flows to local drainage ditches which drain into culverts which flow north under the main east-west runway and discharge to the north flowing drainage ditch just west of Site 10. The ground water from the southern half of Site 8 is presumed to discharge to the drainage ditch on the southern airport boundary (northern trailer park boundary) but this is not certain since there is no hydrologic data from south of the drainage ditch.

Grain size analyses of samples from monitoring wells at which slug tests were performed suggest that the base of the glacial till aquifer is a zone of permeability and preferred ground-water flow. Hydraulic conductivity values for DANGB-3-MW25, DANGB-4-MW22, and DANGB-8-MW16 as computed from slug tests are very similar, ranging from 1.5 to 2.2 gal/day/ft^2. The screens of these wells intersect the base of the till and the bedrock contact. The

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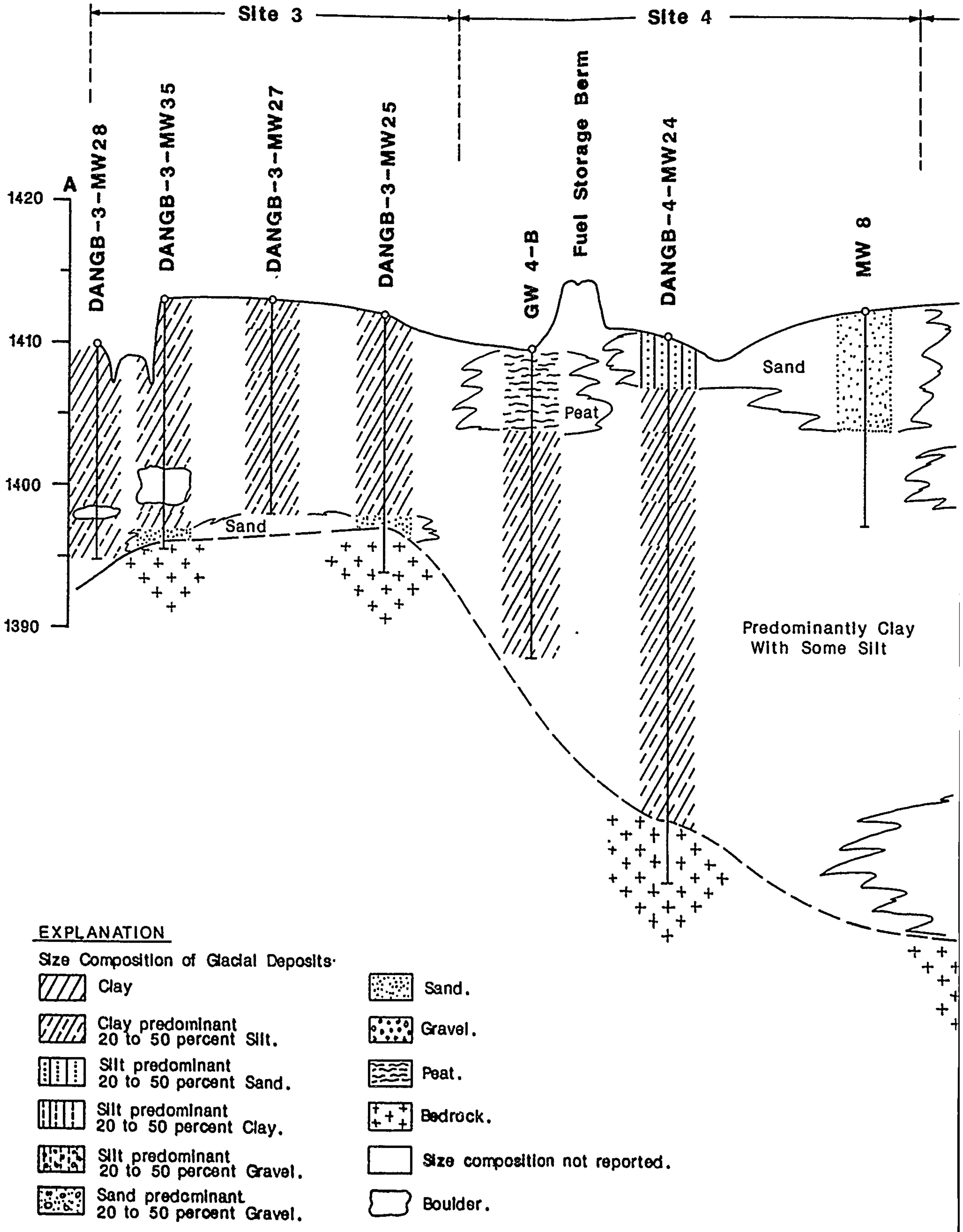
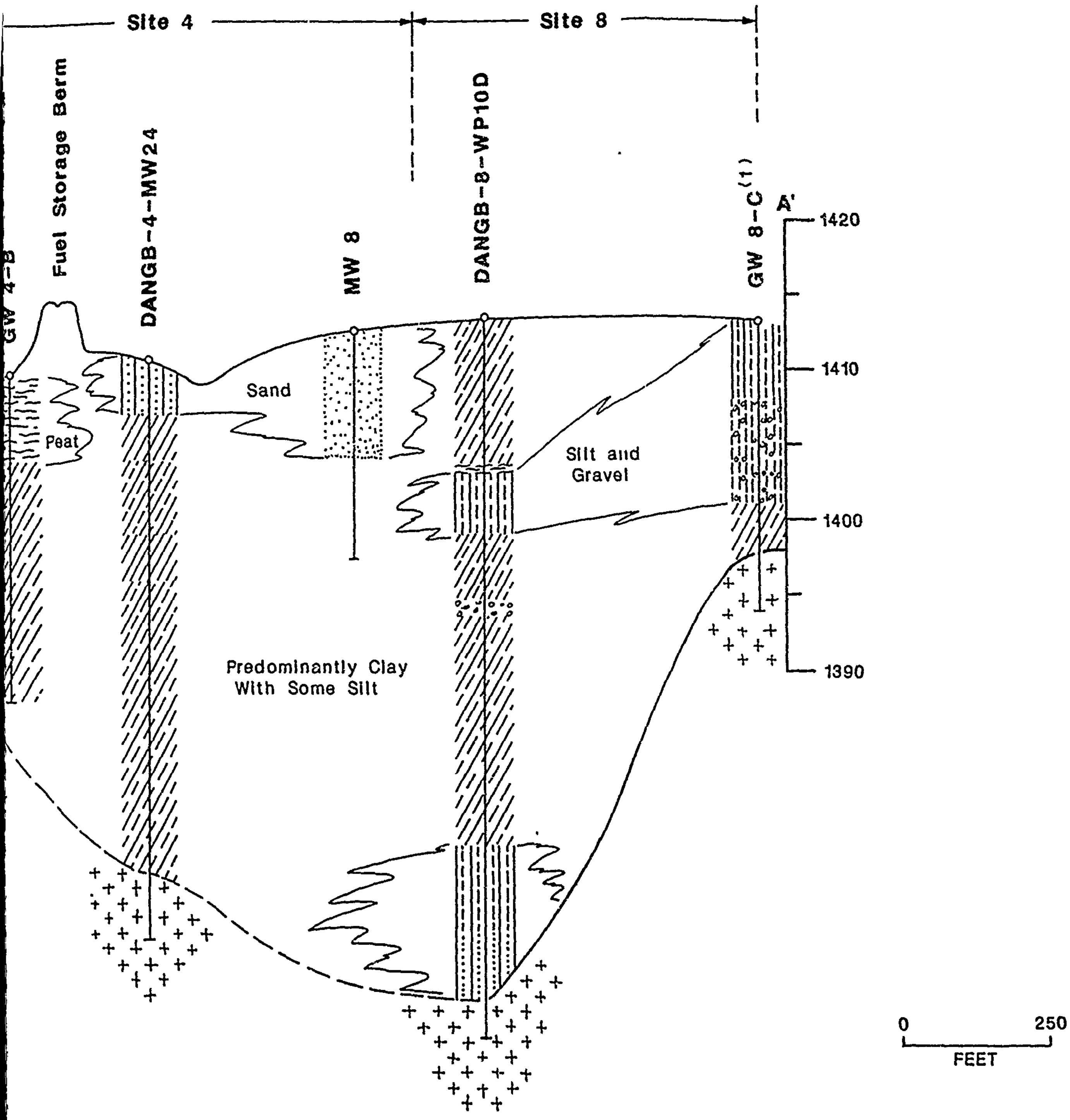


Figure 3-33 Geologic Cross-Section for Sites 3,4, and 8.



tion not reported.

COMMENTS

Line of Sections shown on Figure 3-16.

Vertical exaggeration x 25.

(1) Lithologic log for boring DANGB-8-18 used to construct the Cross-Section.

(2) Lithologic log for boring DANGB-8-19A used to construct the Cross-Section.

Water table altitude data are given in Appendix I, Table I-1.

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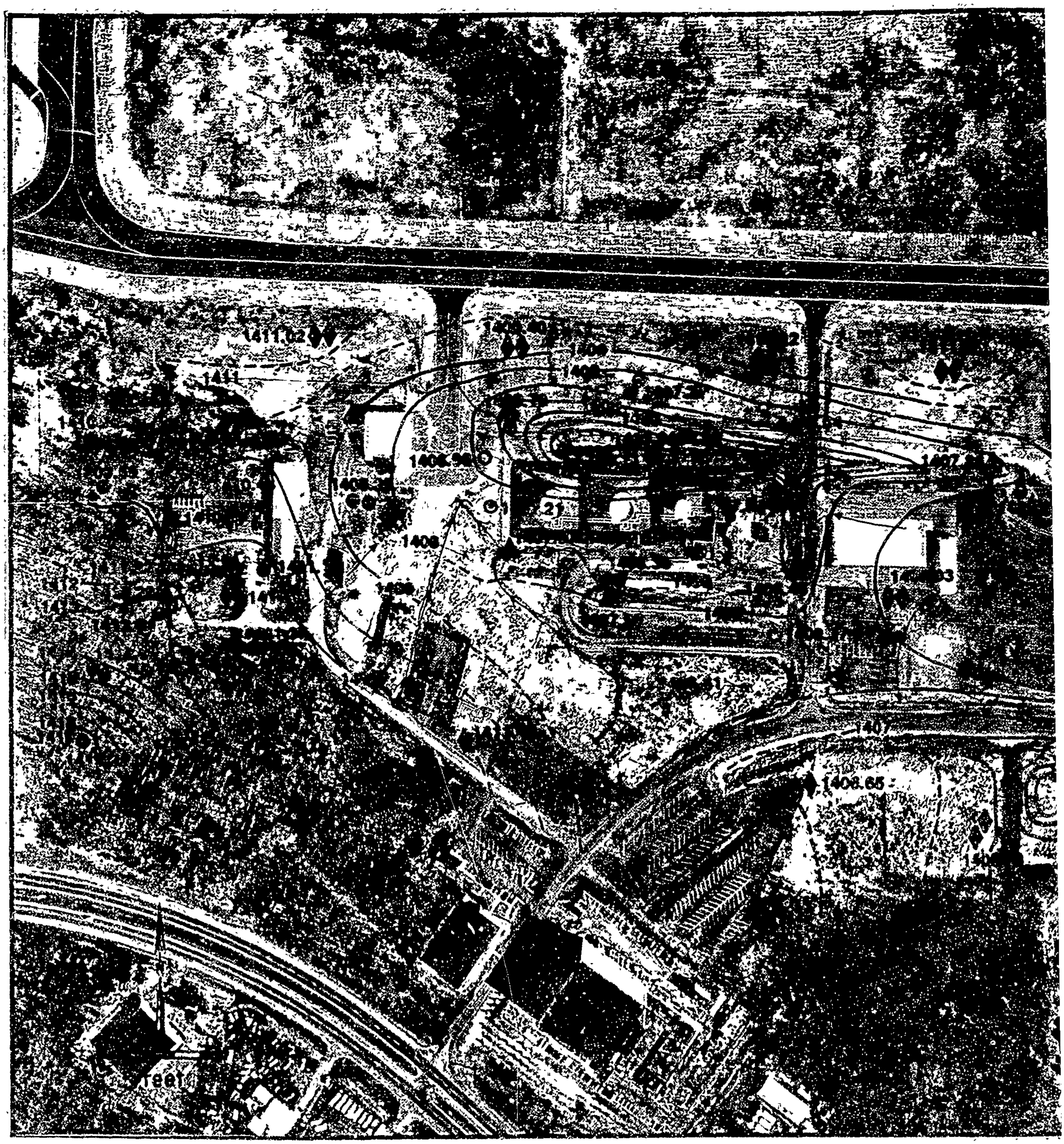


Figure 3-34 Water Table and Direction of Ground-Water Movement for Sites 3, 4 and 8.

EXPLANATION

——1408—	Water table contour. Shows altitude of water table on 27 September 1988. Contour interval is 1 foot. Datum is NGVD of 1929. Line is dashed where inferred.
←———	Generalized direction of ground-water flow.
	Monitoring Wells and water level altitude.
⊙ 1409.58	Phase 2; Stage 2.
● 1405.07	Remedial Investigation.
◆ 1405.93	Well point and water level altitude.
○ 1406.96	Phase II, Stage 1.
←—←	Surface drainage.
☐	Approximate boundary of site.

COMMENT: Water table altitude data are given in Appendix I, Table I-1.

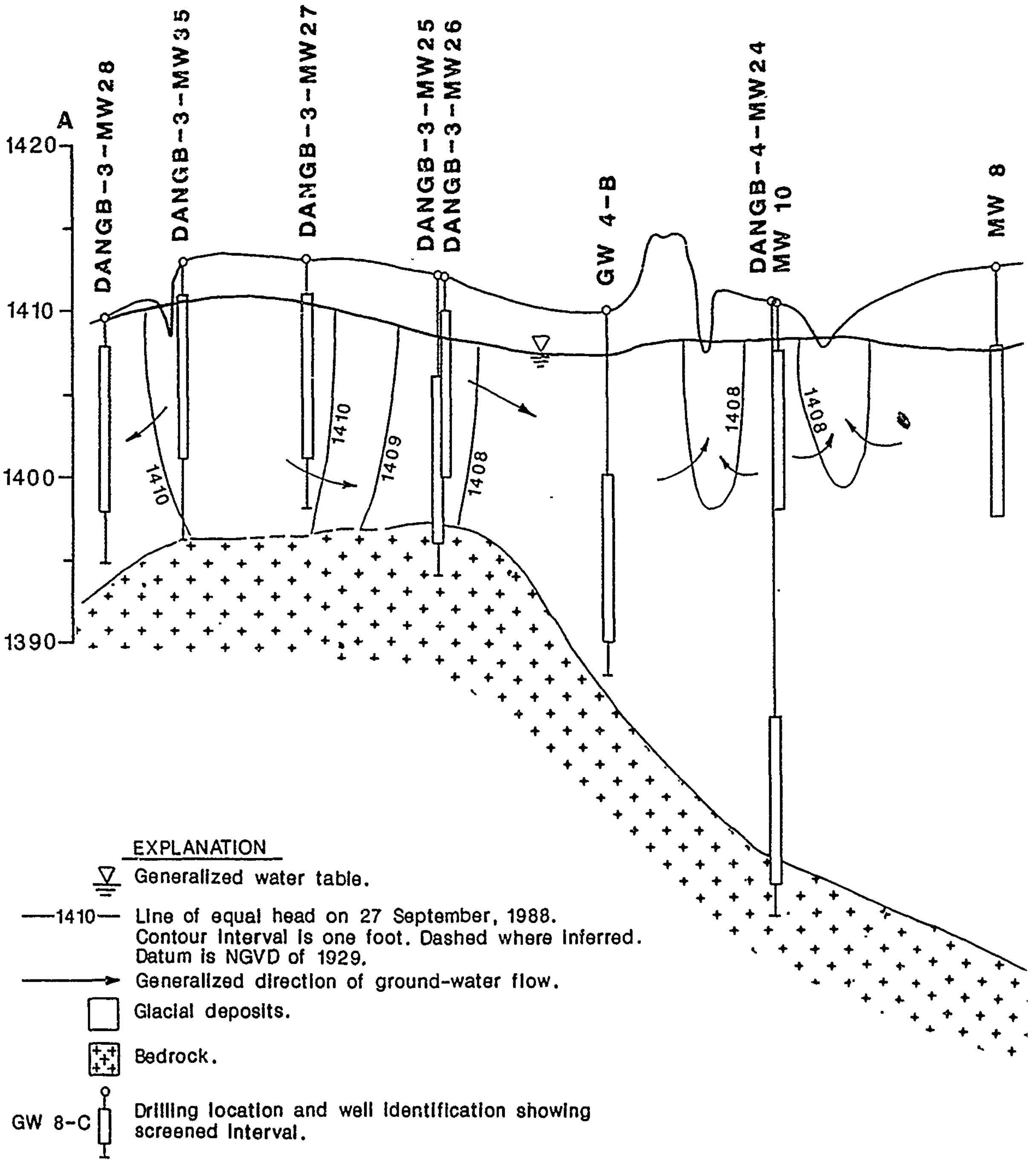
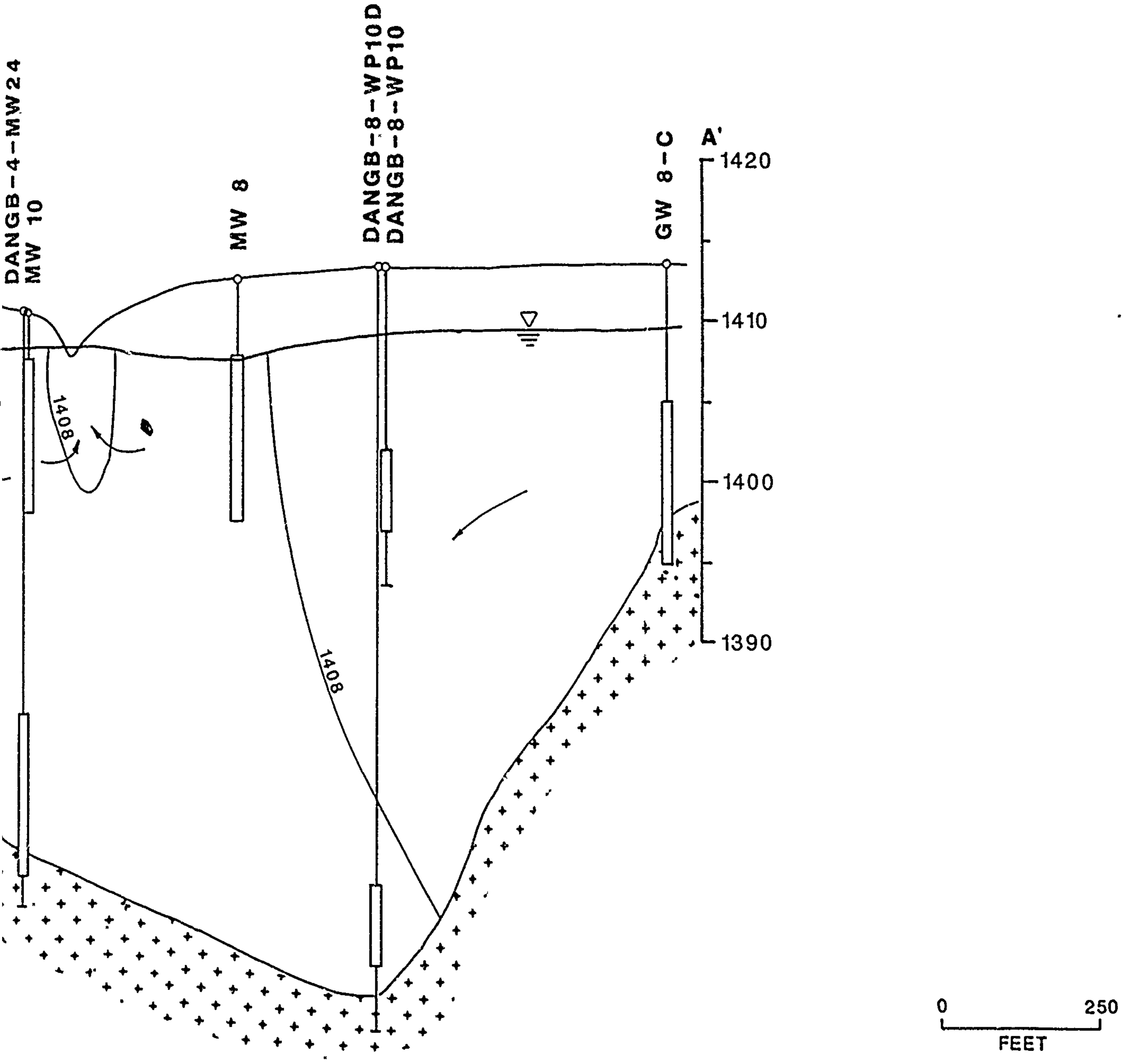


Figure 3-35 Variation in Vertical Hydraulic Head in the Glacial Till at Sites 3, 4 and 8, and Generalized Direction



COMMENTS

Line of Sections shown on Figure 3-16.
Vertical exaggeration x 25.
Water table altitude data are given in Appendix I, Table I-1.

Generalized Direction of Ground-Water Movement.

lowest hydraulic conductivity value, 0.2 gal/day/ft^2, which was calculated from the slug testing data from DANGB-3-MW34, was from a screened interval entirely within the silt and clay of the glacial aquifer. Similar slug test results for DANGB-8-MW16, DANGB-4-MW22, and DANGB-3-MW25 may have resulted from both a zone of high permeability and a dominant component of ground-water flow at the base of the glacial till aquifer.

Grain size distribution curves for samples within the screened intervals of DANGB-8-MW16, DANGB-4-MW22, and DANGB-3-MW25 are similar. Sand content increases just above bedrock. The sand content in DANGB-8-MW16 was greater than in DANGB-3-MW25 but the hydraulic conductivity values were similar.

3.7 SITE 10

Site 10 is a low-level radioactive waste dump which was used in the 1950s to dispose of materials such as dials and cathode ray tubes.

3.7.1 Surface Features

Photographs of Site 10 in 1952, 1965, 1979, and 1988 are shown in Figures 3-36, 3-37, 3-38 and 3-39, respectively.

In a 1952 photograph, Figure 3-34, none of the area of the future Site 10 has been disturbed. The north flowing drainage ditch occupies the central part of the photograph and the airport perimeter road is near the bottom. A private residence is visible in the center left.

In the photograph from 1965, Figure 3-35, the drainage ditch and airport perimeter road have not changed, but only the access road to the private residence can be seen. Building 531 with its fence and access road has been built. The appearance of the area between the access road and the drainage ditch, the suspected location of the radioactive waste dump, has not changed since the 1952 photograph, but to the east of the access road is a large scar which appears to be the result of earth movement or regrading.

The 1979 photograph, Figure 3-36, shows no obvious changes in this site since 1965. The area between the access road and the drainage ditch has not been disturbed, and the access road remains clearly visible.

The 1988 photograph, Figure 3-36, shows no change in this site since 1965. The area between the access road and the drainage ditch has not been disturbed, and the large scar to the east of the access road remains clearly visible.

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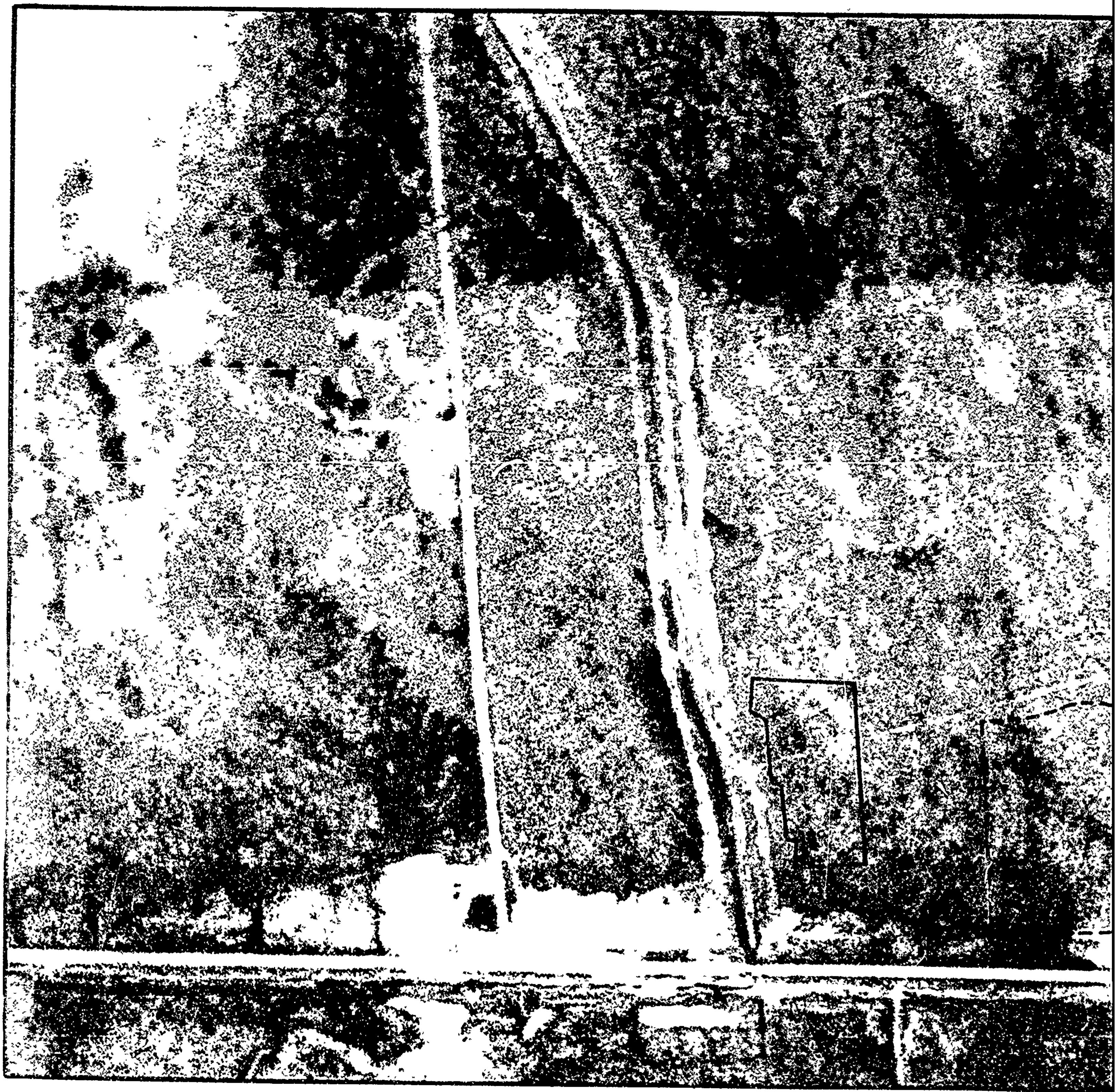


Figure 3-36 Aerial Photograph of Site 10, August, 1952.

EXPLANATION

▭ General location of Phase II, Stage 2 geophysical survey.

⬚ Suspected new location of Site 10.

N

Approximate North

0 250

FEET

Scale Approximate

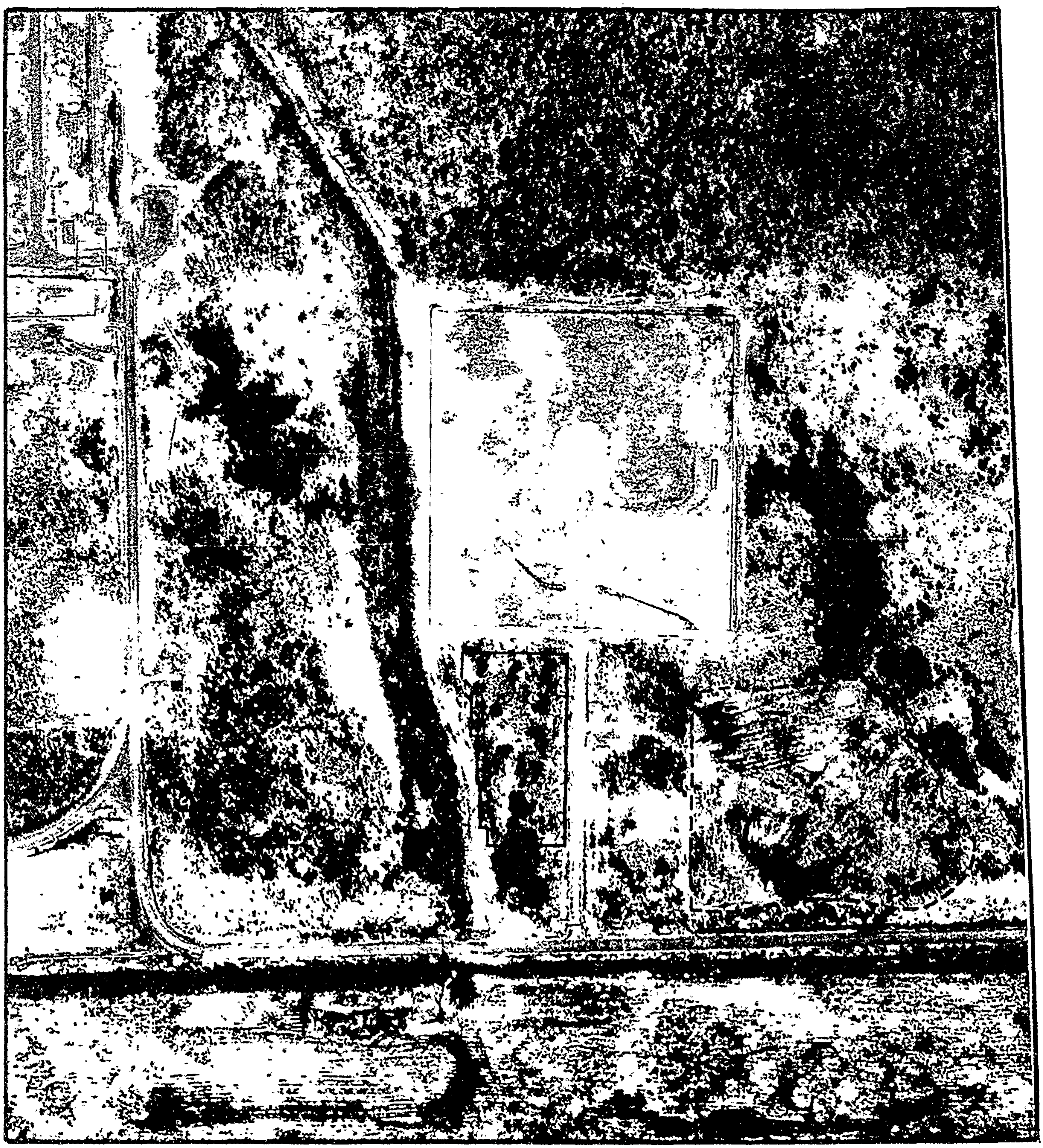
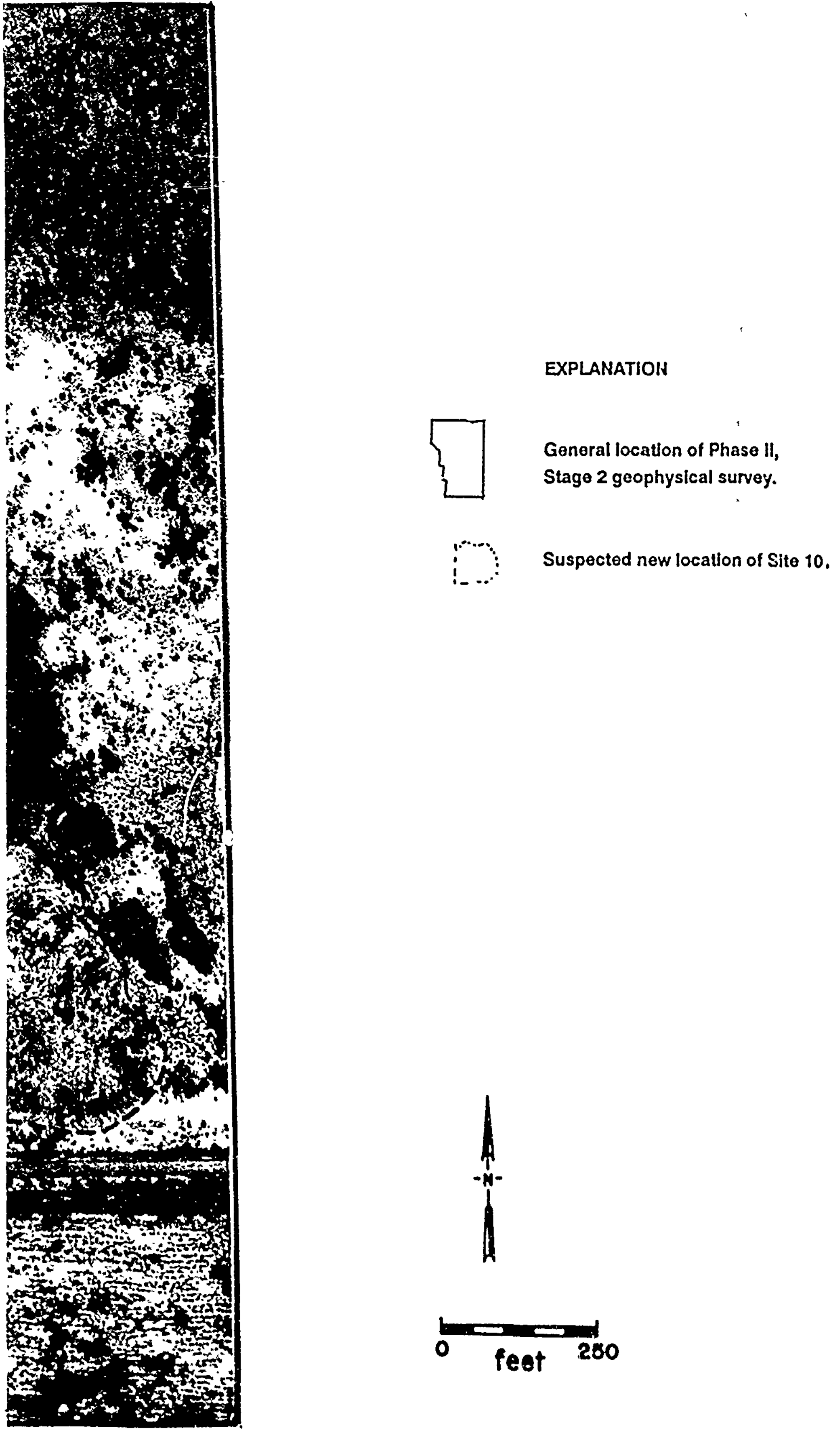


Figure 3-37 Aerial Photograph of Site 10, October, 1965.


EXPLANATION
General location of Phase II, Stage 2 geophysical survey.
Suspected new location of Site 10.
N
0
feet
250

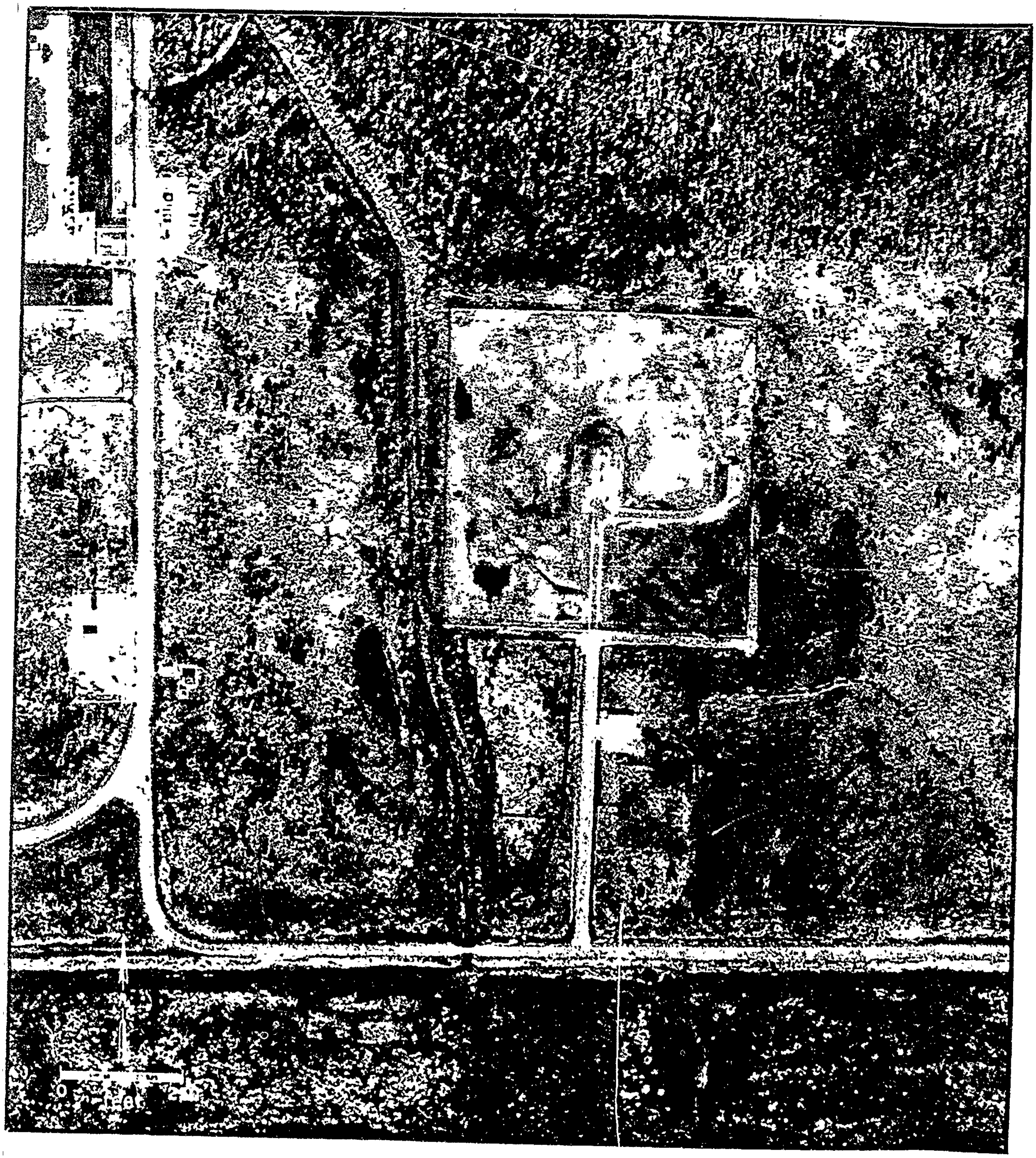


Figure 3-38 Aerial Photograph of Site 10, May 1979.

EXPLANATION

▭ General location of Phase II, Stage 2 geophysical survey.

⬚ Suspected new location of Site 10

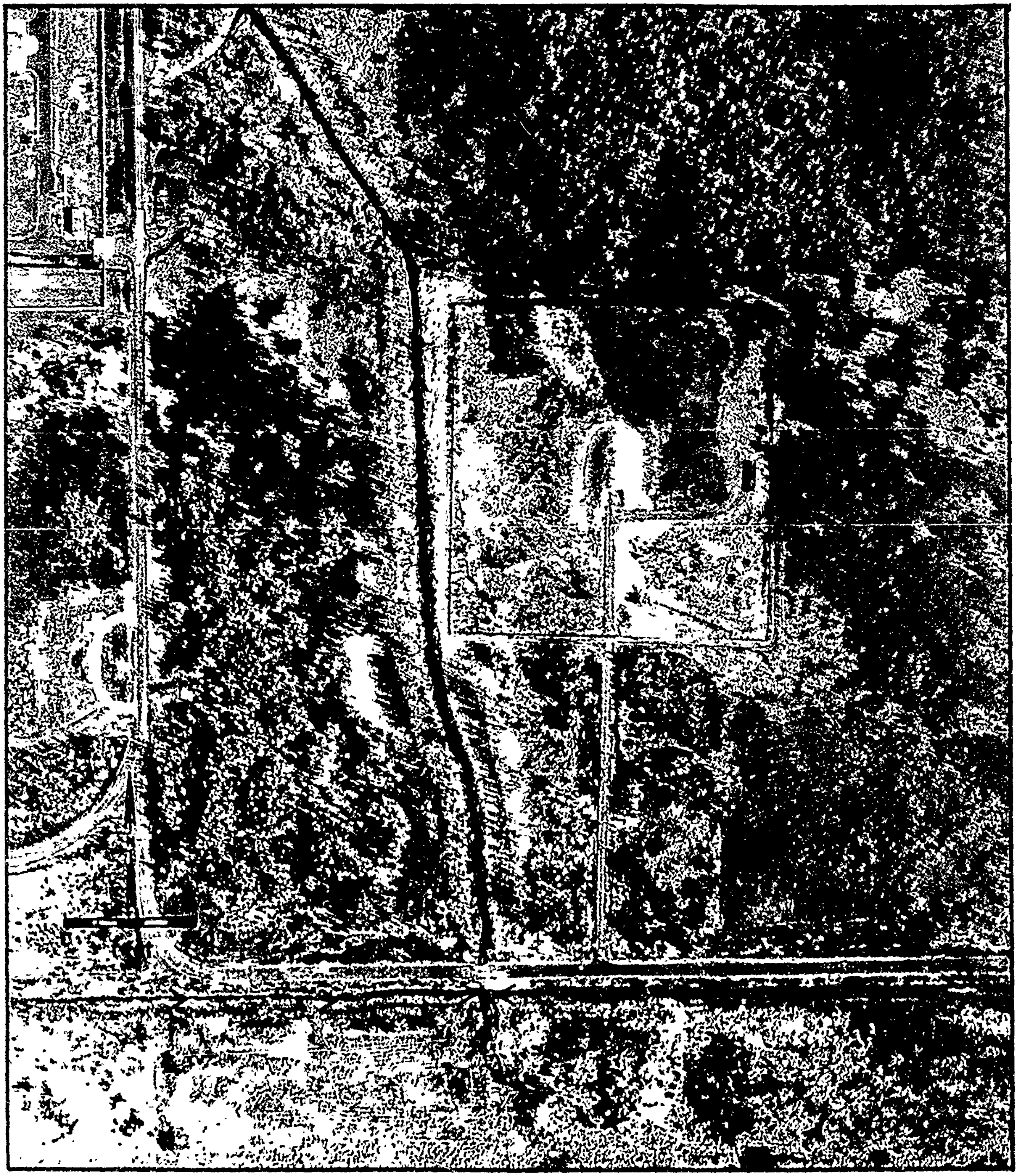


Figure 3-39 Aerial Photograph of Site 10, April, 1988 Showing Surface Drainage.

EXPLANATION

→ – – → Surface drainage location and direction

A 1961 photograph of insufficient quality to be reproduced here shows these same relationships.

The photographs indicate that the low level radioactive waste dump was not located between the access road and the drainage ditch, but was instead located where the large scar to the east of the access road now exists. They also indicate that the dump was not active before 1952 or after 1961.

3.7.2 Surface Water Hydrology

Surface drainage from the area of Site 10 as shown on Figure 3-37 is to Beaver Creek which flows north and eventually empties directly into Wild Rice Lake.

3.7.3 Geology

Geological investigation of Site 10 was not carried out during this study. Data from the IRP Phase II, Stage 2 (Dames & Moore, 1987) study indicates that the unconsolidated glacial material underlying the site is similar to that of the rest of the sites.

3.7.4 Hydrogeology

The general direction of ground-water flow appears to be toward the drainage ditch immediately west of site based on water levels measured in wells as shown on Figure 3-40. Water table altitude data are presented in Appendix I, Table I-1. The water table is probably continuous with surface drainages.

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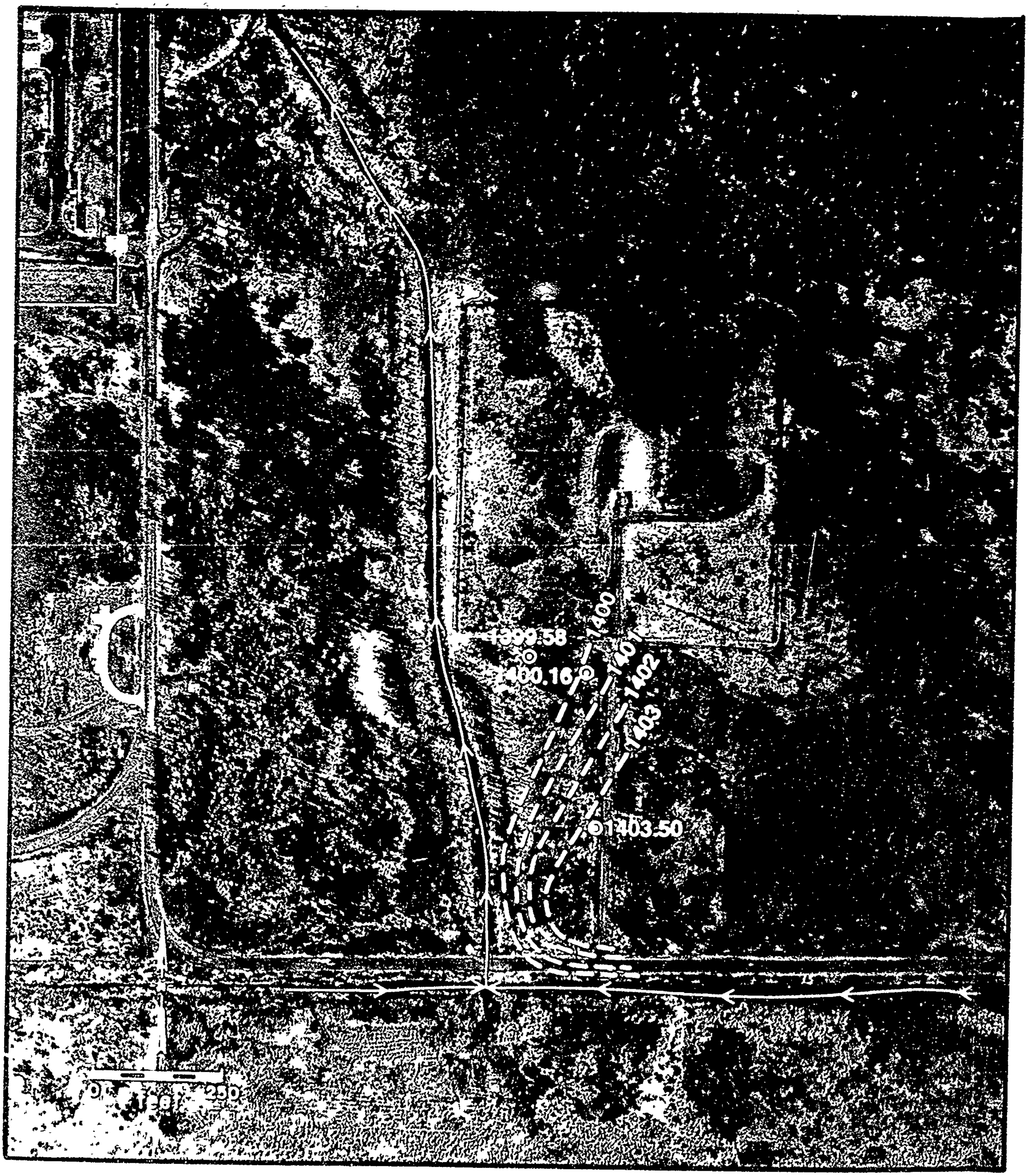

Figure 3-40 Water Table and Direction of Ground-Water Movement for Site 10.

EXPLANATION

1403	Water table contour. Shows altitude of water table on 27 September 1988. Contour Interval is 1 foot. Datum is NGVD of 1929. Line is dashed where inferred.
◉ 1403.50	Monitoring wells and water level altitude. Phase II; Stage 2
←	Surface drainage location and direction

SECTION 4
NATURE AND EXTENT OF CONTAMINATION

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SECTION 4

NATURE AND EXTENT OF CONTAMINATION

This section presents the results of the chemical analyses performed on surface water, sediment, soil, and ground-water samples. Only compounds that were detected are presented in this section. A complete listing of the results for all the compounds analyzed for each sample and the analytical method with the method detection limit is given in Appendix L.

The detections of three volatile organic compounds which are due to sample contamination are not presented in this section. The results not presented are all the detections of chloroform and dichloroethane in all media and the detection of toluene in surface water and ground water. The occurrence of the semi-volatile organic compound, bis(2-ethylhexyl)phthalate is also due to sample contamination and the results are not presented here. The occurrences of all four compounds are presented in Appendix N where they are discussed in detail.

The holding times for many of the semi-volatile analyses were missed, some by a day or two while others were missed by as much as a month. It is thought, however, that the missed holding times have not biased the analytical results. The holding time data is presented in Appendix N where they are discussed in detail.

The words contaminant and contamination are used throughout the text of this section. Contamination, in the context of this report, is defined as the presence of any substance introduced into the environment as a result of man's activities without regard to whether the concentrations have reached levels that may cause a significant level of water quality degradation and does not imply a risk to human health. A contaminant is the substance causing the contamination.

4.1 DEFINITION OF BACKGROUND CONDITIONS

Three background monitoring well locations, DANGB-BG-32, DANGB-BG-42, and DANGB-BG-43 and one surface water and sediment location, DANGB-BG-SL4, were chosen as soil and water sampling locations for determination of the ambient levels of the organic and inorganic parameters that were analyzed at the five sites (see Figure 1-3). All samples were analyzed for volatile and semi-volatile organics, petroleum hydrocarbons, pesticides and PCBs, arsenic, barium, cadmium, chromium, lead and mercury. In addition, the ground-water and surface water samples were analyzed for nitrates and the radiological parameters, gross alpha, gross beta and Radium 226, and the surface water samples only were analyzed for tritium.

4.1.1 Surface Water and Sediment Quality

No volatile or semi-volatile organic compounds, pesticides or PCBs were detected in the surface water or sediment samples from the background surface sampling location, DANGB-BG-SL4. No metals were detected in the surface water from the background site, but barium, chromium, and lead were detected in the sediment at levels of 33.2, 16.3, and 4.8 mg/kg, respectively (Table 4-1).

All radiological parameters were below detection limits.

4.1.2 Soil Quality

Three soil samples were collected from the boreholes drilled for the construction of monitoring wells at the airport area locations. These samples were taken at the ground surface, at the water table, and at the bottom of the borehole.

Volatile and semi-volatile organic compounds, pesticides, polychlorinated biphenols (PCBs) and total petroleum hydrocarbons were below detection limits in the background soil samples.

Trace quantities of barium, cadmium, chromium, and lead were detected in the background soil samples (Table 4-2). Barium concentrations ranged from 34.9 to 103 milligrams per kilogram (mg/kg). Cadmium levels ranged from 6.8 to 13.6 mg/kg. Chromium values varied from 14.4 to 42.2 mg/kg. Lead was present at values of 2.9 to 16.6 mg/kg. Arsenic and mercury were below detection limits in all background samples.

4.1.3 Ground-Water Quality

No volatile organic compounds were detected in ground-water samples. Semi-volatile organic compounds were detected at low levels in some of the samples. Butyl benzyl phthalate at 10 micrograms per liter (ug/L) and bis(2-ethylhexyl)phthalate at 13 ug/L were detected in water at well DANGB-BG-MW43. Bis(2-ethylhexyl)phthalate was reported at 10 ug/L in water from well DANGB-BG-MW42 but was also detected in the laboratory blank indicating that the presence of this compound in the sample is likely due to laboratory contamination.

Pesticides, PCBs, total petroleum hydrocarbons, and nitrates were below detection limits.

Metals were detected at low levels in some of the ground-water samples (Table 4-3). Barium was detected at levels of 120 ug/L at well DANGB-BG-MW32 and 130 ug/L at DANGB-BG-MW43. It was below the

TABLE 4-1

METALS DETECTED IN THE BACKGROUND SEDIMENT SAMPLE

(Results in milligrams per kilogram.)

Sample Location	Metal(1)		
	Barium	Chromium	Lead
DANGB-BG-SL-4	33.2	16.3	4.8

1. Arsenic, cadmium and mercury were analyzed for but were below detection limits.

TABLE 4-2

METALS DETECTED IN BACKGROUND SOIL SAMPLES

(Results in milligrams per kilogram.)

Sample Location	Metal(1)			
	Barium	Cadmium	Chromium	Lead
DANGB-BG-MW32				
SS1 2 to 3 feet	103.0	7.8	17.1	9.9
SS2 11 to 12 feet	49.2	7.6	23.0	4.3
SS3 19 to 20 feet	34.9	6.8	22.8	2.9
DANGB-BG-MW42				
SS1 0 to 1 feet	69.7	11.5	42.2	4.9
SS2 7 to 8 feet	48.4	10.4	20.0	4.7
SS3 14.5 to 15.5 feet	39.7	10.1	27.6	3.4
DANGB-BG-MW43				
SS1 1 to 2 feet	61.8	7.6	14.4	5.1
SS2 14 to 15 feet	96.7	13.6	36.8	4.7
SS3 23 to 24 feet	51.3	9.5	17.2	4.2

1. Arsenic and mercury were analyzed for but were below method detection limits.

TABLE 4-3

METALS DETECTED IN BACKGROUND GROUND-WATER SAMPLES

(Results in milligrams per kilogram.)

Sample Location	Metal(1)	
	Barium	Chromium
DANGB-BG-MW32	120	2.6
DANGB-BG-MW42	U(2)	U
DANGB-BG-MW43	130	U

1. Arsenic, cadmium, lead and mercury were analyzed for but were below method detection limits.
2. U indicates that the compound was analyzed for but was not detected.

detection limit of 50 ug/L at DANGB-BG-MW42. Chromium was detected at 2.6 ug/L at DANGB-BG-MW32, but was below detection limits at the other locations.

Arsenic, cadmium, lead, and mercury were below detection limits of 5, 1, 5, and 0.2 ug/L, respectively, in samples from all three monitoring wells. The ground-water samples were also analyzed for the radiometric parameters gross alpha, gross beta and radium 226 (Table 4-4). Low levels of natural radioactivity occur in the ground water but are below Drinking Water Standards.

The parameters temperature, pH, and specific conductance were determined in the field at the time of sampling (Table 4-5).

4.2 AIRPORT AREA SURFACE WATER AND SEDIMENT SAMPLES

Surface water and sediment samples were collected at the four airport area locations DANGB-BG-SL1, DANGB-BG-SL2, DANGB-BG-SL3 and DANGB-BG-SL5 (Figure 2-1) to test the quality of surface drainage downstream from the study sites. Both surface water and sediment samples were analyzed for volatile and semi-volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, arsenic, barium, cadmium, lead and mercury. In addition, the surface water samples were analyzed for the radiological parameters, gross alpha, gross beta, radium 226 and tritium.

4.2.1 Airport Area Surface Water and Sediment Quality

Benzene and toluene were detected in airport drainage surface waters at 18 ug/L, and 19 ug/L, respectively, at sampling site DANGB-BG-SL3.

Semi-volatile organic compounds, pesticides and PCBs, and total petroleum hydrocarbons were not detected in the surface water samples.

Lead was the only one of six metals detected in background surface water samples. Lead was detected at 6.3 ug/L at DANGB-BG-SL3 but was below detection limits at all other locations.

Concentrations of arsenic, barium, cadmium, chromium, and mercury were below detection limits.

The radiological parameters of gross alpha, gross beta, radium 226, and tritium were below detection limits in all surface water samples.

Semi-volatile organic compounds were detected in sediment at sampling sites DANGB-BG-SL1 and DANGB-BG-SL2. Bis(2-ethylhexyl)phthalate was present at 770 micrograms per kilogram (ug/kg) at DANGB-BG-SL1. Compounds and their concentrations present in the sample from DANGB-BG-SL2 were

TABLE 4-4

RADIOLOGICAL PARAMETERS DETECTED IN BACKGROUND GROUND-WATER AND SURFACE WATER SAMPLES

(Results in picocuries per liter.)

Sample Location	Parameter			
	Gross Alpha [15][1]	Gross Beta [50]	Radium 226 [5]	Tritium [20,000]
Surface Water Sample				
DANGB-BG-SL4	U[2]	U	U	<2,000
Ground-Water Samples				
DANGB-BG-MW32	5.5 ± 2.9	11 ± 4	0.4 ± 0.2	N.T.
DANGB-BG-MW42	U[2]	U	U	N.T.
DANGB-BG-MW43	4.6 ± 2.7	11 ± 4	U	N.T.

1. Numbers in brackets are Federal Drinking Water Standards in picocuries per liter.
2. U indicates that the compound was analyzed for but was not detected.
3. N.T. indicates that the parameter was not analyzed for.

TABLE 4-5

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR BACKGROUND LOCATION WATER SAMPLES

Sample Location	Temperature (^oC)	pH (pH units)	Specific Conductance (umhos/cm)
Surface Water Sample			
DANGB-BG-SL4	10.2	7.12	261
Ground-Water Samples			
DANGB-BG-MW32	9.2	7.36	1,900
DANGB-BG-MW42	11.0	7.72	480
DANGB-BG-MW43	10.2	6.95	1,030

phenanthrene at 790 ug/kg, fluoranthene at 890 ug/kg, pyrene at 590 ug/kg, and chrysene at 420 ug/kg.

Total petroleum hydrocarbons were detected in the sediment sample from DANGB-BG-SL2 at 170 milligrams per kilogram (mg/kg).

Low levels of metals were detected in the sediment samples (Table 4-6). Barium concentrations varied from 31.4 to 46.4 mg/kg. Chromium ranged in concentration from 11.2 to 16.3 mg/kg. Lead was present at levels of 4.0 to 6.3 mg/kg. Levels of arsenic, cadmium, and mercury were below detection limits in all airport area sediment samples. The levels of chromium, lead, and barium are comparable to background values.

Temperature, pH and specific conductance of the surface water were determined in the field at the time of sampling (Table 4-7).

4.2.2 Extent of Airport Area Contamination

Overall, the results indicate that the quality of surface water downstream from the study sites is generally good.

Surface water contaminated with 18 ug/L of benzene was detected at sampling site DANGB-BG-SL3. The source of this contamination is not known. This sampling point is downstream from Sites 3, 4, and 10, which are discussed in this report; may be downstream from other sites not discussed in this report; and is downstream from at least two active facilities, the hazardous materials storage facility comprised of Buildings 511 and 513, and the munitions storage facility.

Of the sites discussed in this report, only Site 4 is a possible likely source of the benzene. The surface water sample from the closest Site 4 sampling location, DANGB-4-SL11, contained 930 ug/L of benzene. This location is, however, over one mile upstream from DANGB-BG-SL3. It is not known whether or not any other sites or the active facilities could be possible sources of benzene. In addition, since this location is at the dead end of a good road where vehicles turn around it is possible that a small localized spill could be the source.

Several semi-volatile compounds were detected in a sediment sample collected at DANGB-BG- SL2. The low levels detected at this location and the presence of a road nearby suggests that these compounds may be of local derivation.

4.3 NATURE AND EXTENT OF CONTAMINATION AT SITE 2

This section presents the results of the chemical analyses on the soil,

TABLE 4-6

METALS DETECTED IN SEDIMENT AT AIRPORT AREA LOCATIONS

(Concentrations in milligrams per kilogram.)

Sample Location	Metal		
	Barium	Chromium	Lead
DANGB-BG-SL1	31.4	12.9	4.8
DANGB-BG-SL2	46.4	15.5	6.3
DANGB-BG-SL3	36.3	11.2	4.0
DANGB-BG-SL5	41.1	14.2	4.0

TABLE 4-7

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR AIRPORT AREA SURFACE WATER SAMPLES

Sample Location	Temperature (^{o}C)	pH (pH units)	Specific Conductance (umhos/cm)
DANGB-BG-SL1	11.6	6.56	110
DANGB-BG-SL2	11.7	6.65	205
DANGB-BG-SL3	14.0	7.45	255
DANGB-BG-SL5	11.6	6.77	458

ground-water, surface water, and sediment samples collected at Site 2. The chemical results are interpreted to determine the extent of contamination in each of the above sampling media.

4.3.1 Source of Contamination

Suspected contaminant sources at Site 2 are Fire Training Area 1 (FTA-1) and Fire Training Area 2 (FTA-2)(see Figures 1-3 and 1-7). During fire training exercises, fuels and drummed materials containing organic solvents were ignited and extinguished at these sites.

4.3.2 Surface Water and Sediment Contamination

Surface water and sediment samples were collected at two locations from a north flowing drainage on the eastern edge of Site 2 as a part of this study (Figure 2-3). Samples were analyzed for volatile and semi-volatile organic compounds, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

4.3.2.1 Surface Water and Sediment Quality

Results from a previous study detected 2.6 ug/L of trans-1,2-dichloroethene from a surface water sample collected west of well MW 2, Table 1-7.

No volatile or semi-volatile organic compounds, petroleum hydrocarbons, or metals were detected in surface water sampled during this study.

The volatile organic compound, trichloroethene, was detected at 0.26 ug/kg in the sediment sample at location DANGB-2-SL7.

Semi-volatile organic compounds were below detection limits in both sediment samples.

Total petroleum hydrocarbons were below detection limits in both sediment samples.

Concentrations of metals in the sediments (Table 4-8) were comparable to background and airport area values (Tables 4-1 and 4-6). Barium concentrations were 45.0 and 53.9 mg/kg. Chromium concentrations were 19.0 and 20.0 mg/kg. Lead concentrations were 4.3 and 4.8 mg/kg. Cadmium was below the detection limit.

The temperature, pH and specific conductance of the surface water samples were determined in the field at the time of sampling (Table 4-9).

4.3.2.2 Extent of Surface Water and Sediment Contamination

Trichloroethene in one sediment was the only contaminant detected above background levels in the surface water and sediment samples at Site 2. The source of the trichloroethene in the sediment sample at location DANGB-2-SL7 could be contaminated ground water discharging from the vicinity of FTA-1

TABLE 4-8

METALS DETECTED IN SITE 2 SEDIMENT SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal[1]		
	Barium	Chromium	Lead
DANGB-2-SL6	53.9	19.0	4.8
DANGB-2-SL7	45.0	20.0	4.3

1. Cadmium was also analyzed for but was below detection limits.

TABLE 4-9

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR SITE 2 WATER SAMPLES

Sample Location	Temperature (^oC)	pH (pH units)	Specific Conductance (umhos/cm)
Surface Water Samples			
DANGB-2-SL6	11.8	7.14	390
DANGB-2-SL7	12.0	7.57	390
Ground-Water Samples			
DANGB-2-MW37	12.1	7.76	362
DANGB-2-MW38	10.9	7.61	501
DANGB-2-MW39	11.7	6.98	659
DANGB-2-MW40	11.6	7.66	324
DANGB-2-MW41	9.8	7.70	350
GW 2-A	12.0	7.23	456
GW 2-B	13.9	6.96	1,081
GW 2-C	11.2	6.76	150
GW 2-D	10.7	7.35	875
GW 2-E	9.7	6.83	1,388
MW 1	11.5	7.64	1,131
MW 2	11.6	7.58	991
MW 4	11.3	6.93	608
MW 5	10.9	7.40	523
MW 6	13.7	7.07	503
MW 7	11.7	7.27	748

into the upgradient areas of the drainage ditch.

4.3.3 Soil Contamination

The numbers of samples as well as the analyses performed are described in Section 2.2.4. All soil samples were collected from drilled boreholes. Soil samples were analyzed for volatile and semi-volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, barium, cadmium, chromium and lead. A few samples were analyzed for arsenic.

4.3.3.1 Soil Quality

Volatile organic compounds generally associated with fuels including benzene, toluene, ethyl benzene, and xylenes were detected in concentrations greater than 1,000 ug/kg in soil samples from boreholes DANGB-2-BH1 R and DANGB-2-BH2 R near the center of FTA-2 (Table 4-10). Xylenes consistently had the highest concentration with up to 180,000 ug/kg. The maximum concentrations for benzene, ethyl benzene, and toluene were 3,100, 25,000, and 36,000 ug/kg, respectively.

Other volatile organic compounds were also detected in samples from these two boreholes. In borehole DANGB-2-BH2 R, tetrachloroethene and trichloroethene were detected in levels of up to 2,300 and 1,600 ug/kg, respectively, but both decreased in concentration with depth. In contrast, trans-1,2-dichloroethene increased in concentration with depth to 10 feet at borehole DANGB-2-BH1 R and a still larger concentration was detected at 10 to 12 feet in borehole DANGB-2-BH2 R.

Dibutyl phthalate was detected in the laboratory blanks in all cases in which it was reported in soil samples at Site 2 making the actual presence of this compound in the soil questionable.

Semi-volatile organic compounds were detected in soil samples from the two soil sampling boreholes (Table 4-11). The highest levels of naphthalene and pyrene detected were 3,700 ug/kg while 2-methylnapthalene was detected up to 6,200 ug/kg in the surface sample from DANGB-2-BH2. The maximum concentration of bis(2-ethylhexyl)phthalate was detected at 6,500 ug/kg at 6 to 8 feet from borehole DANGB-2-BH2. Dibutyl phthalate was reported at up to 2,000 ug/kg in soil samples from DANGB-2-BH1.

Total petroleum hydrocarbons were also found in high levels in soil from the two soil sampling boreholes (Table 4-12). This parameter measures the amount of heavier non-volatile organics present. Concentrations of over 9,000

TABLE 4-10

VOLATILE ORGANIC COMPOUNDS

DETECTED IN SITE 2 SOIL SAMPLES FROM SOIL SAMPLING BOREHOLES

(Results in micrograms per kilogram.)

Parameter	Sample Location (depth in feet)									
	DANGB-2-BH1 R						DANGB-2-BH2 R			
	SS1	SS2	SS3	SS4	SS5	SS6	SS1	SS2	SS3	SS5
	0-2	2-4	6-8	8-10	10-12	15-17	0-2	5-6	10-12	20-22
Benzene	2,500	1,500	1,400	3,100	1,900	2.8	1,200	1,700	1,100	0.43
Ethyl Benzene	4,400	6,600	14,000	22,000	2,400	U(1)	5,200	25,000	500	U
Toluene	2,000B(2)	640B	15,000	1,700	1,100	200	36,000	7,200	570	4.0
Xylenes	24,000	13,000	71,000	27,000	8,600	U	180,000	27,000	2,200	U
1,2-Dichloroethane	U	U	U	U	U	U	1.8	0.8	U	U
Chlorobenzene	U	U	U	U	U	U	80	U	U	U
1,2 Dichlorobenzene	61	U	260	30	36	U	340	21	U	U
Trans-1,2-Dichloroethene	U	U	10	17	7.4	U	90	95	150	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U	U	U	17	U	U
Tetrachloroethene	5.2	U	1.0	0.3	0.3	U	2,300	150	0.7	U
Trichloroethene	1.9	1.8	58	15	6.3	U	1,600	71	24	U

1. U indicates that the compound was analyzed for but not detected.
2. B indicates that the compound was detected in the laboratory blank.

TABLE 4-11

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SITE 2 SOIL SAMPLES

(Results in micrograms per kilogram.)

Sample Location	Naphthalene	Pyrene	2-Methyl-naphthalene	Bis(2-ethylhexyl)-phthalate	Dibutyl Phthalate
DANGB-2-BH1					
SS2 2 to 4 feet	1,500	620	580	1,600	940B[1]
SS4 6 to 8 feet	U[2]	U	U	6,500	U
SS5 8 to 10 feet	480	U	460	U	2,000B
SS6 10 to 12 feet	U	U	U	U	2,000B
DANGB-2-BH2					
SS1 0 to 2 feet	3,700	3,700	6,200	U	U
SS4 6 to 8 feet	U	U	U	650	U

1. B indicates that the compound was detected in the laboratory blank.
2. U indicates that the compound was analyzed for but not detected.

TABLE 4-12

PETROLEUM HYDROCARBONS DETECTED IN SITE 2 SOIL SAMPLES

(Results in milligrams per kilogram.)

Sample Location	Petroleum Hydrocarbons
DANGB-2-BH1	
SS1 0 to 2 feet	9,600
SS2 2 to 4 feet	3,200
SS4 6 to 8 feet	2,200
SS5 8 to 10 feet	2,300
SS6 10 to 12 feet	150
DANGB-2-BH2	
SS1 0 to 2 feet	9,100
SS4 6 to 8 feet	104

mg/kg were recorded with levels decreasing with depth.

Levels of barium and lead in soil samples from boreholes DANGB-2-BH1 and DANGB-2-BH2 (Table 4-13) were comparable to background levels. Two near surface samples from borehole DANGB-2-BH1 were high in barium concentration, however. These two surface samples from borehole DANGB-2-BH1 and the surface sample from borehole DANGB-2-BH2 were also high in lead. Cadmium and chromium concentrations in soil sampled at all depths from boreholes DANGB-2-BH1 and DANGB-2-BH2 were below background levels. Analyzed metal concentrations in all other samples are comparable to background values.

Arsenic was detected at levels of 1.2 to 3.7 mg/kg in soil samples from the boreholes DANGB-2-BH1 and DANGB-2-BH2, but was not analyzed for in any of the other soil samples at Site 2.

4.3.3.2 Extent of Soil Contamination

Contamination of subsurface soil with volatile organic compounds was identified in the two soil sampling boreholes near the center of FTA-2. Soil contamination was also identified along the edge of FTA-2 during the Phase II, Stage 1 study (Section 1.2.4.3). Volatile organic soil contamination appears to extend from land surface to a depth of about 12 feet, or to the top of the water table, in the immediate vicinity of FTA-2.

Barium and lead concentrations were high in the surface and near surface samples from the two soil sampling boreholes near the center of FTA-2. Relatively high levels of barium and lead in soils are limited to the immediate vicinity of FTA-2 as widespread metal enrichment in soils was not identified during this investigation.

Overall results from this and previous investigations (Weston, 1984; Dames & Moore, 1987) suggest that soil contamination appears to be limited to the immediate vicinity of FTA-2.

4.3.4 Ground-Water Contamination

At Site 2, water from sixteen monitoring wells was sampled and analyzed for volatile and semi-volatile organic compounds, total petroleum hydrocarbons, barium, cadmium, chromium lead and nitrates (see Figure 2-6 for sampling locations).

4.3.4.1 Ground-Water Quality

Analysis of water samples indicated the presence of ground-water contamination by volatile organic compounds present in monitoring wells MW 1,

TABLE 4-13

METALS DETECTED IN SITE 2 SOIL SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal			
	Barium	Cadmium	Chromium	Lead
DANGB-2-MW12A				
SS1 0 to 2 feet	64.9	10.9	37.4	6.7
SS3 5 to 15 feet	48.1	12.0	26.7	6.6
SS5 15 to 20 feet	28.2	9.2	22.6	3.4
DANGB-2-MW13A				
SS1 0 to 2 feet	54.9	11.1	31.3	10.9
SS3 8 to 10 feet	38.2	10.1	28.3	3.3
SS4 14 to 15 feet	58.7	11.0	26.0	3.8
DANGB-2-MW37				
SS1 0 to 1 feet	75.0	13.3	37.9	4.2
SS2 5 to 6 feet	52.5	12.2	24.8	3.5
SS3 16 to 17 feet	32.0	11.5	29.6	2.0
SS4 17.5 to 18 feet	38.4	11.2	27.8	4.0
DANGB-2-MW38				
SS1 0 to 1.5 feet	69.2	3.22	33.1	8.0
SS2 9 to 10.5 feet	50.1	12.0	26.5	3.6
SS4 17 to 19 feet	40.2	6.31	20.9	4.5
DANGB-2-MW39				
SS1 0 to 1 foot	61.2	12.0	23.1	4.1
SS2 5 to 6 feet	60.6	10.1	23.9	3.5
SS3 21 to 22 feet	40.3	11.6	22.6	2.6
DANGB-2-MW40				
SS1 0 to 1 foot	54.8	11.9	29.6	3.8
SS2 7 to 8 feet	41.2	9.6	19.2	4.1
SS3 15.5 to 16.5 feet	39.2	9.4	21.2	4.2
DANGB-2-MW41				
SS1 0 to 5 feet	51.7	12.0	27.1	8.6
SS2 5 to 15 feet	62.8	9.8	25.6	5.3
SS3 15 to 20 feet	35.4	11.8	23.1	4.1
DANGB-2-BH1				
SS1 0 to 2 feet	295.0	1.8	U(1)	260.0
SS2 2 to 4 feet	262.0	0.52	U	102.0
SS4 6 to 8 feet	60.0	0.15	U	8.0
SS5 8 to 10 feet	61.0	0.06	U	6.0
SS6 10 to 12 feet	57.0	0.09	U	6.5

TABLE 4-13 (continued)

Sample Location	Metal			
	Barium	Cadmium	Chromium	Lead
DANGB-2-BH1 R				
SS6 15 to 17 feet	67.5	8.6	30.3	4.7
SS7 22 to 24 feet	44.5	7.8	34.6	4.5
DANGB-2-BH2				
SS1 0 to 2 feet	104.0	0.56	U	54.0
SS4 6 to 8 feet	41.0	0.13	U	5.0
SS6 10 to 12 feet	54.0	0.11	U	6.4
DANGB-2-BH2 R				
SS4 14 to 15 feet	62.1	8.4	28.4	11.3
SS5 20 to 22 feet	94.1	6.3	24.8	4.1
SS6 24 to 25 feet	25.4	7.9	24.9	2.9

1. U indicates that the compound was analyzed for but not detected.

MW 2, and GW 2-E near FTA-2 and well DANGB-2-MW38 near FTA-1 (Table 4-14). Trichloroethene was detected in water from three monitoring wells at concentrations of 0.32 ug/L to 33 ug/L. Trans-1,2-Dichloroethene was detected in water from four wells at concentrations of 0.63 ug/L to 1,200 ug/L. Vinyl chloride at 3.1 ug/L was detected in water from well MW 2. The compound, 1,1-dichloroethene was detected at 0.61 ug/L in water from well GW 2-E. A trace of 1,2-dichloroethane was detected in water from well DANGB-2-MW38. Benzene, the only volatile aromatic hydrocarbon detected, was found in water from well GW 2-E at 1.2 ug/L.

Semi-volatile organic compounds were detected at low levels in water from some wells. Dimethyl phthalate was detected at 63 ug/L in water from well MW 6, at 79 ug/L in water from well MW 5 and 144 ug/L in water from well GW 2-A.

Total petroleum hydrocarbons and nitrates were below detection limits in all ground-water samples.

Barium, chromium, cadmium, and lead concentrations were below detection limits in all ground-water samples.

The temperature, pH, and specific conductance of ground-water samples were determined in the field at the time of sampling (Table 4-15). Ground-water temperatures varied from 9.7 to 13.9 degrees Centigrade (^{o}C). The pH varied from 6.76 to 7.76. Specific conductance ranged from 362 to 1,388 micromhos per centimeter (umhos/cm).

4.3.4.2 Extent of Ground-Water Contamination

The principal ground-water contaminants at Site 2 and their maximum concentrations are trichloroethene at 33 ug/L, trans-1,2-dichloroethene at 1,200 ug/L, and vinyl chloride at 3.1 ug/L.

The distribution of trichloroethene and trans-1,2-dichloroethene in the ground water indicates a contaminant plume extending from FTA-2 to the northeast, hydraulically downgradient, toward an unnamed stream as shown on Figures 4-1 and 4-2. The concentration of trans-1,2-dichloroethene decreases downgradient from FTA-2, but in contrast, trichloroethene increases in concentration at the farthest downgradient well.

A contaminant plume may also exist at the site of FTA-1. Contaminants were identified in ground water from the monitoring well located at this location. It is possible that this contaminant plume extends downgradient to the southeast and discharges with the ground water along the steep face of

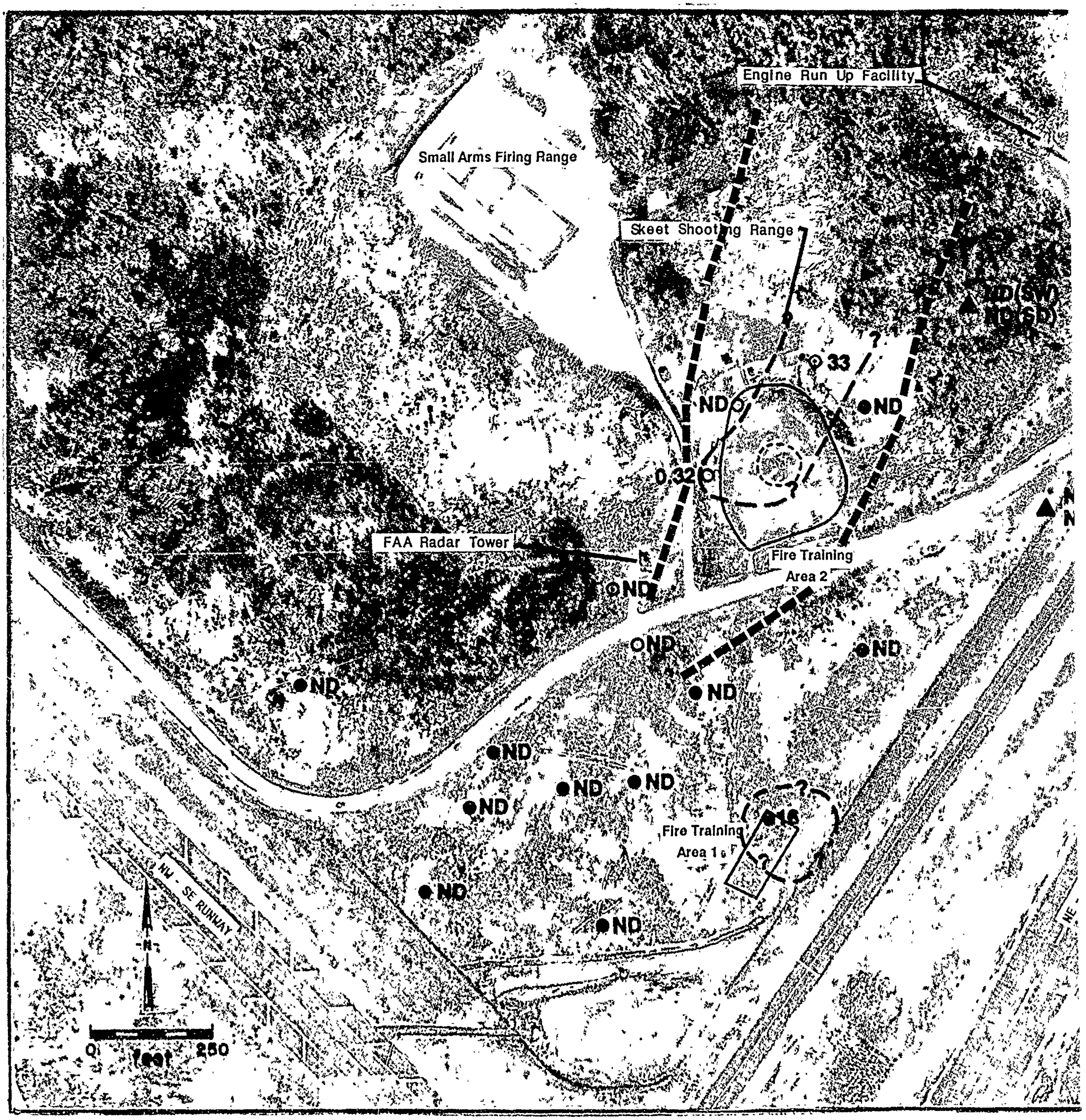
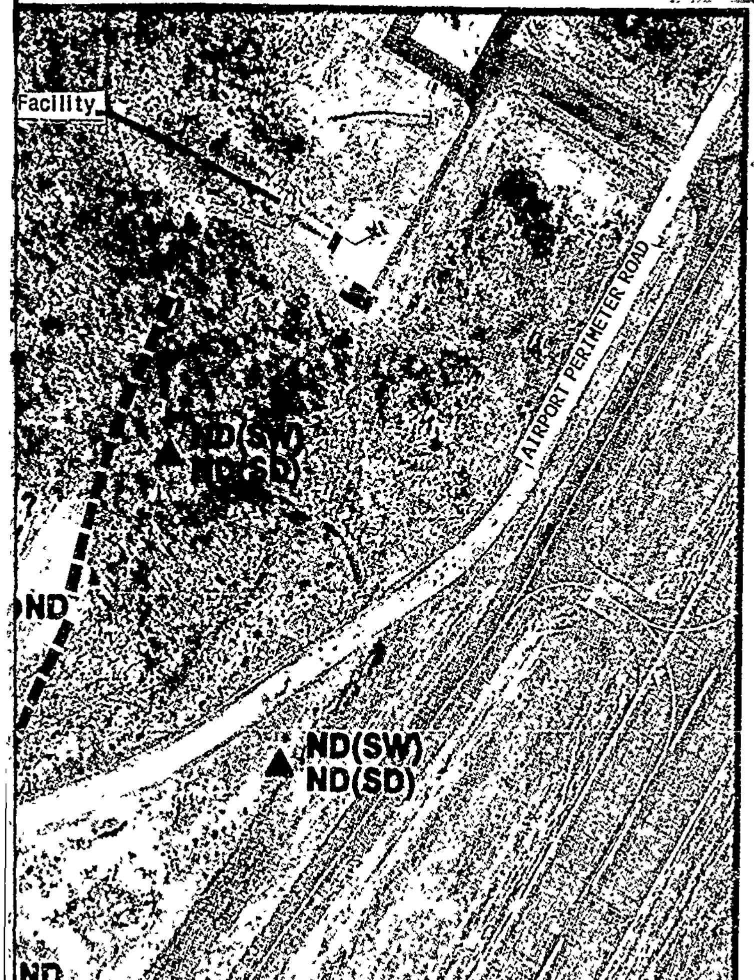


Figure 4-1 Estimated Areal Extent of Trichloroethene Contamination in Ground Water at Site 2.



EXPLANATION

● 33 ⊙ ○	Monitoring well location and TCE Concentration in micrograms per liter. "ND" means not detected.
ND (SW) ND (SD)	Concentration of TCE in surface water (SW) in micrograms per liter and sediments (SD) in micrograms per kilogram.
— —	Estimated extent of TCE contamination
▬ ▬ ▬ ▬	Probable maximum lateral extent of ground-water contamination originating at FTA-2.
⬭	Approximate boundary of fire training area.
◌	Burn pit at FTA-2.

te 2.

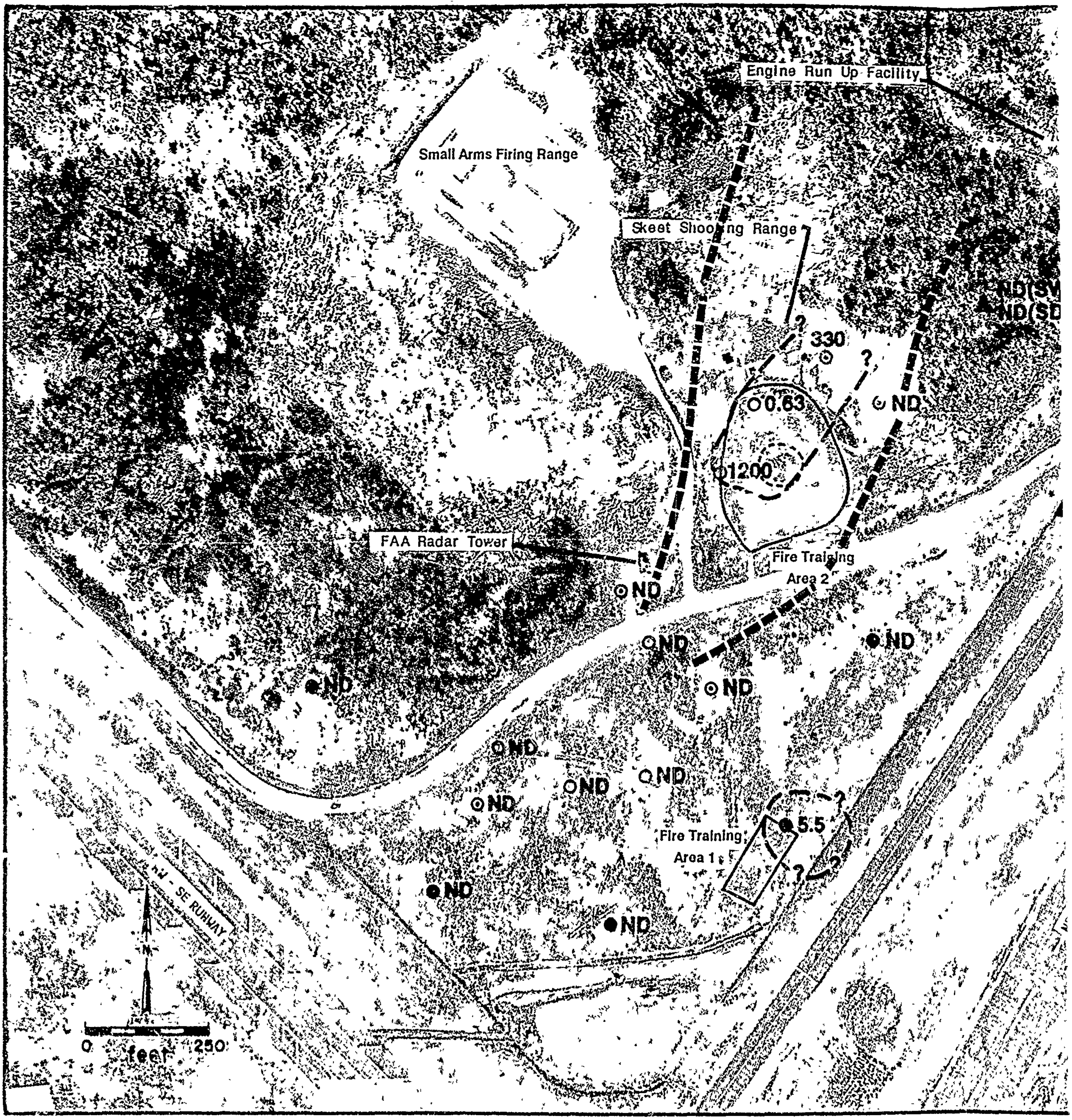
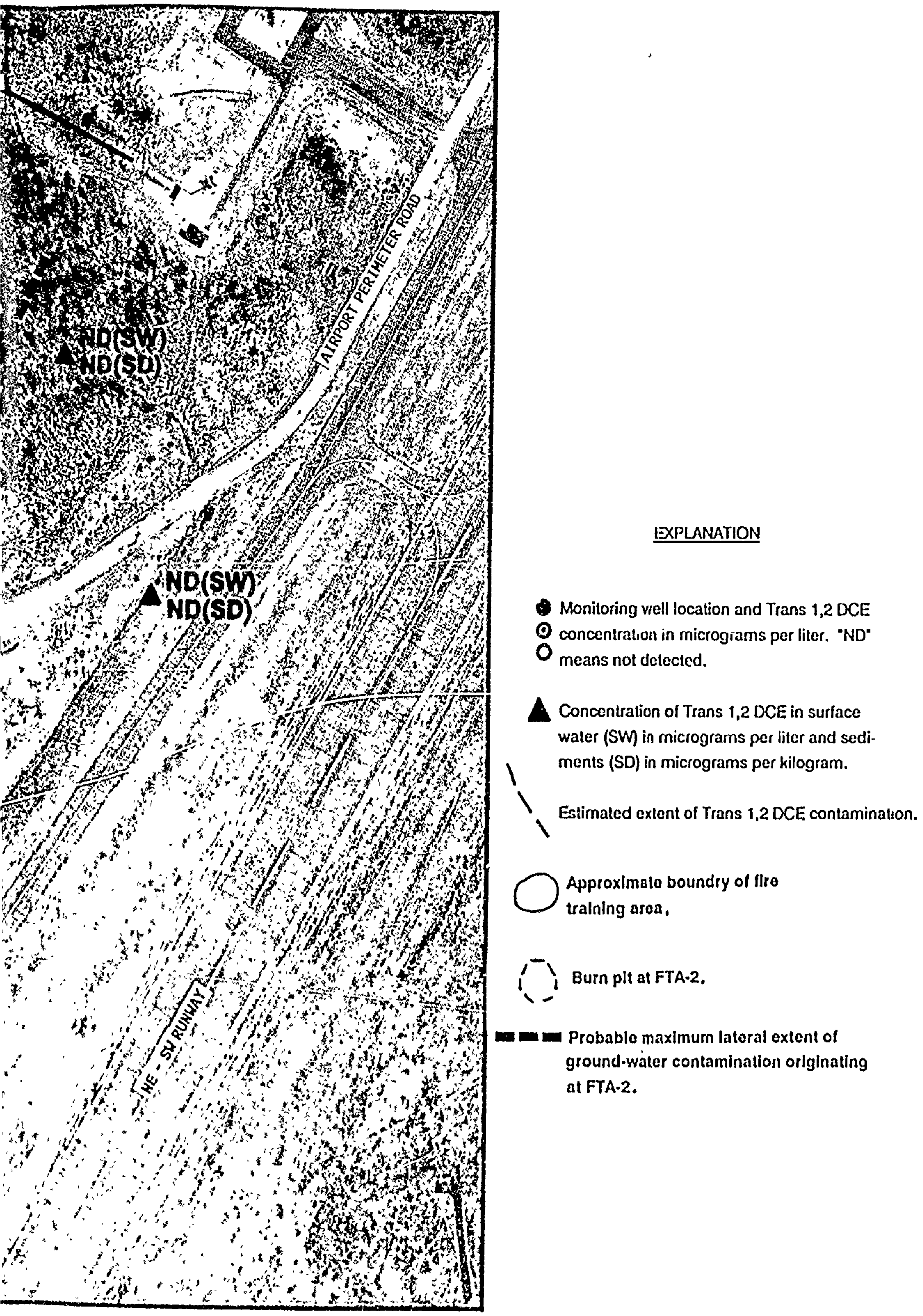


Figure 4-2 Estimated Areal Extent of Trans-1,2-Dichloroethene Contamination in Ground Water at Site 2.


AIRPORT PERIMETER ROAD
ND(SW)
ND(SD)
ND(SW)
ND(SD)
NE - SW RUNWAY
EXPLANATION
Monitoring well location and Trans 1,2 DCE concentration in micrograms per liter. "ND" means not detected.
Concentration of Trans 1,2 DCE in surface water (SW) in micrograms per liter and sediments (SD) in micrograms per kilogram.
Estimated extent of Trans 1,2 DCE contamination.
Approximate boundry of fire training area.
Burn pit at FTA-2.
Probable maximum lateral extent of ground-water contamination originating at FTA-2.

ite 2.

TABLE 4-14

VOLATILE ORGANIC COMPOUNDS DETECTED IN SITE 2 GROUND-WATER SAMPLES

(Results in micrograms per liter.)

Parameter	Location			
	MW 1	MW 2	GW 2-E	DANGB-2-MW38
Benzene	U(1)	U	1.2	U
1,2-Dichloroethane	U	U	U	0.22
1,1-Dichloroethene	U	U	0.61	U
Trans-1,2-Dichloroethene	0.63	1,200	330.0	5.5
Trichloroethene	U	0.32	33.0	16.0
Vinyl Chloride	U	3.1	U	U

1. U indicates that the compound was analyzed for but not detected.

TABLE 4-15

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR SITE 2 WATER SAMPLES

Sample Location	Temperature (^{o}C)	pH (pH units)	Specific Conductance (umhos/cm)
Surface Water Samples			
DANGB-2-SL6	11.8	7.14	390
DANGB-2-SL7	12.0	7.57	390
Ground-Water Samples			
DANGB-2-MW37	12.1	7.76	362
DANGB-2-MW38	10.9	7.61	501
DANGB-2-MW39	11.7	6.98	659
DANGB-2-MW40	11.6	7.66	324
DANGB-2-MW41	9.8	7.70	350
GW 2-A	12.0	7.23	456
GW 2-B	13.9	6.96	1,081
GW 2-C	11.2	6.76	150
GW 2-D	10.7	7.35	875
GW 2-E	9.7	6.83	1,388
MW 1	11.5	7.64	1,131
MW 2	11.6	7.58	991
MW 4	11.3	6.93	608
MW 5	10.9	7.40	523
MW 6	13.7	7.07	503
MW 7	11.7	7.27	748

the drainage ditch located about 100 feet southeast of the well.

Downward migration of the contaminants into the bedrock is unlikely due to the impermeable nature of the gabbro.

4.4 NATURE AND EXTENT OF CONTAMINATION AT SITE 3

This section presents the results of the chemical analyses performed on the soil, ground water, surface water, and sediment samples collected at Site 3. The chemical results are interpreted to determine the extent of contamination in each of the above sampling media.

4.4.1 Source of Contamination

The suspected source area at Site 3 is the former Defense Property Disposal Office (DPDO) Storage Area "C" which is an unpaved area approximately 90 feet long by 75 feet wide behind and to the side of the current Defense Reutilization and Marketing Office (DRMO)(see Figures 1-3 and 1-9). Waste solvents were stored in drums in this area (ES, 1982).

4.4.2 Soil Gas Survey Results

A soil gas survey was done at Site 3 to optimize placement of monitoring wells, soil borings, and other sampling points at the site. Soil gas samples were taken from a 49-point grid with eight additional samples collected from points intermediate to and outside the grid. The samples were analyzed for benzene, toluene, xylenes, 1,1-dichloroethene, cis-1,2-dichloroethene, trichloroethene, and tetrachloroethene. A description of the soil gas sampling and quality assurance and quality control (QA/QC) procedures along with a complete listing of the results is presented in Appendix O.

Soil gas results indicate the presence of several scattered areas containing volatile organic compounds throughout the site, but the principal source area was identified as the storage pad (see Appendix O). The principal contaminants detected in the storage pad area included tetrachloroethene, cis-1,2-dichloroethene, and trichloroethene.

4.4.3 Surface Water and Sediment Contamination

Surface water and sediment samples were collected at three Site 3 locations (Figure 2-4). Samples DANGB-3-SL8 and DANGB-3-SL9 were collected from a drainage ditch bordering Storage Area "C". Sample DANGB-3-SL10 was collected from a drainage ditch south of the storage pad area. Samples were analyzed for volatile and semi-volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

4.4.3.1 Surface Water and Sediment Quality

Volatile organic compounds were detected in water samples from DANGB-3-SL8 and DANGB-3-SL9 (Table 4-16). Trichloroethene was detected at a concentration of 10 ug/L in water sample DANGB-3-SL8 and at 110 ug/L in sample DANGB-3-SL9. Trans-1,2-Dichloroethene, 1,1,1-trichloroethane, tetrachloroethene, and 1,1-dichloroethene were detected in water at DANGB-3-SL9.

The semi-volatile compound dimethyl phthalate was detected at 12 ug/L in surface water at DANGB-3-SL9.

No pesticides or PCBs were detected in the surface water samples.

Total petroleum hydrocarbons were detected in surface water samples only at DANGB-3-SL8 at a concentration of 1.5 mg/L.

Arsenic, barium, cadmium, chromium, lead, and mercury in the surface water samples were below detection limits. Relatively high concentrations of lead and chromium have previously been reported in surface waters (Table 1-14).

Volatile organic compounds were detected in the sediment sample at location DANGB-3-SL9 (Table 4-16). These were 1,1,1-trichloroethane, 1,1-dichloroethene, 1,1-dichloroethane, and tetrachloroethene.

The semi-volatile organic compound bis(2-ethylhexyl)phthalate was detected at 600 ug/kg in the sediments at DANGB-3-SL9.

Pesticides and PCBs were not detected in sediment samples.

Total petroleum hydrocarbons were detected in sediments at concentrations of 110 mg/kg at DANGB-3-SL9, 150 mg/kg at DANGB-3-SL10 and 2,000 mg/kg at DANGB-3-SL8 (Table 4-17).

Concentrations of metals in the sediments (Table 4-18) were comparable to background values (Tables 4-1 and 4-6) except for a trace amount of mercury and a high lead value at DANGB-3-SL8. Lead concentrations ranged from 6.3 to 478 mg/kg in the three samples with the high value at location DANGB-3-SL8. A sediment sample collected during a previous study at a location between DANGB-3-SL9 and DANGB-3-SL8 also had a high lead content (Table 1-12).

Temperature, pH, and specific conductance of the surface water samples were measured in the field at the time of sampling (Table 4-19).

TABLE 4-16

VOLATILE AND SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SITE 3 SURFACE WATER AND SEDIMENT SAMPLES

(Water results in micrograms per liter;
sediment results in micrograms per kilogram.)

Parameter	Sample Location(1)			
	DANGB-3-SL8		DANGB-3-SL9	
	Water	Sediment	Water	Sediment
1,1-Dichloroethane	U(2)	U	1.8	5.6
1,1-Dichloroethene	U	U	0.56	16.0
Trans-1,2-Dichloroethene	U	U	9.3	U
1,1,1-Trichloroethane	U	U	8.6	240
Trichlorethene	10	U	110	U
Tetrachloroethene	U	U	1.1	5.1
Bis(2-ethylhexyl)phthalate	U	U	U	600
Dimethyl Phthalate	U	U	12	U

1. No volatile or semi-volatile organic compounds were detected in either the surface water or sediment samples from DANGB-3-SL10.
2. U indicates that the compound was analyzed for but not detected.

TABLE 4-17

PETROLEUM HYDROCARBONS DETECTED IN SITE 3 SEDIMENT AND SOIL SAMPLES

(Results in milligrams per kilogram.)

Sample Location	Petroleum Hydrocarbons
Sediment Samples	
DANGB-3-SL8	2,000
DANGB-3-SL9	110
DANGB-3-SL10	150
Borehole Samples	
DANGB-3-MW35-SS1, 0 to 1 foot	130
DANGB-3-MW35-SS3, 10 to 11.5 feet	600
Soil Gas Location Samples, 0 to 2 feet	
DANGB-3-SGC2	130
DANGB-3-SGC5	150
DANGB-3-SG49	2,700

TABLE 4-18

METALS DETECTED IN SITE 3 SEDIMENT SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal(1)				
	Barium	Cadmium	Chromium	Lead	Mercury
DANGB-3-SL8	53.7	4.4	54.6	478.0	0.58
DANGB-3-SL9	63.0	U(2)	27.4	6.3	U
DANGB-3-SL10	39.0	U	22.9	20.2	U

1. Arsenic was also analyzed for but was below detection limits in all samples.
2. U indicates that the compound was analyzed for but not detected.

TABLE 4-19

SUMMARY OF TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR SITE 3 WATER SAMPLES

Sample Location	Temperature (°C)	pH (pH units)	Specific Conductance (umhos/cm)
Surface Water Samples			
DANGB-3-SL8	13.0	7.03	294
DANGB-3-SL9	13.9	6.72	514
DANGB-3-SL10	12.7	6.72	649
Ground-Water Samples			
DANGB-3-MW25	12.8	7.81	694
DANGB-3-MW26	14.3	6.80	435
DANGB-3-MW27	11.8	7.05	682
DANGB-3-MW28	11.5	8.17	548
DANGB-3-MW29	15.3	7.24	820
DANGB-3-MW30	9.2	7.38	524
DANGB-3-MW31	10.0	7.82	894
DANGB-3-MW33	8.1	7.49	1,362
DANGB-3-MW34	9.8	7.48	800
DANGB-3-MW35	15.1	7.67	236
GW 3-A	9.5	7.18	420
GW 3-B	9.9	7.48	800
GW 3-C	9.2	7.73	173
GW 3-D	9.6	7.49	720

4.4.3.2 Extent of Surface Water and Sediment Contamination

The principal contaminant in surface water samples DANGB-3-SL9 and DANGB-3-SL8 was trichloroethene while several other volatile organic compounds were also present at DANGB-3-SL9. The Phase II, Stage 2 study (see Table 1-14) reported elevated concentrations of trichloroethene, 1,1,1-trichloroethane, 1,1-dichloroethene, tetrachloroethene, and vinyl chloride at a sampling point about 100 feet downstream from site DANGB-3-SL9.

Sediment contamination from volatile organic compounds, principally 1,1,1-trichloroethane, was detected at DANGB-3-SL9. A downstream location sampled during the Phase II, Stage 2 study showed 1,1,1-trichloroethane and trichloroethene contamination (see Table 1-12).

Results from this investigation and a previous study indicate that surface water and sediment contamination is present in the man-made drainage ditch that curls around the storage pad. The full extent of the surface water and sediment contamination was not determined by sampling since no samples free of contaminants were collected. However, concentrations of contaminants are likely to steadily decrease downstream.

4.4.4 Soil Contamination

At Site 3, three soil samples were taken from each borehole drilled for construction of each monitoring well at the site except where paired wells were installed in which case samples were taken only from the deeper borehole. In addition, 28 soil samples were collected from a depth of one to two feet at selected soil gas sampling locations. Drilling locations at Site 3 are shown on Figure 2-4 and the surface soil sampling locations are shown on Figure 2-5. Soil samples were analyzed for volatile and semi-volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, arsenic, barium, cadmium, chromium, lead and mercury.

4.4.4.1 Soil Quality

Volatile organic compounds were detected in numerous soil samples taken at Site 3. Benzene, ethyl benzene, and xylenes were detected in the surface soil sample from DANGB-3-SG49 located near the center of the storage pad area (Table 4-20).

Semi-volatile compounds were detected in some soil samples. Bis(2-ethylhexyl)phthalate was detected at 590 ug/kg in the surface soil sample collected at DANGB-3-SGA1. It was also detected at 530 ug/kg in the 14- to 15-foot depth sample from the borehole for DANGB-3-MW25 and at

TABLE 4-20

VOLATILE ORGANIC COMPOUNDS DETECTED IN SITE 3 SOIL SAMPLES

(Results in micrograms per kilogram)

Parameter	Sample Location (depth in feet)						
	DANGB-3-						
	SG49	SGB3	MW25-SS3	MW29-SS1	MW29-SS2	MW29-SS3A	MW35-SS3
	1-2	1-2	14-15	0-2	3-4	14-15	10-11.5
Benzene	900	U(1)	U	U	U	U	U
Ethyl Benzene	260	U	U	U	U	U	U
Toluene	1,300B(2)	U	U	U	U	U	U
Xylenes	2,000	U	U	U	U	U	U
1,1-Dichloroethane	1.2	U	U	U	U	U	0.25
Trans 1,2-Dichloro-ethylene	U	0.7	U	U	U	U	U
1,1,1-Trichloroethane	45B	89	U	U	U	U	U
Tetrachloroethylene	37B	15	U	U	U	0.41	U
Trichloroethylene	0.73	U	4.4	0.74	3.1	U	U

1. U indicates that the compound was analyzed for but not detected.
2. B indicates that the compound was detected in the laboratory blank.

430 ug/kg in a sample collected 3 to 4 feet below the surface at DANGB-3-MW27. Diethyl phthalate was only detected in the duplicate samples from surface sample locations DANGB-3-SGD3 and DANGB-3-SGE3.

Pesticides or PCBs were present in eight soil samples collected from the surface sampling grid (see Figure 4-3 and Table 4-21). The most widespread pesticide in the soil was 4,4'-DDT which ranged in concentration from 22 to 500 ug/kg. The pesticide 4,4'-DDD was detected in soil from three locations at concentrations of 62 to 190 ug/kg. Traces of 4,4'-DDE were present in soil at three locations at concentrations of 33 to 61 ug/kg. The compound Arochlor 1254 was found in the duplicate soil sample taken at location DANGB-3-SGC4.

The pesticides 4,4'-DDD, 4,4'-DDT, and delta-BHC were also detected in soil from the pad area during the Phase II, Stage 2 study (Table 1-11).

One pesticide was detected in one deep soil sample. The pesticide, 4,4'-DDT was detected at a level of 22 ug/L in the sample from the borehole drilled for monitoring well DANGB-3-MW29 at a depth of 3 to 4 feet (Table 4-21).

Total petroleum hydrocarbons were detected in four surface and one deep soil sample (Table 4-17). Low levels ranging from 130 to 150 mg/kg were detected in the near surface samples from three scattered surface locations, DANGB-3-SG C2, DANGB-3-SG C5 and DANGB-3-MW35 (SS1) (see Figures 2-5 and 2-6 for locations). A higher level, 600 mg/kg was detected in a deep soil sample, 10 to 11.5 feet, from one of these locations, DANGB-3-MW35-(SS3). A high level, 2,700 mg/kg was detected in the near surface soil sample from location DANGB-3-SG49.

Trace levels of barium, cadmium, chromium, lead, and mercury were present in the soil at Site 3 (Table 4-22). Barium was detected at levels from 30.4 to 121 mg/kg; cadmium in the range of 5.6 to 19.4 mg/kg; chromium ranged from 19.5 to 44.3 mg/kg; lead varied in concentration from 3.1 to 22.5 mg/kg; and mercury was detected in the sample from the 0 to 1 foot sample taken from the borehole for monitoring well DANGB-3-MW28 at a concentration of 0.28 mg/kg. Arsenic was below detection limits in all samples. Concentrations of all six metals were generally comparable to background values see Tables 4-1 and 4-6.

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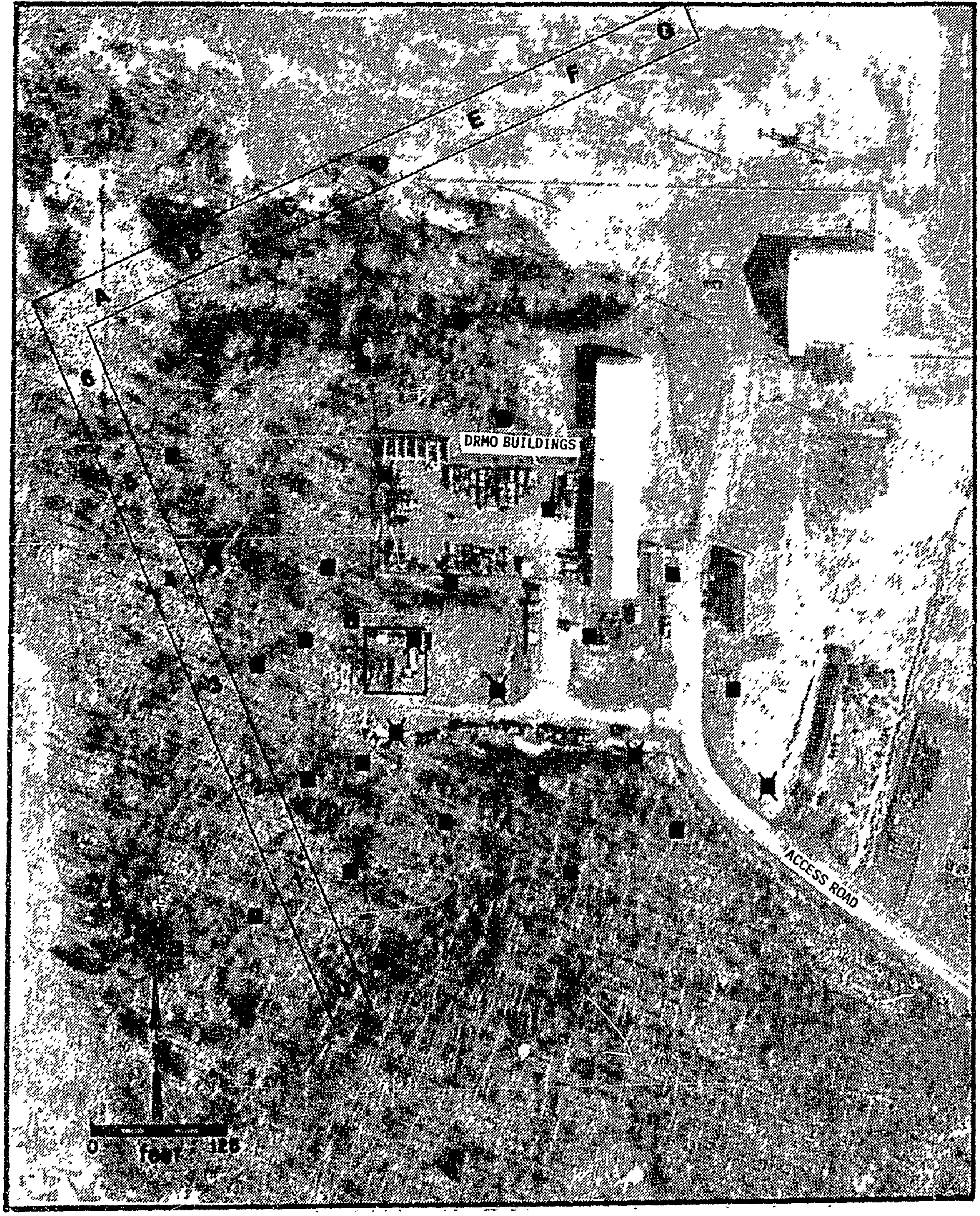

Figure 4-3 Distribution of Near Surface Soil Pesticide and PCB Occurrences at Site 3.

EXPLANATION

■ Shallow soil sample
location and identification.

⊠ Location where pesticides or PCBs
were detected in the soil sample.

□ Approximate location of
Storage Area "C".

TABLE 4-21

ORGANOCHLORINE PESTICIDES AND PCBs

DETECTED IN SITE 3 SOIL AND GROUND-WATER SAMPLES

(Soil results in micrograms per kilogram;
water results in micrograms per liter.)

Sample Location	Compound				
	4,4'-DDD	4,4'-DDE	4,4'-DDT	PCB 1242	PCB 1254
<u>Surface Soil Samples</u>					
DANGB-3-SGA4	U(2)	33	75	U	U
DANGB-3-SGB2	U	U	28	U	U
DANGB-3-SGC1	U	37	63	U	U
DANGB-3-SGC2	110	61	500	U	U
DANGB-3-SGC4(1)	U	U	42	U	1,100
DANGB-3-SGC4 DUP	U	U	U	U	299
DANGB-3-SGC4 R	U	U	U	U	205
DANGB-3-SGC4 R DUP	U	U	U	U	105
DANGB-3-SGD1	62	U	51	U	U
DANGB-3-SGE0	U	U	25	U	U
DANGB-3-SG49	190	U	45	U	U
<u>Deep Soil Sample</u>					
DANGB-3-MW29 -SS2 3 to 4 feet	U	U	22	U	U
<u>Ground-Water Samples</u>					
GW 3-A	U	U	U	24	U
GW 3-B	U	U	U	34	U
GW 3-C	U	U	U	45	U
GW 3-D	U	U	U	26	U

1. Four samples from the same location were analyzed. A sample and a duplicate were collected and then this location was resampled and a second duplicate collected.
2. U indicates that the compound was analyzed for but not detected.

TABLE 4-22

METALS DETECTED IN SITE 3 SOIL SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal[1]				
	Barium	Cadmium	Chromium	Lead	Mercury
Borehole Samples					
DANGB-3-MW25					
SS1 0 to 1 foot	62.5	11.9	40.7	3.9	U[2]
SS2 2 to 3 feet	55.4	9.7	27.3	6.5	U
SS3 14 to 15 feet	41.4	11.1	34.0	3.1	U
DANGB-3-MW27					
SS1 0 to 1 feet	77 [illegible]	10.2	31.0	16.3	U
SS2 5 to 6 feet	[illegible]	10.8	31.5	3.3	U
SS3 14 to 15 feet	46.[illegible]	10.6	30.7	3.2	U
DANGB-3-MW28					
SS1 0 to 1 foot	121.0	11.0	40.1	9.5	0.28
SS2 2 to 3 feet	66.6	7.3	31.9	6.2	U
SS3 14 to 15 feet	45.8	8.7	28.6	3.8	U
DANGB-3-MW29					
SS1 0 to 1 foot	58.6	7.5	36.2	5.8	U
SS2 3 to 4 feet	43.2	7.4	27.6	8.2	U
SS3 14 to 15 feet	31.8	7.6	25.3	4.3	U
DANGB-3-MW30					
SS1 0 to 1 foot	64.0	7.2	30.4	4.5	U
SS2 9 to 11 feet	45.1	9.4	34.1	7.1	U
SS3 14 to 15 feet	32.2	6.1	21.5	3.5	U
DANGB-3-MW31					
SS1 0 to 1 foot	69.5	7.5	38.3	6.4	U
SS2 9 to 10 feet	47.7	8.9	29.8	4.5	U
DANGB-3-MW33					
SS1 0 to 1 foot	102.0	8.7	39.7	12.9	U
SS2 11 to 12 feet	44.5	8.8	27.7	4.3	U
SS3 20 to 21 feet	30.4	8.1	27.3	3.9	U
DANGB-3-MW35					
SS1 0 tol foot	54.8	14.3	43.7	22.5	U
SS2 2 to 3 feet	50.1	9.7	35.4	5.0	U
SS3 10 to 11.5 feet	43.7	10.7	27.3	2.8	U

TABLE 4-22 (continued)

METALS DETECTED IN SITE 3 SOIL SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal(1)				
	Barium	Cadmium	Chromium	Lead	Mercury
<u>Soil Gas Location Samples, 0-2 feet</u>					
DANGB-3-SGA0	78.4	10.4	28.7	12.0	U(2)
DANGB-3-SGA1	73.7	12.9	38.1	7.7	U
DANGB-3-SGA2	79.0	12.3	26.9	3.8	U
DANGB-3-SGA3	69.4	12.5	30.5	12.7	U
DANGB-3-SGA4	76.6	11.0	30.7	8.7	U
DANGB-3-SGA5	114.0	6.2	22.8	30.3	U
DANGB-3-SGB1	96.3	14.7	42.9	8.7	U
DANGB-3-SGB2	85.1	12.5	26.8	13.4	U
DANGB-3-SGB3	69.9	10.4	29.7	12.2	U
DANGB-3-SGC0	73.7	9.7	24.6	7.7	U
DANGB-3-SGC1	78.8	16.4	31.4	12.6	U
DANGB-3-SGC2	62.9	12.3	43.9	10.2	U
DANGB-3-SGC3	50.8	10.3	30.1	10.8	U
DANGB-3-SGC4	57.9	19.2	44.6	12.6	U
DANGB-3-SGC5	109.0	5.6	18.9	9.9	U
DANGB-3-SGD0	104.0	11.9	38.0	6.0	U
DANGB-3-SGD1	43.1	10.4	27.5	4.0	U
DANGB-3-SGD2	38.0	10.6	20.2	17.8	U
DANGB-3-SGD3	55.8	7.4	31.8	4.1	U
DANGB-3-SGD4	44.8	12.0	30.2	9.1	U
DANGB-3-SGD5	56.4	10.9	19.2	9.3	U
DANGB-3-SGE0	57.6	11.5	28.9	5.7	U
DANGB-3-SGE1	98.7	9.4	36.2	10.2	U
DANGB-3-SGE2	60.5	11.0	31.8	6.5	U
DANGB-3-SGE3	55.7	9.9	31.0	4.2	U
DANGB-3-SGE4	39.7	5.7	25.9	4.5	U
DANGB-3-SG49	64.0	11.2	44.3	16.8	U
DANGB-3-SG54	62.5	13.5	36.2	9.0	U
DANGB-3-SG56	59.6	8.9	28.5	7.8	U
DANGB-3-SG57	69.0	10.9	28.5	8.0	U
DANGB-3-SG58	110.0	19.4	44.2	12.6	U

1. Arsenic was also analyzed for but was below detection limits.
2. U indicates that the compound was analyzed for but was not detected.

4.4.4.2 Extent of Soil Contamination

Soil contamination by volatile organic compounds was indicated. Benzene, ethyl benzene, xylenes, tetrachloroethene, 1,1-dichloroethane, and 1,1,1-trichloroethane are present in storage pad area soil. Even though tetrachloroethene and 1,1,1-trichloroethane were detected in the laboratory blanks during analyses of the samples, these compounds are likely present in the soil since they are present in the ground water and tetrachloroethene is present in the soil gas (Appendix O). Xylenes and 1,1,1-trichloroethane were detected in the pad area during a previous study (Table 1-11).

Results from surface soil samples collected during this and prior investigations (Weston, 1984; Dames & Moore, 1987) indicate the areal extent volatile organic soil contamination is primarily confined to the immediate vicinity of the storage pad area. The vertical extent of soil contaminated with volatile organics is uncertain; but, 1,1,1 trichloroethane was detected in samples taken from depths of 2.5-4 and 5-6.5 feet during the Phase II, Stage 2 study (Dames & Moore, 1987) (Table 1-11).

The pesticide 4,4'-DDT was the most prevalent contaminant detected in the soil at Site 3. Except for one very low detection its presence was restricted to the near-surface soil. These pesticide occurrences are shown on Figure 4-3.

Total petroleum hydrocarbons are present at a high level in the near surface soil at one location, DANGB-3-SG49. This location is on the storage pad and is directly upslope from sediment sample location, DANGB-3-SL8 which also contained a high level of petroleum hydrocarbons. These high levels appear localized and are probably the result of a petroleum hydrocarbon spill in the storage pad area. Petroleum hydrocarbons were also detected at low levels in the near-surface soil at three scattered locations. These occurrences do not appear to be related either to each other or to the high level present at DANGB-3-SG49 discussed above and are probably the result of separate spills. One of the near surface soil samples, DANGB-3-MW35-SS1 was from a borehole. A deeper soil sample from this borehole also contained petroleum hydrocarbons. It is not known if the soil at depth corresponding to the other near surface samples is also contaminated. No other deep soil samples contained petroleum hydrocarbons indicating that this source of contamination is limited in extent.

The storage pad area is the most probable source area for contaminants, but patchy surface contamination throughout the site may be present as indicated by the soil analyses and soil gas results (Appendix O).

4.4.5 Ground-Water Contamination

Four existing monitoring wells and ten monitoring wells installed during this investigation were sampled for volatile and semi-volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, arsenic, barium, cadmium, chromium, lead and mercury.

4.4.5.1 Ground-Water Quality

Ten volatile organic compounds were detected in ground-water samples and eight wells contained trace amounts of at least one volatile organic compound (Table 4-23). The compound with the highest level was 1,1,1-trichloroethane. It was detected in seven wells at levels which ranged from 0.34 to 3,100 ug/L. Trichloroethene was detected in six wells at levels ranging from 5.1 to 790 ug/L. Tetrachloroethene was detected in five wells at levels ranging from 3.1 to 540 ug/L. The compound, 1,1-dichloroethane was also detected in five wells but at lower levels ranging from 1.3 to 250 ug/L. Trans-1,2-Dichloroethene was detected in four wells at levels ranging from 1.7 to 450 ug/L. The compound, 1,1-dichloroethene was detected in five wells at low levels ranging from 0.71 to 58 ug/L. The compound, 1,2-dichloroethane was detected at trace levels in two wells. Benzene, toluene and vinyl chloride were detected in the two same wells at trace amounts.

Semi-volatile organic compounds were detected at trace levels in some ground-water samples. Naphthalene was detected at 22 ug/L in ground water from well GW 3-B. Dimethyl phthalate was detected at 18 ug/L in ground water from well GW 3-D and at 16 ug/L in water from well GW 3-C. Bis-(2-ethylhexyl)phthalate was detected in water from monitoring wells GW 3-B, DANGB-3-MW27, DANGB-3-MW28, and DANGB-3-MW31 at levels of 17, 42, 23, and 62 ug/L, respectively.

The PCB 1242 was detected in water from four wells ranging in concentration from 24 to 45 ug/L (see Table 4-21). These four wells are located either on or very close to the storage pad and were installed during the Phase II, Stage 2 study. Soil samples from the well boreholes and ground-water samples were analyzed for pesticides and PCBs during the Phase II, Stage 2 study using the same analytical methods as used during the RI (cf. Tables 1-10, 1-13, 2-19 and 2-21), but no PCBs were detected. It is possible that the detections are attributable to sediment in the samples since samples

TABLE 4-23
VOLATILE ORGANIC COMPOUNDS DETECTED IN SITE 3 GROUND-WATER SAMPLES
(Results in micrograms per liter.)

Parameter	Sample Location							
	GW 3-A	GW 3-B	GW 3-C	GW 3-D	DANGB-3-MW25	DANGB-3-MW26	DANGB-3-MW29	DANGB-3-MW-35
Benzene	U[1]	1.1	U	0.74	U	U	U	U
Toluene	U	21	U	2.9	U	U	U	U
1,1-Dichloroethane	U	250	U	20	4.8	U	1.3	8.9
1,2-Dichloroethane	U	4.4	U	U	1.9	U	U	U
1,1-Dichloroethene	U	26	U	58	5.4	U	0.71	1.0
Trans-1,2-Dichloroethylene	U	50	U	450	100	U	1.7	U
1,1,1-Trichloroethane	0.34	3,100	28	1,300	3.5	U	11	0.88
Tetrachloroethene	4.4	440	280	540	U	U	3.1	U
Trichloroethene	U	6.4	5.1	39	790	0.76	13	U
Vinyl Chloride	U	2.8	U	3.5	U	U	U	U

1. U indicates that the compound was analyzed for but not detected.

from the older wells generally contained sediment as evidenced by the difficulty in filtering samples from them for metals analyses (see Appendox Q.2.5).

Total petroleum hydrocarbons were below detection limits of 1.5 mg/L in all ground-water samples.

Arsenic, barium, cadmium, chromium, lead, and mercury concentrations were below detection limits in all ground-water samples. Chromium concentrations exceeding Federal Drinking Water Standards at Site 3 were reported in the results of the Phase II, Stage 2 study (Table 1-14).

Temperature, pH, and specific conductance were measured for each ground-water sample (Table 4-19). Temperature ranged from 8.1 to 14.3°C. In the paired wells, temperatures were less in. the deep wells which is expected. A variation in pH from 6.80 to 8.17 was observed. Specific conductance ranged from 173 to 1,362 umhos/cm. Specific conductance increased with the depth of the well which is expected.

4.4.5.2 Extent of Ground-Water Contamination

The principal contaminants and their maximum concentrations in the ground water beneath the site are 1,1,1-trichloroethane at 3,100 ug/L, trichloroethene at 790 ug/L, tetrachloroethene at 540 ug/L, trans-1,2-dichloroethene at 450 ug/L and 1,1-dichloroethane at 58 ug/L. Monitoring wells, GW 3-B and GW 3-D located on the storage pad had the maximum amount of contamination. Well GW 3-C also located on the storage pad was contaminated with three compounds. Downgradient well DANGB-3-MW25 was also contaminated.

The distributions of trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane indicate a contaminant plume extending from the area of the storage pad hydraulically downgradient to the northeast toward a drainage ditch that traverses Site 4 (Figures 4-4 to 4-6). The shape of the contaminant plume for trans-1,2-dichloroethene is similar to that of trichloroethene. The shape of the contaminant plume for 1,1-dichloroethane is also similar to that of trichloroethene, but in addition extends further to the north on the upgradient side to include DANGB-3-MW35. Levels of tetrachloroethene 1,1,1-trichloroethane and 1,1-dichloroethane decrease in wells hydraulically downgradient from the source area. In contrast, trichloroethene and trans-1,2-dichloroethene have their highest concentrations in the farthest downgradient well, DANGB-3-MW25.

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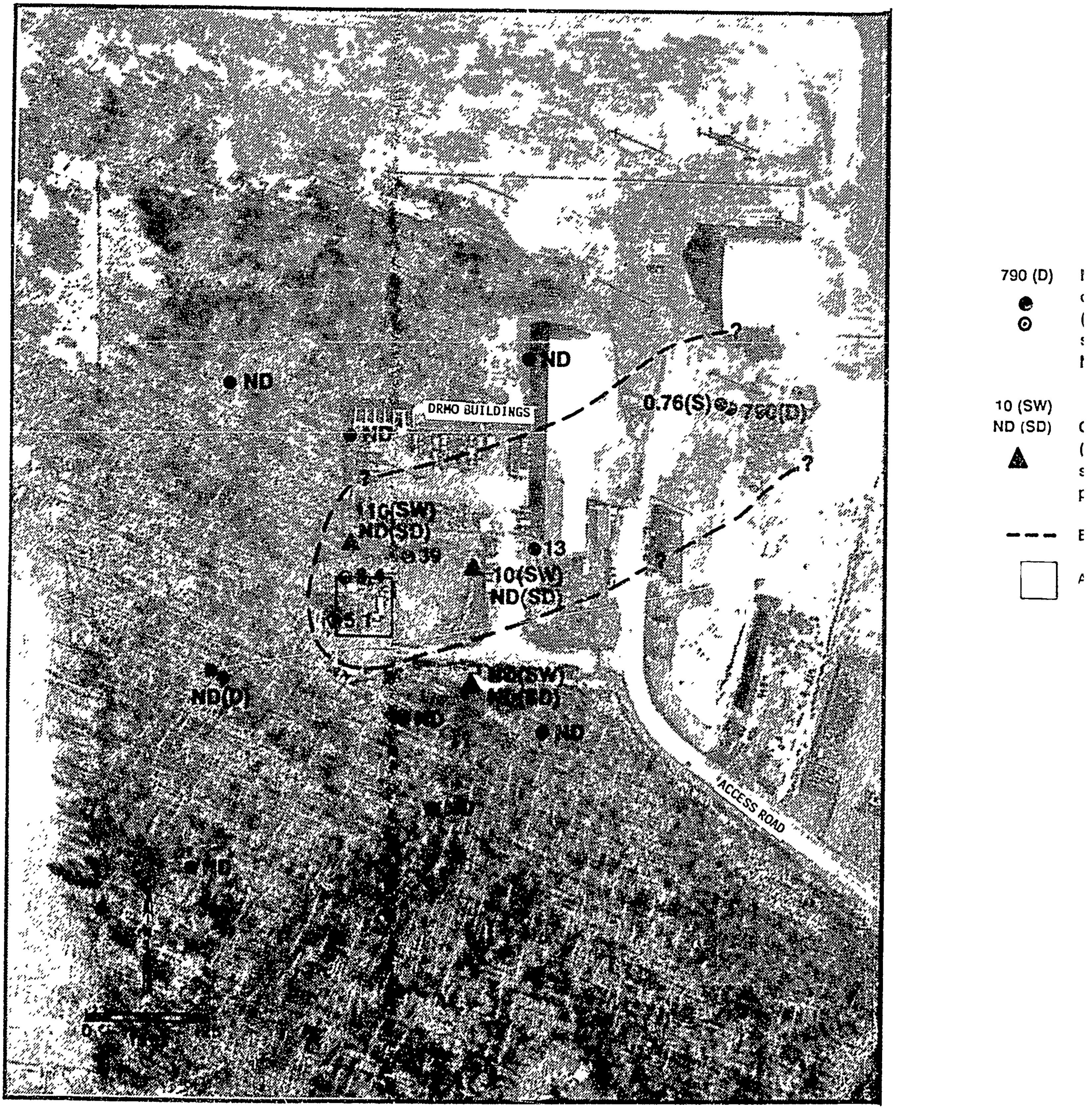

Figure 4-4 Estimated Areal Extent of Trichloroethene Contamination in Ground Water at Site 3.

EXPLANATION

790 (D) ● ⊙	Monitoring well location and TCE concentration in micrograms per liter. (D) indicates deep well and (S) indicates shallow well at multiple well sites. ND indicates not detected.
10 (SW) ND (SD) ▲	Concentration of TCE in surface water (SW) in micrograms per liter and sediments (SD) in micrograms per kilogram. ND indicates not detected.
▬ ▬ ▬	Estimated extent of TCE contamination.
☐	Approximate location of Storage Area "C".

Site 3.

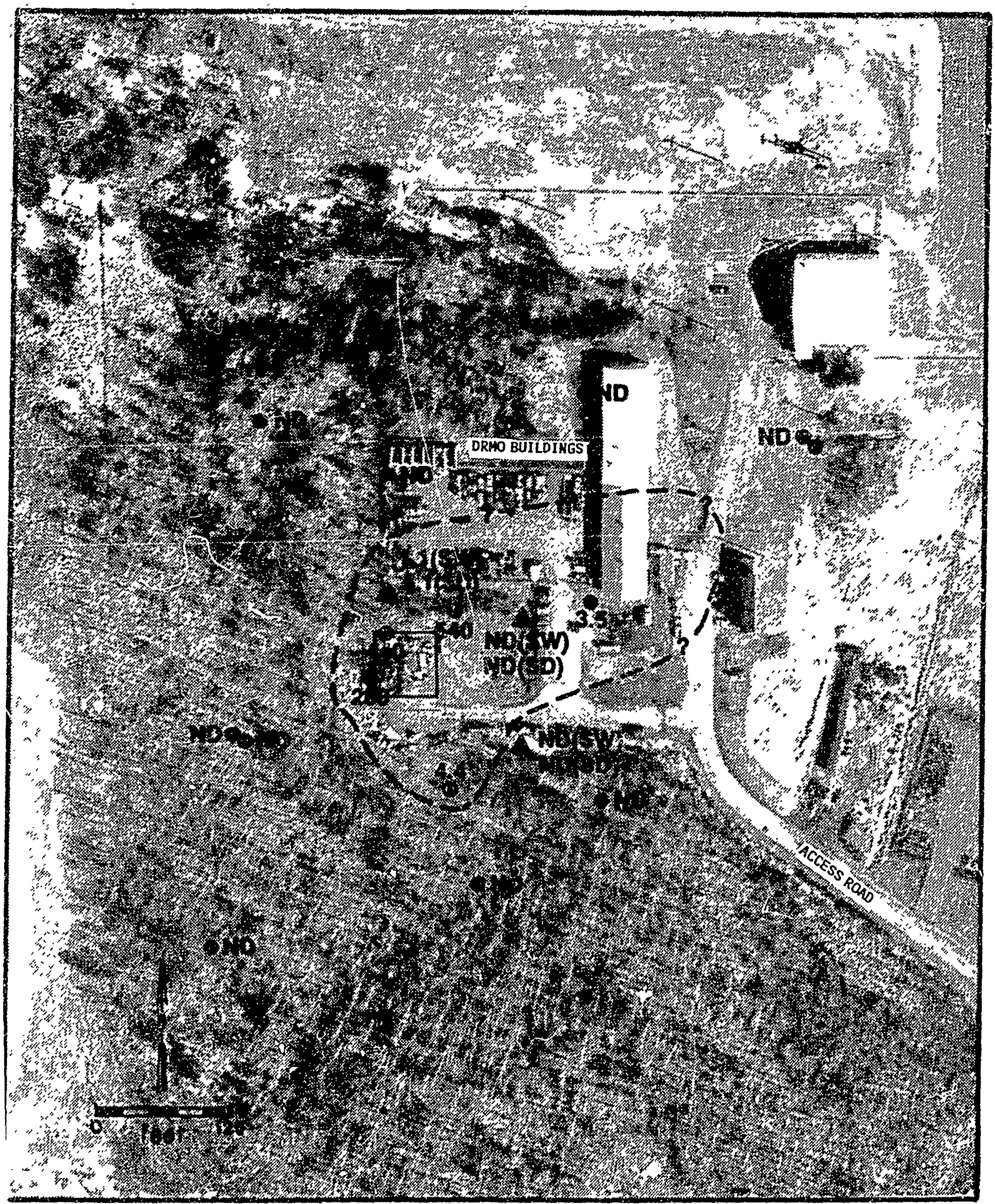

Figure 4-5 Estimated Areal Extent of Tetrachloroethene Contamination in Ground Water at Site 3.

EXPLANATION

● ⊙	Monitoring well location and PCE concentration in micrograms per liter. (D) indicates deep well and (S) indicates shallow well at multiple well sites. "ND" indicates not detected.
▲	Concentration of PCE in surface waters (SW) in micrograms per liter and sediments (SD) in micrograms per kilogram. "ND" indicates not detected.
— — —	Estimated extent of PCE contamination.
☐	Approximate location of Storage Area "C".

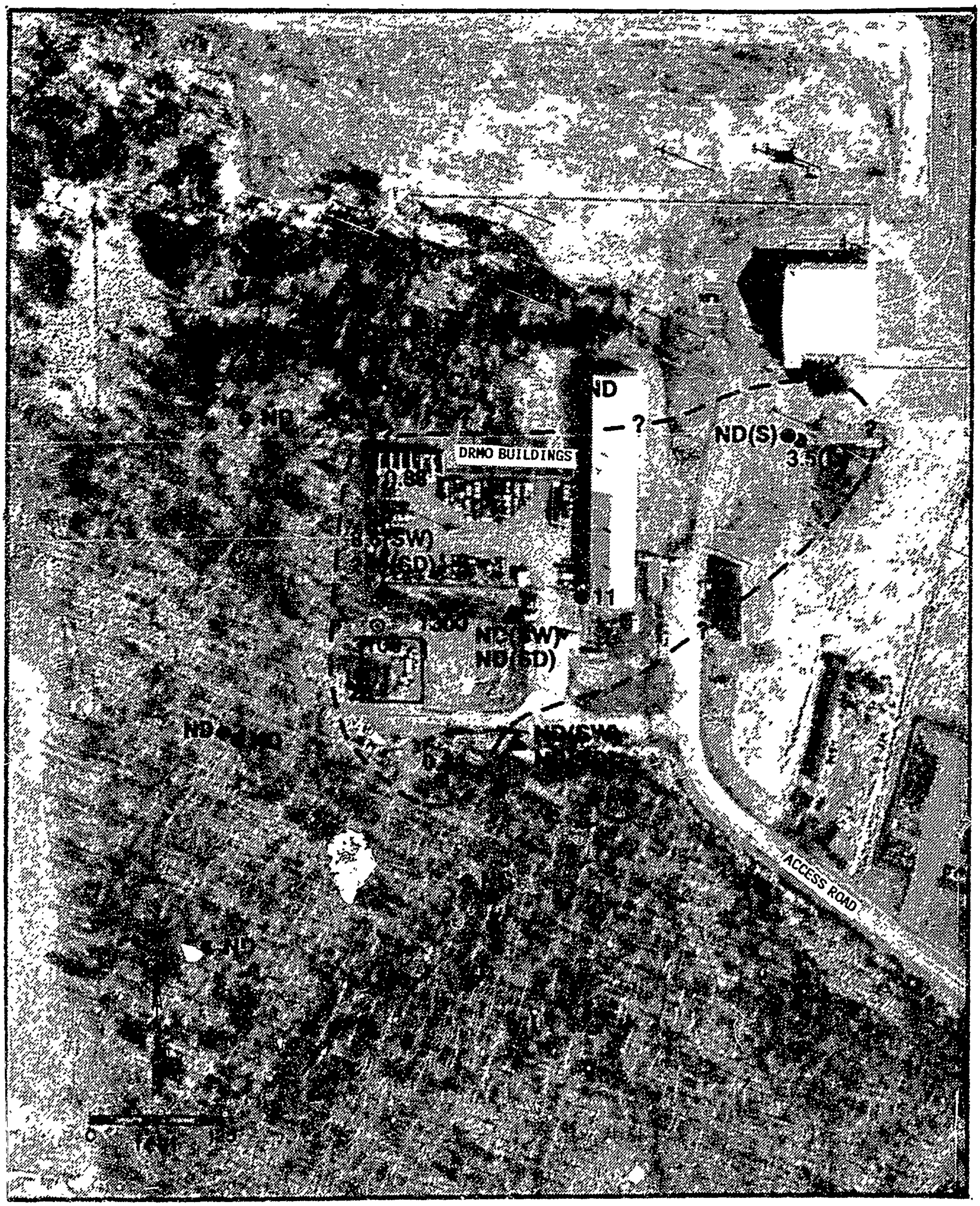

Figure 4-6 Estimated Areal Extent of 1,1,1 Trichloroethane Contamination in Ground Water at Site 3.

EXPLANATION

● Monitoring well location and TCA concentration in micrograms per liter. (D) indicates deep well and (S) indicates shallow well at multiple well sites. "ND" indicates not detected.

▲ Concentration of TCA in surface waters (SW) in micrograms per liter and sediments (SD) in micrograms per kilogram.

— — — Estimated extent of TCA contamination.

☐ Approximate location of Storage Area "C".

Chemical data from wells screened at different depths suggest that vertical as well as horizontal contaminant gradients exist. The vertical distributions of 1,1,1-trichloroethane, tetrachloroethene, and trichloroethene show that concentrations of these contaminants increase with depth in the glacial till and that contaminants are concentrated near the bedrock contact (Figures 4-7 to 4-9). The vertical distributino of trans-1,2-dichloroethene is similar to that of trichloroethane and that of 1,1-dichloroethane is similar to that of 1,1,1-trichloroethene.

Segregation of the organic contaminants with specific gravities greater than that of water to the deeper levels of the glacial till is aided by the downward component of ground-water flow in the storage pad area.

The generally impermeable nature of the bedrock inhibits the spread of contaminants into the bedrock unit.

4.5 NATURE AND EXTENT OF CONTAMINATION AT SITE 4

This section presents the results of the chemical analyses on the soil, ground water, surface water and sediment samples collected at Site 4. The chemical results are interpreted to determine the extent of contamination in each of the above sampling media.

4.5.1 Source of Contamination

Fuel leaks have been reported in the fuel storage area (see Figures 1-3 and 1-11). The source of the fuel leaks is believed to be fuel tank No. 3 and its feeder lines. Tank No. 3 has been taken out of service but oily seepage is present in the drainage ditch north of the storage tanks.

4.5.2 Surface Water and Sediment

Surface water and sediment samples were collected from six locations at Site 4 (Figure 2-1). Four samples were from a drainage ditch that flows along the east and north sides of the site. Two samples were collected from a drainage ditch located along the south side of the fuel storage tanks. The samples were analyzed for volatile organic compounds, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

4.5.2.1 Surface Water and Sediment Quality

Volatile organic compounds including benzene, ethyl benzene, toluene, xylenes, trichloroethene and trans-1,2-dichloroethene were detected in surface water samples (Table 4-24). The highest levels of benzene, ethyl benzene, toluene, and xylenes were recorded at site DANGB-4-SL13, which is the most

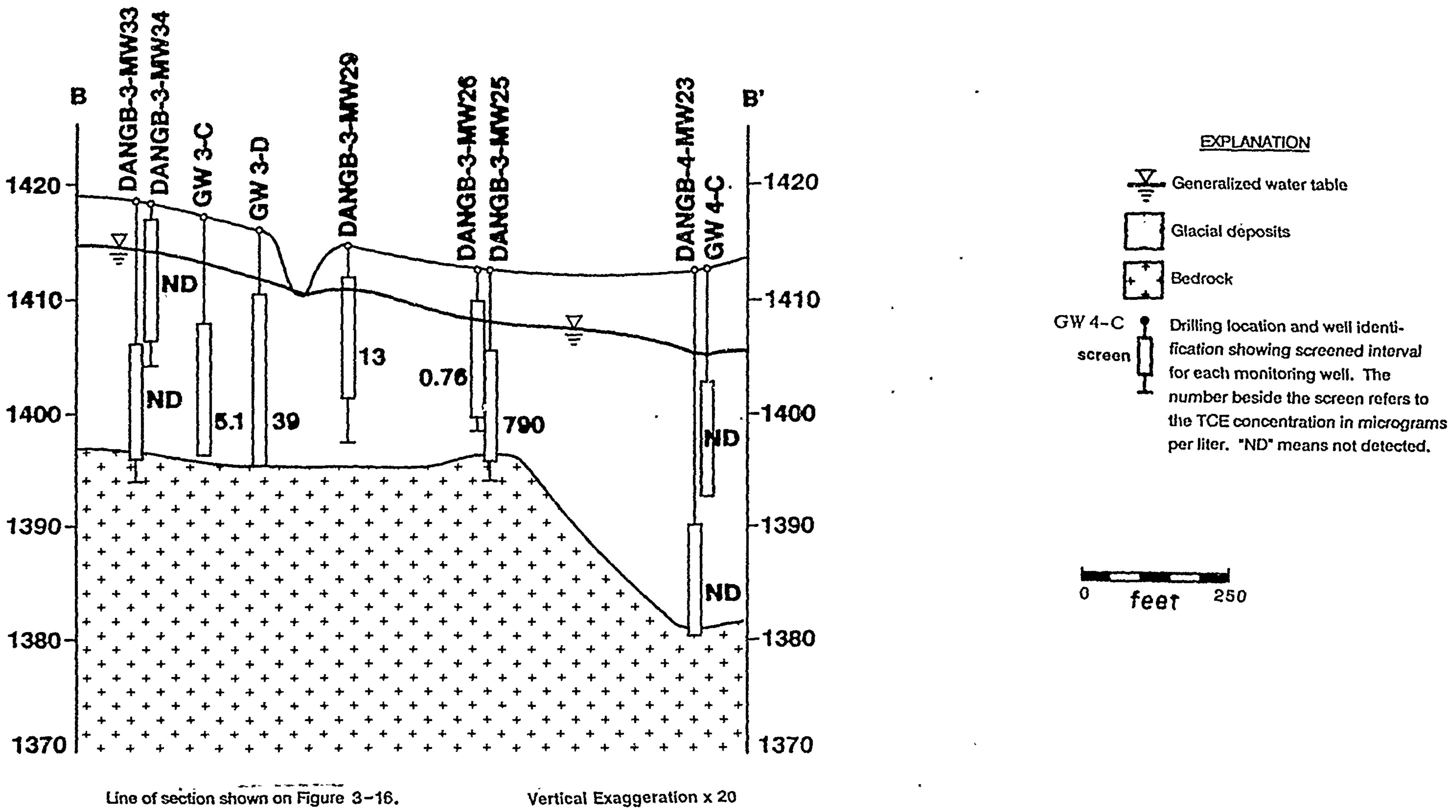

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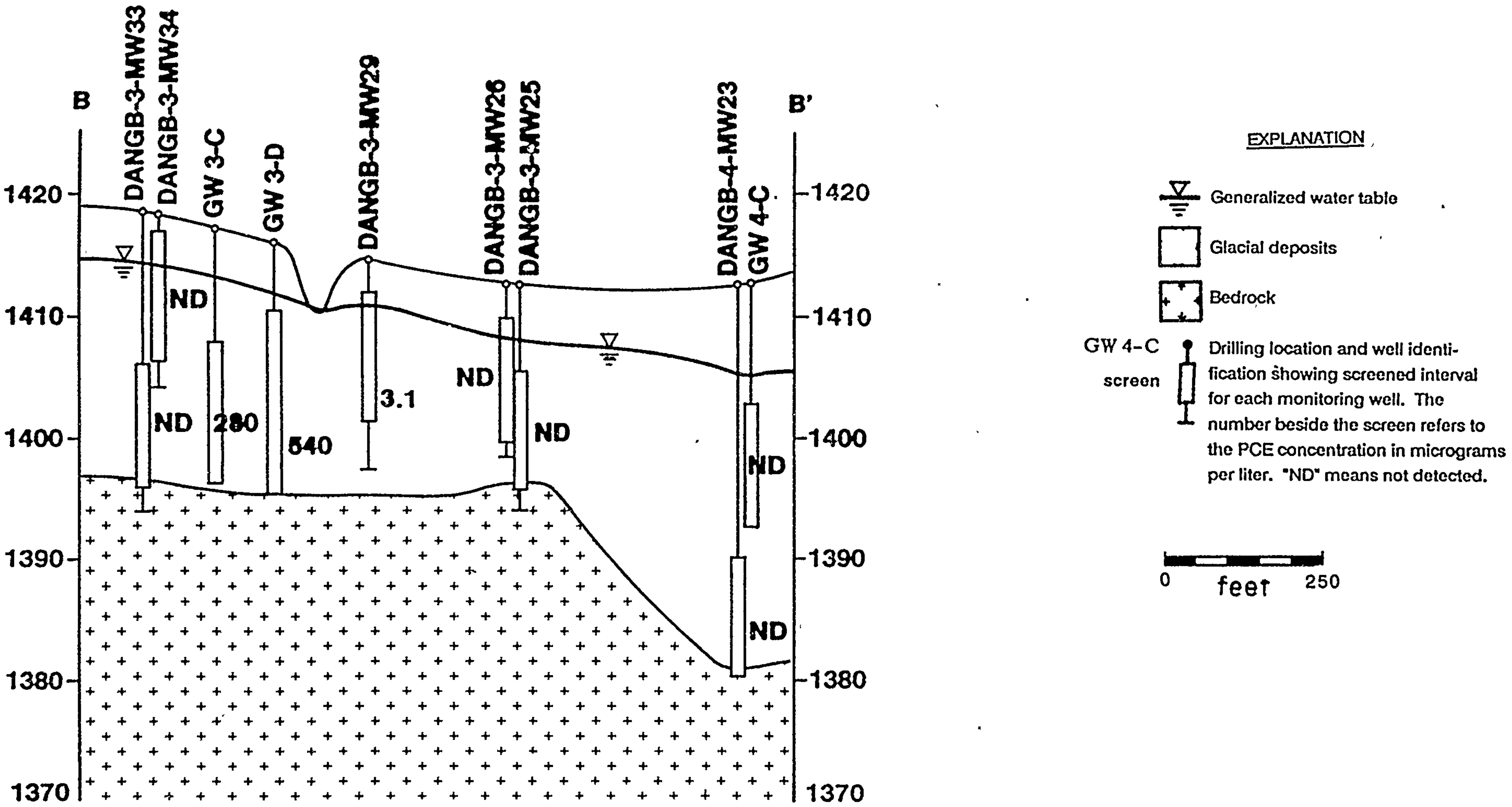
Figure 4-7 Vertical Distribution of Trichloroethene Contamination in Ground Water at Site 3.



Line of section shown on Figure 3-16.

Vertical Exaggeration x 20

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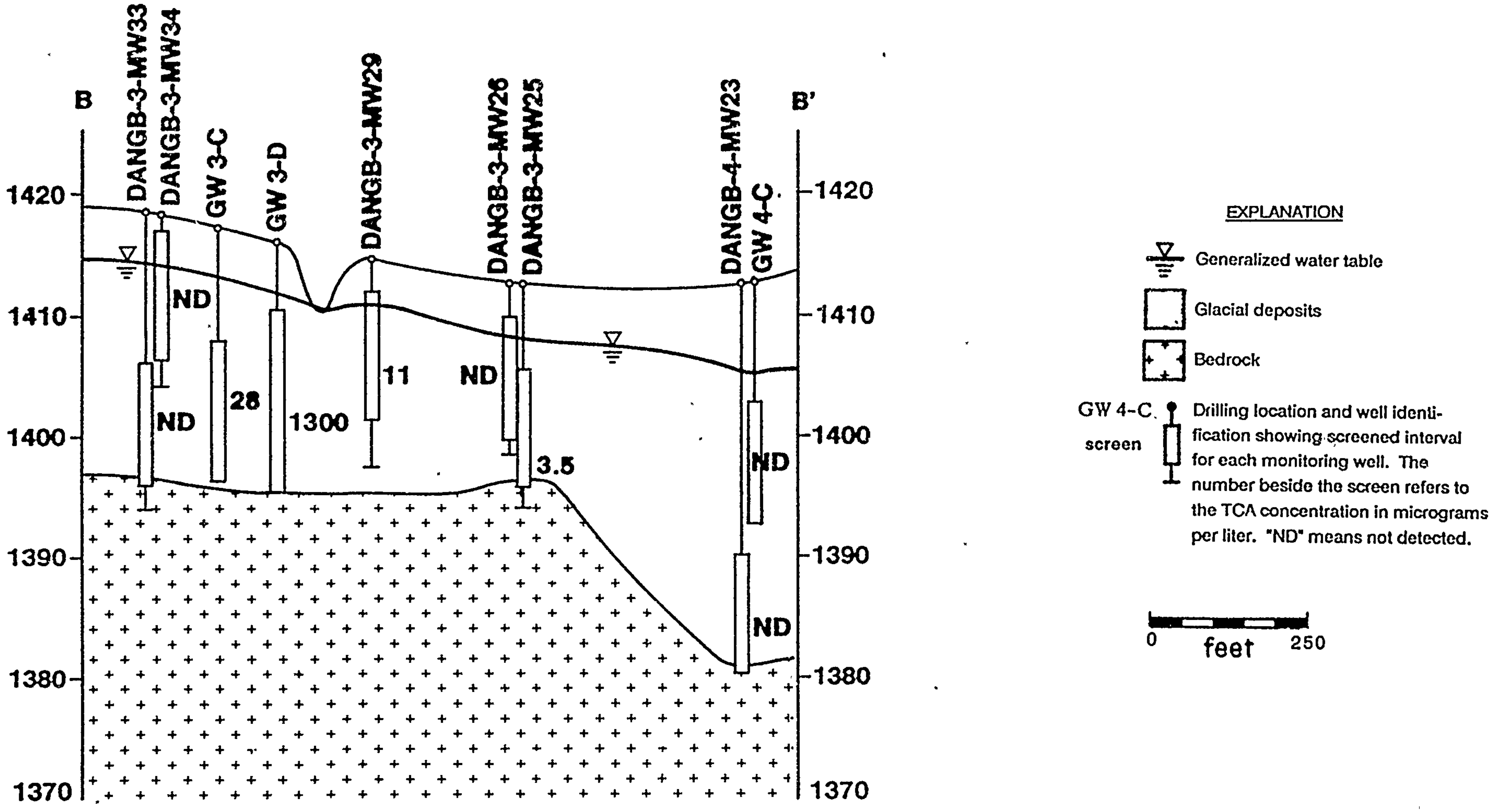
Figure 4-8 Vertical Distribution of Tetrachloroethene Contamination in Ground Water at Site 3.



Line of section shown on Figure 3-16.

Vertical Exaggeration x 20

Figure 4-9 Vertical Distribution of 1,1,1 Trichloroethane Contamination in Ground Water at Site 3.

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TABLE 4-24

VOLATILE ORGANIC COMPOUNDS

DETECTED IN SITE 4 SURFACE WATER AND SEDIMENT SAMPLES

(Water results in micrograms per liter;
sediment results in micrograms per kilograms)

Parameter	Sample Location									
	DANGB-4-SL11		DANGB-4-SL12		DANGB-4-SL13		DANGB-4-SL15		DANGB-4-SL16	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
Benzene	14	240	U(1)	U	930	U	80	2.3	1.2	U
Ethyl Benzene	6.2	550	U	760	74	44,000	6.3	U	U	U
Toluene	4.3	970	U	360	U	54,000	U	5.5	U	U
Xylenes	20.7	3,400	U	3,000	1,020	690,000	103	2.8	U	U
Trichloroethylene	U	U	0.23	U	0.98	U	U	U	0.59	U
Trans 1,2 Dichloroethylene	U	U	U	U	U	U	1.9	U	5.3	U

1. U indicates that the compound was analyzed for but was not detected.

upstream sampling location where flowing water occurs and is near the paired monitoring wells MW 9 and DANGB-4-MW21. Benzene was detected in the ground-water samples from these wells. The highest concentration of trichloroethene was 0.98 ug/L in water from sampling site DANGB-4-SL13 while the highest concentration of trans-1,2-dichloroethene was 5.3 ug/L in water from sampling site DANGB-4-SL16.

Total petroleum hydrocarbons were detected at 2.5 mg/L in the duplicate surface water sample from site DANGB-4-SL13.

Barium, cadmium, chromium, and lead were below detection limits in all surface water samples.

The volatile organic compounds, benzene, ethyl benzene, toluene and xylenes were detected in four sediment samples (Table 4-24). The highest levels of ethyl benzene, toluene and xylenes were detected in sediment at DANGB-4-SL13. The highest benzene level was detected at DANGB-4-SL11 which is the most downstream sampling location.

Total petroleum hydrocarbons were detected in all six sediment samples (Table 4-25). Concentrations in these samples ranged from 160 mg/kg to 7,000 mg/kg.

Barium, chromium and lead were detected in all the sediment samples (Table 4-26). Barium ranged in concentration from 42.1 to 74.1 mg/kg except for one sample with a level of 199 mg/kg at DANGB-4-SL16. Cadmium was detected at DANGB-4-SL12 at a concentration of 1.3 mg/kg. The other samples contained less than 0.9 mg/kg. Chromium levels ranged from 5.9 to 23.4 mg/kg. Lead concentrations ranged from 6.1 to 23.1 mg/kg with the high value occurring at DANGB-4-SL15. At all other locations, concentrations of barium, cadmium, chromium and lead were comparable to background values.

The temperature, pH and specific conductance were measured in the field at the time of sampling (Table 4-27).

4.5.2.2 Extent of Sediment and Surface Water Contamination

The highest level of sediment contamination by volatile organic compounds was detected at the three sampling locations in the drainage ditch immediately north of the fuel storage area. A secondary area of sediment contamination was detected at location DANGB-4-SL15. The most significant area of surface water contamination was also present in the drainage ditch north of the fuel storage area. The principal contaminants were fuel components. Surface water contamination was also present south of the fuel

TABLE 4-25

PETROLEUM HYDROCARBONS DETECTED IN SITE 4 SOIL SAMPLES

(Results in milligrams per kilogram.)

Sample Location	Petroleum Hydrocarbons
Surface Soil Samples	
DANGB-4-MW22-SS1	530
DANGB-4-MW23-SS1	370
DANGB-3-MW24-SS1	150
Sediment Samples	
DANGB-4-SL11	210
DANGB-4-SL12	1,600
DANGB-4-SL13	7,000
DANGB-4-SL14	190
DANGB-4-SL15	640
DANGB-4-SL16	160

TABLE 4-26

METALS DETECTED IN SITE 4 SEDIMENT SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal			
	Barium	Cadmium	Chromium	Lead
DANGB-4-SL11	57.8	U(1)	16.9	6.1
DANGB-4-SL12	42.1	1.3	8.7	13.8
DANGB-4-SL13	62.3	U	15.6	15.8
DANGB-4-SL14	48.0	U	5.9	12.9
DANGB-4-SL15	74.1	U	23.4	23.1
DANGB-4-SL16	199.0	U	21.3	9.6

1. U indicates that the compound was analyzed for but was not detected.

TABLE 4-27

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR SITE 4 WATER SAMPLES

Sample Location	Temperature (°C)	pH (pH units)	Specific Conductance (umhos/cm)
Surface Water Samples			
DANGB-4-SL11	11.6	6.96	401
DANGB-4-SL12	12.9	7.01	396
DANGB-4-SL13	10.3	6.63	592
DANGB-4-SL14	11.9	6.94	348
DANGB-4-SL15	19.3	7.23	667
DANGB-4-SL16	10.9	6.78	455
Ground-water Samples			
DANGB-4-MW21	12.1	7.01	733
DANGB-4-MW22	9.4	7.39	1,260
DANGB-4-MW23	12.0	7.78	1,300
DANGB-4-MW24	8.8	8.51	730
GW 4-A	10.1	6.74	680
GW 4-B	9.8	7.77	429
GW 4-C	9.6	7.60	1,192
GW 4-D	9.0	6.45	1,066
MW 8	14.2	6.49	588
MW 9	13.5	6.74	843
MW 10	17.2	6.96	451
MW 11	11.7	6.90	690

storage tanks at locations DANGB-4-SL15 and DANGB-4-SL16. Benzene was the principal organic volatile contaminant followed by xylenes and ethyl benzene. Trichloroethene and trans-1,2-dichloroethene were also detected.

The contaminated surface water in the north drainage ditch enters a culvert located at the west end of the ditch and flows northward through it. The surface water in the south drainage ditch along which samples DANGB-4-SL15 and DANGB-4-SL16 were taken also enters a culvert which presumably joins the north drainage ditch culvert.

4.5.3 Soil Contamination

Three soil samples were collected from the boreholes drilled for each of the four monitoring wells installed during this investigation (Figure 2-1). Soil samples were analyzed for volatile organic compounds, total petroleum hydrocarbons, barium, cadmium, chromium, and lead.

4.5.3.1 Soil Quality

Benzene was detected in one soil sample, the five- to seven-foot depth sample from the borehole for monitoring well DANGB-4-MW21 at a level of 11 ug/kg.

Trace amounts of tetrachloroethene and methylene chloride were detected in two samples during the Phase II, Stage 2 study (Table 1- 17).

Total petroleum hydrocarbons were detected in the surface soil samples from 3 boreholes. Concentrations were 530 mg/kg in the near surface sample (SS1) from DANGB-4-MW22, 370 mg/kg in the near surface sample (SS1) from DANGB-4-MW23, and 150 mg/kg in the near surface soil sample (SS1) from DANGB-4-MW24. The principal and most widespread parameter detected during prior studies was oil and grease (Tables 1-13 and Section 1.2.6.3).

Concentrations of barium, cadmium, chromium, and lead found in soil samples (Table 4-28) were comparable to background values.

4.5.3.2 Extent of Soil Contamination

The results from this and prior investigations have not indicated widespread soil contamination at this site.

4.5.4 Ground-Water Contamination

Ground-water samples were collected from the eight existing wells and from four wells installed during this investigation. Samples were analyzed for volatile organic compounds, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

TABLE 4-28

METALS DETECTED IN SITE 4 SOIL SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal			
	Barium	Cadmium	Chromium	Lead
DANGB-4-MW21				
SS1 0 to 1 foot	58.3	10.8	30.1	5.4
SS2 5 to 7 feet	67.8	10.9	33.1	7.3
SS3 18 to 19 feet	49.1	10.7	39.4	3.2
DANGB-4-MW22				
SS1 0 to 1 foot	91.7	0.32	11.0	6.5
SS2 5 to 7 feet	85.6	11.0	36.8	5.9
SS3 30 to 31 feet	39.1	9.7	26.7	2.9
DANGB-4-MW23				
SS1 0 to 1 foot	51.3	10.6	23.6	3.2
SS2 8 to 9 feet	51.4	8.5	23.7	4.2
SS3 30 to 31 feet	27.9	9.8	20.4	2.6
DANGB-4-MW24				
SS1 0 to 2 feet	49.0	11.4	32.6	6.4
SS2 3 to 4 feet	40.2	8.8	25.6	2.8
SS3 32 to 34 feet	45.9	11.5	49.3	4.1

4.5.4.1 Ground-Water Quality

Volatile organic compounds were detected in water from monitoring wells MW 9 and DANGB-4-MW21. Benzene at a concentration of 3.2 ug/L and xylenes at a concentration of 2.7 ug/L were detected in MW 9. Benzene at a concentration of 22 ug/L was detected in DANGB-4-MW21.

Volatile organic compounds were detected in ground-water samples from the well pair MW 9 and DANGB-4-MW21 located east of the fuel storage tanks and near the surface drainage ditch.

Total petroleum hydrocarbons were detected in water from well GW 4-A at a concentration of 3.24 mg/L. Total petroleum hydrocarbons levels in water samples from the other wells were below the detection limit of 1.5 mg/L.

Chromium, cadmium, and barium were detected in several samples at levels considered to be in the background range (Table 4-29). Barium was detected at five monitoring wells and ranged in concentration from 60 to 170 ug/L; monitoring wells GW 4-A and GW 4-D both had a concentration of 170 ug/L of barium. Cadmium was detected in monitoring wells GW 4-B and MW 9 at levels of 2.5 and 3.1 ug/L, respectively. Chromium was detected in six samples with the highest level of 3.9 ug/L being detected at GW 4-A. Lead was below detection limits in all samples.

Temperature, pH, and specific conductance of the ground water were determined in the field at the time of sampling (Table 4-27). Temperature ranged from 9.0 to 17.2°C. Variation of pH was from 6.49 to 8.51. Specific conductance ranged from 429 to 1,300 umhos/cm.

4.5.4.2 Extent of Ground-Water Contamination

Ground-water contamination could only migrate off site by discharging into the surface drainage adjacent to the site. Oily seepages were noted in the drainage ditch north of the fuel storage tanks. In vicinity of the storage tanks, ground-water flow is toward the drainage ditch north of the storage tanks which is a ground-water discharge area. In the southwest portion of the site, ground-water flow is toward the drainage ditch on the southwest portion of the site.

4.6 NATURE AND EXTENT OF CONTAMINATION AT SITE 8

This section presents the results of the chemical analyses on the soil, ground water, surface water, and sediment samples collected at Site 8. The chemical results are interpreted to determine the extent of contamination in each of the above sampling media.

TABLE 4-29

METALS DETECTED IN SITE 4 GROUND-WATER SAMPLES

(Concentrations in micrograms per liter.)

Sample Location	Metal(1)		
	Barium	Cadmium	Chromium
DANGB-4-MW21	60	U(2)	U
DANGB-4-MW22	110	U	U
DANGB-4-MW23	140	U	U
DANGB-4-MW24	U	U	2.4
GW 4-A	170	U	3.9
GW 4-B	U	3.1	2.2
GW 4-C	U	U	U
GW 4-D	170	U	2.8
MW 8	U	U	U
MW 9	90	2.5	U
MW 10	U	U	2.2
MW 11	U	U	U

1. Lead was also analyzed for but was not detected.
2. U indicates that the compound was analyzed for but not detected.

4.6.1 Source of Contamination

A significant contaminant source area was not located during this investigation. Site 8 is shown on Figures 1-3 and 1-13.

4.6.2 Surface Water and Sediment Contamination

Surface water samples were collected from two locations and sediment samples were collected from three locations from a drainage ditch along the northern side of the site. Samples were analyzed for volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

4.6.2.1 Surface Water and Sediment Quality

No volatile organic compounds, petroleum hydrocarbons, pesticides, or PCBs were detected in the surface water samples and concentrations of barium, cadmium, chromium, and lead were below detection limits in both samples.

No volatile or semi-volatile organic compounds were detected in the sediment samples.

Total petroleum hydrocarbons at 200 mg/kg was detected in sediment at site DANGB-8-SL19.

Concentrations of barium, cadmium, chromium, and lead in sediment samples were comparable to those of background sediment samples (Table 4-30).

Temperature, pH and specific conductance of surface water samples were determined in the field at the time of sampling (Table 4-31).

4.6.2.2 Extent of Surface Water and Sediment Contamination

Surface water and sediment contamination are not evident at Site 8.

4.6.3 Soil Contamination

Samples were obtained from three soil sampling boreholes and from two boreholes drilled for the construction of monitoring wells. Subsurface soil samples were analyzed for volatile and semi-volatile organic compounds, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

4.6.3.1 Soil Quality

The results of a 24-point surface soil sampling survey indicated the presence of pesticides and PCBs in surface soils (Figure 4-10). The most commonly occurring pesticide, 4,4'-DDT, was present in concentrations ranging from 20 to 1,500 ug/kg (Table 4-32). PCB 1254 was detected at 330 ug/kg in sample DANGB-8-SSD1.

Total petroleum hydrocarbons were detected in two soil samples. A value of 1,540 mg/kg was obtained from the surface soil sample, DANGB-8-SSA0, but

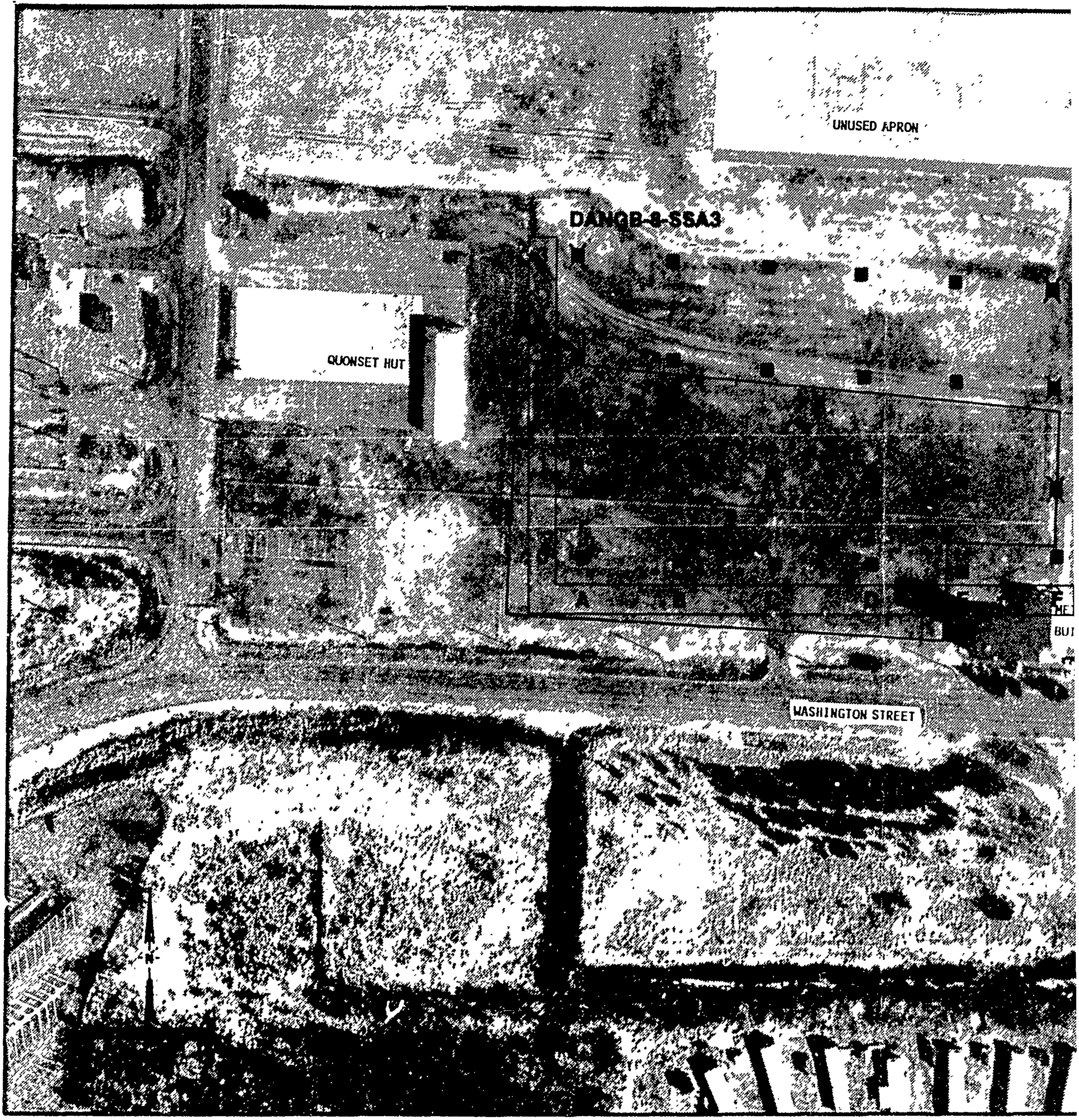
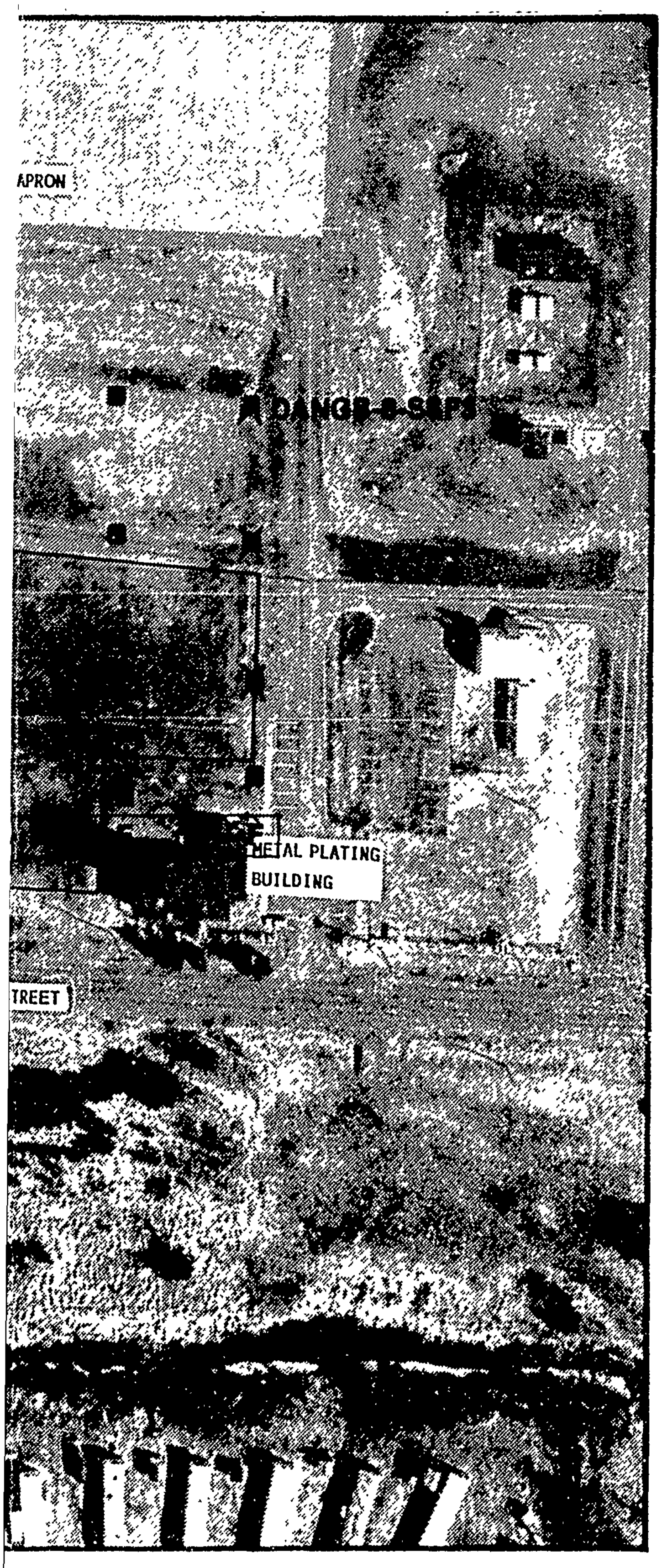


Figure 4-10 Location of Pesticide and PCB Occurrences in Surface Soils at Site 8.



EXPLANATION

■ DANGB-8-SSA3 Shallow soil sample location and identification.

■ Location where pesticides or PCBs were detected in the soil sample.

▢ Approximate boundary of Storage Area (old DPDO office).

TABLE 4-30

METALS DETECTED IN SITE 8 SEDIMENT SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal[1]		
	Barium	Chromium	Lead
DANGB-8-SL17	75.3	14.8	6.5
DANGB-8-SL18	45.5	26.8	5.7
DANGB-8-SL19	84.8	13.2	11.5

1. Cadmium was also analyzed for but was not detected.

TABLE 4-31

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR SITE 8 WATER SAMPLES

Sample Location	Temperature (^{o}C)	pH (pH units)	Specific Conductance (umhos/cm)
Surface Water Samples			
DANGB-8-SL17	14.8	6.98	459
DANGB-8-SL19	18.4	6.37	281
Ground-water Samples			
DANGB-8-MW14	9.8	7.07	260
DANGB-8-MW15	12.3	7.03	353
DANGB-8-MW16	8.8	8.62	384
DANGB-8-MW17	9.9	7.23	670
GW 8-A	12.2	7.04	1,020
GW 8-B	12.2	7.45	1,300
GW 8-C	15.4	6.69	980

TABLE 4-32

ORGANOCHLORINE PESTICIDES AND PCBs DETECTED IN SITE 8 SOIL SAMPLES

(Results in micrograms per kilogram.)

Sample Location	Compound				
	4,4'-DDD	4,4'-DDE	4,4'-DDT	Dieldrin	PCB 1254
DANGB-8-SSA1	25	27	110	U(1)	U
DANGB-8-SSA2	U	U	74	U	U
DANGB-8-SSA3	180	130	1,500	U	U
DANGB-8-SSB0	21	18	U	U	U
DANGB-8-SSB1	131	U	71	U	U
DANGB-8-SSC1	U	U	U	33	U
DANGB-8-SSD1	U	U	U	U	330
DANGB-8-SSF1	U	U	20	U	U
DANGB-8-SSF2	U	U	24	U	U
DANGB-8-SSF3	29	33	77	U	U

1. U indicates that the compound was analyzed for but not detected.

a duplicate sample had a value less than the detection limit of 100 mg/kg. A value just above the detection limit of 160 mg/kg was obtained from a soil sample taken from a depth of 8 to 11 feet at location DANGB-8-MW18.

Levels of barium, cadmium, chromium and lead comparable to background values were present in the soil samples (Table 4-33).

4.6.3.2 Extent of Soil Contamination

The results of a 24-point surface sampling survey for pesticides and total petroleum hydrocarbons identified only one location with high levels of pesticides. The most common pesticide detected was 4,4'-DDT (Table 4-32). During a previous study, soil contamination was noted in the center of the eastern edge and in the center of the western edge of the site (Table 1-20, Section 1.2.7.3).

The results of this investigation indicate that widespread soil contamination is not present at this site.

4.6.4 Ground-Water Contamination

Three existing monitoring wells and four monitoring wells constructed during this investigation were sampled. Samples were analyzed for volatile and semi-volatile organic compounds, pesticides and PCBs, total petroleum hydrocarbons, barium, cadmium, chromium and lead.

4.6.4.1 Ground-Water Quality

No volatile or semi-volatile organic compounds, pesticides and PCBs, or total petroleum hydrocarbons were detected in ground water at Site 8.

Barium was detected in three samples and concentrations ranged from 50 to 220 ug/L with the highest level being present at GW 8-C (Table 4-34). Chromium was detected in three samples with the highest value being 2.7 ug/L at GW 8-C. A previous study found much higher levels of chromium and barium (Table 1-18). Cadmium and lead were below detection limits in all of the ground water samples.

Temperature, pH, and specific conductance of each ground-water sample were determined in the field at the time of sampling (Table 4-29). Temperature varied from 8.9 to 15.4°C. A variation in pH from 6.69 to 8.62 pH units was observed. Specific conductance ranged from 260 to 1,300 umhos/cm. In contrast to other sites, deep wells had lower specific conductances than shallow wells.

4.6.4.2 Extent of Ground-Water Contamination

No ground-water contamination was apparent at Site 8.

TABLE 4-33

METALS DETECTED IN SITE 8 SOIL SAMPLES

(Concentrations in milligrams per kilogram.)

Sample Location	Metal			
	Barium	Cadmium	Chromium	Lead
DANGB-8-MW14				
SS1 0 to 1 foot	49.9	6.7	24.6	9.1
SS3 10 to 12 feet	56.6	10.3	41.0	11.4
SS8 38 to 40 feet	18.9	13.9	36.5	3.5
DANGB-8-MW16				
SS1 0 to 1 foot	20.0	6.2	20.0	10.6
SS2 4 to 5 feet	24.4	7.3	24.4	8.1
SS6 29 to 30 feet	24.7	10.1	21.5	4.7
DANGB-8-MW18				
SS1 0 to 2 feet	31.8	10.1	25.6	3.6
SS2 8 to 11 feet	51.1	11.5	40.5	5.3
SS3 14 to 15 feet	70.7	10.3	30.3	5.3
DANGB-8-MW19				
SS1 0 to 2 feet	37.8	9.9	37.8	7.7
SS2 6.5 to 7.5 feet	43.4	14.4	43.4	4.4
SS3 9 to 10 feet	25.0	9.6	25.0	6.4
DANGB-8-MW20				
SS1 0 to 2 feet	146.0	9.0	38.6	10.5
SS2 6 to 8 feet	56.5	9.0	30.2	4.9
SS4 15 to 20.5 feet	27.2	11.6	24.8	3.2

TABLE 4-34

METALS DETECTED IN SITE 8 GROUND-WATER SAMPLES

(Concentrations in micrograms per liter.)

Sample Location	Metal			
	Barium	Cadmium	Chromium	Lead
GW 8-A	U(1)	U	U	U
GW 8-B	50	U	U	U
GW 8-C	220	U	2.7	U
DANGB-8-MW14	U	U	2.4	U
DANGB-8-MW15	U	U	U	U
DANGB-8-MW16	U	U	2.1	U
DANGB-8-MW17	150	U	2.7	U

1. U indicates that compound was analyzed for but was not detected.

4.7 NATURE AND EXTENT OF CONTAMINATION AT SITE 10

This section presents the results of the radiological analyses for ground-water samples collected at Site 10. No other kinds of samples were collected during this or previous investigations. The chemical results are interpreted to determine the extent of contamination in the above sampling media.

4.7.1 Source of Contamination

The source of the radiological contaminants is believed to be a 15-foot deep ditch approximately 40 feet long containing low level radioactive materials such as cathode ray tubes and instrument dials. The location of the ditch is uncertain, but aerial photographs indicate disturbed ground east of the area originally thought to include Site 10 (see Figures 1-3 and 1-16). This area is east and hydrologically upgradient of monitoring well GW 10-A.

4.7.2 Ground-Water Contamination

Two rounds of sampling were done on the three existing monitoring wells. The first round of samples were collected in late September, 1988 and were analyzed for the parameters gross alpha, gross beta, radium 226, and tritium. The second round of samples were collected in late February 1989 and were analyzed for gross alpha, gross beta, radium 226 and radium 228. Results are given in Table 4-33.

4.7.2.1 Ground-Water Quality

Radioactivity was detected in the ground-water samples taken at Site 10 (Table 4-35). Ground-water samples collected in late September had the following results. Gross alpha was detected in the range of 7.0 ± 3 to 33 ± 10 picocuries per liter (pCi/L) with the highest level being found at GW 10-A. Gross beta was detected in the range of 11 ± 4 to 150 ± 30 pCi/L with the highest level also being recorded at GW 10-A. Concentrations of radium 226 varied from 0.3 ± 0.2 to 4.4 ± 0.6 pCi/L with the highest levels again being found in GW 10-A. Tritium was below detection limits in all samples.

Ground-water samples collected in early March had higher levels of the radiological parameters gross alpha and gross beta than samples collected in late September. Gross alpha varied from 72 ± 41 to as high as 382 ± 154 pCi/L in ground water from well GW 10-A. Gross beta varied from 92 ± 45 to 253 ± 104 with the highest level being present in water from well GW 10-A. Radium 226, radium 228, and tritium were below detection limits.

TABLE 4-35

SUMMARY OF RADIOLOGICAL RESULTS FOR GROUND-WATER SAMPLES TAKEN AT SITE 10

(Results in picocuries per liter)

Parameter	Sample Location							
	GW 10-A			GW 10-B			GW 10-C	
	Sept. 1988	March 1989	March 1989 DUP	Sept. 1988	Sept. 1988 DUP	March 1989	Sept. 1988	March 1989
Gross Alpha [15](1)	33 ± 10	382 ± 154	154 ± 65	10 ±10	U	85 ± 50	7.0 ± 3	72 ± 41
Gross Beta [50]	150 ± 30	253 ± 104	155 ± 57	78 ± 9	34 ± 14	211 ± 67	11 ± 4	92 ± 45
Ra 226 [5]	4.4 ± 0.6	<0.6	<0.6	1.4 ± 0.3	2.4 ± 0.4	<0.6	0.3 ± 0.2	<0.6
Ra 228 [5]	N.T.	<2.5	<2.5	N.T.	N.T.	<2.4	N.T.	<2.9
Tritium [20,000]	<2,000	<339	<339	<2,000	<2,000	<339	<2,000	<339

1. Numbers in brackets are Federal Drinking Water Standards.
2. U indicates that the parameter was analyzed for but not detected.
3. N.T. indicates that the parameter was not analyzed for.

TABLE 4-36*

TEMPERATURE, pH AND SPECIFIC CONDUCTANCE MEASUREMENTS FOR SITE 10 WATER SAMPLES

Parameter	Well		
	GW 10-A	GW 10-B	GW 10-C
Temperature (^oC)			
September 1988	9.9	10.7	10.5
February 1989	-	-0.9	-0.6
pH (pH Units)			
September 1988	7.10	7.02	6.96
February 1989	7.3	9.39	8.09
Specific Conductance (umhos/cm)			
September 1988	550	510	500
February 1989	-	-	-

\- Measurements not taken or validity suspect due to extremely cold air temperatures.

* Revised January 6, 1990.

The parameters, temperature, pH and specific conductance were determined in the field at the time of sampling (see Table 4-36).

4.7.2.2 Extent of Ground-Water Contamination

Results from this and the Phase II, Stage 2 study suggest that levels of radiological parameters are increasing with time. Initial results indicated that gross alpha and radium 226 were at levels equal to the Maximum Contaminant Levels (MCL) promulgated in the Federal Drinking Water Standards only in well GW 10-B (Dames & Moore, 1987). In September of 1988, gross alpha and gross beta exceeded MCLs in water from well GW 10-A. Results of the last sampling round in March of 1989 showed that gross alpha and gross beta exceeded MCLs in all three wells.

The data could indicate that ground water containing radioactive isotopes is migrating in the direction of the Site 10 monitoring wells. To verify the above hypothesis, the radioactive isotopes responsible for the high levels of gross alpha and beta would need to be identified. However, inconsistency in the analytical results may be due to analytical variations among the various labs that the samples were sent to for analysis. Another possibility is that a portion of the radioactivity is due to radon, a decay product of Radium 226. Since radon is a gas, which has a short half life and is also easily lost through volatilization, the amount of radioactivity detected is highly dependent on the time interval between sampling and analysis.

Because of the uncertainty of the source area and the analytical results, the precise nature and extent of contamination at Site 10 is unknown at the present time.

SECTION 5
CONTAMINANT FATE AND TRANSPORT

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SECTION 5
CONTAMINANT FATE AND TRANSPORT

General concepts and specific chemical and physical properties which affect the fate and transport of contaminants are discussed in the introduction. These concepts and properties permit predictions to be made about the amount and extent of contamination in the future which is a result of the present sources. This information is used in subsequent sections to discuss the fate and transport of the contaminants described in Section 4 in relation to the site specific geology and hydrogeology described in Section 3.

5.1 INTRODUCTION

In this section the mechanisms and processes which affect contaminant fate and transport are discussed.

5.1.1 Contaminant Fate

The fate of contaminants is related to their persistence in the environment. Persistence is a measure of how long a chemical will exist in a specific medium and is usually reported in terms of half life. A half life is the time required for the concentration of a substance to decrease from its initial level to one-half of its initial level (Table 5-1). Processes which reduce the concentration of contaminants include biochemical degradation and volatilization.

The chemical transformation of a toxic organic compound to an innocuous substance is biologically mediated in the natural environment and proceeds under either aerobic, oxidative conditions or anaerobic, reducing conditions. The transformation of halogenated organic compounds into intermediate forms which can be readily biodegraded by common metabolic pathways is initiated by certain key processes including: dehalogenation, the removal of a halogen ion; hydrolysis, the substitution of a hydroxyl ion for a halogen ion; hydrogenolysis, the replacement of a halogen ion with a hydrogen ion; dihalo-elimination, where two halogen ions are lost to form an alkene from an alkane; and ring cleavage, the transformation of an aromatic hydrocarbon to the open-chain aliphatic structure. The rate of degradation is influenced by the structure of the pollutant, temperature, salinity, pH and the availability of inorganic nutrients and oxygen. The half lives of these reactions range from days to centuries (Vogel and others, 1987).

TABLE 5-1
SUMMARY OF CHEMICAL AND PHYSICAL PROPERTIES FOR ORGANIC COMPOUNDS DETECTED AT DULUTH ANGB(1)

	Water Solubility (mg/L)	Henry's Law Constant (atm-m^3/mol)	Organic Carbon Partition Coefficient (K_{oc}, ml/g)	Surface Water Half Life Range (days)(2)
<u>Volatile Organics</u>				
Benzene	1.75E+03	5.59E-03	83	1 - 6
Chlorobenzene	4.66E+02	3.72E-03	330	-
1,2-Dichlorobenzene	1.00E+02	1.93E-03	1,700	1.5 - 8.5
1,1-Dichloroethane	5.50E+03	4.31E-03	30	1 - 5
1,2-Dichloroethane	8.52E+03	9.78E-04	14	0.17
1,1-Dichloroethene	2.25E+03	3.40E-02	65	1 - 6
Trans-1,2-Dichloroethene	6.30E+03	6.56E-03	59	1 - 6
Ethyl Benzene	1.52E+02	6.43E-03	1,100	1.5 - 7.5
Tetrachloroethene	1.50E+02	2.59E-02	364	1 - 30
Toluene	5.35E+02	6.37E-03	330	0.17
1,1,1 Trichloroethane	1.50E+03	1.44E-02	152	0.14 - 7
Trichloroethene	1.10E+03	9.10E-03	126	1 - 90
Vinyl Chloride	2.67E+03	8.1E-02	57	1 - 5
Xylenes	1.98E+02	7.04E-03	240	1.5 - 9
<u>Semi-Volatile Organics</u>				
Anthracene	4.50E-02	1.02E-03	14,000	-
Bis(2-ethylhexyl)phthalate	-	-	-	-
Chrysene	1.80E-03	1.05E-06	200,000	0.2
Diethyl Phthalate	8.96E+02	1.14E-06	117	-
Dimethyl Phthalate	-	-	-	-
Floranthrene	2.06E-01	6.46E-06	38,000	1 - 2
Naphthalene	3.17E+01	4.60E-04	940	-
Phenanthrene	1.00E+00	1.59E-04	14,000	-
Pyrene	1.32E-01	5.04E-06	38,000	-
<u>Pesticides and PCBs</u>				
4,4'-DDD	1.00E-901	7.96E-06	7,700,000	-
4,4'-DDE	4.00E-092	6.80E-05	4,400,000	-
4,4'-DDT	5.00E-03	5.13E-04	243,000	56 - 110
Dieldrin	1.95E-01	4.58E-07	1,700	-
PCB-1242	3.10E-02	1.07E-03	530,000	2 - 12.9
PCB-1254	3.10E-02	1.07E-03	530,000	2 - 12.9

1. Data from USEPA, 1986a.
2. These half lives are the result of all removal mechanisms including biotransformation, phase transfer volatilization, and chemical transformation.

Volatilization is the evaporation of an organic compound from the ground water, surface water, or soil to the soil gas or air. A physical property used to estimate the relative ease of release of volatile organic compounds to air is Henry's Law Constant (Table 5-1). The higher this constant, the greater the tendency for a compound to evaporate. Lower molecular weight volatile organic compounds which are commonly used as solvents are characterized by high Henry's Law Constants. In order for volatilization of a chemical to occur in the soil, surface water or ground water, the chemical must be able to move to a soil surface or to the top of the water table surface.

Pesticides and PCBs are nonvolatile. Degradation of PCBs by bacteria has been demonstrated, but heavily substituted PCBs appear to resist degradation and accumulate in environments where less chlorinated PCBs are degraded (Rochkind-Dubinsky, 1987). An indication of the persistence of PCBs is that they have not been produced since 1978 but are still present in the environment.

Unlike organic compounds, metals do not volatilize and are not degradable through biological or chemical actions. They can be considered to be persistent indefinitely in the environment.

5.1.2 Contaminant Transport

The transport of dissolved organic contaminants in ground water is controlled by solubility, advection, diffusion, dispersion, and adsorption onto soil surfaces.

Solubility is the maximum concentration of a chemical that dissolves in pure water at a specific temperature and pH. The solubility of organic compounds in water is a function of their affinity for the water molecule which depends to a great extent on the polarity of the organic compound. Highly soluble chemicals can be rapidly leached from wastes and contaminated soils and are generally mobile in ground water.

Advection is the transportation of contaminants by movement with flowing ground water.

Diffusion is a molecular process that causes a spreading of contaminants from areas of greater to lesser concentration and can occur without water movement.

Dispersion occurs because of mechanical mixing caused by the movement of water through the aquifer.

As a result of diffusion and dispersion, the leading edge of a contaminant front is diluted. The contaminant front will first be detected at a very low concentration. The concentration gradually increases toward the source. This effect is due to some of the water molecules and contaminant molecules traveling at a faster rate than the average linear ground-water velocity and others traveling at a slower rate than the average velocity.

Adsorption onto soil surfaces causes what is known as the hydrophobic effect (Roy and Griffin, 1985) and may slow the transport of dissolved organic compounds in ground water. Hydrophobic compounds generally have a low aqueous solubility and a tendency to be attracted to non-polar or organic surfaces in soil. Hydrophobic compounds tend to be adsorbed to the organic fraction of soil if the organic content is greater than one weight percent (Karikoff and others, 1979).

The soil-water partitioning coefficient, K_{OC}, is a measure of the tendency for organics to be adsorbed to soil where:

$$K_{OC} = \frac{\text{micrograms of chemical / grams of organic matter}}{\text{micrograms of chemical / gram of water}}$$

The higher the K_{OC} value, the greater the tendency of a chemical to be attracted to the organic fraction of the soil and the lower its mobility in the environment. Correlation of K_{OC} to mobility in the environment has been suggested (Griffin and Roy, 1985; Dragun, 1988) and demonstrated at a hazardous waste facility in Indiana (Fetter, 1988).

Sorption of an organic compound onto the organic fraction or mineral fraction of a soil retards the movement of the compound in ground water. The mobility of organic solvents in ground water depends primarily on the K_{OC} value of the compound, the organic content of the saturated soil, and solubility of the chemical. Organic solvent compounds are more strongly sorbed to sediments in surface drainage in direct correlation to the fact that organic materials comprise a larger fraction of sediment compared to soil at depth (see Table 4-16).

Pesticides and PCBs generally have low aqueous solubilities, high K_{OC} values and long half-lives. The high K_{OC} values for the pesticides and PCBs indicate that they will have a low mobility in the environment if water is the primary solvent.

The mobility of metals in the environment depends on pH, oxidation potential, solubility, and availability of complexing agents which affect the solubility. In general, the mobility of metals in the environment is low with sorption onto clay minerals being the most important controlling factor. However, under certain reduction and oxidation conditions, metals can have significantly increased solubility and hence greater mobility. For example, the oxidation of some metals such as arsenic increases its solubility and mobility by forming soluble complexes. Reduction of the mercuric ion can lead to the formation of methylated mercury which greatly increases the mobility of mercury.

5.2 CONTAMINANT FATE AND TRANSPORT AT SITE 2

The chemical and physical properties of the contaminants present at this site are evaluated with respect to the geologic and hydrogeologic conditions at the site to predict transport and fate.

5.2.1 Summary of Contaminants

Surface water is not contaminated at the locations sampled.

Sediment downgradient from FTA-1 is contaminated with trichloroethene.

Soil from near the center of FTA-2 is contaminated with the volatile organic compounds: benzene, toluene, ethyl benzene, xylenes, 1,2-dichloroethane, chlorobenzene, 1,2-dichlorobenzene, trans-1,2-dichloroethene, 1,1,2,2-tetrachloroethane, tetrachloroethene and trichloroethene. It is also contaminated with the semi-volatile organic compounds: naphthalene, pyrene, 2-methylnaphthalene, bis(2-ethylhexyl)phthalate and dibutylphthalate. Petroleum hydrocarbons and the metals: barium, cadmium, chromium and lead were also detected.

Ground water near FTA-1 is contaminated with the volatile organic compounds: trans-1,2-dichloroethene and trichloroethene. Ground water near FTA-2 is contaminated with the volatile organic compounds: benzene, 1,1-dichloroethene, trans-1,2-dichloroethene, trichloroethene and vinyl chloride. Ground water from the area between FTA-1 and FTA-2 and from the western part of the site is contaminated with low levels of the semi-volatile organic compound, dimethyl phthalate.

5.2.2 Potential Routes of Migration

Contaminants may leach from the contaminated soil at FTA-2 into the ground water.

Contaminant migration on site occurs by ground-water transport.

Surface water transport of discharged ground water is a possible future contaminant migration pathway.

5.2.3 Contaminant Persistence

Physical, chemical, and biological processes which affect the persistence of the volatile organic compound contaminants at Site 2 include volatilization, diffusion, and biochemical degradation.

Volatilization will decrease the concentrations of ground-water contaminants in shallow ground water and soil. The low molecular weight aromatic hydrocarbon compounds, benzene, toluene, ethyl benzene and xylenes will tend to cause them to partially evaporate or volatilize. Volatilization of trichloroethene and the other volatile halocarbons is probably also occurring.

Diffusion through the soil gas and into the air is limited by the generally low permeability of the glacial sediments

Biochemical degradation of aliphatic and aromatic hydrocarbons by microorganisms is well known (Wilson and others, 1986; Barker and others, 1987) and is probably occurring. Bacterial action on the hydrocarbons present at FTA-2 will progressively reduce contaminant levels in the soil over time. The volatile aromatic hydrocarbons will be degraded by a combination of bacterial and chemical breakdown. Chlorinated ethenes such as trichloroethene and tetrachloroethene have been shown to undergo progressive dehalogenation to trans-1,2-dichloroethene which can undergo hydrogenolysis to form vinyl chloride (Barrio-Lage and others, 1986). Biodegradation of trichloroethene by bacterial action has been known to occur (Kleopfer and others, 1985; Barrio-Lage and others, 1987) and is probably occurring at this site. Biodegradation of the other detected chlorinated solvents, such as vinyl chloride (Vogel and McCarty, 1985), may also be taking place.

In spite of the many processes that serve to decrease the concentration of trichloroethene in ground water and soil, trichloroethene is generally persistent in the environment. The presence of trichloroethene and its decomposition products in ground water beneath FTA-1 which has not been used since the early sixties demonstrates the persistence of this compound in ground water.

The metals, barium, cadmium, chromium and lead are expected to persist indefinitely.

5.2.4 Contaminant Mobility and Migration

The mobility of the volatile organic compounds in ground water along the route of transport depends primarily on the organic content of the saturated soils and the solubility of the contaminant. Published data indicate that benzene is highly mobile in ground-water/soil systems and trichloroethene, tetrachloroethene, toluene, and ortho xylene are moderately mobile (Roy and Griffin, 1985; USEPA, 1986a). Ethyl benzene and para and meta xylene have low mobilities. The aliphatic organic compounds which compose most of the petroleum hydrocarbons generally have low mobilities since they have negligible solubilities and high adsorption coefficients.

5.2.4.1 Contaminant Migration in Surface Water

It may be that only trace levels of volatile organic compounds are transported by surface water at this site. Dilution of contaminated ground water as it discharges into flowing drainage ditches reduces contaminant concentrations in the water. Levels of contaminants in the ground water are such that a one to ten dilution with surface water will decrease levels below federal drinking water limits.

5.2.4.2 Contaminant Migration in Soil

The presence of volatile organic compounds from the surface down to the top of the water table below FTA-2 indicates that compounds such as benzene, toluene and trans-1,2-dichloroethene have been and probably will be transported downward. Continued releases of these contaminants from the soil to the ground water are likely to occur. The quantity of contaminants available to be released to the ground water will decrease with time due to the loss of contaminants from the system as a result of volatilization, biodegradation and transport

Levels of barium and lead above background were detected in three near surface samples from the center of FTA-2. These metals should be relatively immobile since they form insoluble compounds and are readily sorbed to soil. Since no metal contamination was detected in Site 2 ground water, the metals contamination found in the soil is not likely to affect ground-water quality in the future.

5.2.4.3 Contaminant Migration in Ground Water

Hydrogeologic data indicate that both fire training areas are located on a ground-water recharge area within which there is a downward component to the ground-water flow (see Figures 3-12 and 3-13). Ground-water movement is to the southeast under FTA-1 and to the northeast under FTA-2. The ground water discharges to the drainage ditch on the southwest, southeast and northeast sides and to the marshy area on the north and northwest sides of the site. Evidence that ground-water at Site 2 discharges to the surface drainage at the site is the upward flow component at the paired well point location to the west of FTA-2. This location is the only paired well location at this site and therefore is the only on-site location at which the direction of vertical flow components could be determined. Paired wells at other sites consistently indicate upward flow components near surface drainage features. The only exception to this are the paired monitoring wells, DANGB-4-MW21 and MW-9 which are near a drainage ditch at Site 4, but are also located on a bedrock high which causes a very local variation in the ground-water flow pattern.

Movement of dissolved contaminants from the fire training areas will be the same as that of the ground-water movement and will discharge to the surface drainage ditches which are downgradient from them. Contaminants from FTA-1 will discharge to the drainage ditch which is 75 to 100 feet to the southeast. Discharge may be in the form of seepage during the non-growing season and as evapotranspiration during the growing season. Contaminants from FTA-2 will discharge to the drainage ditch which is 700 feet to the northeast. Contaminants that are heavier than water such as trichloroethene probably migrated downward from their point of release as they dispersed due to diffusion and the existence of a downward flow component.

The Fire Training Area 2 came into use in the early 1960s or about 25 years ago. Monitoring well GW 2-E is contaminated. It is 250 feet, and the farthest downgradient well, from the contaminant source. These data indicate a minimum migration rate of the principal contaminants including trichloroethene of 10 feet per year. The average ground-water flow velocity in glacial materials at this site was estimated to be 25 feet per year from the slug test data (see Section 3.2.4). The maximum extent for the contaminants migrating at this same velocity would be 625 feet. At this migration rate, they should not yet have reached the drainage ditch which is 700 feet away.

5.3 CONTAMINANT FATE AND TRANSPORT AT SITE 3

The physical and chemical properties of contaminants present at this site are evaluated with respect to the site geologic and hydrogeologic conditions to predict their transport and fate.

5.3.1 Summary of Contaminants

The surface water is contaminated with the volatile organic compounds: trichloroethene, 1,1-dichloroethane, 1,1-dichloroethylene, trans-1,2-dichloroethene, 1,1,1-trichloroethane and tetrachloroethene. The organic compounds, 1,1,1-trichloroethane, tetrachloroethene and the dichloroethenes were also detected during the Phase II, Stage 2 study.

Sediment is contaminated with the volatile organic compounds: 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene and the semi-volatile organic compound, bis(2-ethylhexyl)phthalate. One sediment sample had a high concentration of lead.

The soil is contaminated with the volatile organic compounds: benzene, ethyl benzene, xylenes, 1,1-dichloroethane, trans-1,2-dichloroethene, 1,1,1-trichloroethane, tetrachloroethene and trichloroethene. It is also contaminated with the semi-volatile organic compound, bis(2-ethylhexyl)phthalate. The pesticides and PCBs, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT and PCB 1254 were detected at low levels in scattered samples. Total petroleum hydrocarbons were detected. Trace levels of barium, cadmium, chromium, mercury and lead were present.

Ground water is contaminated with the volatile organic compounds: benzene, toluene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethylene, trans-1,2-dichloroethene, 1,1,1-trichloroethane, tetrachloroethene, trichloroethene and vinyl chloride. Trace levels of the semi-volatile organic compounds: naphthalene, dimethylphthalate and bis(2-ethylhexyl)phthalate were detected. The compound PCB 1242 was also detected.

5.3.2 Potential Routes of Migration

Contaminants may leach from the contaminated soil in the storage pad area to the ground water.

Contaminant migration occurs on site by ground-water transport and off site by both surface water and ground-water transport. The ground water at this site discharges to a drainage ditch on the north side of the site and to drainage ditches at Site 4 (see Figures 3-18 and 3-33). The surface water enters culverts either on site or at Site 4. In either case, the water flows northward through culverts under the main east-west taxiway and runway where it is discharged in the vicinity of Site 10. From there the surface water flows northward in an unnamed drainage ditch.

5.3.3 Contaminant Persistence

Physical, chemical, and biological factors affecting the persistence of organic contaminants in the environment at the site include volatilization, diffusion, adsorption and biochemical degradation.

Soil gas results indicate that trichloroethene, tetrachloroethene, and other volatile organic compounds are volatilizing from either the surface of the water table or the soil above it and are being removed from the site in this way (Appendix O).

The type and rate of contaminant breakdown through biochemical degradation depends on the quantity and types of microorganisms present at the site and the type of organic materials the microbial community has previously encountered. Under reducing conditions, biotic dehalogenation or hydrogenolysis of 1,1,1-trichloroethane forms 1,1-dichloroethane, eventually forms chloroethane and finally ethane (Vogel and others, 1987; Fetter, 1988). The abiotic breakdown of 1,1,1-trichloroethane can cause the formation of 1,1-dichloroethene which can be broken down biotically to vinyl chloride (Vogel and others, 1987). Chlorinated ethenes such as trichloroethene and tetrachloroethene have been shown to undergo progressive dehalogenation to trans-1,2-dichloroethene, cis-1,2-dichloroethene, and perhaps 1,1-dichloroethene, all of which can undergo hydrogenolysis to form vinyl chloride (Barrio-Lage and others, 1986; Vogel and others, 1987).

Data on the persistence of tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane in surface water indicates that trichloroethene has the longest half life in surface water with a range of 1 to 90 days followed by tetrachloroethene with a range of 1 to 30 days (Table 5-1). Half lives in surface water of other contaminants such as 1,1,1-trichloroethane, 1,1-dichloroethane, and 1,1-dichloroethene are generally less than a week.

Generally, PCBs, 4,4'-DDT and pesticides are persistent in the environment. Degradation of PCBs by bacteria has been demonstrated but heavily substituted PCBs appear to resist degradation and accumulate in environments where less chlorinated PCBs are degraded (Rochkind-Dubinsky, 1987). Under anaerobic conditions, 4,4'-DDT is converted to 4,4'-DDD but under aerobic conditions is converted to 4,4'-DDE (Rochkind-Dubinsky, 1987).

The half life of 4,4'-DDT is estimated to be in the range of 2.5 to 35 years (Rochkind-Dubinsky, 1987).

5.3.4 Contaminant Mobility and Migration

Data on the distribution of trichloroethene, tetrachloroethene, and 1,1-dichloroethene in ground water and soil samples from wells DANGB-3-MW25, DANGB-3-MW29, and DANGB-3-MW35 indicate that trichloroethene and 1,1-dichloroethene are slightly adsorbed (see Table 4-20). This observation is in agreement with the K_{OC} values listed in Table 5-1. The mobility of these solvents in unsaturated soils may be somewhat more limited due to the possibly higher organic content of the soils and the absence of a pore-saturating fluid such as water which can displace the volatile organics from adsorption sites in the soil. The high K_{OC} values for the pesticides and PCBs indicate that they will have a low mobility in the environment if water is the primary solvent. This was demonstrated by the absence of detectable pesticides and the trace levels of PCBs found in Site 3 ground water.

5.3.4.1 Contaminant Migration in Surface Water

Considering the influence of dilution, volatilization, and adsorption on the migration of volatile organic compounds, the levels of contaminants in surface drainage discharge from Site 3 are strongly attenuated by natural processes. Periods of heavy rain are generally necessary for the drainage ditches to receive enough water to cause the surface water which is standing most of the time for flow to occur and transport contaminants off site. The levels of contaminants will be reduced significantly by dilution during rainfall periods when contaminant transport is most likely. In addition, volatilization of organic compounds such as trichloroethene will be a significant loss pathway. Sorption onto sediments will serve to restrict or slow organic and inorganic contaminant migration.

Since a significant metal contaminant source was not indicated by the extensive soil sampling at this site, levels of the metals detected should not pose a serious surface water contamination threat.

5.3.4.2 Contaminant Migration in Soil

Contaminants may still be leaching from the soil into the ground water in the storage pad area. The relatively high quantities of benzene and toluene in the shallow soil sample at DANGB-SG49 and the presence of these two compounds in ground water at wells GW 3-C and GW 3-D suggest that these contaminants may be leaching from the contaminated soils and migrating into the ground water. It is also possible that many of the contaminants responsible for ground-water contamination such as 1,1,1-trichloroethene and trichloroethene have already leached out of the soil since the pad may not have been used to store solvents for several years. Sampling of soil at depth below the storage pad was not done during this investigation.

Pesticides and PCBs detected at low levels in near surface soils on the site should not pose a potential ground-water threat since these compounds are readily sorbed to the organic carbon fraction of the soil.

5.3.4.3 Contaminant Migration in Ground Water

Hydrogeologic data indicate that ground-water movement is northeasterly to north. There appears to be a strong downward component to flow in the area immediately southwest of the storage pad and a strong upward flow component in the vicinity of the drainage ditch at Site 4 located about 800 feet northeast of the storage pad (see Figures 3-18 and 3-33). Movement of dissolved contaminants from the storage pad will be the same as that of the ground-water movement, and will discharge to the surface drainage ditch on the north side of the site or to drainage ditches at Site 4. Contaminants that are heavier than water, such as trichloroethene, probably migrated downward from their point of release as they dispersed due to diffusion and the existence of a downward flow component in the pad vicinity.

The migration rate of the principal contaminants, including trichloroethene and 1,1,1-trichloroethane, is approximately the same as that of the ground-water velocity. Comparison of the distribution of trichloroethene and 1,1,1-trichloroethane between ground-water samples and corresponding soil samples from wells DANGB-3-MW25 and DANGB-3-MW29 (see Tables 4-20 and 4-23) indicates that these compounds are not strongly sorbed by the glacial material. Thus, these contaminants are expected to migrate at a rate approximately the same as that of the ground water velocity. In contrast, comparison of the distribution of tetrachloroethene between the deepest soil sample, see Table 4-20, and the ground-water sample at location DANGB-3-MW29, see Table 4-23, indicates that tetrachloroethene is more strongly adsorbed than trichloroethene and 1,1,1-trichloroethane. Therefore, the relative migration rate of tetrachloroethene is expected to be somewhat less than that of trichloroethene due to greater interaction with the glacial material.

The rate of trichloroethene migration is at least 19 feet per year. The storage pad came into use in 1965, or 24 years ago, and the distance from the pad to the farthest point of confirmed contamination, monitoring well DANGB-3-MW25, is about 440 feet. The trichloroethene migration rate is greater than the estimated range of ground-water flow velocity of 0.5 to 9 feet per year in the glacial material. This suggests that contaminants are migrating through a more permeable member of the glacial till such as the sand lens observed at the base of monitoring wells DANGB-3-MW29 and DANGB-3-MW25. Alternatively, another contaminant source area downgradient from the storage pad may have contributed the contaminants observed at well DANGB-3-MW25.

The rate of tetrachloroethene migration appears to be much less than that of trichloroethene. Although tetrachloroethene has likely been in the environment as long as trichloroethene, it was detected only in wells close to the storage pad. (Compare Figures 4-4 and 4-5.) This observational evidence agrees with the chemical data (Table 5-1), which suggest that tetrachloroethene with a K_{OC} value of 364 should migrate at a rate less than half that of trichloroethene with a K_{OC} value of 126.

In the vicinity of the storage area, the solubility and release of PCB 1242 to ground water may have been aided by the presence of organic solvents. However, ground-water samples confirm that this compound has not migrated beyond the limits of the storage area. Thus, the data acquired during this investigation confirm the theoretical predictions that PCBs are generally not mobile in the environment.

5.4 CONTAMINANT FATE AND TRANSPORT AT SITE 4

The physical and chemical properties of contaminants present at this site are evaluated with respect to the site geologic and hydrogeologic conditions to determine the transport and fate of the contaminants at this site.

5.4.1 Summary of Contaminants

The surface water is contaminated with the volatile organic compounds: benzene, ethyl benzene, toluene, xylenes, trichloroethene and trans-1,2-dichloroethene. Petroleum hydrocarbons were also detected.

The sediment is contaminated with the volatile organic compounds: benzene, ethyl benzene, toluene and xylenes. Petroleum hydrocarbons and trace levels of barium, cadmium, chromium and lead were also detected

The soil is contaminated with the volatile organic compounds: benzene, trace amounts of tetrachloroethene and methylene chloride. Petroleum hydrocarbons were also detected.

The ground water is contaminated with the volatile organic compounds: benzene and xylenes. Low levels of petroleum hydrocarbons were also detected

The principal surface water contaminants are aromatic hydrocarbons such as benzene and toluene while the principal ground-water contaminant is benzene.

5.4.2 Potential Routes of Migration

Surface drainage is the primary route for contaminants to migrate off site. The hydrogeology indicates that contaminated ground water discharges into the drainage ditch north of the fuel storage tanks, where it enters a culvert. Contaminated surface water in the drainage ditch southwest of the fuel storage tanks also enters a culvert. Contaminated surface water flows north through the system of culverts under the main east-west taxiway and runway, where it is discharged to an unnamed drainage ditch in the vicinity of Site 10. It eventually drains into Beaver Creek which flows into Wild Rice Lake.

5.4.3 Contaminant Persistence

Physical, chemical and biological processes which affect the persistent contaminants at Site 4 include volatilization, diffusion and biochemical degradation.

Volatilization of aromatic hydrocarbons is occurring in surface drainage at the site. The smell of petroleum products is present in the drainage ditch just north of the fuel storage tanks.

Experimental studies indicate that dissolved oxygen is the parameter which controls aromatic hydrocarbon biodegradation (Barker and others, 1987). Surface water should have an adequate supply of dissolved oxygen to promote the biochemical transformation of the aromatic hydrocarbons to innocuous intermediate products.

Half lives for the principal surface water contaminants such as benzene, toluene, ethyl benzene, and xylenes range from 0.17 to 9 days (Table 5-1). These half lives are the result of all removal mechanisms including biotransformation, volatilization, and chemical transformation.

In spite of the numerous mechanisms for the loss of chlorinated solvents from the surface water, soil and ground water, tetrachloroethene, trichloroethene and 1,1,1-trichloroethane are generally persistent in the environment.

5.4.4 Contaminant Migration in Surface Water and Ground Water

Contaminants in the ground water at Site 4 discharge into surface drainage since the site is located in a ground-water discharge area (see Figures 3-21 and 3-22). The surface drainage in the ditch north of the fuel storage tanks was flowing into the culvert at location DANGB-4-SL11 at a rate of approximately 1,900 gallons per day in September, 1988.

Contaminant levels in surface water will decrease downstream due to dilution and biochemical degradation. A stream flow measurement made at DANGB-BG-SL2, which is located downstream from location DANG-BG-SL11, indicated a discharge of over 172,000 gallons per day. Thus, surface water from the north drainage ditch at Site 4 will be diluted by almost two orders of magnitude. The surface water sample collected at the airport area location DANGB-BG-SL3, which is downstream from Site 4 as well as other sites, contained benzene and toluene but other than Site 4 is possible for the contamination detected at that sampling site. Volatile organic compounds were not detected in the surface water sample collected at location DANGB-BG-SL2, which is downstream from sampling location DANGB-BG-SL3.

5.5 CONTAMINANT FATE AND TRANSPORT AT SITE 8

The chemical and physical properties of contaminants present at this site are evaluated with respect to site hydrogeological conditions to determine the transport and fate of contaminants at this site.

5.5.1 Summary of Contaminants

Neither the surface water nor the sediment are contaminated.

The soil is contaminated with the pesticides 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, dieldrin and PCB 1254 at one location.

The ground water is contaminated with barium and chromium.

5.5.2 Potential Routes of Migration

Possible routes for contaminant migration would be by surface water.

5.5.3 Contaminant Persistence

The pesticides are expected to be persistent in the environment. An indication of the persistence of PCBs is given by the fact that they have not been produced since 1978 but are still present in the environment.

5.5.4 Contaminant Mobility and Migration in Soil

The high K_{OC} values for the pesticides and PCBs indicate a low mobility in the environment if water is the primary solvent and transport media. Pesticides and PCBs should remain in place with levels decreasing over time.

5.6 CONTAMINANT FATE AND TRANSPORT AT SITE 10

The physical and chemical properties of contaminants present at this site are evaluated with respect to the site geologic and hydrogeologic conditions to determine the transport and fate of the contaminants at this site.

5.6.1 Summary of Contaminants

The known contaminants at Site 10 are radiological parameters expressed by the presence of gross alpha and gross beta radiation in the ground water.

5.6.2 Potential Routes of Migration

The primary route of contaminant transport is by ground water, with the probability of ground water discharging into surface drainages.

5.6.3 Contaminant Persistence

Determination of the persistence of the alpha and beta radiation depends on their source. The levels of gross alpha and gross beta have an approximate ratio of one, indicating that their source is a naturally occurring radionuclide rather than one which is man-made. A source of alpha radiation is radium 226 which has a half life of 1,600 years. The amount of radium 226 detected is insufficient to be the direct source of all the alpha radiation detected. A source of beta radiation is tritium which has a half life of 12.3 years. Tritium was below detection limits in all samples collected during this study.

5.6.4 Contaminant Mobility and Migration

It may be that the source of the radiation is radium 226 which is not very mobile in the environment. One of the decay products of radium 226 is radon which is mobile, and it may be that radon is the immediate radiation source. Samples were not tested for radon.

Hydrogeological data indicate that ground-water flow is to the west toward an unnamed drainage ditch. Given the long time span over which the radiological debris has been present, contaminated ground water will have had ample opportunity to discharge into surface drainage.

Upon entering the surface drainage contaminant levels will be reduced by dilution. Radiological parameters were nondetectable in a surface water sample collected downstream from Site 10.

SECTION 6
RISK ASSESSMENT

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SECTION 6
RISK ASSESSMENT

Section 6 documents the risk assessments performed. The methodology used to conduct a risk assessment is described in Section 6.1. The risk assessments for Sites 2, 3, 4 and 8 are presented in Sections 6.2 through 6.5. Calculations and backup data for these assessments are provided in Appendix P. Section 6.6 summarizes the risk to human health and the environment posed.

The impacts of Sites 2, 3, 4, and 8 on public health are additive. They are addressed separately in this risk assessment in order to determine whether an individual site may require further study and/or remediation.

This risk assessment does not include evaluation of Site 10, since the present USEPA guidelines do not include provisions to assess the risk of radiological contamination.

6.1 EVALUATION METHODOLOGY

A public health evaluation or risk assessment was conducted for Sites 2, 3, 4 and 8 at the Duluth ANGB Base in accordance with methodology described in the Superfund Public Health Evaluation Manual (USEPA, 1986a) and the USEPA Superfund Exposure Assessment Manual (USEPA, 1988). The USEPA approach is designed to evaluate possible threats to public health from a site under existing conditions. The analysis provides an understanding about the nature of chemical releases from the site, the potential pathways for human exposure, the degree to which such releases, if any, could violate applicable standards and criteria, and a measure of the potential threat to public health as a result of such releases. The evaluation consists of five steps:

Step 1: selection of indicator chemicals;
Step 2: estimation of exposure point concentrations;
Step 3: estimation of chemical intake;
Step 4: toxicity assessment; and
Step 5: risk characterization.

In Step 1, selection of indicator chemicals, available information is evaluated regarding hazardous substances present at the site. This step is conducted when more than 10 to 15 chemicals are detected in environmental media, reducing the number of chemicals carried through to Step 5. A relative ranking is assigned to the detected chemicals according to toxicity and concentration. Indicator chemicals are then chosen on the basis of relative rank, toxicological class, chemical properties, and frequency of detection. Steps 2 through 5 in the risk assessment process are then focused on the selected indicator chemicals.

Step 2, estimation of exposure point concentrations, requires the identification of possible human exposure points associated with the site and possible pathways for exposure. Identification of potential exposure pathways helps in conceptualizing how contaminants may migrate from a source to an existing or potential point of human contact. After releases from the site are estimated, the environmental fate and transport are modeled in order to project exposure levels via air, ground water, surface water, soils, and sediments at each potential point of human contact. Both best estimates or averages, and upper bound estimates or maximums, are used. Projected exposure levels are then compared to Applicable or Relevant and Appropriate Requirements (ARARs). This analysis includes not only identification of currently exposed populations, but also exposures that may occur in the future if no action is taken.

Step 3, estimation of chemical intake, quantifies the amount of actual human exposure. Human exposure is expressed in terms of intake, or the amount of a substance taken into the body per unit body weight per unit of time, and is calculated separately for exposure to each environmental medium. For each population at risk, intakes for the same route of exposure are summed, resulting in a total oral exposure, a total inhalation exposure and a total dermal exposure.

Step 4, the toxicity assessment, requires collection of critical toxicity values for the selected indicator chemicals to be used in conjunction with the results from the total exposure estimates. The USEPA provides reference values which describe the degree of toxicity posed by noncarcinogens and potential carcinogenic compounds (USEPA, 1986a). These values are generally derived from experimental dose response information.

In Step 5, data developed during the exposure and toxicity assessment are used to characterize the potential noncarcinogenic and carcinogenic risks. For noncarcinogens, the potential risk is evaluated by calculating a hazard index. Hazard index values are obtained by dividing each projected intake by the USEPA acceptable chronic intake. The hazard index values are summed to evaluate the possible effects of multimedia exposure to noncarcinogens. A hazard index greater than one indicates a potential health hazard. For carcinogens, risk is calculated by multiplying the projected intake by the USEPA potency factor. The possible effects of multimedia exposure are evaluated by summing the calculated risks from each media. The USEPA target for acceptable risk is generally between 10^{-4} (1 additional case of cancer per 10,000 individuals) and 10^{-7} (1 additional case of cancer per 10 million individuals), depending on site conditions.

The final assessment summarizes the risks associated with a site including each projected exposure route for contaminants of concern and the distribution of carcinogenic and noncarcinogenic risk across various sectors of the population.

6.1.1 Step 1, Selection of Indicator Chemicals

Data used in the selection of indicator chemicals and the subsequent public health evaluation were compiled from the Remedial Investigation (RI) field work performed by Engineering Science and from previous studies done in 1983 (Weston, 1984) and in 1986 (Dames & Moore, 1987). Summaries compiling the results of detected compounds from the three investigations are provided for each individual site in Appendix P and include the maximum concentration detected for each chemical in each medium, the average concentration, and the number of samples in which the chemical was detected compared to the total number of samples analyzed.

Compounds that persistently appeared in laboratory blanks, trip blanks, and bailer rinsates were excluded from the indicated chemical selection process. These compounds included chloroform, bromoform, dichloromethane (methene chloride), bis (2-ethylhexyl)phthalate and dibutylphthalate. These parameters were not believed to be representative of the contamination present but are present as the result of laboratory cross-contamination. Dimethyl phthalate and diethyl phthalate occurred sporadically, but were also excluded from the indicator chemical selection process due to lack of toxicity data for these compounds.

Toluene was included as an indicator chemical at each site since this compound was detected in soils, sediments, ground water and/or surface water. The presence of toluene in some soil samples may have been due to contamination introduced in the field through the usage of electrical tape on sample containers. Although toluene data from previous investigations was included to obtain maximum and representative concentrations, these concentrations may be slightly over-valued as a result of this field contamination. It should be noted, however, that the calculated risk to human health and the environment due to toluene, a noncarcinogen, was in each case negligible.

Average concentrations were determined by taking the arithmetic mean of the values from samples in which the compound was detected above the Method Detection Limit (MDL) or the reporting limit. If the compound was detected in only one sample, the average concentration was determined by halving the single value, as suggested by the USEPA (1986a). Data from samples in which the compound was not detected or was below reporting limits were excluded from the averaging process.

The procedure used to select indicator chemicals involved evaluation of concentration, toxicity, mobility, and persistence for each compound detected in each medium. Tables in Appendix P present these evaluation parameters for the compounds identified at each site. These parameters are defined as follows:

Toxicologic class. This class indicates whether a compound has been identified as a potential carcinogen (PC) or noncarcinogen (NC).

Severity rating (RVe). The RVe for oral and inhalation exposure routes is a quantitative rating based on qualitative severity of noncarcinogenic health effects for a given compound. Low values denote minimal effects such as reversible cellular changes, whereas high values denote more serious adverse effects including physiological dysfunction, birth defects, and death. Table 6-1 presents the severity rating categories and their associated health effects.

Carcinogen Assessment Group (CAG). The CAG for each compound indicates whether or not there is sufficient evidence to classify a compound as carcinogenic. Compounds for which there is inadequate evidence of carcinogenicity or no evidence of carcinogenicity are classified in Groups D and E, respectively. Compounds which are known or suspected carcinogens are classified in Groups A through C. The rationale used to assign CAGs is presented in Table 6-2.

Toxicity constant. The toxicity constant for a given compound is a potency factor provided by the USEPA based on either carcinogenic or noncarcinogenic endpoints for soil and water.

TABLE 6-1

SEVERITY RATINGS FOR NONCARCINOGENS

Effect	Severity Rating (RVe)
Enzyme induction or other biochemical change with no pathologic changes and no change in organ weights.	1
Enzyme induction and subcellular proliferation or other changes in organelles but no other apparent effects.	2
Hyperplasia, hypertrophy, or atrophy with change in organ weights. .	3
Hyperplasia, hypertrophy, or atrophy with changes in organ weights.	4
Reversible cellular changes: cloudy swelling, hydropic change, or fatty changes.	5
Necrosis, or metaplasia with no apparent decrement of organ function. Any neuropathy without apparent behavioral, sensory, or physiologic changes.	6
Necrosis, atrophy, hypertrophy, or metaplasia with a detectable decrement of organ functions. Any neuropathy with a measurable change in behavioral, sensory, or physiologic changes.	7
Necrosis, atrophy, hypertrophy, or metaplasia with definitive organ dysfunction. Any neuropathy with gross changes in behavior, sensory, or motor performance. Any decrease in reproductive capacity or any evidence of fetotoxicity.	8
Pronounced pathologic changes with severe organ dysfunction. Any neuropathy with loss of behavioral or motor control or loss of sensory ability. Reproductive dysfunction. Any teratogenic effect with maternal toxicity.	9
Death or pronounced life-shortening. Any teratogenic effect without signs of maternal toxicity.	10

Source: U.S. Environmental Protection Agency, (1986a).

TABLE 6-2

WEIGHT-OF-EVIDENCE CATEGORIES FOR POTENTIAL CARCINOGENS

Carcinogen Assessment Group	Description of Group	Description
A	Human Carcinogen	Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer.
B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiologic studies.
B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans.
C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals.
D	Not Classified	Inadequate evidence of carcinogenicity in animals.
E	No evidence of Carcinogenicity	No evidence of carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies.

Source: U.S. Environmental Protection Agency, (1986a).

After the values were assigned for the toxicologic class, the severity rating, the CAG, and the toxicity constants, "CT" values, defined as the product of concentration and toxicity, were calculated for each compound in each medium. The CT values were calculated by multiplying either the maximum or representative concentration of a compound in a given medium by the medium-specific toxicity constant for that compound. If both carcinogenic and noncarcinogenic endpoints were observed for a given compound, CT values for both categories were calculated. The CT values for compounds present at the Base are given in Appendix P for each site.

The CT values were used to calculate indicator scores (IS) for each compound. The IS is calculated for both maximum and average concentrations of a compound by summing the CT values for all media. If both ground water and surface water have an associated CT value, only the highest of the two is used to calculate the IS. Compounds present were ranked according to IS value and are given for each site in Appendix P.

Indicator chemicals were chosen by taking into account ranking by IS value, toxicity class, physical properties, mobility, and persistence. A compound was chosen if it had a high rank and was detected in a number of samples. If little or no toxicity data were available for a compound, or if the compound was found in only one or two samples, it was not chosen as an indicator chemical. A comprehensive list of all the indicator chemicals used to represent the contamination present at Sites 2, 3, 4 and 8 and relevant toxicological, chemical and physical properties is presented in Table 6-3.

6.1.2 Step 2, Estimation of Exposure Point Concentrations

The next step in the public health evaluation was to determine concentrations of indicator chemicals at exposure points. This was done by determining human exposure points and identifying potentially complete exposure pathways. Each step in calculating exposure point concentrations is discussed below.

6.1.2.1 Exposure Pathway Analysis

An exposure pathway analysis was performed to identify possible complete pathways for exposure. A completed exposure pathway is comprised of the following four elements:

a source and mechanism of chemical release;
an environmental transport medium;
an exposure point; and
a feasible route of human exposure at the exposure point.

TABLE 6-3
INDICATOR CHEMICALS AND RELEVANT PHYSICAL PROPERTIES
SITES 2, 3, 4 AND 8

Parameter	CAS (a) Number	Toxicity Class	Water Solubility (mg/L)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m3/mol)	KOC (b) (mL/g)	Molecular Weight (g/mole)
Arsenic	7440-38-2	NC, PC (c)	NA (d)	0	NA	NA	75
Barium	7440-39-3	NC	NA	NA	NA	NA	137
Benzene	71-43-2	NC, PC	1750	95.2	0.00559	83	78
Cadmium	7740-43-9	NC, PC	NA	0	NA	NA	112
Chlorobenzene	108-90-7	NC	466	11.7	0.00372	330	113
Chromium	7440-47-3	NC, PC	NA	0	NA	NA	52
4,4'-DDT	50-29-3	NC, PC	0.005	0.0000055	0.000513	243000	355
Dibutyl Phthalate	84-74-2	NC	13	0.00001	0.000000282	170000	278
1,1-Dichloroethane	75-34-3	NC	5500	182	0.00431	30	99
1,1-Dichloroethene	75-35-4	NC, PC	2250	600	0.034	65	97
Trans-1,2-Dichloroethene	540-59-0	NC	6300	324	0.00656	59	97
Diethyl Phthalate	84-66-2	NC	896	0.0035	0.00000114	142	222
Dieldrin	60-57-1	NC, PC	0.195	0.000000178	0.000000458	1700	381
Endosulfan I	115-29-7	NC	NA	NA	NA	NA	407
Ethyl Benzene	100-41-4	NC	152	7	0.00643	1100	106
Lead	7439-92-1	NC, PC	NA	0	NA	NA	207
Mercury	7439-97-6	NC	NA	0.002	NA	NA	201
Tetrachloroethene	127-18-4	NC, PC	150	17.8	0.0259	364	166
Toluene	108-88-3	NC	535	28.1	0.00637	300	92
1,1,1 Trichloroethane	71-55-6	NC	4500	30	0.00117	56	133
Trichloroethene	79-01-6	NC, PC	1100	57.9	0.0091	126	131
Vinyl Chloride	75-01-4	NC, PC	2670	2660	0.0819	57	63
Xylenes	1330-20-7	NC	198	10	0.00704	240	106

a. CAS = Chemical Abstracts Service
b. KOC = Octanol/water partition coefficient
c. NC = Noncarcinogenic Effects PC = Potential Carcinogen
d. NA = Not applicable to this compound

If any element is missing, exposure by that route is not possible because the exposure pathway is incomplete.

Potential release sources at the Base include contaminated surface water, sediment, soil and ground water. Potential mechanisms for release include volatilization, fugitive dust generation, surface runoff, surface water seepage, tracking, and site leaching. The environmental transport media include air, surface water, soil, and ground water. Feasible routes of human exposure exist when human receptors may be present at potential exposure points currently or in the future. An integrated analysis of release sources, mechanisms and potential receptors is presented in Table 6-4.

Current sources of contamination were determined to be surface water and surface soil (soil from 0 to 2 feet in depth). Potential human receptors to contamination found in surface water are onsite workers through inhalation of volatilized contaminants and offsite residents using surface water for recreational purposes downstream of Sites 2, 3, 4 or 8. Potential human receptors for contamination found in surface soils were considered to be onsite workers through soil ingestion and inhalation of fugitive dust. Offsite residents may be exposed to onsite soil contamination through incidental soil ingestion and fugitive dust inhalation while visiting the Base.

Future sources of contamination were determined to be ground water and soil at depths greater than two feet. Although improbable, pathway completion through these routes could occur in the event that institutional controls limiting access to Sites 2, 3, 4 and 8 should be eliminated, such as through future transfer of property to private ownership. Pathway completion is assumed to occur through ingestion of ground water and incidental ingestion of soil. Potential future human receptors are future onsite residents and construction workers.

6.1.2.2 Exposure Point Concentrations

Concentrations of indicator chemicals were calculated for each exposure point associated with a potentially complete pathway. Depending on the environmental transport mechanism, this step usually includes quantifying release of indicator chemicals from the source in terms of release rates (mass per unit time). The release rate is then used to predict environmental fate of the indicator chemicals and thereby their exposure point concentrations. Specifying release rates may not be necessary if actual sampling data at the

TABLE 6-4
MATRIX OF POTENTIAL EXPOSURE PATHWAYS

Transport Medium	Release Source and Mechanism	Primary Exposure Point	Primary Exposure Route	Sites Where Pathway Completion Possible	Probability of Pathway Completion
Air (Current Use)	Affected soils/ Fugitive dust generation (FDG)	Workers on site, nearby residents	Inhalation	2	Moderate to low: Site 2 includes a former fire training area with surface soils which are contaminated with JP-4 residue. Military personnel (and sometimes members of their families) frequent the firing range that is within 200 yards of this fire training area, and nearby office workers jog on an adjacent road, passing within 100 yards.
	Affected soils, surface waters/ volatilization	Workers on site	Inhalation	3 and 4	Low to none: Although surface water at Sites 3 and 4 were found to contain significant levels of volatile organic compounds, the exposure point concentrations would be insignificant due to natural dispersion of the contamination in the air.
		Adults and children using Beaver Creek and Wild Rice Lake for recreational purposes such as boating, swimming and fishing	Inhalation	None	Low to none: Dilution and natural attenuation would reduce the concentrations of the surface water contaminants to negligible levels as they moved toward the nearest offsite exposure point.

TABLE 6-4 (Continued)

Transport Medium	Release Source and Mechanism	Primary Exposure Point	Primary Exposure Route	Sites Where Pathway Completion Possible	Probability of Pathway Completion
Surface Water (Current Use)	Affected soils, ground water/ seepage of ground water, surface runoff	Workers on site	Dermal	None	Low to none: It is unlikely that workers would intentionally walk in ponded water or ditches without dermal protection, and access is restricted to the site.
		Adults and children using Beaver Creek and Wild Rice Lake for recreational purposes such as boating, swimming and fishing	Ingestion, dermal	3 and 4	Low to none: Although dilution and natural attenuation would reduce the surface water contaminants to negligible levels at the nearest offsite exposure point, this pathway is being considered in order to demonstrate the negligible health risk.
		Hunters and fishermen consuming game animals and/or fish	Ingestion	None	None: Levels of contaminants would have an insignificant effect on the food chain.
		Persons utilizing local surface water for withdrawals	Ingestion, dermal	None	None: Withdrawals not noted at this time, contaminant levels expected to be negligible.
Ground Water (Current Use)	Affected soils/leaching	Domestic wells used as potable water sources; industrial and agricultural intakes	Ingestion, dermal, inhalation	None	None: Onsite wells are not utilized as a source of water, and ground water discharges to the surface water well within the Base boundaries.

TABLE 6-4 (Continued)

Transport Medium	Release Source and Mechanism	Primary Exposure Point	Primary Exposure Route	Sites Where Pathway Completion Possible	Probability of Pathway Completion
Soil (Current Use)	Affected soils, ground water, surface water/Site leaching, runoff, tracking	Workers on-site	Ingestion, dermal	2, 3, 4, and 8	Low to none: This pathway was considered for all sites. Site 2 has the most soil contamination, but is located in a remote area away from the Perimeter Road or the firing range. Sites 2, 3, and 4 have little surficial soil contamination.
		Persons consuming game animals feeding in contaminated areas	Ingestion	None	None: Levels of contaminants would have an insignificant effect on the food chain. No significant wildlife was observed in the vincinity of any site, which have all been altered to some degree for the construction of Base facilities, roads and runways.
		Trespassers, including children	Ingestion	None	None: Access to Site 2 is guarded 24 hours per day due to its close proximity to military facilities, and Sites 3, 4 and 8 are surrounded by fences with on-site personnel present during normal working hours.
		Persons consuming produce grown near site	Ingestion	None	None: There are no residential dwellings within 0.2 miles of the site.

TABLE 6-4 (Continued)

Transport Medium	Release Source and Mechanism	Primary Exposure Point	Primary Exposure Route	Sites Where Pathway Completion Possible	Probability of Pathway Completion
Sediments (Current Use)	Affected soils, sediments, ground water, surface water/ Site leaching, surface runoff	Workers on site, trespassers	Dermal	None	Low to none: Few workers would intentionally walk in ponded water or ditches without dermal protection, and access is restricted to the site.
		Adults and children using Beaver Creek and Wild Rice Lake for recreational purposes such as boating, swimming and fishing	Dermal, ingestion	None	None: The levels of contaminants found in the sediments would probably be reduced to insignificant concentrations due to attenuation and absorption, in the unlikely case that they migrate outside the Base boundaries.
Surface Water (Future Use)	Affected soils, ground water/ seepage of ground water, surface runoff	Persons utilizing local surface water for withdrawals	Ingestion, dermal inhalation	None	None: Natural physical and biological processes would probably reduce the currently low levels of contamination in the surface water to negligible levels in the future.

TABLE 6-4 (Continued)

Transport Medium	Release Source and Mechanism	Primary Exposure Point	Primary Exposure Route	Sites Where Pathway Completion Possible	Probability of Pathway Completion
Ground Water (Future Use)	Affected soils, surface water/ Site leaching, percolation of surface water to ground water	Future hypothetical on-site workers or residents	Ingestion, dermal inhalation	2, 3, 4 and 8	Moderate to low: Natural physical and biological processes would probably reduce the currently low levels of contamination in the ground water to negligible levels in the future. Water withdrawals would be far more likely to occur from the abundant surface water supply in this area.
Soil (Future Use)	Affected soils, ground water, surface water/Site leaching,	Future hypothetical construction workers	Ingestion	2, 3, 4 and 8	Moderate to low: Future conditions may require excavation in this area.

point of human contact are available. Models which are used to estimate human exposure point concentrations and subsequent intake are discussed in detail in Section 6.1.3.

The current exposure point concentrations for the pathways involving surface soil ingestion, surface water ingestion and dermal contact with surface water were all considered to be represented by analyses of the onsite shallow soil and surface water samples. The exposure point concentration for the ingestion of soil can be realistically represented by soil data collected from onsite sampling. However, the assumption that offsite surface water exposure points contain detectable levels of contaminants found at Sites 2, 3, 4 and 8 is very conservative. This worst case scenario was used to depict the negligible impact of the contaminated surface water to human health.

Air data is currently unavailable to quantify the current exposure point concentrations for surface water contamination inhaled through volatilization or soil contamination inhaled through fugitive dust generation. Instead, two models which are discussed in Section 6.3 were used.

Future pathways of concern which can be quantified with existing data are the ingestion of onsite ground water and exposure to onsite contaminated soil during construction activities. Since it is impossible to speculate when future unrestricted construction or private development might occur, the worst case assumption that these events take place in the near future was used. The exposure point concentrations for soil related to incidental ingestion during potential construction are assumed to be represented by soil analyses to a 20 foot depth. Onsite ground water, which could be hypothetically ingested as drinking water, was assumed to be equivalent to the concentrations detected in onsite monitoring wells.

6.1.2.3 Applicable or Relevant and Appropriate Requirements and Other Criteria

The last part of Step 2 is comparison of the exposure point concentrations to available Applicable or Relevant and Appropriate Requirements (ARARs) or other criteria.

Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA) establishes cleanup criteria for superfund sites. This section of the statute sets forth the need for appropriate remedial actions, consistent with the National Contingency Plan (NCP), that provide a cost effective response.

Subsection (d) of Section 121 requires that remedial actions attain a level or standard of control at least equivalent to ARARs promulgated under federal or state laws. "Applicable Standards" are those cleanup or control standards, or other substantive environmental protection requirements, criteria or limitations, promulgated under federal or state law which specifically address a hazardous substance, pollutant, contaminant, remedial action location, or other circumstance at a CERCLA site. "Relevant and Appropriate Standards" refer to those cleanup or control standards, and other substantive environmental protection requirements, criteria or limitations, promulgated under federal or state law that, while not strictly applicable, address problems or situations sufficiently similar to those encountered at a superfund site so that their use is well suited to the particular site.

The USEPA has identified three categories of ARARs:

chemical specific;
location specific (wetlands limitations or historic sites); and
action specific (performance and design standards).

In this risk assessment, chemical and location specific ARARs were considered.

At present, the USEPA considers drinking water Maximum Contaminant Levels (MCLs), Federal Ambient Water Quality Criteria (AWQC), National Ambient Air Quality Standards (NAAQS), and state environmental standards to be potentially applicable, relevant, and appropriate requirements for ambient concentrations.

Since ARARs are often unavailable for contaminants in ground and surface waters, and since ARARs do not exist for contaminants in soils or sediments, this report includes other criteria for comparison purposes. Other criteria include Maximum Contaminant Level Goals (MCLGs), Proposed MCLGs, State of Minnesota Recommended Action Levels (RALs), adjusted Threshold Limit Values (TLVs) in air, soil background concentrations and MCLs adjusted for soils. Available ARARs and other criteria are summarized for the indicator chemicals present at Sites 2, 3, 4 and 8 in Table 6-5.

For organics in soil, a comparison value was computed from drinking water standards using a model based on the relationship between soil concentrations and resulting leachate concentrations. The Resource Conservation and Recovery Act (RCRA) EP Toxicity multiplier of 100 for inorganics was multiplied by the drinking water standard to determine an

TABLE 6-5
APPLICABLE, RELEVANT AND APPROPRIATE REQUIREMENTS AND OTHER CRITERIA FOR INDICATOR CHEMICALS AT SITES 2, 3, 4 AND 8

Indicator Chemical	ARARs (a)			Other Criteria					
	Safe Drinking Water Act (b) MCL (c) (mg/L)	USEPA Ambient Water Quality Criteria (d) for Drinking Water and Aquatic Organisms (mg/L)	Clean Air Act NAAQS (e) (mg/m3)	State of Minnesota RAL (f) (mg/L)	Safe Drinking Water Act MCLG (g) (mg/L)	Safe Drinking Water Act Proposed MCLG (h) (mg/L)	Soil Background Metal Concentration (i) (mg/kg)	MCL Adjusted for Soils (j) (mg/kg)	Threshold Limit Value (TLV) in Air/420 (k) (mg/m3)
Arsenic	0.05	0 (0.0000022)		0.05		0.05	<5	1.0	0.00048
Barium	1.0			1.5		1.5	34 -103	20	0.0012
Benzene	0.005	0 (0.00066)		0.012	0			0.1	0.071
Cadimium	0.01	0.01		0.005		0.005	6.8 - 13.6	0.1	0.00012
Chlorobenzene		0.488	0.06					1.2	0.83
Chromium	0.05	0.05		0.12		0.012	14.4 - 46.8	1.0	0.00012
4,4'-DDT		0 (2.4 E-08)		0.001				0.02	0.0024
Dibutyl Phthalate									0.012
1,1-Dichloroethane									1.9
1,1-Dichloroethene	0.007	0 (0.000033)		0.007	0.007			0.14	0.048
Trans-1,2-Dichloroethene				0.07		0.07		1.4	1.89
Diethyl Phthalate									0.012
Dieldrin		0 (7.1 E-08)							0.0006
Endosulfan I		0.074							0.0002
Ethyl Benzene		1.4		0.68		0.68		13.6	1.04
Lead	0.05	0.05	1.5 (90 day) (l)			0.02	2.9 - 16.6	1.0	0.0004
Mercury	0.002	0 (0.000144)		0.003		0.003	<0.1	0.04	0.0002
Tetrachloroethene		0 (0.0008)		0.0069		0		0.138	1.6
Toluene		14.3		2 0		2.0		40	0.89
1,1,1-Trichloroethene	0.2	18.4		0.2	0.2			4.0	4.5
Trichloroethene	0.005	0 (0.0027)		0.0312	0			0.1	0.64
Vinyl Chloride	0.002	0 (0.002)		0.00015	0			0.003	0.024
Xylenes				0.44		0.44		8.8	1.04

TABLE 6-5 (Continued)

a. Applicable, Relevant and Appropriate Requirements.
b. USEPA (1986a), updated to 1989 USEPA ARARs where appropriate.
c. Maximum Contaminant Level.
d. USEPA (1986a).
e. National Ambient Air Quality Standards (USEPA, 1986a).
f. Minnesota Department of Health, Release No. 1, Recommended Allowable Limits for Drinking Water (1986).
g. Maximum Contaminant Level Goal (USEPA, 1986a).
h. USEPA (1986a).
i. Background concentrations at the Base (Engineering-Science, Inc., 1988).
j. The lowest value between the USEPA MCL and the Minnesota RAL was used in this calculation..
k. American Conference of Governmental Hygenists (1987).
l. Maximum concentration not to be exceeded more than once per year..

acceptable leachate concentration. The multiplier for converting leachate concentrations to soil concentrations was determined by assuming, as is the case in the EP Toxicity test, that 100 grams of soil are used to produce two liters of leachate. Thus, the resulting multiplier is two liters per 100 grams.

To illustrate this computational process, trichloroethene is used as an example. Using the MCL for trichloroethene of 5 micrograms per liter (ug/L) as the drinking water standard and the RCRA EP Toxicity multiplier of 100, the resulting maximum leachate concentration standard is 500 ug/L. Assuming that 100 grams (g) of soil produces two liters of leachate, the resulting soil comparison standard for trichloroethene is 10 micrograms/gram (ug/g) computed in the following manner:

$$\text{Trichloroethene Soil Standard} = \frac{500\ \text{ug/L} \times 2\text{L}}{100\text{g}} = 10\ \text{ug/g}.$$

Similar calculations were performed for other organic indicator chemicals, and the results are shown in Table 6-5.

Air exposure point concentrations were compared to Threshold Level Values (TLVs) which are the time weighted average air pollutant concentrations to which healthy workers can be exposed without adverse effect. They are generally based on a worker being exposed for 8 hours per day during a 5-day work week. The USEPA recommends dividing the TLV by 420 for application to potentially sensitive nonworker populations which are continuously exposed (TLV/420).

6.1.3 Step 3, Estimation of Chemical Intakes

To assess potential adverse health effects associated with contamination detected at the Base, human chemical intake, or "chronic daily intake," was estimated from exposure point concentrations at each completed pathway. Chronic daily intake is expressed as the amount of a substance taken into the body per unit body weight per unit time. It is calculated for oral, inhalation or dermal exposures to contaminants found in each environmental medium separately. For each population at risk, intakes for the same route of exposure were summed to yield total oral, inhalation and dermal exposure. The effects of short term exposures, expressed as subchronic daily intake, were not addressed due to the lack of toxicity information for such exposure.

The chronic daily intakes by human receptors were estimated for each potential pathway completion by multiplying the exposure point concentrations by corresponding "human intake factors." The human intake factors were determined by assuming values for parameters such as the length of time spent at an exposure point, inhalation rate, ingestion rate, permeability of the compounds, the body weight of the human receptor and exposed skin area. The particular parameters used for the human intake factor were selected with the goal of obtaining a chronic daily intake with units of milligram of contaminant per kilogram body weight per day (mg/kg/day).

The emission, transport, and human uptake of contamination originating from Sites 2, 3, 4, and 8 are represented in the models described below. Model selection was made by reviewing models presented in several referenced sources and should be viewed as simplified representations of complex phenomena. Since the methods are conservative in order to protect the public health, the degrees of exposure are over-predicted. Worst case assumptions were typically used..

6.1.3.1 Fugitive Dust Generation Resulting from Wind Erosion

The model used to calculate current and future human uptake of fugitive dust contamination by onsite workers and nearby residents is described by Cowherd (Cowherd and others, 1984). The exposure point concentrations of contaminants are assumed to be the measured concentrations contained in the surface soil.

The chronic daily intake, CDI, resulting from fugitive dust generation is calculated as follows:

$$CDI = C \times HIF$$

where:

CDI = chronic daily intake of contaminant, in milligrams of contaminant per kilogram body weight per day (mg/kg/day);

C = long term exposure point concentration of contaminant,in milligrams per cubic meter (mg/m^3); and

HIF = human intake factor, in cubic meters per kilogram body weight per day (m^3/kg/day).

The human intake factor, HIF, is calculated as follows:

$$HIF = T \times I \times F \times (1/bw) \times \frac{1\ \text{week}}{7\ \text{days}} \times \frac{1\ \text{day}}{24\ \text{hours}}$$

where:

T = duration of contact, assumed to be 2 hours per week (hour/week);

I = inhalation rate, approximated as 20 cubic meters per day (m^3/day) for adults and 5 m^3/day for children (USEPA, 1986a);

F = the fraction of life span that intake occurs, assumed to be 40 years out of a 70 year lifespan (40/70) for onsite workers and offsite residents and 15 years out of a 70 year lifespan (15/70) for offsite children, no dimensions; and

bw = body weight, assumed to be 70 kilograms (kg) for adults and 10 kg for children.

For a particular contaminant, the long term exposure point concentration, C, is calculated by first estimating a release rate and then modeling the fate of that contaminant. In the case of fugitive dust generation, this is done by calculating the emission rate from the soil and then the dispersion of the contaminant. Slightly unstable conditions, represented by the Pasquill stability classification C (Pasquill, 1961), were selected for determining the standard deviation of crosswind concentration distribution. The following equation takes advection and dispersion into account and estimates ground-level atmospheric concentrations of pollutants at selected points directly downwind from a ground-level source (Turner, 1970):

$$C = Q_{10} \text{ x } \frac{1 \text{ hour}}{3600 \text{ sec}} \;/\; (\quad \text{x} \quad \text{x } [u] \text{ x} \quad)$$

where:

C = concentration of contaminant at a distance 0.1 kilometers (km) from the site, for onsite workers or 0.2 km for nearby residents, in mg/m^3;

Q_{10} = emission rate of contaminant, in milligrams of contaminant per hour (mg/hour);

σ_x = dispersion coefficient in the lateral, or crosswind, direction, calculated to be 12.5 meters for onsite workers or 25 meters for nearby residents by the method suggested by Turner (1970);

σ_y = dispersion coefficient in the vertical direction, calculated to be 7.5 meters for onsite workers or 18 meters for nearby residents by the method suggested by Turner (1970);

[u] = mean wind speed, approximated as 5.4 meters per second (m/sec) (average of mean wind speeds in Table 1-1) and

= 3.141593.

The emission rate of contamination from soils through fugitive dust generation is described by the following equation:

$$Q_{10} = [a\, A_c\, E_{10}] \times 10^{-6}$$

where:

a = mass fraction of contaminant in particulate emissions determined by site survey, in parts per million;

A_c = contaminated area determined by site survey, assumed to be square meters (m^2) for Site 2; and

E_{10} = emission rate for particles ten microns and below, in milligrams per square meter per hour ($mg/m^2/hour$).

The emission rate, $\dot{E}_{10}$, is described by the equation:

$$E_{10} = 0.036\,(1 - f_v)\,([u]/u_t)^3\,(F(x))$$

where:

f_v = fraction of contaminated area covered by vegetation, assumed to be zero, no dimensions;

$[u]$ = mean annual wind speed of 5.4 m/sec (average of mean wind speeds in Table 1-1);

$F(x)$ = function of the ratio of threshold wind speed to mean annual wind speed and equal to 1.85 (dimensionless) (value calculated by procedure suggested by Cowherd and others, 1984);

x = $0.886\,(u_t/[u])$; and

u_t = erosion threshold wind speed at seven meters above ground surface, in m/sec.

The erosion threshold wind speed, u_t, is defined by the equation:

$$u_t = u^{*}\, 2.5\,(\ln 700/Z_o)$$

where:

u^{*} = friction velocity which is 0.28 m/sec (value calculated by procedure suggested by Cowherd and others, 1984);

Z_o = roughness height equal to 3.0 centimeters (cm) (value suggested by Cowherd and Guenther, 1976); and

ln = natural logarithm.

6.1.3.2 Volatilization of Organic Compounds from Surface Water

Shultz and others (1986) recommend a procedure for estimating volatilization releases of organic contaminants from hazardous waste lagoons.

Their model was used to estimate volatilization of contaminants from the slow moving water in the drainage ditches on Sites 3 and 4 and the potential subsequent uptake of the contaminants through inhalation by onsite workers. Volatilization of contaminants contained in surface water is considered to be negligible for adults and children using surface water offsite for recreational purposes since surface water samples collected downstream from Sites 2, 3, 4 and 8 did not contain volatile organic contaminants at detectable levels. The chronic daily intake, CDI, resulting from volatilization of organic compounds from surface water is calculated as follows:

$$CDI = C \times HIF$$

where:

CDI = chronic daily intake of contaminant, in mg/kg/day;

C = long term exposure point concentration of contaminant, in mg/m^3; and

HIF = human intake factor, in $m^3/kg/day$.

The human intake factor, HIF, for onsite workers is calculated as follows:

$$HIF = I \times T \times F \times (1/bw) \times \frac{1\text{ week}}{7\text{ days}} \times \frac{1\text{ day}}{24\text{ hours}}$$

where:

I = inhalation rate, approximated as 20 m^3/day (USEPA, 1986a);

T = duration of each contact event, assumed to be 2 hours per week;

F = fraction of lifetime that contact event occurs, assumed to be (40/70), dimensionless; and

bw = body weight assumed to be 70 kg.

The long term exposure point concentration, C, is calculated by first estimating a release rate and then modeling the fate of that contaminant. In the case of volatilization of organic contaminants from surface water, C is obtained by calculating the emission rate and the subsequent dispersion of the contaminant from the water surface. The following equation takes advection and dispersion into account and converts emission rates into ground-level atmospheric concentrations of pollutants at selected points directly downwind from a ground-level source (Turner, 1970):

$$C = E \, x \, \frac{1\ \text{hour}}{3{,}600\ \text{sec}} / (\quad x \quad x\ [u]\ x \quad)$$

where:

C = concentration of contaminant at distance x from the site, assuming x equals 0.1 kilometers;

E = emission rate of contaminant, in mg/hour;

σ_x = dispersion coefficient in the lateral, or crosswind, direction, calculated to be 12.5 meters by the method suggested by Turner (1970);

σ_y = dispersion coefficient in the vertical direction, calculated to be 7.5 meters by the method suggested by Turner (1970);

$[u]$ = mean wind speed, approximated as 5.4 m/sec (average of mean wind speeds in Table 1-1); and

= the value pi, equal to 3.141593.

The estimation of concentrations to which on-site workers could be exposed included the estimation of mass emission rates. Mackay and Leinonen (1975) developed an equation for estimating the overall emission rate of a low-solubility contaminant in water bodies using the concentrations of contaminants measured in surface water. The equation is:

$$E = K C_w A$$

where:

K = overall mass transfer coefficient for the contaminant, in centimeters per hour (cm/hour);

C_w = contaminant liquid phase concentration in surface water, in milligrams per cubic centimeter (mg/cm^3); and

A = effective surface area for volatilization, conservatively estimated as 1,500,000 square centimeters (cm^2) for Sites 3 and 4.

The rate at which an organic chemical volatilizes from water depends on its solubility, molecular weight, vapor pressure and the nature of the air-water interface through which it must pass. Thomas (1982) devised the following equations to estimate the overall mass transfer coefficient K:

$$K = [1/k_l + RT/(H\, k_g)]^{-1}$$

where:

R = ideal gas law constant, equal to 0.000082, in cubic atmosphere meters per mole per degree Kelvin (atm m^3/mol/$^{\circ}$K);

T = temperature, assumed to be 298^o Kelvin;

H = Henry's Law constant of the compound, in cubic atmosphere-meters per mole (atm m^3/mol);

k_l = liquid phase mass transfer coefficient, in cm/hour; and

k_g = gas phase mass transfer coefficient, in cm/hour.

The liquid and gas phase mass transfer coefficients are given by the equations:

$k_l = 23.51 \, (V_{curr}^{0.969}/Z_o^{0.673}) \, (32/M)^{0.5}$ and

$k_g = 1137.5 \, (V_{wind} + V_{curr}) \, (18/M)^{0.5}$

where:

V_{curr} = current velocity, approximated as 8 x 10^{-4} m/sec (from the discharge rate at Site 4 of 1916 gallons per day discussed in Section 3.4.2, using a cross-sectional stream area of 0.1 M^2);

Z = mean depth of water, approximated as 0.1 meters;

M = molecular weight of contaminant, dimensionless; and

V_{wind} = wind velocity, assumed to be 5.4 m/sec (average of mean wind speeds in Table 1-1).

6.1.3.3 Dermal Contact With Surface Water

Dermal contact and the subsequent intake of contamination found in surface water could potentially occur on site or downstream beyond the airport boundaries. In this model described by Whitmyer and others (1987), adults and children are the potential receptors during swimming activities. The conservative assumption that no dilution or attenuation of the contamination in the surface water occurs is made in order to project a worst case scenario. Therefore, the concentrations of contaminants measured in the surface water at the sites are used as the exposure point concentrations, C, off site.

The chronic daily intake, CDI, resulting from dermal contact with surface water is calculated as follows:

$CDI = C \times HIF$

where:

CDI = chronic daily intake of contaminant, in mg/kg/day;

C = exposure point concentration of contaminant in surface water, in mg/L; and

HIF = human intake factor, in liters of water per kilogram body weight per day (L/kg/day).

Whitmyre and others (1987) compiled a table of exposure parameters commonly used in recreational risk assessment from which the assumptions used to evaluate the human intake factor for offsite adults and children were adopted. The human intake factor for offsite adults was determined by assuming that an adult exposes his or her entire body to surface water during swimming activities for 20 out of 70 years. Offsite children could potentially spend their entire childhood, 15 years out of a 70 year lifespan, exposing their entire bodies while swimming.

Calculation of the human intake factor assumes an absorption factor of 100 percent for all organic compounds, while this factor varies for different inorganic compounds. Cassaret and Doull (1986) suggest reference values for the absorption of metals by the gastrointestinal tract, ranging from 8 percent for cadmium to 100 percent for arsenic. Indicator metals not discussed by Cassaret and Doull were assumed to have absorptions of 50 percent.

The human intake factor, HIF, is calculated as follows:

$$HIF = f \times T \times (1/bw) \times F \times p \times A \times \frac{1\ L}{1000\ cm^3} \times \frac{1\ year}{365\ days}$$

where:

f = annual frequency of contact event, assumed to be 19 events per year for onsite adults or 25 events per year for offsite adults and children;

T = duration of each contact event, assumed to be 2.6 hours per event;

bw = body weight assumed to be 70 kg for adults and 10 kg for children;

F = fraction of lifetime that contact event occurs, assumed to be (40/70) for onsite workers, (15/70) for offsite children, and (20/70) for offsite adults, dimensionless;

p = dermal permeability constant of contaminant, provided for certain organic compounds in the Superfund Exposure Assessment Manual (USEPA, 1988), in cm/hour; and

A = exposed skin area, assumed to be 2,800 square centimeters (cm^2) for onsite workers, 18,150 cm^2 for offsite adults, and 9,400 cm^2 for offsite children.

6.1.3.4 Ingestion of Surface Water During Recreation

The model suggested by Whitmyer and others (1987) was adapted and used in determining the human ingestion of surface water during recreation. Offsite adults and children are potential receptors of surface water contamination originating from Sites 2, 3, 4 and 8. In order to project a worst case scenario, it is assumed that human intake occurs through ingestion of surface water during recreation and that no dilution or attenuation of onsite contamination occurs.

The chronic daily intake, CDI, resulting from ingestion of surface water during recreation is calculated as follows:

$$CDI = C \times HIF$$

where:

CDI = chronic daily intake, in mg/kg/day;

C = exposure point concentration of contaminant in surface water, in mg/L; and

HIF = human intake factor, in L/kg/day.

Calculation of the human intake factor assumes an absorption factor of 100 percent for all organic compounds. This factor varies for different inorganic compounds. Cassaret and Doull (1986) suggest reference values for the absorption of metals by the gastrointestinal tract ranging from 8 percent for cadmium to 100 percent absorption of arsenic. Indicator metals found at the Base but not discussed by Cassaret and Doull were assumed to have absorptions of 50 percent.

The human intake factor, HIF, is calculated as follows:

$$HIF = G \times T \times f \times (1/bw) \times F \times A \times (1\ \text{yr}/365\ \text{days}) \times (1\text{L}/1000\ \text{mL})$$

where:

G = rate of ingestion of surface water, assumed to be 50 milliliters per hour (mL/hour);

T = duration of each recreational event, assumed to be 2.6 hours per event;

f = annual frequency of contact event, assumed to be 19 events per year for on-site adults and 25 events per year for off-site adults and children;

bw = body weight, assumed to be 70 kg for adults and 10 kg for children;

F = fraction of lifetime that recreational event occurs, assumed to be (15/70) for children and (20/70) for adults, dimensionless; and

A = fraction absorbed, dimensionless.

6.1.3.5 Ingestion of Ground Water as Drinking Water

A hypothetical future exposure to contamination in ground water is through the ingestion of drinking water originating from wells on site. In order to project a worse case situation, the exposure point concentration, C, used on site is assumed to be the concentrations of contaminants measured in the ground water during the recent investigations.

The chronic daily intake, CDI, as a result of ingestion of ground water as drinking water is calculated as follows:

$$CDI = C \times HIF$$

where:

CDI = chronic daily intake, in mg/kg/day;

C = exposure point concentration of contaminant in ground water, in mg/L; and

HIF = human intake factor, in L/kg/day.

Calculation of the human intake factor assumes an absorption factor of 100 percent for all organic compounds, while this factor varies for different inorganic compounds. Cassaret and Doull (1986) suggest reference values for the absorption of metals by the gastrointestinal tract, ranging from 8 percent for cadmium to 100 percent absorption of arsenic. Indicator metals detected during this and previous investigations but not discussed by Cassaret and Doull were assumed to have absorptions of 50 percent. The USEPA has published adult and child ingestion rates of 2.0 and 1.0 liters per day, respectively, for use in superfund site analyses (1986a). They are used here.

The human intake factor, HIF, is calculated as follows:

$$HIF = G \times (1/bw) \times F \times A$$

where:

G = ingestion rate, assumed to be 1 liter/day (L/day) for children and 2 L/day for adults;

bw = body weight, assumed to be 10 kg for children and 70 kg for adults;

F = fraction of life that intake occurs, assumed to be (15/70) for children and (70/70) for adults, dimensionless; and

A = fraction absorbed, dimensionless.

6.1.3.6 Ingestion of Soil

Incidental ingestion of soil during current routine daily activities or future excavation may expose onsite workers to soil contamination. Nearby residents are also included as potential receptors while participating in activities that take place at the Base. The exposure point concentrations, C, of contaminants used in this model are the measured contaminant concentration in surface soil for current exposure and the measured contaminant concentration in soil at depth for future exposure.

The chronic daily intake, CDI, for ingestion of soil is calculated as follows:

$$CDI = HIF \times C$$

where:

CDI = chronic daily intake, in mg/kg/day;

HIF = human intake factor, in kg/kg/day; and

C = concentration of contaminant in soil, in mg/kg.

Calculation of the human intake factor assumes an absorption factor of 100 percent for all organic compounds, while this factor varies for different inorganic compounds. Cassaret and Doull (1986) suggest reference values for the absorption of metals by the gastrointestinal tract ranging from 8 percent for cadmium to 100 percent absorption of arsenic. Indicator metals at the Base not discussed by Cassaret and Doull were assumed to have absorptions of 50 percent.

The human intake factor, HIF, is calculated as follows:

$$HIF = cr \times f \times A \times F \times (1/bw) \times \frac{1\ \text{year}}{365\ \text{days}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}$$

where:

cr = contact rate, assumed to be 25 mg of soil per day (mg/day) for adults or 10 mg/day for children;

f = frequency of contact, assumed to be 3 days/year;

A = fraction of contaminant absorbed, dimensionless;

F = fraction of life that contact occurs, assumed to be (40/70) for onsite workers and offsite residents and (15/70) for offsite children, dimensionless;

bw = body weight, approximated as 70 kg for adults and 10 kg for children.

6.1.4 Step 4, Toxicity Assessment

This part of the public health analysis presents critical toxicity values for use with the results of the exposure assessment to characterize risk. The USEPA (1986b) has derived values with which to characterize the toxicity of a given compound. Noncarcinogens typically have assigned acceptable intakes for chronic exposure (AIC), while carcinogenic potency factors are used to quantify the toxicity of potential carcinogens.

The USEPA-derived AICs for noncarcinogens and potency factors for carcinogens were obtained, if available, for each indicator chemical. These values have received extensive review within the USEPA and within the scientific community. In some instances, both an AIC and a carcinogenic potency factor are assigned to a single compound. In these cases, both values are used such that both carcinogenic and noncarcinogenic effects of the compound are factored into the risk assessment. Table 6-6 presents a comprehensive list of all indicator chemicals used in this risk assessment at Sites 2, 3, 4 and 8, along with all available toxicity information.

When available, USEPA-derived reference doses (RfDs) are used as AIC values. The RfD for a compound is ideally based on a study where the test animal or human population was exposed to the compound of interest over a major portion of the subject's lifespan (referred to as a chronic study). If animal studies are used as the basis for an RfD, a No Observed Effect Level (NOEL), No Observed Adverse Effect Level (NOAEL), or Lowest Observed Adverse Effect Level (LOAEL) is determined for the most appropriate study, and is subsequently divided by a series of uncertainty factors to arrive at an RfD for humans. The uncertainty factors reflect uncertainties associated with extrapolation between species, sensitive subgroups within a population, using a LOAEL to approximate a NOAEL if a NOEL or NOAEL was not determined, and for using subchronic data to estimate chronic exposure when chronic data are not available.

TABLE 6-6
SITES 2, 3, 4 AND 8
CRITICAL TOXICITY VALUES

Indicator Chemical	Inhalation Route			Oral Route		
	Acceptable Intake Chronic (mg/kg/day)	Carcinogenic Potency Factor (mg/kg/day)	CAG (a)	Acceptable Intake Chronic (mg/kg/day)	Carcinogenic Potency Factor (mg/kg/day)	CAG
Arsenic	NA (b)	5.00E+01	A	NA	1.50E+01	A
Barium	1.40E-04	- (c)	D	5.10E-02	-	D
Benzene	NA	2.90E-02	A	NA	2.90E-02	A
Cadmium	NA	6.10E+00	B1	2.90E-04	NA	NA
Chlorobenzene	5.70E-03	-	D	2.70E-02	-	D
Chromium	NA	4.10E+01	A	5.00E-03	NA	NA
4,4'-DDT	NA	3.40E-01	B2	5.00E-04	3.40E-01	B2
Dibutyl Phthalate	NA	-	D	1.00E-01	-	D
1,1-Dichloroethane	1.38E-01	-	D	1.20E-01	-	D
1,1-Dichloroethene	NA	1.16E+00	C	9.00E-03	6.00E-01	C
Trans-1,2-Dichloroethene	NA	-	D	2.00E-02	-	D
Diethyl Phthalate	NA	-	D	1.30E+01	-	D
Dieldrin	NA	NA	B2	5.00E-05	1.60E+01	B2
Endosulfan I	NA	-	D	5.00E-05	-	D
Ethyl Benzene	NA	-	D	1.00E-01	-	D
Lead	NA	NA	B2	NA	NA	B2
Mercury	5.10E-05	-	D	2.00E-03	-	D
Tetrachloroethene	NA	-	D	1.00E-02	-	D
Toluene	1.50E+00	-	D	3.00E-01	-	D
1,1,1-Trichloroethane	6.30E+00	-	D	3.00E-01	-	D
Trichloroethene	NA	NA	B2	1.30E-02	1.10E-02	B2
Vinyl Chloride	NA	2.50E-02	A	NA	2.30E+00	A
Xylenes	4.00E-01	-	D	1.00E-02	-	D

a. CAG = Carcinogen Assessment Group; see Table 6.2 for explanation.
b. Data not available
c. Not applicable to this compound

Source: U.S. Environmental Protection Agency (1986a) and IRIS (Integrated Risk Information System) through USEPA (1988)

Carcinogenic potency factors are derived only for compounds which have been shown to cause an increased incidence of tumors in either human or animal studies. The potency factor is an upper 95 percent confidence limit on lifetime risk and is determined by low dose extrapolation modeling of animal or human data. When an animal study is used, the final potency factor is adjusted to account for interspecific extrapolation. If the studies used to derive the potency factor were conducted for less than the lifespan of the animal or human, the final potency factor is adjusted to reflect risk associated with lifetime exposure.

Acceptable intake for chronic exposure and carcinogenic potency factors were used for this risk assessment. Available AIC values and carcinogenic potency factors for the indicator chemicals are presented in section 6.2.4, 6.3.4, 6.4.4, and 6.5.4 for each site.

It should be noted that the USEPA has not, to date, derived either AIC or carcinogenic potency factors for the dermal exposure pathway.

6.1.5 Step 5, Risk Characterization

In Step 5, the characterization of risk, the reference values, AIC and potency factors, from Step 4 are compared with the estimated chronic daily intakes from Step 3. Noncarcinogenic and carcinogenic effects are considered separately.

6.1.5.1 Noncarcinogenic effects

To assess the overall potential for noncarcinogenic effects associated with exposure to multiple chemicals, a hazard index approach has been developed based on USEPA guidance (USEPA, 1986c). This approach assumes that multiple sub-threshold exposures may result in an adverse effect and that the magnitude of the adverse effect will be proportional to the sum of the ratios of the sub-threshold exposures to acceptable exposures. This is expressed as:

$$\text{Hazard Index} = E_1/RL_1 + E_2/RL_2 + \ldots + E_i/RL_i$$

where:

Hazard Index = index value devised by the USEPA to assess risk from noncarcinogens, dimensionless;

E_i = exposure level, or chronic daily intake (CDI), for the i^{th} toxicant, in mg/kg/day; and

RL_i = USEPA reference level, or acceptable chronic intake (AIC), for the i^{th} toxicant, in mg/kg/day.

This equation is constructed so that any single chemical with an exposure level greater than the reference level will cause the hazard index to exceed one, indicating a possible risk to public health. Multiple sub-threshold exposures may also cause the total hazard values to exceed one.

The assumption of dose additivity expressed in the hazard index is best applied to compounds that induce the same effects by the same mechanism. Applying the hazard index to cases where the known compounds do not induce the same effect may overestimate risk.

The hazard index is not a mathematic prediction of incidence or severity of effects. It is simply a numerical index to aid in identifying potential exposure problems. In cases where AIC values are not available for all compounds, the hazard index may not be reflective of the actual hazard at the site.

For each receptor, the ratio of CDI to AIC was computed for each compound by route for both maximum and average values. Tables in Appendix P summarize the total of the chemical-specific hazard index values for each site to give the hazard index via the inhalation route and the oral route. The total hazard index for all routes of exposure is presented in Sections 6.2.5, 6.3.5, 6.4.5, and 6.5.5 for each receptor at each site.

6.1.5.2 Potential Carcinogenic Effects

For potential carcinogens, risk is estimated as a probability. The USEPA (1986a) describes the carcinogenic potency factor as an upper 95 percent confidence limit on the probability of response per unit intake of a chemical over a lifetime. This means that there is only a five percent chance that the probability of response could be greater than the estimated value for the experimental data used.

At low doses, risk associated with carcinogenic compounds is described by the equation:

$$\text{Risk} = \text{CDI} \times \text{PF}$$

where:

CDI = chronic daily intake (CDI) of the potential carcinogen, in mg/kg/day; and
PF = carcinogenic potency factor, a factor devised by USEPA to assess risk from a potential carcinogen in $(\text{mg/kg/day})^{-1}$.

For purposes of the public health evaluation, USEPA assumes that the risks associated with exposure to multiple carcinogens are additive. That is to say:

$$\text{Total Risk} = (CDI_1 \times PF_1) + (CDI_2 \times PF_2) + \ldots + (CDI_i \times PF_i)$$

where:

CDI_i = exposure level, or CDI for the i^th carcinogen, in mg/kg/day; and

PF_i = carcinogenic potency factor for the i^th carcinogen, in $(mg/kg/day)^{-1}$.

Risk addition is valid when doses are low; no synergistic or antagonistic interactions occur; and similar endpoints are evaluated. For purposes of this evaluation, it is also assumed that cancer risk from all routes are additive. For each receptor, risk was computed for each compound by route for both maximum and average values. Tables in Appendix P summarize the total of the chemical-specific risks from potential carcinogens for each site to give the risk from potential carcinogens via the inhalation route and oral route. The total risk for all routes of exposure is presented for each receptor at each site in Sections 6.2.5, 6.3.5, 6.4.5 and 6.5.5. According to USEPA guidance, the target overall individual lifetime carcinogenic risk from exposure should be in the range of 10^{-4} (1 additional case of cancer per 10,000 individuals) and 10^{-7} (1 additional case of cancer per 10,000,000 individuals), with 10^{-6} being the nominal value, depending on the location and condition of the site.

6.2 SITE 2 RISK ASSESSMENT

The risk assessment for Site 2 is presented in this section.

6.2.1 Selection of Indicator Chemicals

Indicator chemicals used in the risk assessment for Site 2 included metals and semi-volatile and volatile organic compounds. These parameters were selected on the basis of ranking of indicator scores, toxicological class, chemical properties, and frequency of detection. Table 6-7 summarizes the concentrations of these compounds in ground water, surface water, sediments, surface soil and soil at depth. Data used in the selection of indicator chemicals were compiled from data collected as a part of this investigation and the Phase II, Stage 2 investigation (Dames & Moore, 1987). These data are summarized in Appendix P.

Compounds which were detected at Site 2, but were not included as indicator chemicals, were cadmium, chromium, chlorobenzene, 1,2-

TABLE 6-7

SITE 2 INDICATOR CHEMICAL CONCENTRATIONS

Indicator Chemical	Ground-Water Concentration (mg/L)		Surface Water Concentration (mg/L)		Sediment Concentration (mg/kg)		Surface Soil Concentration (mg/kg)		Soil at Depth (b) Concentration (mg/kg)	
	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative
Arsenic	ND (a)	ND	ND	ND	1.30E+00	1.02E+00	3.70E+00	2.70E+00	2.70E+00	1.66E+00
Barium	ND	ND	ND	ND	5.39E+01	5.03E+01	2.95E+02	8.72E+01	2.62E+02	5.69E+01
Benzene	1.20E-03	6.00E-04	ND	ND	ND	ND	2.50E+00	1.24E+00	3.10E+00	1.34E+00
Dibutyl Phthalate	ND	ND	ND	ND	ND	ND	ND	ND	2.00E+00	1.65E+00
1,1-Dichloroethene	6.10E-04	3.05E-04	ND	ND	ND	ND	ND	ND	ND (b)	ND
Trans-1,2 Dichloroethene	1.20E+00	2.31E-01	2.60E-03	1.30E-03	ND	ND	9.00E-02	4.50E-02	8.00E-04	4.00E-04
Diethyl Phthalate	1.44E-01	1.22E-02	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl Benzene	ND	ND	ND	ND	ND	ND	5.20E+00	3.33E+00	2.50E+01	8.81E+00
Lead	ND	ND	ND	ND	5.26E+00	6.70E+00	5.40E+01	1.32E+01	1.02E+02	8.01E+00
Mercury	ND	ND	ND	ND	ND	ND	2.00E-01	1.00E-01	1.00E-01	5.00E-02
Tetrachloroethene	4.30E-04	2.15E-04	ND	ND	ND	ND	2.30E+00	1.15E+00	1.50E-01	2.54E-02
Toluene	ND	ND	ND	ND	2.50E-02	1.25E-02	3.60E+01	3.23E+00	1.50E+01	9.89E-01
Trichloroethene	3.30E-02	1.73E-02	ND	ND	2.60E-04	1.30E-04	1.60E+00	8.01E-01	7.10E-02	2.94E-02
Vinyl Chloride	3.10E-03	1.55E-03	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes	ND	ND	ND	ND	ND	ND	1.80E+02	6.86E+01	7.10E+01	2.13E+01

a. ND = Not Detected

b. "Soil at depth" refers to soil two feet or more below the surface.

Note: 1.00E-01 = 1 x 0.1
0.01 = 1 x 0.01
0.001 = 1 x 0.001
0.0001 = 1 x 0.0001

dichlorobenzene, 1,2-dichloroethane, pyrene, 1,1,2,2-tetrachloroethane and 1,1,1 trichloroethane. Cadmium and chromium, although not ranked in Table P-5 due to inavailability of toxicity constants, were not selected since the detected levels in surface and subsurface soil were below concentrations detected at background soil sampling locations. Pyrene, also not ranked, was not chosen as an indicator chemical since it was detected in only 2 of 43 soil samples. The other compounds listed above were not selected due to low indicator scores.

6.2.2 Estimation of Exposure Point Concentrations or Emission Rates

The second step in the risk assessment process was to determine human exposure points associated with Site 2 and to identify potentially complete exposure pathways. Exposure point concentrations of indicator chemicals were then determined.

6.2.2.1 Exposure Pathway Analysis

The exposure pathway analysis entailed identifying possible sources of contaminant release, transport media, human exposure points, and potentially complete exposure routes at each exposure point. These are listed in Table 6-4. Table 6-8 summarizes all Site 2 exposure pathways identified in Table 6-4.

Air Pathways

A source of fugitive dust at this site is a former fire training area, FTA-2, that is almost completely devoid of vegetation. This contaminated area covers approximately 7900 square feet, and is located adjacent to the airport perimeter road which has a gravel surface (Figure 1-7). Potential receptors of contaminated fugitive dust are people that drive on the perimeter road on a semi-regular basis. This includes 10 to 15 workers traveling to the munitions storage building, one worker who maintains the radar facility, and 20 to 25 adults and children who are members of a skeet shooting club that meets at a skeet shooting range north of FTA-2 during the summer. Workers occasionally jog or walk on this road or use the nearby target range during the summer months. Health effects resulting from exposure to fugitive dust at Site 2 are unlikely considering dispersion and natural advection forces.

Surface water and soil can be dismissed as sources for chemical release through volatilization. Surface water was eliminated as a possible release ource since only one volatile chemical, trans-1,2-dichloroethene, was detected. Although a number of volatiles were detected in the fire training area surface

TABLE 6-8
PATHWAYS CONTRIBUTING TO TOTAL EXPOSURE FOR EACH POTENTIAL RECEPTOR AT SITE 2

Potential Receptor	Exposure Pathway
Current Use	
On-Site Workers (Adults Only)	. Incidental ingestion of surface soils . Fugitive dust inhalation
Nearby Residents (Adults and Children)	. Fugitive dust inhalation while visiting firing range . Incidental ingestion of surface soils while visiting firing range
Future Use	
On-Site Workers (Adults Only)	. Incidental ingestion of soil at depth
On-Site Residents or Workers (Adults and Children)	. Ingestion of ground water as drinking water

soils (Table 6-7), they were not considered to be a significant source of volatilized contaminants in their current undisturbed state.

Surface Water Pathways

Site 2 has very little flowing surface water, and that which exists is located in an area that is not frequented by workers or visiting skeet shooting club members. The exposure of onsite workers or offsite residents to contamination through onsite surface water was therefore not considered as a potential pathway.

Surface water originating from Site 2 would play an insignificant role in elevating contaminant levels in water bodies off site due to the very low discharge and the low to non-detectable concentrations of indicator chemicals. Moreover, no significant contamination was detected in a surface water sample collected from an offsite location, DANGB-BG-SL1, which is downstream from the site. This pathway was therefore not considered in this assessment, since the impact on public health is probably negligible.

Ground-Water Pathways

Current exposure pathways involving the onsite or offsite ingestion of contaminated ground water originating from Site 2 were not included in this risk assessment. Although off-site domestic wells exist within a one mile radius of the site, the shallow aquifer serving these off-site wells is not in hydraulic communication with ground water at Site 2. Site 2 ground water discharges as surface water in the immediate vicinity of the site. This hydraulic "break" interrupts the flow of contaminated ground water from Site 2 to offsite wells where pathway completion could occur. Current exposure to onsite ground water through ingestion by on-site workers is also unlikely due to the availability of Duluth city water to the airport and Air National Guard (ANG) facilities.

A future pathway through the ingestion of ground water by hypothetical onsite residents was considered as a potential route of exposure. Should the property used be relinquished by the ANG and subsequently developed for commercial or private use, the remote possibility exists that the removal of institutional controls formerly imposed by the Base would result in exposure to the contaminated ground water through ingestion. The probability of adverse health effects occurring through this future pathway is very low, due to the reduction of current levels of indicated chemicals over time through natural flushing of the contamination and attenuation by biological processes.

Soil Pathways

Current exposure of workers to surface soil through incidental ingestion was included as a current potential pathway at Site 2, although the probability of pathway completion is small. Future excavation at Site 2, which would expose construction workers to soil at depth through incidental ingestion, was also considered as a potential pathway.

Potential receptors to Site 2 soil contamination are the skeet shooting club members which include some children. The probability of pathway completion is very low, since the club meets at an area approximately 200 yards from the fire training area, and it is unlikely that members would walk over the contaminated area. Access to Site 2 by the general public is prevented by locked gates and guards at the main entry to the Air National Guard Base.

Sediment Pathways

The exposure of onsite workers or offsite resident to Site 2 sediments was not considered as a pathway. It is unlikely that workers would walk in the limited amount of surface water present at Site 2. The distance between Site 2 and the nearest offsite exposure point is over one mile. This distance would probably prevent the migration of contaminated sediment to areas outside the Base boundaries.

6.2.2.2 Exposure Point Concentrations

Following the exposure pathway analysis, the environmental concentrations for each indicator chemical at each significant exposure point were determined for each possible pathway.

Two steps were needed to determine the exposure point concentrations for each potential receptor. The first step was to quantify the amount of the chemical released from the source in terms of release rate (mass per unit time). The second step was to use the release rates to predict the environmental fate of the indicator chemicals and their exposure point concentrations. A summary of the pathways resulting in exposure to human receptors is presented in Table 6-8. Exposure point concentrations were derived from sampling data collected at Site 2 during the RI and a previous study (Dames & Moore, 1987).

The surface soil exposure point concentrations of the indicator chemicals were estimated to be equal to the concentrations measured during the two sampling efforts (Table 6-7). Potential receptors include any Air National

Guard personnel that work in the vicinity of the site and members of the skeet shooting club which use the skeet range located near Site 2.

The fugitive dust exposure point concentrations of the indicator chemicals were obtained by substituting the surface soil exposure point contaminant concentrations as measured on site into the model presented in Section 6.1.3.1. Potential receptors are onsite workers or offsite residents using the skeet shooting range located near Site 2. The exposure point concentrations are given in Table 6-9 along with the adjusted Threshold Limit Values (TLVs) for these compounds which are discussed further in Section 6.2.2.3.

The exposure point concentrations used for the future ingestion of ground water are assumed to be the same as the concentrations measured on site during the RI and the previous study. Table 6-7 lists these concentrations for Site 2 indicator chemicals. This is a worst case scenario since attenuation, adsorption, or other chemical and biological processes would serve to reduce concentrations in the ground water over time. Potential receptors are future onsite residents who utilize ground water as a source of drinking water.

Future exposure point concentrations for soil contacted by construction workers during excavation of Site 2 were based on the current sampling data collected for soil over two feet below the surface. This data is shown in Table 6-7.

6.2.2.3 Comparison of Exposure Point Concentrations to ARARs

Table 6-5 lists ARARs and other criteria for Site 2 indicator chemicals against which the Site 2 exposure point concentrations are compared. Exposure point concentrations for indicator chemicals adsorbed to fugitive dust are presented in Table 6-9. All other exposure point concentrations are assumed to be equivalent to concentrations measured on site in the medium of interest, listed in Table 6-7.

All ground-water indicator chemicals except tetrachloroethene exceed the AWQCs. The future ground-water exposure point concentrations of trans-1,2-dichloroethene, trichloroethene and vinyl chloride exceed both the federal MCLs and state RALs. The future ground-water exposure point concentrations for benzene, 1,1-dichloroethene and tetrachloroethene were below federal MCLs and state RALs.

The exposure point concentrations in surface soil and subsurface soil for barium and lead were above the range of background concentrations while arsenic was within the background concentration range. The surface soil

TABLE 6-9
COMPARISON OF EXPOSURE POINT CONCENTRATIONS OF SITE 2 INDICATOR CHEMICALS IN AIR

Indicator Chemical	Threshold Limit Value (TLV) in Air/420 (a) (mg/m3)	Exposure Point Concentration (mg/m3) Fugitive Dust. (Onsite Workers) Upper Bound	Best Estimate	Fugitive Dust (Nearby Residents) Upper Bound	Best Estimate
Arsenic	0.00048	2.16E-10	1.58E-10	1.12E-11	8.16E-12
Barium	0.0012	1.73E-08	5.10E-09	8.91E-10	2.63E-10
Benzene	0.071	1.46E-10	7.24E-11	7.55E-12	3.74E-12
Dibutyl Phthalate	0.012	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1 Dichloroethylene	0.048	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Trans-1,2 Dichloroethylen	1.89	5.26E-12	2.63E-12	2.72E-13	1.36E-13
Diethyl Phthalate	0.012	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethyl Benzene	1.04	3.04E-10	1.95E-10	1.57E-11	1.00E-11
Lead	0.0004	3.16E-09	7.72E-10	1.63E-10	3.99E-11
Mercury	0.0002	1.17E-11	5.85E-12	6.04E-13	3.02E-13
Tetrachloroethylene	1.6	1.34E-10	6.74E-11	6.95E-12	3.48E-12
Toluene	0.89	2.11E-09	1.89E-10	1.09E-10	9.75E-12
Trichloroethylene	0.64	9.36E-11	4.68E-11	4.83E-12	2.42E-12
Vinyl Chloride	0.024	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	1.04	1.05E-08	4.01E-09	5.44E-10	2.07E-10

a. American Conference of Governmental Hygenists (1987) exposure point concentrations of arsenic, trans-1,2-dichloroethene, ethyl benzene and toluene were below the adjusted MCLs outlined in Table 6-5 for soil, while barium, benzene, lead, tetrachloroethene, trichloroethene and xylenes were above this guideline. Subsurface soil exposure point concentrations of trans-1,2-dichloroethene, toluene and trichloroethene were below the adjusted MCLs, while arsenic, barium, benzene, ethyl benzene, lead, tetrachloroethene and xylenes concentrations were above.

The exposure point concentrations for the fugitive dust pathway were below the TLVs adjusted for exposure by nonworker populations for all the Site 2 indicator chemicals listed in Table 6-9.

6.2.3 Estimation of Chemical Intakes

The chronic daily intakes by human receptors were estimated for each potential pathway completion by multiplying the exposure point concentrations by corresponding human intake factors. Both upper bound and best estimate chronic daily intakes for each potential pathway for each population at risk were calculated from the maximum and average indicator chemical concentrations, respectively. Chronic daily intakes for pathways categorized as oral or inhalation routes were summed to yield total chronic daily intake via a particular route for a target population. The process for estimating chemical intakes is described in Section 6.1.3, and the detailed tables are in Appendix P.

6.2.4 Toxicity Assessment

Acceptable Intake for Chronic Exposure (AIC) values and potency factors are presented for inhalation and oral routes of exposure for Site 2 indicator chemicals in Table 6-6 (USEPA, 1986a and 1988). No toxicity values are available through USEPA for the dermal route of exposure.

Acceptable Intake for Chronic Exposure values are available for all of the Site 2 noncarcinogenic indicator compounds for the oral route, but only barium, toluene and xylenes have AIC values for the inhalation route. The only AIC values available for Site 2 potential carcinogens via the oral route are 1,1-dichloroethene and trichloroethene; no AIC values were available for the inhalation route.

Of the seven potentially carcinogenic compounds detected at Site 2, potency factors were available for all but lead for exposure through ingestion. Potency factors for lead and trichloroethene were not available via the inhalation route.

No toxicity values are currently available for lead, causing it to drop out of the final risk characterization. Although it is not possible to quantify the contribution of lead to the total risk, lead is considered to pose a potential threat to human health when present at any concentration in environmental media to which human receptors may be exposed.

6.2.5. Risk Characterization

The risk to public health from Site 2 is characterized separately for noncarcinogens and potential carcinogens through the determination of hazard index values and risk from potential carcinogens, respectively. This procedure is described in detail in Section 6.1.5, and the details for this site are given in Appendix P.

6.2.5.1 Risk Characterization of Noncarcinogenic Compounds

The exposure route or pathway at this site which contributes the most risk from exposure to noncarcinogenic compounds is the future ingestion of ground water originating at Site 2. Hazard index computations based on maximum chemical concentrations indicate a potential risk to hypothetical onsite adults and children primarily through the future ingestion of trans-1,2-dichloroethene. Otherwise, the presence of these noncarcinogenic compounds at Site 2 present no threat to human health via all identified current pathways.

Tables 6-10 and 6-11 summarize the total hazard index values for each population at risk, for upper bound and best estimate values, respectively. With the exception of the future ingestion of ground water by onsite residents (upper bound only), the CDI:AIC ratios for all potential receptors fall well below one indicating no significant chronic health hazard exists at this site at this time. The potential noncarcinogenic risk posed by the future ingestion of ground water is probably overvalued due to the conservative assumptions employed in estimating the future onsite exposure point concentrations. Dilution and natural physical and biological processes will probably play a significant role in reducing the concentrations of contaminants in ground water over time.

6.2.5.2 Risk Characterization of Potentially Carcinogenic Compounds

Calculation of risk from potential carcinogens indicated that Site 2 poses no threat to current onsite and offsite potential receptors via all identified current pathways. However, the exposure of future hypothetical onsite residents to potential carcinogens showed a slight risk, which was contributed

TABLE 6-10
SUMMARY OF HAZARD INDEX VALUES FOR SITE 2
UPPER BOUND

Potential Receptor	Sum of CDI:AIC Ratios (a) Inhalation	Sum of CDI:AIC Ratios Oral	Sum of CDI:AIC Ratios Total
Current Use			
On-Site Workers			
(adult)	1.00E-07	3.59E-05	3.60E-05
Nearby Residents			
(adult)	2.08E-08	3.59E-05	3.60E-05
(child)	1.37E-08	3.77E-05	3.78E-05
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	1.79E+00	1.79E+00
On-Site Residents			
(child)	0.00E+00	1.34E+00	1.34E+00

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake

TABLE 6-11
SUMMARY OF HAZARD INDEX VALUES FOR SITE 2
BEST ESTIMATE

Potential Receptor	Sum of CDI:AIC Ratios (a) Inhalation	Sum of CDI:AIC Ratios Oral	Sum of CDI:AIC Ratios Total
Current Use			
On-Site Workers			
(adult)	2.96E-08	1.33E-05	1.34E-05
Nearby Residents			
(adult)	6.17E-09	1.33E-05	1.33E-05
(child)	4.05E-09	1.40E-05	1.40E-05
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	3.70E-01	3.70E-01
On-Site Residents			
(child)	0.00E+00	2.77E-01	2.77E-01

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake

TABLE 6-12
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITE 2
UPPER BOUND

Potential Receptor	Sum of Risk From Inhalation	Sum of Risk From Ingestion	Sum of Risk Total
Current Use			
On-Site Workers			
(adult)	8.77E-12	9.32E-08	9.33E-08
Nearby Residents			
(adult)	1.83E-12	9.32E-08	9.32E-08
(child)	1.20E-12	9.79E-08	9.79E-08
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	2.26E-04	2.26E-04
On-Site Residents			
(child)	0.00E+00	1.69E-04	1.69E-04

TABLE 6-13
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITE 2
BEST ESTIMATE

Potential Receptor	Sum of Risk From Inhalation	Sum of Risk From Ingestion	Sum of Risk Total
Current Use			
On-Site Workers			
(adult)	2.07E-10	6.80E-08	6.82E-08
Nearby Residents			
(adult)	1.33E-12	6.80E-08	6.80E-08
(child)	8.74E-13	7.14E-08	7.14E-08
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	1.13E-04	1.13E-04
On-Site Residents			
(child)	0.00E+00	8.48E-05	8.48E-05

to mostly by the ingestion of vinyl chloride in Site 2 ground water. Computations of upper bound and best estimate carcinogenic risk to these populations (Tables 6-12 and 6-13, respectively) indicated slightly above 1 additional case of cancer per 10,000 individuals (10^{-4}), which is just above the USEPA's maximum recommended risk level of 10^{-4}. The probability of overestimation of the future exposure point concentrations of these compounds significantly reduces the carcinogenic threat to future onsite residents.

6.3 SITE 3 RISK ASSESSMENT

The risk assessment for Site 3 is presented in this section.

6.3.1 Selection of Indicator Chemicals

Indicator chemicals used in the risk assessment for Site 3 included metals, volatile organic compounds, and a pesticide. These parameters were selected on the basis of ranking of indicator scores, toxicological class, chemical properties, and frequency of detection. Table 6-14 summarizes the concentrations of these compounds in ground water, surface water, sediments, surface soil and soil at depth. Data used in the selection of indicator chemicals were compiled from data collected as a part of this remedial investigation, the Phase II, Stage 2 investigation (Dames & Moore, 1987) and the Phase II, Stage 1 investigation (Weston, 1984). These data are summarized in Appendix P.

Compounds which were detected at Site 3, but were not included as indicator chemicals, were volatile organic compounds, 1,4 dichlorobenzene, 1,2-dichloroethane, ethyl benzene, toluene and xylenes; the semi-volatile organic compound, diethyl phthalate; PCBs; and the pesticides, 4,4'-DDD, 4,4'-DDE, delta BHC, and endosulfan sulfate. The volatile organic compounds were not selected due to low indicator scores and infrequency of detection. Diethyl phthalate was not chosen due to infrequency of detection and its low indicator score. All PCB compounds were eliminated due to lack of toxicity data. The pesticides were not selected due to infrequency of detection and lack of available toxicity data with which to characterize risk.

6.3.2 Estimation of Exposure Point Concentrations or Emission Rates

The second step in the risk assessment process was to determine human exposure points associated with Site 3 and to identify potentially complete exposure pathways. Exposure point concentrations of indicator chemicals were then determined.

TABLE 6-14
SITE 3 INDICATOR CHEMICAL CONCENTRATIONS

Indicator Chemical	Ground-Water Concentration (mg/L)		Surface Water Concentration (mg/L)		Sediment Concentration (mg/kg)		Surface Soil Concentration (mg/kg)		Soil at Depth (b) Concentration (mg/kg)	
	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative
Arsenic	ND (a)	ND	2.00E-02	1.00E-02	5.90E+01	3.23E+01	ND	ND	ND	ND
Barium	1.00E+00	6.33E-01	6.00E-01	3.50E-01	3.10E+02	8.90E+01	1.21E+02	6.98E+01	1.20E+02	4.85E+01
Benzene	3.60E-02	1.02E-02	ND	ND	ND	ND	9.00E-01	4.50E-01	ND	ND
Cadmium	ND	ND	1.40E-01	1.00E-01	9.03E+00	7.88E+00	1.94E+01	1.04E+01	1.10E+01	8.99E+00
Chromium	7.10E-01	3.05E-01	2.00E-01	1.00E-01	7.80E+01	3.49E+01	4.43E+01	3.19E+01	3.80E+01	2.82E+01
4,4'-DDT	ND	ND	ND	ND	ND	ND	5.00E-01	8.94E-02	1.10E-01	4.88E-02
1,1-Dichloroethane	3.10E-01	1.11E-01	3.70E-02	2.04E-02	5.60E-03	3.29E-03	2.20E-02	1.35E-02	2.50E-04	1.25E-04
1,1-Dichloroethene	5.80E-02	2.16E-02	3.50E-02	1.68E-02	2.40E-02	2.10E-02	3.70E-02	1.95E-02	ND	ND
Trans-1,2-Dichloroethene	4.50E-01	1.24E-01	8.20E-02	5.41E-02	5.00E-01	3.15E-01	1.40E-02	1.00E-02	ND	ND
Lead	3.00E-02	1.50E-02	7.60E-01	3.13E-01	4.78E+02	1.26E+02	3.03E+01	9.70E+00	8.20E+00	4.27E+00
Mercury	ND	ND	ND	ND	5.80E-01	4.40E-01	2.80E-01	1.40E-01	ND	ND
Tetrachloroethene	1.00E+00	4.06E-01	1.00E-02	7.30E-03	5.10E-03	3.80E-03	3.00E+00	8.23E-02	4.10E-04	2.05E-04
1,1,1-Trichloroethane	3.10E+00	1.08E+00	1.40E+00	6.01E-01	2.40E-01	4.58E-02	2.10E-01	4.89E-02	ND	ND
Trichloroethene	7.90E-01	8.89E-02	7.40E-01	3.56E-01	1.40E-01	4.63E-02	9.40E-01	1.93E-01	4.00E-03	3.75E-02
Vinyl Chloride	9.10E-03	4.98E-03	6.00E-03	4.60E-03	4.20E-03	8.40E-03	ND	ND	ND	ND

a. ND = Not Detected

b. "Soil at depth" refers to soil two feet or more below the surface.

Note: 1.00E-01 = 1 x 0.1
1.00E-02 = 1 x 0.01
1.00E-03 = 1 x 0.001
1.00E-04 = 1 x 0.0001

6.3.2.1 Exposure Pathway Analysis

The exposure pathway analysis entailed identifying possible sources of contaminant release, transport media, human exposure points, and potentially complete exposure routes at each exposure point, as summarized in Table 6-4. Table 6-15 summarizes all Site 3 exposure pathways identified in Table 6-4.

Air Pathways

The likelihood of fugitive dust generation is very low, and was not considered in this assessment since surface soils at Site 3 are covered with pavement, gravel, grass, or are located in an unused wooded area with typical woodland undergrowth.

Surface water presents the possibility of pathway completion via volatilization and subsequent inhalation by onsite workers, since a large number of volatile indicator chemicals were detected (Table 6-14). Although this exposure pathway is considered in this risk assessment, the possibility of pathway completion is probably very low, since the eight Department of Defense personnel who regularly work on Site 3 perform most of their duties inside an office facility. Workers occasionally are required to go outdoors in order to move or maintain equipment stored on a fenced-in paved area, which is located near one section of the stream that traverses the site. It is unlikely that adverse health effects would occur due to the natural dispersion of the volatilized contaminants in the air.

Although a number of volatiles were detected in Site 3 surface soils (Table 6-14), they were not considered as a significant source of volatilized contaminants in their current undisturbed state.

Surface Water Pathways

Exposure of workers to surface water contamination could possibly occur via the dermal route, but it is very unlikely that workers would go near any of the ditches without dermal protection. The exposure of onsite workers to exposure of intruders to surface water contamination was not considered as a potential pathway.

Trespassers are prohibited access to the site by onsite workers during the day, and a locked fence across the access road during all other times. Since Site 3 is not entirely fenced, it is possible to gain access to Site 3 afterhours via other unrestricted routes. The lack of any heavily populated residential areas in the immediate proximity greatly decreases the likelihood of offsite children or adults becoming exposed to Site 3 contamination. Thus the

TABLE 6-15
PATHWAYS CONTRIBUTING TO TOTAL EXPOSURE FOR EACH POTENTIAL RECEPTOR AT SITE 3

Potential Receptor	Exposure Pathway
Current Use	
On-Site Workers (Adults Only)	. Incidental ingestion of surface soils . Fugitive dust inhalation
Nearby Residents (Adults and Children)	. Fugitive dust inhalation while visiting firing range . Incidental ingestion of surface soils while visiting firing range
Future Use	
On-Site Workers (Adults Only)	. Incidental ingestion of soil at depth
On-Site Residents or Workers (Adults and Children)	. Ingestion of ground water as drinking water

exposure of intruders to surface water contamination was not considered as a potential pathway.

Although no significant contamination was detected in a surface water sample collected from an offsite location downstream from Site 3 (DANGB-BG-SL1), the exposure of nearby residents to offsite surface water which could possibly originate at Site 3 was considered. This pathway was included because of the large number of indicator chemicals detected in onsite surface water which have the potential to migrate downstream from Site 3. Ingestion was the surface water exposure route used in this assessment; dermal exposure was not considered due to lack of dermal permeability data for the compounds detected in Site 3 surface water.

Ground-Water Pathways

Current exposure pathways involving the onsite or offsite ingestion of contaminated ground water originating at Site 3 were not included in this risk assessment. Although offsite domestic wells exist within a one mile radius of the site, the shallow aquifer serving these offsite wells is not in hydraulic communication with ground water at Site 3. Site 3 water discharges as surface water in the immediate vicinity of the site. This hydraulic "break" interrupts the flow of contaminated ground water from Site 3 to offsite wells where pathway completion could occur. Current exposure to onsite ground water through ingestion by onsite workers is also unlikely due to the availability of Duluth city water to the airport and Air National Guard (ANG) facilities.

A future pathway through the ingestion of ground water by hypothetical onsite residents was considered as a potential route of exposure. Should the property use be relinquished by the ANG and subsequently developed for commercial or private use, the remote possibility exists that the removal of institutional controls formerly imposed by the Base would result in exposure to the contaminated ground water through ingestion. The probability of adverse health effects occurring through this future pathway is very low due to the reduction of current levels of indicator chemicals over time through natural flushing of the contamination and attenuation by biological processes.

Soil Pathways

Exposure of workers to surface soil through incidental ingestion was included as a current potential pathway at Site 3, although the probability of pathway completion is small. The exposure of trespassers to onsite soil was not considered due to the lack of any heavily populated residential areas, which may contain children, in the immediate proximity of Site 3. Future excavation, which would expose construction workers to soil at depth through incidental ingestion, was also considered as a potential future pathway of exposure.

Sediment Pathways

The exposure of onsite workers or offsite residents to Site 3 sediments was not considered as a pathway. It is unlikely that workers would walk in the surface water without dermal protection. The distance between Site 3 and the nearest downgradient exposure point is over one mile. This distance would probably be prohibitive to the migration of contaminated sediment to areas outside the Base boundaries.

6.3.2.2 Exposure Point Concentrations

Following the exposure pathway analysis, the environmental concentrations for each indicator chemical at each significant exposure point were determined for each possible pathway.

Two steps were needed to determine the exposure point concentrations for each potential receptor. The first step was to quantify the amount of chemical released from the source in terms of release rate (mass per unit time). The second step was to use the release rates to predict the environmental fate of the indicator chemicals and their exposure point concentrations. A summary of the pathways resulting in exposure to human receptors is presented in Table 6-15. Exposure point concentrations were derived from sampling data collected at Site 3 during the RI and previous studies (Dames & Moore, 1987 and Weston, 1984).

The surface soil exposure point concentrations of the indicator chemicals were estimated to be equal to the concentrations measured during the sampling efforts (Table 6-14). Potential receptors include anyone who may work at the site.

Offsite surface water contaminant exposure point concentrations used in this assessment were considered to be the same as the concentrations measured on site as given in Table 6-14. This is a very conservative assumption, since the levels of contamination of onsite surface water would probably be reduced by dilution and natural physical and biological processes as the water migrated offsite.

Volatilized surface water contaminant exposure point concentrations were obtained by substituting the surface water exposure point contaminant concentrations measured on site into the model described in Section 6.1.3.2. Potential receptors are onsite workers. The exposure point concentrations are given in Table 6-16, along with the adjusted Threshold Limit Values (TLVs) for these compounds, which are discussed further in Section 6.3.2.3.

Future exposure point concentrations used for the future onsite ingestion of ground water are the same as the concentrations measured on site during this investigation and previous studies. Table 6-14 lists the concentrations for Site 3 indicator chemicals. This is a worst case scenario since attenuation, adsorption, or other chemical and biological processes would probably reduce concentrations of contaminants in the ground water over time. However, the conservative assumption must be used, due to the inability to predict when future exposures could potentially occur. Potential receptors are future onsite residents who utilize ground water as a source of drinking water.

Future exposure point concentrations for soil contacted by construction workers during excavation of Site 3 were based on the chemical analysis results for soil samples collected from depths greater than two feet below the surface sampled during this investigation. This data is shown in Table 6-14.

6.3.2.3 Comparison of Exposure Point Concentrations to ARARs

Table 6-5 lists ARARs and other criteria for Site 3 indicator chemicals, against which the Site 3 exposure point concentrations are compared. Exposure point concentrations for indicator chemicals which have volatilized from site surface water are presented in Table 6-16. All other exposure point concentrations are assumed to be equivalent to concentrations measured onsite in the medium of interest, listed in Table 6-14.

Of the future ground water exposure point concentrations, only barium was below state and federal guidelines.

Of the offsite surface water exposure point concentrations, only arsenic and barium were below all of the recommended levels in Table 6-5, except for the arsenic AWQC. The offsite surface water exposure point concentration of vinyl chloride was below the federal MCL, but above the Minnesota RAL.

The surface soil exposure point concentrations for arsenic, barium, cadmium and lead were above the range of background soil concentrations for these metals. Mercury and chromium were within the background concentration ranges. Only mercury was below the adjusted MCL.

TABLE 6-16
COMPARISON OF AMBIENT EXPOSURE POINT CONCENTRATIONS WITH AIR CRITERIA
SITE 3

Indicator Chemical	Threshold Limit Value (TLV) in Air/420 (a) (mg/m3)	Volatiles from Surface Water (On-Site Workers) Exposure Point Concentration (mg/m3)	
		Upper Bound	Best Estimate
Arsenic	0.00048	0.00E+00	0.00E+00
Barium	0.0012	0.00E+00	0.00E+00
Benzene	0.071	0.00E+00	0.00E+00
Cadmium	0.00012	0.00E+00	0.00E+00
Chromium	0.00012	0.00E+00	0.00E+00
4,4'-DDT	0.0024	0.00E+00	0.00E+00
1,1-Dichloroethane	1.9	8.33E-09	4.59E-09
1,1-Dichloroethene	0.048	7.96E-09	3.82E-09
Trans-1,2-Dichloroethene	1.89	1.87E-08	1.23E-08
Lead	0.0004	0.00E+00	0.00E+00
Mercury	0.0002	0.00E+00	0.00E+00
Tetrachloroethene	1.6	1.74E-09	1.27E-09
1,1,1-Trichloroethane	4.5	2.72E-07	1.17E-07
Trichloroethene	0.64	1.45E-07	6.97E-08
Vinyl Chloride	0.024	1.69E-09	1.30E-09

a. American Conference of Governmental Hygenists (1987).

Subsurface soil exposure point concentrations for cadmium and lead were within the range of background concentrations. The maximum subsurface concentrations for barium and chromium are just above the background concentration range. All subsurface soil exposure point concentrations were above the adjusted MCLs.

Table 6-16 compares the TLVs adjusted for exposure by nonworker populations to the calculated exposure point concentrations for the volatilization pathways, for all the Site 3 indicator chemicals. All of these theoretical concentrations were well below the suggested limits.

6.3.3 Estimation of Chemical Intakes

The chronic daily intakes by human receptors were estimated for each potential pathway completion by multiplying the exposure point concentrations by corresponding human intake factors. Both upper bound and best estimate chronic daily intakes for each potential pathway for each population at risk were calculated from the maximum and average indicator chemical concentrations, respectively. Chronic daily intakes for pathways categorized as oral, dermal or inhalation routes were summed to yield total chronic daily intake via a particular route for a target population. The process for estimating chemical intakes is described in Section 6.1.3, and the detailed tables for this site are in Appendix P.

6.3.4 Toxicity Assessment

Acceptable Intake for Chronic Exposure (AIC) values and potency factors are presented for inhalation and oral routes of exposure for Site 3 indicator chemicals in Table 6-6 (USEPA, 1986a and 1988). No toxicity values are available through USEPA for the dermal route of exposure.

Acceptable Intake for Chronic Exposure values are available for all of the Site 3 noncarcinogenic compounds for the oral route, but there are no trans-1,2-dichloroethene and tetrachloroethene AIC values for the inhalation route. The only AIC values available for Site 4 potential carcinogens via the oral route of exposure were 4,4'-DDT, 1,1-dichloroethene and trichloroethene. No AIC values were available for these potential carcinogens via inhalation.

Of the seven potentially carcinogenic indicator compounds, potency factors were available for all but lead for exposure through ingestion. Potency factors for all but lead and trichloroethene were available via the inhalation route.

No toxicity levels are currently available for lead, causing it to drop out of the final risk characterization. Although it is not possible to quantify the contribution of lead to the total risk, lead is considered to pose a potential threat to human health when present at any concentration in environmental media to which human receptors may be exposed.

6.3.5. Risk Characterization

The risk to public health from Site 3 is characterized separately for noncarcinogens and potential carcinogens, through the determination of hazard index values and risk from potential carcinogens, respectively. This procedure is described in detail in Section 6.1.5, and the details for this site are given in Appendix P.

6.3.5.1 .Risk Characterization of Noncarcinogenic Compounds

The exposure route or pathway at this site which contributes the most risk from exposure to noncarcinogenic compounds is the future ingestion of ground water originating at Site 3. Hazard index computations based on maximum chemical concentrations indicate a potential risk to hypothetical onsite adults and children primarily through the future ingestion of chromium, tetrachloroethene and trichloroethene.

Tables 6-17 and 6-18 summarize the total hazard index values for each population at risk, for upper bound and best estimate values, respectively. The CDI:AIC ratios for all current potential receptors fall well below one, indicating that no significant chronic health hazard exists at this site at this time. A significant risk to future hypothetical onsite residents is reflected in the CDI:AIC ratios. This potential noncarcinogenic risk posed by the future ingestion of ground water is probably overvalued due to the conservative assumption employed in estimating future onsite exposure point concentrations. Dilution and natural physical and biological processes will probably play a significant role in reducing the concentrations of contaminants in ground water over time.

6.3.5.2 Risk Characterization of Potentially Carcinogenic Compounds

Calculations of risk from potential carcinogens indicated that Site 3 poses no threat to current onsite and offsite potential receptors via all identified current pathways. The exposure of future hypothetical onsite residents to potential carcinogens showed a slight risk. This was due to the ingestion of vinyl chloride and 1,1-dichloroethene in Site 3 ground water. Computations of upper bound and best estimate carcinogenic risk to these populations

TABLE 6-17
SUMMARY OF HAZARD INDEX VALUES FOR SITE 3
UPPER BOUND

Potential Receptor	Sum of CDI:AIC Ratios (a) Inhalation	Sum of CDI:AIC Ratios Oral	Sum of CDI:AIC Ratios Total
Current Use			
On-Site Workers			
(adult)	1.88E-10	2.07E-05	2.07E-05
Nearby Residents			
(adult)	0.00E+00	4.92E-03	4.92E-03
(child)	0.00E+00	2.58E-02	2.58E-02
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	8.10E+00	8.10E+00
On-Site Residents			
(child)	0.00E+00	6.07E+00	6.07E+00

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake.

TABLE 6-18
SUMMARY OF HAZARD INDEX VALUES FOR SITE 3
BEST ESTIMATE

Potential Receptor	Sum of CDI:AIC Ratios (a) Inhalation	Sum of CDI:AIC Ratios Oral	Sum of CDI:AIC Ratios Total
Current Use			
On-Site Workers			
(adult)	9.39E-11	1.17E-05	1.17E-05
Nearby Residents			
(adult)	0.00E+00	2.76E-03	2.76E-03
(child)	0.00E+00	1.45E-02	1.45E-02
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	2.78E+00	2.78E+00
On-Site Residents			
(child)	0.00E+00	2.08E+00	2.08E+00

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake.

(Tables 6-19 and 6-20, respectively) indicate a maximum of 1.83 additional cases of cancer per 100 individuals (1.83 x 10^{-2}). The lowest risk to these populations as indicated by USEPA methodology was 5.84 additional cases of cancer per 1000 individuals (5.84 x 10^{-4}). Both of these projected risks were above the USEPA target overall individual lifetime carcinogenic risk range of 10^{-4} to 10^{-7}. The risk posed by the future ingestion of ground water is probably overvalued, as explained in Section 6.3.5.1. The probability of overestimation of the future exposure point concentrations of these compounds significantly reduces the carcinogenic threat to future onsite residents.

6.4 SITE 4 RISK ASSESSMENT

The risk assessment for Site 4 is presented in this section.

6.4.1 Selection of Indicator Chemicals

Indicator chemicals used in the risk assessment for Site 4 included metals and volatile organic compounds. These parameters were selected on the basis of ranking of indicator scores, toxicological class, chemical properties, and frequency of detection. Table 6-21 summarizes the concentrations of these compounds in ground water, surface water, sediments, surface soil and soil at depth. Data used in the selection of indicator chemicals were compiled from data collected as a part of this remedial investigation and the Phase II, Stage 2 investigation (Dames & Moore, 1987). These data are summarized in Appendix P.

The assignment of indicator scores to compounds detected at Site 4 was unnecessary, since only 12 compounds were detected in the two studies. The purpose of rating compounds based on indicator scores is to reduce a large field of detected compounds to a maximum of 15 representative parameters. All 12 compounds detected at Site 4 were used in this risk assessment.

6.4.2 Estimation of Exposure Point Concentrations or Emission Rates

The second step in the risk assessment process was to determine human exposure points associated with Site 4 and to identify potentially complete exposure pathways. Exposure point concentrations of indicator chemicals were then determined.

6.4.2.1 Exposure Pathway Analysis

The exposure pathway analysis entailed identifying possible sources of contaminant release, transport media, human exposure points, and potentially

TABLE 6-19
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS
FOR SITE 3
UPPER BOUND

Potential Receptor	Sum of Risk From Inhalation	Sum of Risk From Ingestion	Sum of Risk Total
Current Use			
On-Site Workers (adult)	1.68E-11	3.84E-10	4.00E-10
Nearby Residents			
(adult)	0.00E+00	1.25E-05	1.25E-05
(child)	0.00E+00	6.54E-05	6.54E-05
Future Use			
On-Site Residents and Workers (adult)	0.00E+00	1.87E-03	1.87E-03
On-Site Residents (child)	0.00E+00	1.40E-03	1.40E-03

TABLE 6-20
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITE 3
BEST ESTIMATE

Potential Receptor	Sum of Risk From Inhalation	Sum of Risk From Ingestion	Sum of Risk Total
Current Use			
On-Site Workers			
(adult)	6.54E-05	3.33E-05	9.87E-05
Nearby Residents			
(adult)	0.00E+00	6.34E-06	6.34E-06
(child)	0.00E+00	3.33E-05	3.33E-05
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	7.34E-04	7.34E-04
On-Site Residents			
(child)	0.00E+00	5.51E-04	5.51E-04

TABLE 6-21
SITE 4 INDICATOR CHEMICAL CONCENTRATIONS

Indicator Chemical	Ground-Water Concen. (mg/L)		Surface Water Concen. (mg/L)		Sediment Concen. (mg/kg)		Surface Soil Concen. (mg/kg)		Soil at Depth (b) Concen. (mg/kg)	
	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative
Barium	1.70E-01	1.30E-01	ND (a)	ND	8.37E+01	5.54E+01	9.17E+01	6.24E+01	8.56E+01	5.20E+01
Benzene	2.20E-02	1.26E-02	9.30E-01	2.23E-01	1.60E+01	4.64E+00	ND	ND	6.20E+00	2.09E+00
Cadmium	3.10E-03	2.80E-03	ND	ND	1.30E+00	6.50E-01	1.57E+01	7.70E+00	1.15E+01	1.01E+01
Chlorobenzene	ND	ND	2.20E-03	1.90E-03	ND	ND	ND	ND	ND	ND
Chromium	3.90E-03	2.74E-03	ND	ND	2.34E+01	1.53E+01	4.97E+01	2.99E+01	4.93E+01	3.21E+01
Trans-1,2-Dichloroethene	5.80E-03	2.60E-03	5.30E-03	3.56E-03	ND	ND	ND	ND	ND	ND
Ethyl Benzene	ND	ND	1.50E-01	5.91E-02	4.00E+02	1.00E+02	ND	ND	1.20E+01	6.00E+00
Lead	ND	ND	ND	ND	2.31E+01	1.37E+01	2.16E+01	8.00E+00	7.30E+00	4.09E+00
Toluene	ND	ND	2.30E-02	9.77E-03	5.40E+01	1.78E+01	3.30E-01	1.23E-01	2.50E+01	2.72E+00
1,1,1-Trichloroethane	ND	ND	1.90E-02	1.45E-02	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	2.20E-02	8.23E-03	ND	ND	ND	ND	ND	ND
Xylenes	2.70E-03	1.35E-03	1.02E+00	4.31E-01	6.90E+02	1.27E+02	ND	ND	3.15E+02	7.71E+01

a. ND = Not Detected.

b. "Soil at depth" refers to soil two feet or more below the surface.

Note: 1.00E - 01 = 1 x 0.1
1.00E - 02 = 1 x 0.01
1.00E - 03 = 1 x 0.001
1.00E - 04 = 1 x 0.0001

complete exposure routes at each exposure point, as summarized in Table 6-8. Table 6-22 summarizes all Site 4 exposure pathways identified in Table 6-4.

Air Pathways

The likelihood of fugitive dust generation is very low, and was not considered in this assessment since surface soils at Site 4 are covered with either pavement or grass.

Surface water presents the possibility of pathway completion via volatilization and subsequent inhalation by onsite workers, due to the large number of volatile indicator chemicals detected (Table 6-21). Although this exposure pathway is being considered in this risk assessment, the potential for adverse health effects via this route of exposure is very low, due to the relatively low concentrations of volatile compounds in the surface water and the natural dispersion of these contaminants in the air.

Volatilization of contamination from surface soil was not considered as a potential pathway for human exposure since only one volatile compound, toluene, was detected in the surface soil at low levels (Table 6-21).

Surface Water Pathways

Surface water on Site 4 would not normally be contacted by onsite workers, since the type of work performed on this site is the maintenance of the three large fuel storage tanks and the refueling of fuel transporters. Exposure to surface water contamination could possibly occur via the dermal route, but it is very unlikely that workers would go near the ditch without dermal protection. Trespassers are prohibited access to the site by personnel during the day, and a locked fence during all other times. The dermal exposure of onsite workers or trespassers to contamination through Site 4 surface water was therefore not considered as a potential pathway.

Although no significant contamination was detected in a surface water sample collected from an offsite location downgradient from Site 4 (DANGB-BG-SL2), the exposure of nearby residents to offsite surface water which could possibly originate at Site 4 was considered. This pathway was included because of the large number of indicator chemicals detected in onsite surface water which have the potential to migrate downstream from Site 4. Ingestion and dermal contact were the potential surface water exposure routes used in this assessment.

TABLE 6-22
PATHWAYS CONTRIBUTING TO TOTAL EXPOSURE FOR EACH POTENTIAL RECEPTOR AT SITE 4

Potential Receptor	Exposure Pathway
Current Use	
On-Site Workers (Adults Only)	. Incidental ingestion of surface soils . Inhalation of volatilized contaminants in surface water
Nearby Residents (Adults and Children)	. Ingestion of surface water during recreation . Dermal contact with surface water during recreation
Future Use	
On-Site Workers (Adults Only)	. Incidental ingestion of soil at depth . Ingestion of ground water as drinking water
On-Site Residents or Workers (Adults and Children)	. Ingestion of ground water as drinking water . Ingestion of ground water as drinking water

Ground-Water Pathways

Current exposure pathways involving the on-site or off-site ingestion of contaminated ground water originating at Site 4 were not included in this risk assessment. Although offsite domestic wells exist within a one mile radius of the site, the shallow aquifer serving these offsite wells is not in hydraulic communication with ground water at Site 4. Site 4 ground water discharges as surface water in the immediate vicinity of the site. This hydraulic "break" interrupts the flow of contaminated ground water from Site 4 to offsite wells where pathway completion could occur. Current exposure to onsite ground water through ingestion by onsite workers is also unlikely due to the availability of Duluth city water to the airport and Air National Guard (ANG) facilities.

A future pathway through the ingestion of ground water by hypothetical onsite residents was considered as a potential route of exposure. Should the property use be relinquished by the ANG, and subsequently developed for commercial or private use, the remote possibility exists that the removal of institutional controls formerly imposed by the Base would result in exposure to the contaminated ground water through ingestion. The probability of adverse health effects occurring through this future pathway is very low, due to the reduction of current levels of indicator chemicals over time through natural flushing of the contamination and attenuation by biological processes.

Soil Pathways

Exposure of workers to surface soil through incidental ingestion was included as a current potential pathway at Site 4, although the probability of pathway completion is small. The exposure of trespassers to onsite soil was not considered due to restricted access to Site 4. Future excavation, which would expose construction workers to soil at depth through incidental ingestion, was also considered as a potential future pathway of exposure.

Sediment Pathways

The exposure of onsite workers or offsite residents to Site 4 sediments was not considered as a pathway. It is unlikely that workers would walk in the surface water without dermal protection. The distance between Site 4 and the nearest offsite downgradient exposure point is over one mile. This distance would probably be prohibitive to the migration of contaminated sediment to areas outside the Base boundaries.

6.4.2.2 Exposure Point Concentrations

Following the exposure pathway analysis, the environmental concentrations for each indicator chemical at each significant exposure point for each possible pathway were determined. Two steps were needed to determine the exposure point concentrations for each potential receptor. The first step was to quantify the amount of chemical released from the source in terms of release rate (mass per unit time). The second step was to predict the environmental fate of the indicator chemicals and their exposure point concentrations. A summary of the pathways resulting in exposure to human receptors is presented in Table 6-22. Exposure point concentrations were derived from sampling data collected at Site 4 during this remedial investigation and the Phase II, Stage 2 investigation (Dames & Moore, 1987).

The surface soil exposure point concentrations of the indicator chemicals were estimated to be equal to the concentrations measured during the two sampling efforts (Table 6-21). Potential receptors include anyone who may work at the site.

Offsite surface water exposure point concentrations used in this assessment were considered to be the same as the onsite measured concentrations (Table 6-21). This is a conservative assumption, since the levels of contamination of onsite surface water would probably be reduced by dilution and natural physical and biological processes as the water migrated offsite.

Volatilized surface water exposure point concentrations were obtained by substituting the onsite surface water contaminant exposure point concentrations into the model described in Section 6.1.3.2. Potential receptors are onsite workers. The exposure point concentrations are shown in Table 6-23, along with the adjusted TLVs for these compounds, which are discussed further in Section 6.4.2.3.

It is assumed that the future exposure point contaminant concentrations for the future ingestion of ground water found onsite are the same as the current concentrations measured onsite during the two studies. Attenuation, adsorption, or other chemical and biological processes which have the potential to reduce concentrations in the ground water over time were not considered in order to estimate a worst case scenario. Table 6-21 lists these concentrations for Site 4 indicator chemicals. Potential receptors are future onsite residents who utilize ground water as a source of drinking water.

TABLE 6-23

COMPARISON OF AMBIENT EXPOSURE POINT CONCENTRATIONS WITH AIR CRITERIA

SITE 4

Indicator Chemical	Threshold Limit Value (TLV) in Air/420 (a) (mg/m3)	Volatiles from Surface Water (On-Site Workers) Exposure Point Concentration (mg/m3)	
		Upper Bound	Best Estimate
Barium	0.0012	0.00E+00	0.00E+00
Benzene	0.071	2.36E-07	5.66E-08
Cadmium	0.00012	0.00E+00	0.00E+00
Chlorobenzene	0.83	4.64E-10	3.99E-10
Chromium	0.00012	0.00E+00	0.00E+00
Trans-1,2-Dichloroethene	1.88	1.21E-09	8.10E-10
Ethyl Benzene	1.04	3.26E-08	1.29E-08
Lead	0.0004	0.00E+00	0.00E+00
Toluene	0.89	5.37E-09	2.28E-09
1,1,1-Trichloroethane	4.5	3.69E-09	2.82E-09
Trichloroethene	0.64	4.31E-09	1.61E-09
Xylenes	1.04	2.22E-07	9.39E-08

a. American Conference of Governmental Industrial Hygenists (1987).

Future exposure point concentrations for soil contacted by construction workers during excavation of Site 4 were based on the current analytical results for soil samples collected from over two feet below the surface. This data is shown in Table 6-21.

6.4.2.3 Comparison of Exposure Point Concentrations to ARARs

Table 6-5 lists the ARARs and other criteria for Site 4 indicator chemicals, against which the Site 4 exposure point concentrations are compared. Exposure point concentrations for indicator chemicals which have volatilized from site surface water are presented in Table 6-23. All other exposure point concentrations are assumed to be equivalent to concentrations measured onsite in the medium of interest, listed in Table 6-21.

The future ground-water exposure point concentrations for all detected indicator chemicals were below federal MCLs and AWQCs, except for benzene, which narrowly exceeded both the federal MCL and the Minnesota RAL for drinking water. The future ground-water exposure point concentration of cadmium was below the recommended federal MCL, but was above the Minnesota RAL.

The offsite surface water exposure point concentrations for all detected indicator chemicals were below both Minnesota RALs and federal AWQCs, except for benzene, which was above the federal MCL. The offsite surface water exposure point concentration for trichloroethene was above the federal MCL and AWQCs but below the state RAL. The projected offsite surface water exposure point concentration for benzene was above the state RAL; no federal MCL was available for comparison.

The surface soil exposure point concentrations for barium, cadmium, chromium and lead (Tables 6-21) were just above the range of background concentrations. Barium was within the background concentration range. Only toluene was below the adjusted MCL.

The subsurface soil exposure point concentrations of barium, cadmium and lead were within the range of background concentrations. However, the maximum subsurface concentration of chromium was just above the background concentration range. All subsurface soil exposure point concentrations were above the adjusted MCLs, except for ethyl benzene and toluene.

Table 6-23 compares the TLVs adjusted for exposure by nonworker populations to the calculated exposure point concentrations for the volatilization pathways, for all Site 4 indicator chemicals. All of these theoretical concentrations were well within the suggested limits.

6.4.3 Estimation of Chemical Intakes

The chronic daily intakes by human receptors were estimated for each potential pathway completion by multiplying the exposure point concentrations by corresponding human intake factors. Both the upper bound and best estimate chronic daily intakes for each potential pathway for each population at risk were calculated from the maximum and average indicator chemical concentrations, respectively. Chronic daily intakes for pathways categorized as oral, dermal or inhalation routes were summed to yield total chronic daily intake via a particular route for a target population. The process for estimating chemical intake is described in Section 6.1.3, and detailed tables for this site are in Appendix P.

6.4.4 Toxicity Assessment

Acceptable Intake for Chronic Exposure (AIC) values and potency factors are presented for inhalation and oral routes of exposure for Site 4 indicator chemicals in Table 6-6 (USEPA, 1986a and 1988). No toxicity values are available through USEPA for the dermal route of exposure.

AIC values are available for all of the Site 4 noncarcinogenic compounds for the oral route, but there are no AIC values for trans-1,2-dichloroethene and ethyl benzene for the inhalation route. The only AIC values available for Site 4 potential carcinogens via the oral route of exposure were cadmium and chromium. No AIC values were available for these potential carcinogens via inhalation.

Of the seven potentially carcinogenic indicator compounds, only trichloroethene has a potency factor for exposure through ingestion. The potency factor for lead was not available via the ingestion or inhalation routes.

No toxicity levels are currently available for lead, causing it to drop out of the final risk characterization. Although it is not possible to quantify the contribution of lead to the total risk, lead must be considered to pose a potential threat to human health when present at any concentration in environmental media to which human receptors may be exposed.

6.4.5. Risk Characterization

The risk to public health from Site 4 is characterized separately for noncarcinogens and potential carcinogens, through the determination of hazard index values and risk from potential carcinogens, respectively. This procedure is described in detail in Section 6.1.5, and the details for this site are given in Appendix P.

6.4.5.1 Risk Characterization of Noncarcinogenic Compounds

Tables 6-24 and 6-25 summarize the total hazard index values for each population at risk, for upper bound and best estimate values, respectively. Since the CDI:AIC ratios for all potential receptors fall well below one, there is probably no chronic health hazard posed by Site 4.

6.4.5.2 Risk Characterization of Potentially Carcinogenic Compounds

Calculations of risk from potential carcinogens in Tables 6-26 and 6-27 indicate no significant risk to any of the potential receptors, since all risks fall well below the USEPA maximum recommended level of 10^{-4} (1 additional case of cancer per 10,000 individuals).

6.5 SITE 8 RISK ASSESSMENT

The risk assessment for Site 8 is presented in this section.

6.5.1 Selection of Indicator Chemicals

Indicator chemicals used in the risk assessment for Site 8 included metals, pesticides and volatile organic compounds. These parameters were selected on the basis of ranking of indicator scores, toxicological class, chemical properties, and frequency of detection. Table 6-28 summarizes the concentrations of these compounds in ground water, surface water, sediments, surface soil and soil at depth. Data used in the selection of indicator chemicals were compiled from data collected as a part of this remedial investigation and the Phase II, Stage 1 investigation (Dames & Moore, 1987). These data are summarized in Appendix P.

Compounds which were detected at Site 8, but were not included as indicator chemicals, were the pesticides 4,4'-DDD and 4,4'-DDE, and PCB Table compounds. The two pesticides were not selected due to the lack of available USEPA risk characterization constants, including acceptable intake and potency factor values. PCB compounds were not included due to their infrequency of detection (1 detection out of 36 samples) and were therefore not considered to be present at Site 8 at levels high enough to pose a threat to human health.

6.5.2 Estimation of Exposure Point Concentrations or Emission Rates

The second step in the risk assessment process was to determine human exposure points associated with Site 8 and to identify potentially complete exposure pathways. Exposure point concentrations of indicator chemicals were

TABLE 6-24

SUMMARY OF HAZARD INDEX VALUES FOR SITE 4
UPPER BOUND

Potential Receptor	Sum of CDI:AIC Ratios (a Inhalation	Sum of CDI:AIC Ratios Oral	Sum of CDI:AIC Ratios Total
Current Use			
On-Site Workers (adult).	1.30E-09	1.71E-05	1.71E-05
Nearby Residents			
(adult)	0.00E+00	3.78E-03	3.78E-03
(child)	0.00E+00	1.99E-02	1.99E-02
Future Use			
On-Site Residents and Workers (adult)	0.00E+00	9.93E-02	9.93E-02
On-Site Residents (child)	0.00E+00	7.44E-02	7.44E-02

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake.

TABLE 6-25
SUMMARY OF HAZARD INDEX VALUES FOR SITE 4
BEST ESTIMATE

Potential Receptor	Sum of CDI:AIC(a) Ratio Inhalation	Sum of CDI:AIC Ratios Oral	Sum of CDI:AIC Ratios Total
Current Use			
On-Site Workers			
(adult)	8.91E-12	9.61E-06	9.61E-06
Nearby Residents			
(adult)	0.00E+00	1.61E-03	1.61E-03
(child)	0.00E+00	8.43E-03	8.43E-03
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	7.39E-02	7.39E-02
On-Site Residents			
(child)	0.00E+00	5.54E-02	5.54E-02

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake.

TABLE 6-26
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITE 4
UPPER BOUND

Potential Receptor	Sum of Risk From Inhalation	Sum of Risk From Ingestion	Sum of Risk Total
Current Use			
On-Site Workers			
(adult)	1.40E-11	0.00E+00	1.40E-11
Nearby Residents			
(adult)	0.00E+00	9.89E-07	9.89E-07
(child)	0.00E+00	5.19E-06	5.19E-06
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	1.82E-05	1.82E-05
On-Site Residents			
(child)	0.00E+00	1.37E-05	1.37E-05

TABLE 6-27
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITE 4
BEST ESTIMATE

Potential Receptor	Sum of Risk From Inhalation	Sum of Risk From Ingestion	Sum of Risk Total
Current Use			
On-Site Workers			
(adult)	3.37E-12	0.00E+00	3.37E-12
Nearby Residents			
(adult)	0.00E+00	2.39E-07	2.39E-07
(child)	0.00E+00	1.25E-06	1.25E-06
Future Use			
On-Site Residents and Workers			
(adult)	0.00E+00	1.04E-05	1.04E-05
On-Site Residents			
(child)	0.00E+00	7.83E-06	7.83E-06

TABLE 6-28
SITE 8 INDICATOR CHEMICAL CONCENTRATIONS

Indicator Chemical	Ground-Water Concentration (mg/L)		Surface Water Concentration (mg/L)		Sediment Concentration (mg/kg)		Surface Soil Concentration (mg/kg)		Soil at Depth (b) Concentration (mg/kg)	
	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative	Maximum	Representative
Barium	1.00E+00	2.88E-01	ND (a)	ND	1.00E+03	7.65E+01	2.00E+02	7.70E+01	8.50E+01	4.73E+01
Cadmium	ND	ND	ND	ND	ND	ND	1.01E+01	8.43E+00	1.44E+01	1.06E+01
Chromium	5.20E-01	1.16E-01	ND	ND	4.80E-02	2.40E-02	4.00E-02	2.80E-02	4.34E-02	2.88E-02
4,4' DDT	ND	ND	1.00E-02	5.00E-03	ND	ND	1.50E+00	2.46E-01	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	1.00E-03	5.00E-04	ND	ND
Endosulfan I	ND	ND	ND	ND	4.00E-02	4.00E-02	ND	ND	ND	ND
Lead	ND	ND	4.00E-02	3.50E-02	1.90E+02	4.66E+01	1.80E+01	1.02E+01	2.75E+00	6.16E+00
Toluene	ND	ND	6.50E-03	3.25E-03	4.10E+01	4.10E+01	1.40E+00	2.85E-01	7.20E-01	1.10E-01
Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	5.60E-03	2.80E-03

a. ND = Not Detected.

b. "Soil at depth" refers to soil two feet or more below the surface.

Note: 1.00E-01 = 1 x 0.1
0.01 = 1 x 0.01
0.001 = 1 x 0.001
0.0001 = 1 x 0.0001

then determined.

6.5.2.1 Exposure Pathway Analysis

The exposure pathway analysis entailed identifying possible sources of contaminant release, transport media, human exposure points and potentially complete exposure routes at each exposure point, as summarized in Table 6-4. Table 6-29 summarizes all Site 8 exposure pathways identified in Table 6-4.

Air Pathways

The likelihood of fugitive dust generation is very low, and was not considered in this assessment since surface soils at Site 8 are almost completely covered with grass, with the exception of dirt tracks caused by vehicles which occasionally drive across the northern part of site.

Both surface water and soil present the possibility of pathway completion via volatilization and subsequent inhalation by onsite workers and nearby residents. These pathways were considered unlikely to be completed since only one volatile chemical, toluene, was detected in these media. Health effects resulting from exposure are unlikely, because of the low concentrations of toluene detected in the surface water and soil samples.

Surface Water Pathways

Flowing surface water at Site 8 occurs only during storms in a narrow grassy drainage ditch that crosses the northern part of site. There are no active facilities on the site, and workers rarely visit except to mow the grass during the short growing season. Trespassers are prohibited access to this site by a fence and locked gates. Exposure to surface water contamination could possibly occur via the dermal route, but it is very unlikely that workers would go near the ditch without dermal protection. The exposure of onsite workers to contamination through Site 8 surface water was therefore not considered as a potential pathway.

Exposure through offsite surface water was considered in this assessment, through the ingestion and dermal routes of exposure of nearby residents using surface water for recreational purposes. However, the impact on public health is probably negligible due to low to non-detectable concentrations of indicator chemicals. No significant contamination was detected in a surface water sample collected from an offsite location downgradient from Site 8 (DANGB-BG-SL5).

Ground-Water Pathways

Current exposure pathways involving the onsite or offsite ingestion of

TABLE 6-29
PATHWAYS CONTRIBUTING TO TOTAL EXPOSURE FOR EACH POTENTIAL RECEPTOR AT SITE 8

Potential Receptor	Exposure Pathway
Current Use	
On-Site Workers (Adults Only)	. Incidental ingestion of surface soils
Nearby Residents (Adults and Children)	. Ingestion of surface water during recreation . Dermal contact with surface water during recreation
Future Use	
On-Site Workers (Adults Only)	. Incidental ingestion of soil at depth . Ingestion of ground water as drinking water
On-Site Residents or Workers (Adults and Children)	. Ingestion of ground water as drinking water

contaminated ground water originating from Site 8 were not included in this risk assessment. Although offsite domestic wells exist within a one mile radius of the site, the shallow aquifer serving these offsite wells is not in hydraulic communication with ground water at Site 8. Site 8 ground water discharges as surface water south of the site. Current exposure to onsite ground water through ingestion by onsite workers is also unlikely due to the availability of Duluth city water to the airport and Air National Guard (ANG) facilities.

A future pathway through the ingestion of ground water by hypothetical onsite residents was considered as a potential route of exposure. Should the property use be relinquished by the ANG and subsequently developed for commercial or private use, the remote possibility exists that the removal of institutional controls formerly imposed would result in exposure to the ground water through ingestion. The probability of adverse health effects occurring through this future pathway is very low, due to the low levels of the two indicator chemicals, barium and chromium, currently detected in Site 8 ground water and the reduction of current levels of these indicator chemicals over time through natural flushing of the contamination and attenuation by biological processes.

Soil Pathways

Exposure to surface soil through incidental ingestion was included as a current potential pathway at Site 8, although the probability of pathway completion is small. Future excavation at Site 8, which would expose construction workers to soil at depth through incidental ingestion, was also considered as a potential future pathway of exposure.

All exposure pathways involving off-site adults and children as receptors to Site 8 soil contamination were viewed as too improbable for consideration, due to restricted access to trespassers, and the proximity of Site 8 to an airport runway.

Sediment Pathways

The exposure of onsite workers or offsite residents to Site 8 sediments was not considered as a pathway. It is unlikely that workers would walk in the surface water without dermal protection. The distance between Site 8 and the nearest downgradient offsite exposure point is over one mile. This distance would probably be prohibitive to the migration of contaminated sediment to areas outside the Base boundaries.

6.5.2.2 Exposure Point Concentrations

Following the exposure pathway analysis, the environmental concentrations for each indicator chemical at each significant exposure point were determined for each possible pathway. Sample data were used to represent the exposure point concentrations at each point of potential human contact. A summary of the pathways resulting in exposure to human receptors is presented in Table 6-29. Exposure point concentrations were derived from sampling data collected at Site 8 during the RI and the previous study (Dames & Moore, 1987).

The surface soil exposure point concentrations of the indicator chemicals were estimated to be equal to the concentrations measured during the two sampling efforts (Table 6-28). Potential receptors include anyone who may work at the Base. Offsite children and adults were not considered to be potential receptors because access is restricted by fencing.

Offsite surface water exposure point contaminant concentrations were based on current surface water data (Table 6-28) in order to approximate a hypothetical worst case. Offsite surface water contaminant concentrations were not considered to have been affected by dilution or chemical and biological processes which would reduce the onsite concentrations as the water traveled off site. Potential receptors include offsite children and adults who may contact local surface water during recreation.

It is assumed that the exposure point contaminant concentrations for future ingestion of onsite ground water are the same as the concentrations measured in onsite ground water during the two studies. Table 6-28 lists these concentrations for Site 8 indicator chemicals. Attenuation, adsorption, or other chemical and biological processes which would reduce concentrations in the ground water over time were not considered, in order to estimate a worst case scenario. However, the conservative assumption must be used, due to the inability to predict when future exposure could potentially occur. Potential receptors are future onsite residents who utilize ground water as a source of drinking water.

Future exposure point concentrations for soil contacted by construction workers during excavation of Site 8 were based on the current sampling data for soil collected from two feet below the surface. This data is shown in Table 6-28.

6.5.2.3 Comparison of Exposure Point Concentrations to ARARs

Table 6-5 lists ARARs and other criteria for Site 8 indicator chemicals against which Site 8 exposure point concentrations are compared. All exposure point concentrations are assumed to be equivalent to concentrations measured onsite in the medium of interest, listed in Table 6-28.

The surface soil and soil at depth exposure point concentrations for metals are within the range of metal concentrations found in the two background sampling locations indicating that the levels found at Site 8 were not out of the ordinary for this area. The exposure point concentrations were below the adjusted MCL for soils.

The future ground water exposure point concentration for barium was below the ARARs and other criteria listed in Table 6-5; chromium was slightly above.

The surface water exposure point concentrations for toluene was within the ARARs and other criteria. Surface water exposure point concentrations for lead was below the federal MCL but above the Minnesota RAL. The projected surface water exposure point concentration for 4,4'-DDT was above the AWQC guideline, the only guideline available for this compound.

6.5.3 Estimation of Chemical Intakes

The chronic daily intakes by human receptors were estimated for each potential pathway completion by multiplying the exposure point concentrations by corresponding human intake factors. Both upper bound and best estimate chronic daily intakes for each potential pathway for each population at risk were calculated from the maximum and average indicator chemical concentrations, respectively. Chronic daily intakes for pathways categorized as dermal, oral, or inhalation routes were summed to yield total chronic daily intake via a particular route for a target population. The process for estimating chemical intakes is described in Section 6.1.3, and the detailed tables for this site are in Appendix P.

6.5.4 Toxicity Assessment

Acceptable Intakes for Chronic Exposure (AIC) values and potency factors are presented for Site 8 indicator chemicals in Table 6-6 (USEPA, 1986a and 1988). There were no completed pathways using inhalation routes of exposure considered for Site 8. No toxicity values are available through USEPA for the dermal route of exposure.

Acceptable Intake for Chronic exposure values are available for all Site 8 indicator chemicals except lead. Of the five potentially carcinogenic indicator compounds, potency factors are available only for 4,4'-DDT and dieldrin.

No toxicity levels are currently available for lead, causing it to drop out in the final risk characterization. Although it is not possible to quantify the contribution of lead to the total risk, lead is considered to pose a potential threat to human health when present at any concentration in environmental media to which human receptors may be exposed.

6.5.5 Risk Characterization

The risk to public health from Site 8 is characterized separately for noncarcinogens and potential carcinogens, through the determination of hazard index values and risk from potential carcinogens, respectively. The procedure for obtaining these values is described in detail in Section 6.1.5., and the details for this site are in Appendix P.

6.5.5.1 Risk Characterization of Noncarcinogenic Compounds

Hazard index computations based on maximum chemical concentrations indicate a potential risk to hypothetical onsite adults and children through the future ingestion of barium and chromium. The exposure route which contributes the most risk is the future ingestion of ground water originating from Site 8.

Table 6-30 summarizes the total hazard index values for each population at risk, for upper bound and best estimate values. With the exception of the future ingestion of ground water by future hypothetical onsite residents, the CDI:AIC ratios for all potential receptors fall well below one indicating no significant chronic health hazard exists at this site at this time. The potential noncarcinogenic risk posed by the future ingestion of ground water is probably overvalued due to the conservative assumption employed in estimating future onsite exposure point concentrations. Dilution and natural physical and biological processes will probably play a significant role in reducing the concentrations of contaminants in ground water over time.

Wide variations in the data from the current RI and the Phase II, Stage 2 investigation (Dames & Moore, 1987) were noted. The maximum detected values of chromium and lead in the ground water were 520 mg/L and 1000 mg/L, respectively, in 1986 (Dames & Moore, 1987). This compares with maximum values of 2.7 mg/L for chromium and 220 mg/L for barium in the ground water observed during this investigation. If the current lower concentrations were used in lieu of the higher concentrations to represent the current quality of ground water at Site 8, the calculated risk of noncarcinogenic exposure for future hypothetical onsite residents would be

TABLE 6-30
SUMMARY OF HAZARD INDEX VALUES FOR SITE 8

Potential Receptor	Sum of Upper Bound CDI:AIC Ratios (a)	Sum of Best Estimate CDI:AIC Ratios
Current Use		
On-Site Workers		
(adult)	1.30E-05	6.01E-06
Nearby Residents		
(adult)	7.28E-04	3.64E-04
(child)	3.82E-03	1.91E-03
Future Use		
On-Site Residents and Workers		
(adult)	1.77E+00	4.12E-01
On-Site Residents		
(child)	1.32E+00	3.09E-01

a. CDI = Chronic Daily Intake. AIC = Acceptable Chronic Intake.

reduced further.

6.5.5.2 Risk Characterization of Potentially Carcinogenic Compounds

Calculations of risk from potential carcinogens in Table 6-31 indicated no significant risk to any of the potential receptors, since all risks fell well below the USEPA maximum recommended level of 10^{-4} (1 additional case of cancer per 10,000 individuals).

6.6 SUMMARY AND CONCLUSIONS

The primary objective of this public health evaluation was to assess public health impacts at Sites 2, 3, 4 and 8 at the Minnesota Air National Guard Base, Duluth, Minnesota, under existing site conditions. The assessment was completed in accordance with the guidelines presented in the USEPA Superfund Public Health Evaluation Manual (1986a).

Using data collected during this and previous investigations current and future exposure pathway analyses were performed to identify all possible pathway completions. Potential receptors for current pathways include onsite workers and offsite adults and children. Hypothetical future receptors for future pathways are adults and children who might live in the areas now occupied by Sites 2, 3, 4 and 8. Worst case scenarios were devised in order to estimate the exposure point concentrations of contaminants detected at the sites. The calculation of chronic daily intake of contaminants found at the exposure points used standard human intake factors suggested in the USEPA Superfund Exposure Assessment Manual (1988), as well as in other references (Cowherd, 1984 and Whitmeyer, 1987).

A risk assessment was then performed to assess potential noncarcinogenic and carcinogenic effects resulting from exposure to chemical contaminants detected at the sites. The risk assessment indicates that no unacceptable risks are expected to result from current exposure of onsite or offsite potential receptors to contamination detected on Sites 2, 3, 4, and 8. Under the hypothetical future use scenario, future onsite residents were found to be at increased risk. This potential future exposure problem is based on ingestion of ground water. Tables 6-32 and 6-33 summarize the total risk to each group of potential receptors through current and future contaminant exposure.

The USEPA has established guidelines for assessing the potential hazard to human health from exposure to chemical contaminants. For noncarcinogens,

TABLE 6-31

SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITE 8

Potential Receptor	Sum of Upper Bound Risk	Sum of Best Estimate Risk
Current Use		
On-Site Workers (adult)	7.40E-09	1.21E-09
Nearby Residents		
(adult)	1.07E-06	5.34E-07
(child)	5.61E-06	2.81E-06
Future Use		
On-Site Residents and Workers (adult)	0.00E+00	0.00E+00
On-Site Residents (child)	0.00E+00	0.00E+00

TABLE 6-32
SUMMARY OF HAZARD INDEX VALUES FOR SITES 2, 3, 4 AND 8

Potential Receptor	Site 2		Site 3		Site 4		Site 8	
	Upper Bound	Best Estimate	Upper Bound	Best Estimate	Upper Bound	Best Estimate	Upper Bound	Best Estimate
On-Site Workers (adult)	3.60E-05	1.34E-05	2.07E-05	1.17E-05	1.71E-05	9.61E-06	1.30E-05	6.01E-06
Nearby Residents								
(adult)	3.60E-05	1.33E-05	4.92E-03	2.76E-03	3.78E-03	1.61E-03	7.28E-04	3.64E-04
(child)	3.78E-05	1.40E-05	2.58E-02	1.45E-02	1.99E-02	8.43E-03	3.82E-03	1.91E-03
Future Use								
On-Site Residents and Workers (adult)	1.79E+00	3.70E-01	8.10E+00	2.78E+00	9.93E-02	7.39E-02	1.77E+00	4.12E-01
On-Site Residents (child)	1.34E+00	2.77E-01	6.07E+00	2.08E+00	7.44E-02	5.54E-02	1.32E+00	3.09E-01

TABLE 6-33
SUMMARY OF RISK FROM POTENTIAL CARCINOGENS FOR SITES 2, 3, 4 AND 8

Potential Receptor	Site 2		Site 3		Site 4		Site 8	
	Upper Bound	Best Estimate	Upper Bound	Best Estimate	Upper Bound	Best Estimate	Upper Bound	Best Estimate
Current Use								
On-site Workers (adult)	9.33E-08	6.82E-08	4.00E-10	9.87E-05	1.40E-11	3.37E-12	7.40E-09	1.21E-09
Nearby Residents								
(adult)	9.32E-08	6.80E-08	1.25E-05	6.34E-06	9.89E-07	2.39E-07	1.07E-06	5.34E-07
(child)	9.79E-08	7.14E-08	6.54E-05	3.33E-05	5.19E-06	1.25E-06	5.61E-06	2.81E-06
Future Use								
On-site Residents and Workers (adult)	2.26E-04	1.13E-03	1.87E-03	7.34E-04	1.82E-05	1.04E-05	0.00E+00	0.00E+00
On-site Residents (child)	1.69E-04	8.48E-05	1.40E-03	5.51E-04	1.37E-05	7.83E-06	0.00E+00	0.00E+00

a hazard index greater than one indicates the possibility of adverse health effects. For carcinogens, risks from exposures should range from 10^{-4} to 10^{-7}, with 10^{-6} being the nominal value, depending on the site location and condition and the degree of conservativeness used in determining exposure point concentrations. The potential for adverse health effects to hypothetical future adult and child residents from exposure to noncarcinogens may exist because the hazard index values exceed one for Sites 2, 3 and 8. The total carcinogenic risk to this same category of future receptors, exceeded 10^{-4} at Sites 2 and 3, which is above the target risk range.

To give some perspective to risks of cancer from chemical contamination at Sites 2, 3, 4 and 8, risks from common activities can be used for comparison. Table 6-34 shows lifetime risks ranked in order from the greatest to the smallest risk associated with various occupations, personal habits, lifestyles and other activities that human receptors may encounter during routine living experiences.

Evaluation of the potential risks determined in this risk assessment should take into consideration the numerous assumptions which contribute uncertainty to the risk estimate. The assessment did not include risk from dermal contact which cannot be quantified at this time; however, risk from this pathway is expected to be minimal. The final hazard index values and carcinogenic risks did not include the potential toxic effects of lead, since no toxicity values are currently available for this compound. Exposure to lead at any concentration is considered to pose a potential threat to human health. Also, current exposure pathways through inhalation (fugitive dust and volatilized surface water contaminants) used very conservative models for estimating exposure point concentrations. The probable overestimation of these current air and surface water exposure point concentrations did not result in unacceptable risk, as shown in Tables 6-32 and 6-33. Finally, the higher risks associated with ingestion of ground water by hypothetical future onsite residents are also probably overvalued, due to the improbability of residential development on the land now occupied by Sites 2, 3, 4 and 8. Should this group of receptors exist in the future, the likelihood of ground-water usage would also be extremely low, since Duluth city water is readily available to this area. It is also likely that ground-water contaminant concentrations in the future, and therefore potential risks, will be lower than those predicted.

This risk assessment concludes that Sites 2, 3, 4 and 8 pose no current

TABLE 6-34
COMMONPLACE RISKS

Action	Lifetime Risk of Death
Cigarette Smoking (one pack per day)	2.50E-01
Mountaineering	4.20E-02
Motor Vehicle Accident	1.70E-02
Duty as a Policeman	1.50E-02
Home Accidents	7.70E-03
Frequent Airline Flights	3.50E-03
Sea-Level Background Radiation	1.40E-03
Alcohol Consumption (light drinker)	1.40E-03
Consumption of Four Tablespoons Peanut Butter Per Day	5.60E-04
Electrocution	3.70E-04
Drinking Water with the USEPA Limit of Chloroform	4.20E-05
Drinking Water with the USEPA Limit of Trichloroethene	1.40E-07

Source: Wilson and Crouch (1987).

Note: 1.00E-01 = 1 x 0.1
1.00E-02 = 1 x 0.01
1.00E-03 = 1 x 0.001
1.00E-04 = 1 x 0.0001
1.00E-05 = 1 x 0.00001
1.00E-07 = 1 x 0.0000001

public health threat in the absence of remediation. A slight health risk may be present if hypothetical future onsite residents were to ingest ground water. This future risk may be overstated due to the conservative (i.e., worst case) assumptions used in estimating future exposure point concentrations. This conservative approach was adopted, however, so that no potential risks would be underestimated.

SECTION 7
SUMMARY AND RECOMMENDATIONS

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SECTION 7
SUMMARY AND RECOMMENDATIONS

In this section the criteria used for determining the significance of contamination are explained in the introduction. The significant contamination at each site is discussed in following subsections. This section concludes with recommendations for the next step in the remediation process for each site.

7.1 INTRODUCTION

This section describes, by site, the significance of detected contamination in soils and water based on established U.S. Environmental Protection Agency (USEPA) maximum concentration limits (MCLs), State of Minnesota recommended allowable limits (RALs) and background levels and concentration. Current requirements are summarized in Table 6-5. A summary of contaminants detected by sampling media and their relationship to MCLs, RALs, and background levels is presented in Tables 7-1 through 7-4.

Three criteria are used to judge the significance of a contaminant in ground water and surface water. First, the contaminant is considered to be significant if its concentration in the water exceeds the MCL. Second, the contaminant is considered to be significant if its concentration in the water exceeds the RAL. Third, health risk criteria are used to judge significance of the contamination when neither a MCL nor a RAL exists.

The criteria used to judge the significance of contamination in soil and sediment varied depending upon the general types of contaminants. The significance of volatile and semi-volatile organic compounds in soil and sediment was judged on a health risk basis and their continued impact as a source for ground-water contamination. The presence of metals in soil and sediment was judged to be significant if maximum background levels for these parameters, as determined by soil sampling at area background locations for background levels, were exceeded.

The State of Minnesota RALs were used for evaluating the risk of total petroleum hydrocarbons. There are no criteria established for this parameter by the USEPA. The important constituents of total petroleum hydrocarbons from the perspective of risk to human health are benzene, ethylbenzene, toluene and xylenes. Risks from these constituents were assessed separately when detected in addition to the risk from total petroleum hydrocarbons.

TABLE 7-1
SUMMARY OF SURFACE WATER CONTAMINANTS BY SITE
(Results in micrograms per liter unless otherwise noted)

Parameter	Maximum Contaminant Level (MCL), State Recommended Allowable Limit (RAL) or Background Level (BG)	Site 2	Site 3	Site 4	Site 8	Site 10
Volatile Organic Compounds						
Tetrachloroethylene	6.9 (RAL)	U	U to 1.1	U	U	NA
Trichloroethylene	5.0 (MCL)	U	U to 110	U to 0.98	U	NA
trans 1,2 Dichloroethylene	70 (RAL)	U	U to 9.3	U to 5.3	U	NA
1,1,1 Trichloroethane	200 (MCL)	U	U to 8.6	U	U	NA
1,1 Dichloroethylene	7.0 (RAL)	U	U to 0.56	U	U	NA
Benzene	5.0 (MCL)	U	U	U to 930	U	NA
Xylenes	440 (RAL)	U	U	U to 1020	U	NA
Ethyl Benzene	680 (RAL)	U	U	U to 150	U	NA
Semi-volatile Organic Compounds						
Dimethyl phthalate	U (BG)	U	U to 12	U	U	NA
Total Petroleum Hydrocarbons (mg/L)	U (BG)	U	U	U to 2.5	U	NA

TABLE 7-1 (continued)
SUMMARY OF SURFACE WATER CONTAMINANTS BY SITE
(Results in micrograms per liter unless otherwise noted)

Parameter	Maximum Contaminant Level (MCL), State Recommended Allowable Limit (RAL) or Background Level (BG)	Site 2	Site 3	Site 4	Site 8	Site 10
Metals						
Arsenic	50 (MCL)	NA	U	NA	NA	NA
Barium	1000 (MCL)	U	U	U	U	NA
Cadmium	10 (MCL)	U	U	U	U	NA
Chromium	50 (MCL)	U	U	U	U	NA
Lead	50 (MCL)	U	U	U	U	NA
Mercury	2 (MCL)	NA	U	NA	NA	NA
Radiological (pCi/L)						
Gross Alpha	15 (MCL)	NA	NA	NA	NA	NA
Gross Beta	50 (MCL)	NA	NA	NA	NA	NA
Radium 226	5 (MCL)	NA	NA	NA	NA	NA
Tritium	20,000 (MCL)	NA	NA	NA	NA	NA

1. U means parameter not detected at levels above the practical quantitation limit.
2. NA means not analyzed.

TABLE 7-2

SUMMARY OF SEDIMENT CONTAMINANTS BY SITE

(Results in micrograms per kilogram unless otherwise noted.)

Parameter	Background Level	Site 2	Site 3	Site 4	Site 8	Site 10
Volatile Organic Compounds						
Tetrachloroethene	U(1)	U	U to 5.1	U	U	NA(2)
Trichloroethene	U	U to 0.26	U	U	U	NA
1,1 Dichloroethene	U	U	U to 16	U	U	NA
1,1,1-Trichloroethane	U	U	U to 240	U	U	NA
1,1-Dichloroethane	U	U	U to 5.6	U	U	NA
Benzene	U	U	U	U to 240	U	NA
Ethyl Benzene	U	U	U	U to 44000	U	NA
Toluene	U	U	U	U to 54000	U	NA
Xylenes	U	U	U	U to 690000	U	NA
Semi-Volatile Organic Compounds						
Bis(2-ethylhexyl)-phthalate	U	U	600	U	U	NA
Total Petroleum Hydrocarbons (mg/kg)	U	U	110 to 2000	U to 200	U to 200	NA
Metals (mg/kg)						
Arsenic	U	NA	U	NA	NA	NA
Barium	34.9 to 103	45.0 to 53.9	39.0 to 53.7	42.1 to 199	45.5 to 84.8	NA
Cadmium	6.8 to 13.6	U	U to 4.4	U to 1.3	U	NA
Chromium	14.4 to 42.2	19 to 20	22.9 to 54.6	5.9 to 23.4	13.2 to 26.8	NA
Lead	2.9 to 9.9	4.3 to 48	6.3 to 478	6.1 to 23.1	5.7 to 11.5	NA
Mercury	U	NA	U to 0.58	NA	NA	NA

1. U means parameter not detected at levels above the practical quantitation limit.
2. NA means not analyzed.

TABLE 7-3
SUMMARY OF SOIL CONTAMINANTS BY SITE
(Results in micrograms per kilogram unless otherwise noted.)

Parameter	Background Level	Site 2	Site 3	Site 4	Site 8	Site 10
Volatile Organic Compounds						
Tetrachloroethene	U(1)	U to 2300	U to 37	U	U	NA(2)
Trichloroethene	U	U to 1600	U to 4.4	U	U	NA
Trans-1,2-Dichloroethene	U	U to 150	U	U	U	NA
1,1-Dichloroethene	U	U	U to 0.7	U	U	NA
1,1,1-Trichloroethane	U	U	U to 89	U	U	NA
1,1-Dichloroethane	U	U	U to 1.2	U	U	NA
1,2-Dichloroethane	U	U to 1.8	U	U	U	NA
Benzene	U	U to 3100	U to 900	U	U	NA
Ethyl Benzene	U	U to 25000	U to 260	U	U	NA
Chlorobenzene	U	U to 80	U	U	U	NA
1,2-Dichlorobenzene	U	U to 340	U	U	U	NA
Toluene	U	U to 36000	U to 1300	U	950	NA
Xylenes	U	U to 180000	U to 2000	U	U	NA
Semi-Volatile Organic Compounds						
Bis(2-ethylhexyl) phthalate	U	U to 6500	U to 590	NA	NA	NA
4,4'-DDD	U	NA	U to 190	NA	U to 180	NA
4,4'-DDE	U	NA	U to 61	NA	U to 130	NA
4,4'-DDT	U	NA	U to 500	NA	U to 1500	NA
Dieldrin	U	NA	U	NA	U to 33	NA
PCB 1254	U	NA	U to 1100	NA	U to 330	NA
Total Petroleum Hydrocarbons (mg/kg)	U	U to 9600	U to 2700	U to 530	U to 1540	NA
Metals (mg/kg)						
Arsenic	U	NA	NA	NA	NA	NA
Barium	34.9 to 103	25.4 to 295	30.4 to 121	27.9 to 67.8	18.9 to 146	NA
Cadmium	6.8 to 13.6	0.06 to 13.3	5.6 to 19.4	8.5 to 11.5	6.2 to 14.4	NA
Chromium	14.4 to 42.2	19.2 to 37.9	18.9 to 44.6	11.0 to 49.3	20.0 to 43.4	NA
Lead	2.9 to 9.9	2.8 to 260	2.8 to 30.3	2.6 to 7.3	3.2 to 11.4	NA
Mercury	U	U	U to 0.28	NA	NA	NA

1. U means parameter not detected at levels above the practical quantitation limit.
2. NA means not analyzed.

TABLE 7-4
SUMMARY OF GROUND-WATER CONTAMINANTS BY SITE
(Results in micrograms per liter unless otherwise noted)

Parameter	Maximum Contaminant Level (MCL), State Recommended Allowable Limit (RAL) or Background Level (BG)	Site 2	Site 3	Site 4	Site 8	Site 10
Volatile Organic Compounds						
Tetrachloroethylene	6.9 (RAL)	U(1)	U to 540(2)	U	U	NA(2)
Trichloroethylene	5.0 (MCL)	U to 33	U to 790	U	U	NA
trans 1,2 Dichloroethylene	70 (RAL)	U to 1200	U to 450	U	U	NA
1,1 Dichloroethylene	7.0 (RAL)	U to 0.61	U to 58	U	U	NA
Vinyl Chloride	2.0 (MCL)	U to 3.1	U to 3.5	U	U	NA
1,1,1 Trichloroethane	200 (MCL)	U	U to 3100	U	U	NA
1,1 Dichloroethane	5.0 (MCL)	U	U to 250	U	U	NA
1,2 Dichloroethane	U (BG)	U to 0.22	U to 4.4	U	U	NA
Benzene	5.0 (MCL)	U to 1.2	U to 1.1	U to 22	U	NA
Toluene	2000 (RAL)	U	U to 21	U	U	NA
Xylenes	440 (RAL)	U	U	U to 2.7	U	NA
Semi-volatile Organic Compounds						
Dimethyl phthalate	U (BG)	U to 63	U to 18	U	U	NA
Diethyl Phthalate	U (BG)	U to 144	U to 16	U	U	NA
Naphthalene	U (BG)	U	U to 22	U	U	NA
PCB 1242	0.08 (RAL)	U	U to 45	U	U	NA
Total Petroleum Hydrocarbons (mg/L)	U (BG)	U	U	U to 3.24	U	NA

TABLE 7-4 (Continued)

Parameter	Maximum Contaminant Level (MCL), State Recommended Allowable Limit (RAL) or Background Level (BG)	Site 2	Site 3	Site 4	Site 8	Site 10
Metals						
Arsenic	50 (MCL)	NA	U	NA	NA	NA
Barium	1000 (MCL)	U	U	U to 170	U to 220	NA
Cadmium	10 (MCL)	U	U	U to 3.1	U	NA
Chromium	50 (MCL)	U	U	U to 3.9	U to 2.7	NA
Lead	50 (MCL)	U	U	U	U	NA
Mercury	2 (MCL)	NA	U	NA	NA	NA
Radiological (pCi/L)						
Gross Alpha	15 (MCL)	NA	NA	NA	NA	7.0±3
Gross Beta	50 (MCL)	NA	NA	NA	NA	1 to 382±154
Radium 226	5 (MCL)	NA	NA	NA	NA	11±4 to 253±104
Tritium	20,000 (MCL)	NA	NA	NA	NA	U

1. U means parameter not detected at levels above the practical quantitation limit.
2. NA means not analyzed.

7.2 SIGNIFICANT CONTAMINATION CONTAMINATION AT SITE 2

The surface water and sediment were generally free of contamination. No volatile organic compounds, semi-volatile organic compounds, petroleum hydrocarbons or metals were found in the surface water. Trichloroethene was found at a trace level of 0.26 ug/kg in one sediment sample. Metals in the sediment were within the range found in soil sampled at background locations. No semi-volatile organic compounds or petroleum hydrocarbons were detected in the sediment samples.

Volatile organic compounds were detected in the soil at Fire Training Area 2 (FTA-2). The halogenated volatile organic compounds, tetrachloroethene, trichloroethene, trans-1,2-dichloroethene , and 1,2-dichloroethane, were detected at maximum levels of 2,300, 1,600, 150, and 1.8 ug/kg, respectively. These maximum levels occur above the water table. The aromatic volatile organic compounds, benzene, ethyl benzene, 1,2-dichlorobenzene, toluene, and total xylenes, were detected at maximum levels of 3,100, 25,000, 340, 36,000, and 180,000 ug/kg, respectively. Again, these maximum levels occur above the water table.

The presence of the volatile organic compounds in the soil is considered significant. The compounds are highly soluble, particularly the halogenated compounds detected at the site, making them likely to leach into the underlying ground water. It is probable that a continuing source for the volatile organic compounds found in the ground water is the unsaturated soil within FTA-2.

Petroleum hydrocarbons were detected in the soil at a level as high as 9,600 mg/kg in soil at FTA-2 and are significant.

The levels of some metals in the soil at FTA-2 are above background levels for the airport and are therefore significant. Both barium and lead are present in the soil at FTA-2 at high levels.

Volatile organic compounds were found at significant levels in the ground water at Site 2. Trichloroethene, trans-1,2-dichloroethene, and vinyl chloride were found in the water at levels exceeding either MCLs set by the USEPA or RALs set by the State of Minnesota. Trichloroethylene occurred above acceptable levels in water from wells GW 2-E and DANGB-2-MW38; trans-1,2 dichloroethene occurred above acceptable levels in water from wells MW 2 and GW 2-E; vinyl chloride in water from well MW 2 was above acceptable levels. The origin of trans 1,2-dichloroethene and vinyl chloride may be trichloroethene that was burned during fire training exercises. These two compounds are degradation products of trichloroethene.

Two semi-volatile organic compounds were detected at trace levels in the ground water. Diethyl phthalate, was detected at 63 ug/L in water from well MW 6 and dimethyl phthalate was detected at concentrations of 79 ug/L and 144 ug/L in water from wells MW 5 and GW 2-A, respectively. The source for these compounds is not known. Phthalates are commonly used in plastics and consequently can be found almost anywhere in the environment.

7.3 SIGNIFICANT CONTAMINATION AT SITE 3

Surface water and sediment at Site 3 both had volatile organic compounds present in samples taken from the drainage ditch that adjoins the storage pad. Trichloroethene was detected in water from both sampling locations on this drainage ditch at concentrations above the MCL for that compound. This same compound was not detected in the sediment. Other volatile organic compounds detected in surface water were below enforceable limits for those compounds. The levels of volatile organic compounds detected in the sediment are low and probably not significant.

The levels of some metals in sediment sampled from the drainage ditch are above background levels for soil and, therefore, are significant. The levels of chromium and mercury in the sediment at one sampling location marginally exceeded background levels in soil, while the level of lead in the sediment at the same sampling location was far in excess of the background level found in the soil.

Petroleum hydrocarbons were detected at a level as high as 2,000 mg/kg in the sediment and are significant.

Volatile organic compounds were detected in the soil at Site 3. The halogenated volatile organic compounds, tetrachloroethene and 1,1,1-trichloroethane, were found in two soil samples and had maximum concentrations of 37 and 89 ug/kg, respectively. Some other halogenated compounds were also found in the soil but were at much lower concentrations. The maximum concentrations occur above the water table. The aromatic volatile organic compounds, benzene, ethyl benzene, toluene, and total xylenes, were detected in one soil sample and were at levels of 900, 260, 1,300, and 2,000 ug/kg, respectively.

The presence of these volatile organic compounds in the soil is considered significant. The compounds are highly soluble, particularly the halogenated compounds detected at the site, making them likely to leach into the underlying ground water. It is possible that a continuing source for the volatile organic compounds found in ground water is contaminants in the unsaturated soil at the site.

Petroleum hydrocarbons were detected in the soil at a level as high as 2,700 mg/kg at Site 3 and are significant.

Surface soil sampling for the presence of pesticides and PCBs at 32 locations identified 8 locations where 1 or more of these compounds were present. The presence of low levels of pesticides in the soil may be due to past spraying of pesticides in the area and may not be significant. The presence of PCB compounds in the soil is significant.

The levels of some metals in the soils are above background levels and are therefore significant. Lead is present in the soil at Site 3 at concentrations above background levels.

Volatile organic compounds were detected at significant levels in the ground water at Site 3. The compounds, tetrachloroethene, trichloroethene, trans-1,2-dichloroethene, 1,1-dichloroethene, vinyl chloride, and 1,1,1-trichloroethane, were in ground water at levels exceeding either the USEPA MCLs or State of Minnesota RALs for these compounds. The compound, 1,2-dichloroethane, was detected in the ground water at a level close to the MCL and 1,1-dichloroethane was detected in the water above the background level. The compound, 1,1,1-trichloroethane, was found in the water most often and at the highest concentrations. The origin of most of these compounds is probably from spillage or leakage of the compounds onto the ground surface during the period that the storage area was in use.

A number of semi-volatile organic compounds were detected in the ground water. The compound PCB 1242 was detected at concentrations in the water greater than the Minnesota RAL for PCBs and was the most prevalent semi-volatile organic compound detected.

7.4 SIGNIFICANT CONTAMINATION AT SITE 4

Surface water and sediment both had volatile organic compounds at significant levels. The benzene concentration in surface water at sampling locations DANGB-4-SL11, DANGB-4-SL13, and DANGB-4-SL15 exceeded the

MCL for that compound, while the xylenes concentrations in surface water at sampling location DANGB-4-SL13 exceeded the RAL for that compound. Benzene, ethyl benzene, toluene and xylenes, were detected in the sediment at maximum concentrations of 240, 44,000, 54,000, and 690,000 ug/L, respectively. The contaminated sediment provides a source of contamination for the surface water and is significant.

The levels of some metals in sediment sampled from the drainage ditches are significant. Barium was found in the sediment at location DANGB-4-SL16 at a level above background levels for soil while lead was found in the sediment at location DANGB-4-SL15 at levels above background levels for soil.

Total petroleum hydrocarbons were detected at significant levels in soil and sediment samples at Site 4. The surface soil samples taken from the boreholes for monitoring wells DANGB-4-MW22, DANGB-4-MW23, and DANGB-4-MW24 all had total petroleum hydrocarbons concentrations in excess of 100 mg/kg. The sediment sampled at all six surface water and sediment sampling locations also had total petroleum hydrocarbons at concentrations in excess of 100 mg/kg.

Volatile organic compounds, semi-volatile organic compounds, and metals were not found at significant levels in the soils at Site 4.

Benzene from ground-water in one well was detected above the USEPA MCL and is therefore significant. This occurred at well DANGB-4-MW21 located near the drainage ditch which is a ground-water discharge area for Site 4 and much of Sites 3 and 8.

Total petroleum hydrocarbons at 3.24 mg/L in ground water sampled from well GW 4-A can be considered significant. The Minnesota Water Pollution Code allows a maximum total petroleum hydrocarbons concentration of 0.5 mg/L for water in streams. Ground water at Site 4 discharges to nearby drainage ditches.

No other contaminants were detected in the ground water at significant levels.

7.5 SIGNIFICANT CONTAMINATION AT SITE 8

Volatile organic compounds, semi-volatile organic compounds, and petroleum hydrocarbons were not detected in the surface water, and concentrations of metals in these waters were in the background range.

The sediment sample at location DANGB-8-SL19 had a petroleum hydrocarbon concentration in excess of 100 mg/kg, making contamination significant at this one location.

The maximum concentrations of barium, cadmium, chromium, and lead in the soil at Site 8 marginally exceeded background levels for the airport, but are not considered significant.

The total petroleum hydrocarbon concentrations in the surface soil samples at locations DANGB-8-SSA1 and DANGB-8-SSA3 exceeded 100 mg/kg and are considered significant while the concentration of 4,4'-DDT in the soil was 1,500 ug/kg at DANGB-8-SSA3.

Volatile organic compounds, semi-volatile organic compounds were not detected in the ground water and concentrations of metals in these waters were in the background range.

7.6 SIGNIFICANT CONTAMINATION AT SITE 10

Significant radiological contamination of ground water is occurring at Site 10. The gross alpha radiation and gross beta radiation in water from wells exceed the USEPA MCLs for these parameters.

7.7 SUMMARY OF SIGNIFICANT CONTAMINATION AT ALL SITES

Surface water at Sites 3 and 4 had significant levels of contamination. Trichloroethylene at concentrations above the MCL was detected in the surface waters at two locations within Site 3 and benzene at concentrations above the MCL was detected at three locations at Site 4. Additionally, xylenes at a concentration exceeding the RAL was detected in water from one sampling location at Site 4.

The sediment in drainage ditches at Sites 3, 4, and 8 have been adversely impacted by past activities at these sites. Significant levels of trace metals were found in the sediments from drainage ditches at each site. Lead at significant levels was common to the sediment from the drainage ditches. Petroleum hydrocarbons at significant levels were also detected in the sediment at the sites. Only trace levels of volatile organic compounds were found in the sediments at Site 3 but significant levels of contaminants were detected in the sediments at Site 4.

Soil from Sites 2, 3, 4, and 8 have significant levels of some contaminants. Those volatile organic compounds generally associated with fuels were detected at high levels at Sites 2 and 3. Petroleum hydrocarbons were found in the soil at high levels at Sites 2, 3, 4, and 8 and elevated trace metals were found in the soil at Sites 2 and 3. Additionally, a PCB compound was found at a significant level in one soil sample from Site 3.

Ground water at Sites 2, 3, 4, and 10 contains significant levels of contamination. Volatile organic compounds at levels in excess of either USEPA MCLs or State of Minnesota RALs were present in the ground water at Sites 2, 3, and 4. Radiation levels in excess of MCLs were found in the ground water at Site 10. The compound, trans 1,2 dichloroethylene, was the prevalent volatile organic compound found at Site 2, while 1,1,1 trichloroethane was the prevalent volatile organic compound found at Site 3. Benzene was the dominant volatile organic compound at Site 4 and only occurred at one well. Additionally, PCBs were detected in the ground water at Site 3 and total petroleum hydrocarbons were detected in the ground water at Site 4 at levels above RALs.

Table 7-5 summarizes the significance of findings by site.

7.8 RECOMMENDATIONS

The potential for future risk to human health exists at Sites 2, 3, 4 and 8. Therefore, it is recommended that Focused Feasibility Studies for Sites 2, 3, 4 and 8 be performed.

Insufficient data exists with respect to Site 10. In particular the exact location of the burial trench is not known; the type and quantity of the radiation source is not fully known; whether the cover material, which reportedly consisted of local refuse, is contributing hazardous waste contaminants is not known; the geologic and hydrogeologic regimes are not fully understood; and finally, the amount and extent of contamination is not known. Therefore, it is recommended that a Site 10 Remedial Investigation be performed to provide the data required to fully understand the contamination at this site.

TABLE 7-5

SUMMARY OF FINDINGS BY SITE

Site Number	Site Descriptor	Significant Results
2	Fire Training Areas 1 and 2	Ground water and soil contaminated with significant levels of organic compounds. A trace level of organics in one sediment sample.
3	Storage Pad Behind the DRMO (DPDO Storage Area "C")	Ground water and surface water contaminated with significant levels of organic compounds. Three soil samples and sediments at two locations also contained significant levels of one or more trace metals. Total petroleum hydrocarbons were at significant levels in sediments at all three sampling locations. Soil contamination at significant levels by aromatic volatile organic compounds noted in one soil sample.
4	Fuel Storage Area	Ground water, surface water, sediments, and soil contaminated with significant levels of organic compounds. Sediments also contained significant levels of barium and lead.
8	Old DPDO Storage Area	Sediments at one location and soil at two locations contaminated with petroleum hydrocarbons. Significant level of pesticides found in one soil sample. Trace levels of PCBs found in one soil sample.
10	Low Level Radioactive Waste Disposal Site	Ground water contaminated with significant levels of radiation.

SECTION 8
REFERENCES

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SECTION 8

REFERENCES

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