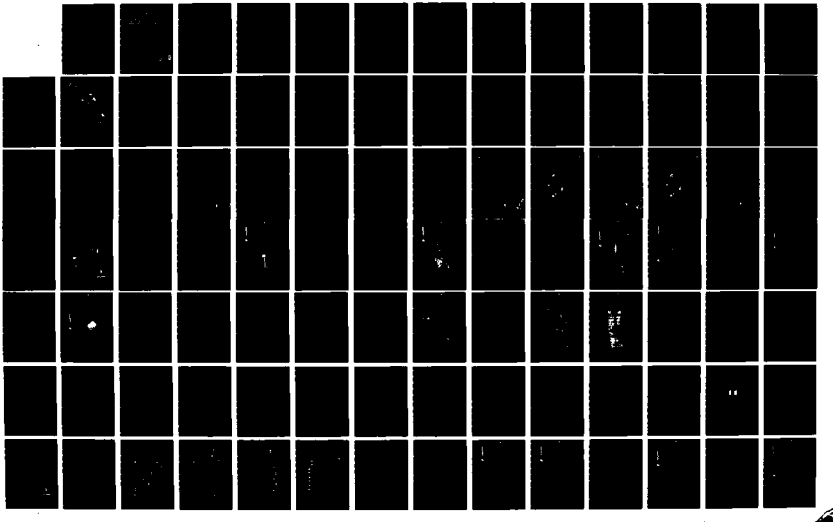
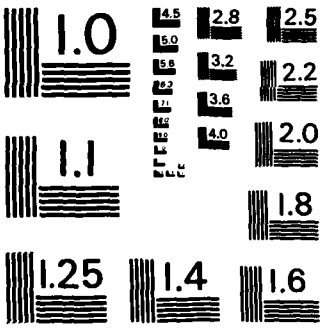
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Installation Restoration Program

Final Report
Phase II Stage I Study
Wright-Patterson Air Force Base
Dayton, Ohio

Prepared For:

United States Air Force
Occupational and Environmental Health Laboratory (OEHL)
Brooks Air Force Base, Texas

September 1985

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INSTALLATION RESTORATION PROGRAM
PHASE II - CONFIRMATION/QUANTIFICATION
STAGE I

FINAL REPORT

FOR

WRIGHT-PATTERSON AIR FORCE BASE
DAYTON, OHIO

AIR FORCE SYSTEMS COMMAND
HEADQUARTERS AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AFB, OHIO

1 AUGUST 1985

PREPARED BY

ROY F. WESTON, INC.

WEST CHESTER, PENNSYLVANIA 19380

CONTRACT NO. F33615-80-D-4006, ORDER 22

OEHL TECHNICAL MONITOR - CAPT ROBART W. BAUER
TECHNICAL SERVICES DIVISION (TS)

PREPARED FOR

UNITED STATES AIR FORCE
OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY (OEHL)
BROOKS AIR FORCE BASE, TEXAS 78235-5501

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PREFACE

The purpose of the Report is to document the accomplishment of the Phase II Stage I, Problem Confirmation Study of the United States Air Force Installation Restoration Program (IRP) at Wright-Patterson Air Base, Dayton Ohio. This work was conducted by Roy F. Weston, Inc. under Contract No. F33615-80-D-4006, Task Order No. 0022.

Mr. Peter J. Marks is Program Manager for this contract. Mr. Frederick Bopp III, PhD., managed this Task Order. Laboratory analyses were accomplished at WESTON's Laboratory in West Chester, Pennsylvania, under the supervision of Dr. Theodore F. Them. Roy F. Weston, Inc. wishes to acknowledge Major Wiley Taylor, USAF, Wright-Patterson Air Force Base Bioenvironmental Engineer, for his kind assistance in conducting this project.

This work was accomplished during the period November 1983 to August 1984. Captain Robart W. Bauer, USAF BSC, Technical Services Division , USAF Occupational and Environmental Health Laboratory (USAF OEHL/TS) was the Technial Monitor.

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Zone	Recommendations	Rationale
4	Resample existing wells	Verify Stage 1 results
	Install 7 additional monitor wells	Spill plume evaluation and Base boundary monitoring
	Sampling and analysis	Determine magnitude and extent of contamination
5	Resample existing wells	Verify Stage 1 results
	Install 5 additional monitor wells	Establish effective groundwater monitoring
	Priority pollutant screening	Leachate characterization
	Surface water and sediment monitoring	Evaluate transport of contamination
	Sampling and analysis	Magnitude and extent of contamination
6	Resample existing well	Verify Stage 1 results
	Install 2 additional monitor wells	Expanded monitoring at Base boundary
	Surface water and sediment monitoring	Evaluate transport of contaminants
	Sampling and analysis	Magnitude and extent of contamination
7	Resample existing well	Verify Stage 1 results
8	Resample existing well	Verify Stage 1 results

Table ES-1
Summary of Recommendations

Zone	Recommendations	Rationale
1	Refer both sites to Phase IV for immediate action. Phase IV activity would include a thorough characterization of gases and leachate.	Mitigation of human health hazard.
2	Resample existing wells	Verify Stage 1 results.
	Install 2 additional monitor wells	Expanded monitoring at Base boundary.
	Priority pollutant screening	Ground water and leachate characterization.
	Surface water and sediment monitoring	Evaluate transport of contaminants.
	Sampling and analysis	Determine magnitude and extent of contamination.
3	Resample existing wells	Verify Stage 1 results.
	Install 10 additional monitor wells	Establish effective ground water monitoring network.
	Priority pollutant screening	Ground water and Leachate characterization.
	Surface water and sediment monitoring	Evaluate transport of contaminants.
	Sampling and analysis	Magnitude and extent of contamination.

Stage 1 results are verified, then no further evaluation is necessary for Zone 7.

ES-5.9 Zone 8 - Recommendations

Based upon the results obtained to date, the following recommendation is made for Zone 8:

1. Resample and analyze the existing monitor well in this zone to verify Stage 1 results. If Stage 1 results are verified, then no further evaluation is necessary for Zone 8.

ES-5.10 Summary of Recommendations

The aforedescribed set of zone-by-zone recommendations is summarized in Table ES-1.

5. If present, leachate seepages at or around landfills should be sampled.

6. Water samples from the remaining monitor wells, from surface water staff gauge stations, and from the nearby Base production wells should be sampled and analyzed for a list of analytes based upon the results of priority pollutant screening.

ES-5.7 Zone 6 - Recommendations

Based upon the results obtained to date, the following recommendations are made for Zone 6:

1. Resample and analyze the existing monitor well in this zone to verify Stage 1 results.

2. Install two new monitor wells along the west side of the landfill in order to ensure that any contamination that may be present is sampled and characterized.

3. Establish three surface water staff gauge and sampling stations for surface water and sediment sampling along the creek which flows adjacent to the landfill, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. If present, leachate seepages should be sampled.

5. Sample the three monitor wells and three staff gauge stations for the Stage 1 list of analytes plus the USEPA priority pollutant list volatile organic compounds (VOC).

ES-5.8 Zone 7 - Recommendations

Based upon the results obtained to date, the following recommendation is made for Zone 7:

1. Resample and analyze the existing monitor well in this zone to verify Stage 1 results. If

recommended between the coal storage pile and the south Base boundary.

3. Sample and analyze the six new and all existing monitor wells in the zone for oil and grease and USEPA priority pollutant volatile organic compounds (VOC) plus xylene. Analyze the two Coal Storage Pile wells for Safe Drinking Water Act primary metals and base/neutral extractable organics. Analyze Burial Site 1 wells for Safe Drinking Water Act Primary metals.

ES-5.6 Zone 5 - Recommendations

Based upon the results obtained to date, the following recommendations are made for one site in Zone 5

1. Resample and analyze the existing monitor wells in this zone to verify Stage 1 analytical results. If the Stage 1 results are verified, then no further evaluation is necessary for Fire Training Area 1.

2. Install additional monitor wells around Landfill 5. Five additional monitor wells are necessary to ensure that all possible leachate seepage from the site is sampled and characterized.

3. Six surface water staff gauge and sampling stations should be established for surface water and sediment sampling -- one on each of the Twin Lakes and the gravel pond, and three on Hebble Creek, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. Water samples from selected upgradient and downgradient monitor wells should be sampled and analyzed for the complete list of USEPA priority pollutants, in order to determine 1) the "worst case" contamination scenario, and 2) key analytes of concern for assessing the magnitude and extent of contamination.

2. Install additional monitor wells around landfills 4, 6 and 7 in order to ensure that all possible leachate seepage from the landfills is sampled and characterized. Ten additional monitor wells should be installed around the three landfills in order to ensure that the complex hydrogeological flow patterns in this zone are determined.

3. Eight staff gauge and sampling stations should be established for surface water and sediment sampling along Hebble Creek and the tributaries flowing through and around the landfills, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. Water samples from selected upgradient and downgradient monitor wells should be sampled and analyzed for the complete list of USEPA priority pollutants, in order to determine 1) the "worst case" contamination scenario, and 2) key analytes of concern for assessing the magnitude and extent of contamination.

5. Water samples from the remaining monitor wells and from the surface water staff gauge stations should be sampled and analyzed for a list of analytes to be based upon the results of priority pollutant screening.

6. If present, leachate seepages at Landfills 3, 4, 6, and 7 should be sampled.

ES-5.5 Zone 4 - Recommendations

Based upon the results obtained to date, the following recommendations are made for two sites within Zone 4:

1. Resample and analyze the existing monitor wells in the zone to verify Stage 1 analytical results.

2. Install additional monitor wells around Spill Sites 2 and 3 and the coal storage pile. Six additional monitor wells are necessary to evaluate potential fuel contamination from Spills 2 and 3, and one additional well is

sampled and characterized. Two additional monitor wells should be installed, one along the Mad River at the western portion of the landfill toe facing the river, and one at the extreme western edge of the landfill.

3. Four surface water staff gauge and sampling stations for surface water and sediment sampling should be established along the surface water course running south and west of the landfill, and discharging into the Mad River, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. Water samples from selected upgradient and downgradient monitor wells should be sampled and analyzed for the complete list of USEPA priority pollutants, in order to determine 1) the "worst case" contamination scenario, and 2) key analytes of concern for addressing the magnitude and extent of contamination.

5. Water samples from the remaining monitor wells and from the surface water staff gauge stations should be sampled and analyzed for a list of analytes to be based upon the results of priority pollutant screening.

6. The Base should implement a post-closure monitoring plan to monitor water quality in the monitor wells around Landfill 11. The base should test the drums presently at Landfill 12 for USEPA hazard characteristics and remove them from the site for proper disposal. If present, leachate seepages at Landfills 11 and 12 should also be sampled.

ES-5.4 Zone 3 - Recommendations

Based upon the results obtained to date, the following recommendations are made for three sites within Zone 3:

1. Resample and analyze the existing monitor wells in this zone to verify Stage 1 analytical results. If the Stage 1 results are verified, then no further evaluation is necessary for Landfill 3.

ES-5.1 General

The findings of the Phase II Stage I study at eight zones on WPAFB indicate the need for follow-up work. This work includes the following:

1. General verification of the initial round of water quality sampling and analysis in seven of the zones.

2. An expanded monitoring program in five of the zones with an emphasis on determining the nature, magnitude and extent of contamination.

3. Referral of one zone to Phase IV for implementation of immediate remedial action and site closure.

ES-5.2 Zone 1 - Recommendations

Based upon the results obtained to date, the following recommendation is made for the two landfills in Zone 1:

1. Refer both landfills in Zone 1 to Phase IV. The rationale for this recommendation is that both landfills represent potential hazards to human health. Both landfills are generating leachate as well as hydrogen sulfide and methane gases. Further site evaluation without concurrent remedial actions would only prolong this potential hazard to nearby residents and to children playing in the parks built on both landfills. Phase IV activity would include a thorough characterization of gases and leachate.

ES-5.3 Zone 2 - Recommendations

Based upon the results obtained to date, the following recommendations are made for sites within Zone 2:

1. Resample and analyze the existing monitor wells in this zone to verify Stage 1 analytical results.

2. Because this zone is so close to the Base boundary, install additional monitor wells around landfill 11 in order to ensure that all possible leachate seepage from the landfill is

7. Three landfills in Zone 3 appear to be generating leachate, and TOX analyses indicate that USEPA Priority Pollutant compounds are present in the leachate. One monitoring well exceeded the Safe Drinking Water Standards for chloride, while two wells exceeded Secondary Standards for iron and manganese.

8. Oil and grease was detected in monitor wells adjacent to the Spill Areas 2 and 3 in Zone 4 at levels above the aesthetic standard for taste and odor, although no floating hydrocarbon layer was detected. USEPA Priority Pollutant solvents were also detected in samples from one of these wells. Fuel contamination was apparent.

9. Landfill 5 in Zone 5 appears to be generating leachate, and TOX analyses indicate that USEPA Priority Pollutant compounds are present in the leachate. One monitor well contained sulfate in excess of the Secondary Safe Drinking Water Standard, while three wells exceeded the Secondary Safe Drinking Water Standards for iron and manganese.

10. Landfill 2 in Zone 6 appears to be generating leachate, although there is no analytical evidence that USEPA Priority Pollutant compounds are part of that leachate. The one well in the Zone contained manganese slightly in excess of the Secondary Safe Drinking Water Standard.

11. Landfill 9 in Zone 7 does not appear to be generating leachate.

ES-5.0 RECOMMENDATIONS

Based upon the findings and conclusions of this Phase II Stage 1 Study, the following recommendations have been made concerning follow-up work at Wright-Patterson Air Force Base.

shallow discharge of ground water contaminated with metals, nitrate, TOC and TOX into Hebble Creek and then into the Mad River. At Zone 4 a ground-water mound was detected in the vicinity of the Coal Storage Pile, and flow vectors indicate the potential for migration of ground water contaminated with Oil and Grease, TOX and VOA compounds in a generally southerly off-Base direction. Flow vectors at Zone 5 indicate the potential for ground water contaminated with Metals, TOC and TOX to migrate from the landfill toward the nearby Mad River. At Zone 6 there is the possibility of ground-water mounding beneath the landfill, but even without such mounding the regional flow gradient would carry ground water contaminated with metals and TOC across the adjacent Base boundary.

4. Measurable amounts of gases, including methane, hydrogen sulfide and trace amounts of organic compounds are being generated by both landfills in Zone 1. These seeps make both landfills potential health risks to residents immediately adjacent to the sites. Both sites are also generating leachate, which contains up to two USEPA Priority Pollutants and several non-priority pollutant volatile solvents, further aggravating the health hazard associated with these sites.

5. Results of the Zone 1 geophysical surveys on Landfills 8 and 10 indicated areas of high magnetic contour gradients, disturbed subsoil, suspected trenches, and buried drum-like targets on both the landfills.

6. The landfills in Zone 2 appear to be generating some leachate, although there is no analytical evidence of USEPA Priority Pollutant compounds being part of that leachate. Two monitoring wells in this Zone contained iron in excess of Secondary Safe Drinking Water Standards, and one contained manganese in excess of the Secondary Safe Drinking Water Standard. Drums are present at Landfill 12.

a high probability that these health criteria are exceeded in the case of one or more of these compounds.

The landfills comprising Zone 1 (Landfills 8 and 10) are producing leachate with elevated TOC, TOX, VOA compounds (including 940 ug/L each of acetone and methethyl ketone) and heavy metals levels, and are producing malodorous gases which are emanating from the landfill surfaces. The close proximity of housing units to both of these sites, combined with the usage of both sites as playgrounds, makes the leachate and gas generation problems ones of hazards to human health.

ES-4.0 CONCLUSIONS

Based upon the results of the Phase II (Stage 1) survey at Wright-Patterson Air Force Base, the following conclusions have been drawn:

1. Ground water occurs under shallow, water table conditions in and around all sites investigated. Base-wide regional ground-water gradients average between 0.001 and 0.002, reflecting the highly permeable, coarse-grained glacial outwash sediments underlying most of the Base. The hydraulic driving force for ground-water contaminant migration is fairly small, due to this low gradient, although the high hydraulic conductivities characteristic of much of the Base allow very rapid transport of large volumes of ground water.

2. The regional water table flow is generally west-southwesterly, in the same direction as the flow of the Mad River, toward the major City of Dayton wellfield at Rohrer's Island. Locally this regional flow trend is modified by creeks and by mounding induced either by landfilling or by storage of coal.

3. There exists a potential for off-Base migration of contaminants at several sites. Zones 2 and 8 are along the shore of the Mad River, ground-water and dissolved metals and Oil and Grease would be in transport in that direction. In Zone 3 the potential exists for

- Zone 6 (Landfill 2)
- Zone 7 (Landfill 9)
- Zone 8 (Fire Training Area 2)

The scope of the investigation includes: drilling and construction of 27 groundwater monitoring wells and four methane gas monitoring wells; sampling and analysis of groundwaters and leachate seeps; conducting ground penetrating radar and magnetometry surveys at two landfill sites; surveying elevations of monitor wells and surface water stations; preparation of water table maps for the whole Base as well as for specific zones; data interpretation and preparation of this Final Report. One round of water quality analyses was accomplished for a range of analytes, and all analyses were accomplished in WESTON's laboratory in accordance with United States Environmental Protection Agency Standard Methods.

ES-3.0 MAJOR FINDINGS

Based upon the analyses performed, levels of contamination were found in groundwater and in leachate seeps which warrant further investigation and possible future actions.

The major groundwater contaminants indicated by the available data are heavy metals associated with landfill leachate. Iron was detected in a wide range of concentrations, but exceeded the Safe Drinking Water Act Secondary Standard of 0.3 mg/L in 7 of the 27 wells, and in all six leachate seeps tested. Manganese exceeded the Safe Drinking Water Act Secondary Standard of 0.05 mg/L in 9 of the 27 monitor wells tested. Sulfate exceeded the Safe Drinking Water Act Secondary Standard of 250 mg/L in two of the wells and two of the leachate seeps tested. Oil and grease exceeded the taste and odor threshold of 0.01 mg/L in four of the monitor wells associated either with fuel spills or with fire training areas. Total organic halogens (TOX) was detected in the range of from 5.2 to 94.0 ug/L in 7 of the monitor wells tested. TOX is an indicator parameter, indicative of synthetic chlorinated solvents. USEPA water quality criteria for human health have been published for many compounds falling within the group contributing to TOX levels. Some of these criteria are in the range of 1 ug/L or less. Thus, TOX concentrations in the wells samples from WPAFB indicate

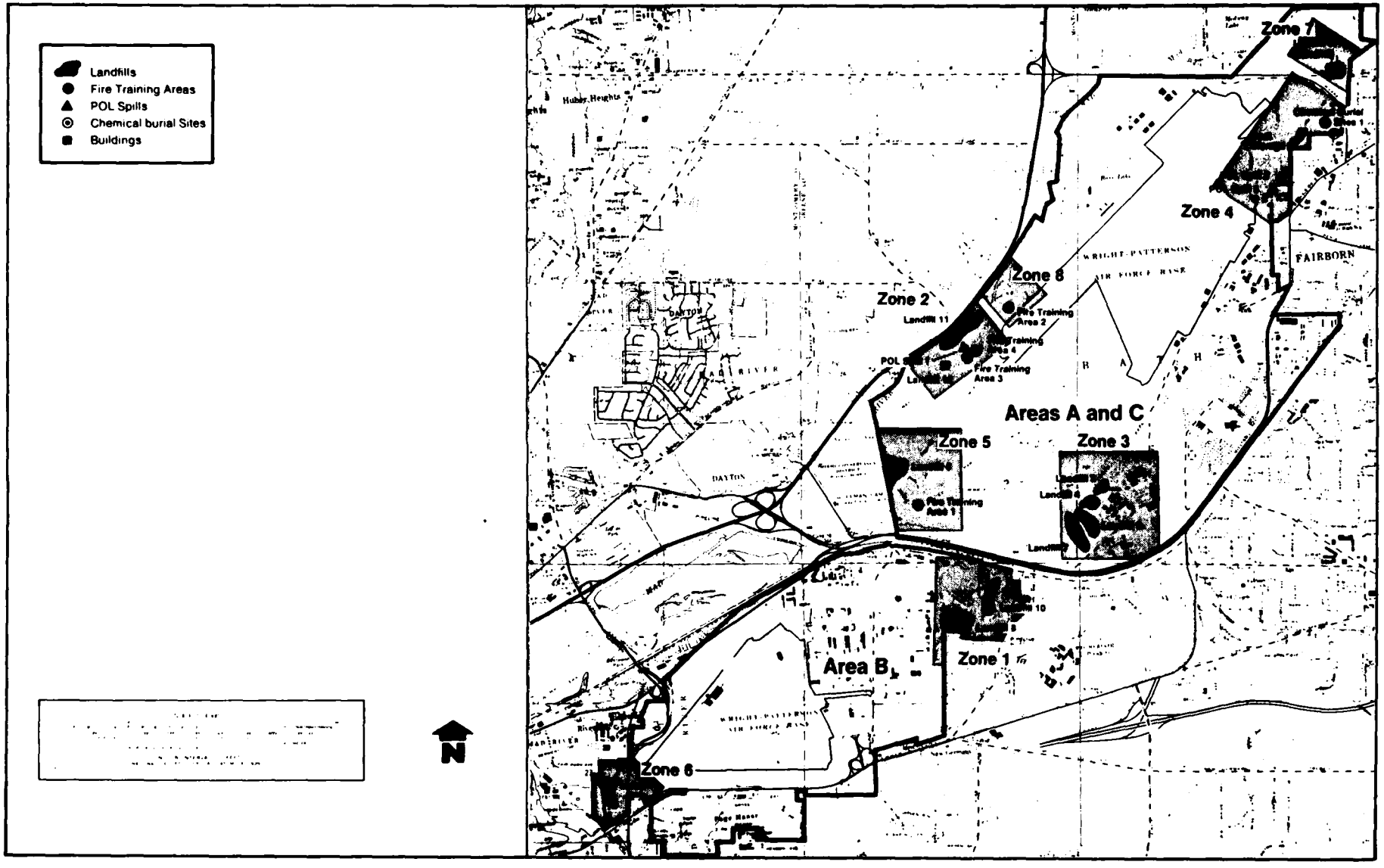


Figure ES-1 Location of all Phase II Sites and Zones at Wright-Patterson AFB

EXECUTIVE SUMMARY

ES-1.0 INTRODUCTION

Roy F. Weston, Inc. (WESTON) was retained by the U. S. Air Force Occupational and Environmental Health Laboratory (OEHL) under Contract No. F33615-80-D-4006 to provide general engineering, hydrogeological and analytical services. These services were applied to the Installation Restoration Program (IRP) Phase II effort at Wright-Patterson Air Force Base under Task Order 22 of this contract.

The purpose of the Phase II (Stage I) investigation was to determine if environmental contamination had resulted from waste disposal practices at Wright Patterson AFB. In addition, the purpose of the investigation included an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and the recommendation of additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants.

Only the Phase II (Stage 1) portion of the IRP effort at Wright-Patterson Air Force Base was part of this Task Order.

ES-2.0 SCOPE OF WORK

Wright-Patterson Air Force Base (WPAFB) is located in the Miami River Valley northeast of Dayton, Ohio. Field operations under this task order evaluated 21 sites located within eight zones at WPAFB. The sites and zones evaluated are identified below and shown in Figure ES-1.

- Zone 1 (Landfill 8; Landfill 10)
- Zone 2 (Landfill 11; Landfill 12; Fire Training Areas 3 and 4; POL Spill Site 1)
- Zone 3 (Landfills 3, 4, 6 and 7)
- Zone 4 (Coal Storage Pile; Chemical Burial Sites 1; POL Spill Sites; POL Spill Sites 2 and 3)
- Zone 5 (Landfill 5; Fire Training Area 1)

SECTION 1

INTRODUCTION

1.1 INSTALLATION RESTORATION PROGRAM

The purpose of the Installation Restoration Program (IRP) is to assess and control migration of environmental contamination that may have resulted from past operations and disposal practices on DoD facilities, and probable migration of hazardous contaminants. In response to the Resource Conservation and Recovery Act of 1976 (RCRA) and in anticipation of the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA, or "Superfund"), the DoD issued a Defense Environmental Quality Program Policy Memorandum (DEQPPM) dated June, 1980 (DEQPPM 80-6), requiring identification of past hazardous waste disposal sites DoD agency installations. The U.S. Air Force implemented DEQPPM 80-6 by message in December, 1980. The program was revised by DEQPPM 81-5 (11 December 1981) which reissued and amplified all previous directives and memoranda on the IRP. The Air Force implemented DEQPPM 81-5 by message on 21 January 1982. The Installation Restoration Program has been developed as a four-phase program as follows:

Phase I - Problem Identification/Records Search
Phase II - Problem Confirmation and Quantification
Phase III - Technology Base Development
Phase IV - Corrective Action

The purpose of the Phase II (Stage I) investigation was to determine if environmental contamination has resulted from waste disposal practices at Wright-Patterson AFB. In addition, the purpose of the investigation included an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and the recommendation of additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants.

Definitions of the terms and acronyms used in this report are in Appendix A.

1.2 PROGRAM HISTORY AT WRIGHT-PATTERSON AIR FORCE BASE

Roy F. Weston, Inc. (WESTON) has been retained by the United States Air Force Occupational and Environmental Health Laboratory (OEHL) under Contract Number F33615-80-D-4006, to

provide general engineering, hydrogeological and analytical services. The Phase I, Problem Identification/Records Search for Wright-Patterson Air Force Base (WPAFB) was accomplished by Engineering Science Inc. (ESI) in late 1981, and their Final Report was dated February 1982. In response to the findings contained in the ESI Phase I Final Report, the OEHL issued Task Order 0009 to WESTON, directing that a pre-survey site inspection be conducted at WPAFB. The purpose of this pre-survey was to obtain sufficient information to develop a work scope and cost estimate for the conduct of a Phase II, Stage 1 study at WPAFB.

The Pre-Survey report for WPAFB was initially submitted by WESTON in August 1982, and was revised and resubmitted in November, 1982. Following modifications in the scope of work, Task Order 0022, dated 14 September 1983, was issued, which authorized a Phase II Stage I Study for 9 sites at WPAFB. A copy of the formal Task Order authorizing this work is included here as Appendix B.

On 31 October 1983 WESTON met with representatives of the Air Force Logistics Command (AFLC) Bioenvironmental Engineer and Civil Engineer, the Base Bioenvironmental Engineer, and the Civil Engineering and Public Affairs Departments of Wright-Patterson Air Force Base. The drilling subcontractor, Bowser-Morner Testing Laboratories, Inc., and representatives of the Ohio Environmental Protection Agency, (OEPA) were also in attendance. The purpose of the meeting was to review the goals of the investigation, review drilling procedures and locations, and to establish the field schedule. Geophysical investigations commenced on 1 November 1983. Soil borings and construction of the first 19 ground-water monitoring wells commenced on 28 November 1983 and were completed by 9 December. The last eight monitor wells were drilled and constructed between 6 and 10 February 1984. Ground-water sampling was completed during the week of 27 February 1984. Leachate seep sampling was accomplished during the week of 30 April 1984. Monitor wells were resampled for analysis of Total Organic Carbon (TOC) during the week of 11 June 1984. Four methane gas monitoring wells were completed on 28 August, 1984.

1.3 BASE PROFILE

Wright-Patterson Air Force Base is located in southwestern Ohio northeast of the City of Dayton. It is approximately 60 miles northeast of Cincinnati and approximately 50 miles southwest of Columbus.



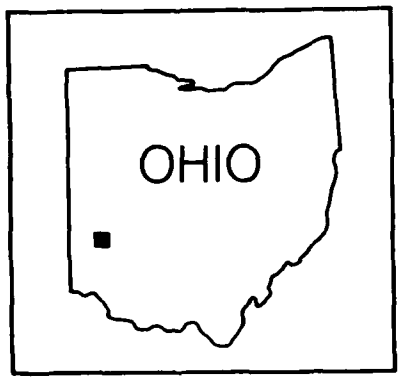
The installation is composed of two air fields (Wright and Patterson) separated by State Route 444 and the Consolidated Rail Corporation tracks (see Figure 1-1). Wright Field, designated Area B, is situated in both Montgomery and Greene Counties. Patterson Field, composed of Areas A and C, is located within Greene County except for about 15 acres lying along the Mad River in Montgomery County. Clark County abuts the Base at the northeast property line. Area B encompasses approximately 2,800 acres and is bordered on the north by State Route 444, on the east by Wright State University, on the south by Airway Road and on the west by Springfield Pike. Area B is made up of a complex of over 200 buildings (not including family housing) with a gross floor area of over 6,000,000 square feet. The western half of Area B was once solely occupied by the runway system. Today, the runways are no longer in service.

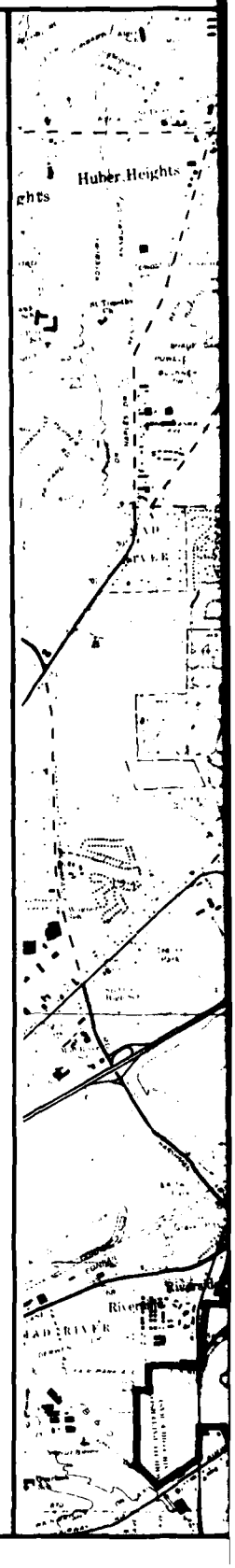
Areas A and C encompass 5,711 acres and are physically separated from Area B by State Route 444 on the south and east. It is bordered to the north by State Route 235 and to the west by the Mad River. Area A has a mixture of land uses ranging from storage and warehousing to offices and classrooms. Area C is largely occupied by the air field. The built-up area adjacent to the city of Fairborn is comprised of offices, storage, industrial and flight line facilities. Dormitories for enlisted personnel and support facilities are located in Kitty Hawk Center. Several new facilities have recently been constructed in this area. The largest is the Air Force Museum.

The host activity for Wright-Patterson AFB is the 2750th Air Base Wing, which employs 16 percent of the approximately 24,000 persons assigned to the Base. In its responsibility for this installation, the 2750th is charged with the operation and maintenance of real property at Wright-Patterson AFB. This includes to 18,683,454 square feet of floor space. Through host-tenant support agreements, the Wing provides utilities, communications, supplies, transportation, staff assistance and other services necessary for the tenants to accomplish their individual missions.

Tenant missions at Wright-Patterson AFB include:

- Air Force Logistics Command Headquarters
- Air Force Acquisition Logistics Division





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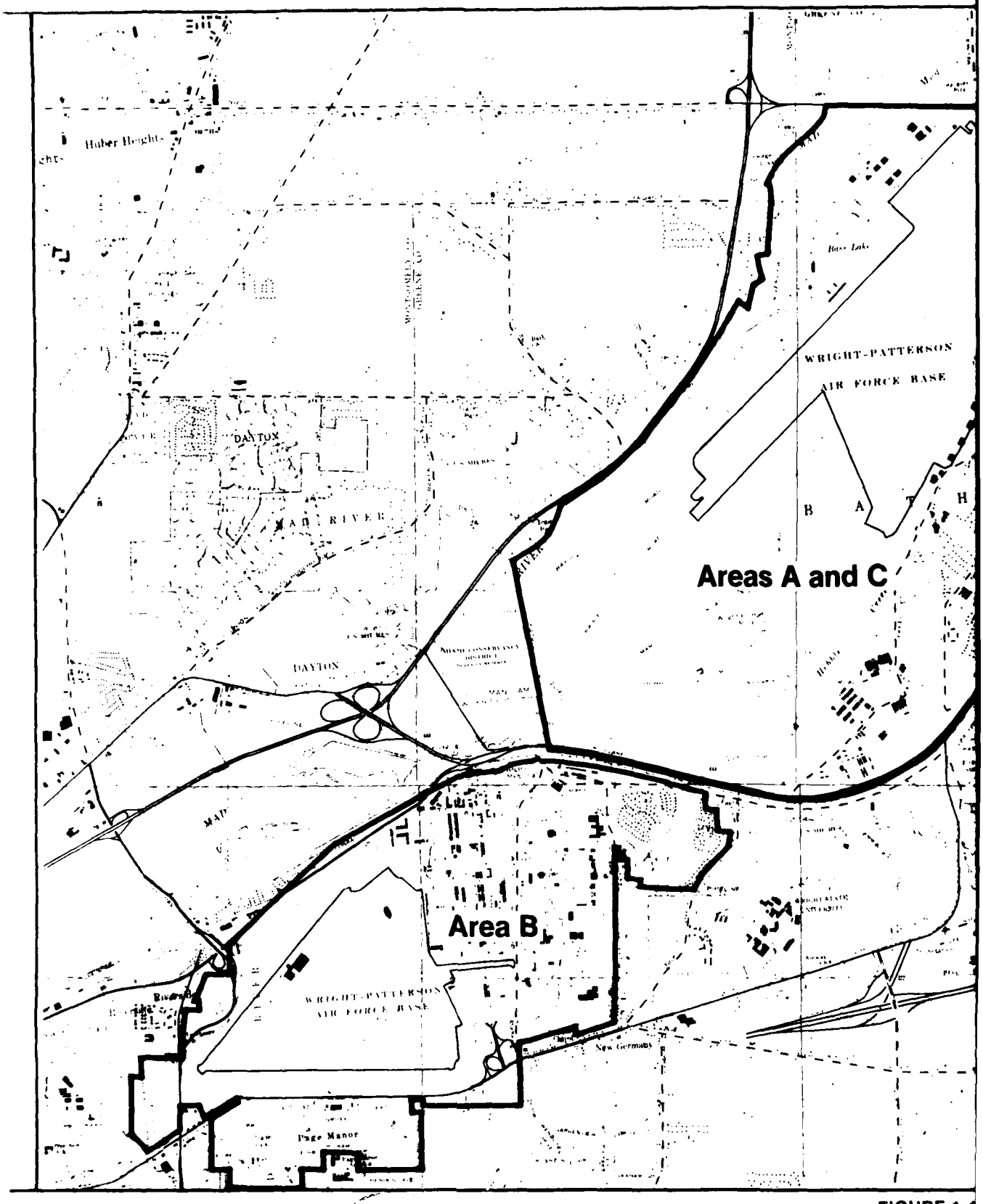
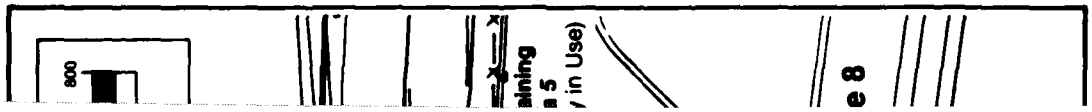


FIGURE 1-1

2

WESTON



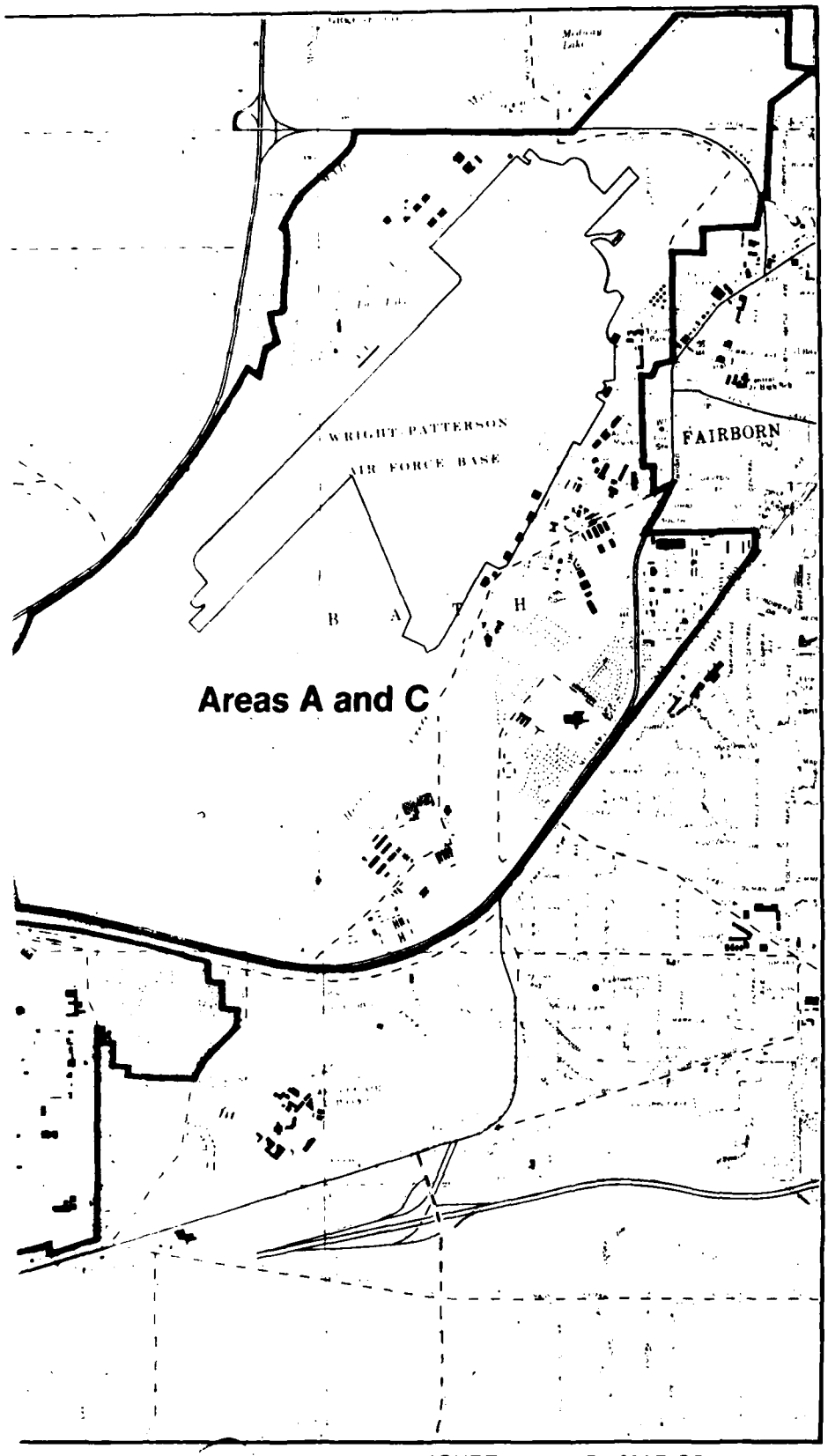


FIGURE 1-1 INDEX MAP OF
WRIGHT PATTERSON AFB

- Air Force Systems Command organizations
- Air Force Institute of Technology
- 2046th Communications Group
- USAF Regional Medical Center for Northeast and North Central U.S.
- Air Force Museum
- Military Airlift Command organizations

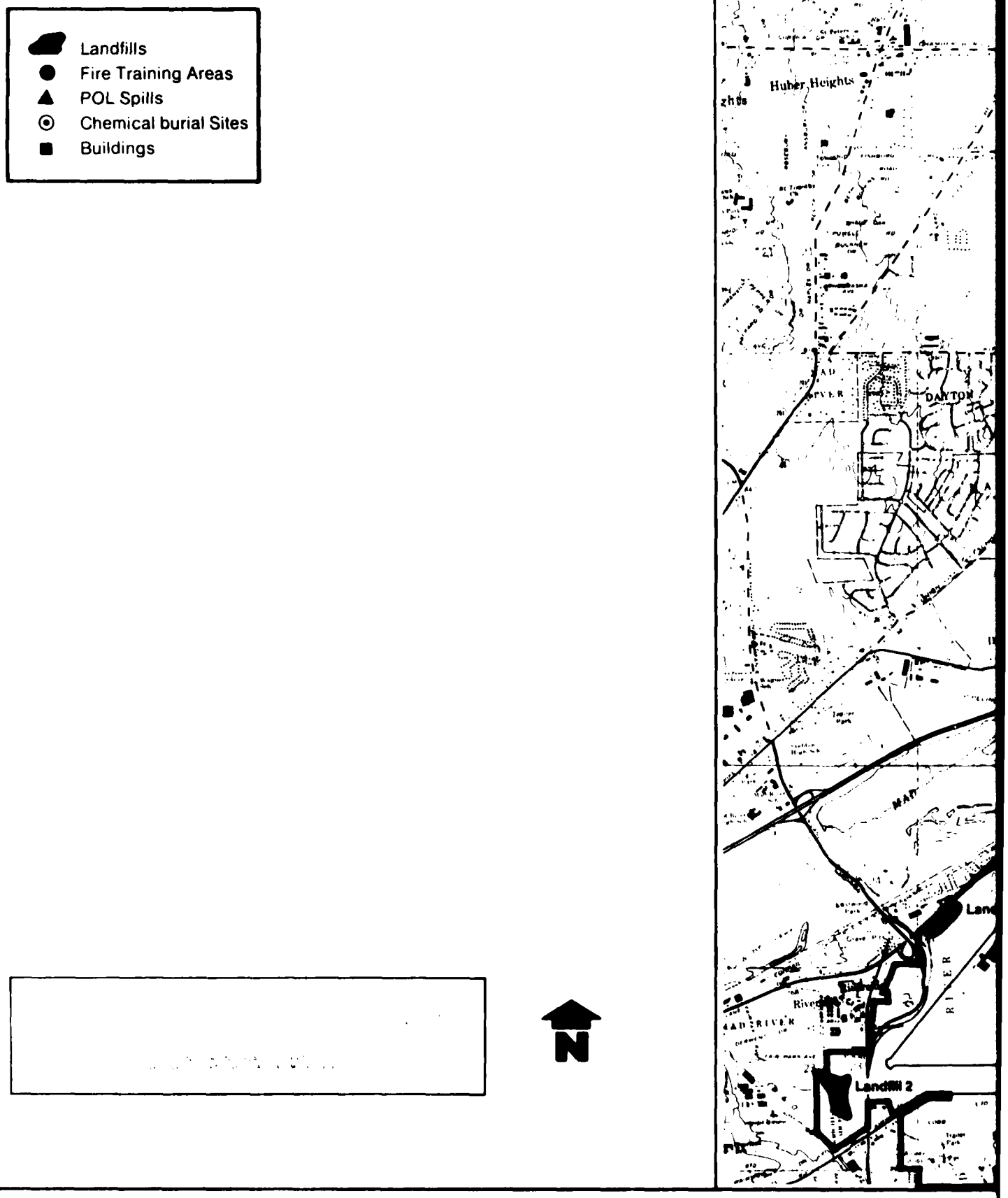
Past Air Force activities at WPAFB in support of operational missions have resulted in the occurrence on the Base of several waste disposal sites of potential concern. Each of these sites was rated by ESI during Phase I activities in accordance with the IRP Hazard Assessment Rating Method (HARM). The results of these ratings are summarized in Table 1-1 from the ESI report. Figure 1-2 shows the locations of all sites receiving HARM score rankings. Based on these rankings, ESI recommended that Phase II activities concentrate on the sites ranked 1 through 14, all of which had HARM scores of 60 or greater.

From the Phase II Pre-Survey report eight areas were identified for Confirmatory investigations. Five of these areas are Zones which contain two or more sites, and are treated in this Phase II investigation as single sites. The following listed sites comprise the sites evaluated in the Phase II, stage 1 study. The site locations are shown on Figure 1-3.

- Zone 1 (Landfill 8; Landfill 10)
- Zone 2 (Landfill 11, Landfill 12; Fire Training Areas 3 and 4, POL Spill Site 1)
- Zone 3 (Landfills 3, 4, 6 and 7)
- Zone 4 (Coal Storage Pile; Chemical Burial Sites 1; POL Spill Sites; POL Spill Sites 2 and 3)
- Zone 5 (Landfill 5; Fire Training Area 1)
- Zone 6 (Landfill 2)

Table 1-1
Priority Ranking of Potential
Contamination Sources at Wright Patterson AFB

Rank	Site Names	Period of Operation	Overall Score
1	Landfill No. 10 (Woodland Hills)	1965-1968	82
2	Landfill No. 8	1955-1962	79
3	Fire Training Areas 3 & 4/Spills No. 1	1960-1980	77
4	Spill No. 2	Apr. 1976	74
5	Landfill No. 12	1968-1973	73
6	Spill No. 3	Mar. 1981	72
7	Landfill No. 11	1968-1977	71
8	Landfill No. 5 (Twin Lakes)	1945-Present	63
9	Fire Training Area No. 1	1950-1955	63
10	Landfill No. 2 (Tillman Pit)	1941-1955	62
11	Landfills No. 3,4,6 & 7	1945-1962	61
12	Fire Training Area No. 2	Late 1950's	61
13	Landfill No. 9 (Sandhill)	1962-1964	60
14	Coal Storage Pile	Long Term	60
15	Central Heating Plant No. 2 (Bldg. 271)	1940's-1980	59
16	Burial Site No. 1	1966-1971	58
17	Burial Site No. 2	1971-1975	56
18	Landfill No. 1	1920's-1940	56
19	Central Heating Plant No. 1 (Bldg. 66)	1930-1980	55
20	Central Heating Plant No. 3 (Bldg. 170)	1939-1980	50
21	Radioactive Waste Burial Site	Before 1951	47
22	Deactivated Nuclear Reactor	1965-1970	47
23	Central Heating Plant No. 4 (Bldg. 1240)	1957-Present	46
24	Central Heating Plant No. 5 (Bldg. 770)	1956-Present	44


Landfills
Fire Training Areas
POL Spills
Chemical burial Sites
Buildings
Huber Heights
DAYTON
Landfill 2
N

1692

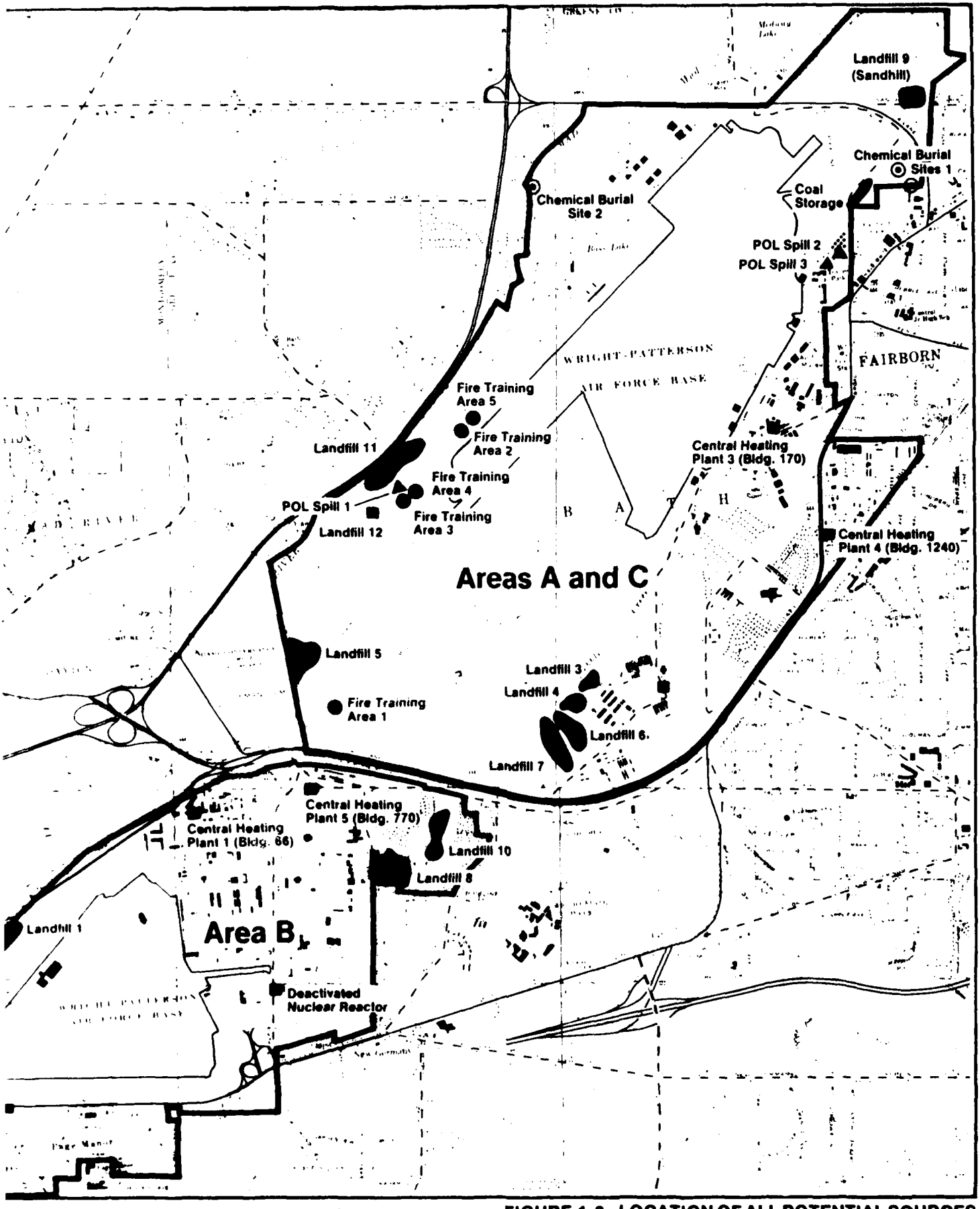
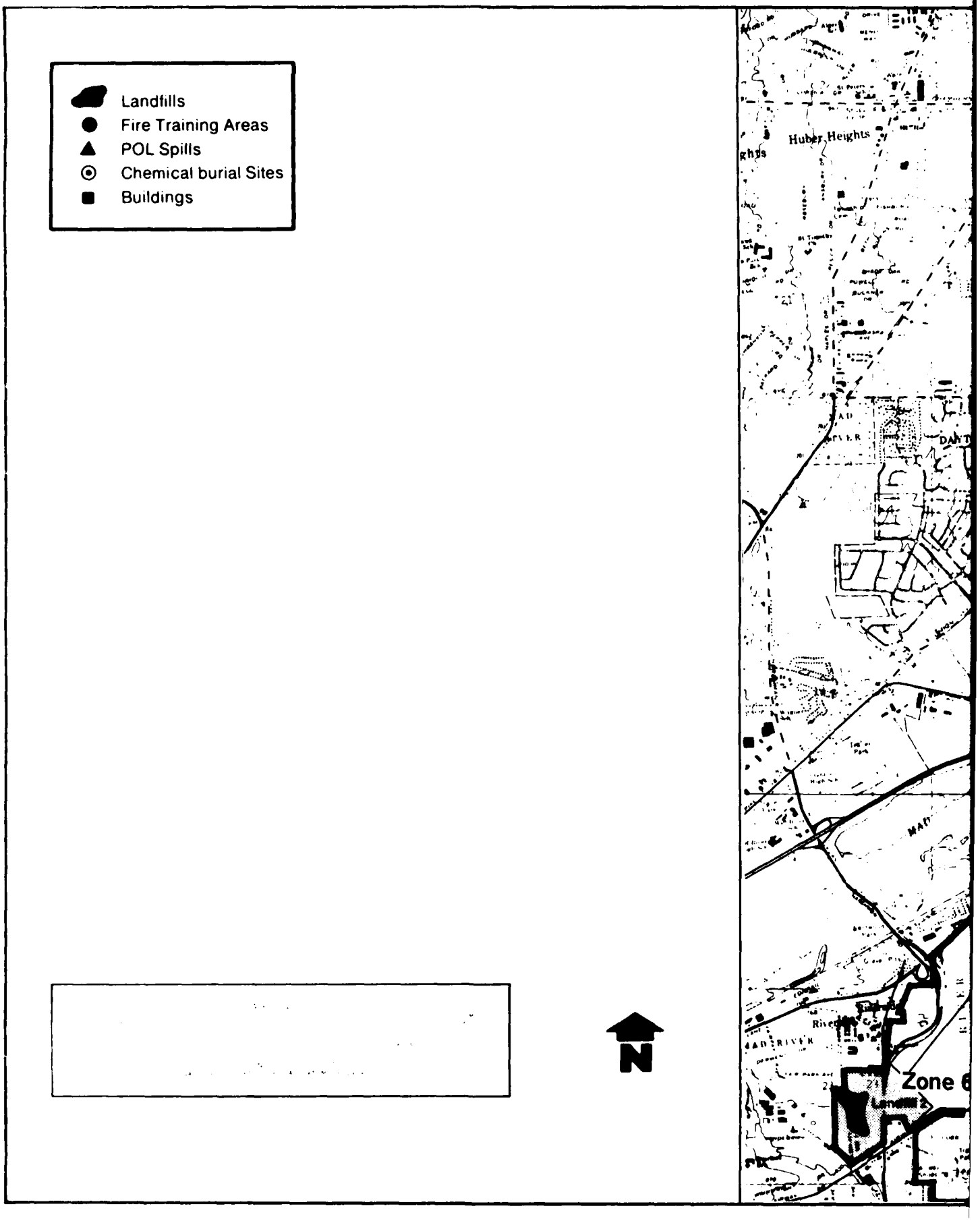


FIGURE 1-2 LOCATION OF ALL POTENTIAL SOURCES OF CONTAMINATION AT WRIGHT PATTERSON AFB RECEIVING PHASE 1 HARM SCORE RANKING


Landfills
Fire Training Areas
POL Spills
Chemical burial Sites
Buildings
Huber Heights
N
Zone 6

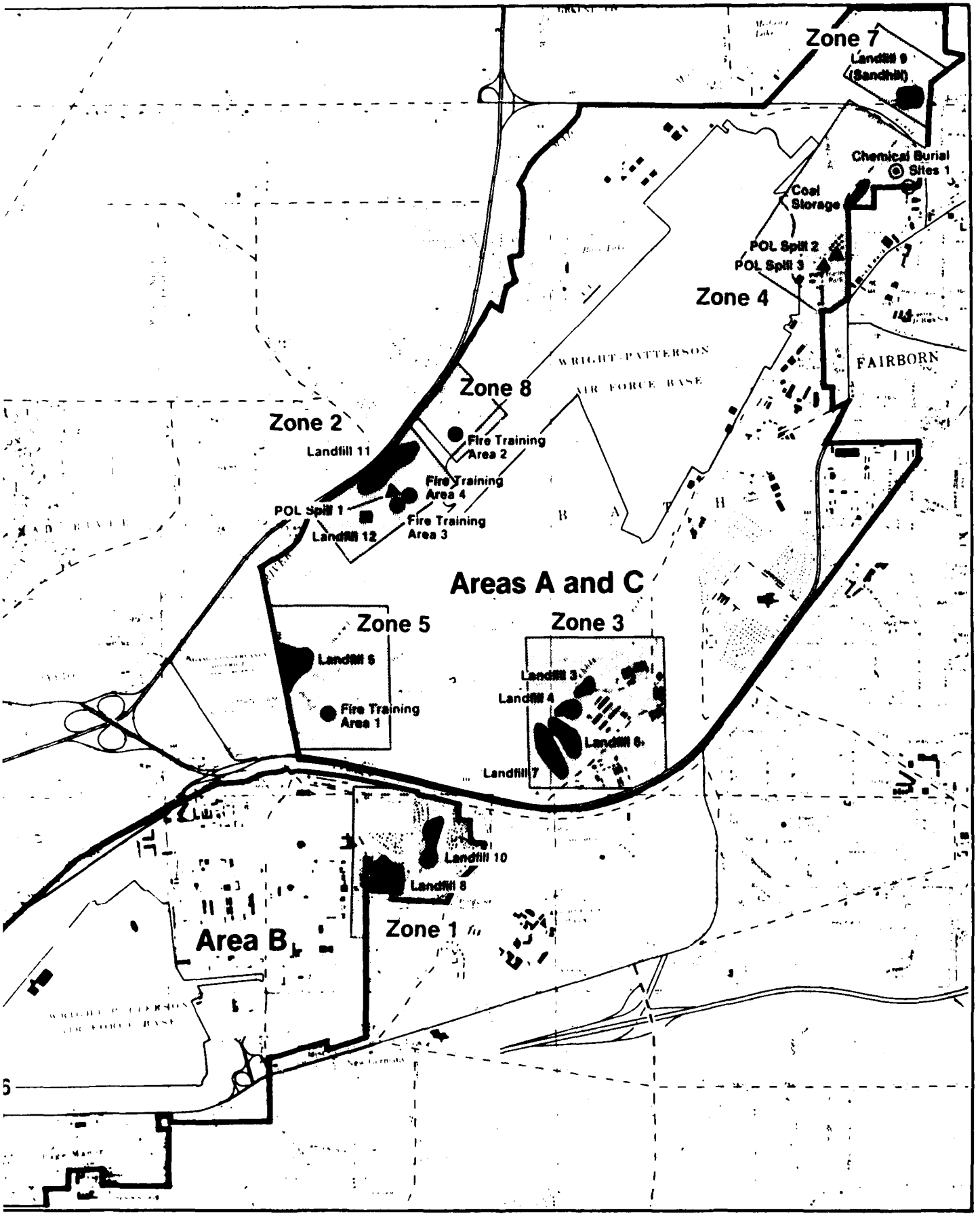
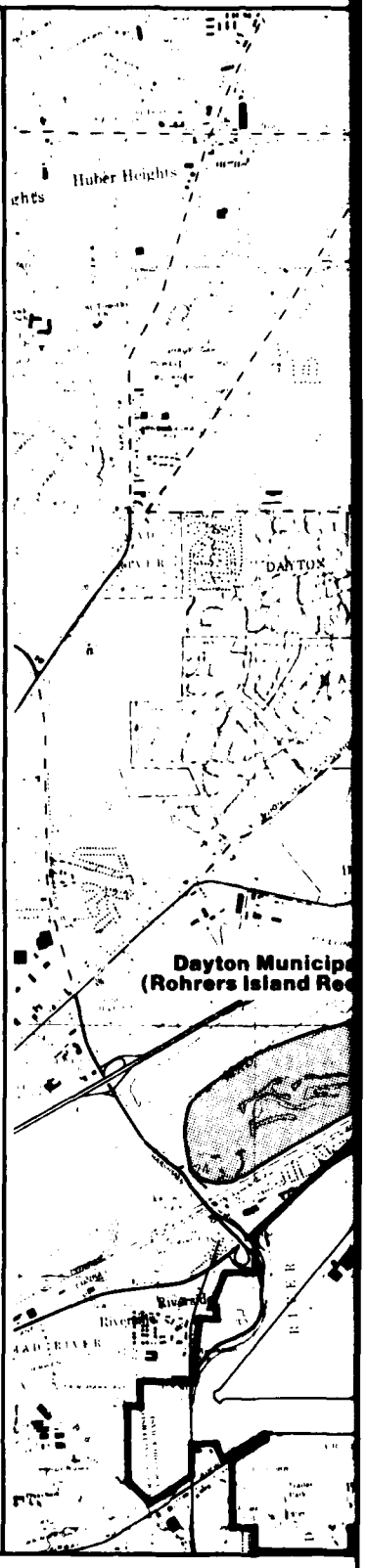


FIGURE 1-3 LOCATION OF ALL PHASE II SITES AND ZONES AT WRIGHT PATTERSON AFB


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Huber Heights
DAYTON
Dayton Municip
(Rohrers Island Re

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WESTON

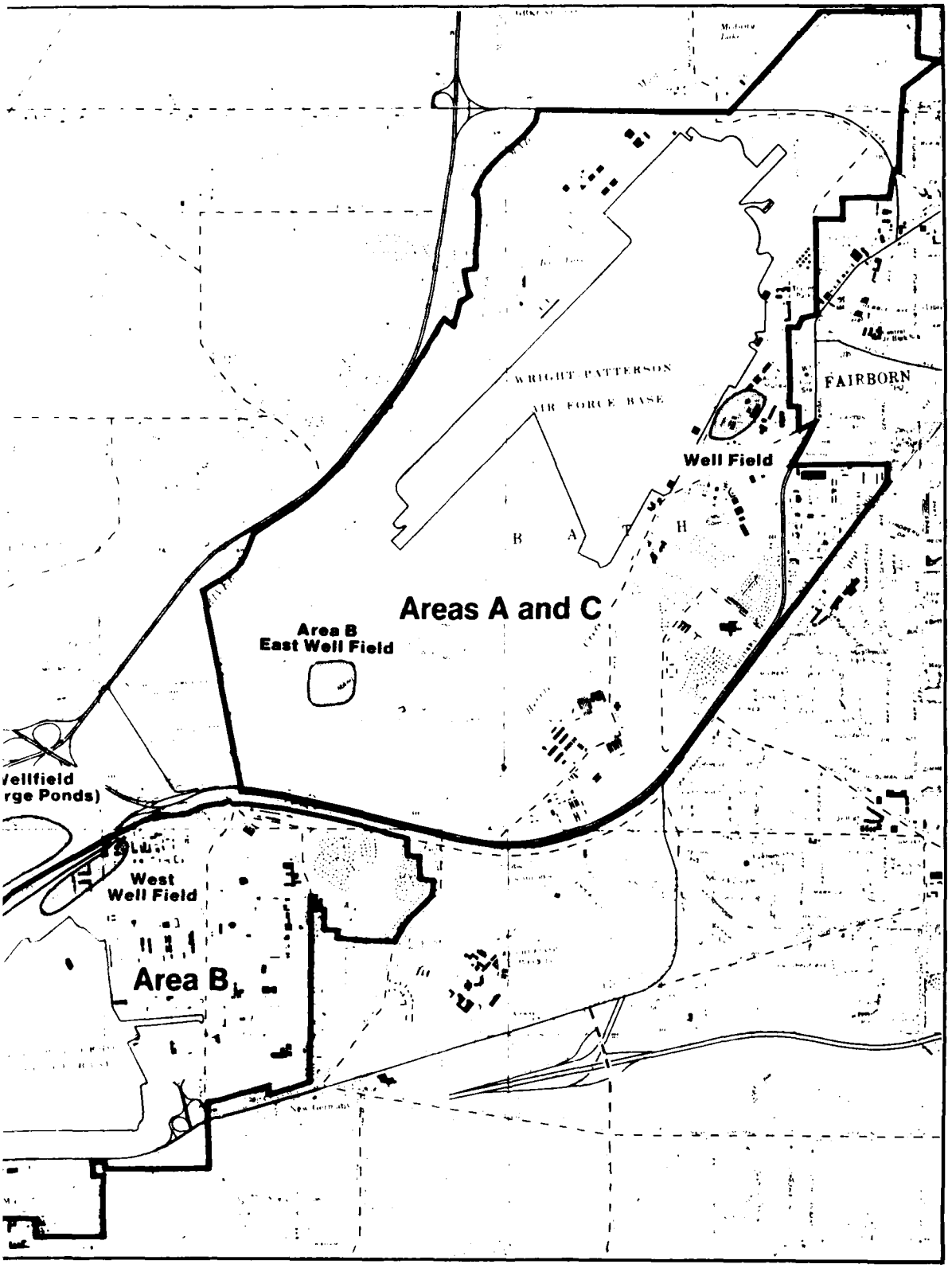


FIGURE 2-4 LOCATION OF WATER SUPPLY WELL FIELDS AT WPAFB AND ROHRERS ISLAND



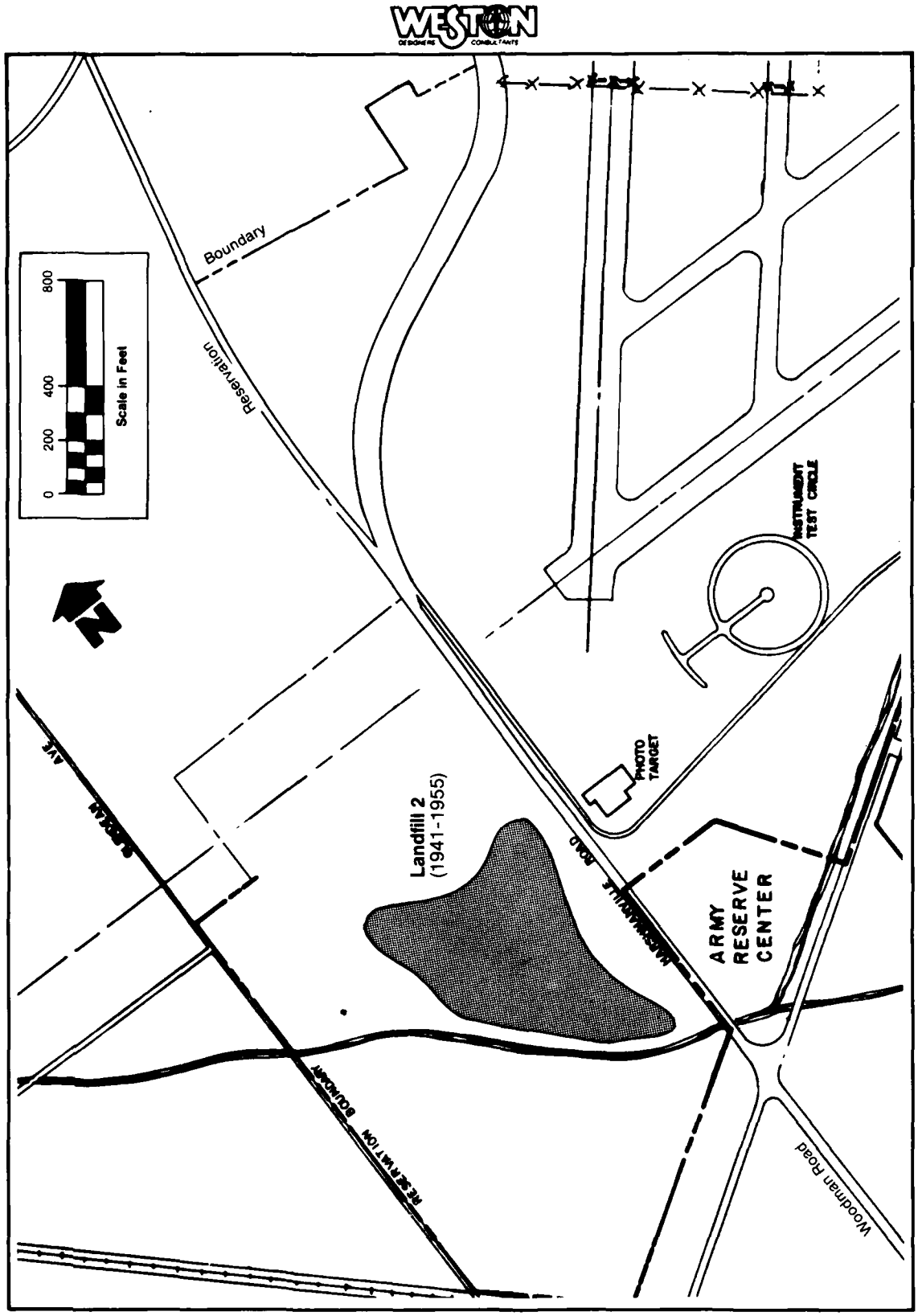


FIGURE 1-9 GENERAL SITE MAP OF ZONE 6

was initially operated during the 1940's as a lumber reclamation area where scrap lumber was accumulated and sold to the public. It was then handled as general residential refuse as a surface dump operation. Landfill 5 was also the site of a waste petroleum handling operation. Two tanks (actually halves of a 10,000 gallon tank) were used to burn off flammable petroleum waste products. These tanks no longer remain at the site and should not have contributed to surface or ground-water contamination. In addition to these tanks, there was a 15,000-gallon below-ground storage tank used to collect waste oil for a 15 to 20 year period. The tank was serviced by an off-Base waste oil reclaimer. In 1978, the tank was sold, and the waste oil reclaim operation moved.

Today at Landfill 5, there is a 10,000-gallon horizontal steel tank modified to act as an oil-water separator. The tank was used in the early 1970's.

At the present time, Landfill 5 accepts flyash from the Base heating plants, and hardfill from construction and landscaping activities.

1.3.5.2 Fire Training Area 1

Fire Training Area 1 was operated from 1950 to 1955. At this location, contaminated fuels were burned in a dirt pit with a surrounding earthen dike, after first saturating the ground with water to reduce percolation. At present, there are no visible traces of an earthen dike or pit in the vicinity of the Phase I Report location of Fire Training Area 1.

1.3.6 History and Description of Zone 6

Zone 6, as seen on Figure 1-3, is located at the far southwest corner of Wright-Patterson AFB. The area is drained by an unnamed tributary of the Mad River which flows along the southwest border of Landfill 2. A general site map of Zone 6 showing the location of Landfill 2 is shown on Figure 1-9.

1.3.6.1 Landfill 2

Landfill 2, also called Tillman Pit, was initially a gravel pit approximately nine acres in size. From 1941 to 1955, the landfill was operated as a surface dump for general refuse from Area B. Refuse was placed into the gravel pit in

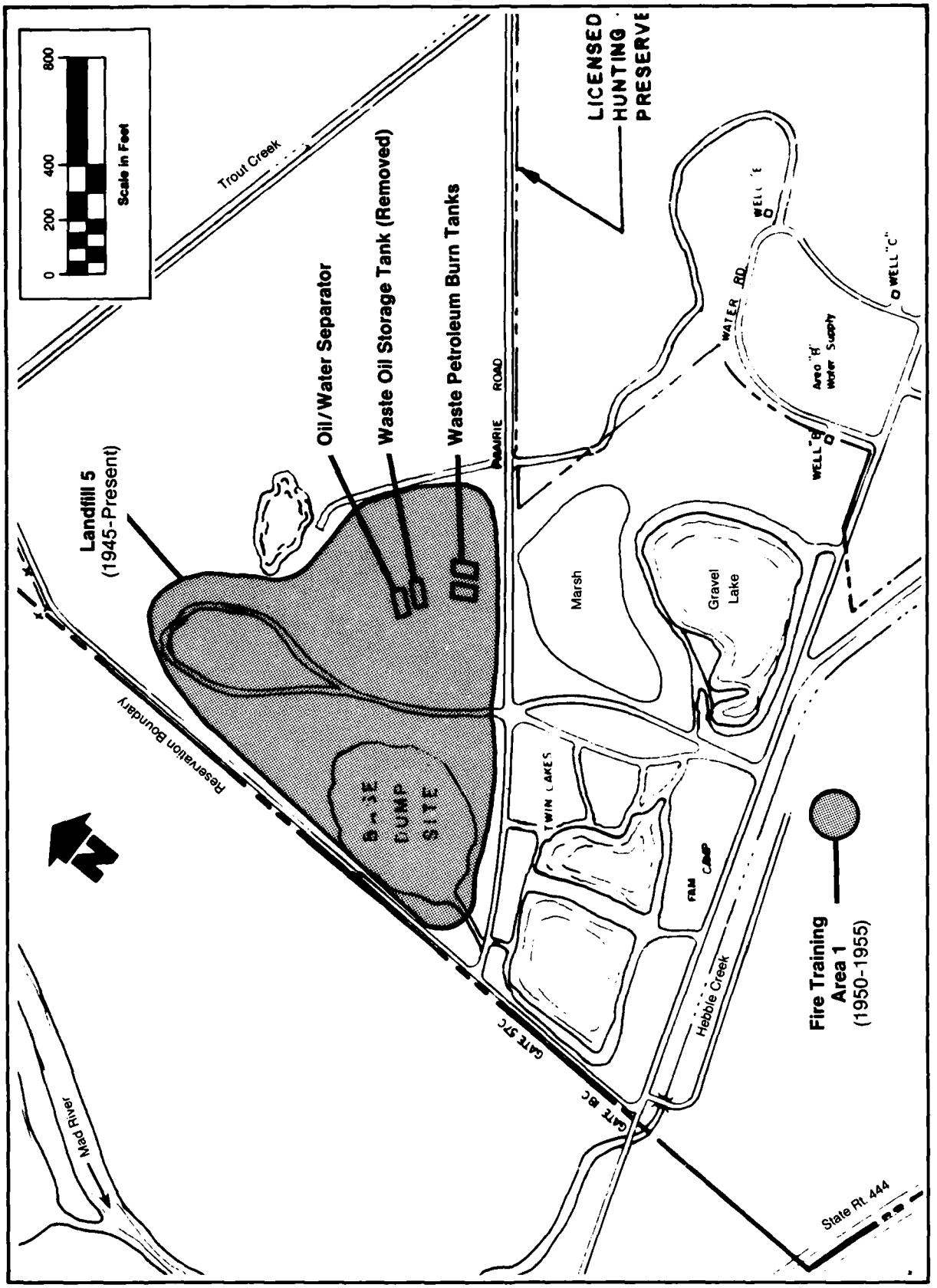


FIGURE 1-8 GENERAL SITE MAP OF ZONE 5

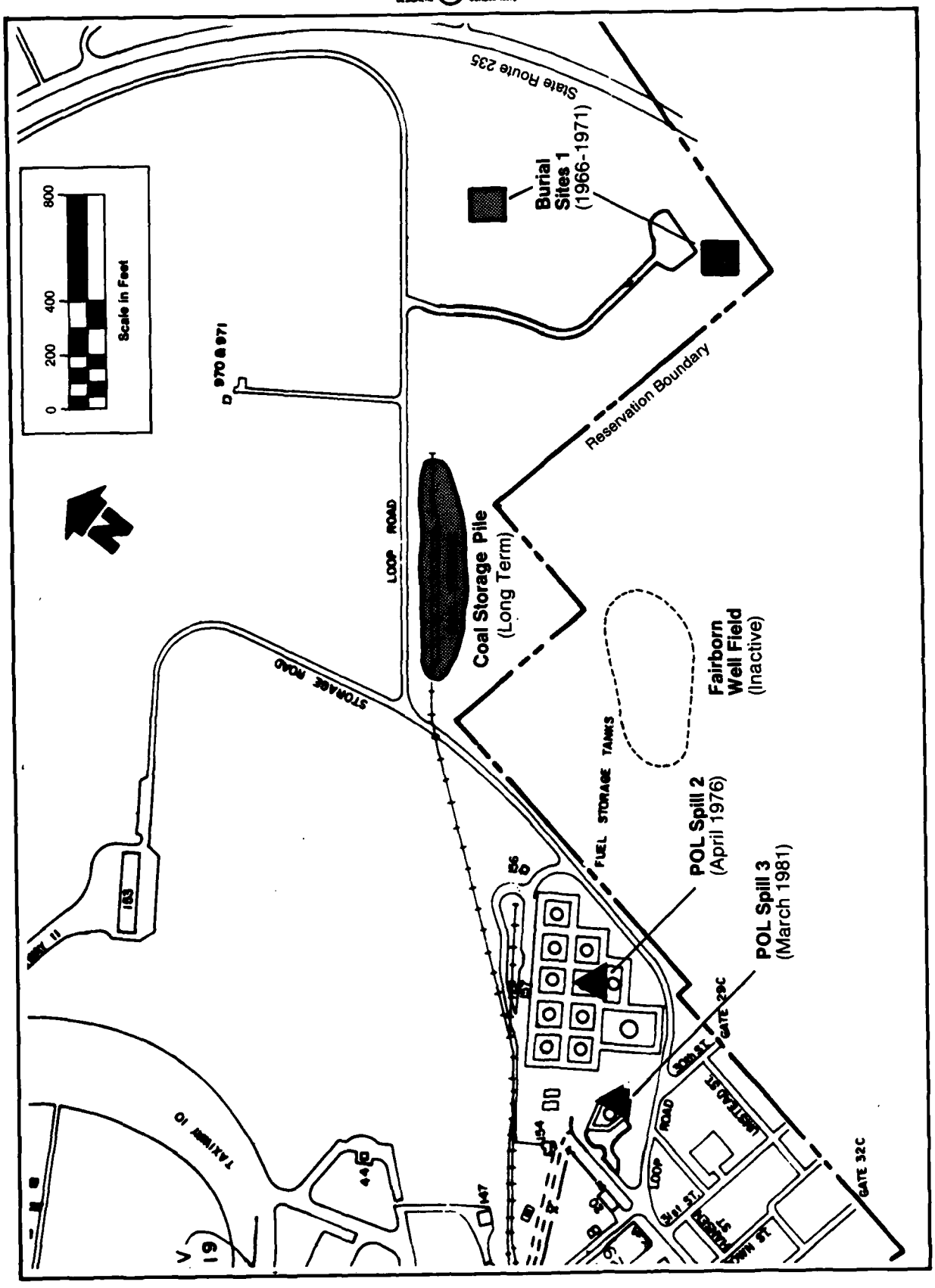


FIGURE 1-7 GENERAL SITE MAP OF ZONE 4

1.3.4 History and Description of Zone 4

The Zone 4 sites are located in the northeast portion of Area C, as shown on Figure 1-3. The area is drained by an intermittent stream and stormwater ditches that flow into Hebble Creek. Zone 4, shown in more detail on Figure 1-7, consists of the Coal Storage Pile, two fuel spills in the POL Fuel Storage Area and Chemical Burial Site 1.

1.3.4.1 Coal Storage Pile

The Coal Storage Pile has been maintained in the same area during the operating life of the Base. Runoff from this pile poses a potential for contamination of both surface and ground water.

1.3.4.2 POL Spills 2 and 3

Spill 2, in April 1976, involved the release of approximately 8,000 gallons of JP-4 Tank 256 in the POL Tank Farm. Approximately 4,000 gallons of spilled fuel were recovered using ground-water wells. Spill 3, in March, 1981, involved the release of 1,200 to 2,500 gallons of No. 2 fuel oil in an area between Tank 252 and the fill stand in the POL tank farm. Although a recovery trench was dug, no oil was recovered from this spill.

1.3.4.3 Chemical Burial Site 1

Two areas, shown in Figure 1-7, compose Burial Site 1. These locations were used to dispose of sludges, containing tetraethyl lead, from bottom residues of leaded gasoline storage tanks. Cleaning of the storage tanks generated approximately 700 gallons of the sludge each year. Burial Sites were in use from 1966 to 1971. The precise locations of these two burial sites cannot be determined either from field evidence or from historical aerial photographs.

1.3.5 History and Description of Zone 5

Zone 5 is located in the Twin Lakes area at the western edge of Area A, as shown on Figure 1-3. The zone contains two sites: Landfill 5 and Fire Training Area 1. A general site map of Zone 5 is shown on Figure 1-8.

1.3.5.1 Landfill 5

Landfill 5 is a 23-acre site located in the Twin Lakes area between Riverview and Prairie Roads (see Figure 1-8). It

operation. At present, the landfill area is covered with soil and supports the lush grass and small trees of a golf course.

1.3.3.2 Landfill 4

Landfill 4 was a 5.5 acre disposal site operated from 1944 to 1949. It was constructed in an abandoned water-filled gravel pit. During initial operations, large objects such as automobile bodies were placed in the pit in order to bring the fill up above the 20 to 30 feet of water in the pit. Once above the water surface, the landfill was operated as a trench and cover operation for general refuse with the trenches oriented in a northwest to southeast direction. At present, Landfill 4 is covered with soil and gravel, is fenced, and serves as a parking and equipment storage area.

1.3.3.3 Landfill 6

Landfill 6, an 8.5 acre site, was operated from 1949 to 1952 and received general refuse from Areas A and B. It was conducted as a trench and cover operation. An intermittent stream crosses Landfill 6 and flows into Hebble Creek. The landfill is presently used as pasture land.

1.3.3.4 Landfill 7

Landfill 7, approximately 18 acres in size, was operated from 1952 to 1962 and received general refuse from Areas A and B. An intermittent stream flows through a portion of the landfill and then into Hebble Creek. Landfill 7 was a trench and cover operation. Long areas of differential settlement are visible across the parking lot of the horse stables which have since been built over top of the old landfill. The hay barns in this stable complex are sagging and shifting due to differential settlement. Most of Landfill 7 is presently used as pasture. During disking and planting operations, refuse is occasionally uncovered, indicating only a thin soil cover above the landfill itself. The west side of the landfill has steep 10 to 20-foot slopes where uncovered general trash such as metal pieces, old rubber hoses and concrete rubble have been pushed over the edges.

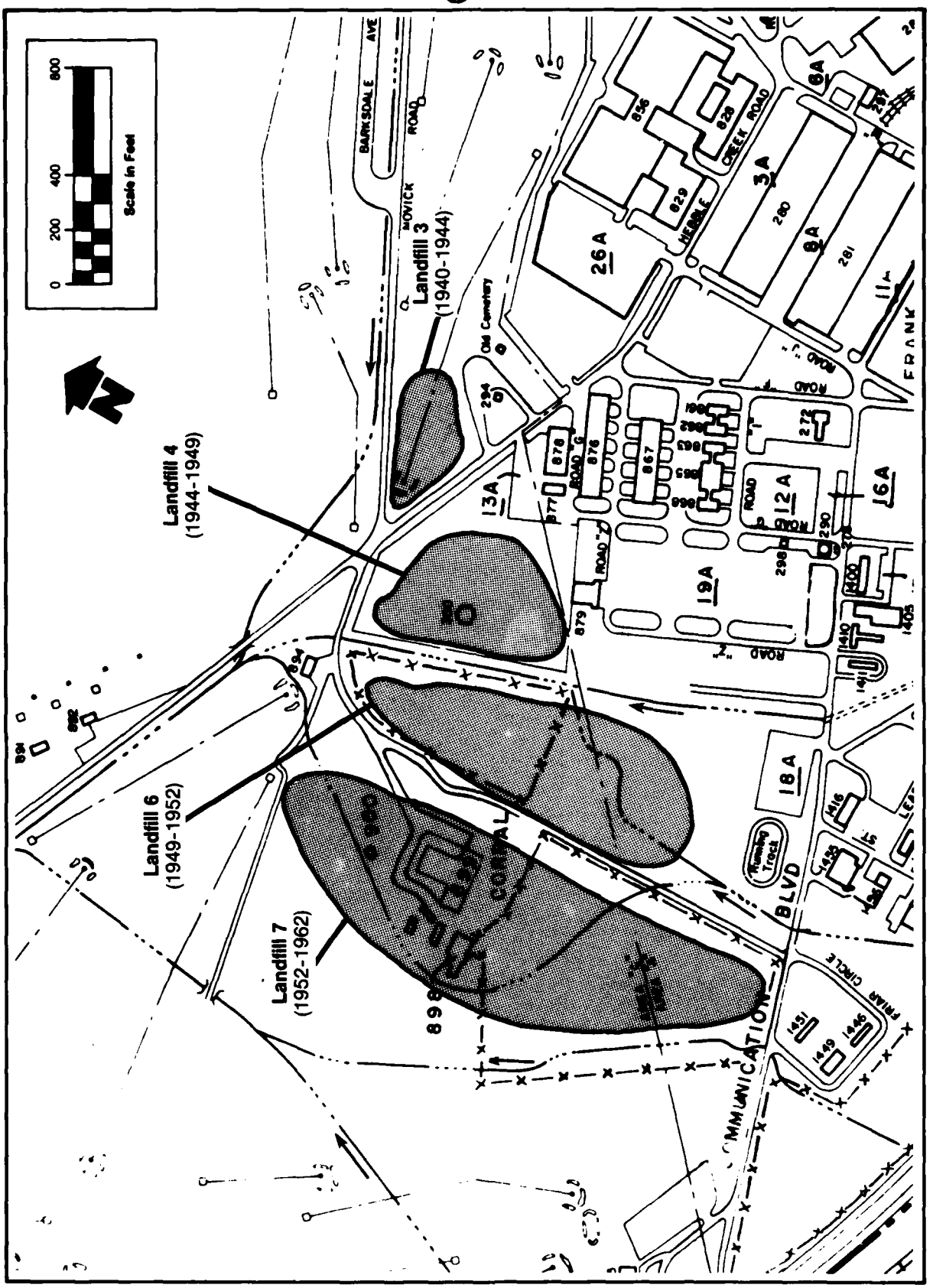


FIGURE 1-6 GENERAL SITE MAP OF ZONE 3

within the fenced area. North of Landfill 12 is a stagnant backed-up slough of the Mad River. The water surface is covered with algae growth and an oily sheen was observed along the edges of the water.

1.3.2.3 Fire Training Areas 3 and 4 and POL Spill No. 1

Fire Training Areas 3 and 4 are located adjacent to each other in a roughly triangular area between Riverview Road and Landfill 11. These areas were in use for a 21-year period from 1960 to 1980. Fire training operations were conducted by first saturating the ground with water to minimize percolation, then applying contaminated fuel and JP-4 onto the areas and igniting. The contaminated fuel was stored in a tank constructed north of Fire Training Areas 3 and 4. Contaminated fuel was applied from the tank directly to the FT areas, and trucks containing JP-4 were brought to the site and this fuel also sprayed directly onto the fire training areas. In 1972, a 1000 to 2000 gallon contaminated fuel spill (Spill No. 1) occurred north of Fire Training Area 3. The fuel was reportedly intercepted before it reached the Mad River but no records of recovered amounts have been documented.

Fire Training Areas 3 and 4 were dirt pits with surrounding earthen dikes during the time of operation. At present, the area they occupied is dirt and gravel covered, with none to very sparse vegetation. A surface water runoff ditch or intermittent stream is located north of the fire training areas. It discharges to the stagnant slough north of Landfill 12 and, apparently, during periods of heavy rain, to the Mad River.

1.3.3 History and Description of Zone 3

As shown on Figure 1-3, Zone 3 is located at the southern edge of Area A. This zone contains four sites, Landfills 3, 4, 6 and 7, shown in more detail on Figure 1-6. Several small streams, tributaries of Hebble Creek, drain Zone 3 and flow both around and through the landfill areas.

1.3.3.1 Landfill 3

Landfill 3, located east of the intersection of Novick and Hebble Creek Roads, accepted general refuse from Areas A and B from 1940 to 1944. The landfill was approximately three acres in size and was conducted as a surface dump and burn

an old channel of the Mad River. Over time the river has moved toward the northwest away from this channel. Sections of Landfill 11 are reportedly up to 50 feet deep.

The site was initially operated as a trench and cover activity and later as a ramp dump and compaction procedure with daily cover. Various chemical wastes were reportedly disposed of in Landfill 11, and Base personnel reported occasions of fires starting during the compaction procedure which were extinguished by the bulldozer operator.

The landfill is built up 40 to 50 feet above the shallow banks of the Mad River, with steep side slopes. Uncovered large refuse including concrete pieces, cut metal storage tanks and several empty drums were visible on and at the base of the side slopes. The top surface of Landfill 11 is covered with soil and sparsely vegetated with grasses. Several swampy areas supporting reed growth, and areas of ponded surface water were also observed. The side slopes are wooded with a mixture of small to medium trees and shrubs.

1.3.2.2 Landfill 12 (Hazardous Storage Area)

Landfill 12 is a 3000 square foot, cyclone-fenced disposal area that was operated from 1968 to 1973, the same time period as Landfill 11. Initially Landfill 12 was used as a chemical disposal site and an acid neutralization area. Trenches approximately two feet wide by three feet deep were used to dispose of hazardous chemicals. Acids were neutralized through the same procedures as at Landfills 8 and 10, and neutralized wastes were then allowed to percolate into the soil. During the late 1970's Landfill 12 was used as a storage place for waste chemicals, including materials contaminated with herbicide orange. These materials were reportedly not opened within the storage area, and were later removed and disposed off-site. In 1973, the Base contracted to have all the stored waste chemicals removed from the fenced area.

Landfill 12 is overgrown and is located in a heavily wooded area southwest of Landfill 11. The cyclone fence is still standing, although the gate is unlocked and rusted open. A visual survey around the perimeter of the fenced area revealed the remains of what was probably the acid neutralization area inside the fence: several large rusted tanks cut in half to form vats. A number of drums was also observed

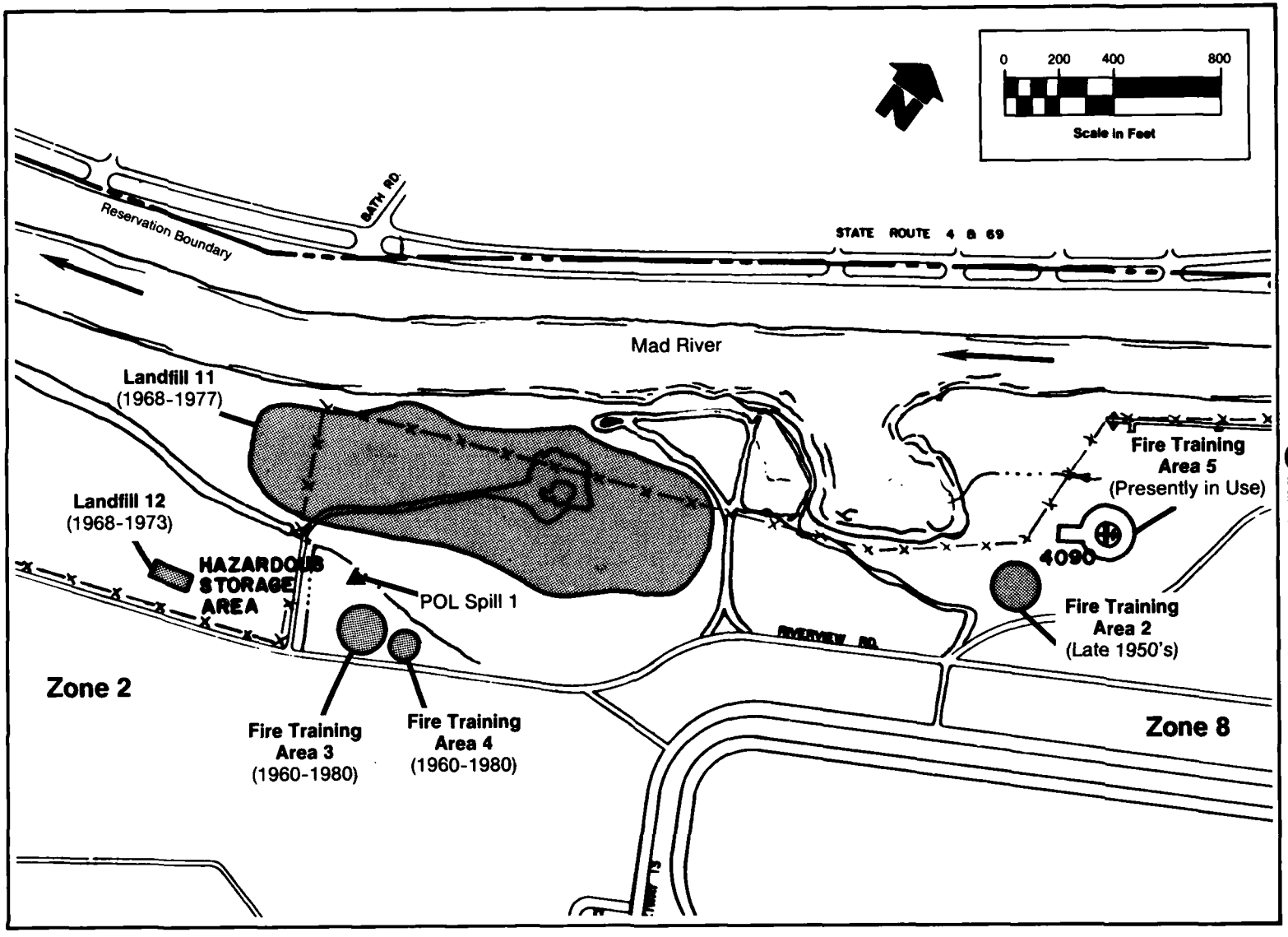


FIGURE 1-5 GENERAL SITE MAP OF ZONES 2 AND 8

on the eastern side were responded to in the late 1970's by extensive regrading of the landfill. On the western portion, leachate had been observed seeping from the hillside behind the homes. The situation was addressed by installing perforated plastic drainage pipes into the hillside and directing the leachate into existing storm water catch basins. The storm sewer system ultimately discharges to Hebble Creek. On the southern portion of Landfill 10, west of the demolished housing unit on Weitzel Way (now a parking area), is a small grove of trees containing an oily and iron-stained leachate seep. During and after periods of heavy rainfall, the seep actively produces leachate which overflows in an iron-stained stream across the grass and into a nearby storm water drain.

On the northern portion of the landfill in the approximate vicinity of the old chemical disposal trench, a leachate seep was discovered flowing from the side slope of the landfill into the back yard of a residence on Buell Court. This seep was iron-stained and extremely odorous. After complaints from residents of the military housing, the Base installed french drains in both of these seeps in June 1984 to carry the leachate into the storm sewer system. At the northern toe of Landfill 10, the storm water sewer empties into an open drainage ditch that flows west along Kauffman Avenue into a tributary of Hebble Creek. Iron-stained leachate can be seen flowing out of the concrete storm sewer into the drainage ditch. Several smaller seeps were observed along the upper side slopes on the western side of Landfill 10. The northern portion of Landfill 10 is sparsely vegetated with grass and consists primarily of exposed soil and numerous areas of ponded surface water. A faint odor of hydrogen sulfide was detected on this portion of the landfill but no visible gas seeps like those on Landfill 8 were observed.

1.3.2 History and Description of Zone 2

Zone 2, containing Landfills 11 and 12, Fire Training Areas 3 and 4 and POL Spill 1, is located along the northwest boundary of Area C adjacent to the Mad River (see Figure 1-3). A map of this Zone is shown on Figure 1-5.

1.3.2.1 Landfill 11

Landfill 11 is a 16 acre site that was used for general refuse disposal from 1968 to 1977. The landfill is located in

to the nearest stream. No visible surface evidence of the acid neutralization area was found during site visits. During a reconnaissance along the stream at the eastern base of Landfill 8, a number of iron-stained and oily leachate seeps were observed flowing out of the the landfill and the stream bank into the stream. Iron-stained leachate was also observed breaking out of the hillside through a concrete retaining wall on Longstreet Lane, to the northeast of Landfill 8.

Immediately north of the tennis court area of Hadden Park, several gas vents have opened in the ground surface and are releasing an odorous mixture of methane, hydrogen sulfide and trace amounts of organic compounds. Surface soil around each of the vents has been discolored to black. The area surrounding the seeps has been fenced and posted as Off Limits by the Base.

1.3.1.2 Landfill 10

Landfill 10 is an oblong shaped 10 acre site which received wastes from all areas of the Base during the period 1965 to 1968. Like Landfill 8, the same three distinct disposal operations were conducted. General refuse disposal in the northern portion of the site was conducted using a north to south oriented trench and cover operation. In the southern part of the site, refuse trenches ran in an east to west direction. Areas of differential settlement are visible in the southern portion of the landfill near Weitzel Way and the grassed playground area. One of the residential units on Weitzel Way was demolished and removed, because of settlement and the area paved.

Toxic and hazardous chemicals at Landfill 10 reportedly were disposed of in a single trench on the eastern side of the landfill. During the subsequent construction of residential homes at Woodland Hills, this trench was uncovered by the contractor. Base personnel removed the unearthed chemicals and they were transported to Landfill 12 in the early 1970's for ultimate burial. An acid neutralization facility was also located in the center of Landfill 10. Acids were dumped into a vat, neutralized with lime, and then discharged to the ground surface to follow natural drainage pathways.

Complaints have been received in the past from a number of military housing units built on the eastern and western borders of Landfill 10. Initial complaints from the occupants

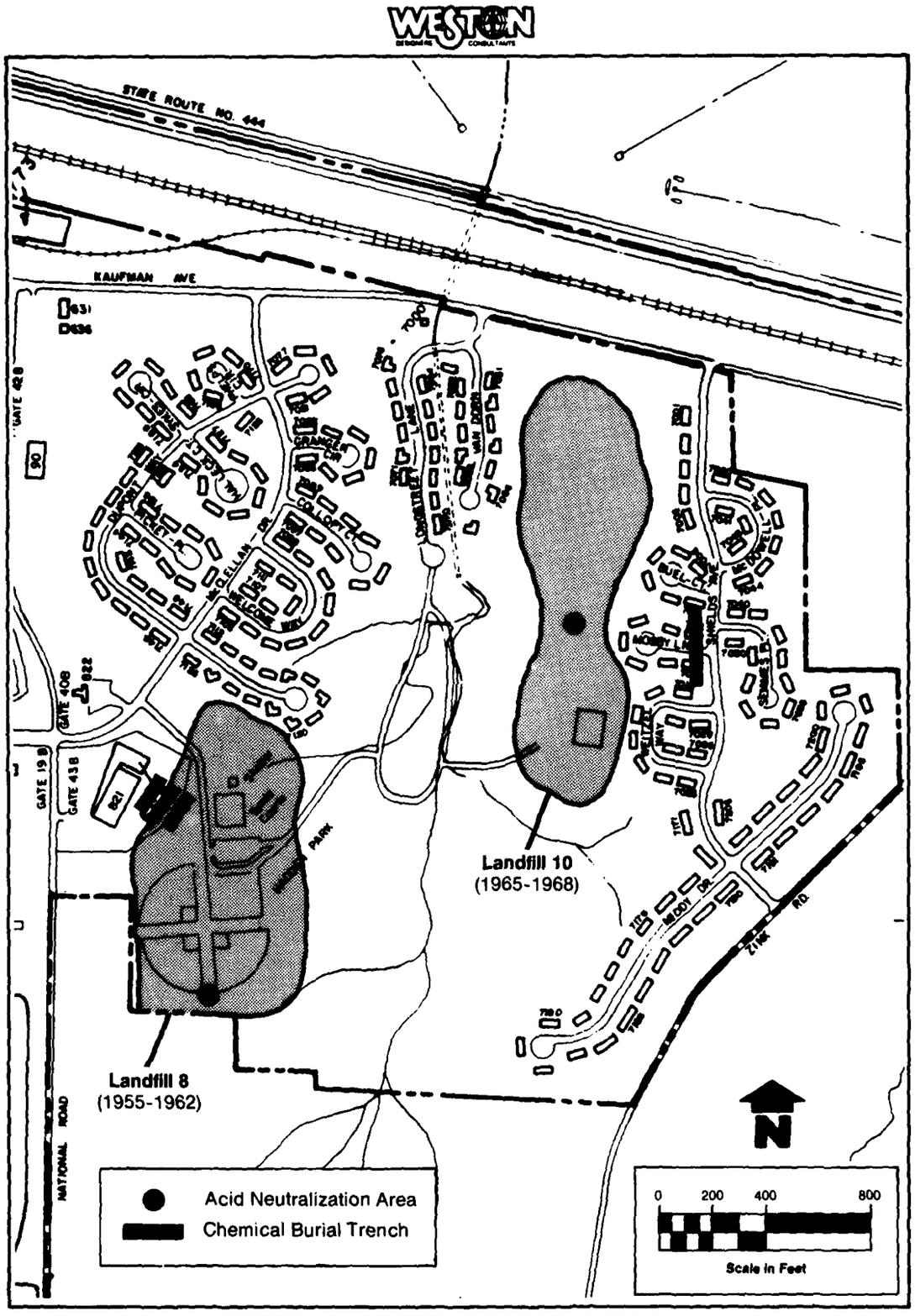


FIGURE 1-4 GENERAL SITE MAP OF ZONE 1

- Zone 7 (Landfill 9)
- Zone 8 (Fire Training Area 2).

The following text provides a brief history and description of each site.

1.3.1 History and Description of Zone 1

As shown on Figure 1-3, Landfills 8 and 10, which comprise Zone 1, lie to the northeast of Wright Airfield in Area B of the installation. Figure 1-4 is a map of Zone 1 showing the locations and approximate boundaries of Landfills 8 and 10. The two landfill areas are separated and drained by an unnamed stream that flows north into Hebble Creek and, in turn, to the Mad River. Military housing units have been built on the northern border of Landfill 8 and on the eastern and western borders of Landfill 10.

1.3.1.1 Landfill 8

Landfill 8 is a roughly rectangular 13-acre site which received wastes from Area B from 1955 to 1962. The depth of the landfill is reportedly 50 to 60 feet. Landfill 8 contained three distinct operations:

- General refuse disposal
- Hazardous chemical disposal
- Acid neutralization.

General refuse was disposed in a trench and cover operation with trench orientation north to south. Areas of differential settlement due to trenching operations are visible in the area of the tennis and basketball courts and parking lot in Hadden Park. Hazardous chemicals were reportedly disposed of in separate trenches southeast of Building 821. The typical operating procedure was to throw individual glass bottles containing chemicals into the trenches to try to break them. No surface evidence of the chemical trenches is visible at the site. An acid neutralization area was operated on the southern portion of the landfill. Acids were poured into small tanks and lime added to neutralize the liquid. The pH was monitored and, when neutralized, the liquid was discharged to the ground and allowed to run off

direct contact with the ground water. From 1955 to 1975, the landfill was used as a hardfill disposal area.

1.3.7 History and Description of Zone 7

As shown in Figure 1-3, Zone 7, containing Landfill 9 (Sandhill), is located across State Route 235 from the Base-proper, in the far northeast corner of the reservation. A general site map of Zone 7 is presented on Figure 1-10.

1.3.7.1 Landfill 9

Landfill 9, also called Sandhill, was operated for a two-year period from 1962 to 1964. It was constructed in a sand pit and covered an area of approximately nine acres. Landfill 9 was the first to receive wastes, including hazardous chemicals, from Areas A, B and C combined. It was conducted as a trench and cover operation with the trenches running in a north-south orientation. Depths of the trenches was approximately 20 feet. Landfill 9 was abandoned for the following reasons:

1. Proximity to the approach path of the major runway at Area C
2. Concerns about bird hazards
3. Complaints from neighbors about blowing trash
4. Its remote location from the refuse generating centers on the Base complex.

1.3.8 History and Description of Zone 8

Zone 8, as shown on Figure 1-3, is located along the northwest border of Area C, just north of Zone 2. Zone 8 contains one Phase II site, Fire Training Area 2, and also the currently operated Fire Training Area 5. A detailed map of Zone 8 can be found together with Zone 2 on Figure 1-5. The area is bordered on the northwest by the Mad River. An abandoned channel of the Mad River forms a pooled area which separates Zone 8 from Zone 2.

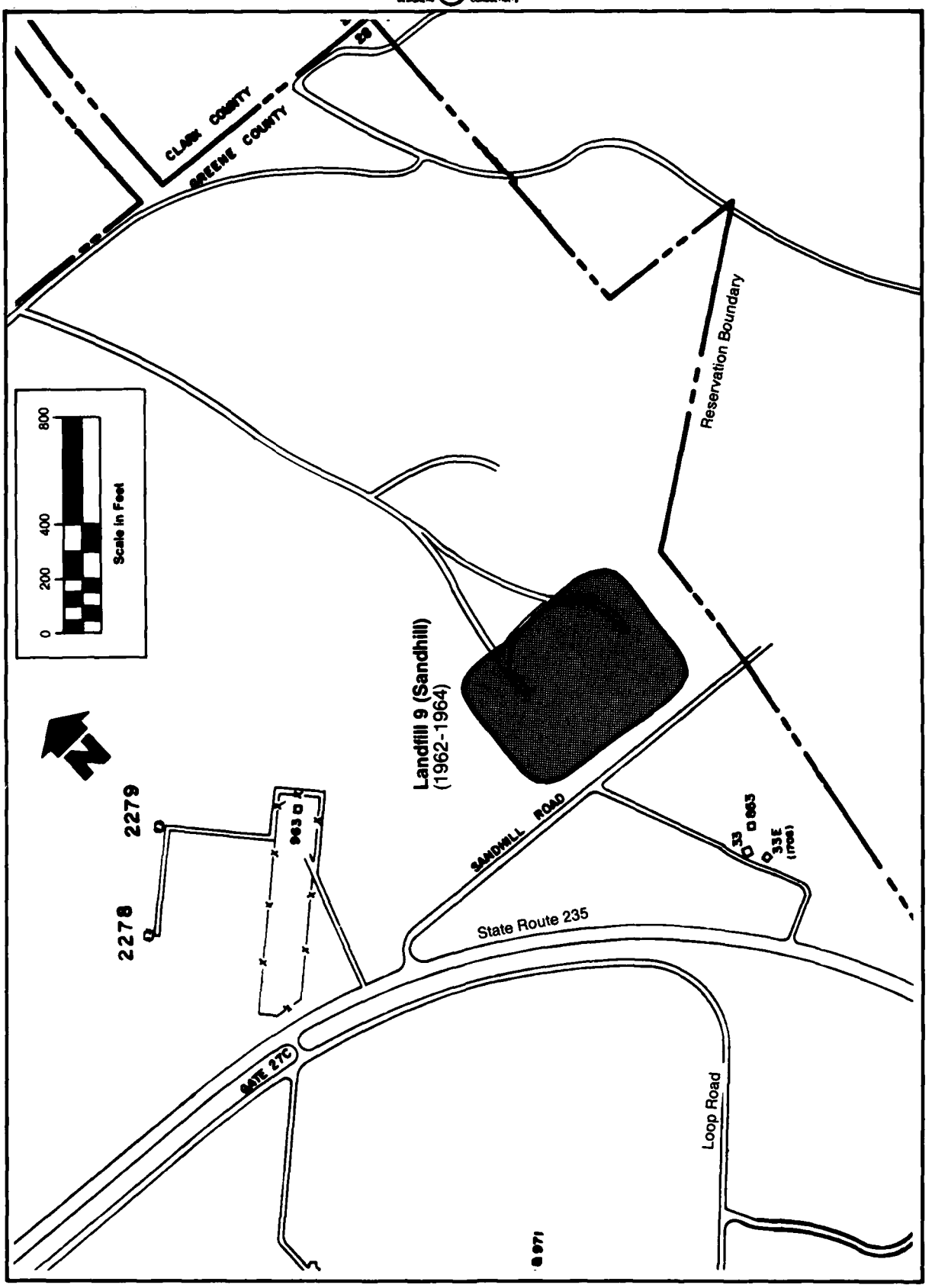


FIGURE 1-10 GENERAL SITE MAP OF ZONE 7

1.3.8.1 Fire Training Area 2

Fire Training Area 2 was used for a five-year period from 1955 to 1960. At this location, contaminated fuels were burned in a dirt pit with a surrounding earthen dike. The ground was saturated with water to reduce percolation before pouring in the soil. At present there are not visible traces of an earthen dike or pit in the vicinity of the Phase I Report location of Fire Training Area 2. Fire Training Area 5 is not a Phase II site. This area was placed in service in 1981 and has a concrete lining which contains all of the petroleum products used during fire training exercises.

1.4 CONTAMINATION PROFILE

Historically, most of the wastes containing hazardous substances have been generated by industrial aircraft maintenance or overhaul missions. Waste oils and solvents from cleaning and painting operations are the primary wastes of concern. Fuel sludges from storage tanks or tank cleaning operations also were generated in the past and pose a concern. Much of the combustible wastes have either been burned in fire training exercises or disposed of through DPDO.

Prior to 1973, however, quantities of industrial chemicals were reportedly disposed of in installation Landfills 5, 8, 10, 11 and 12. In addition, acid-neutralized chemicals were allowed in the past to enter the soils during acid neutralization operations at Landfills 8, 10, and 12, and oil separation and burning operations at Landfill 5. Several major fuel spills also occurred near the POL Tank Farm and adjacent to Fire Training Areas.

Based on the WPAFB Phase I Records Search, the key parameters of potential concern are volatile organic compounds, oils and greases, and select metals. To develop an initial determination of whether or not past operational and disposal practices have adversely impacted the environment, groundwater samples collected from the 27 monitor wells installed in the eight Zones, and leachate samples collected from two of the landfills were analyzed for the parameters listed in Table 1-2. The details of the field work accomplished at WPAFB are described in Section 3 of this report.

Table 1-2 Analytical Protocol

Site	Potential Contaminant	Medium	Analytes
Landfills 8 and 10 (Zone 1) Landfills 11 and 12 (Zone 2) Landfills 3,4,6,7 (Zone 3) Chemical Burial Site (Zone 4) and Coal Pile Landfill 5 (Zone 5) Landfill 2 (Zone 6) Landfill 9 (Zone 7)	Industrial Chemicals, Trace Metals, Sulfates and Chloride	Groundwater and Leachate	Nitrate Chloride Boron Iron *Manganese *Sodium Total Organic Carbon (TOC) Total Organic Halogen (TOX) Phenol *(Groundwater only)
Fire Training Areas 3 and 4 and POL Spill Area (Zone 2) Fire Training Area 1 (Zone 5) POL Spills 3 and 4 (Zone 4)	Waste petroleum products and spent solvents	Groundwater	Oil and Grease Volatile Organic compounds

1.5 PROJECT TEAM

The Phase II Confirmation Study at WPAFB was conducted by staff personnel of Roy F. Weston, Inc. and was managed through WESTON's home office in West Chester, Pennsylvania. The following personnel served lead functions in this project:

PETER J. MARKS, PROGRAM MANAGER: Corporate Vice President and Manager of Laboratory Services, Master of Science (M.S.) in Environmental Science, 18 years of experience in laboratory analysis and applied environmental sciences.

FREDERICK BOPP, III, PH.D., P.G. PROJECT MANAGER: Doctor of Philosophy (Ph.D.) in Geology and Geochemistry, Registered Professional Geologist (P.G.), over 8 years of experience in hydrogeology and applied geological sciences.

MARIAN R. DZEDZY, PROJECT SCIENTIST: Bachelor of Science (B.S.) in Agronomy, four years of experience in soil science and hydrogeology.

WALTER M. LEIS, P.G., GEOTECHNICAL QUALITY ASSURANCE OFFICER: Corporate Vice President and Manager of the Geosciences Department, M.S. in Geological Sciences, Registered Professional Geologist, over 10 years of experience in hydrogeology and applied geological services.

JAMES S. SMITH, PH.D., LABORATORY QUALITY ASSURANCE OFFICER: Ph.D. in Chemistry, over 16 years of experience in laboratory analysis.

THEODORE F. THEM, PH.D., PROJECT CHEMIST: Ph.D. in Analytical Chemistry, over 10 years of experience in laboratory analysis.

Professional profiles of these key personnel, as well as other project personnel are contained in Appendix C.

1.6 FACTORS OF CONCERN

Several factors of concern should be highlighted at the outset of this Confirmation Study Report for consideration by the reader in the review of the following sections.

Wright-Patterson AFB overlies highly permeable valley fill deposits of glacial outwash and till. Ground water occurs in this unit under both water table (unconfined) and artesian (confined) conditions. Ground-water flow direction in the vicinity of WPAFB is toward the southwest in the same direction as the flow of the Mad River. Water supplies for both Wright-Patterson AFB and for the City of Dayton are obtained from wells completed in the outwash aquifer. In addition, all but one of the Phase II sites included in this investigation are located very close to surface streams which drain into the Mad River. The City of Dayton's wellfield is located at Rohrer's Island Recharge Area in the Mad River, downstream of WPAFB Areas A and C. At Rohrer's Island, the outwash deposits form the region's most productive aquifer, with ground-water yields to wells on the order of 1,000 gallons per minute.

Contaminants from Wright-Patterson AFB have the potential to migrate toward the Rohrer's Island Recharge Area by both ground water and surface water routes.

SECTION 2

ENVIRONMENTAL SETTING

2.1 TOPOGRAPHY AND SURFACE DRAINAGE

WPAFB lies on the southeastern portion of the Mad River Valley, approximately 3 miles north of the confluence of the Mad River and the Great Miami River. The terrain is generally level, within the river valley itself where the airfields are located, to gently rolling in the higher areas to the southeast where much of the Base housing and support facilities are located. Total relief for the facility is as much as 200 feet with the lowest elevation being approximately 780 feet above mean sea level (MSL) at the southern end of Area B, and the highest elevation (975 feet above MSL) being located in Area B near the intersection of Airway Road and National Road.

Besides the northeast-southwest trending Mad River Valley, the other principle topographic feature is a high salient running southeast to northwest. This feature, caused by the protrusion of underlying bedrock, produces a bottleneck in the river valley which separates the old Wright Field from the active runway area. The Huffman Dam, an earthen structure, spans the valley at this narrow point.

Surface drainage from the Base runs ultimately to the Mad River by way of Hebble and Trout Creeks and a number of small unnamed tributaries. Surface drainage patterns are summarized on Figure 2-1 (from the Phase I Report).

2.2 GEOLOGY

The bedrock of the Wright-Patterson AFB consists of gently dipping sedimentary rock of Ordovician and Silurian age that forms part of the Cincinnati Arch. The Richmond group, consisting of shales with thin limestone interbeds, is of Ordovican age, and directly underlies the unconsolidated sedimentary deposits of the Mad River valley. In areas of higher topography, the Richmond group is overlain by the Brassfield Limestone, which is a relatively pure grey to brown fossiliferous limestone which occasionally crops out on the hillsides and is exposed in roadcuts. The Brassfield is

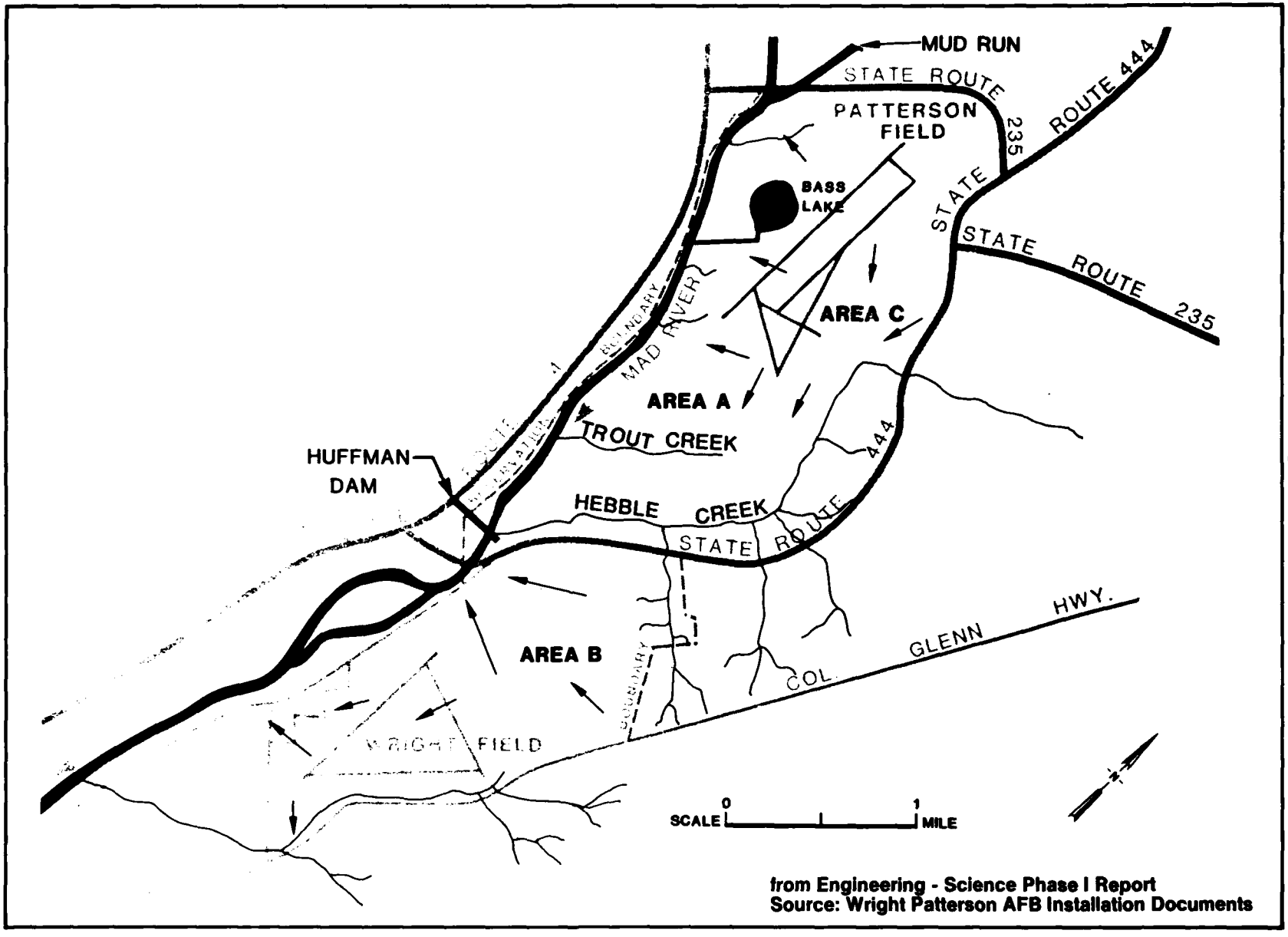


FIGURE 2-1 SURFACE DRAINAGE AT WRIGHT PATTERSON AFB

reportedly 30 feet or less in thickness in this area. (Norris and Spieker 1966).

During the glacial periods the bedrock terrain was dissected by glaciers and glacial streams that produced a deeply eroded stream valley in the same general path now occupied by the Mad River Valley. Erosion took place in two stages: the first stage, called the Teay's Stage, eroded the valley down to elevation 550 feet (MSL); the second stage, called the Deep Stage, eroded the center of the valley down below 500 feet (MSL). This deeply cut valley was subsequently backfilled with almost 300 feet of sediments of glacial origin which now underly the Mad River Valley and most of the installation.

Unconsolidated, glacially related outwash and tills are the predominant sediments directly underlying the installation. Over 250 feet of sand and gravel outwash fills the ancient valley which underlies the airfields. Interbedded in the porous sand and gravel outwash are thick lenses of relatively impermeable clay till. This till occupies two principle horizons in the valley sediment column: the major till zone is about 60 feet below the valley floor and is up to 40 feet thick. While not continuous in all areas, this till does appear from existing boring logs to be continuous in the area around WPAFB, and divides the outwash sediments into upper and lower hydraulic zones. A thinner, less continuous till occurs in the valley sediments at depths of 10 to 30 feet.

The southeastern side of the Mad River Valley, including the airfield areas, is directly underlain by a thin veneer of recent fluvial outwash that consists of variable mixtures of sands, silts and clays deposited by drainage from the adjacent high areas. Sand and gravel kame deposits and a thin veneer of moraine sediments cover the higher elevations of the installation. The surficial geology of WPAFB is summarized in Figure 2-2 (from the Phase I Report). Figure 2-3 is a stratigraphic cross-section along the approximate axis of the Mad River Valley southwest of Areas A and B, illustrating the relationships among the shale bedrock, the glacial outwash (drift), and till deposits.

2.3 GROUND-WATER OCCURRENCE

The Richmond group of shales and interbedded limestones are not significant as existing or potential sources of

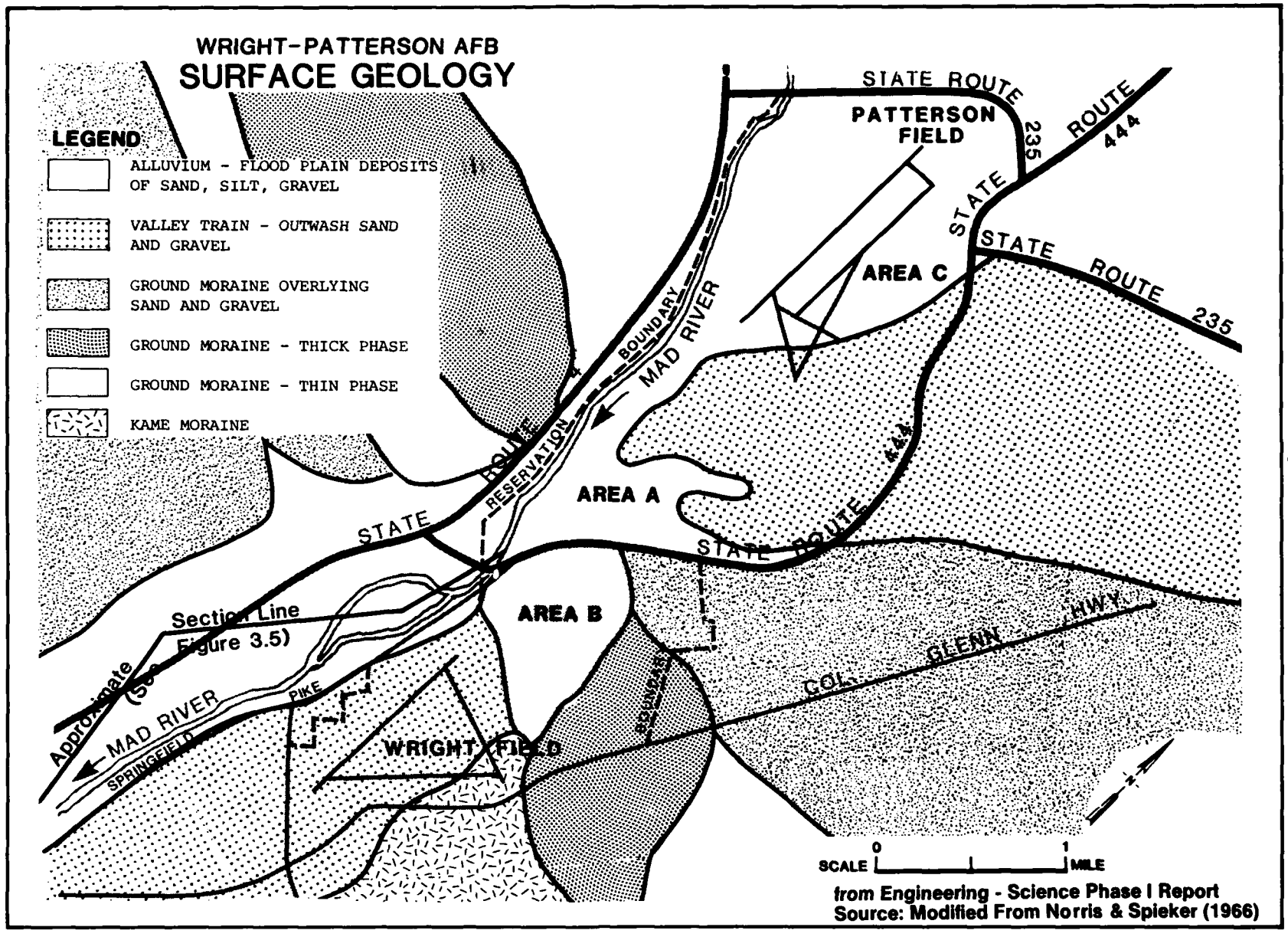
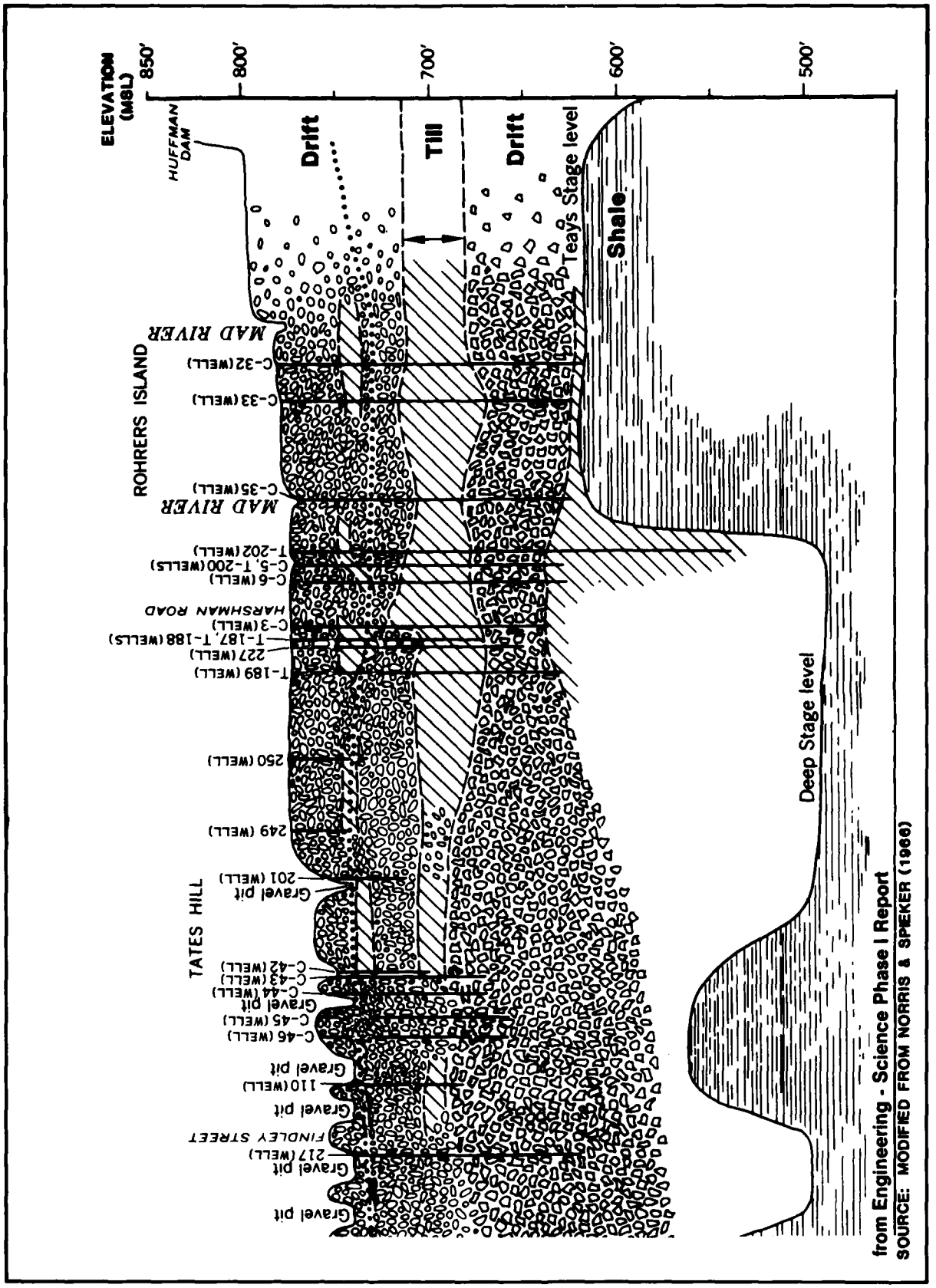


FIGURE 2-2 SURFICIAL GEOLOGY AT WRIGHT PATTERSON AFB



from Engineering - Science Phase I Report
SOURCE: MODIFIED FROM NORRIS & SPEKER (1966)

FIGURE 2-3 GEOLOGIC CROSS SECTION OF THE MAD RIVER VALLEY

ground water in the area. These relatively impermeable rocks yield water volumes barely sufficient for domestic use (Norris and Spieker, 1966). The Brassfield limestone, found in higher topography, yields moderate amounts of water for domestic and farm use. The major aquifers in the Dayton area, however, are the valley sediments. These sediments are the major source of water for the City of Dayton, area industry, and Wright-Patterson AFB.

The principle water-bearing zones in the valley aquifer are in the highly transmissive outwash sediments that are up to 200 feet thick and saturated from a few feet below the ground surface. The till occurring at about 60 feet (see section 2.2) divides the aquifer into a lower and upper system with the lower system being locally semi-confined. The upper aquifer appears unconfined throughout the installation although some near-surface occurrences of till in the area produce locally confining conditions and inhibit recharge to the aquifer along Mad River.

Transmissivities of the valley aquifer are reported to be as high as 400,000 gallons per day per foot, which is a very high value for an aquifer of this relatively small thickness (Norris and Spieker, 1966). Recharge to the water table is by direct percolation through soils, and by recharge from surface streams, including the Mad River and its tributaries, Hebble Creek and Trout Creek, which run through the installation. The installation in general is a recharge area. Artificial ponds on Neville Island have been maintained specifically to enhance recharge around the Rohrer's Island wellfield which serves the City of Dayton.

Ground-water flow in the valley is generally to the southwest in the same direction as surface water flow. Locally, ground water flow is affected by depressions caused by pumping, such as at the Rohrer's Island wellfield of the City of Dayton, and by mounding of the ground-water table produced by areas of recharge.

2.4 GROUND-WATER DEVELOPMENT AT WPAFB

Wright-Patterson Air Force Base obtains its fresh water resources from actively pumping ground-water production wells in Areas A and C of the Base. There are eight active production wells at the Base, with the available capacity to pump up to 9.1 mgd (based upon records from the Phase I Report). The locations of the active Base pumping wells are

shown on Figure 2-4. Also shown on that figure is the location of the Rohrer's Island wellfield operated by the City of Dayton. All installation water supply wells are completed in the highly permeable glacial outwash deposits, described above, and average approximately 55 feet in depth. Static water levels in the Base wells range between five and 22 feet below ground surface. The extremely high transmissivity of the glacial outwash deposits is documented by the results of a production pump test on Well No. 7, conducted in 1954. The well was pumped at up to 1,200 gallons per minute with only 13 feet of drawdown (Engineering-Science, 1982, Phase I Report).

SECTION 3

FIELD PROGRAM

3.1 PROGRAM DEVELOPMENT

Task Order 22 (Appendix B) was issued on the basis of the Phase II Pre-Survey Report. All sites recommended for Phase II investigation in the Phase I report were addressed in the Phase II program, with modifications incorporated from the Phase II Pre-Survey Report.

The following text discusses the approved field investigation for all eight zones considered in this Phase II, Stage I Study Report.

3.1.1 Zone 1

By design of the Phase II work Plan developed by WESTON, Zone 1 included two sites:

- Landfill 8
- Landfill 10.

The WESTON Phase II Pre-Survey Report recommended that the investigation in Zone 1 include aerial photograph analyses, geophysical surveys, ground-water monitor well and methane well installation, and sampling of ground water, leachate and surface water. Since Landfills 8 and 10 are close to each other and are drained by the same surface water system, the monitoring of ground-water flow and contaminant migration was approached on a general area scale. The final approved Scope of Work included the following tasks:

- Evaluate historic aerial photographs to determine the areal extent of the landfills.
- Conduct brief geophysical surveys involving magnetometer and Ground Penetrating Radar on Landfills 8 and 10 to determine actual locations of chemical burial trenches and acid neutralization areas.
- Sample three leachate seeps from each landfill for the parameters shown on Table 1-2.

3.2.3.1 Zone 1: Landfills 8 and 10

A total of five monitor wells, screened in the upper part of the ground-water table, were installed in Zone 1. Locations of the wells, numbered MW-1 through MW-5, are shown on Figure 3-2. MW-1 is located upgradient of Landfill 8. MW-2 and MW-3 are located downgradient of Landfill 8, between the landfill and the small unnamed creek that drains the area. MW-4 and MW-5 are placed downgradient of Landfill 10. The monitor wells range in depth from 44 to 65 feet below ground surface, and the ground water surface was encountered at depths of from 26 to 33 feet. Wells 1 through 4 were screened in fine to coarse silty and clayey sands. Twenty to thirty-foot lengths of screen were used in these wells to ensure an adequate flow of water.

Well MW-5 was screened in medium to coarse sand and gravel, a material which yielded a high ground-water flow. A ten-foot screen was used in this well. Special care was taken while grouting the annular space above the well screen to ensure that vertical infiltration of water and leachate from the landfills would not occur around the well casing. A complete discussion of subsurface conditions is presented in Section 4.1. Table 3-3 summarizes the well construction details. Figures 3-3, 3-4 and 3-5 illustrate well construction details for all the monitor wells. Zone 1 monitor wells are found on Figure 3-3.

Four methane gas monitor wells, screened in the unsaturated zone, were installed in Zone 1. The methane wells were drilled into Landfills 8 and 10 in order to collect any gases emanating from these landfills. Locations of the wells, numbered GW-1 through GW-4, are shown on Figure 3-2. A summary of well completion details is shown on Figure 3-6. GW-1 and GW-2 monitor Landfill 8 and are located at Hadden Park. GW-1 is in the playground area on the north end of the park, and GW-2 is in the ball field area to the south of the basketball courts. GW-3 and GW-4 monitor Landfill 10 and are located at Woodland Hills. GW-3 is in the playground west of Weizel Way, and GW-4 is west of Buel Court.

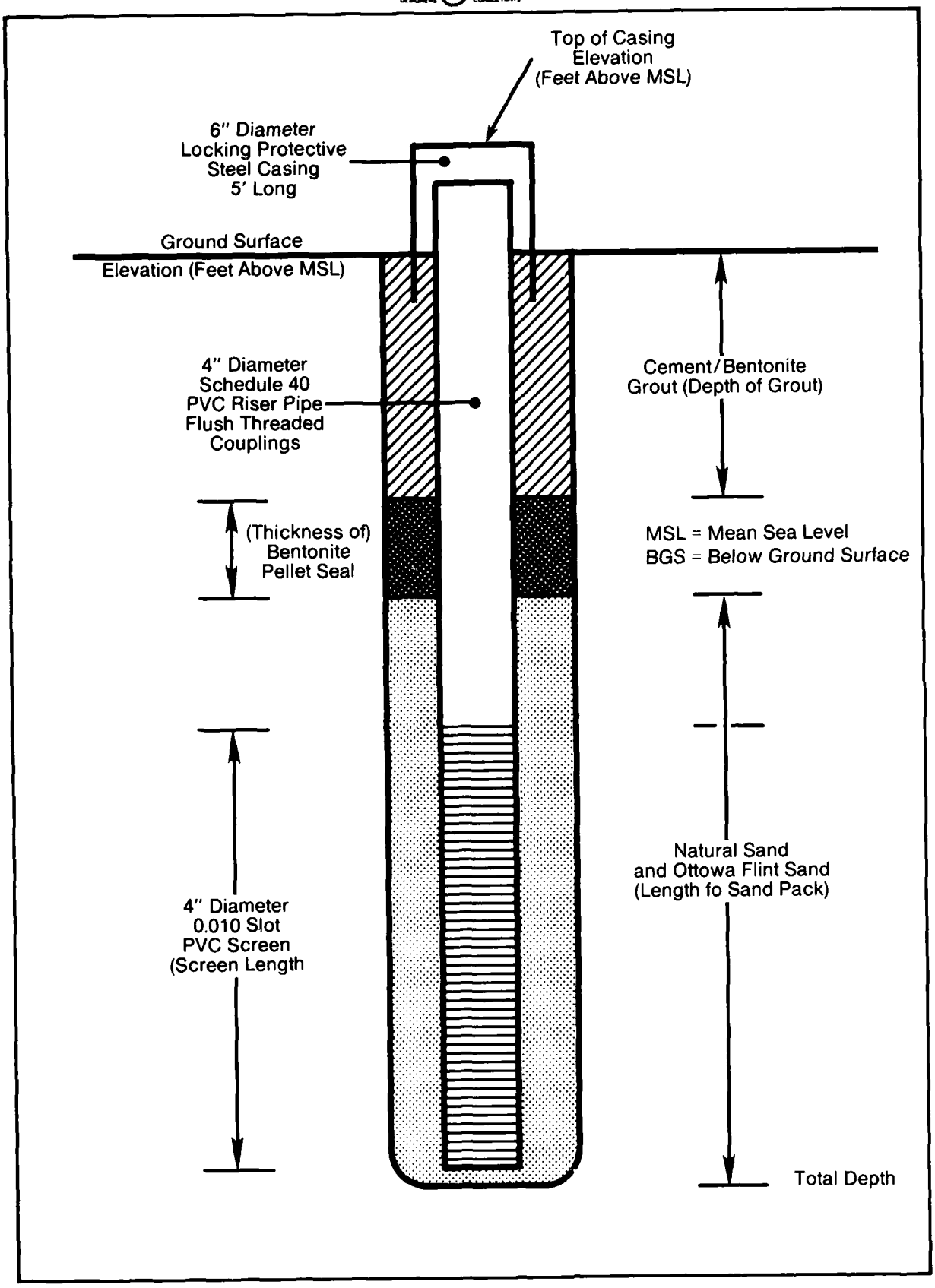


FIGURE 3-1 TYPICAL WELL CONSTRUCTION DIAGRAM

ing a tremie pipe in the annular space and pumping a bentonite-cement grout to the top of the Bentonite Pellet Seal as the augers or casings were withdrawn. Care was taken to prevent collapse of the annular space and to produce a continuous grout seal to the ground surface. Each well was completed with the installation of a six-inch diameter steel protective casing equipped with a locking cap, cemented in place over the top of the PVC riser pipe. A typical well construction diagram is presented in Figure 3-1. Well completion details for all monitor wells are summarized in Appendix D. Each well was developed using a submersible pump to remove fine soil particles until the water pumped clear. Development times per well ranged from 15 minutes to two hours. It was observed that wells drilled using the cable tool method produced clearer water more rapidly, and therefore required less development time than auger-drilled wells. This is probably due to bailing of the cuttings and water slurry during the cable tool drilling operation. A smooth-sided borehole resulted and most of the fines were removed before setting the well. The auger method drilled with a churning action causing more disturbance of the unconsolidated sediments resulting in muddy water in the well.

The four methane monitor wells were drilled to the top of the water table using the auger method. A four-inch PVC screen was placed from several feet below ground surface to the top of the water table, in order to collect gases from the entire unsaturated zone. The screen was packed with coarse sand to allow rapid entry of gases into the well. Sealing against surface infiltration was accomplished by a bentonite pellet layer above the sand pack and cement grout to the ground surface. A six-inch steel protective casing, with locking cap, was set over each PVC riser pipe.

At the request of Base personnel, painted metal guard posts, filled with cement and cemented into the ground, were installed adjacent to selected monitor wells in order to protect them from maintenance machinery.

The slurry was removed at intervals from the borehole using a four-inch diameter bailer with a check valve at the bottom. The steel casing was then driven several more feet and the process continued. Additional lengths of steel casing were welded on as needed to increase the depth of the borehole. When first water was encountered, evidenced by the increase of water inside the steel casing, it was no longer necessary to add water to form the slurry. At this point, a split spoon sample of the saturated material was collected to describe the composition of the water-bearing zone. After examination of the sample, the borehole and steel casing were advanced to the required depth below the water table and the monitor well was constructed at this depth.

3.2.3 Monitor Well Installation and Construction

The monitor wells were constructed of four-inch diameter wound PVC screen (0.010-inch slot openings) and flush-joint threaded PVC pipe. No glued joints or fittings were used. Screen length for each well was determined by the type of material in the water-bearing zone. The objective was a well which would produce a good flow of from five to 15 gallons per minute, more than adequate for development, purging and sampling procedures.

A minimum length ten-foot screen was used in a coarse sand or gravel. If the material was finer sand or contained a high proportion of fine silt or clay particles, a longer screen was used to ensure an adequate flow of water. Once the boring was drilled to the required depth, appropriate lengths of screen and pipe were threaded together and lowered through the hollow stem auger or the cable tool steel casing to the bottom of the hole. The augers or steel casing were withdrawn to several feel above the screen to allow the sand and gravel formation to collapse against the screen, forming a natural sand pack. Additional sand was added to the annulus to bring the sand pack up to at least five feet above the top of the screen.

The augers or steel casing were again raised and bentonite pellets poured slowly into the annulus, forming a seal to isolate the screened interval from vertical infiltration through the annular space. The seal was completed by plac-

Augering is a rapid method of drilling in unconsolidated, medium-textured formations. Coarse saturated sands and large cobbles can cause problems for augers when sand rises inside the hollow stem or the augers become jammed and unable to rotate. Augers cannot drill in solid rock formations.

Although the process is slower, the cable tool is capable of drilling in solid rock, as well as unconsolidated formations, by first pounding and crushing the material, then advancing the casing and bailing out the pulverized rock and water slurry.

Although the completed monitor wells are of the same final construction, the drilling methods for these two rigs are very different. They are each explained in the following sections.

3.2.2.1 Auger Drilling Method

In this method, the borehole was drilled using rotating six-inch inside diameter hollow stem augers to cut the unconsolidated material and lift the cuttings to the surface. The augers are of the continuous-flight type, and generally manufactured in five foot lengths, and the external auger blades lift cuttings from the borehole in the same fashion as a carpenter's conventional twist drill. The augers were advanced until first water was encountered in the boring, evidenced by saturated cuttings. At this point a split spoon sample of the saturated material was collected in order to describe the composition of the water-bearing zone. After examination of the sample, the augers were advanced to the required depth below the water table and the monitor well was constructed at this depth.

3.2.2.2 Cable Tool Drilling Method

In this drilling method, a drive shoe made of tempered steel was attached to a length of six-inch diameter steel casing. The borehole was advanced by driving (pounding) the casing several feet at a time into the formation. This results in a plug of the unconsolidated material rising inside the casing. Water was then poured into the casing and a heavy drilling chisel regularly dropped and lifted to loosen and crush the material and mix it with the water to form a slurry.

TABLE 3-2

FIELD ACTIVITY SCHEDULE

Date	Activity
31 October 1983	Site visit with drilling contractor to locate geophysical survey areas and ground water and methane well sites, and confirm schedule.
1 - 4 November 1983	Geophysical investigations: Ground penetrating radar, magnetometer and resistivity surveys.
28 November through 9 December 1983	Drilling rigs on site. Installation of 19 monitor wells in Zones 1-4.
6-10 February 1984	Drilling rigs on site. Installation of eight monitor wells in Zones 5-8.
27 February through 3 March 1984	Monitor well sampling. Sampled ground water from 27 wells.
30 April to 3 May 1984	Sampled water from six leachate seeps and surveyed monitor wells and stream elevations.
11-17 June 1984	Re-sampled monitor wells for TOC. Sampled six base water supply wells for TOC.
31 July 1984	Sampled leachate seeps for TOC and VOA.
27-31 August 1984	Installed four methane monitor wells in Landfills 8 and 10. Screened air quality in completed wells. Installed guard posts at groundwater and methane monitor wells.

Table 3-1 (cont.)

Zone 6	
Landfill 2	Install one monitor well. Sample well for pH, specific conductance, nitrate, chloride, sulfate, boron, iron, manganese, sodium, TOC, TOX and phenol. Survey well, ground water and stream elevations.
Zone 7	
Landfill 9	Install one monitor well. Sample well for pH, specific conductance, nitrate, chloride, sulfate, boron, iron, manganese, sodium, TOC, TOX and phenol. Survey well and ground water elevations.
Zone 8	
Fire Training Area 2	Install one monitor well. Sample well for pH, specific conductance, oil and grease, and volatile organics. Survey well and ground water elevations.

Table 3-1 (cont.)

Zone 4	
POL Spills 2 and 3	Install two monitor wells. Sample wells for pH, specific conductance, oil and grease, and volatile organics.
Coal Storage Pile	Conduct fixed depth resistivity survey to locate possible leachate plume. Install one monitor well. Sample well for pH, specific conductance, nitrate, chloride sulfate, boron, iron, manganese sodium, TOC, TOX and phenol.
Chemical Burial Site 1	Install two monitor wells. Sample wells for pH, specific conductance, nitrate, chloride sulfate, boron, iron, manganese, sodium, TOC, TOX and phenol. Survey well and ground water elevations for all five monitor wells.
Zone 5	
Landfill 5	Install four monitor wells. Sample wells for pH, specific conductance, nitrate, chloride sulfate, boron, iron, manganese, sodium, TOC, TOX and phenol.
Fire Training Area 1	Install one monitor well. Sample well for pH, specific conductance, oil and grease, and volatile organics. Survey well and ground water elevations for all five wells; survey stream and lake elevations.

TABLE 3-1

SUMMARY OF FIELD PROGRAM

Site	Activity
Zone 1	
Landfills 8 and 10	Perform Ground Penetrating Radar and Magnetometer surveys at both landfills. Install five monitor wells. Sample wells for pH, specific conductance, nitrate, chloride, sulfate, boron, iron manganese, sodium, TOC, TOX, and phenol. Sample six leachate seeps for specific conductance, chloride, sulfate, boron, iron, TOX, TOC, VOA and phenol. Survey well and ground water elevations. Install four methane monitor wells, two in each landfill and screen air quality in completed wells.
Zone 2	
Landfills 11 and 12	Install three monitor wells. Sample wells for pH, specific conductance, nitrate, chloride, sulfate, boron, iron manganese, sodium, TOC, TOX, and phenol.
Fire Training Areas 3 and 4, and POL spill 1	Install two monitor wells. Sample wells for pH, specific conductance, oil and grease and volatile organics. Survey well and ground water elevations for all five wells; survey river water level.
Zone 3	
Landfills 3,4,6 and 7	Install four monitor wells. Sample wells for pH, specific conductance, nitrate, chloride, sulfate, boron, iron, manganese, sodium, TOC, TOX, and phenol. Survey well, ground water and stream level elevations.

3.2 HYDROGEOLOGIC INVESTIGATION

A field investigation was conducted to define the geologic and hydrogeologic setting at Wright-Patterson AFB and to identify the presence of any hazardous environmental contaminants that may have resulted from past product storage and handling practices, fire training activities, and waste disposal operations at the Base. Information regarding potential or actual impacts of the 15 sites on area ground water was obtained from laboratory analysis of samples from 27 on-site monitor wells installed by WESTON and six landfill leachate seeps. During the well drilling a limited number of samples were taken of the unconsolidated sediments in the unsaturated and saturated zones for visual examination. The monitor wells also provided measuring points for the determination of ground water flow gradients and directions at each site. Elevations of streams near the sites were measured to provide additional information on the interrelationship between ground and surface water gradients. Geophysical investigations were conducted at selected sites on the Base using Ground Penetrating Radar, Fixed-depth Resistivity and Magnetometer in order to locate subsurface trends identifying fill and leachate characteristics. Four methane monitor wells were installed in Zone 1 and screened for air quality inside the completed well. The field program is summarized according to Zones and specific sites in Table 3-1.

3.2.1 Schedule of Activity

The hydrogeologic investigation at Wright-Patterson AFB started with the geophysical investigation on 1 November 1983 and ended with the completion of the methane monitor wells on 31 August 1984. Table 3-2 summarizes WESTON'S field activity schedule to date at Wright-Patterson AFB.

3.2.2 Drilling Program

The drilling program at Wright-Patterson AFB specified the installation of 27 ground water monitor wells and four methane monitor wells. Drilling and installation of the ground-water monitor wells and methane wells was conducted by crews of Bowser-Morner Testing Laboratories, Inc., and their subcontractor, Patterson Well Drilling Company; both of Dayton, Ohio. Two drilling rigs were on site to complete the work: a truck-mounted Mobil Drill Model B-61 auger rig, and a truck-mounted Bucyrus Erie cable-tool rig.

the boundaries of Landfill 2 and the installation and sampling of one downgradient monitor well. One round of samples from this well would be analyzed for the parameters shown on Table 1-2. Elevations of the monitor well and adjacent stream would be measured to determine ground-water flow directions and gradients.

3.1.7 Zone 7

WESTON's Pre-Survey Report designated Landfill 9 (Sandhill) as Zone 7. The proposed work plan for this site recommended the installation and sampling of one monitor well downgradient of the landfill. The final approved Scope of Work followed these recommendations: install one downgradient monitor well, survey elevation of the well, measure depth to ground water, and conduct one round of sampling for the parameters listed on Table 1-2.

3.1.8 Zone 8

WESTON's Pre-Survey Report identified Zone 8 as containing one site, Fire Training Area 2. The proposed work plan for this zone involved the installation and sampling of one monitor well to identify the presence of subsurface oil residues from activities at this area. The final approved Scope of Work included the following: examine historic air photos to identify locations of the site, install a single monitor well downgradient of Fire Training Area 2; survey elevation and depth to water of this well; collect one round of samples from the well and analyze for the parameters listed on Table 1-2.

3.1.9 Analytical Protocol

The analytical protocol summarized in Table 1-2 was selected for the 19 sites addressed in this Phase II study. The parameters chosen are specific and non-specific indicators of contamination.

3.1.10 Formal Scope of Work

Task Order 0022 formalized the proposed work and is included in this report in Appendix B. Task Order 0022 provided the basis for the implementation of the field program described in the following sections.

- Survey elevations of the wells and measure water levels to determine ground-water flow directions and gradients.

- Analyze one round of ground-water samples from the wells for the parameters shown on Table 1-2

3.1.5 Zone 5

WESTON's Pre-Survey Report grouped Landfill 5 and Fire Training Area 1 into Zone 5. WESTON's proposed Work Plan included a resistivity survey of Landfill 5, water level measurements in nearby Base water supply wells, collection of surface water samples, and installation of monitor wells surrounding Landfill 5 and adjacent to Fire Training Area 1.

The final approved Scope of Work included the following tasks:

- Evaluate historic aerial photos of the sites in Zone 5.

- Conduct a single profile resistivity survey to evaluate boundaries of Landfill 5 and effects on water quality in the area. Results of this survey will be used to locate monitor wells in the area.

- Install a total of five monitor wells, four wells located surrounding the downgradient sides of Landfill 5 and one well adjacent to Fire Training Area 1.

- Survey elevations of the monitor wells, surface water bodies, and base water supply wells within 1/4 mile of Landfill 5, and measure water levels in the wells to determine ground-water flow direction and gradients.

- Analyze one round of ground-water samples from the wells for the parameters shown on Table 1-2.

3.1.6 Zone 6

WESTON's Pre-Survey Report identified Zone 6 as consisting of Landfill 2. The proposed work plan for this site involved air photo analysis, installation of one downgradient well, and sampling of ground water and stream water. The final approved Scope of Work included air photo evaluation of

3.1.3 Zone 3

Zone 3, as described by the WESTON Pre-Survey Report, consisted of Landfill 3, 4, 6, and 7. WESTON's recommended Work Plan for Zone 3 included historic aerial photo analysis, installation of monitor wells to define a contaminant profile, and analysis of ground water and surface stream water samples. The final approved Scope of Work for Zone 3 included the following tasks:

- Install four ground-water monitor wells within the zone to define a contaminant profile. Screen the wells at a minimum depth of 10 feet below the surface of the ground-water table.
- Survey elevations of the wells and surface water streams and measure water levels to determine ground water and surface water flow gradients.
- Analyze one round of ground-water samples from the wells for the parameters shown on Table 1-2.

3.1.4 Zone 4

WESTON's Pre-Survey Report grouped the following four sites into Zone 4:

- POL Spill Sites 2 and 3
- Coal Storage Pile
- Chemical Burial Site 1

WESTON recommended a work plan for the zone to include an earth resistivity survey adjacent to the coal pile to detect acidic leachate, and monitor wells downgradient of each site.

The final approved Work Scope for Zone 4 included the following tasks:

- Conduct an earth resistivity of the area surrounding the coal pile.
- Install a total of five monitor wells, one within each spill area, one between the coal pile and the Fairborne Well Field and one downgradient of each Burial Site.

- Install one ground-water monitor well upgradient in Zone 1 and four wells downgradient of the landfills. Screen the wells at a minimum depth of 10 feet below the surface of the ground-water table.

- Survey elevations of the wells and measure water levels to determine ground-water flow directions and gradients.

- Sample one round from the monitor wells for analysis of the parameters shown on Table 1-2.

- Install four methane monitor wells, two on each landfill, to determine if gases are being generated inside the landfills.

3.1.2 Zone 2

The WESTON Pre-Survey Report grouped the following five sites into Zone 2:

- Landfill 11
- Landfill 12
- Fire Training Areas 3 and 4
- POL Spill Site 1.

WESTON's recommended work plan for Zone 2 included aerial photograph evaluation, resistivity surveys, monitor well installation and ground water and surface water (Mad River) sampling. The final approved Scope of Work included the following tasks for Zone 2:

- Conduct a fixed-depth resistivity survey at Landfills 11 and 12 to detect the presence of any leachate plumes migrating toward the Mad River.

- Install a total of five ground-water monitor wells, to be located downgradient of each of the landfills and Fire Training areas, and in the vicinity of the Spill Site.

- Survey elevations of the wells and measure water levels to determine ground-water flow directions and gradients.

- Take one round of samples from the wells and analyze for the parameters shown on Table 1-2.

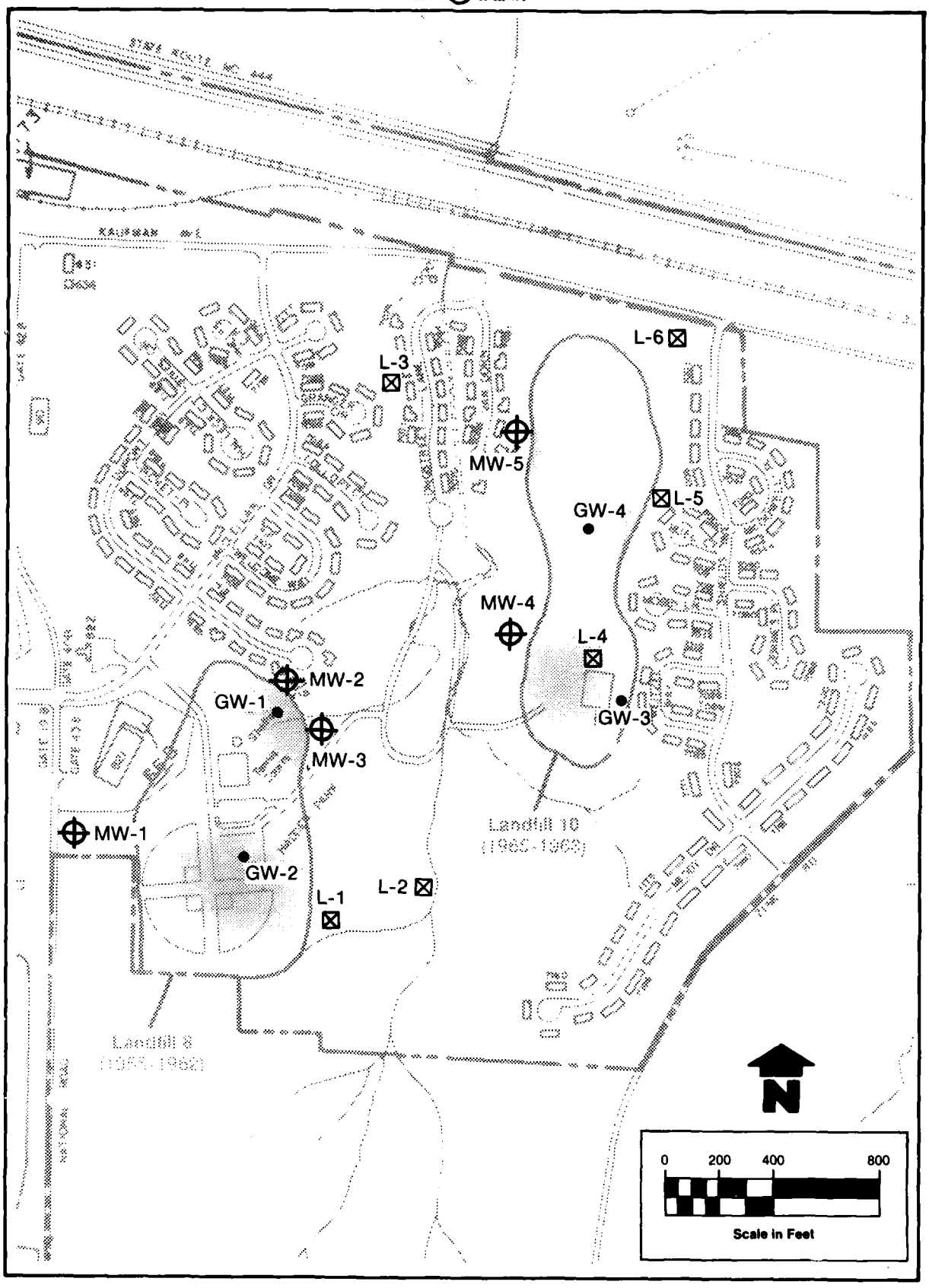


FIGURE 3-2 LOCATION OF MONITOR WELLS, METHANE GAS WELLS AND LEACHATE SAMPLING POINTS IN ZONE 1

Table 3-3 Summary of Well Construction Details, Wright Patterson AFB

Monitor Well Number	Approx. Land Surface Elevation In Feet	Top of PVC Casing Elevation in Feet	Screen Interval Depth in Feet	Screened Formation	Sediment Descriptions In Screened Zones
1	915.7	917.88	35-65	Till	Interbeds of fine to coarse SAND and sandy Clay. Grey CLAY layers at top and base of screened interval.
2	906.7	908.16	30-60	Till	Interbeds of brown, green and grey sandy CLAY.
3	848.0	850.24	24-44	Till	Brown to green-grey sandy CLAY, with interbeds of clayey SAND (m-c).
4	879.4	883.23	33-63	Outwash	Brown medium to coarse SAND with some med. to coarse gravel, trace silt.
5	837.8	840.01	36-46	Outwash	Brown medium to coarse SAND with some med. coarse gravel and cobbles.
6	806.1	808.26	41-51	Alluvium	Medium to Coarse SAND with a little clay and gravel.
7	808.8	811.62	27-37	Alluvium	Brown medium SAND, trace silt with dense green CLAY at base of screen.
8	798.1	800.72	8-23	Alluvium	CLAY with some Sand and gravel., Some Clay
9	798.3	800.92	8-23	Alluvium	Brown med. to very coarse SAND, little gravel and trace of clay.
10	796.3	798.48	30-40	Alluvium	Brown medium SAND with gravel, trace silt.
11	809.1	810.87	19-29	Alluvium	Brown medium SAND with gravel, trace silt.
12	808.1	810.32	30-40	Alluvium	Brown coarse SAND, little gravel.
13	806.5	809.09	17-27	Alluvium	Brownish grey fine coarse SAND, trace gravel and clay.
14	808.6	810.86	30-50	Till	Brown CLAY, some silt at top of screen, Interbedded SAND with gravel and sandy CLAY at base.
15	818.4	820.79	15-25	Outwash	Brown SAND, tr. clay, some gravel.
16	818.6	821.44	8-28	Outwash	GRAVEL and m-c SAND, tr. clay.
17	819.5	822.51	6-16	Outwash	Greenish brown dense CLAY, over gravel and sand.
18	824.5	826.84	21-31	Outwash	Coarse SAND with some med. gravel, trace clay.
19	823.6	825.09	29-39	Outwash	Green-Brown SAND and GRAVEL.
20	788.2	791.12	11-21	Outwash	Brown SAND and GRAVEL, some cobbles, trace silt and clay.
21	788.4	791.00	13-23	Outwash	Brown SAND and GRAVEL, some cobbles, trace silt and clay.
22	794.0	796.24	26-36	Outwash	Brown SAND and GRAVEL, some cobbles, trace silt and clay.
23	789.6	791.94	24-34	Outwash	Medium GRAVEL with some sand.
24	792.6	796.24	2.5-12.5	Outwash	GRAVEL and f-c SAND, trace silt.
25	782.8	784.20	16-26	Outwash	Brown SAND and GRAVEL, some cobbles, trace silt and clay.
26	826.0	828.89	32-42	Outwash	Fine to coarse SAND, little med. gravel, trace silt.
27	803.5	805.91	10-35	Alluvium	Interbeds of SAND and brown-green sandy CLAY.

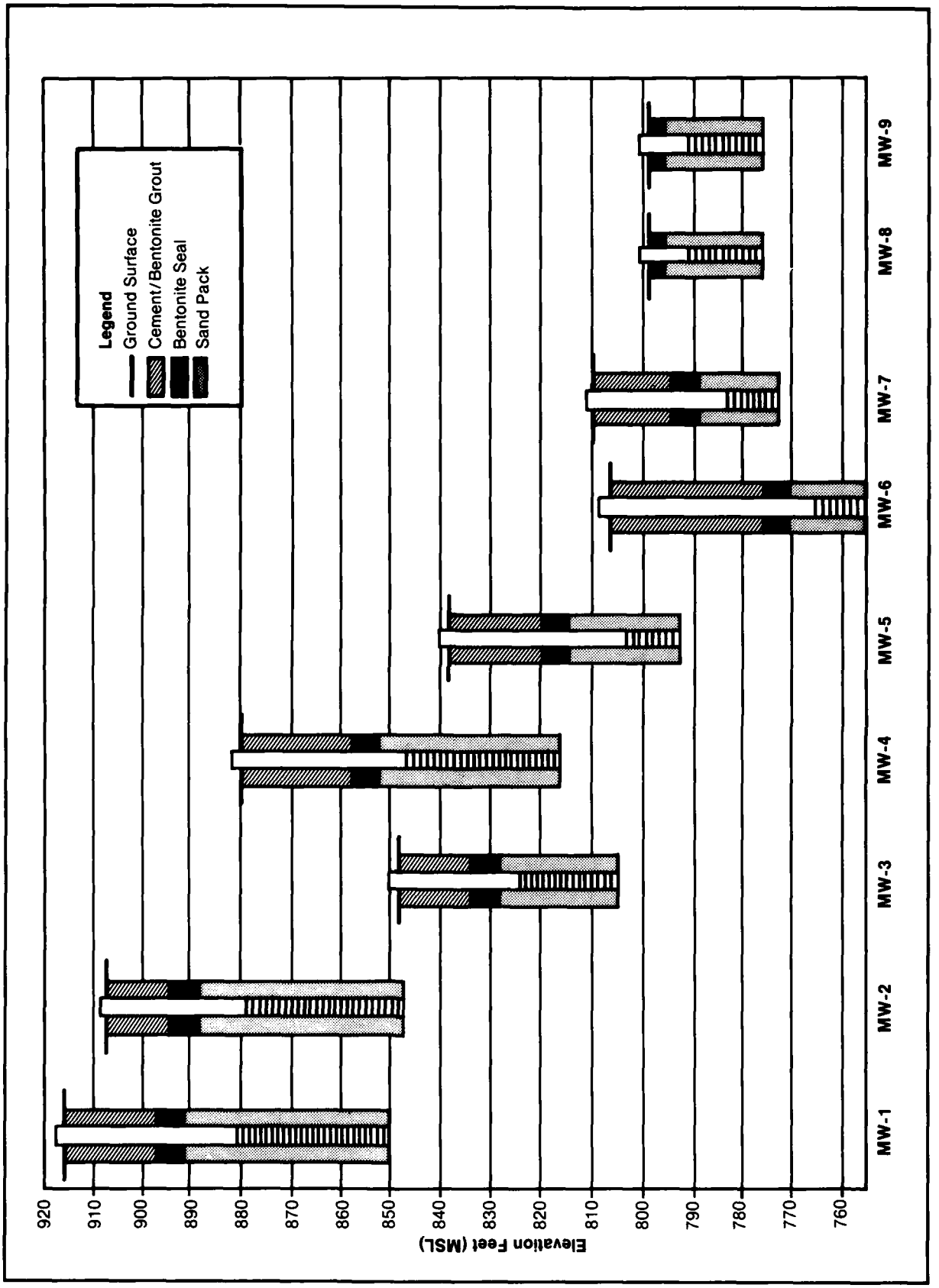


FIGURE 3-3 WELL CONSTRUCTION SUMMARY: WELLS MW-1 THROUGH MW-9

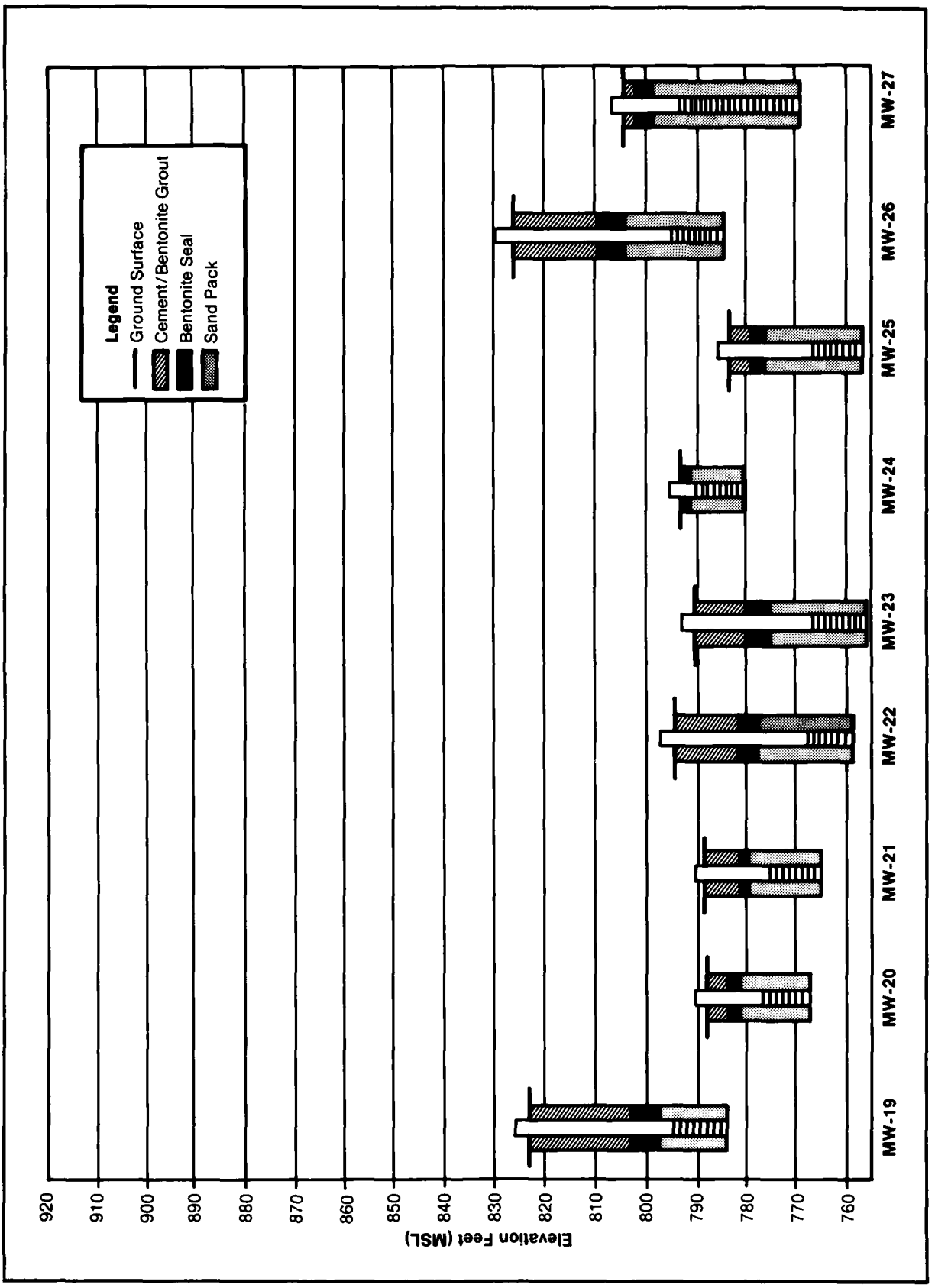


FIGURE 3-4 WELL CONSTRUCTION SUMMARY: WELLS MW-10 THROUGH MW-18

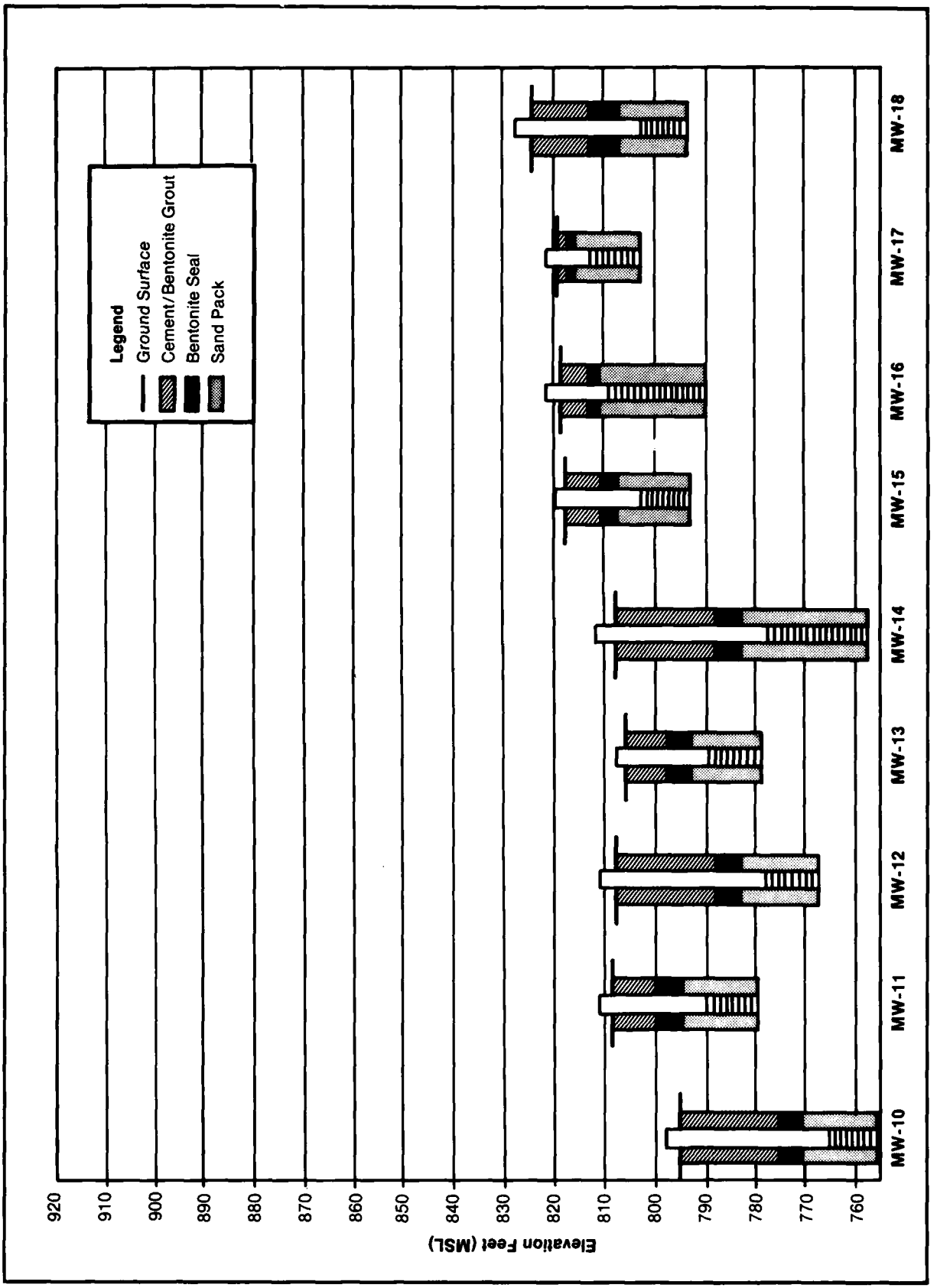


FIGURE 3-5 WELL CONSTRUCTION SUMMARY: WELLS MW-19 THROUGH MW-27

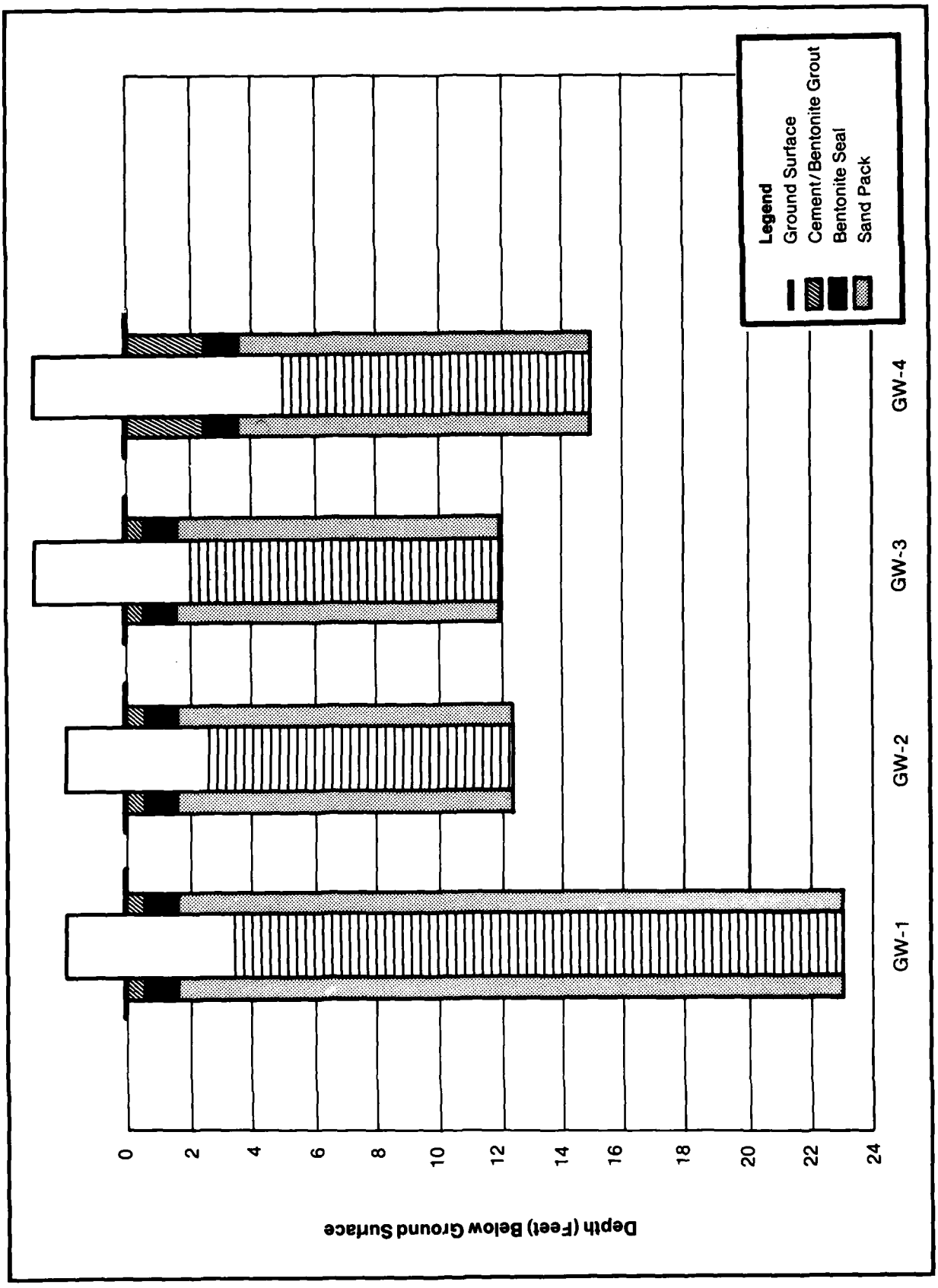


FIGURE 3-6 METHANE GAS WELL CONSTRUCTION SUMMARY WELLS GW-1 THROUGH GW-4

GW-1 was drilled in Landfill 8 to a depth of 25.5 feet through fill material consisting of trash (wood, paper, metal, concrete rubble) and black sandy clay with a tarry smell. The boring ended in natural silty clay loam sediments. GW-1 was screened from 3.5' to 23.5' below ground surface. GW-2 was drilled in Landfill 8 12.5' below ground surface. At this point the water table was encountered. Cuttings of black clayey fine sand were observed for the entire length of the boring. The material appeared to be a foundry sand, used as fill in the past. This gas well was screened from 2.5' to 12.5' below ground surface.

GW-3 was drilled in Landfill 10 in the playground area west of Weitzel Way. The boring encountered trash, including metal, concrete and wire as well as dark gray sandy fill before reaching the water table surface at 9.5 feet. Total depth of the well was 12 feet; the well was screened from 2 to 12 feet below ground surface. GW-4 was drilled in Landfill 10 in the open field area west of Buel Court. This boring encountered a one-foot sandy clay loam cover above five feet of sandy fill mixed with pieces of wood, wire, concrete rubble and rags. From 6 to 15 feet, general refuse, primarily compressed paper, was observed in the drill cuttings and split spoon samples. A strong "garbage" odor was evident as the cuttings were brought to the surface. The water table was encountered at 11 feet. Gas Well 4 was completed to a total depth of 15 feet and screened from 5' to 15' below ground surface.

The annular space around each of the gas monitor wells was packed with a coarse sand from total depth to 0.5' to 1.5' above the top of the screen. A one-foot bentonite pellet seal was placed above the sand pack, and the remaining hole filled with cement grout. Detailed drilling logs and well construction logs are in Appendix D.

3.2.3.2 Zone 2: Landfills 11 and 12, Fire Training Areas 3 and 4, POL Spill 1

A total of five monitor wells were installed in Zone 2. Locations of the wells, numbered MW-6 through MW-10, are shown on Figure 3-7. MW-6 and MW-7 are located downgradient of Landfill 11, between the edge of the landfill and the Mad River. A bulldozer was used to cut access roads to these two well sites, and the Base perimeter fence was breached and repaired with a gate, with prior Base approval, in order to gain access for drilling. MW-8 and MW-9 are located downgradient of Fire Training Areas 3 and 4, respectively. MW-8 is also adjacent to POL Spill 1. MW-10 is located immediately downgradient of Landfill 12.

The wells range in depth from 23 to 51 feet below land surface. Ground water was encountered in the wells at depths of seven to 20 feet. The wells were screened in fine to medium sand and gravel. Ten-foot lengths of screen were used in wells MW-6, MW-7 and MW-10. Wells MW-8 and MW-9 monitored fire training areas and a POL spill where oil and grease were suspected contaminants. These compounds float on the ground water surface. In order to collect floating oily compounds in a monitor well, the well screen must extend above the surface of the ground water table. Fifteen-foot lengths of screen were used in wells MW-8 and MW-9 to bring the top of the screen two to three feet above the ground water surface and allow any floating oils to enter the well. All of the wells were carefully sealed and grouted to ensure against vertical infiltration of water, oil and leachate from the landfills and fire training areas. A complete discussion of subsurface conditions in Zone 2 is presented in Section 4.1. Table 3-3 summarizes the well construction details and Figures 3-3 and 3-4 graphically present the well construction details.

3.2.3.3 Zone 3: Landfills 3, 4, 6 and 7

Four monitor wells were installed in Zone 3. Each well is located close to a downgradient side of one of the four landfills in this zone. The selection of exact positions for the wells was limited by accessibility constraints and Base clearance permits. Locations of the wells, numbered MW-11 through MW-14, are shown on Figure 3-8.

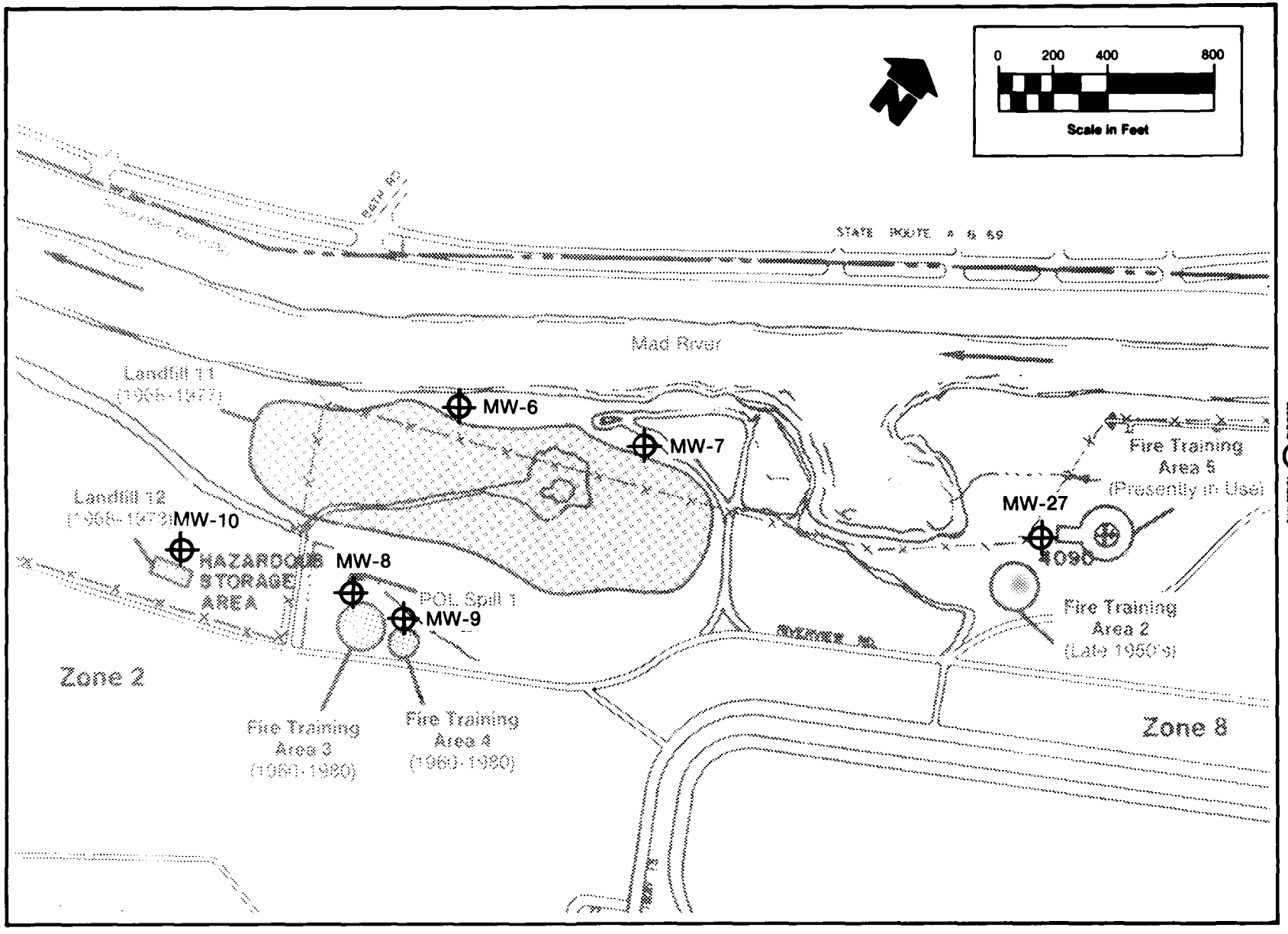


FIGURE 3-7 LOCATION OF MONITOR WELLS IN ZONE 2 AND ZONE 8

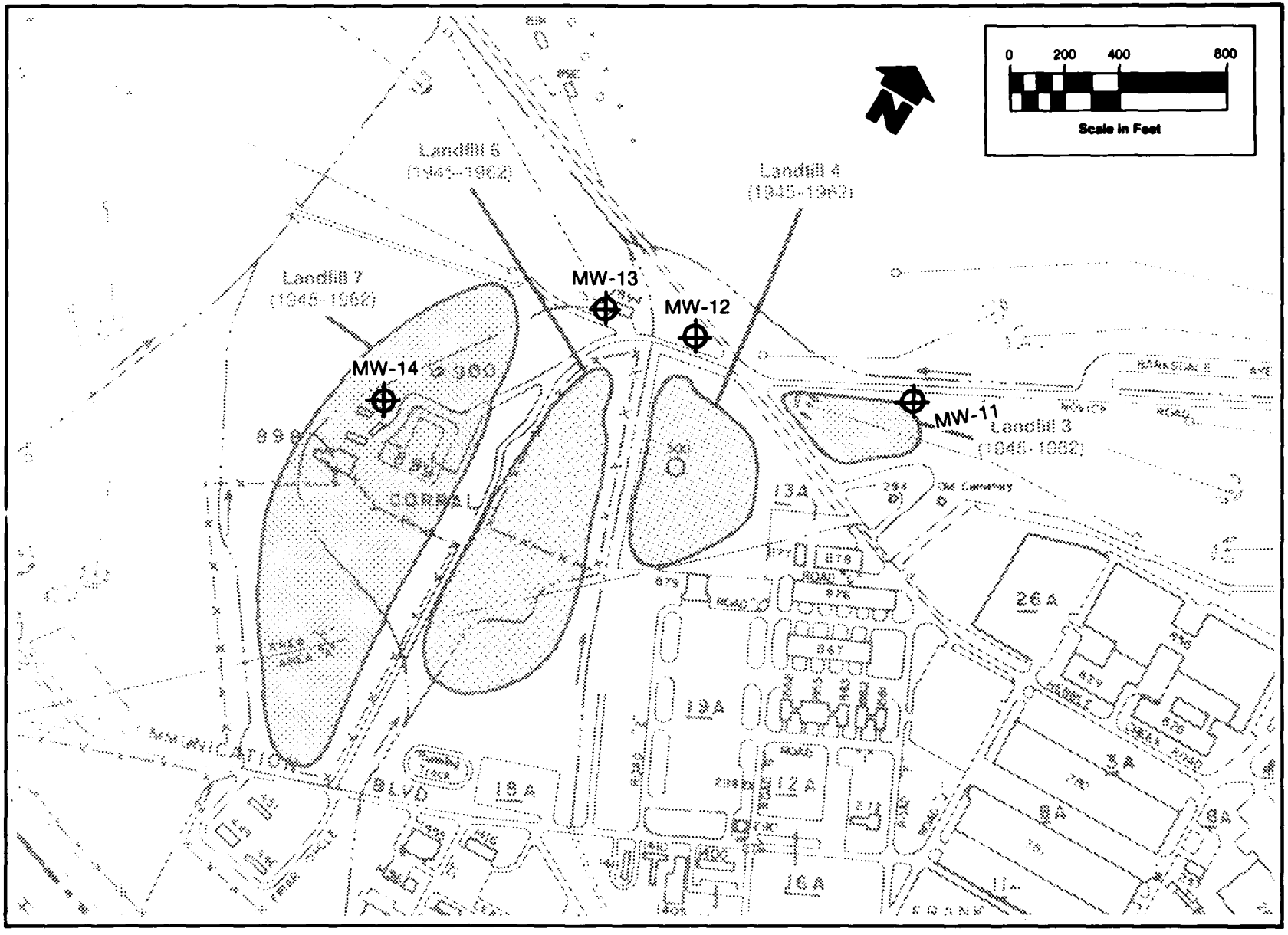


FIGURE 3-8 LOCATION OF MONITOR WELLS IN ZONE 3

MW-11 is located on the golf course at the edge of Novick Road, between Landfill 3 and Hebble Creek. One foot of brick and rubble fill was encountered while drilling this well. MW-12 is located in a grassy triangle formed by the intersection of Hebble Creek Road and Novick Road, between Landfill 4 and Hebble Creek. MW-13 is located on the west side of Building No. 894, between Landfill 6 and Hebble Creek. MW-14 is located near the western edge of Landfill 7 near an unnamed tributary of Hebble Creek. The zone map on Figure 3-7 shows the area of Landfill 7 as interpreted by the Phase I contractor from historic aerial photographs. WESTON's review of historical aerial photographs, available from the Miami Valley Regional Planning Commission, could not improve upon the delineation of boundaries within this zone. This was due mainly to the fact that landfilling predated construction of many building and road landmarks. Field reconnaissance in the vicinity of Landfill 7 indicated that the location selected for MW-14 was outside the boundary of Landfill 7. No fill material was encountered during drilling at the location of MW-14, bearing out the results of the field reconnaissance.

The monitor wells ranged in depth from 27 to 50 feet below land surface. Ground water was encountered at depths of from seven to 25 feet. The wells were screened in silty sands and gravel. Ten-foot screens were used in MW-11, 12 and 13. MW-14 contained a number of thin sandy clay seams in the saturated zone, and a 20-foot length of screen was used to complete this well to ensure an adequate flow of water for sampling purposes. Grouting procedures were carefully monitored to ensure a competent seal that would prevent vertical infiltration of surface water and leachate around the casing. A complete description of subsurface conditions is presented in Section 4.1. Table 3-3 summarizes the well construction details and Figure 3-4 graphically presents the well construction details.

3.2.3.4 Zone 4: POL Spills 2 and 3, Coal Storage Pile and Chemical Burial Site 1

Five wells, numbered MW-15 through MW-19, were drilled and completed in Zone 4. Locations of the wells are shown on Figure 3-9. MW-15 and MW-16 are located downgradient of the fenced fuel storage area at the edge of the airfield. The monitor wells were originally proposed within the fuel storage area, but fire and explosion hazards dictated that drilling operations be removed from the immediate vicinity of

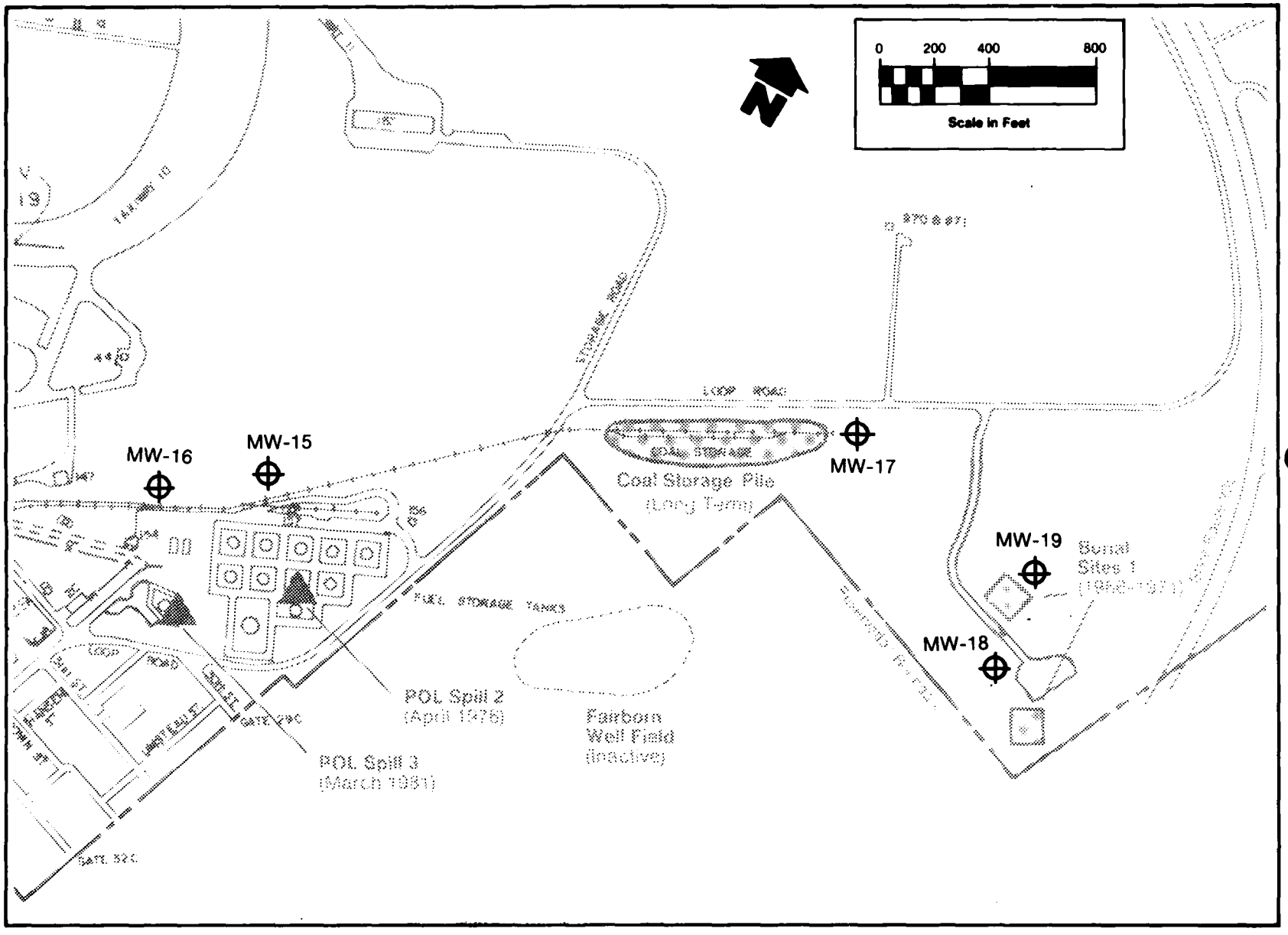


FIGURE 3-9 LOCATION OF MONITOR WELLS IN ZONE 4

the fuel handling facility. Since the Fairborn wellfield is no longer in production, there was no reason to believe that flow at the Coal Storage Pile would be induced in a southerly direction. An alternate location was selected immediately adjacent to the pile to monitor for radial flow and mounding induced by infiltration through the pile. MW-17 is located at the eastern toe of the coal storage pile in an area stained by surface runoff from the coal pile. MW-18 and MW-19 are located near the two approximate areas of chemical burial, collectively called Burial Site 1.

Historic aerial photographs were examined for surface features or disturbed ground that would indicate exact locations of these burial sites, but only faint indications could be seen. After walking the site, the wells were located in two areas with sparser vegetation than the surrounding thick grass. Wells in Zone 4 ranged from 16 to 40 feet below ground surface. Ground water was encountered at depths from seven to 22 feet. All the wells except MW-16 were screened in coarse sands and gravels using 10-foot lengths of screen. MW-16 contained silty sand with traces of clay in the saturated zone. A 20-foot length of screen was used in this well to ensure an adequate water supply for sampling. The screens in wells MW-15 and MW-16 were installed two to three feet above the surface of the water table in order to capture any floating oils carried by the ground water. The annular spaces were sealed and grouted carefully to prevent vertical infiltration of surface water around the casing. A complete discussion of subsurface conditions in Zone 4 is presented in Section 4.1. Table 3-3 summarizes the well construction details. Graphic diagrams of the well construction are shown in Figures 3-4 and 3-5.

3.2.3.5 Zone 5: Landfill 5 and Fire Training Area 1

Five monitor wells, numbered MW-20 through MW-24 were installed in Zone 5. Locations of the wells are shown on Figure 3-6. Four of the wells are located at the edges of Landfill 5, a currently active hilltop dumping area in use since 1945. MW-20 and 21 are located next to Riverview Road on the western flank of Landfill 5, between the landfill and the Mad River, which is approximately 1500 feet away. MW-22 is located between Landfill 5 and the Twin Lakes, old gravel pits now filled with water. MW-23 is located at the eastern corner of Landfill 5, upgradient from a marshy area that receives runoff from the landfill. MW-24 is located near Fire Training Area 1. This Fire Training Area, used during the period 1950-1955, could not be located accurately using historic aerial photographs back as far as 1962. Earlier

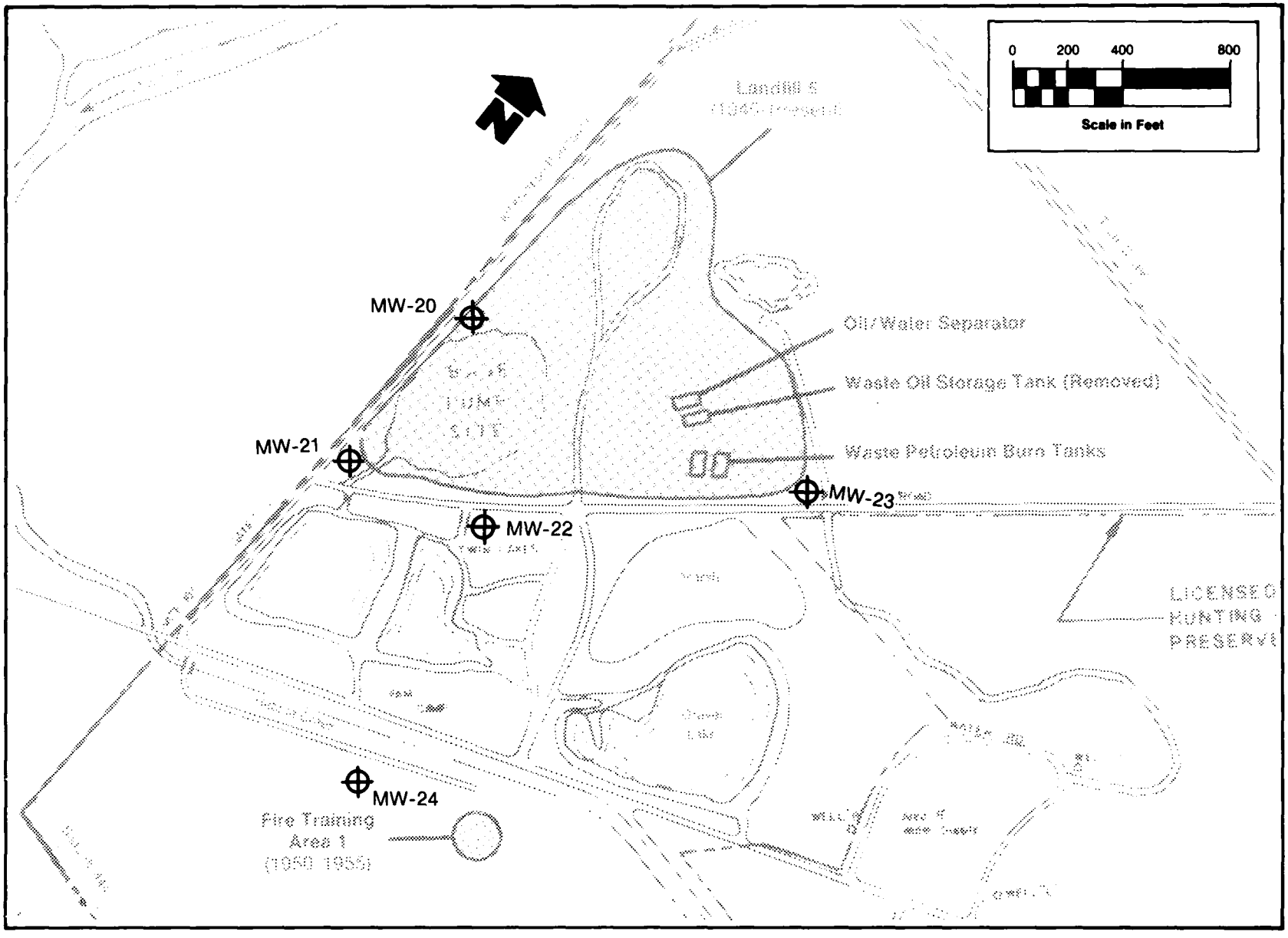
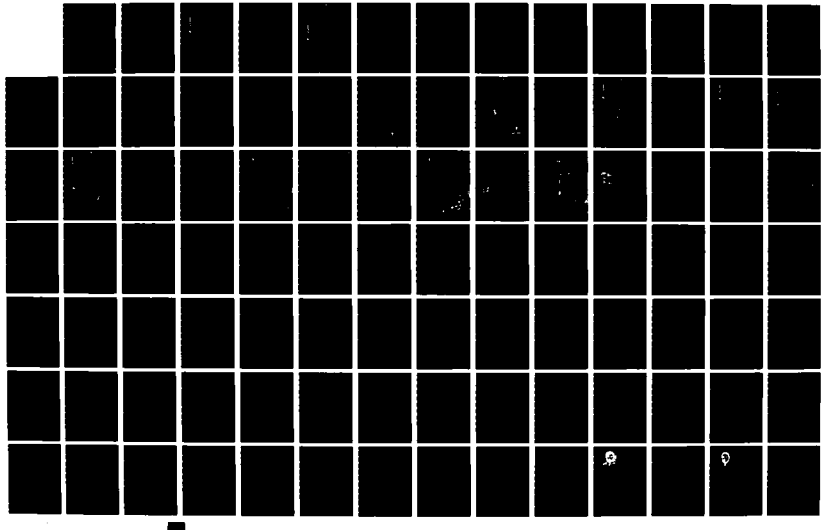
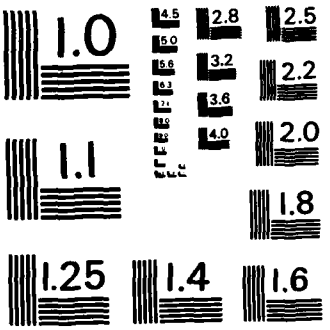


FIGURE 3-10 LOCATION OF MONITOR WELLS IN ZONE 5

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WEST CHESTER PA SEP 85 F33615-80-D-4006

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

photos were not available. The area was examined visually and the project team spoke with the Phase I Report authors and met with Base Fire Department personnel to find a more accurate location. From all indications, FT-1 was in the vicinity of the mapped circle, but no exact location was found. The well could not be drilled in a location closer to the mapped location of the Fire Training Area, due to the proximity of utilities, and utility clearances could only be obtained after moving the well site to its present location approximately 400 feet west of the mapped FT-1 location.

Depths of the wells in Zone 5 ranged from 12.5 to 36 feet below ground surface. Ground water was encountered in the wells at depths from six to 25 feet. All five of the wells were screened in medium sand and gravel or cobbles using 10-foot lengths of screen. MW-24, drilled with augers, encountered large cobbles at 6.5 feet and ended in refusal on a boulder at 12.5 feet. The boring was bailed out several times with the augers still inside the hole and allowed to recover to determine rate of flow. The augers filled immediately each time to within three feet of ground surface. An adequate ground water flow was ensured and the well was completed to 12.5 feet below ground surface. The top of the screen was extended one foot above the ground water table surface to capture any floating oils. Since the bentonite and grout seals were each only one foot thick, special care was taken when installing them to build up a thick cement mixture around the base of the casing to prevent surface water infiltration. A discussion of subsurface conditions in Zone 5 is presented in Section 4.1. Table 3-3 summarizes well construction details; Figure 3-5 graphically presents those construction details.

3.2.3.6 Zone 6: Landfill 2

One monitor well was constructed in Zone 6. MW-25, shown on Figure 3-11, is located on the southwestern edge of Landfill 2 between the landfill and an unnamed creek which flows into the Mad River. MW-25 is 26 feet deep. Ground water was encountered at 18.5 feet and rose to 14 feet after drilling. The well is screened from 16 to 26 feet in medium to coarse sand and gravel with some cobbles. Grout was carefully emplaced to prevent vertical surface infiltration around the casing. A discussion of the sediments encountered in MW-25 is found in Section 4.1. Table 3-3 summarizes the well construction details and Figure 3-5 contains a graphic diagram of the well.

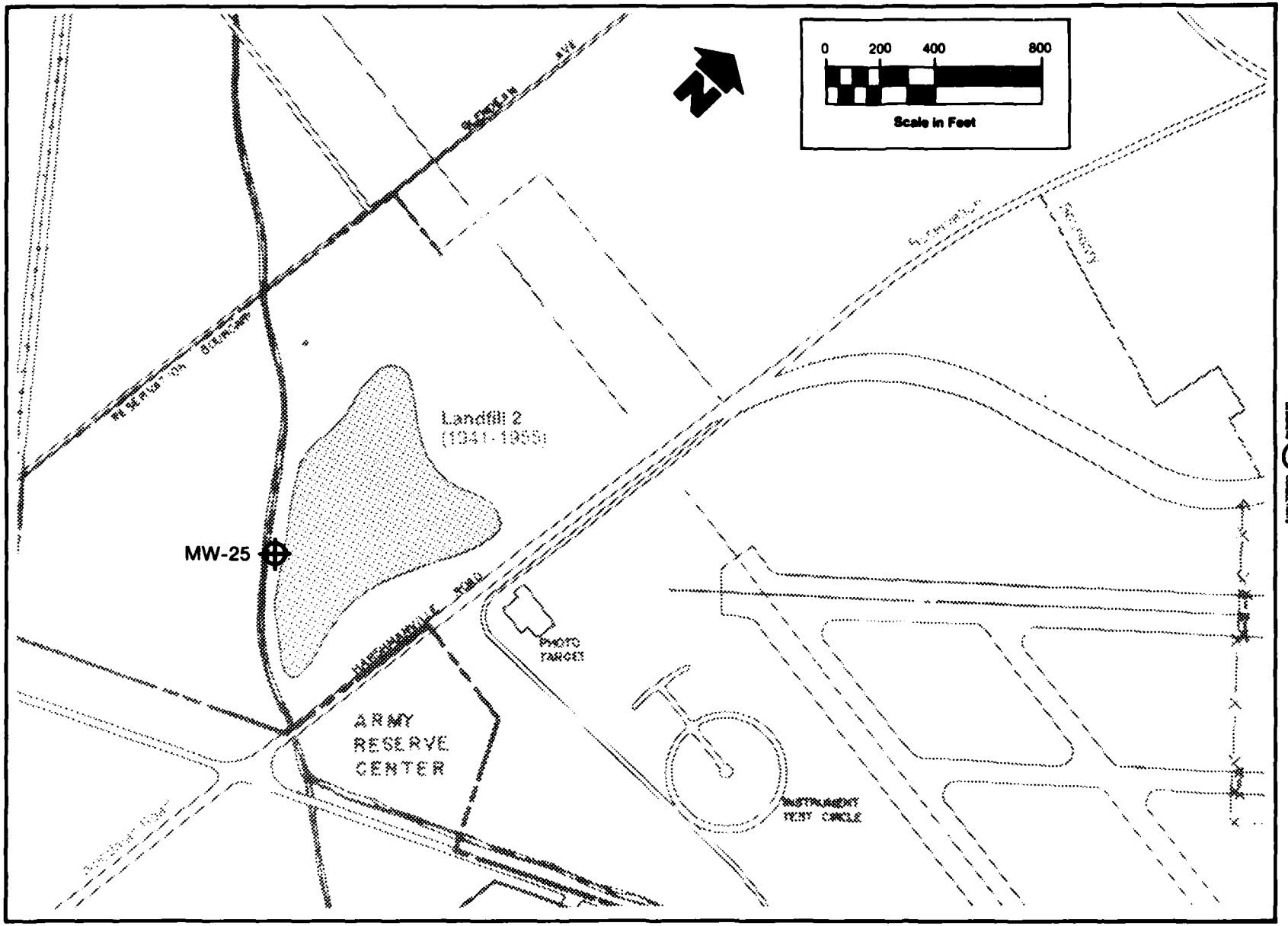


FIGURE 3-11 LOCATION OF MONITOR WELL IN ZONE 6

3.2.3.7 Zone 7: Landfill 9 (Sandhill)

One monitor well, MW-26, was installed in Zone 7. Shown on Figure 3-12, the well is located in a field downslope of the western edge of Landfill 9. MW-26 is 42 feet deep. Groundwater was encountered at 32 feet below ground surface, and the well is screened from 32 to 42 feet in fine to coarse sand and gravel. Grouting was carefully accomplished to ensure a competent seal and prevent vertical surface water or leachate infiltration around the casing. A discussion of the sediments encountered in MW-26 is included in Section 4.1. Table 3-3 summarizes well construction details and Figure 3-5 contains a graphic diagram of MW-26.

3.2.3.8 Zone 8: Fire Training Area 2

One well was installed in Zone 8 between the location of Fire Training Area 2 and the Mad River. Figure 3-7, which is also the map of Zone 2, shows the location of MW-27. No visible surface staining or disturbance was present in the mapped area for Fire Training Area 2. The project team examined historical aerial photographs and spoke with Phase I Report authors and Base Fire Department personnel to try to identify an exact location. Well MW-27 was located downgradient of FT-2 according to best available information. The well is 35 feet deep and is screened in clayey sand and fine sand from 10 to 35 feet. Water was first encountered at 22 feet below ground surface. A 25-foot length of screen was used in this well to ensure an adequate flow of water from the clayey sediments and to elevate the top of the screen above the surface of the water table to encounter any floating oils on the ground water surface. The annulus was carefully sealed and grouted to prevent vertical surface water infiltration around the casing. A discussion of subsurface sediments encountered in this well is found in Section 4.1. Table 3-3 summarizes well construction details and Figure 3-5 graphically illustrates those details.

3.2.4 FIELD TESTING

3.2.4.1 Ground-Water Elevation Survey

The tops of permanent steel casings of all 27 monitoring wells were surveyed for elevation by the WESTON field team using a standard optical leveling device. The purpose of the survey was to establish references from which to measure hydraulic ground-water elevations in order to determine gradients and dissection of flow. Stream and pond elevations were also measured at the time of the survey to

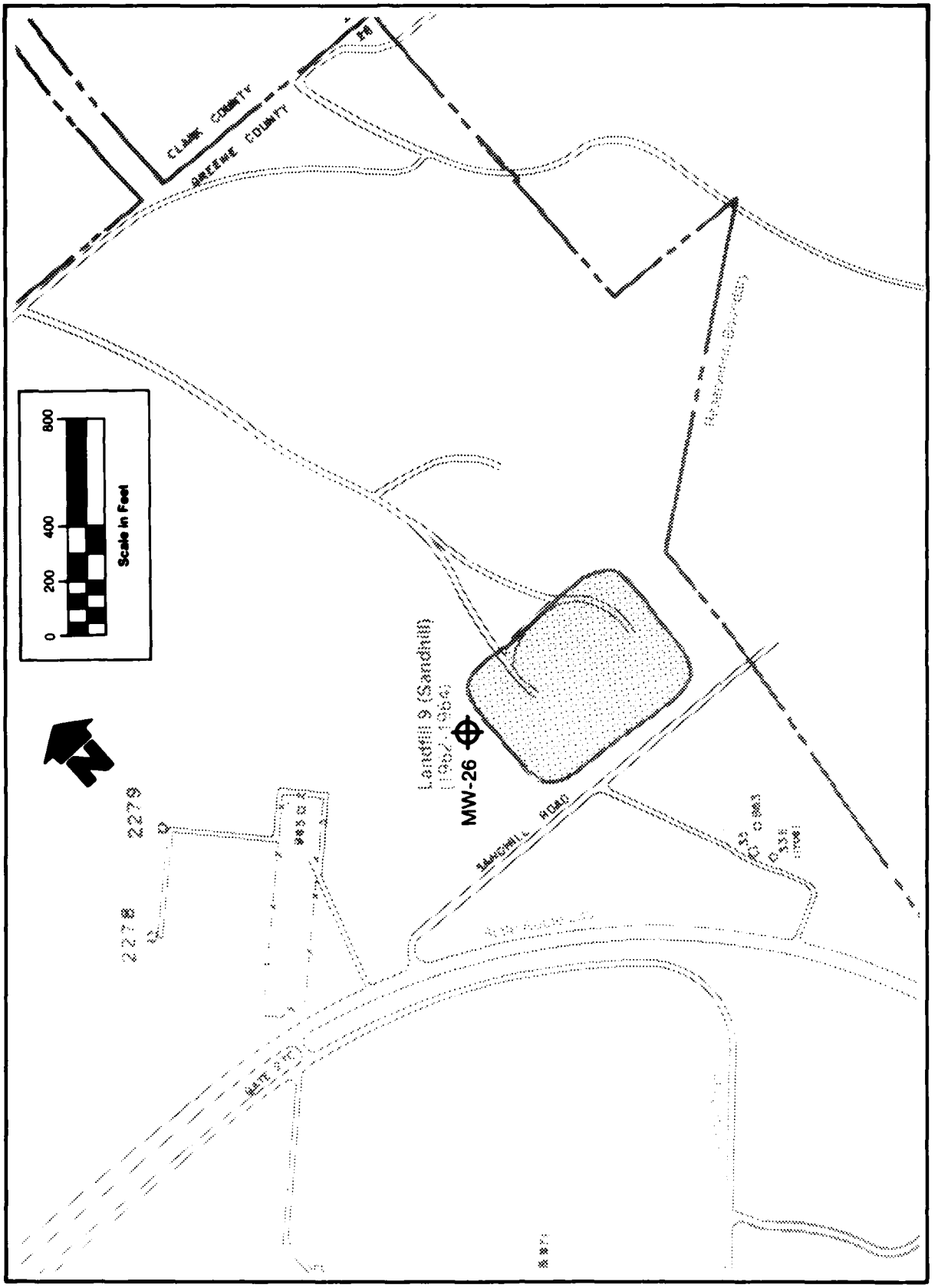


FIGURE 3-12 LOCATION OF MONITOR WELL IN ZONE 7

establish the gradient between the water table and adjacent surface water bodies. Elevations were determined to the nearest 0.01 foot and referenced to nearby permanent benchmarks which were located from Base drawings. A summary of all water level and reference elevations is presented in Table 3-4. The locations of monitoring wells are shown on Figures 3-7 through 3-12. Surface water survey points are shown on Figures 4-3 through 4-6 in the following Section of this report.

3.2.4.2 Water Level Measurements

Three complete rounds of water level measurements were made in the 27 monitoring wells during the periods 10 February, 1 May and 11-17 June 1984. A battery operated Soil Test Model DR-760-A water level probe was used and measurements were obtained to the nearest 0.01 feet. Table 3-4 contains a summary of all surveyed elevations, depth to water measurements and ground-water elevations.

3.2.4.3 Field Testing for Water Quality

While taking ground-water samples for laboratory analyses during the week of 27 February, the WESTON field team also analyzed grab samples from each well for temperature, specific conductance and pH. The pH was measured with a Markson Model-6 portable pH meter. Temperature and specific conductance was measured with a Markson Model 36 Conductivity Meter. The results of these tests are presented in Table 3-5.

3.2.5 Geophysical Survey

A geophysical field investigation of Zone 1 (Landfills 8 and 10) was conducted by WESTON between 1 November and 9 December 1983 (see Figure 1-4). Geophysical mapping on both landfills provided a direct comparison of results obtained from the application of two different geophysical sensing techniques: (1) Ground Penetrating Radar (GPR) and (2) Magnetometry. Appendix E contains a brief discussion of the methods and techniques used during the geophysical surveys. The two types of data were used in a complimentary fashion to locate disturbed subsoils and buried objects suspected to be associated with waste burial sites. Since the exact locations of the chemical trenches and acid neutralization basins suspected to be buried in Zone 1 were not known, the field survey was conducted in grid fashion. Concurrently with the geophysical field investigation conducted at Zone 1 earth resistivity surveys were scheduled to be conducted at

Table 3-4 Summary of Monitor Well and Surface Water Elevation Survey

Location	Well	Depths to Water in Feet 10 Feb	1 May	11-16 June	Elev. Top of Casing (in feet)	Groundwater Elevations in Feet (MSL) 10 Feb.	1 May	11-16 June
Zone 1	1	21.70	17.35	20.12	917.88	896.2	900.5	896.2
Zone 1	2	19.50	17.12	17.96	908.16	887.2	889.6	890.2
Zone 1	3	2.51	0.69	1.56	850.24	847.7	849.6	848.7
Zone 1	4	32.90	30.33	31.76	883.23	850.3	852.9	851.5
Zone 1	5	9.72	6.11	9.45	840.01	830.3	833.9	830.6
Zone 2	6	17.30	16.51	17.19	808.26	791.0	791.8	791.1
Zone 2	7	22.02	21.56	22.21	811.62	789.6	790.1	789.4
Zone 2	8	9.81	6.31	9.95	800.72	790.9	794.4	790.8
Zone 2	9	9.80	6.33	10.05	800.92	791.1	794.6	790.9
Zone 2	10	7.49	6.87	7.64	798.48	791.0	791.6	790.9
Zone 3	11	14.03	12.27	13.46	810.87	796.8	798.6	797.4
Zone 3	12	13.91	12.15	13.36	810.32	796.4	798.2	797.0
Zone 3	13	13.09	11.32	12.71	809.09	796.00	797.8	796.4
Zone 3	14	9.33	9.65	8.33	810.86	801.5	801.2	802.5
Zone 4	15	9.76	9.19	7.83	818.38	811.6	811.6	810.6
Zone 4	16	13.10	10.34	8.33	821.44	811.1	811.1	813.1
Zone 4	17	9.82	9.03	8.02	826.84	813.5	813.5	818.8
Zone 4	18	13.98	9.79	11.61	826.84	817.	817.1	815.2
Zone 4	19	12.23	8.11	9.98	825.09	817.1	817.0	815.1
Zone 5	20	-	11.35	12.01	791.12	779.8	779.8	779.1
Zone 5	21	13.57	11.45	12.03	791.00	779.6	779.6	779.0
Zone 5	22	17.44	15.32	16.02	796.24	780.9	780.9	780.0
Zone 5	23	6.73	5.72	7.74	791.94	786.2	786.2	784.2
Zone 5	24	10.23	6.26	10.43	796.24	790.0	790.0	785.8
Zone 6	25	16.40	15.72	15.61	784.20	768.5	768.5	768.6
Zone 7	26	24.11	20.71	22.91	828.89	808.2	808.2	806.0
Zone 8	27	13.72	13.03	13.73	805.9I	792.9	792.9	792.2

Table 3-4 (cont.)

	Reference	Reference Elevation In Feet	Depth To Water In Feet	Water Surface Elevation In Feet
Zone 2				
S-1	Direct Measurement	-	-	791.2
S-2	Direct Measurement	-	-	789.6
Zone 3				
S-3	Top of Culvert	805.81	5.41	800.4
S-4	Bridge Curb	806.26	8.21	798.1
S-5	Bridge Abutment	806.18	7.17	799.1
Zone 6				
S-6	Direct Measurement	-	-	772.6
S-7	Bridge Abutment	786.01	6.28	779.7
Zone 5				
S-8	Bridge Deck	793.13	6.94	786.2
S-9	Top South Pond Culvert	785.28	4.63	780.7
S-10	Top North Pond Culvert	785.21	3.70	781.5

Table 3-5
Summary of Field Tested
Water Quality Parameters

Well Number	Location Monitored	pH	Spec. Cond.	Temp. °C
		(pH units)	(umhos/cm)	(°C)
1	Upgradient of Landfill 8	6.74	688	13
2	Landfill 8	7.21	602	14
3	Landfill 8	6.72	621	11
4	Landfill 10			14
5	Landfill 10	8.80	348	13.5
6	Landfill 11	6.91	1025	13
7	Landfill 11	6.60	1698	12
8	Fire Training Area 3			10
9	Fire Training Area 4	6.53	886	10
10	Landfill 12	6.98	898	12
11	Landfill 3	6.75	1088	14
12	Landfill 4	9.15	1215	13.5
13	Landfill 6	6.53	1056	12
14	Landfill 7	6.39	1195	11
15	Tank Farm (Tank 256)	7.2	1012	10
16	Tank Farm (Tank 272)	7.2	1079	11
17	Coal Storage Pile	7.0	1238	10
18	Chemical Burial Area	7.1	1223	11
19	Chemical Burial Area	7.1	1126	10
20	Landfill 5	6.70	1390	13
21	Landfill 5	6.76	1620	13
22	Landfill 5	6.81	996	16
23	Landfill 5	6.83	1272	12
24	Fire Training Area 1	6.85	898	10
25	Landfill 2			12
26	Landfill 9 (Sand Hill)	7.1	973	11
27	Fire Training Area 2	6.97	970	12

the Coal Storage Pile (Zone 4) and at Landfills 11 and 12 (Zone 2). A fixed depth resistivity survey of the Coal Storage Pile was attempted on 7 December 1983. The purpose of this survey was to locate regions of contrasting electrical resistivities in the subsoils that may refect sensitive boundary conditions of acid leachate plume migration from the Coal Storage Pile. However, after multiple attempts to conduct the survey, below freezing temperatures (constantly draining the power source of the resistivity meter), and ground frost (inhibiting penetration of ground electrodes and limiting ground contact) the resistivity survey was aborted. Since the principle reason for conducting the resistivity survey was the correct selection of a monitor well site, and since drilling could not be postponed until warm weather, it was decided not to pursue the resistivity survey further.

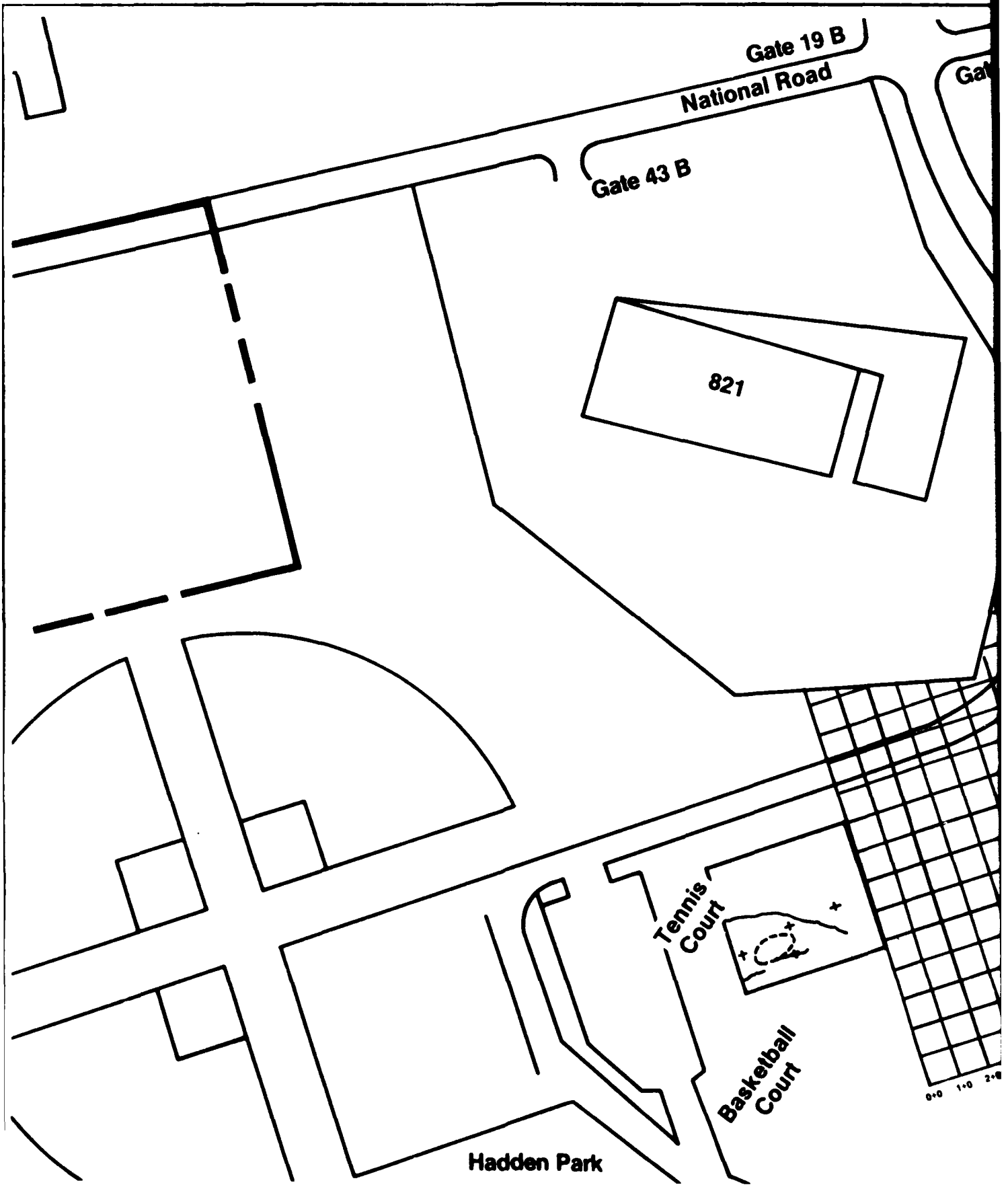
3.2.5.1 Objectives of the Geophysical Survey

The purpose of the geophysical surveying program was to identify, insofar as possible at the level of a confirmation survey, the location, depth and areal extent of disturbed areas and buried objects that may be associated with waste depositories in the immediate subsurface environment. The combination of Magnetometer and GPR response signatures indicated the presence of a variety of subsurface anomalies within Landfills 8 and 10.

The magnetic data were used to provide a semi-quantitative measure of the distribution of magnetic anomalies produced by subsurface metallic sources. The GPR provided qualitative information characteristic of the substructure and its components. Utilizing both geophysical techniques in an integrated approach allowed a rapid convergence of information necessary for assessing subsurface conditions within the two landfills. A correlation between data acquired by these two techniques is reported in the following Sections.

3.2.5.2 Magnetometer Survey

Magnetometer surveys of Landfills 8 and 10 were conducted on 2 November and 9 December 1983, respectively. A comprehensive magnetometer survey was conducted at Landfill 8 utilizing a 25' X 25' survey grid (see Figure 3-13). Magnetometer readings were measured at twenty-five foot mode spacings. Additional readings were taken outside of the survey grid at random locations to insure complete areal coverage of the site.


Gate 19 B
National Road
Gate 43 B
821
Tennis Court
Basketball Court
Hadden Park

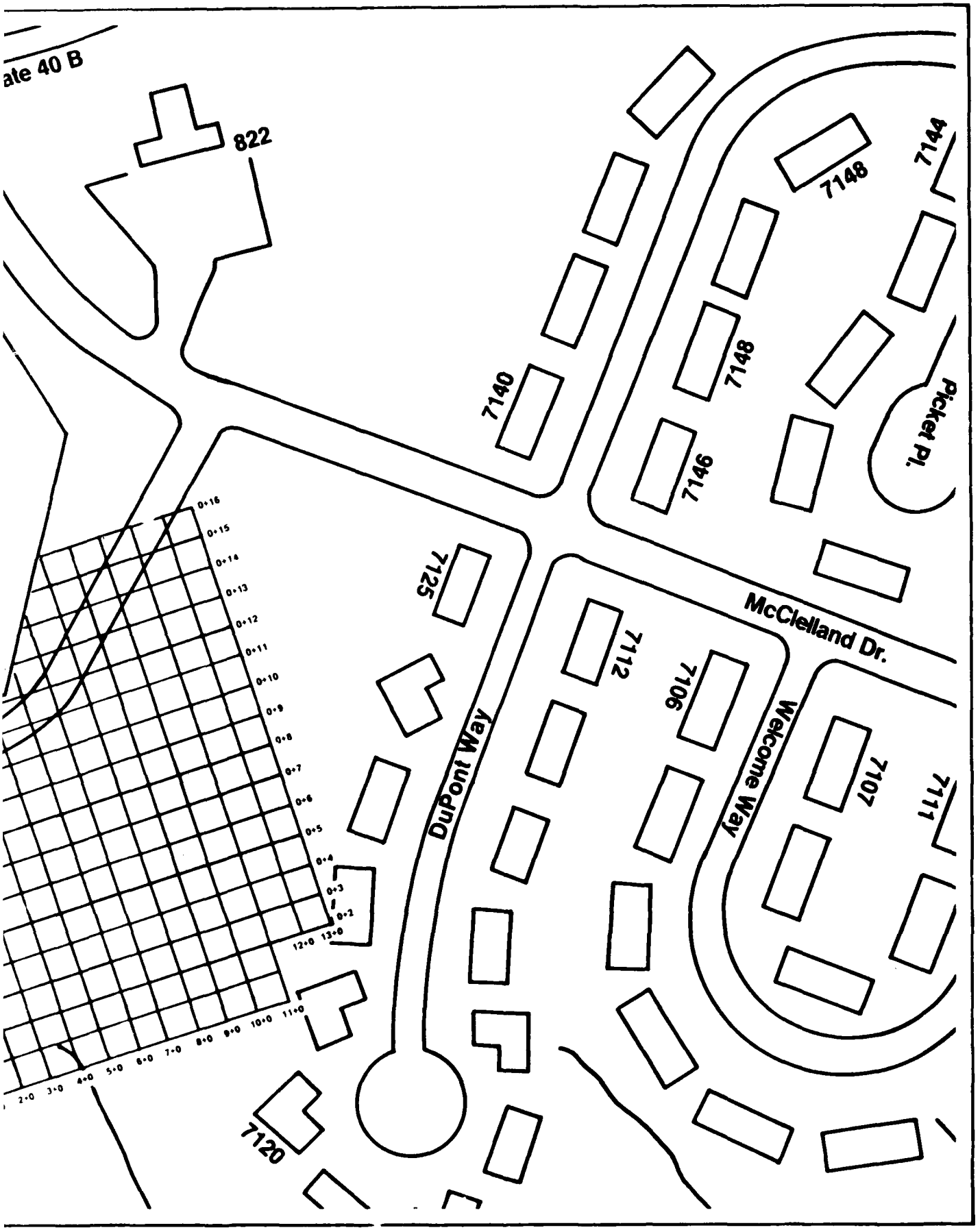


FIGURE 3-13 LANDFILL 8 - TRAVERSE GRID LAYOUT FOR GEOPHYSICAL SURVEY

Unfavorable surface conditions at Landfill 10 (ponded water, mud swales) were not conducive to conducting the survey in grid fashion. Since the magnetometer is responsive to these types of conditions, subsequently biasing the results, it was necessary to avoid these areas. This was accomplished by conducting a "random type" survey. Magnetic readings were measured throughout the site at approximately 25' to 50' intervals, covering the portion of the site that was accessable.

Background magnetic signatures were established at selected locations outside the survey areas where similar surface conditions existed. Magnetic signatures were measured at each grid node using a vertical field flux gate magnetometer. Results of these measurements were compared against ambient background signatures and magnetic anomaly maps were constructed.

3.2.5.3 Ground Penetrating Radar Survey

The Ground Penetrating Radar (GPR) Survey of Zone 1 (Landfill 8 and Landfill 10) was conducted by WESTON on 1 and 2 November and 3 and 4 November 1983 respectively. After establishing the survey grid the next step was to calibrate the GPR system. To calibrate the system either the dielectric constant (E_r) of the survey medium, or the depth to a particular object or interface must be known. Calibration of the Radar system was performed at Zone 1 using a two-step operation. Initial calibration was calculated using a dielectric constant (E_r) of 16, based upon on-site soil and moisture conditions (a heterogeneous mixture of moist clay, sands, and gravel). Next, for quality assurance purposes, calibration traverses were conducted over 1.5 feet diameter culvert buried at a measured depth of two feet. From this calibration procedure a vertical depth profile scale of 1" to approximately 1.9' was constructed. Subsequent to the system's calibration, survey traverses were conducted over the landfills. The product of the GPR Survey was a series of real-time subsurface graphic profiles. To standardize the data, identification marks were fixed on the profile for each traverse, at twenty-five foot intervals and grid intersections. Upon completion of the survey, the profiles were transported back to the WESTON lab for analysis and interpretation.

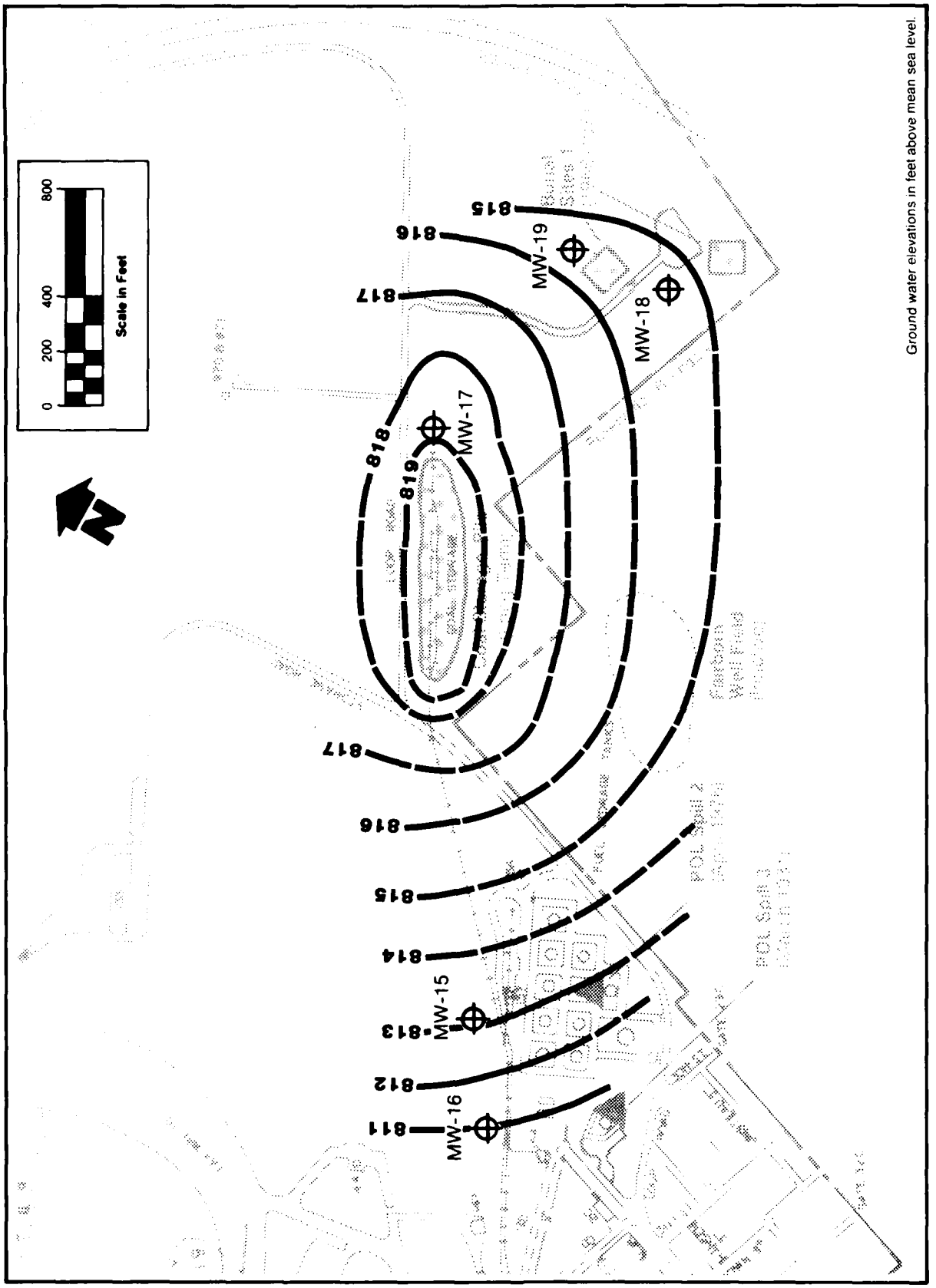


FIGURE 4-5 GROUNDWATER SURFACE MAP OF ZONE 4 (11-16 JUNE 1984 DATA)

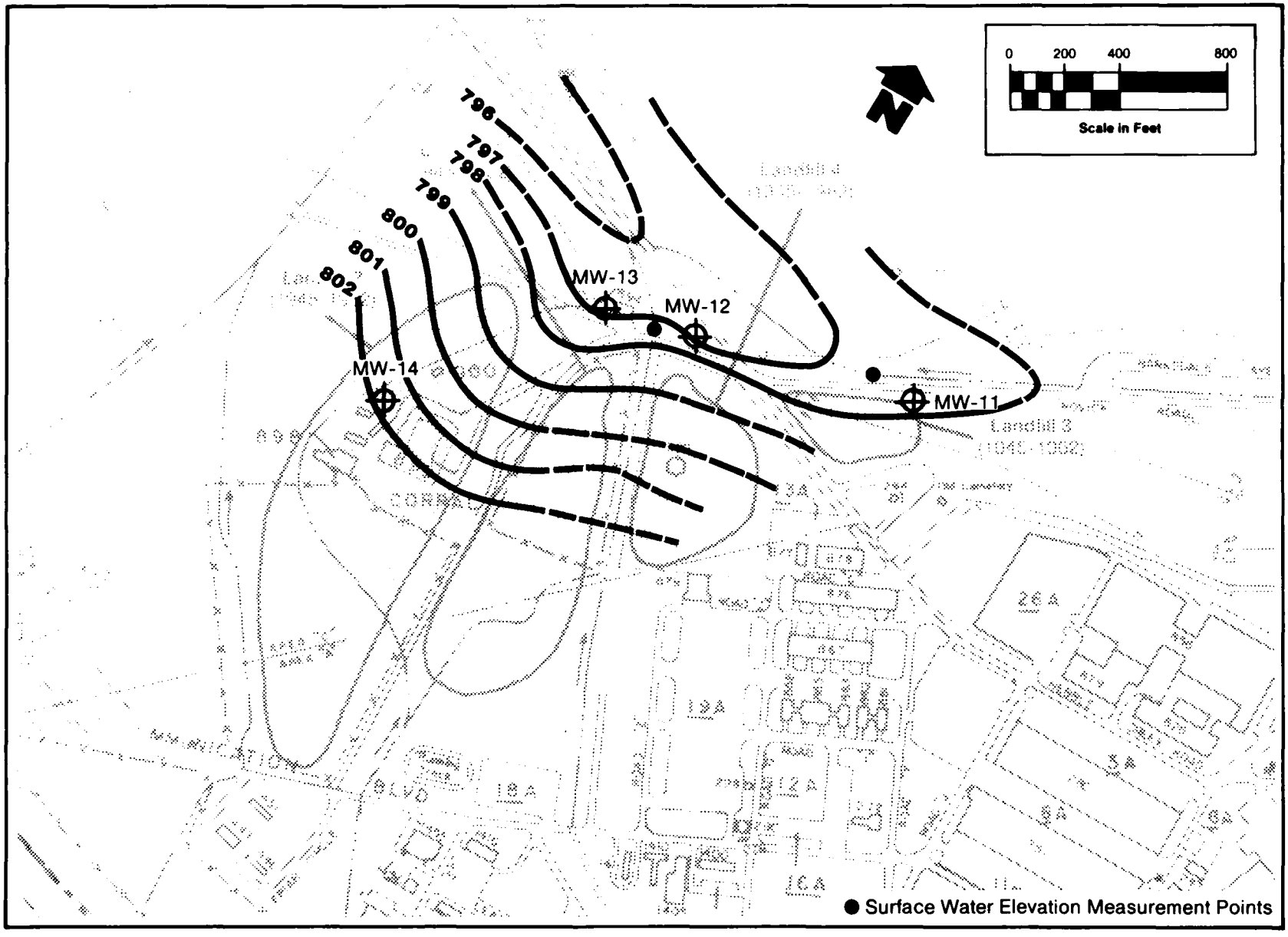


FIGURE 4-4 GROUNDWATER SURFACE MAP OF ZONE 3 (11-16 JUNE 1984 DATA)

configuration. From the map it can be seen that the principal flow direction within the Zone is toward the Mad River. Hydraulic gradients are generally low, with the maximum gradient being about 0.015. The borings in this Zone encountered highly permeable sands and gravels having an estimated hydraulic conductivity of from 10^{-2} cm/sec (10,000 ft/yr) to 10^{-1} cm/sec (100,000 ft/yr). Porosity of these materials is estimated at 30 percent. Thus, seepage velocities in the range of from 500 to 5,000 feet per year are expected in Zone 2. This means that any contaminants generated by sites within Zone 2 will: 1) be subject to very large dilution factors, due to the large volume of groundwater flowing beneath the Zone, and 2) will be transported very rapidly into the Mad River by ground-water discharge.

4.2.3 Zone 3 - Ground-Water Flow Conditions

The 11 to 16 June 1984 ground-water elevation data were used to contour a site specific water table map for Zone 3, as shown in Figure 4-4. In contouring this map it was assumed that the water table surface is continuous with surface water elevations surveyed at the marked measuring points. Solid contour lines indicate adequate data control between measuring points, while dashed contours indicate an inferred configuration. From the map it can be seen that the principal flow direction within the Zone is northerly across the landfills and then northwesterly following Hebble Creek. Hydraulic gradients are generally low, with the maximum gradient being about 0.005. The borings in this Zone encountered highly permeable sands and gravels having an estimated hydraulic conductivity from 10^{-2} cm/sec (10,000 ft/year) to 10^{-1} cm/sec (100,000 ft/yr). Porosity of these materials is estimated at 30 percent. Thus, seepage velocities in the range of from 170 to 1,700 feet per year are expected in Zone 3. This means that any contaminants generated by sites within Zone 3 will: 1) be subject to large dilution factors, due to the large volume of ground water flowing beneath the Zone, and 2) will be transmitted fairly rapidly (in only a few years) beyond the limits of the Zone and into the regional flow system.

4.2.4 Zone 4 - Ground-Water Flow Conditions

The 11 to 16 June 1984 ground-water elevation data were used to contour a site specific water table map for Zone 4, as shown in Figure 4-5. Solid contour lines indicate adequate data control between measuring points, while dashed contours indicate an inferred configuration. From the map it can be

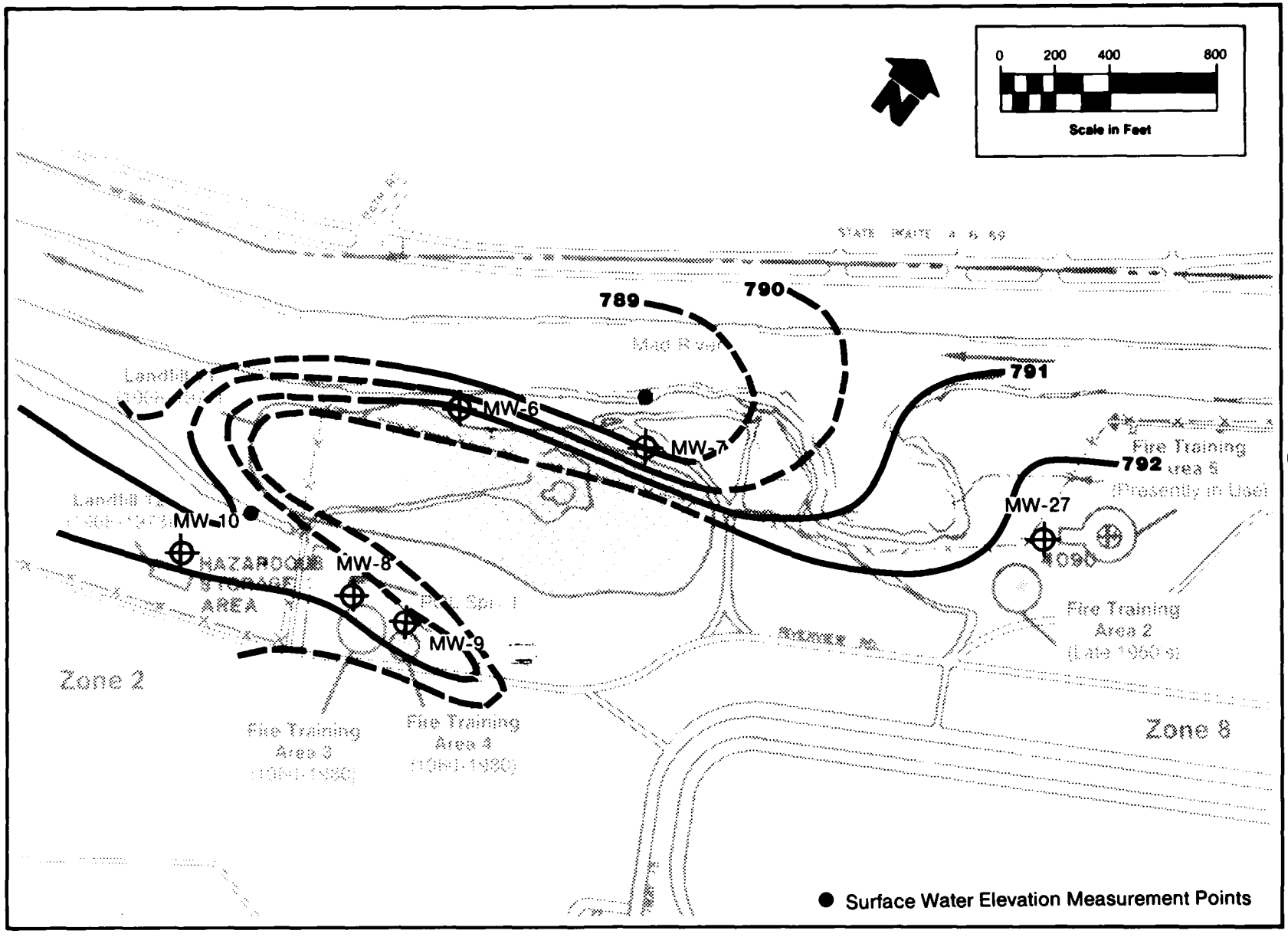


FIGURE 4-3 GROUNDWATER SURFACE MAP OF ZONE 2 (11-16 JUNE 1984 DATA)

$$v_s = \frac{Ki}{N_e}$$

Where: v_s = Seepage velocity (L/T)

K = Average hydraulic conductivity (L/T)
i = Hydraulic gradient (dimensionless)
N_e = Effective porosity (dimensionless)

In the absence of aquifer characteristics testing on site specific monitor wells, values for hydraulic conductivity (K) must be assumed based upon sediment grain-size distributions in the well screen zones. The materials penetrated in this zone were dominantly very rich in silty and clay, although some lenses of fine sands were encountered. A wide range of permeabilities is possible in this zone. Todd (1964) and Freeze and Cherry (1979) provide data relating grain-size distribution to hydraulic conductivity. From those references a reasonable range of hydraulic conductivities for Zone 1 is represented by K values from 10^{-6} cm/sec to 10^{-4} cm/sec. In more convenient units, this ranges is from approximately one to 100 feet per year. Assuming an average porosity (N_e) for till to be 25 percent, then substitution can be made of this value, the K values and the gradient values (i) noted above into the equation for seepage velocity. In this way, calculated seepage velocities for Zone 1 range from less than one foot per year to about 80 feet per year. In the vicinity of Landfill 8, where high gradients are combined with relatively low permeability materials, seepage velocities can be expected to be in the lower end of this range. In the vicinity of Landfill 10, where high gradients are combined with relatively higher permeabilities, seepage velocities can be expected in the upper end of this range. In the valley fill materials between the sites, lower hydraulic gradients are estimated on Figure 4-2, and seepage velocities on the order of 10 feet per year are expected.

4.2.2 Zone 2 - Ground-Water Flow Conditions

The 11 to 16 June 1984 ground-water elevation data were used to contour a site specific water table map for Zone 2, as shown in Figure 4-3. In contouring this map it was assumed that the water table surface is continuous with surface water elevations surveyed at the marked measuring points. Solid contour lines indicate adequate data control between measuring points, while dashed contours indicate an inferred

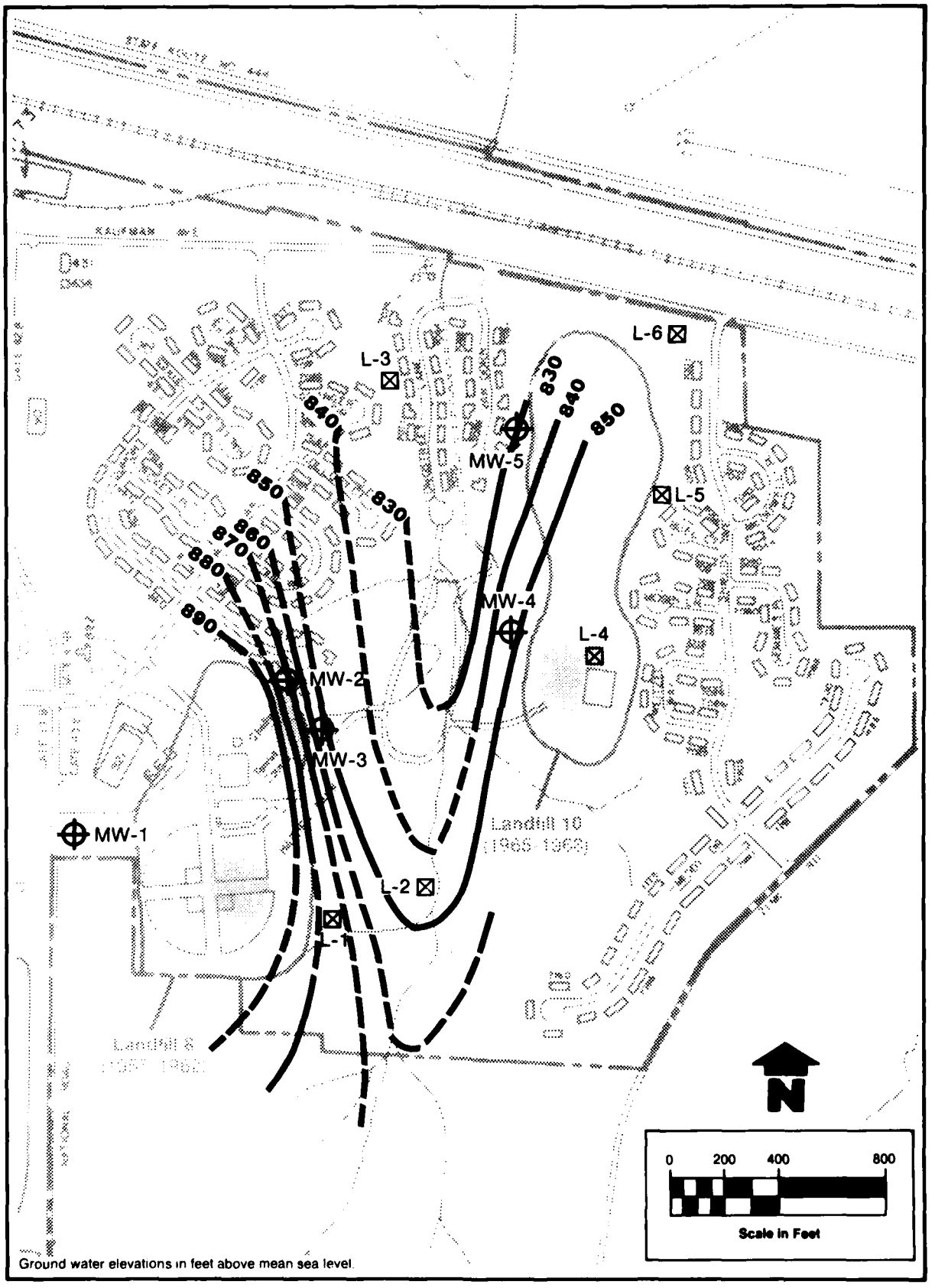


FIGURE 4-2 GROUNDWATER SURFACE MAP OF ZONE 1 (11-16 JUNE 1984 DATA)

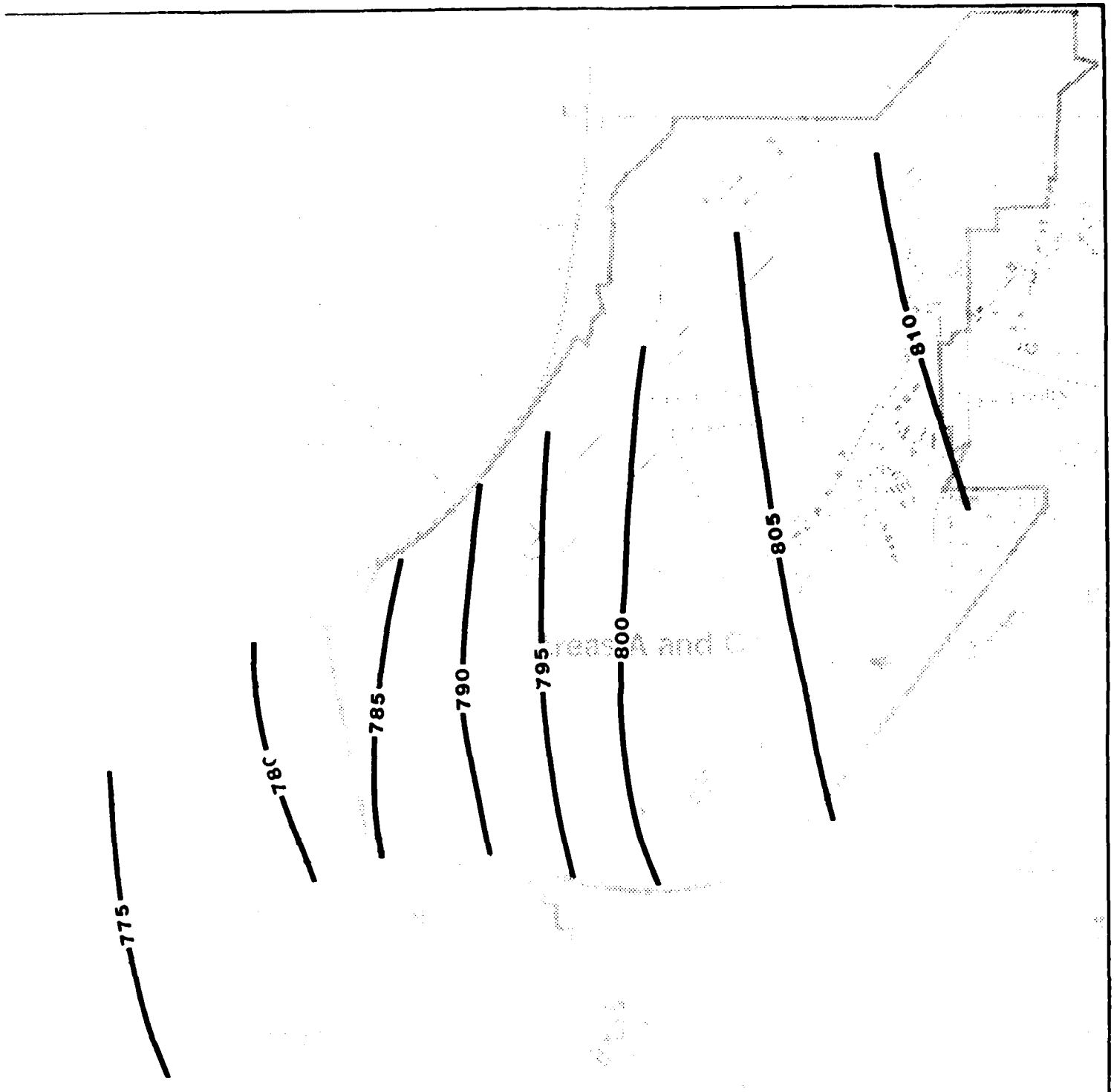
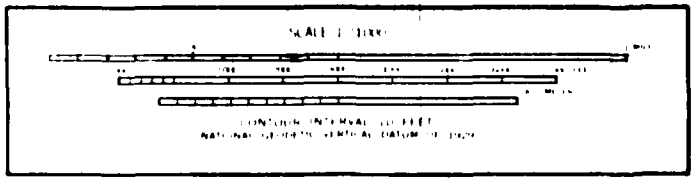
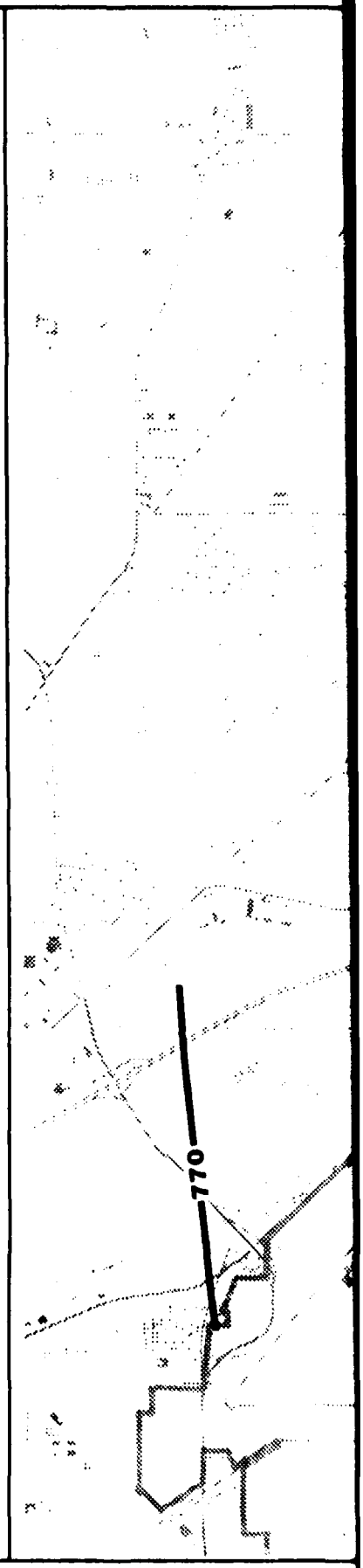


FIGURE 4-1 GENERAL GROUNDWATER SURFACE MAP OF WRIGHT PATTERSON AFB









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within Zones 2 through 8 (Zone 1 lies outside the valley-fill unconsolidated deposits) will join the regional flow pattern at some small distance from the source.

4.2 SITE GROUND-WATER CONDITIONS

The results of water level readings from the 27 newly installed monitor wells in eight zones at WPAFB indicate that ground water occurs under generally unconfined or water table conditions. Depths to ground water ranged from less than one foot to over 30 feet, and averaged approximately 13 feet. Water level data for the 27 wells from the 11 to 16 June 1984 round of measurements (Table 3-4) were plotted on a map of WPAFB, and the generalized ground-water surface map shown in Figure 4-1 was contoured from this Table. Zone 1 in Area B was not included in this map because it is not in the valley-fill, unconsolidated aquifer. It can be seen that the regional ground-water flow direction over most of WPAFB is to the west-southwest along the general axis of the Miami River Valley. Therefore, most ground water, flowing through as well as infiltrating within the Base boundaries, will flow in the general direction of the City of Dayton Rohrer's Island Wellfield.

4.2.1 Zone 1 - Ground-Water Flow Conditions

The 11 to 16 June 1984 ground-water elevation data were used to contour a site specific water table map for Zone 1, shown in Figure 4-2. Due to the fact that only five wells were used to monitor two large sites, the data coverage is inadequate to contour an accurate map, and Figure 4-2 was contoured using assumptions concerning the relationships among water table configuration, surface topography and surface drainage. Solid contour lines indicate adequate data control, while dashed contour lines indicate inferred contours. From Figure 4-2 it can be seen that principal flow directions follow topography toward the valley separating the two sites, and then turn northward toward the main part of the Base. As shown on the map, ground-water flow gradients are steep toward the surface drainageway separating the two sites. Water table gradients as high as 0.2 are documented by monitor Wells MW-2 and MW-3 for the northeastern side of Landfill 8, with lower gradients (0.1) associated with Landfill 10 and much lower gradients associated with the valley between the landfills (0.02).

The rate at which ground water migrates, or the seepage velocity, is calculated according to the formula:

SECTION 4

RESULTS OF THE FIELD INVESTIGATION

4.1 SITE INTERPRETIVE GEOLOGY

A detailed review of available geologic data obtained during the Records Search and subsequent on-site data generated during the Phase II investigation confirmed that WPAFB is underlain by unconsolidated sedimentary deposits. These deposits tended to group into two sediment types, a gravelly sand consistent with the interpretation of ice contact deposits, and a poorly sorted clayey, silty sand consistent with the interpretation of glacial till deposits. The sediment types penetrated, as documented in the boring logs contained in Appendix D, and the interpretation of their genesis, is consistent with the background material on descriptive geology presented in Section 2.

The unconsolidated deposits at WPAFB are far from homogeneous layers of outwash and till deposits; rather, the deposits penetrated in the upper 40 to 50 feet of the subsurface during Phase II drilling tend to be relatively thin units of interfingered fine and coarse-grained till and ice contact deposits. In some areas, such as in Zone 2 (MW-6) and Zone 4 (MW-17), the very fine-grained till and clay units are at or very near ground surface, thereby impeding infiltration from the surface. In other areas, such as Zone 2 (MW-9 and MW-10) and Zone 5 (MW-20 and MW-21), the coarse-grained ice contact deposits are at or very near the surface, thereby providing a direct recharge route for infiltration from the ground surface. In Zone 1 (MW-3) a low permeability till zone was encountered overlying a higher permeability sand and gravel layer, and water rose in the well under artesian pressure, indicating at least local confined conditions.

From the foregoing discussion it is apparent that local ground-water flow patterns are likely to be extremely variable and complex. However, considering the unconsolidated deposits as a whole, these materials will act as a single water producing aquifer, and complex local flow patterns will tend to be lost as a regional scale is attained. Thus, any contaminants entering the groundwater flow regime from sites

A second sampling of the leachate seeps for Total Organic Carbon (TOC) and Volatile Organic Compounds (VOA) was conducted on 31 July 1984. At this time, it was observed that two of the seeps on Landfill 10, L-4 and L-5, had been repaired by the WPAFB Civil Engineering Department after numerous complaints from nearby residents. The two seeps had been dug up and the soil replaced with stone to drain the leachate into the storm water system. The areas were then recovered with soil and seeded. No leachate was present at the ground surface in these two locations.

In order to collect samples of the leachate from these seeps, a bailer was lowered into the two storm water catch basins directly downgradient of the seeps, and a sample of the drainage was collected.

Each of the six seep locations (except L-2 which was dry at the time of sampling) was sampled separately for TOC. Composite samples for each of the two landfills were analyzed for volatile organic compounds.

3.2.7 Methane Gas Well Monitoring

The purpose of the methane gas well monitoring program was to determine if gases were being generated inside Landfills 8 and 10. Prior to drilling these wells, an area of gas seeps in the soil surface was discovered on Landfill 8, north of the tennis courts. The four gas monitor wells were drilled through the landfills in order to monitor any gas generation on other portions of the landfills. Installation of the wells was completed on 28 August 1984.

After completion, each well was monitored using three detector instruments; a MSA Combustible Gas Alarm, a Century Organic Vapor Analyzer, and a MSA Samplair pump with detector tubes for hydrogen sulfide. Results of this monitoring are discussed in Section 4.7.

Table 3-6
Description of Leachate Seep Sample Locations in Zone 1

Seep Number	Vicinity	Location and Description
L-1	Landfill 8	East of Landfill 8, on stream bank at base of landfill slope, oily and iron-stained.
L-2	Landfill 8	East of Landfill 8, next to stream northeast of L-1, oily.
L-3	Landfill 8	In side yard of home, 13 Longstreet Lane; iron-stained, seeping through concrete retaining wall.
L-4	Landfill 10	In small tree grove west of Weitzel Lane; large seep, oily, iron-stained.
L-5	Landfill 10	In back yard of house number 201/203 Buel Court; oily, iron-stained, very strong odor.
L-6	Landfill 10	Stormwater drainage culvert near intersection of Shields and Kauffman Sts., iron-stained.

3.2.6 Water Quality Sampling

Between 27 February and 4 March 1984 a complete round of ground-water samples was taken from the 27 monitor wells installed at Wright-Patterson AFB. In addition, liquid samples were collected on 3 May 1984 at each of six leachate seeps occurring at Landfills 8 and 10 in Zone 1. Samples from each well and seep were packaged and preserved according to analyses required at each sampling location and outlined in Section 3.1

3.2.6.1 Ground-Water Sampling

The purpose of the ground-water quality sampling program was to identify, insofar as possible at the level of a confirmation study, the location, concentration and areal extent of any contamination present in the hydrogeologic environment. From this information it would be possible to deduce the general direction in which these contaminants are migrating and their probable origin. To achieve these goals efficiently, specific field procedures were followed for purging the wells, collecting the samples, and ensuring field quality control. These procedures have been used to obtain a single complete set of representative samples for chemical analysis from the monitoring wells. The sampling and quality assurance plans used to accomplish these goals are contained in Appendix F. Sample chain-of-custody documentation is contained in Appendix G. Standard laboratory analysis protocols used in the analysis of these samples are contained in Appendix H.

3.2.6.2 Leachate Seep Sampling

The scope of work for Zone 1 included the collection of liquid from six leachate seeps on or near Landfills 8 and 10. During monitor well sampling in February and March, 1984, these two landfills were visually scanned for seeps but no active seeps were observed due to the cold weather. As the season progressed, a number of seeps began to appear on these landfills and were flowing heavily during April and May. The leachate seep sampling was conducted 3 May 1984, following a period of heavy rainfall. Three seeps in the vicinity of each of the two landfills were sampled by using a shovel to dig into the seep, allowing the sediment to settle, and then placing collection bottles directly under the flow. Locations of the seeps are shown on Figure 3-2, and descriptions of the locations are found on Table 3-6.

3.2.5.4 Geophysical Survey Analysis

Prior to tabulating and contouring the magnetic data, certain correction factors had to be applied. The (diurnal) daily variation of the earth's magnetic field had to be taken into account in reducing data taken with the field magnetometer. A diurnal variation curve and subsequently a correction factor was established for Zone 1 by returning to a pre-determined base station adjacent to Building 822 and taking readings at fixed intervals throughout the survey period. By plotting the reading at the base station against time, it was possible to construct a variation curve for each day's work.

WESTON used a Radian CPS-1 computer graphic contour plotting system to construct the contour solutions for the node locations surveyed. After the reduced magnetic readings were computer plotted and contoured on base maps of the landfills, a qualitative examination of the contour map was performed, and structural trends, discontinuities, and magnetic deviations were noted.

Analysis of GPR survey data involved the interpretation of each profile individually and then collective comparison of the results. The interpretation process had two objectives:

- Apply specific knowledge of known signature densities and configurations to the identification of pipes, drums, trenches, soil structures, discontinuities and surface disturbances.

- Identify trends and conditions by comparing standard profiles one to another. This process identified soil interfaces, buried utilities and groundwater data.

The GPR profiles produced as a result of this survey exhibited good resolution, defining variations in soil characteristics and pinpointing individual targets beneath the landfills. Upon incorporating the results from both surveys it was then possible to confirm or discount previously suspect anomalies. However, it must be kept in mind that, as with most remote sensing devices, certain data ambiguities do arise through a variety of mechanisms (e.g. structural interference, magnetic storms) which are beyond the control of the survey techniques. Raw data from the GPR surveys are contained in Appendix E.

seen that the regional flow direction is interrupted by mounding of ground water beneath the Coal Storage Pile. This mounding induces a southerly, off-Base component of flow. Hydraulic gradients are generally low, with the maximum gradient being about 0.004.

The borings in this Zone encountered highly permeable sands and gravels having an estimated hydraulic conductivity of from 10^{-2} cm/sec (10,000 ft/yr) to 10^{-1} cm/sec (100,000 ft/yr). Porosity of these materials is estimated at 30 percent. Thus, seepage velocities in the range of from 130 to 1,300 feet per year are expected in Zone 4. This means that any contaminants generated by sites within Zone 4 will: 1) be subject to large dilution factors, due to the large volume of ground-water flowing beneath the Zone, 2) will flow away from the site boundaries within a few years, and 3) have the potential to migrate in a southerly direction from the coal pile, in an off-Base direction, and cross the Base boundary within only two or three years of introduction into the ground water.

Well 10 in the adjacent Fairborn Well Field was shutdown reportedly due to chromimum contamination. It has been confirmed that Well 10 was shutdown, but the cause of the shutdown has not been confirmed. Other wells in this field were contaminated with jet fuel prior to inactivation.

4.2.5 Zone 5 - Ground-Water Flow Conditions

The 11 to 16 June 1984 ground-water elevation data were used to contour a site specific water table map for Zone 5, as shown in Figure 4-6. In contouring this map it was assumed that the water table surface is continuous with surface water elevations surveyed at the marked measuring points. From the map it can be seen that the principal flow direction within the Zone is westerly toward the Mad River. A measured elevation of 792.4 feet MSL for the static water level in Base Well F on Marl Road confirms the westerly flow direction. The static water level in this Base supply well is six feet above that of the closest monitor well (MW-23) installed approximately 2000 feet away on the eastern side of Landfill 5.

Hydraulic gradients are generally low, although steep gradients are encountered between the Twin Lakes and Hebble Creek. Gradients in the principal flow direction were low, with the dominant gradient being approximately 0.005. The

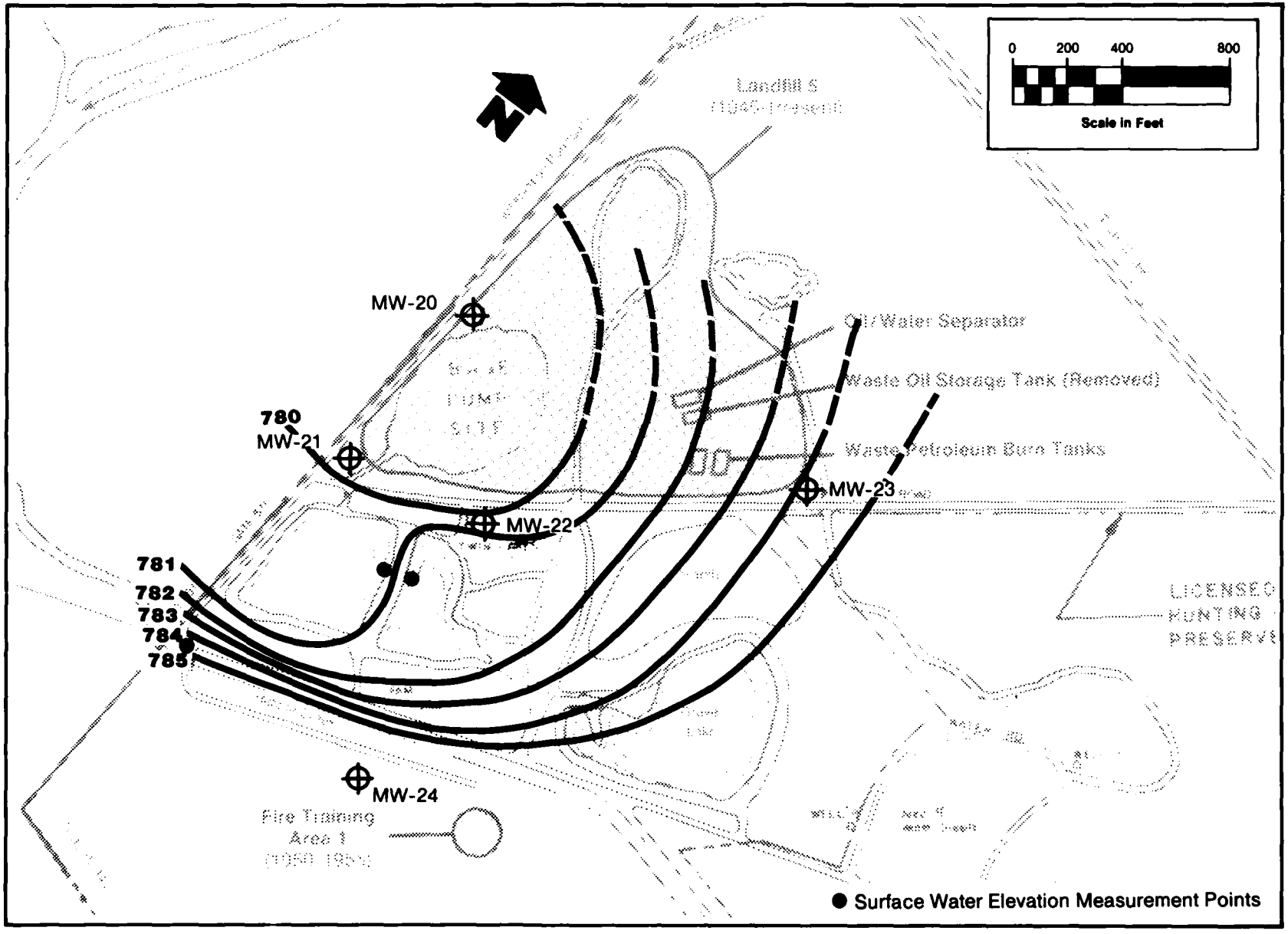


FIGURE 4-6 GROUNDWATER SURFACE MAP OF ZONE 5 (11-16 JUNE 1984 DATA)

borings in this Zone encountered highly permeable sands and gravels having an estimated hydraulic conductivity of from 10^{-2} cm/sec (10,000 ft/yr) to 10^{-1} cm/sec (100,000 ft/yr). Porosity of these materials is estimated at 30 percent. Thus, seepage velocities in the range of from 170 to 1,700 feet per year are expected in Zone 5. This means that any contaminants generated by sites within Zone 5 will: 1) be subject to large dilution factors, due to the large volume of ground-water flowing beneath the Zone, and 2) will be transported fairly rapidly in the direction of the Mad River.

4.2.6 Zone 6 - Ground-Water Flow Conditions

Only one monitor well was installed in this Zone, so no water table map could be contoured. The Zone lies in close proximity to the western boundary of the Base. From Figure 4-1, any contaminants generated by the landfill would enter the regional flow system and migrate to the west-southwest in an off-Base direction. The general regional gradient for the Base is low, between 0.001 and 0.002. Using the estimated hydraulic conductivity range of from 10,000 ft/yr to 100,000 ft/yr, the estimated regional seepage velocity is in the range of from 33 ft/yr to 670 ft/yr. Mounding of ground water from the landfill would increase the local gradient and would increase the site-specific seepage velocity. Therefore, any contaminants entering the ground water in this Zone have the potential for migrating across the Base boundary within a short time.

4.2.7 Zone 7 - Ground-Water Flow Conditions

Only one monitor well was installed in this Zone, so no water table map could be contoured. The Zone lies in close proximity to the eastern boundary of the Base. From Figure 4-1, any contaminants generated by the landfill would enter the regional flow system and migrate to the west-southwest in an on-Base direction. The general regional gradient for the Base is low, between 0.001 and 0.002. Using the estimated hydraulic conductivity range of from 10,000 ft/yr to 100,000 ft/yr, the estimated regional seepage velocity is in the range of from 33 ft/yr to 670 ft/yr. Mounding of ground water from the landfill would increase the local gradient and would increase the site-specific seepage velocity. Most contaminants which might enter the ground-water flow system

would migrate in an on-Base direction, unless local mounding occurs beneath the landfill. In this event, there would be a potential for fairly rapid migration for short distances in an off-Base direction before the regional gradient would reverse this flow trend back toward on-Base.

4.2.8 Zone 8 - Ground-Water Flow Conditions

This site is in close proximity to Zone 2, and the reader should refer to Section 4.2.2 for a discussion of ground-water flow conditions in Zone 8.

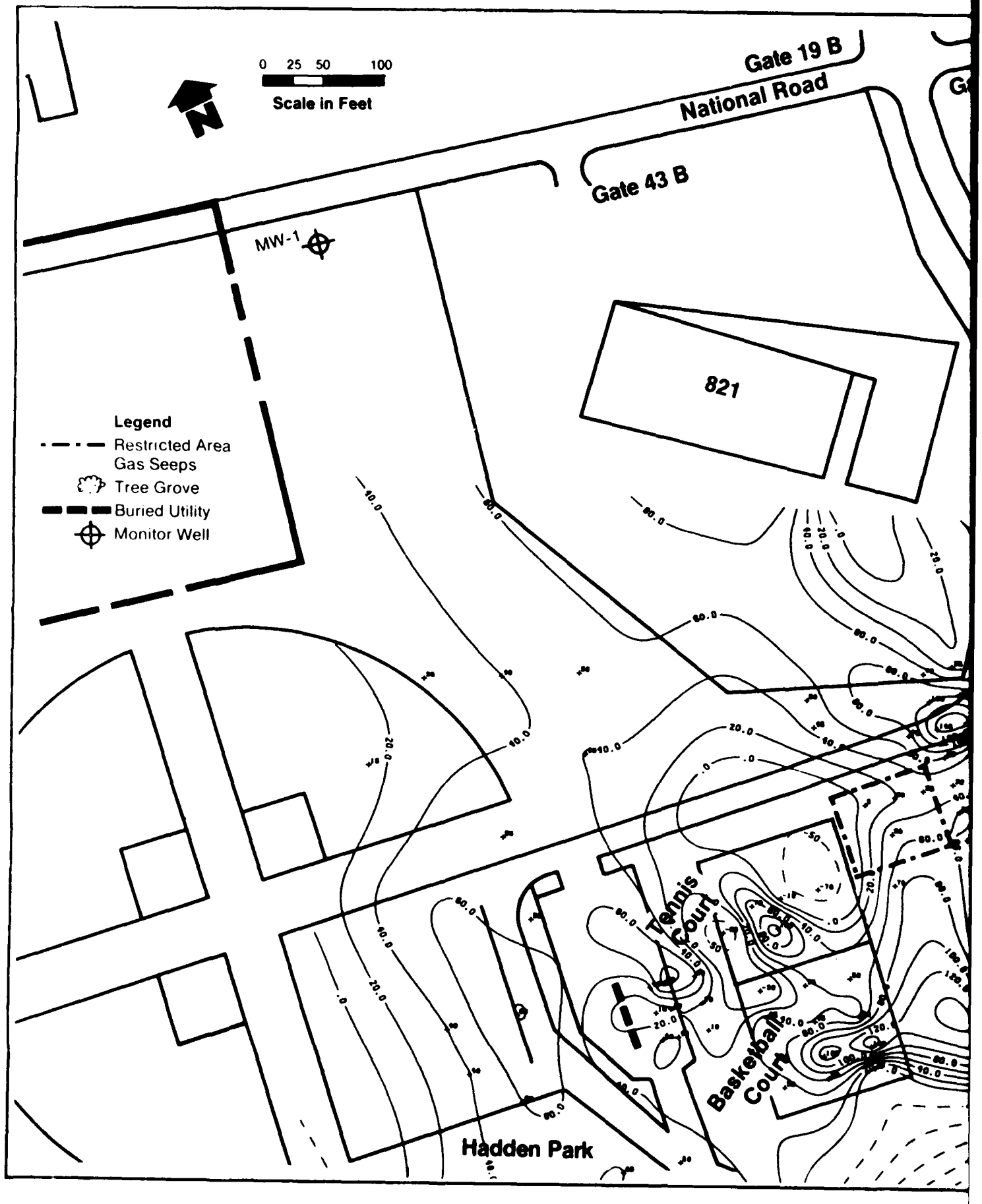
4.3 RESULTS OF THE GEOPHYSICAL INVESTIGATION

The magnetometer and Ground Penetrating Radar (GPR) surveys produce results which require individual interpretations. The interpretations of the data are enhanced by comparing the results of each method. The inherent limitations of any single technique of remote sensing can be lessened by cross-referencing two or more geophysical techniques. The following subsections describe the results of the geophysical survey.

4.3.1 Landfill 8 - Geophysical Investigation

Figure 4-7 shows the magnetic anomaly contour map of Landfill 8 developed from the vertical magnetic intensities obtained in the field. Magnetic highs and lows in the contour gradient are evident over a large portion of the site.

Magnetic relief observed over a sedimentary basin area is generally controlled by lithology. However, since there is little variation in lithology over the site area, these steep gradients and high relief in the magnetic contours are characteristic of local magnetic force fields generated by subsurface magnetic sources. Examples of these high relief contours are evident within the basketball court extending approximately 100 feet due east, on the southwest side of the tennis court, and in the area extending approximately 250 feet east and northeast of the restricted area immediately adjacent to the access road.


0 25 50 100
Scale in Feet
N
Gate 19 B
National Road
Gate 43 B
MW-1
821
Legend
Restricted Area
Gas Seeps
Tree Grove
Buried Utility
Monitor Well
Tennis Court
Basketball Court
Hadden Park

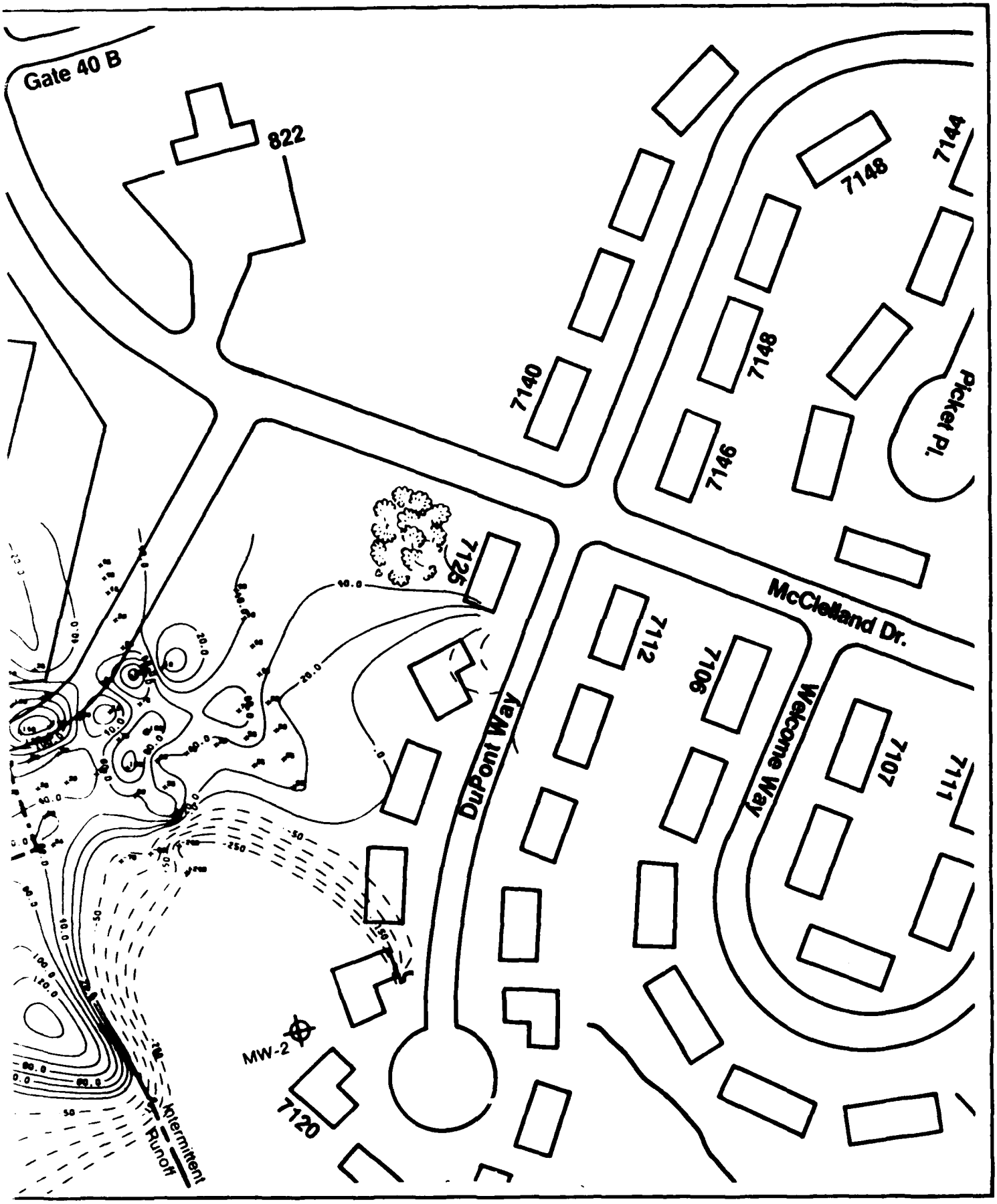


FIGURE 4-7 LANDFILL 8 - MAGNETIC ANOMALY MAP

2-2

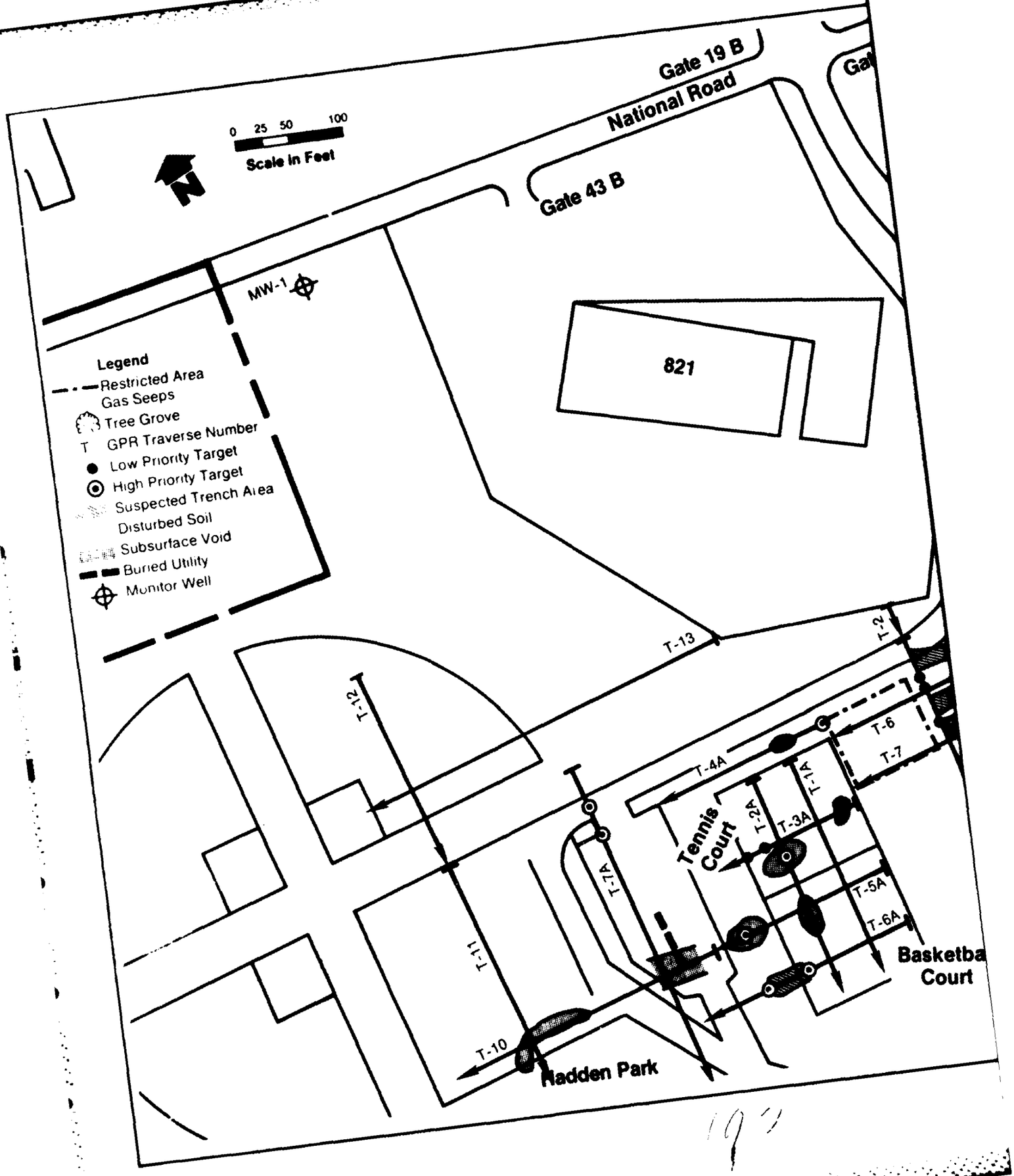
Figure 4-8 represents an interpretive subsurface plot map of Landfill 8, depicting the various subsurface phenomena encountered by the GPR. Individual targets were prioritized as either high or low depending upon the density and geometric configuration of the profile signature. These highly suspect targets are plotted on Figure 4-8. The raw data from which this figure was constructed are contained in Appendix E.

High priority targets were extremely good signal reflectors exhibiting a dense, parabolic signature. This type of signature is characteristic of rounded objects such as pipes, boulders, or drums. In contrast, the signatures produced by the low priority targets were characteristically less dense and more variable in geometric configuration. Occasionally this signature difference is a result of the orientation of the buried object with respect to the antenna traverse, (ie: a buried drum in a vertical plane with the ground surface, typically exhibits a hyperbolic signature).

Figure 4-8 also shows areas of disturbed subsoil and suspected trench locations. The plots of these phenomena were located as a result of collective interpretations of the GPR. The combination of the magnetometer and GPR data indicate a high probability for the presence of buried drums in several trenches and pits within Landfill 8.

4.3.2 Landfill 10 - Geophysical Investigation

Figure 4-9 represents the magnetic anomaly contour map of Landfill 10 generated from the magnetic intensities measured in the field. Contrasting magnetic highs and lows, similar to those detected at Landfill 8, exist throughout portions of the site. Examples of these high magnetic contour gradients are evident within the following areas: 1) approximately northwest and northeast of the basketball court; 2) the cul-de-sac west of the Buel Court extending northwest across the site to the "Scrap Metal Area"; 3) approximately 120 feet east of the Scrap Metal Area extending approximately 200 feet north; and 4) across the northern edge of the area investigated.


Gate 19 B
National Road
Gate 43 B
0 25 50 100
Scale in Feet
MW-1
821
Legend
Restricted Area
Gas Seeps
Tree Grove
T GPR Traverse Number
Low Priority Target
High Priority Target
Suspected Trench Area
Disturbed Soil
Subsurface Void
Buried Utility
Monitor Well
T-13
T-12
T-6
T-7
T-4A
T-1A
T-2A
T-3A
Tennis Court
T-7A
T-5A
T-6A
Basketba
Court
T-11
T-10
Hadden Park

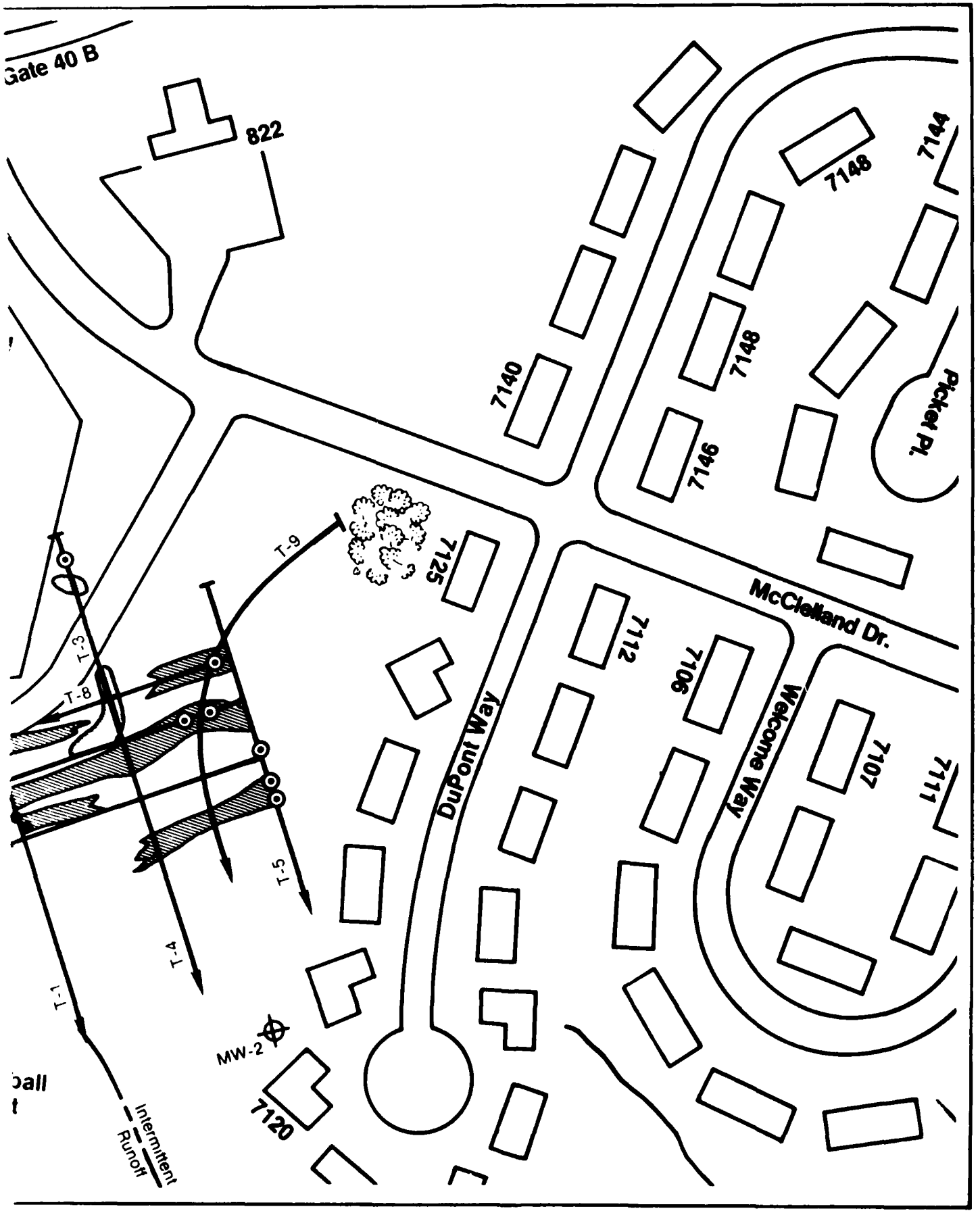
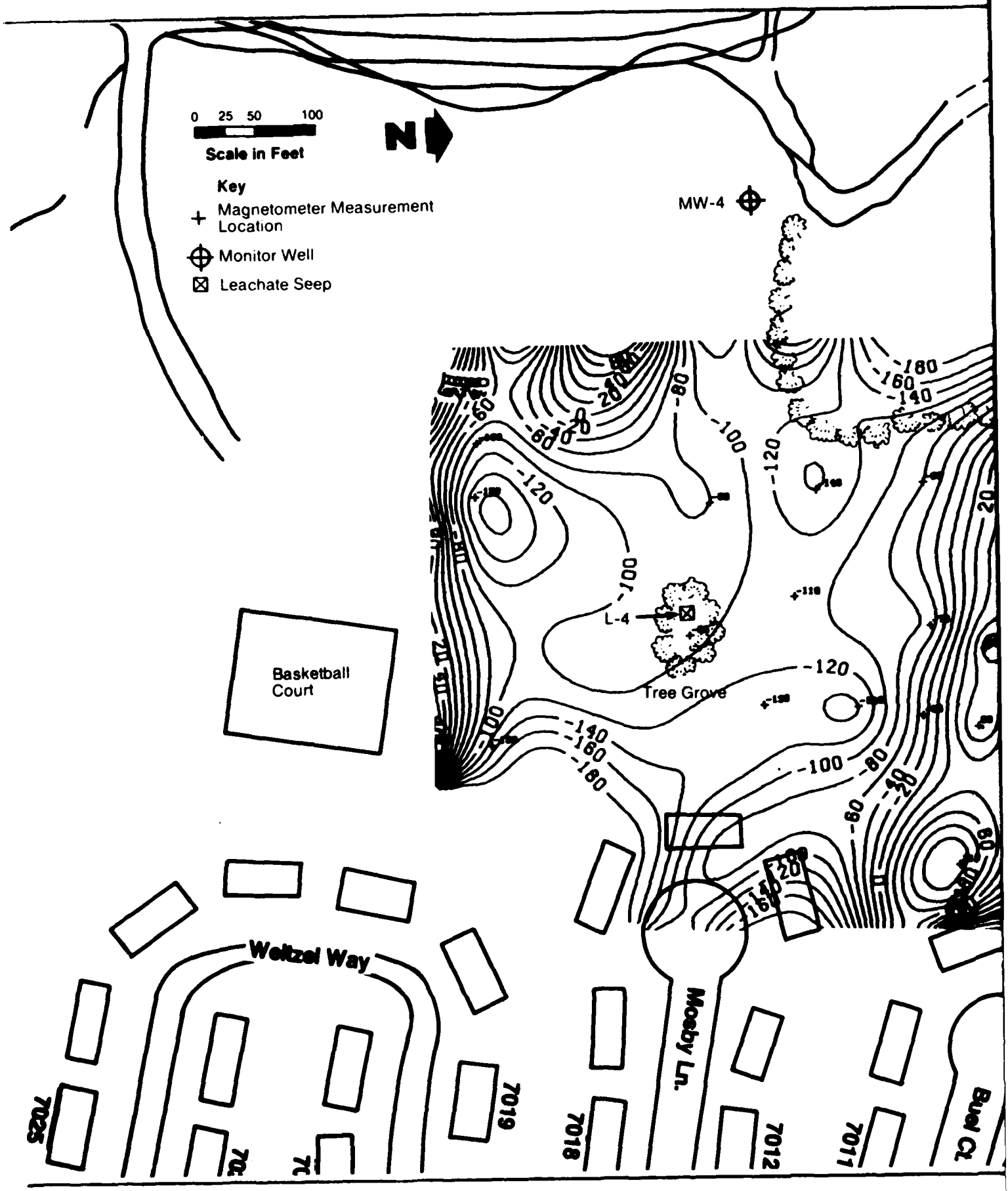


FIGURE 4-8 LANDFILL 8 - INTERPRETIVE MAP OF SUBSURFACE CONDITIONS BASED ON GROUND PENETRATING RADAR DATA


0 25 50 100
Scale in Feet
N
Key
Magnetometer Measurement Location
Monitor Well
Leachate Seep
MW-4
L-4
Basketball Court
Tree Grove
Weltzel Way
Mosby Ln.
Buel Ct.
7025
7021
7017
7019
7018
7012
7011
-20
-40
-60
-80
-100
-120
-140
-160
-180

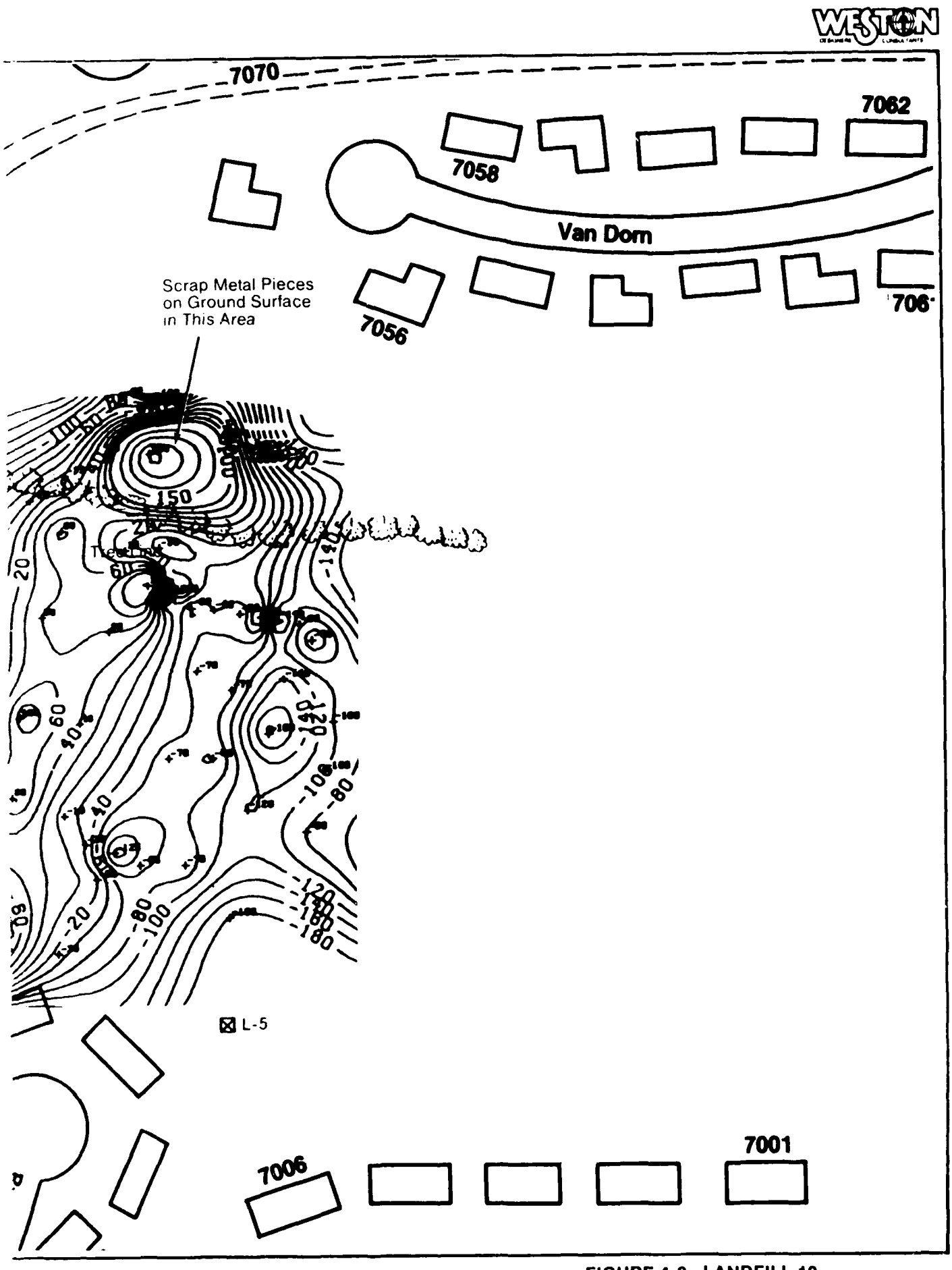


FIGURE 4-9 LANDFILL 10 -
MAGNETIC ANOMALY MAP

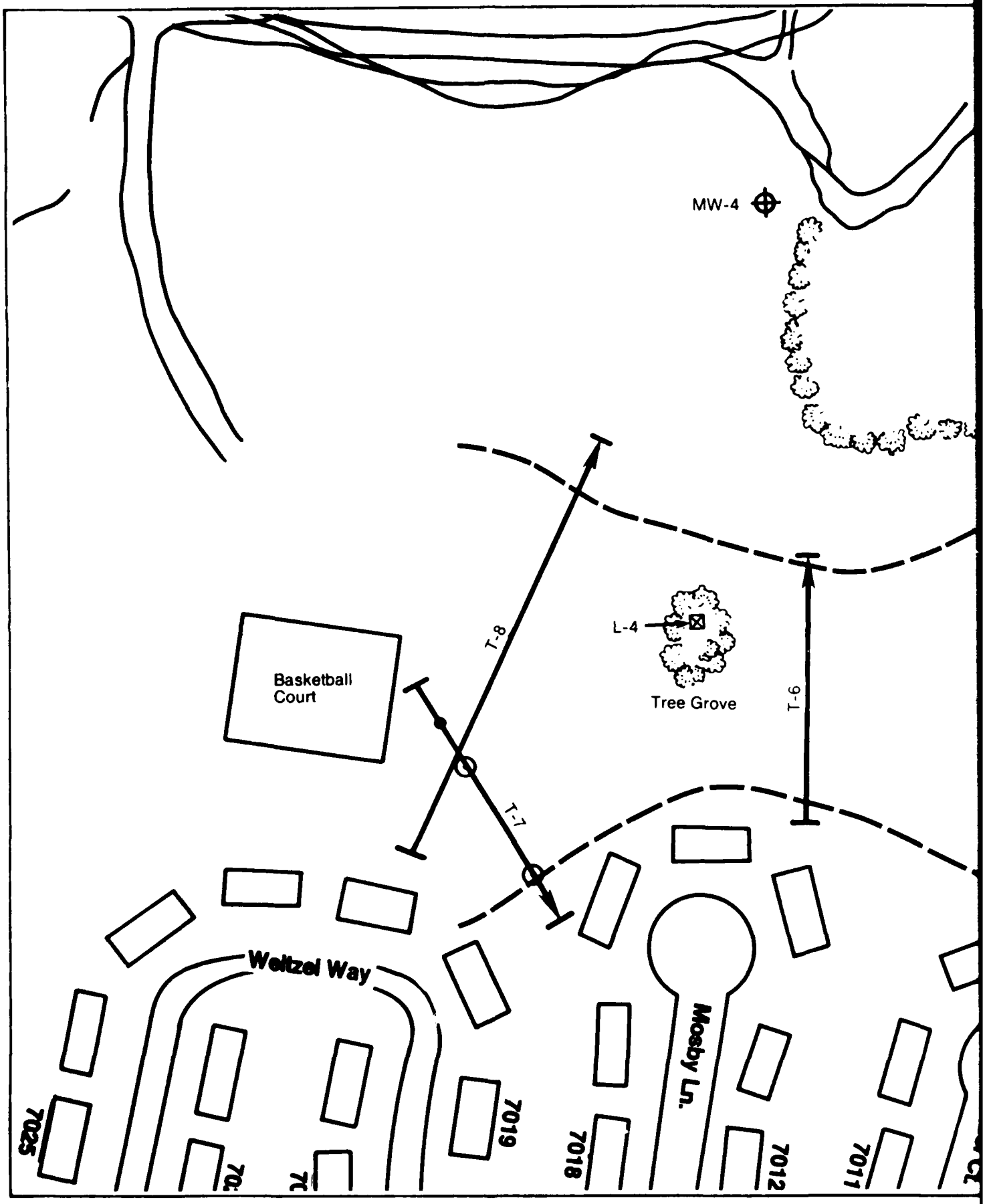
Figure 4-10 depicts an interpretive subsurface GPR plot map of Landfill 10. To standardize the interpretation, subsurface phenomena encountered were identified based on the same criteria discussed in Section 4.3.1. High priority, drum-like targets were detected along several of the transects. The raw data supporting this Figure are contained in Appendix E.

4.3.3 Summary of Geophysical Findings

When the magnetic anomaly maps are superimposed upon the GPR plot maps, similar subsurface trends are reflected. Most of the suspect trench and the disturbed soil areas are characterized by magnetically high contours. Individual targets are represented by varying magnetic contours and can only be located with some degree of confidence from the GPR plot maps.

A field inspection at Landfill 8 confirmed surficial features associated with the geophysical results. Symmetrical swales, or areas of differential settlement, were located in the area east and northeast of the restricted gas seep area, possibly the surficial expressions of former chemical trenches. The southwest gradient of the tennis court is presently undergoing subsidence and surface cracking as a result of a subsurface cavity. Surficial depressions within the basketball court exhibited high magnetic contour gradients. In general, varying degrees of disturbed subsoils and individual targets were located underlying the tennis and basketball courts and extending approximately 100 feet east, and in the restricted gas seep area extending approximately 250 feet east and northeast.

At Landfill 10 it is suspected that the high magnetic contour gradient and individual targets are local features of a broader fill depository extending beyond the survey area. Drum-like targets were found along several GPR transects, and a suspected chemical disposal trench was detected. The magnetometer data, because it encompasses a larger site area, is felt to be more definitive than the GPR data in indicating those areas in which drums may be buried.


MW-4
L-4
Tree Grove
T-8
T-7
T-6
Basketball Court
Weltzel Way
Mosby Ln.
7025
7019
7018
7012
7011

1 of 2

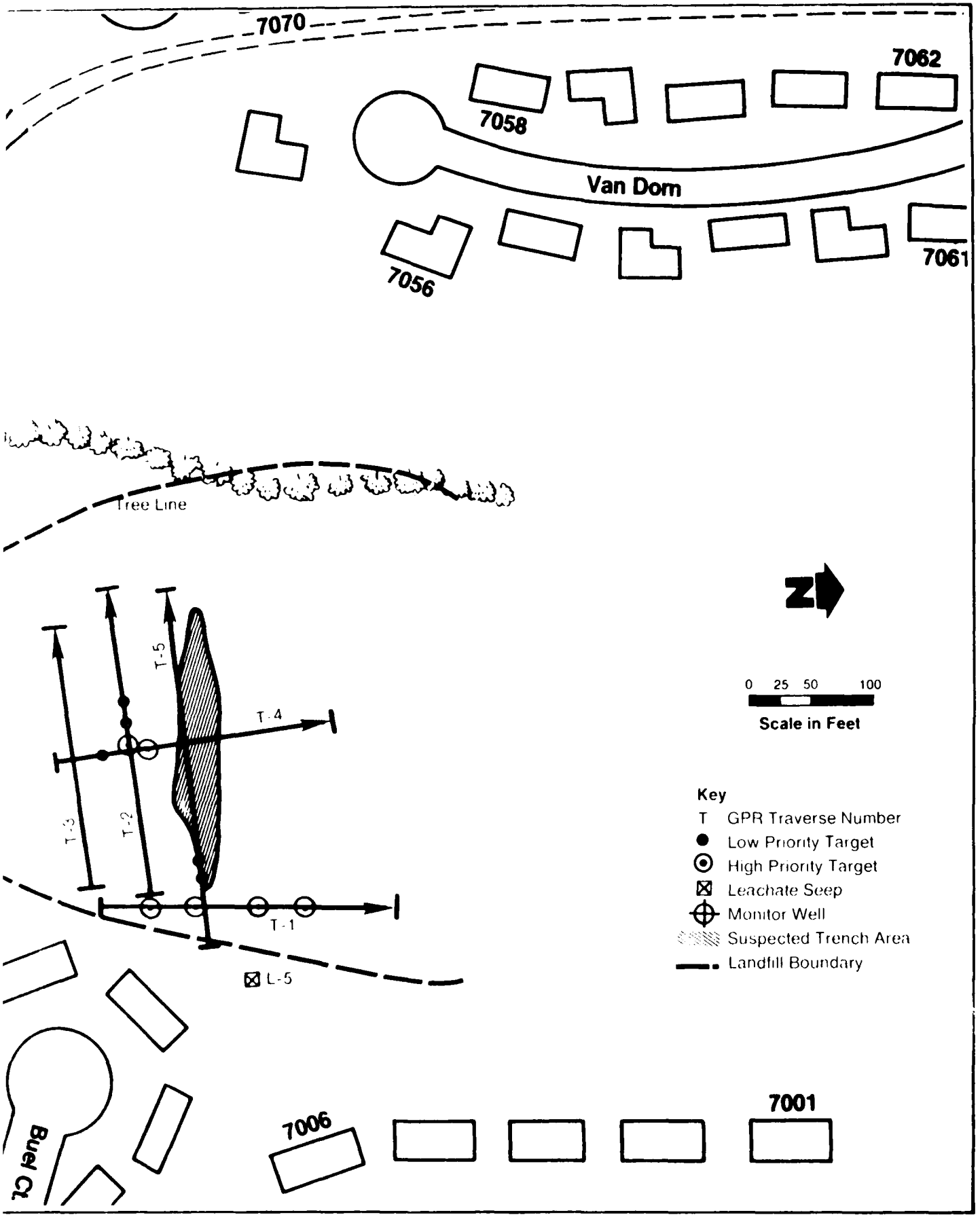


FIGURE 4-10 LANDFILL 10 - INTERPRETIVE MAP OF SUBSURFACE CONDITONS BASED ON GROUND PENETRATING RADAR DATA

TABLE 4-5

INSTRUMENTS USED FOR AIR QUALITY SCREENING
INSIDE METHANE MONITORING WELLS

MSA PORTABLE COMBUSTIBLE GAS ALARM, MODEL 100

The combustible gas meter determines the level of organic vapors and gases present in an atmosphere as a percentage of the lower explosive limit (% LEL) by measuring the change in electrical resistance in a Wheatstone Bridge circuit. The LEL is the lowest concentration of a gas or vapor in air, by volume, that will explode or burn when there is an ignition source. The alarm system can be set to activate when a specified LEL percentage is exceeded.

CENTURY PORTABLE ORGANIC VAPOR ANALYZER, MODEL OVA-128

The Organic Vapor Analyzer (OVA) utilizes a flame ionization detector which is sensitive to the presence of organic vapors delivered to it by means of a small diaphragm air pump. When an organic vapor is exposed to the hydrogen flame via the air flow, the molecules ionize and a current is carried between the detector electrodes. This current is then amplified and displayed by the meter. The meter response of the OVA is expressed relative to a standard (methane). Readings are in parts per million (ppm).

MSA SAMPLAIR PUMP, MODEL A, WITH MSA HYDROGEN SULFIDE DETECTOR TUBES CALIBRATED FOR THE 10-2000 PPM RANGE

The tubes used during this screening carried an expiration date of November 1984. This detector tube provides a quantitative method for estimating the concentration of hydrogen sulfide in air. Indication is based on the reaction of hydrogen sulfide with silver cyanide. Readings are in parts per million (ppm).

the Drinking Water Standard of 0.05 mg/l. MW-25 contained 26 mg/l of sodium. Total organic carbon (TOC) was found at 3.3 mg/l. No phenols or TOX (total organic halogen) were detected in MW-25. TOC and TOX are ground-water quality indicator parameters. Their significance is discussed in Section 4.6.

4.4.7 Zone 7 - Ground-Water Quality

Zone 7 contains one site, Landfill 9 (Sandhill), and one well, MW-26, to monitor that site. Results of the ground-water quality analysis of this well are shown on Tables 4-1 and 4-2. Nitrate was detected at 0.3 mg/l, below the Primary Drinking Water Standard of 10 mg/l. MW-26 contained 105 mg/l or sulfate, an amount below the Drinking Water Standard of 250 mg/l. No boron, iron or manganese was detected in this well. Sodium was found at a concentration of 14 mg/l. No phenol or TOX was detected in MW-26. TOC was found at 3.4 mg/l. TOC and TOX are water quality indicator parameters. Their significance is discussed in Section 4.6.

4.4.8 Zone 8 - Ground-Water Quality

Zone 8 contains one Phase II site, Fire Training Area 2. Well MW-27 was installed to detect any residual oils from the past operations at the site. Oil and grease was found in MW-27 at a level of 0.71 mg/l. This level is higher than the taste and odor threshold of 0.01 mg/l for oil and grease. No volatile organic compounds (VOA) were detected in ground water from MW-27.

4.5 RESULTS OF THE METHANE GAS WELL AIR QUALITY SCREENING

After installation of the four methane gas wells in Landfills 8 and 10, the air quality within the completed well casings was monitored using three screening instruments: an MSA Combustible Gas Alarm, Model 100; a Century Organic Vapor Analyzer, Model OVA-128; and a MSA Samplair Pump, Model A, with MSA Hydrogen Sulfide Detector Tubes. A brief discussion on the operation of these instruments is presented in Table 4-5.

0.60 to 1.25 mg/l, all above the Secondary Drinking Water Standard of 0.3 mg/l for iron. Manganese concentrations ranged from 0.016 to 1.89 mg/l in Wells MW-20, MW-21 and MW-23. All were above the Drinking Water Standard of 0.05 mg/l. Sodium was detected at levels of 11 to 19 mg/l in all four wells. Low concentrations of phenol were found in MW-20 and MW-21, at 0.014 and 0.011 mg/l. These levels are below the taste and odor threshold of 0.3 mg/l for phenol. TOC concentrations in the wells ranged from 2.7 to 12.1 mg/l. No TOX was found in MW-23. TOX levels of 5.4 and 6.8 ug/l were found in MW-22 and MW-20, respectively. Well MW-21 contained 94 ug/l of TOX. TOC and TOX are general indicator parameters of ground-water quality. Their significance is discussed in Section 4.6.

Well MW-24, also in Zone 5, was located downgradient of Fire Training Area 1 to intercept any residual oils in the ground water from this past operation. Oil and grease was found at a level of 0.21 mg/l in this well, an amount which is higher than the taste and odor threshold of 0.01 mg/l. Nitrate was not found in MW-24. Chloride and sulfate were detected at 54 and 65 mg/l, respectively. These levels are below the Secondary Drinking Water Standards for chloride and sulfate which are both 250 mg/l. Boron, iron and manganese were not found in this well. Sodium was detected at 9.0 mg/l. Phenol was found at 0.02 mg/l, a level below the taste and odor threshold of 0.3 mg/l. TOC was detected at 3.0 mg/l, but no TOX or volatile organic compounds (VOA) were detected in MW-24.

4.4.6 Zone 6 - Ground-Water Quality

Zone 6 contains one site, Landfill 2, and one well to monitor that site, MW-25. The results of the ground-water quality analyses from this well are shown on Tables 4-1and 4-2. Nitrate was not detected in this well. Chloride and sulfate were found in MW-25 at levels of 78 and 75 mg/l, respectively. These levels are below the Drinking Water Standards of 250 mg/l for both chloride and sulfate. No boron was detected in this well. Iron was found at a level of 0.15 mg/l, below the Drinking Water Standard of 0.3 mg/l. Manganese was detected at 0.06 mg/l in MW-25, slightly above

No VOA compounds were detected in MW-15; however, MW-16 contained 1.0 ug/l of 1,3 dichlorobenzene, 2.0 ug/l of ethylbenzene, 4.0 ug/l of toluene and 10.0 ug/l of 1,4-dichlorobenzene.

MW-17 was located near the long term coal storage pile to intercept any leachate generated off the pile. Ground water from MW-17 contained 85 mg/l of chloride and 114 mg/l of sulfate. The National Secondary Drinking Water Standard for both chloride and sulfate is 250 mg/l. Nitrate was detected at 2.20mg/l in this well , below the Primary Drinking Water Standard of 10 mg/l for nitrate. No boron, iron or manganese were found in MW-17. Sodium was detected at 35 mg/l in the well. Phenol, TOC and TOX were not found in MW-17. TOC and TOX are general indicators of ground-water quality. Their significance is discussed in Section 4.6.

Wells MW-18 and MW-19 monitor Burial Sites 1, where gasoline tank bottoms were buried. These wells contained 71 to 75 mg/l of chloride and 134 to 150 mg/l of sulfate. These levels are below the National Secondary Drinking Water Standard for chloride and sulfate which are both 250 mg/l. Nitrate was detected at levels of 1.8 and 1.82 in these wells. The Drinking Water Standard for nitrate is 10 mg/l. No boron, iron or manganese was found in these wells. Sodium was found at levels of 28 to 31 mg/l. No phenol, TOC or TOX was detected in MW-19. TOX was found at 5.2 mg/l in MW-18.

4.4.5 Zone 5 - Ground-Water Quality

Results of the ground-water quality analyses for Wells MW-20 through MW-24, all located in Zone 5, are presented on Tables 4-1 and 4-2. Wells MW-20 through MW-23 are located adjacent to Landfill 5 to intercept downgradient groundwater flow. These four wells contained 65.5 to 108.5 mg/l of chloride, all below the Secondary Drinking Water Standard of 250 mg/l. Sulfate was found in Well MW-22, at 65 mg/l, but the other three wells, MW-20, MW-21 and MW-23, contained sulfate levels of 210 to 260 mg/l, approaching and slightly above the Drinking Water Standard of 250 mg/l. Nitrate was not detected in any of these wells. Boron was found in only one well, MW-21, at 0.17 mg/l. Iron was detected in three of the wells, MW-21, MW-22 and MW-23, at levels ranging from

Wells MW-8 and MW-9 were analyzed for oil and grease and Volatile Organic Compounds. These two wells were found to contain 1.05 and 0.55 mg/l of oil and grease respectively. The taste and odor threshold for oil and grease is 0.01 mg/l. No volatile organic compounds were detected in the ground water from MW-8 and MW-9.

4.4.3 Zone 3 - Ground-Water Quality

The results of the ground-water quality analyses for Wells MW-11 through MW-14, located in Zone 3, are shown on Tables 4-1 and 4-2. The four wells in this zone, MW-11, 12, 13 and 14, are located downgradient of Landfills 3, 4, 6 and 7, respectively. Nitrate was detected in Wells MW-11 and MW-12 at levels of 2.05 and 0.14 mg/l, respectively. Chloride was found in all four wells at levels ranging from 113.5 to 250 mg/l. The Secondary Drinking Water Standard for chloride is 250 mg/l. Sulfate was detected at concentrations of 52.1 to 79.4 mg/l, all below the Drinking Water Standard of 250 mg/l. Boron was detected in Wells 13 and 14 at 0.14 to 0.27 mg/l. Iron was found at concentrations of 19 and 9.5 mg/l in Wells 13 and 14. Levels of sodium ranged from 30 to 90 mg/l in all four wells. Phenols were not found in any of the wells.

TOC concentrations ranged from 3.2 to 6.4 mg/l in Wells 12, 13 and 14. TOX was found at levels of 7 to 65 ug/l, also in Wells 12, 13 and 14. No TOC or TOX were detected in MW-11. TOC and TOX are general ground-water quality indicator parameters. Their significance is discussed in Section 4.6.

4.4.4 Zone 4 - Ground-Water Quality

Ground-water quality analyses for Wells MW-15 through MW-19, located in Zone 4, are shown in Tables 4-1 and 4-2. MW-15 and MW-16 are located downgradient of the POL Fuel Storage Tank Farm. They were placed to intercept residual oil that may have seeped into the ground water after two spills occurred in the Tank Farm Area. Water from the wells was analyzed for oil and grease and volatile organic compounds (VOA). Oil and grease was found at levels of 0.24 and 1.03 mg/l in MW-15 and MW-16, respectively. The taste and odor threshold for oil and grease is 0.01 mg/l.

TABLE 4-4

Summary of Groundwater Analyses for
USEPA Priority Pollutant VOA Compounds
(Methods 601 and 602)

Analyte	Detection Limit	MW-8	MW-9	MW-15	MW-16	MW-24	MW-27
Benzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromoform	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromomethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorobenzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorodibromomethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2-Chloroethyl vinyl ether	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Choromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichlorobenzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3-Dichlorobenzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,4-Dichlorobenzene	1.0	<1.0	<1.0	<1.0	10.0	<1.0	<1.0
Dichlorodifluoromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,2-Dichloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
cis-1,3-Dichloropropene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,3-Dichloropropene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	1.0	<1.0	<1.0	<1.0	2.0	<1.0	<1.0
Fluorotrichloromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	1.0	<1.0	<1.0	<1.0	4.0	<1.0	<1.0
Vinyl Chloride	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

*Concentrations are in ug/l.

400 ug/l of TOX respectively. The TOC levels in these seeps were 24.8, 1780.0 and 352.0 mg/l, respectively. The Landfill 10 leachate composite sample for volatile organic compounds contained 940 ug/l of acetone, 940 ug/l of 2-butanone (methylethyl ketone), 40 ug/l of 4-methyl-2-pentanone (methyl isobutyl ketone) and 10 ug/l of toluene. Toluene is on the U.S. Environmental Protection Agency's list of Priority Pollutants. The ambient water criterion for toluene is 14.3 ug/l. Acetone, methylethyl ketone and methyl isobutyl ketone are not listed on the EPA Priority Pollutant List; however, these compounds are industrial chemicals with established acute toxicity data in high concentrations (over 1000 mg/kg body weight). None of the ketones has been shown to have a high degree of chronic toxicity (Sax, N. Irving: 1979). The significance of TOX as a general indicator parameter will be discussed in Section 4.6.

4.4.2 Zone 2 - Ground-Water Quality

The results of the ground-water quality analyses for wells MW-6 through MW-10, located in Zone 2, are shown on Tables 4-1 and 4-4. MW-6 and MW-7 are located downgradient of Landfill 11. MW-10 is downgradient of Landfill 12. Nitrate was detected in MW-7 at 0.82 mg/l. This value is below the Primary Drinking Water Standard of 10 mg/l. Chloride was detected in all three of these wells at concentrations from 64.5 to 115 mg/l. Sulfate was also found in all three wells at 67.3 to 73.3 mg/l. These levels are below the Secondary Drinking Water Standards for chloride and sulfate, which are both 250 mg/l. No boron was detected in these three wells. Iron was found in wells MW-6 and MW-10 at 0.34 and 0.45 mg/l, levels which are slightly above the Secondary Drinking Water Standard for iron of 0.3 mg/l. Manganese was detected in all three wells at levels from 0.02 to 0.40 mg/l. Only MW-7, at 0.40 mg/l, was in excess of the Secondary Drinking Water Standard of 0.05 mg/l for manganese. Sodium was found in all three wells at concentrations of 24 to 27 mg/l. Total organic carbon (TOC) was found in MW-10 at 1.2 mg/l. TOC is a general indicator parameter and is not referenced to a specific standard. Phenols and TOX (total organic halogen) were not detected in Wells 6, 7 and 10. The significance of the general indicator parameters TOC and TOX is discussed in Section 4.6.

TABLE 4-3

Summary of Leachate Analyses
for Volatile Organic Compounds

Landfill 8, Leachate Seep Composite	
Acetone	25 ug/l
Landfill 10, Leachate Seep Composite	
Acetone	940 ug/l
2-Butanone (methylethyl ketone)	940 ug/l
4-Methyl- 2-Pentanone (methyl isobutyl ketone)	40 ug/l
Toluene	10 ug/l

Table 4-2 Summary of Leachate Analyses

Sample Number	Location	Specific Conductance (μmhos-cm)	Cl (mg/l)	SO_4 (mg/l)	B (mg/l)	Fe (mg/l)	TOX (ug/l)	TOC (mg/l)	Phenol (mg/l)
L1	Landfill 8	1760	50.2	550.0	0.56	9.9	44	14.1	< 0.01
L2	Landfill 8	1370	46.2	340.0	0.77	1.5	45	*	< 0.01
L3	Landfill 8	660	11.8	44.0	<0.10	125.0	12	2.33	< 0.01
L4	Landfill 10	1880	118.5	44.0	0.61	143.0	940	24.8	0.16
L5	Landfill 10	12100	1030.0	90.0	5.71	694.0	900	1780.0	2.06
L6	Landfill 10	1890	144.0	30.0	0.69	56.0	400	352.0	0.32
Detection Limit	-	1.0	1.0	1.0	0.10	0.1	5.0	2.0	0.01

* TOC Samples were collected 7/31/84. At that time, the site of L-2 was dry.

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Locations and numbers of the seeps are shown on Figure 3-2, and physical descriptions of each seep are presented in Table 3-6. A summary of the leachate analyses is found in Tables 4-2 and 4-3.

Leachate seeps L-1, L-2 and L-3 occurred downgradient of Landfill 8. Specific conductivity measurements on these seeps found levels of 660 to 1760 umhos/cm in the liquid leachate.

The seeps contained chloride levels of 11.8 to 50.2 mg/l, values which are below the Secondary Drinking Water Standard of 250 mg/l. Sulfate was found in L-3 at 44 mg/l and in L-1 and L-2 at 550 and 340 mg/l, respectively. The concentrations in L-1 and L-2 are above the Secondary Drinking Water Standard of 250 mg/l for sulfate. Boron concentrations of 0.56 and 0.77 mg/l were detected in L-1 and L-2. Iron was found in all three seeps at concentrations of 1.54 to 125 mg/l. These levels are well in excess of the Secondary Drinking Water Standard of 0.3 mg/l for iron. Phenols were not found in leachate from the three seeps downgradient of Landfill 8. Total organic halogen (TOX) was detected in the three Landfill 8 seeps at levels of 12 to 45 ug/l. Total organic carbon (TOC) was detected in the two sampled Landfill 8 seeps at levels of 14.1 and 2.33 mg/l. The Landfill 8 leachate composite sample for volatile organic compounds contained 24 ug/l of acetone. The significance of TOC and TOX as general indicator parameters is discussed in Section 4.6.

Leachate seeps L-4, L-5 and L-6 occurred downgradient of Landfill 10. Specific conductivity measurements on these seeps detected levels of 1880 to 12,100 umhos/cm in the liquid leachate. The seeps contained chloride levels of 118.5 to 1030 mg/l. L-5, at 1030 mg/l, was well above the Secondary Drinking Water Standard for chloride of 250 mg/l. Sulfate was found in the seeps at levels ranging from 44 to 90 mg/l, all below the Secondary Drinking Water Standard for sulfate of 250 mg/l. Boron was found at levels of 0.61 mg/l in L-4, 5.71 mg/l in L-5 and 0.69 mg/l in L-6. Iron concentrations ranged from 56 to 694 mg/l, well above the Secondary Drinking Water Standard of 0.3 mg/l. Phenols were detected in all three Landfill 10 seeps at levels of 0.159 to 2.06 mg/l. The taste and odor threshold for phenol is 0.3 mg/l. TOX (total organic halogen) levels in the Landfill 10 seeps were much higher than those in the Landfill 8 seeps. L-4, L-5 and L-6 contained 940, 900 and

Table 4 - 1

SUMMARY OF GROUNDWATER ANALYSES
WRIGHT-PATTERSON AFB

Well Number	Location Monitored	Nitrate (mg/L)	Cl (mg/L)	SO_4 (mg/L)	B (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	TOC (mg/L)	TOX (ug/L)	Phenol (mg/L)	Oil & Grease (mg/L)
20	Landfill 5	< 0.1	65.5	250.0	< 0.1	< 0.1	0.71	12	12.1	6.8	0.014	NR
21	Landfill 5	< 0.1	99.5	260	0.17	0.90	1.89	19	3.7	94.0	0.011	NR
22	Landfill 5	< 0.1	108.5	65	< 0.1	0.60	<0.05	12	5.3	5.4	< 0.01	NR
23	Landfill 5	< 0.1	92.5	210	< 0.1	1.25	0.16	11	4.0	<5	< 0.01	NR
24	Fire Training Area 1 (near garden plots)	< 0.1	54.0	65	< 0.1	< 0.1	<0.05	9	3.0	<5	0.020	0.21
25	Landfill 2 (Woodman Rd)	< 0.1	78.0	75	< 0.1	0.15	0.06	26	3.3	<5	< 0.01	NR
26	Landfill 9 (Sand Hill)	0.30	-	105	< 0.1	< 0.1	<0.05	14	3.4	<5	< 0.01	NR
27	Fire Training Area 2 (near present F.T. area)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.71
	Detection Limit	0.1	1.0	1.0	0.1	0.1	0.05	1.0	1.0	5.0	0.01	0.1

NR indicates not required by the Task Order

Table 4 - 1

SUMMARY OF GROUND WATER ANALYSES
WRIGHT-PATTERSON AFB

Well Number	Location Monitored	Nitrate (mg/L)	Cl (mg/L)	SO_4 (mg/L)	B (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	TOC (mg/L)	TOX (ug/L)	Phenol (mg/L)	Oil & Grease (mg/L)
11	Landfill 3 (golf course)	2.05	126.5	52.1	<0.1	<0.1	<0.05	36	<1.0	< 5	<0.01	NR
12	Landfill 4	0.14	250.0	79.4	<0.1	<0.1	<0.05	90	3.2	18.8	<0.01	NR
13	Landfill 6	<0.1	113.5	77.5	0.14	9.5	0.17	30	3.8	7.0	<0.01	NR
14	Landfill 7 horse barn)	<0.1	120.0	44.3	0.27	19.0	0.43	39	6.4	65.0	<0.01	NR
15	Tank Farm (Tank 256)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.24
16	Tank Farm (Tank 272)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1.03
17	Coal Storage Pile	2.20	85.0	114.0	<0.1	<0.1	<0.05	35	<1.0	<5	<0.01	NR
18	Chemical Burial Area	1.80	75.0	134.0	<0.1	<0.1	<0.05	31	<1.0	5.2	<0.01	NR
19	Chemical Burial Area	1.82	71.0	150.0	<0.1	<0.1	<0.05	28	<1.0	<5	<0.01	NR
	Detection Limit	0.1	1.0	1.0	0.1	0.1	0.05	1.0	1.0	5.0	0.01	0.1

Table 4 - 1

SUMMARY OF GROUND WATER ANALYSES
WRIGHT-PATTERSON AFB

Well Number	Location Monitored	Nitrate (mg/L)	Cl (mg/L)	SO_4 (mg/L)	B (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	TOC (mg/L)	TOX (ug/L)	Phenol (mg/L)	Oil & Grease (mg/L)
1	Upgradient Landfill 8	< 0.1	41.2	15.3	0.20	<0.1	<0.05	11.0	< 1.0	< 5	0.011	NR
2	Landfill 8	< 0.1	8.6	35.8	0.25	<0.1	<0.05	10.0	3.9	< 5	<0.01	NR
3	Landfill 8	< 0.1	15.4	< 1.0	0.11	<0.1	0.11	15.0	< 1.0	< 5	<0.01	NR
4	Landfill 10	< 0.1	34.8	104	<0.1	<0.1	0,12	10.0	7.9	< 5	<0.01	NR
5	Landfill 10	< 0.1	36.0	56.6	<0.1	<0.1	<0.05	27	< 1.0	< 5	<0.01	NR
6	Landfill 11	< 0.1	115.0	73.3	<0.1	0.34	<0.05	24	< 1.0	< 5	<0.01	NR
7	Landfill 11	0.82	97.0	67.3	<0.1	<0.1	0.40	24	< 1.0	< 5		NR
8	Fire Training Area	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1.05
9	Fire Training Area	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.55
10	Landfill 12	< 0.1	64.5	73.3	<0.1	0.45	<0.05	27	1.2	< 5	0.01	NR
	Detection Limit	0.1	1.0	1.0	0.1	0.1	0.05	1.0	1.0	5.0	0.01	0.1

4.4 WATER QUALITY ANALYSES

4.4.1 Zone 1 - Ground-Water and Leachate Quality

The results of the ground-water quality analyses for wells MW-1 through MW-5, located in Zone 1, are presented in Table 4-1. MW-1 is located upgradient of Landfill 8 and can, therefore, be considered a background well for Landfill 8. However, MW-1 may be influenced by other upgradient contaminant sources. MW-2 and MW-3 are located downgradient of Landfill 8, and MW-4 and MW-5 are located downgradient of Landfill 10.

Nitrate was not detected in any of the wells in Zone 1. Chloride was found in all five of the wells at concentrations ranging from 8.6 to 41.2 mg/l, all below the Secondary Drinking Water Standard of 250 mg/l. Sulfate was found in all the wells except MW-3 at concentrations ranging from 15.3 to 104 mg/l. These levels are below the Secondary Drinking Water Standard of 250 mg/l.

Boron, a leachate indicator parameter, was found in MW-1, MW-2 and MW-3 at low levels from 0.11 to 0.25 mg/l. There are no water quality standards regulating boron in drinking water. Manganese was detected in wells MW-3 and MW-4 at concentrations of 0.11 and 0.12 mg/l, in excess of the Secondary Drinking Water Standard of 0.05 mg/l. Iron was not detected in samples from any of the wells. Sodium was found in all five wells at levels ranging from 10 to 27 mg/l.

Phenols were detected in MW-1 at 0.011 mg/l, which is below the taste and odor threshold of 0.3 mg/l. TOC (total organic carbon) concentrations were found in MW-2 and MW-4 at 3.9 and 7.9 mg/l. TOC is a general water quality indicator and is not referenced to a specific standard. Total organic halogen (TOX) was not detected in the Zone 1 monitor wells. The significance of TOC and TOX as general indicator parameters is discussed in Section 4-6.

In addition to ground-water sampling in Zone 1, liquid from six leachate seeps was also sampled and analyzed. Three seeps on each landfill (Landfills 8 and 10) were sampled for chloride, sulfate, specific conductance, boron, iron, phenol, total organic carbon (TOC) and total organic halogen (TOX). A separate composite of leachate from each landfill was collected for volatile organic compounds analysis.

TABLE 4-6

METHANE MONITORING WELLS

Air Quality Screening Results
Inside Completed Wells

Well No.	Location	Monitor Probe Placement Below TOC* (inches)	MSA Combustible Gas Alarm M-100 (% LEL)	Century Organic Vapor Analyzer-128 (ppm)	MSA Samplair Pump with H_2S Detector Tubes (ppm)
GW-1	Hadden Park: Playground	1	14	>1000	
		12	25	>1000	<10
		24	36	>1000	
GW-2	Hadden Park: Field	1	7	120	
		12	8	400-700	<10
		24	12	>1000	
GW-3	Woodland Hills: West of Weitzel Way	1	9	160	
		12	12	>1000	<10
		24	16	>1000	
GW-4	Woodland Hills: West of Buel Court	1	17	>1000	
		12	32	>1000	<10
		24	36	>1000	

*Top of Casing

Results of the air quality screening inside the completed gas monitor wells are shown on Table 4-6. Hydrogen sulfide screening in the four wells did not cause any reaction in the detector tubes used, indicating that levels of this gas, if present at all, were below 10 mg/l. The other two instruments are calibrated on methane as a standard; however, the Organic Vapor Analyzer is a more sensitive instrument, measuring organic vapors in the part per million range as opposed to the percent range for the Combustible Gas Alarm. The results of the gas well screening indicate that gases containing organic compounds are being generated inside the two landfills at levels up to 1000+ parts per million.

At the same time the gas wells were monitored, the vent area north of the tennis courts on Landfill 8 was also screened using the same detector instruments. This area had been regraded and fenced by WPAFB Civil Engineering to reduce surface gas generation and restrict passersby from the immediate area. An examination of the ground surface inside the fence showed one area where the gas had broken through the new cover and was again discoloring the surrounding soil. Instrument readings directly over the open vent revealed 100 to 250 ppm on the Organic Vapor Analyzer and 25 to 50 ppm of hydrogen sulfide using the MSA Pump and Detector Tubes. At six inches above ground surface, the hydrogen sulfide level dropped to less than 10 ppm.

Further analytical work is needed in both the vent area and the gas monitor wells to define the composition of the gas, determine the degree of its potential health hazard to nearby residents and to control its emission from the landfills.

4.6 SIGNIFICANCE OF FINDINGS

4.6.1 Water Quality - General

The principal objective of the Phase II Confirmation Study was to determine whether past hazardous waste operations or disposal practices had resulted in environmental degradation. The analytical results of the Phase II study represent a single round of sampling of selected leachate seeps and newly installed monitor wells. The conclusions drawn from this information should be evaluated with this understanding.

Ground water and leachate water quality results are presented in Tables 4-1, 4-2, 4-3 and 4-4. Appendix I includes all analytical results from monitoring the Phase II sites. Appendix J contains a complete listing of Federal and State

drinking water and human health standards, criteria, and guidelines applicable in the State of Ohio.

In evaluating the significance of the chemical data, comparisons with background levels are often made. No background water quality wells were authorized for zones within the valley-train deposits (in which seven of the eight zones are located), so no direct comparisons with background well analyses are possible. Many analytes in Tables 4-1 throguh 4-4 were below detection limits in one or more wells, so it is reasonable to believe that background levels for those analytes are at or below the detection limit. Given that belief, then, levels of analytes well above the detection limit should be considered as potential contamination. For example, iron was below the detection level of 0.1 mg/l in 14 of the 22 wells tested for iron. Iron was detected at levels between 1.5 and 190 times the detection level in the other eight wells, and, at least in the more extreme cases, where the level detected exceeds the Secondary Safe Drinking Water Standard, these levels are being considered to represent contamination. A similar scenario can also be developed for manganese, where it was below the detection limit of 0.05 mg/l (also the Secondary Safe Drinking Water Standard) in 13 of the 22 wells tested. In the other nine wells manganese was detected at levels between 1.2 and 37.5 times the detection limit, and in the more extreme cases these levels are being considered to represent contamination.

On November 28, 1980, the U.S. Environmental Protection Agency issued criteria for 64 toxic pollutants or pollutant categories which could be found in surface waters. The criteria established recommended maximum concentrations for acute and chronic exposure to these pollutants by both humans and aquatic life. The derivation of these exposure values was based upon cancer risk, toxic properties, and organoleptic properties.

The limits set for the cancer risk are not based upon a safe level for carcinogens in water. The criteria state that for maximum protection for human health, the concentration should be zero. However, where this cannot be achieved, a range of concentrations corresponding to incremental cancer risks of from 1 to 10 million to 1 in 100,000 was presented (10^{-7} to 10^{-5}).

Toxic limits were established at levels for which no adverse effects would be produced. These are the health related limits which have been used in this report to evaluate potential impacts. It should be noted that the cancer risk column is based upon one cancer case in one million, (10^{-6}). The EPA's evaluation criteria under CERCLA (Annex XIII) for selecting contaminant levels to protect public

health call for the remedial action to "attain levels of contamination which represent an incremental risk of contracting cancer between 10^{-5} and 10^{-6})". The 10^{-6} value was used to achieve the maximum protection to the public.

In addition to the cancer risk assessment criteria, the U.S. EPA Office of Drinking Water provides advice on health effects upon request, concerning unregulated contaminants found in drinking water supplies. This information suggests the level of a contaminant in drinking water at which adverse health effects would not be anticipated with a margin of safety; it is called a SNARL (Suggested No Adverse Response Level). Normally values are provided for one-day, 10-day and longer-term exposure periods where available data exists. A SNARL does not condone the presence of a contaminant in drinking water, but rather provides useful information to assist in the setting of control priorities in cases when they have been found.

SNARLs are not legally enforceable standards. They are not issued as an official regulation, and they may or may not lead ultimately to the issuance of a national standard or Maximum Contamination Level (MCL). The latter must take into account occurrence and relative source contribution factors, in addition to health effects. It is quite conceivable that the concentration set for SNARL purposes might differ from an eventual MCL. The SNARLS may also change as additional information becomes available. In short, SNARLs are offered as advice to assist those who are dealing with specific contamination situations to protect public health.

The above information concerning SNARLs was taken directly from guidance documentation authorized by the EPA and made available to WESTON. The SNARLs levels for various compounds were also used in evaluating the results of ground and surface water sampling.

On June 12, 1984, the U.S. Environmental Protection Agency published a set of proposed rules under the Safe Drinking Water Act that would establish Recommended Maximum Contaminant Levels (RMCLs) for the following volatile synthetic organic chemicals (VOCs) in drinking water: trichloroethylene; tetrachloroethylene; carbon tetrachloride; 1,1,1-trichloroethane; vinyl chloride; 1,2-dichloroethane; benzene; 1,1-dichloroethylene; and p-dichlorobenzene.

RMCLs are non-enforceable health goals which are to be set at levels which would result in no known or anticipated adverse health effects with an adequate margin of safety. This proposal is the initial stage of rulemaking for the establishment of primary drinking water regulations for the VOCs. Following this proposal, Maximum Contaminant Levels (MCLs)

and monitoring/reporting requirements will be proposed when the RMCLs are promulgated. MCLs are enforceable standards and are to be set as close to the RMCLs as is feasible and are based upon health, treatment technologies, cost and other factors. It is anticipated that RMLCs for most of the above compounds would be set in the range of 5 to 50 ug/l. EPA anticipates proposing additional RMCL's for other VOC compounds in the near future.

4.5.2 Water Quality at Wright-Patterson AFB

A comparison of Wright-Patterson water quality results with applicable standards and guidelines is presented in Table 4-7. Detailed reference material is included in Appendix J.

Chloride was found in concentrations at or above the Drinking Water Standard in two locations: MW-12 in Zone 3 contained 250 mg/l of chloride, and L-5, a leachate seep on Landfill 10 in Zone 1, contained 1,030 mg/l of chloride. Sulfate was detected at levels at or above the drinking water standard in two wells and two leachate seeps as follows: MW-20 and MW-21, both in Zone 5, contained 250 and 260 mg/l of sulfate, respectively; leachate seeps L-1 and L-2, both from Landfill 8 in Zone 1, contained 550 and 340 mg/l of sulfate, respectively.

Of the metals included in the analysis, iron and manganese were found in concentrations exceeding drinking water standards. The Safe Drinking Water Act standard for iron is 0.3 mg/l. Eight monitor wells and all six leachate seeps sampled contained levels of iron above 0.3 mg/l as follows: in Zone 2, MW-6 and MW-10 contained 0.34 and 0.45 mg/l; in Zone 3, MW-13 and MW-14 contained 9.5 and 19 mg/l; in Zone 5, MW-21, MW-22 and MW-23 contained 0.90, 0.60 and 1.25 mg/l or iron, respectively. In Zone 1, all six leachate seeps sampled contained iron ranging from 1.5 to 694 mg/l. The Safe Drinking Water Act standard for manganese is 0.05 mg/l. Nine monitor wells contained levels of manganese above 0.05 mg/l as follows: in Zone 1, MW-3 and MW-4 contained 0.11 and 0.12 mg/l; in Zone 2, MW-7 contained 0.4 mg/l; in Zone 3, MW-13 and MW-14 contained 0.17 and 0.43 mg/l; in Zone 5, MW-20, MW-21 and MW-23 contained manganese ranging from 0.16 to 1.89 mg/l; in Zone 6, MW-25 contained 0.06 mg/l.

TABLE 4-7

COMPARISON OF WATER QUALITY RESULTS
WITH APPLICABLE STANDARDS, GUIDELINES AND CRITERIA

PARAMETER (mg/l Unless Noted)	WATER QUALITY STANDARD AND REFERENCE	MONITORING POINTS AT OR EXCEEDING STANDARD
pH (Standard Units)	6.5 - 8.5 (2)	MW-12
Nitrate	10.0 (1)	None
Chloride	250.0 (2)	MW-12, L-5
Sulfate	250.0 (2)	MW-20, MW-21, L-1, L-2
Iron	0.3 (2)	MW-6, MW-10, MW-13, MW-14, MW-21, MW-22, MW-23, L-1, L-2, L-3, L-4, L-5, L-6
Manganese	0.05 (2)	MW-3, MW-4, MW-7, MW-13, MW-14 MW-20, MW-21, MW-23, MW-25
TOC	None (4)	Not Applicable
TOX (ug/l)	None (4)	Not Applicable
Phenol	0.3 (3)	None
Oil and Grease	0.01 (3)	MW-15, MW-16, MW-24, MW-27

MW = Monitor Well

L = Leachate Seep

References for Water Quality Standards

(1) Federal Primary Drinking Water Standard
(2) Federal Secondary Drinking Water Standard
(3) Taste and Odor Threshold
(4) General Water Quality Indicator

Oil and grease was found in four wells at concentrations above the taste and odor threshold of 0.01 mg/l. Concentrations ranged from 0.55 to 1.03 mg/l. All four wells were located in areas of past POL spills or Fire Training activities.

No standards exist for the general indicator parameters TOC (total organic carbon) and TOX (total organic halogen). TOC is a generalized screening parameter used to detect organic contaminants. Background levels of TOC in ground water are usually below 1.0 mg/l, although it is not uncommon for TOC in a shallow water table aquifer to range up to 10 mg/l. When TOC concentrations rise above 10 mg/l there is an indication of contamination; however, the elevated levels may be caused by natural phenomena including vegetative decay. At Wright-Patterson AFB, only one well, MW-20, located in Zone 5, contained a TOC level higher than 10 mg/l. The concentration was 12.1 mg/l. The leachate seeps, however, contained TOC levels higher than 10 mg/l at the following locations: L-1 at 14.1 mg/l; L-4 at 24.8 mg/l; L-5 at 1780.0 mg/l; L-6 at 352.00 mg/l. TOX is an indicator parameter of halogenated organic compounds. These compounds are synthetic and do not occur naturally, so there is no natural background level in ground water for them. Any level of TOX indicates manmade chemical contamination. Because more than half of the USEPA list of volatile organic Priority Pollutants are halogenated, the TOX parameter provides a method of screening samples for these contaminants before proceeding to specific analyses. At Wright-Patterson AFB, TOX was detected in seven wells and all six leachate seeps sampled at levels ranging from 5.2 to 94 ug/l in the wells and 12 to 940 ug/l in the leachate seeps. Wells containing TOX were as follows: in Zone 3, MW-12, MW-13 and MW-14 contained 18.8, 7.0 and 65.0 ug/l of TOX respectively; in Zone 4, MW-18 contained 5.2 ug/l; in Zone 5, MW-20, MW-21 and MW-22 contained 6.8. 94.0 and 5.4 ug/l, respectively; In Zone 1 leachate seeps on Landfill 8 contained from 12 to 44 ug/l of TOX. Seeps on Landfill 10 contained from 400 to 940 ug/l of TOX. USEPA water quality criteria for Human Health

have been set for numerous compounds falling within the group contributing to TOX levels. Many of these standards are in the range of 1 ug/l or less. Thus, TOX concentrations in some well samples and all leachate samples from Wright-Patterson AFB indicate a high probability that these health criteria are exceeded in the case of one or more compounds.

Composite samples of leachate at Landfills 8 and 10 contained several volatile organic compounds, one of which (toluene) is included on the USEPA Priority Pollutant List. Toluene was found at 10 ug/l in the Landfill 10 leachate composite. In addition, the Landfill 10 composite sample included 940 ug/l each of acetone and methylethyl ketone, and 40 ug/l of methyl isobutyl ketone. The leachate composite sample from Landfill 8 contained 25 ug/l of acetone.

4.5.3 Conclusions

Based upon the results of the Phase II Stage 1 Confirmation Study conducted at WPAFB, the following key conclusions have been drawn:

1. Ground water occurs under shallow, water table conditions in and around all sites investigated. Base-wide regional ground-water gradients average between 0.001 and 0.002, reflecting the highly permeable, coarse-grained glacial outwash sediments underlying most of the Base. The hydraulic driving force for ground-water contaminant migration is fairly small, due to this low gradient, although the high hydraulic conductivities characteristic of much of the Base allow very rapid transport of large volumes of ground water.

2. The regional water table flow is generally west-southwesterly, in the same direction as the flow of the Mad River, toward the major City of Dayton wellfield at Rohrer's Island. Locally this regional flow trend is modified by creeks and by mounding induced either by landfilling or by storage of coal.

3. There exists a potential for off-Base migration of contaminants at several sites. Zones 2 and 8 are along the shore of the Mad River ground-water flow vectors are directly toward the river, and dissolved metals and Oil and Grease would be in transport in that direction. In Zone 3 the potential exists for shallow discharge of ground water contaminated with metals, nitrate, TOC and TOX into Hebble Creek and then into the Mad River. At Zone 4 a ground-water mound was detected in the vicinity of the Coal Storage Pile, and flow vectors indicate the potential for migration of groundwater contaminated with Oil and Grease, TOX and VOA compounds in a generally southerly off-Base direction. Flow vectors at Zone 5 indicate the potential for groundwater contaminated with metals, TOC and TOX to migrate from the landfill toward the nearby Mad River. At Zone 6 there is the possibility of ground-water mounding beneath the landfill, but even without such mounding the regional flow gradient would carry groundwater contaminated with metals and TOC across the adjacent Base boundary.

4. Measurable amounts of gases, including methane, hydrogen sulfide and trace amounts of organic compounds are being generated by both landfills in Zone 1. These seeps make both landfills potential health risks to residents immediately adjacent to the sites. Both sites are also generating leachate, which contains up to two USEPA Priority Pollutants and several non-priority pollutant volatile solvents, further aggravating the health hazard associated with these sites.

5. Results of the Zone 1 geophysical surveys on Landfills 8 and 10 indicated areas of high magnetic contour gradients, disturbed sub-

soil, suspected trenches, and buried drum-like targets on both the landfills.

6. The landfills in Zone 2 appear to be generating some leachate, although there is no analytical evidence of USEPA Priority Pollutant compounds being part of that leachate. Two wells in this Zone contained iron in excess of the Secondary Safe Drinking Water Standard, and one contained manganese in excess of the Secondary Safe Drinking Water Standard. Drums are present at Landfill 12.

7. Three landfills in Zone 3 appear to be generating leachate, and TOX analyses indicate that USEPA Priority Pollutant compounds may be present in the leachate. One well exceeded the Safe Drinking Water Standard for chloride, while two wells exceeded the Secondary Standards for iron and manganese.

8. Oil and grease was detected in monitor wells adjacent to the Spill Areas 2 and 3 in Zone 4 at levels above the aesthetic standard for taste and odor, although no floating hydrocarbon layer was detected. USEPA Priority Pollutant solvents were also detected in samples from one of these wells. Fuel contamination is apparent.

9. Landfill 5 in Zone 5 appears to be generating leachate, and TOX analyses indicate that USEPA Priority Pollutant compounds may be present in the leachate. One monitor well contained sulfate in excess of the Secondary Safe Drinking Water Standard, while three wells exceeded the Secondary Safe Drinking Water Standards for iron and manganese.

10. Landfill 2 in Zone 6 appears to be generating leachate, although there is no analytical evidence that USEPA Priority Pollutant compounds are part of that leachate. One well in the Zone contained manganese slightly in excess of the Secondary Safe Drinking Water Standard.

11. Landfill 9 in Zone 7 does not appear to be generating leachate.

SECTION 5

ALTERNATIVES

5.1 GENERAL

The principal goal of the Phase II, Stage I Confirmation Study at WPAFB was to determine whether or not environmental degradation was occurring as the result of past practices of materials handling or disposal at WPAFB. The conclusions presented in Section 4 confirm that each of the eight zones investigated have affected groundwater, surface water or soils in their immediate area. These are preliminary findings, based upon a single set of analyses, which require additional verification.

The alternative measures discussed below focus mainly upon problem definition aspects of environmental contamination detected at WPAFB. The alternative actions to be discussed at this point fall into the following categories:

ACTION	ZONES
1. Immediate referral for Phase IV remedial action	Zone 1 (Landfills 8 and 10)
2. Stage II Quantification Study water quality monitoring at existing monitor wells	Zone 2 through 8
3. Expanding the groundwater monitoring network	Zone 2 (Landfill 11) Zone 3 (Landfills 4,6 and 7) Zone 4 (Spills 2 and 3 Coal Storage Pile) Zone 5 (Landfill 5) Zone 6 (Landfill 2)
4. Establishing a surface water monitoring network	Zone 2 (Landfill 11) Zone 3 (Landfills 4,6 and 7) Zone 5 (Landfill 5) Zone 6 (Landfill 2)

5.	Expanded analytical protocol	Zones 2 through 7
6.	Actions to be undertaken by the base	Zone 2 (Landfill 11 and 12)

These alternative measures are discussed by zone in the following sections. Based upon the possible alternatives discussed here, specific recommendations are presented in Section 6.

5.1.1 Zone 1 - Alternative Measures

Zone 1 needs considerable additional evaluation with respect to groundwater impacts, transport of contaminants off-site in leachate and surface water, and generation of noxious and toxic gases. However, in view of the potential hazard to human health due to the proximity of residences in the immediate vicinity, Weston feels that Zone 1 should be referred immediately to Phase IV.

5.1.2 Zone 2 - Alternative Measures

Due to the location of this Zone, immediately adjacent to the Mad River, the analytical data obtained during Stage 1 should be verified with additional sampling and analysis. Two wells are not considered to be an adequate number to monitor the long flank of the landfill along the river, and additional monitor wells should be installed in order to ensure that other pollutants are not contained in leachate being generated. Surface water monitoring stations should be established along the small tributary separating landfills 11 and 12, in order to ensure that contaminants are not discharging to the Mad River via surface water. The base should initiate a post-closure monitoring program for Zone 2 monitoring wells to ensure early detection of pollutants which may discharge from the landfill in the future.

5.1.3 Zone 3 - Alternative Measures

An additional round of groundwater and analysis should be accomplished in this zone to verify the first round of results. Due to the elevated TOX levels, additional monitor

wells should be installed in order to evaluate the magnitude and extent of groundwater contamination. Surface water monitoring stations should be established along Hebble Creek and its tributaries in order to evaluate contaminant transport in surface waters. Samples of groundwater and surface water should be analyzed for an expanded list of analytes in order to characterize the chemical nature of contaminants. A preliminary concept engineering evaluation should be conducted with the purpose of attaining proper closure of the landfills and remediating any contaminant migration which has occurred.

5.1.4 Zone 4 - Alternative Measures

An additional round of sampling and analysis should be accomplished to verify the Stage 1 results. Additional groundwater monitoring wells should be installed in order to 1) quantify the magnitude and extent of contamination resulting from the fuel spills, and 2) to ensure that contaminants from the coal pile storage area are not migrating off-base to the south toward Fairfield. Groundwater samples should be analyzed for an expanded list of analytes in order to characterize the chemical nature of contaminants.

5.1.5 Zone 5 - Alternative Measures

An additional round of sampling and analysis should be accomplished to verify the Stage 1 results. Additional groundwater monitoring wells should be installed in the vicinity of Landfill 5 in order to quantify the magnitude and extent of contamination. Under Phase II, Stage 2, also establish monitoring west of Landfill 5 on Miami Conservancy District (MCD) property if off-Base work is required. Surface water monitoring stations should be established on Hebble Creek and the lakes in the zone in order to evaluate contaminant transport in surface waters. Samples of groundwater and surface water, as well as from the nearby base production wells, should be analyzed for an expanded list of analytes in order to characterize the chemical nature of contaminants.

5.1.6 Zone 6 - Alternative Measures

An additional round of sampling and analysis should be accomplished to verify the Stage 1 results. Due to the proximity of this site to the Base boundary and the potential for

off-Base migration of as-yet undetermined contaminants, either in ground water or in surface water, a limited additional evaluation program should be undertaken. Additional monitor wells should be installed along the western side of the landfill in order to ensure that any contamination that may be present is not flowing across the west base boundary. Surface water monitoring stations should be established along the creek running adjacent to the landfill in order to evaluate contaminant transport in surface waters. Samples of groundwater and surface water should be analyzed for an expanded list of analytes in order to characterize the chemical nature of contaminants.

5.1.7 Zone 7 - Alternative Measures

An additional round of sampling and analysis should be accomplished to verify the Stage 1 results. If the Stage 1 results are verified, then no further action is considered necessary in this zone.

5.1.8 Zone 8 - Alternative Measures

An additional round of sampling and analysis should be accomplished to verify the Stage 1 results. If the Stage 1 results are verified, then no further action is considered necessary in this zone.

Seepage Velocity	Rate of migration of groundwater
TAC	Tactical Air Command
Till	Nonsorted, nonstratified sediment carried or deposited by a glacier.
TOC	Total Organic Carbon
TOX	Total Organic Halogens, which are organic compounds containing any of the elements of Group Vii-b of the Periodic Table (F, Cl, Br, I)
ug/l	Micrograms per liter (equivalent to parts per billion in water).
umho/cm	Micromhos per centimeter (units of Specific Conductance).
Unconfined aquifer	An aquifer in which the water table surface forms the upper boundary of the aquifer.
Unconsolidated Sediments	Sediments that are uncemented and thus contain interconnected void space (primary porosity) that allow for the storage and transmission of groundwater.
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOA	Volatile Organic Compounds
WPAFB	Wright-Patterson Air Force Base

	site and waste characteristics, pathways of migration and potential receptors of contamination. The HARM system is used to indicate the realtive need for follow-up action.
Hydraulic Conductivity	Same as permeability. The rate at which groundwater moves through a geologic formation in a given interval of time under a given hydraulic gradient.
Hydraulic gradient	Change in pressure or head in the ground water over a given distance of flow
IRP	Installation Restoration Program
mg/l	Milligrams per liter (equivalent to parts per million in water).
mgd	Million gallons per day
MSL	Mean Sea Level Datum
N	North
OEHL	Occupational and Environmental Health Laboratory
Outwash	Drift deposited by meltwater streams beyond active glacier ice
pH	Negative logarithm of the hydrogen ion concentration in water.
P.G.	Registered Professional Geologist
Porosity	The ratio of the volume of pore spaces in rock or unconsolidated sediments to its total volume.
ppb	Parts per billion (equivalent to ug/l in water).
ppm	parts per million (equivalent to mg/l in water)
RCRA	Resource Conservation and Recovery Act

ACRONYMS, DEFINITIONS, NOMENCLATURE AND UNITS OF MEASUREMENT

Alluvium	Sedimentary deposits laid down through the actions of rivers.
ANG	Air National Guard
Artesian	Refers to ground water under sufficient hydrostatic pressure to rise above the aquifer containing it.
ASTM	American Society for Testing and Materials
Aquifer	Zone beneath the earth's surface capable of producing water for a well.
BGS	Below Ground Surface
CERCLA	Comprehensive Environmental Response Compensation and Liability Act of 1980
cm/s	Centimeters per second
Confined aquifer	The aquifer is confined between two less permable beds in a stratigraphic sequence
DEQPPM	Defense Environmental Quality Program Policy Memorandum
DPDO	Defense Property Disposal Office
DoD	Department of Defense
Ground Water Divide	A line on the water table on each side of which the ground water table slopes away from the line.
Ground Water Surface	The level below which the earth is saturated.
HARM	Hazard Assessment Rating Methodology. A numerical scoring system used to evaluate potentially contaminated sites. The system takes into account

APPENDIX A

ACRONYMS, DEFINITIONS, NOMENCLATURE AND UNITS OF MEASUREMENT

LIST OF REFERENCES

Engineering-Science, Inc., 1982, Installation Restoration Program, Phase I Records Search, Final Report: prepared for U.S. Air Force AFESC/DEV, Tyndall AFB, Florida, February 1982, 93 p. plus appendicies.

Norris, S.E., and Spieker, A. M., 1966, Ground-Water Resources of the Dayton Area, Ohio: U.S. Geological Survey Water-Supply Paper 1808, U.S. Government Printing Office, Washington, D.C., 167 p plus plates.

LIST OF REFERENCES

Table 6-1, Summary of Recommendations (cont.)

Zone	Recommendations	Rationale
4	Resample existing wells	Verify Stage 1 results
	Install 7 additional monitor wells	Spill plume evaluation and Base boundary monitoring
	Sampling and analysis	Determine Magnitude and extent of contamination
5	Resample existing wells	Verify Stage 1 results
	Install 5 additional monitor wells	Establish effective groundwater monitoring
	Priority pollutant screening	Leachate characterization
	Surface water and sediment monitoring	Evaluate transport of contamination
	Sampling and analysis	Magnitude and extent of contamination
6	Resample existing well	Verify Stage 1 results
	Install 2 additional monitor wells	Expanded monitoring at Base boundary
	Surface water and sediment monitoring	Evaluate transport of contaminants
	Sampling and analysis	Magnitude and extent of contamination
7	Resample existing well	Verify Stage 1 results
8	Resample existing well	Verify Stage 1 results

Table 6-1
Summary of Recommendations

Zone	Recommendations	Rationale
1	Refer both sites to Phase IV for immediate action. Phase IV activity would include a thorough characterization of gases and leachate.	Mitigation of human health hazard.
2	Resample existing wells	Verify Stage 1 results.
	Install 2 additional monitor wells	Expanded monitoring at Base boundary.
	Priority pollutant screening	Ground water and leachate characterization.
	Surface water and sediment monitoring	Evaluate transport of contaminants.
	Sampling and analysis	Determine magnitude and extent of contamination.
3	Resample existing wells	Verify Stage 1 results.
	Install 10 additional monitor wells	Establish effective ground water monitoring network.
	Priority pollutant screening	Ground water and Leachate characterization.
	Surface water and sediment monitoring	Evaluate transport of contaminants.
	Sampling and analysis	Magnitude and extent of contamination.

6.1.7 Zone 7 - Recommendations

Based upon the results obtained to date, the following recommendation is made for Zone 7:

1. Resample and analyze the existing monitor well in this zone to verify Stage 1 results. If Stage 1 results are verified, then no further evaluation is necessary for Zone 7.

6.1.8 Zone 8 - Recommendations

Based upon the results obtained to date, the following recommendation is made for Zone 8:

1. Resample and analyze the existing monitor well in this zone to verify Stage 1 results. If Stage 1 results are verified, then no further evaluation is necessary for Zone 8.

6.2 SUMMARY OF RECOMMENDATIONS

The aforedescribed set of zone-by-zone recommendations is summarized in Table 6-1.

4. Water samples from selected upgradient and downgradient monitor wells should be sampled and analyzed for the complete list of USEPA priority pollutants, in order to determine 1) the "worst case" contamination scenario, and 2) key analytes of concern for assessing the magnitude and extent of contamination.

5. If present, leachate seepages at or around the landfills should be sampled.

6. Water samples from the remaining monitor wells, from surface water staff gauge stations, and from the nearby Base production wells should be sampled and analyzed for a list of analytes based upon the results of priority pollutant screening.

6.1.6 Zone 6 - Recommendations

Based upon the results obtained to date, the following recommendations are made for Zone 6:

1. Resample and analyze the existing monitor well in this zone to verify Stage 1 results.

2. Install two new monitor wells along the west side of the landfill in order to ensure that any contamination that may be present is sampled and characterized.

3. Establish three surface water staff gauge and sampling stations for surface water and sediment sampling along the creek which flows adjacent to the landfill, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. If present, leachate seepages should be sampled.

5. Sample the three monitor wells and three staff gauge stations for the Stage 1 list of analytes plus the USEPA priority pollutant list volatile organic compounds (VOC).

1. Resample and analyze the existing monitor wells in the zone to verify Stage 1 analytical results.

2. Install additional monitor wells around Spill Sites 2 and 3 and the coal storage pile. Six additional monitor wells are necessary to evaluate potential fuel contamination from Spills 2 and 3, and one additional well is recommended between the coal storage pile and the south Base boundary.

3. Sample and analyze the six new and all existing monitor wells at the spill sites for oil and grease and USEPA priority pollutant volatile organic compounds (VOC) plus xylene. Analyze the two Coal Storage Pile wells for Safe Drinking Water Act primary metals and base/neutral extractable organics. Analyze Burial Site 1 wells for Safe Drinking Water Act Primary metals.

6.1.5 Zone 5 - Recommendations

Based upon the results obtained to date, the following recommendations are made for one site in Zone 5:

1. Resample and analyze the existing monitor wells in this zone to verify Stage 1 analytical results. If the Stage 1 results are verified, then no further evaluation is necessary for Fire Training Area 1.

2. Install additional monitor wells around Landfill 5. Five additional monitor wells are necessary to ensure that all possible leachate seepage from the site is sampled and characterized.

3. Six surface water staff gauge and sampling stations should be established for surface water and sediment sampling -- one on each of the Twin Lakes and the gravel pond, and three on Hebble Creek, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

6.1.3 Zone 3 - Recommendations

Based upon the results obtained to date, the following recommendations are made for three sites within Zone 3:

1. Resample and analyze the existing monitor wells in this zone to verify Stage 1 analytical results. If the Stage 1 results are verified, then no further evaluation is necessary for Landfill 3.

2. Install additional monitor wells around landfills 4, 6 and 7 in order to ensure that all possible leachate seepage from the landfills is sampled and characterized. Ten additional monitor wells should be installed around the three landfills in order to ensure that the complex hydrogeological flow patterns in this zone are determined.

3. Eight staff gauge and sampling stations should be established for surface water and sediment sampling along Hebble Creek and the tributaries flowing through and around the landfills, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. Water samples from selected upgradient and downgradient monitor wells should be sampled and analyzed for the complete list of USEPA priority pollutants, in order to determine 1) the "worst case" scenario, and 2) key analytes of concern for assessing the magnitude and extent of contamination.

5. Water samples from the remaining monitor wells and from the surface water staff gauge stations should be sampled and analyzed for a list of analytes to be based upon the results of priority pollutant screening.

6. If present, leachate seepages at Landfills 3, 4, 6, and 7 should be sampled.

6.1.4 Zone 4 - Recommendations

Based upon the results obtained to date, the following recommendations are made for two sites within Zone 4:

1. Resample and analyze the existing monitor wells in this zone to verify Stage 1 analytical results.

2. Because this zone is so close to the base boundary, install additional monitor wells around landfill 11 in order to ensure that all possible leachate seepage from the landfill is sampled and characterized. Two additional monitor wells should be installed, one along the Mad River at the western portion of the landfill toe facing the river, and one at the extreme western end of the landfill.

3. Four surface water staff gauge and sampling stations for surface water and sediment sampling should be established along the surface water course running south and west of the landfill, and discharging into the Mad River, in order to determine the nature, magnitude and extent of potential surface water and sediment contamination.

4. Water samples from selected upgradient and downgradient monitor wells should be sampled and analyzed for the complete list of USEPA priority pollutants in order to determine 1) the "worst case" contamination scenario, and 2) key analytes of concern for assessing the magnitude and extent of contamination.

5. Water samples from the remaining monitor wells and from the surface water staff gauge stations should be sampled and analyzed for a list of analytes to be based upon the results of priority pollutant screening.

6. The Base should implement a post-closure monitoring plan to monitor water quality in the monitor wells around Landfill 11. The Base should test the drums presently at Landfill 12 for USEPA hazard characteristics and remove them from the site for proper disposal. If present, leachate seepages at Landfills 11 and 12 should also be sampled.

SECTION 6

RECOMMENDATIONS

6.1 GENERAL

The findings of the Phase II Stage I study at eight zones on WPAFB indicate the need for follow-up work. This work includes the following:

1. General verification of the initial round of water quality sampling and analysis in seven of the zones.

2. An expanded monitoring program in five of the zones with an emphasis on determining the nature, magnitude and extent of contamination.

3. Referral of one zone to Phase IV for implementation of immediate remedial action and site closure.

6.1.1 Zone 1 - Recommendations

Based upon the results obtained to date, the following recommendation is made for the two landfills in Zone 1:

1. Refer both landfills in Zone 1 to Phase IV. The rationale for this recommendation is that both landfills represent potential hazards to human health. Both landfills are generating leachate as well as hydrogen sulfide and methane gases. Further site evaluation without concurrent remedial actions would only prolong this potential hazard to nearby residents and to children playing in the parks built on both landfills. Phase IV activity would include a thorough characterization of gases and leachate.

6.1.2 Zone 2 - Recommendations

Based upon the results obtained to date, the following recommendations are made for sites within Zone 2:

APPENDIX B

SCOPE OF WORK, TASK ORDER 0022

INSTALLATION RESTORATION PROGRAM

84 APR 30

Phase II Field Evaluation

Wright-Patterson AFB, Ohio *

Revision No. 2 to Description of Work

I. Description of Work

The purpose of this task is to determine if environmental contamination has resulted from waste disposal practices at Wright-Patterson AFB OH; to provide estimates of the magnitude and extent of contamination, should contamination be found; to identify any additional investigations and their attendant costs necessary to identify the magnitude, extent and direction of movement of discovered contaminants.

The presurvey report (mailed under separate cover) and Phase I IRP report (mailed under separate cover) incorporated background and description of the sites for this task. To accomplish the survey effort, the contractor shall take the following steps:

A. General

1. Determine the areal extent of each zone by reviewing available aerial photos of the base, both historical and the most recent panchromatic and infrared.

2. Locations where surface water or leachate samples are collected shall be marked with a permanent marker, and the location recorded on a project map for the zone.

3. A total of 27 monitoring wells shall be installed. The exact location of wells shall be determined in the field.

4. Water sampling shall be accomplished only once at each location.

5. Leachate samples shall be analyzed for total organic carbon (TOC), boron, chloride, total iron, sulfates, specific conductance, phenol and total organic halogen (TOX) unless otherwise specified in site specific actions, paragraph I.B. Groundwater samples shall be analyzed for nitrates, chloride, boron, total iron, manganese, sodium, sulfate, total organic carbon (TOC), phenols, and total organic halogen (unless otherwise specified in site specific actions, paragraph I.B.). All water samples shall be analyzed on site by the contractor for pH, temperature and specific conductance. Sampling, maximum holding time and preservation of samples shall strictly comply with the following references: Examination of Water and Wastewater, 15th Ed. (1980), pp. 35-42; ASTM, Part 31, pp. 72-82, (1976), Method D-3370; and Methods for Chemical Analysis of Waters and Wastes, EPA Manual 600/4-79-020, pp. xiii to xix (1979). Detection limits for sample analyses enumerated in Attachment I shall be strictly adhered to.

*Highlights of Modification are underscored.

6. Groundwater monitoring wells installed during this effort shall be completed to a minimum depth of 10 feet below the surface of the ground water table. Standard penetration tests and split spoon sampling shall be accomplished at one well per zone. All wells shall be developed, water levels measured and locations surveyed and recorded on a project map and specific zone map. Groundwater monitoring wells shall as a minimum comply with Environmental Protection Agency Guidelines and State of Ohio requirements for monitoring well installation. Only screw type joints shall be used. Glued fittings are not permitted.

7. Field data collected for each zone shall be plotted and mapped. The nature of contamination and the magnitude and potential for contaminant flow within each zone to receiving streams and groundwaters shall be determined or estimated. Upon completion of the sampling and analysis, the data shall be tabulated in the next R&D Status report as specified in Item VI below.

B. In addition to items delineated in A above, conduct the following specific actions at sites identified on Wright-Patterson AFB.

1. Zone 1. Landfills 8 & 10

a. Conduct geophysical investigations using both magnetometer and ground penetrating radar techniques to determine the actual locations of chemical trenches and acid neutralization areas at the sites.

b. Collect six leachate samples, one from each of six different leachate seeps adjacent to the sites.

c. Each of the leachate samples collected from seeps at each landfill shall be split into two portions: One portion (total of six) shall be analyzed as indicated in I.A.4. above, the other portions shall be combined into two composite samples, one composite per landfill. Each composite sample shall be analyzed by the contractor laboratory for volatile aromatic and volatile halocarbon compounds using Gas Chromatography.

d. Install five groundwater monitoring wells and four methane monitoring points at the sites. A maximum of two wells shall be located downgradient from each landfill. Collect one water sample from each well.

2. Zone 2 Landfills 11 & 12, Fire Training Areas 3 & 4 and Spill Site 1

a. Conduct a fixed depth resistivity survey at Landfills 11 & 12 to detect the presence of leachate plumes which may be migrating toward the Mad River.

b. Install five groundwater monitoring wells. One or two wells shall be installed in the vicinity of Fire Training Areas 3 & 4 and one or two wells shall be located downgradient from Landfills 11 & 12. One well shall be installed in the vicinity of the spill site.

c. One groundwater sample shall be collected from each well.

d. The samples collected at the fire training and spill areas shall be analyzed by the contractor for oil and grease content using EPA IR method 413.2 and volatile halocarbon and volatile aromatic compounds using GC techniques. Analyses specified for groundwater samples in I.A.4. shall not be accomplished for these samples.

3. Zone 3. Landfills 3, 4, 6 & 7

a. Install four groundwater monitoring wells within the zone to define a contaminant profile.

b. Collect one groundwater sample from each installed well.

4. Zone 4. Coal Storage Pile, Spill Areas 1 & 2 and Chemical Burial Sites 1 & 2

a. Conduct an earth resistivity survey of the area surrounding the coal pile to determine the presence of acidic leachate migration. At the same time, conduct a field inspection of the spill areas and chemical burial sites to determine if any environmental stress is observable.

b. Install five groundwater monitoring wells within the zone. One well shall be installed within each spill area, one well shall be installed between the coal pile and the Fairborn well field, one well shall be installed downgradient of each burial site.

c. Collect one sample from each groundwater well installed.

d. Samples collected from the wells located within each spill area shall be analyz only for oil and grease by EPA IR method 413.2 and for volatile aromatic and volatile halocarbon contents using GC techniques.

5. Zone 5. Landfill 5 and Fire Training Area 1

a. Conduct a single profile resistivity survey to evaluate the boundaries of the landfill and its effect on water quality within the zone. The results of the resistivity survey shall be used to locate monitoring wells in the area.

b. The groundwater levels of the nearby base wells (within 1/4 mile) shall be monitored utilizing either an electric well monitor or existing air lines at the wells. Survey elevations shall be established with respect to groundwater level at these wells to evaluate groundwater flow direction in the zone.

c. Install five shallow groundwater monitoring wells. Two wells shall be located from the base of the landfill toward the boundary of the base. A third well shall be located near Prairie Road. The fourth well shall be located on the eastern toe of the landfill north of Prairie Road and the fifth well located immediately adjacent to Fire Training Area 1.

d. One groundwater sample shall be collected from each well installed by the contractor.

e. The samples collected from the well near the fire training area shall also be analyzed for oil and grease by EPA IR method 413.2 and for volatile aromatic and volatile halocarbon compounds using GC techniques.

6. Zone 6. Landfill 2

Install one groundwater monitoring well downgradient of the landfill between the fill and the surface stream. Collect one groundwater sample from this well.

7. Zone 7. Landfill 9

Install a single monitoring well downgradient of this landfill. Collect one groundwater sample from the well.

8. Zone 8. Fire Training Area 2

a. Install a single monitoring well downgradient of this area.

b. Collect one groundwater sample from the well.

c. The sample collected from this well shall be analyzed only for oil and grease and volatile aromatic and volatile halocarbon compounds. The oil and grease analyses shall be accomplished utilizing EPA IR method 413.2 only. The volatile aromatic and volatile halocarbon analyses shall be accomplished using GC techniques only.

C. Well Installation and Cleanup

1. Well installations shall be cleaned up following the completion of the well. Drill cuttings shall be removed and the general area cleaned. The exact location of wells in each zone shall be determined in the field.

2. Each monitoring well shall be provided with 8-ft metal fence posts installed approximately 2 ft from the well (in all cases, posts shall be outside the grout surface seal). Posts shall be installed as follows:

a. Monitoring wells requiring two posts, one on each side of the well: Wells No. 2, 5, 8, 9, 11, 12, 15, 16, 17, 18, 19, 22.

b. Monitoring wells requiring one post: Wells No. 1, 13, 20, 21, 23, 24, 25, 26, 27.

D. Site Restoration

1. Zone 1, Landfills 8 and 10. The contractor shall restore the landscaped areas around Landfills 8 and 10 after well installation is complete. Base personnel will inform the contractor if the landscape work performed under subcontract is not satisfactory.

2. Zone 2, Landfill 11. The contractor shall obtain access to Landfill 11 by cutting the fence between the landfill and the Mad River; the fence shall be repaired and a lockable gate installed.

E. Data Review

Results of sampling and analysis shall be tabulated and incorporated into the monthly R&D Status Reports and forwarded to the USAF OEHL for review as soon as they become available as specified in Item VI below. Results of sampling and analyses shall be tabulated and incorporated into the Informal Technical Information Report (Sequence 3, Attachment 1 as reflected in Item VI below), and forwarded to USAF OEHL/TS for review.

F. Reporting

1. A draft report delineating all findings of this field investigation shall be prepared and forwarded to the USAF OEHL as specified in Item VI below for Air Force review and comment. This report shall include a discussion of the regional hydrogeology, well logs of all project wells, data from water level surveys, water quality analysis results, resistivity, magnetometer and ground penetrating radar survey results and maps, available geohydrologic cross sections, groundwater surface and gradient vector maps, vertical and horizontal flow vectors and Laboratory quality assurance information. The report shall follow the USAF OEHL supplied format (mailed under separate cover).

2. Estimates shall be made of the magnitude, extent and direction of movement of contaminants discovered. Potential environmental consequences of discovered contamination shall be identified or estimated. Where survey data are insufficient to properly determine or estimate the magnitude, extent and direction of movement of discovered contaminants, specific recommendations, fully justified, shall be made for additional efforts required to properly evaluate contamination migration and included in a separately bound appendix to the draft final report (see I below).

3. Specific requirements, if any, for future groundwater and surface water monitoring must be identified.

G. Quality Assurance

The Contractor shall strictly adhere to all procedures (described in Chapter 7 of the Presurvey Report (Task Order 9 of the same contract) relating to laboratory coordination; on site coordination; engineering coordination; program management; project management; sampling procedures; chain of custody; field sampling operations; laboratory operations, calibration procedures, analytical procedures, data reduction, validation and reporting, internal quality

control checks, performance and system audits, laboratory preventive maintenance, specific procedures used to assess data precision accuracy and completeness; field methods including well installation procedures, well surveying, stream measurements; and all sampling and analysis. A copy of this report shall be supplied to the contractor by USAF OEHL under separate cover.

H. Health and Safety

All procedures relating to health and safety described in Chapter 6 of the presurvey report for Wright-Patterson AFB will be strictly adhered to by the contractor during this survey.

I. Cost Estimates

The contractor shall provide cost estimates for all additional work recommended to permit proper determination of contaminants. The recommendations provided shall include all efforts required to determine the magnitude, extent and direction of movement of discovered contaminants along with an estimate of the time required to accomplish the proposed effort. This information shall be provided in a separately bound appendix to the draft final report.

II. Site Location and Dates:

Wright-Patterson AFB OH
USAF Medical Center/SGB
Dates to be established

III. Base Support: None

IV. Government Furnished Property: None

V. Government Points of Contact:

1. Dee Ann Sanders
USAF OEHL/TS
Brooks AFB TX 78235
(512) 536-2158
AV 240-2158

2. Col Harry Russell
HQ AFLC/SGPB
Wright-Patterson AFB OH 45433
(513) 257-6210
AV 787-6210

3. Maj Wiley Taylor
USAF Medical Center/SGB
Wright-Patterson AFB OH 45433
(513) 255-6815
AV 785-6815

VI. In addition to sequence numbers 1, 5 and 11 listed in Atch 1 to the contract, which are applicable to all orders, the reference numbers below are applicable to this order. Also shown are data applicable to this order.

Sequence Nr	Block 10	Block 11	Block 12	Block 13	Block 14
4	ONE/R	84 JUL 03	84 JUL 10	84 OCT 09	*
3	O/TIME	**	**		

*A minimum of two draft reports will be required. After incorporating Air Force comments concerning the first draft report, the contractor shall supply the USAF OEHL with a second draft report. The report shall be forwarded to the applicable regulatory agencies for their comments. Contractor shall supply the USAF OEHL with 25 copies of each draft report and 50 copies plus the original camera ready copy of the final report.

**Upon completion of analyses

Required Sample Detection Limits

Chemical	Concentration
Total Organic Carbon (TOC)**	1 mg/L
Boron	100 µg/L
Chloride	1 mg/L
Total Iron	100 µg/L
Manganese	50 µg/L
Sodium	1 mg/L
Sulfate	1 mg/L
Specific Conductance	1 micromho
Phenols	1 µg/L
Total Organic Halogen (TOX)**	5 µg/L
Nitrate	0.1 mg/L
Oils and Greases (IR Method)	0.1 mg/L
Volatile Organic Compounds	*

*Detection limits for volatile aromatics and volatile halocarbons shall be as specified for compounds listed in EPA methods 601 and 602.

**For TOX and TOC analyses, report the noise levels of the analytical instrumentation. Laboratory water used as a blank must show a level less than three times the noise level, or be corrected for before reporting of results. TOC samples must be treated to remove inorganic carbon and results reported as nonpurgeable TOC.

APPENDIX C

PROFESSIONAL PROFILES OF PROJECT PERSONNEL



Peter J. Marks

Fields of Competence

Project management; environmental analytical laboratory analysis; hazardous waste, groundwater and soil contamination; source emissions/ambient air sampling; wastewater treatment; biological monitoring methods; and environmental engineering.

Experience Summary

Eighteen years in Environmental Laboratory and Environmental Engineering as Project Scientist, Project Engineer, Process Development Supervisor, and Manager of Environmental Laboratory with WESTON. Experience in analytical laboratory, wastewater surveys, hazardous waste, groundwater and soil contamination, DoD-specific wastes, stream surveys, process development studies, and source emission and ambient air testing. In-depth experience in pulp and paper, steel, organic chemicals, pharmaceutical, glass, petroleum, petrochemical, metal plating, food industries and DoD.

Applied research on a number of advanced wastewater treatment projects funded by Federal EPA.

Credentials

B.S., Biology—Franklin and Marshall College (1963)

M.S., Environmental Engineering and Science—Drexel University (1965)

American Society for Testing and Materials

Water Pollution Control Federation

Water Pollution Control Association of Pennsylvania

Employment History

1965-Present	WESTON
1963-1964	Lancaster County General Hospital Research Laboratory for Analytical Methods Development

Key Projects

USAF/OEHL Brooks AFB. Program Manager for this three-year BOA contract provides technical support in environmental engineering surveys, wastewater characterization programs, geological investigations, hydrogeological studies, landfill leachate monitoring and landfill siting investigations, bioassay studies, wastewater and hazardous waste treatability studies, and laboratory testing and/or field investigations of environmental instrumentation/equipment. Collection, analysis, and reporting of contaminants present in water and wastewater samples in support of Air Force Environmental Health Programs.

United States Army Toxic and Hazardous Materials Agency (USATHAMA), Aberdeen Proving Ground, Maryland. Program Manager for three-year basic ordering agreement contract to provide research and development for technology in support of the DOD Installation Restoration Program. The objective of the Program is to identify and develop treatment methods/technology for containment and/or remedial action. Technology development for remedial action is to include groundwater, soils, sediments, and sludges.

Confidential Client, Ohio. Project Manager of an on-going contract to conduct corporate environmental testing and special projects at client's U.S. and overseas plants. WESTON must be able to assign up to four professionals to a project within a two week notice.

Confidential Client (Inorganic and Organic Chemicals). Product Manager of a current contract to conduct wastewater sampling and analysis of plant effluent for priority pollutants. The project also includes a wastewater treatability study to evaluate a number of process alternatives for removal of priority pollutants from the present effluent.

Confidential Client, Utah. Technical Project Manager for in-depth wastewater survey, in-plant study, treatability study, and concept engineering study in support of the client's objectives to meet 1983 effluent limitations. WESTON had two project engineers, two chemists, five technicians and an operating laborator in the field. Field effort is six months duration.

Professional Profile

In conjunction with University of Delaware College, WESTON analyzed more than 500 biological and marine sediment samples for eleven constituent trace metals as part of a program to identify and trace the migration of metals from ocean dumping of sludges on the continental shelf off the coast of the State of Delaware, acted as Technical Project Manager.

Project Manager in charge of a wastewater analysis and biological treatability project for industrial client for the identification and degradation of six pesticide-containing wastewaters.

U.S. EPA Environmental Monitoring and Support Laboratory. Multi-year contract to provide reference laboratory analysis on QA/QC samples produced from the EPA Analytical Laboratory QA/QC program.

Publications

"Microbiological Inhibition Testing Procedure," Biological Methods for the Assessment of Water Quality, A.S.T.M. Publication STP 528.

"Heat Treatment of Waste Activated Sludge" (with V.T. Stack).

"Biological Monitoring in Activated Sludge Treatment Process," a joint paper with Stover/Woldman.



Frederick Bopp III, Ph.D., P.G.

Registration

Registered Professional Geologist in the State of Indiana

Fields of Competence

Groundwater resources evaluation; hydrogeologic evaluation of sanitary landfills and other waste disposal sites; detection and abatement of groundwater pollution; digital modeling of groundwater flow and solute transport; statistical analysis of geological and geochemical data; geochemical prospecting; estuarine geology and geochemistry; trace metal and aqueous geochemistry.

Experience Summary

Seven years experience in hydrogeology and geochemistry, involving such activities as: assessment of subsurface water and soil contamination; development of contamination profiles; evaluation of remediation actions for groundwater quality restoration; quantitative chemical analysis of water and soil; ore assay and ore body evaluation; drilling supervisor; hydrogeologic assessment; pollution detection and abatement; estuarine pollution analysis; application of flow and solute transport computer models; computer programming; project management; teaching environmental geology and geochemistry.

Credentials

B.A., Geology—Brown University (1966)

M.S., Geology—University of Delaware (1973)

Ph.D., Geology—University of Delaware (1979)

Sigma Xi, The Scientific Research Society of North America

Geological Society of America, Hydrology Division

National Water Well Association, Technical Division

American Association for the Advancement of Science

Estuarine Research Federation: Atlantic Estuarine Research Society

Employment History

1979-Present	WESTON
1977-1979	U.S. Army Corps of Engineers Waterways Experiment Station
1976-1977	University of South Florida Department of Geology
1970-1976	University of Delaware Department of Geology
1974-1976	Earth Quest Associates President and Principal Partner
1974 (Summer)	WESTON
1966-1970	United States Navy Commissioned Officer

Key Projects

Project manager on seven task orders for environmental assessment services at United States Air Force facilities in nine states.

Task manager for a Superfund site evaluation in Ohio.

Site manager for drum recovery operations in Pennsylvania and New Jersey.

Project manager for site assessments of oil and fuel spills in four states.

Project manager for closure plan development at a hazardous waste landfill in New Jersey.

Definition and abatement of groundwater contamination from chemical manufacturing in Delaware.

Flow and solute transport digital model of a heavily-pumped regional aquifer in southern New Jersey.

Definition and abatement of groundwater contamination from chemical manufacturing in the Denver area.

Hydrogeologic impact assessment of on-land dredge spoil disposal in coastal North Carolina.

Geochemical prospecting and ore body analysis in Arizona.

Professional Profile

Definition and abatement of groundwater contamination from a hazardous waste site in northern New England.

Definition and abatement of groundwater contamination from plating and foundry wastes in eastern Pennsylvania.

Operational test and evaluation of new naval mine ordinances in southern Florida.

Publications

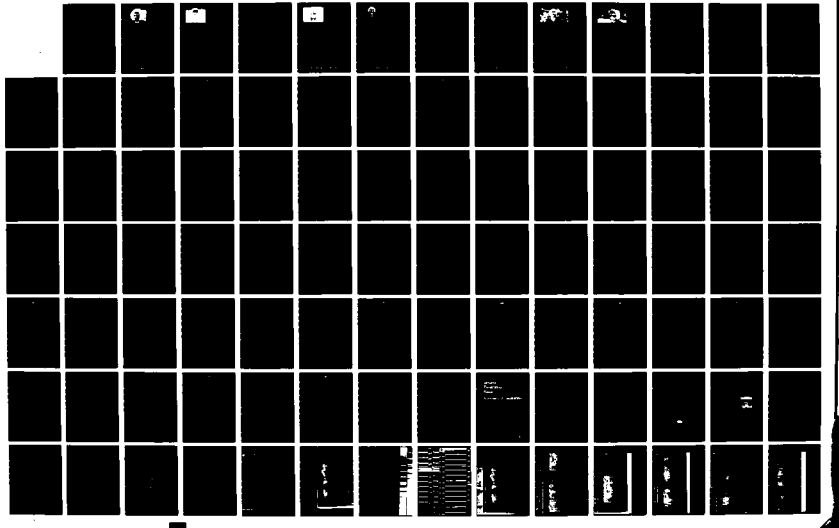
"Metals in Estuarine Sediments: Factor Analysis and Its Environmental Significance". *Science*, 214 (1981): 441-443.

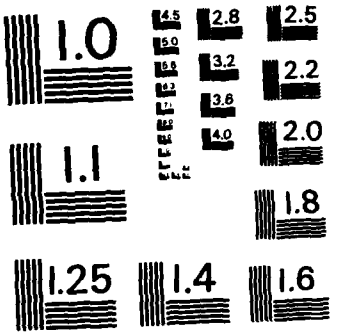
"The Remobilization of Trace Metals from Suspended Sediments Entering the Delaware Estuary". Presented at the 27th Annual Meeting, Southeastern Section, Geological Society of America, Chattanooga, Tennessee, April 1978.

"Trace Metals in Delaware Bay Sediments and Oysters". Presented at the International Conference on Heavy Metals in the Environment, Toronto, Canada, October 1975.

AD-A159 573 INSTALLATION RESTORATION PROGRAM PHASE II 3/5
CONFIRMATION/QUANTIFICATION STA..(U) WESTON (ROY F) INC
WEST CHESTER PA SEP 85 F33615-80-D-4006

UNCLASSIFIED F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



Marian R. Dzedzy

Fields of Competence

Soil evaluation and suitability for specific use purposes; field and laboratory soils investigations; groundwater pollution detection and abatement.

Experience Summary

Three years experience in soil and hydrogeological investigations including field soil descriptions and evaluations for on-site waste disposal, landfill siting, and liner construction; soil and groundwater sampling; piezometric surface mapping; pump test performance and analysis; percolation and infiltration tests; soil erosion and sediment control plan preparation and implementation.

Credentials

B.S., Agronomy—Delaware Valley College of Science and Agriculture (1980)

American Society of Agronomy

Soil Science Society of America

Pennsylvania Association of Professional Soil Scientists

Employment History

1980-Present WESTON

Key Projects

Soils and hydrogeologic investigation to determine extent of trichloroethylene (TCE) contamination from a southeastern Pennsylvania metal processing plant.

Evaluation of area soils to determine suitability as liner material for a secure landfill in western Pennsylvania.

Principal investigator for court-ordered hydrogeological and soils study at a petroleum terminal to determine extent of spilled oil contamination.

Preparation of state-required discharge permits for a New Jersey chemical manufacturer.

Soil suitability evaluation for on-lot waste disposal in Chester County, Pennsylvania.

Document search and regulations review to determine feasibility of in-situ lagoon closure at DoD installations.

Soil evaluation to determine suitability for siting a hazardous waste landfill.

Intensive hydrological characterization, including well installation, testing, and monitoring, at radioactive disposal sites in western Pennsylvania.

Soil and groundwater investigations to determine extent of PCB (poly-chlorinated biphenyl) contamination at four industrial and storage facilities in Pennsylvania and New Jersey.

Professional Profile



Walter M. Leis, P.G.

Registration

Registered Professional Geologist in the States of Georgia (No. 440) and Indiana.

Fields of Competence

Detection and abatement of groundwater contamination; design of artificial recharge wells; deep well disposal; simulation of groundwater systems; hydrogeologic evaluation of hazardous waste sites and landfills; practical applications of geophysical surveys to hydrologic systems, site investigations, and borehole geophysical surveys. Geochemical studies of acid mine drainage and hazardous wastes.

Experience Summary

Sixteen years experience as field hydrogeologist, field supervisor, project director, research director. Six years research involving two consecutive projects: 1) application of geophysical techniques in evaluating groundwater supplies in fractured rock terrain in Delaware and Pennsylvania; 2) project director for an artificial recharge and deep well disposal study. Provided consultation for waste disposal and aquifer quality problems for coastal communities.

Developed geochemical sampling techniques for deep mine sampling. Evaluated synthetic and field hydrologic data for deep formulational analysis in coal field projects.

Earlier research experience involved developing techniques for mapping subsurface regional structures having interstate hydrologic significance, and defining ore bodies by geochemical prospecting.

Credentials

B.S., Biochemistry—Albright College (1966)

M.S., Hydrogeology—University of Delaware (1975)

Cooperative Program Environmental Engineering—University of Pennsylvania

Additional special course work in Geology and Hydrology, Franklin and Marshall College and Pennsylvania State University

Remote Sensing Data Processing Training, Goddard Space Center (1978)

OWRR Research Fellow, 1973

National Water Well Association, Technical Division.

Geological Society of America, Engineering Geological Division.

Society of Economic Paleontologists and Mineralogists

Employment History

1974-Present	WESTON
1973-1974	University of Delaware Water Resources Center
1971-1973	University of Delaware
1967-1971	Pennsylvania Department of Environmental Resources

Key Projects

Definition of groundwater contamination from sanitary landfill leachate and recovery of contaminants to protect heavily used aquifer in Delaware.

Field design studies for artificial recharge and waste disposal wells.

Design and construction of hydrologic isolation systems for various class hazardous wastes.

Design and supervision of chemical and physical rehabilitation of groundwater collection systems in fractured rock and coastal plain areas.

Principal investigator for six projects involving subsurface migration of PCB's in New York, New Jersey, Pennsylvania, and Oklahoma.

Design and construction supervision of hydrocarbon recovery wells in Pennsylvania.

Professional Profile

Geochemical evaluation of coal mine pools in West Virginia.

Geochemistry of subsurface migration of toxic substances.

Principal investigator for eight projects involving migration of volatile chlorinated hydrocarbons in groundwater.

Mineable reserve evaluations for coal, sand and gravel, limestone, clay deposits, mine reclamation, and monitoring.

Design geophysical and remote sensing assessments of hazardous waste disposal areas.

Publications

Leis, W., and R.R. Jordan, 1974, "Geologic Control of Groundwater Movement in a Portion of the Delaware Piedmont", OWRR—DEL 20.

Leis, W., 1976, "Artificial Recharge for Coastal Sussex County, Delaware", University of Delaware Press, Water Resources Center.

Leis, W., D.R. Clark, and A. Thomas, 1976, "Control Program for Leachate Affecting a Multiple Aquifer System, Army Creek Landfill, New Castle County, Delaware", National Conference on Management and Disposal of Residue on Land.

Leis, W., W.F. Beers, J.M. Davidson, and G.D. Knowles, 1978, "Migration of PCB's by Groundwater Transport—A Case Study of Twelve Landfills & Dredge Disposal Sites on the Upper Hudson Valley, New York", Proceedings of the 1st Annual Conference of Applied Research & Practice on Municipal and Industrial Waste.

Leis, W., R.D. Moose, and W.F. Beers, "Critical Area Maps, a Regional Assessment for Karst Topography", Association of Engineering Geologists 1978 Annual Meeting.

Leis, W., and W.F. Beers, "Soil Isotherm Studies to Predict PCB Migration Within Groundwater", (Abstract) ASTM 1979 Annual Meeting, Philadelphia, Pennsylvania.

Thomas, A., and W. Lein, "Physical & Chemical Rehabilitation of Contaminant Recovery Wells", Association of Engineering Geologists 1978 Annual Meeting.

Leis, W., W.F. Beers, and F. Benenati, "Migration of PCB's from Landfills and Dredge Disposal Sites in the Upper Hudson River Valley", New York Academy of Science Symposium on PCB's in the Hudson River.

Leis, W., "Subsurface Reclamation by Counter Pumping Systems: Geologic and Geotechnical Aspects of Land Reclamation", ASCE/AEG 1979 Symposium.

Leis, W., and A. Metry, "Field Characterization of Leachate Quality", Water Pollution Control Federation 1979 Annual Meeting.

Leis, W., and A. Metry, "Multimedia Pathways of Contaminant Migration", Water Pollution Control Federation 1980 Annual Meeting.

Leis, W., and K. Sheedy, "Geophysical Location of Abandoned Waste Disposal Sites", 1980 National Conference on Management of Uncontrolled Hazardous Waste Sites.

Sheedy, K., and W. Leis, 1982, "Hydrogeological Assessment in Karst Environments (chapter)."



John A. Williams, Jr.

Fields of Competence

Geologic and geophysical investigations; geological and groundwater sampling techniques and instrumentation technology; design, operation, and evaluation of geophysical survey, equipment, testing and analysis of aquifers, and groundwater pollution.

Experience Summary

Three years experience in geologic and geophysical investigtions including subsurface profiling using Ground Penetrating Radar (GPR), electrical resistivity and electromagnetic conductivity for numerous private and government facilities; groundwater sampling and aquifer pump tests, six years experience in bathymetric, hydrographic and biological studies.

Credentials

A. S., Marine Technology - Cape Fear Technical Institute (1975)

B. S., Earth Science (Geology) - West Chester State College (1983)

Certified Ground Penetrating Radar Operator

Certified NAUI/PADDI Scuba Diver

Geological Society of America

Employment History

1982 - Present	WESTON
1980-1982	Environmental Resources Management, Inc.
1977-1980	WESTON
1976-1977	Highway Service Marineland
1975-1976	Lawler, Matusky, Skelly Engineers

Key Projects

Coordinated and supervised geophysical investigations to locate buried drums and to delineate the boundaries of a buried waste lagoon for a scrap recovery plant in Rhode Island.

Geophysical field investigation to locate buried trenches and waste lagoons for a government facility in California.

Geophysical field investigation, well installation and sample collection to determine the distribution of leachate, and the extent of contamination in a heavily-used aquifer in New York.

Geophysical investigation to define the lateral and vertical effect of fill deposition for a facility in Massachusetts.

Soils investigation to determine the extent of contamination from old waste lagoons and fire training areas for a government facility in Arizona.

Hydrogeologic investigation for a scrap recovery facility in western Pennsylvania.

Responsible for deploying benthic and water quality sampling gear and an electronic navigation system for a dredge spoils disposal study in Lake Erie.

Geophysical investigation (ground penetrating radar and electrical resistivity) to locate buried drums and delineate trench boundaries for a government facility in Ohio.

Professional Profile



Theodore F. Them, Ph.D.

Fields of Competence

Inorganic and organic chemistry; instrumental analytical techniques; synthesis of organic chemicals; laboratory management; chemical research and education.

Experience Summary

Nine years experience in inorganic and organic chemistry with strong synthetic organic and instrumental analytical background. Experienced researcher and teacher. Background in conceptualizing, founding, effecting, and administering a chemical consulting firm.

Credentials

M.S., Chemistry—University of New Mexico (1975)

Ph.D., Chemistry—University of New Mexico (1977)

American Chemical Society

The Society of Sigma Xi

Southwest Association of Forensic Scientists—Associate Member

Society of Applied Spectroscopy, Rio Grande Section

Employment History

1982-Present	WESTON
1981-1982	Bell Petroleum Services, Inc.
1982-1982	Bell Petroleum Laboratories
1977-1981	AnaChem, Inc. Co-Founder, Vice President
1975-1977	University of New Mexico

Practical Experience

Familiarity with use, maintenance, and operation of gas chromatographs with flame ionization, electron capture, thermal conductivity, and photoionization detectors. Experience includes methods development, separation optimization, and data reduction.

Familiarity with use, maintenance, and operation of gas chromatograph/mass spectrometer/data system (GC/MS/DS) in separations and identifications of complex mixtures and molecules. Experience includes methods development, separation enhancement, packed and capillary column techniques, and data reduction.

Familiarity with use and operation of various infrared, nuclear magnetic resonance (NMR), atomic absorption (AA), and liquid chromatographic (LC) instrumentation.

Familiarity with use, maintenance, and operation of Tekmar Models LSC-2 and ALS purge/trap and liquid sample concentrator devices and associated gas chromatographic methods.

Familiarity with use, maintenance, and operation of Fisher Model 490 Coal Analyzer for analysis of moisture, volatiles and ash in coal.

Familiarity with use, maintenance, and operation of Fisher Sulfur Analyzer System for analysis of sulfur in coal and hydrocarbon fuels.

Familiarity with use, maintenance, and operation of Parr Adiabatic Bom Calorimeter and associated Master Controller in calorimetric analysis of coal and coke, foodstuffs, and fuels.

Familiarity with use, maintenance, and operation of Fisher Models Titralyzer II (Fixed End Point) and Tritrimeter II automatic titration systems for analysis of water by pH or millivolt-sensitive methods.

Publications

Hazardous Properties and Environmental Effects of Materials Used in Solar Heating and Cooling (SHAC) Technologies: Interim Handbook, J.Q. Search (ed.), August 1978. Sandia Laboratories report Sand 78-0842, available from National Technical Information Service, Springfield, Virginia.

Professional Profile

"Isomerism in Complexes of Bidentate Ligands with Enantiotopic Donor Atoms", R.E. Tapscott, J.D. Mather, and T.F. Them, *Coordination Chemistry Reviews*, Vol. 19, Nos. 2/3, September 1979.

"Stereochemical Studies on Diastereomers of Tris (2,3-butanediamine)-Colbalt (III)", C.J. Hilleary, T.F. Them, R.E. Tapscott, *Inorganic Chemistry*, Vol. 19, No. 102, 1980.

"Staying Abreast of PCB Regulations: TESTING", R.M. Holland and T.F. Them, *Professional Trade Publication*, June 1980.

"Stereochemistry of Arsenic (III) and Antimony (III) 1,2-DihydroxyEychohexane-1,2-dicarboxylates," D. Marcovich, E.N. Duesler, R.E. Tapscott, and T.F. Them, *Inorganic Chemistry*, 1982.

David E. Epps

Fields of Competence

Field studies for municipal and private groundwater supply and monitor well projects; state-of-the-art soil, water, and air sampling techniques for hazardous waste sites; use of high technology, air and water monitoring instruments; drilling and installation of groundwater monitoring wells for hazardous waste sites.

Experience Summary

Experience in groundwater supply and hazardous waste projects including locating monitor and supply wells and supervision of drilling, logging, and sampling of the completed wells. Determined aquifer characteristics using pump test data along with computer modeling.

Credentials

B.S., Geology—Bloomsburg State College (1983)

Employment History

Present	WESTON
1983	SMC Martin, Inc.
1981-1982	Earth Data, Inc.

Key Projects

Participated in an investigation to assess the groundwater contamination at a major United States Air Force base. The project included drilling and installing groundwater monitoring wells to be sampled at regular intervals.

Participated in an investigation to assess the extent of a contamination plume. Duties involved resistivity surveys, complete priority pollutant sampling of approximately 20 monitoring wells, and use of computer groundwater modeling techniques to determine possible remedial actions.

Participated in an investigation to determine hydrologic characteristics of an aquifer. 4- and 12-hour step texts were used to determine pumping rates for 24- and 48-hour pump tests. Water level recorders were placed on surrounding monitor wells to determine water level data during the pump test. Recovery rates were also measured at the end of each pump test.

Professional Profile



Joseph R. Althouse

Fields of Competence

Data collection; wastewater sampling; flow measurement in house treatability systems; analytical methods in wet laboratory; air pollution testing; maintenance of laboratory and field equipment for field projects; infiltration and inflow programs; construction estimating; quantity take-off; pricing; and on-site sewer construction inspection.

Experience Summary

Eight years experience in coordinating field equipment and supplies on various projects ranging from stream surveys to air pollution testing. Experience in developing and fabricating equipment for wastewater sampling. Sampling technician for infiltration/inflow studies, fish bioassays; air pollution, and wastewater sampling, construction estimating and on-site construction inspection.

Employment History

1980-Present	WESTON
1979-1980	Charles E. Moore Associates
1974-1979	Rexnord Instrument Products
1967-1974	WESTON
1965-1967	Lukens Steel Company
1963-1965	Firestone Tire and Rubber Company

Key Projects

Sewer construction inspection for West Whiteland Township, Pennsylvania.

Infiltration/inflow analyses and sewer system evaluation studies, including surface inspection, physical inspection and flow measurements for a township.

Source emissions and ambient air testing of air pollutants.

Wastewater survey of a major steel producing plant in Texas including collecting flow data and wastewater samples and constructing and maintaining test equipment.

Wastewater survey of 2 major electric power companies in Pennsylvania collecting flow data and wastewater samples for National Pollution Discharge Elimination System.

Professional Profile



Richard C. Johnson

Fields of Competence

Hydrologic and geologic investigations of waste disposal sites; engineering properties of soil and rock; laboratory determination of mechanical properties of soils; laboratory investigation of physical properties of sulfite sludges and coal burning wastes; hydrogeological analysis of limestone karst terrains; optical and x-ray diffraction analysis of geological materials.

Experience Summary

Three years experience in geotechnical and engineering geology, including hydrologic and geological investigation of landfill sites, industrial waste disposal assessment, evaluation of soil mass stability and bearing capacity at proposed sites of building and tank structures; development of remedial actions for sinkhole collapse around structures in limestone terrains; supervision of engineering of laboratory programs for soil and waste material testing.

Credentials

B.S.—LaSalle College (1969)

M.A. Geology—Temple University (1976)

Graduate course work in soil mechanics, engineering geology and hydrology—Drexel University (1979-1981)

Geological Society of America, Engineering Geology Division

U.S. National Group of Engineering Geology

Philadelphia Geologic Society

Employment History

1981-*Present*	WESTON
1979-1981	Valley Forge Laboratories Devon, Pennsylvania Engineering Geologist Supervisor, Soils and Materials Testing Laboratory
1978-1979	Ambric Engineering Philadelphia, Pennsylvania Field Geologist
1976-1977	American Cancer Society Philadelphia, Pennsylvania Director of Development and Education
1972-1975	Temple University Department of Geology Teaching and Research Assistant
1969-1971	City of Philadelphia Department of Licenses and Inspections Housing and Fire Inspector

Key Projects

Supervision of investigations in New Jersey and Pennsylvania to determine subsurface conditions at proposed waste disposal sites. Studies included developing geologic profiles of the sites, locating groundwater, and determining the engineering properties of undisturbed and remolded soils samples.

Project Manager and Principal Investigator for a subsurface investigation to determine soil conditions at the proposed site of 55,000 barrel fuel storage tanks in a flood plain area in northeast Pennsylvania. Supervised soil borings and performed analyses to predict settlement probabilities for flexible pad foundations.

Investigated geologic and hydrologic conditions in an expanding suburban area in southeastern Pennsylvania to determine past and future impacts of on-site sanitary systems.

Supervised exploratory drilling and developed foundation recommendations for proposed building construction projects in southeastern Pennsylvania.

Conducted site investigations in limestone sinkhole areas to develop recommendations for remedial action around threatened structures.

Developed and directed a testing program to evaluate preliminary rock anchor designs in a sewage facility construction project, Montgomery County, Pennsylvania.

Supervised laboratory testing program for sulfite sludges and coal burning wastes. Evaluated alternative methods of physical and chemical stabilization of the wastes, and developed applications for stabilized material in landfill, and earth stabilization problems.

Professional Profile

Publications

Johnson, R. and Myer, G., "Sillimanite Nodules in the Wissahickon Schist, Philadelphia," *Journal of the Pennsylvania Academy of Sciences*, vol. 49, 1975.

APPENDIX D

BORING LOGS AND WELL COMPLETION SUMMARIES

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-1 OWNER:
LOCATION: Zone 1 ADDRESS:
TOTAL DEPTH 65'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C. PATTERSON DRILLING METHOD: Cable Tool DATE DRILLED: 5 DEC. 1983 - 6 DEC. 1983
DRILLER: S. Patterson HELPER: JOE PATTERSON
LOG BY: D. Epps

SKETCH MAP

NOTES:
7 DEC 1983 DTW = 15.0'

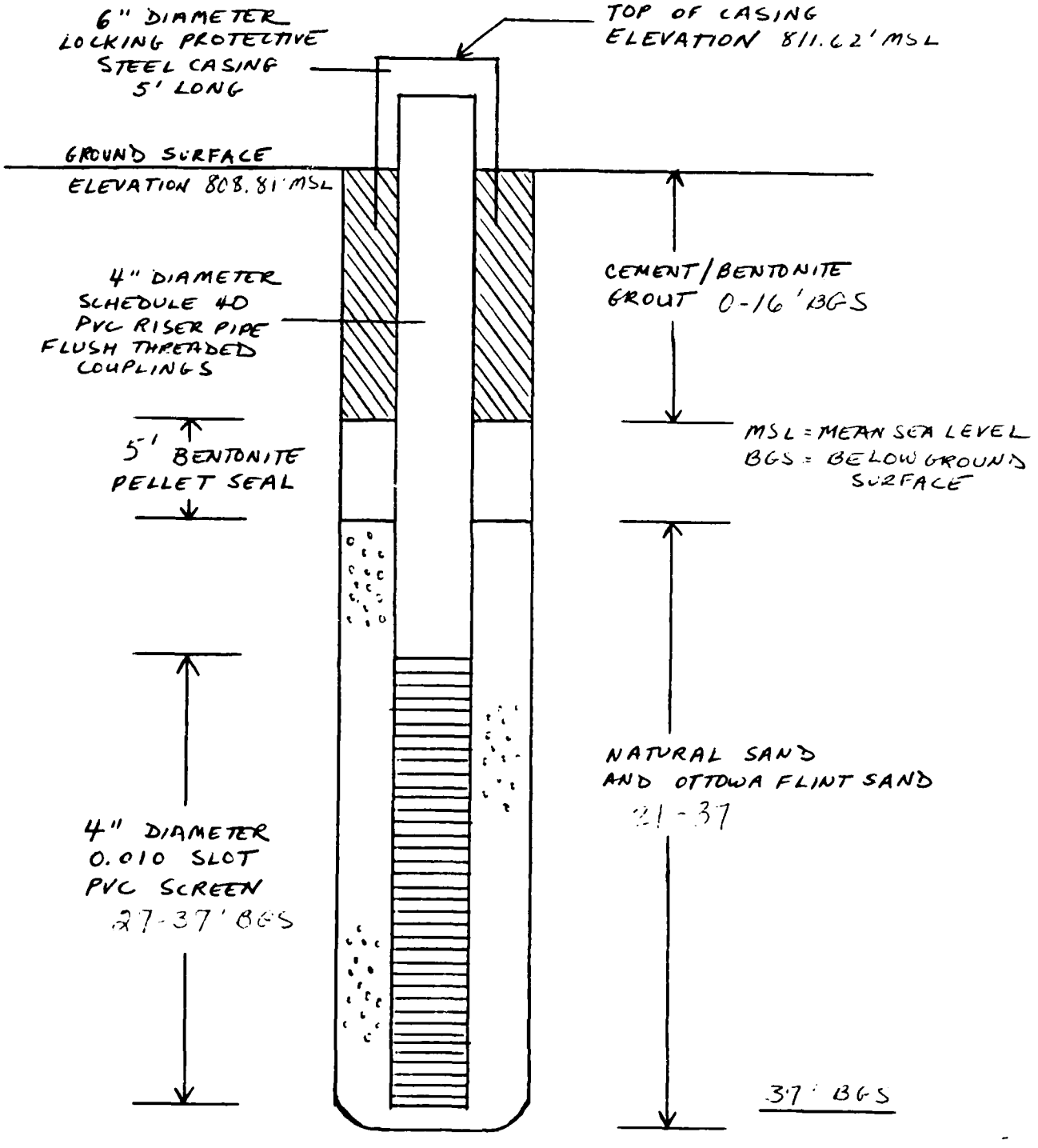
DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
					TAN soil - clay mixed with 3/8" gravel
					Brownish - GRAY clay with Fine sandy matrix
					Medium to Coarse Sand with clay MATRIX
					GRAY clay mixed with Fine to Medium Sand
					* FIRST WATER
					GRAY Sandy clay Medium to Fine matrix
					Fine to Very Coarse Sand with some clay
					GRAY Fine to Medium grain Sandy Clay.
50'-51.5'	1	REC 55	53/18"		M-C sand (4") mixed with GRAY clay and cobble (12")
					Brownish - RED Sandy clay
					HARD GRAY Clay

* ASTM D1586

SHEET ___ OF ___

WESTON
DESIGNERS CONSULTANTS

_____ DATE _____ DIV _____ SHEET _____ OF _____
IKD BY _____ DATE _____ DEPT _____ W.O. NO. _____
OJECT _____
BJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-7

REV. 335-5-84

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-7 OWNER: USAF
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH _____
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: HSA DATE DRILLED: 12-7-83
DRILLER: B. C. HELPER: R. H.
LOG BY: Bowser Morner

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
5					Brown-Green - Sandy clay, trace gravel
6		7	SS	22,53 47	Hard Green clay, some silt, trace sand and gravel

* ASTM D1586

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-7 OWNER: USAF
LOCATION: _____ ADDRESS: Wright-Patterson AFB
_____ TOTAL DEPTH _____
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: HSA DATE DRILLED: 12-7-83 12-8-83
DRILLER: B.C HELPER: _____
LOG BY: Bowser-Morner

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
1					Topsoil Dark Brown Silt, trace of clay and sand. Bricks, Asphalt mixed in with cuttings
4					Dark Brown Silt, trace of clay ~~and~~ sand and gravel
5-6.0		1	SS	6,9,13 26	Rec. 10" Brown Silt, trace clay, Sand gravel
		2	SS		
9					Brown Sand and gravel, trace silt
11.0		2	SS	100	No recovery
14.5					Brown Sand and gravel, trace silt
15-16		3	SS	32,18 8	Brown Sand and gravel, trace silt, Rec. 8", moist
19.5					Brown Sand and gravel, trace silt, moist
5-21		4	SS	10,16 16	Same as above, Rec. 10", wet @ 19
24.5					Same as above wet
5-26		5	SS	7,6 8	Brown Sand and gravel, some silt, wet, Rec. 6"
29.5					Same as above
5-31		6	SS	12,15 22	Same as above, inc. in clay and silt content

*ASTM D1586

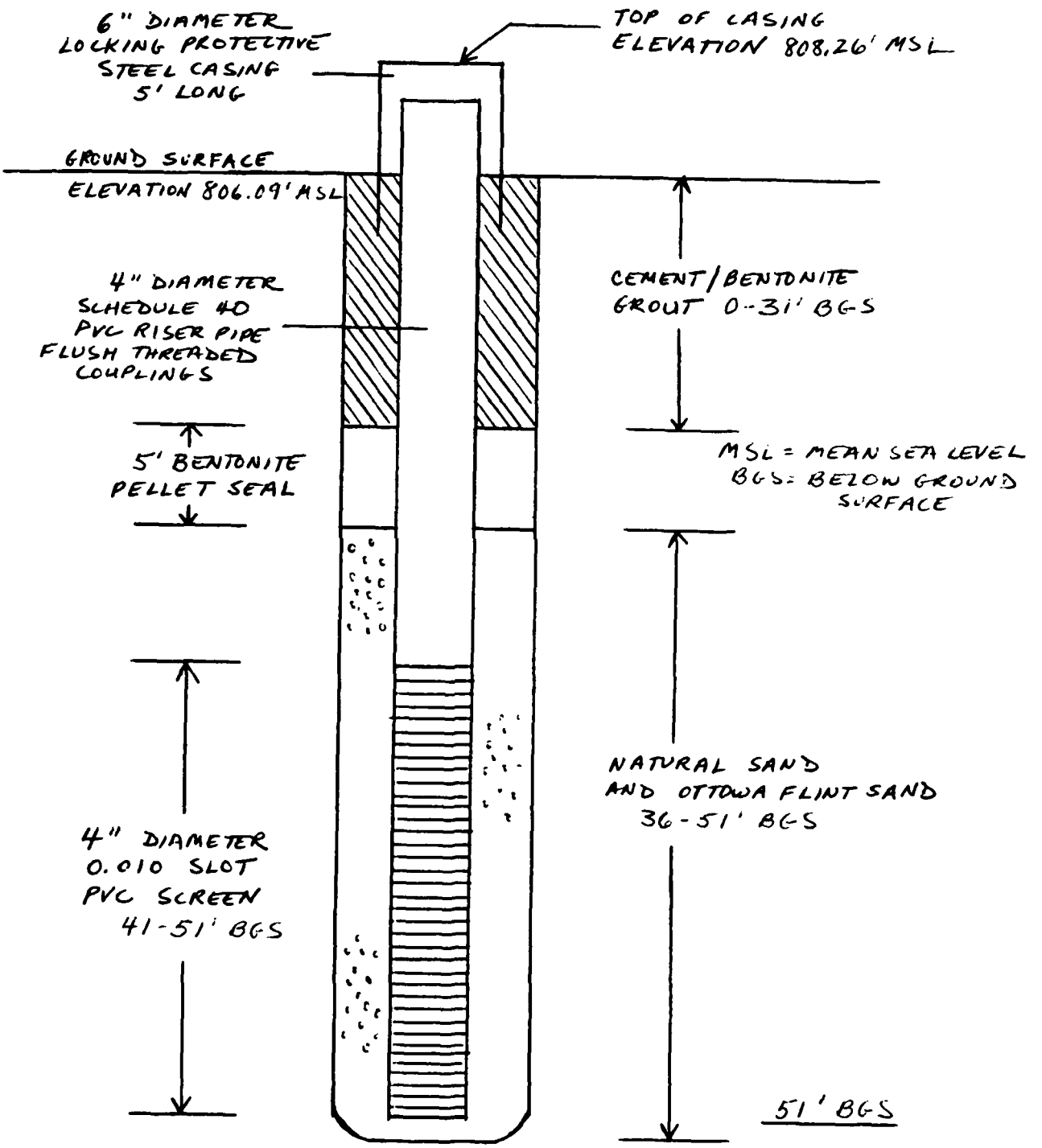
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-6

RFW 338-5-81

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-6 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH 51.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C. Patterson DRILLING METHOD: Cable Tool DATE DRILLED: 1 Dec. 1983
DRILLER: S.C. Patterson HELPER: J. Patterson
LOG BY: J. Williams

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2'					Soil mixed with 3/8" gravel
-15'					Green-Brown Clay with minor Fine sand.
-19'					Fine Sand with clay matrix
-23'					Coarse to Medium Sand, minor clay, mixed with sub-angular gravel * First water
-31'					3/8" - 3/4" gravel mixed with Medium to Very Coarse Sand, minor clay.
-35'					Medium to Coarse Sand, some gravel, minor clay
-45'					Medium to Coarse Sand, some gravel, clay matrix
-51					Medium to Coarse Sand mixed with clay.

* ASTM D1586

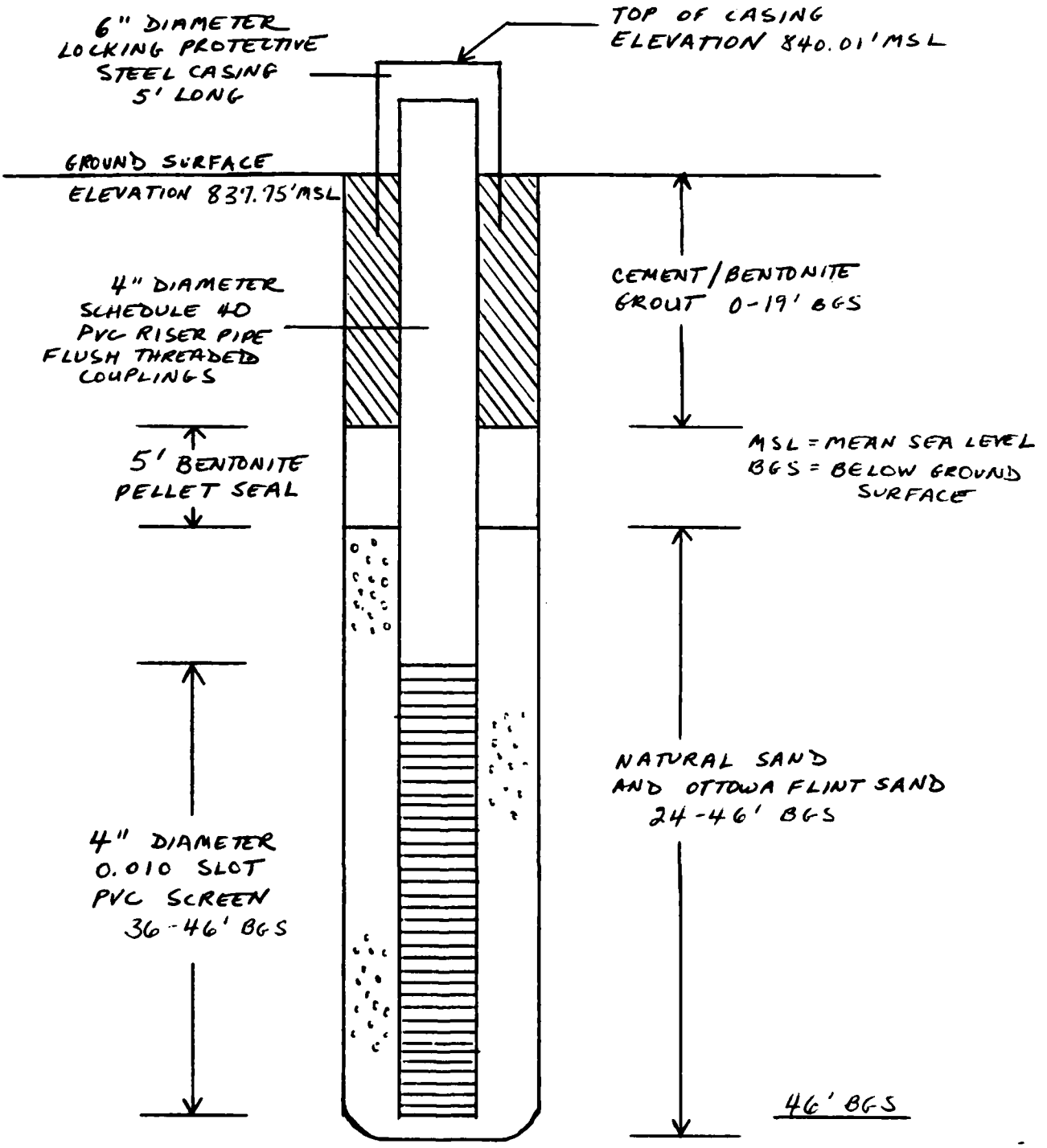
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB

WELL NUMBER MW-5

WESTON DESIGNSM CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-5 OWNER: _____
LOCATION: _____ ADDRESS: _____
TOTAL DEPTH 46.0'
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: S.C. Patterson DRILLING METHOD: _____ DATE DRILLED: 8 DEC. 1983
DRILLER: S.C. PATTERSON HELPER: J. Patterson
LOG BY: D. Eggs

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2					Green-Brown Clay soil mixed w/ Fine Sand.
2-25					Greenish-Brown Sandy Clay, Fine grain
					* First water
25-27					Brownd Sand, Medium to Fine grain, with a clay matrix
27-33					Grey Clay, very dense
33.0'-34.5'		1	1.000 SS		Medium to Coarse grain yellow sand. (moist)
33 38					Brownish-yellow Medium grain Sand with 1/4-3/8 gravel Saturated
38 44					Brown Medium to very coarse sand with 1/2" gravel and cobbles.
44 46					Brown Medium grain sand

* ASTM D1586

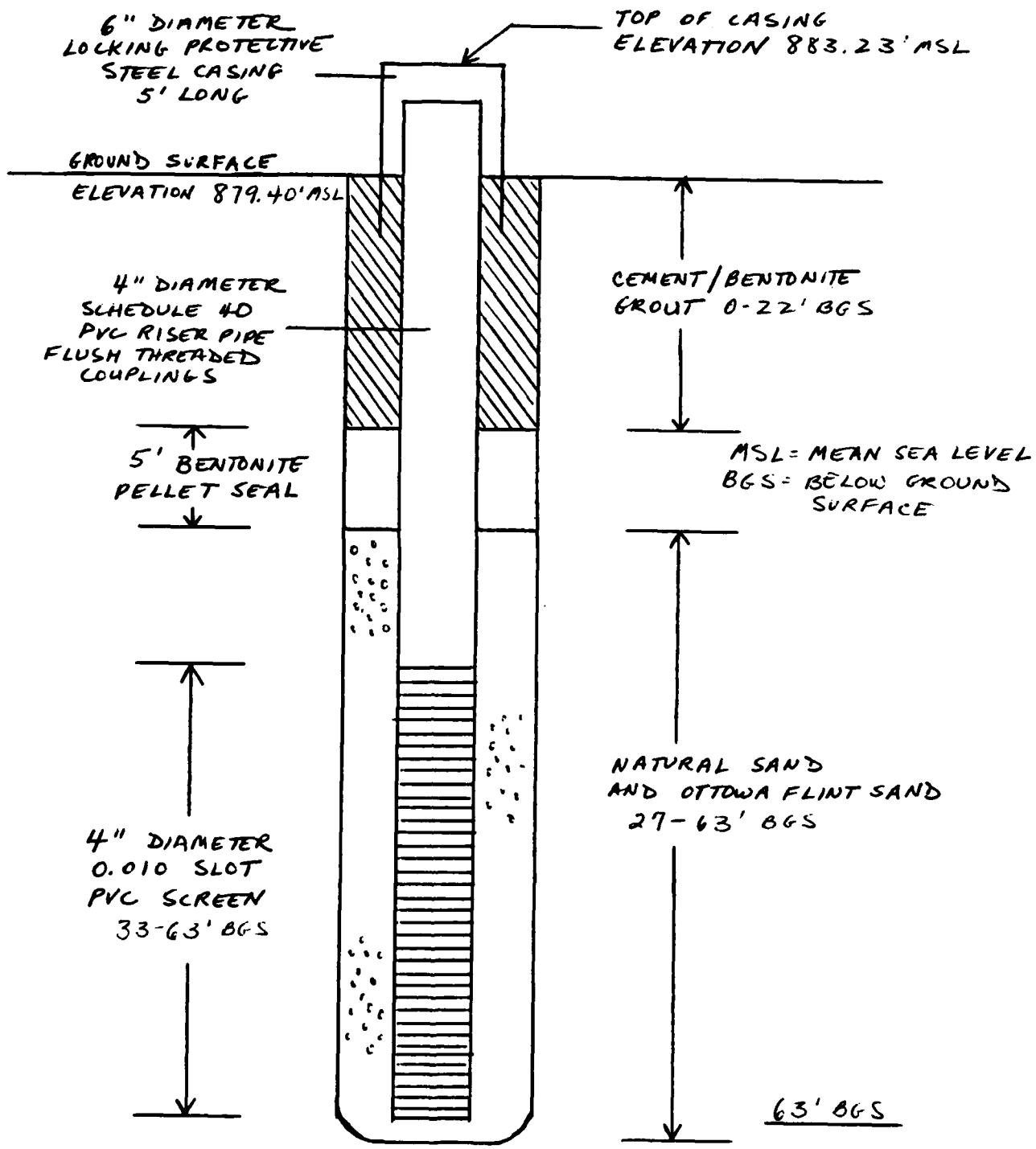
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-4

RFW 338-5-81

WESTON
DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-4 OWNER: USAF
LOCATION: _____ ADDRESS: Wright-Patterson
~~Dunbar~~ AFB
TOTAL DEPTH 63
SURFACE ELEVATION: _____ WATER LEVEL: 38
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: HSA DATE DRILLED: 12-9-83 12-10-83
DRILLER: Bill Chrastek HELPER: _____
LOG BY: Bowser-Morner

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1					Topsoil, Brown Clay, some silt [redacted] trace sand, moist
1-6					Green clay, some silt, trace sand and gravel, moist
6-38					Green Clay, some silt, 1"-3" interbedded Sand Layers, wet
38-49					Brown Sand, trace silt, wet
49-50.5		1	SS		Brown Sand, trace silt wet
50.5-63					Green Silt, some sand wet
54-60		2	SS		Green Silt, some sand wet

* ASTM D1586

SHEET ___ OF ___

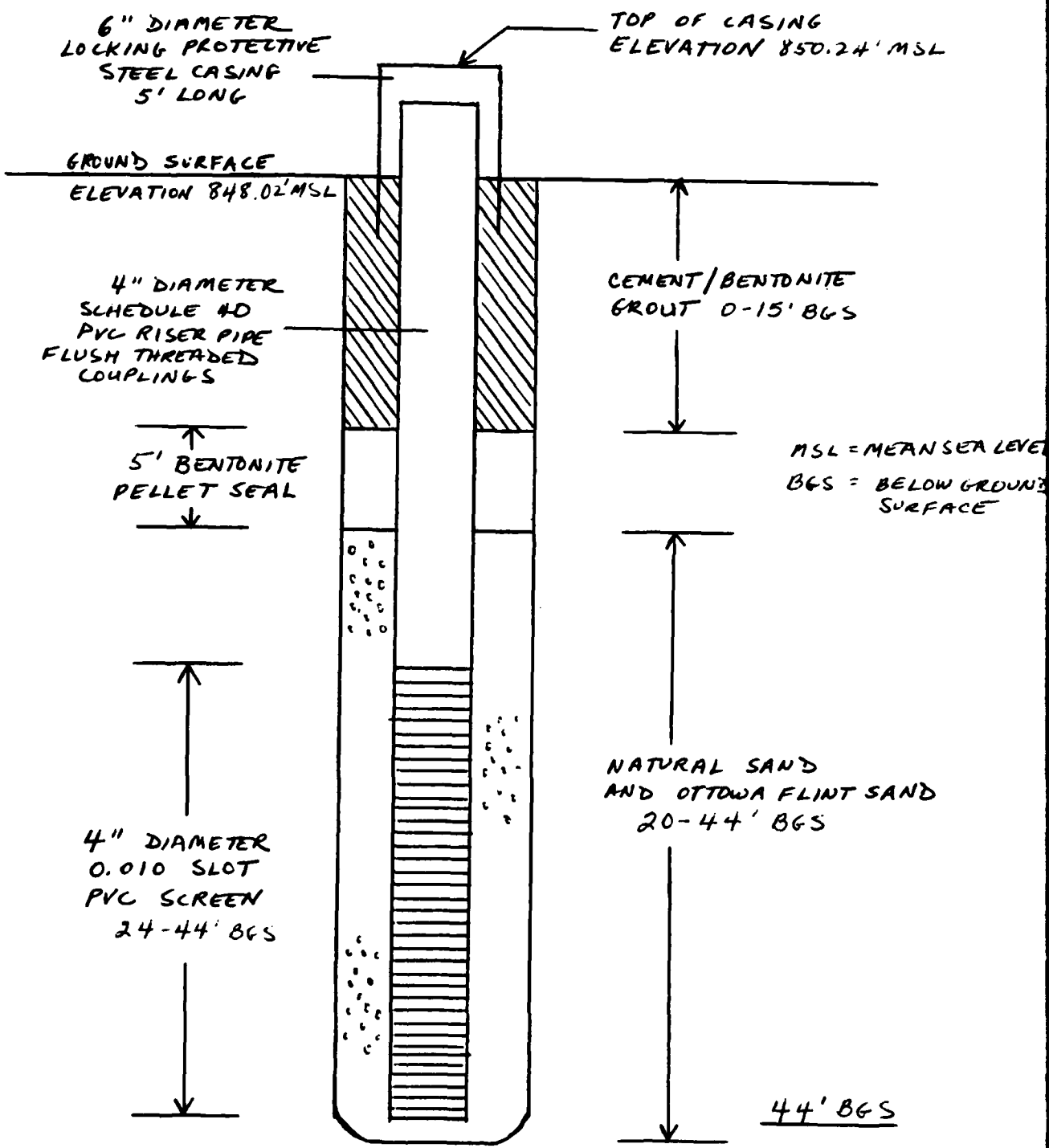
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-3

RFW 338-5-81

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW 3 OWNER: _____
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH _____
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: S.C. Patterson DRILLING METHOD: Cable Tool DATE DRILLED: 7 DEC. 1983
DRILLER: S.C. PATTERSON HELPER: J. PATTERSON
LOG BY: D. Epps

SKETCH MAP

NOTES:
8 DEC 1983 DTW = 8.0'

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-9					GREENISH-BROWN clay
9-13					GREENISH-BROWN Sandy Clay, Medium to Fine grain
13-15					Greenish-Brown Sandy Clay, Fine grain
15-16					Medium to Coarse Sand with Clay matrix
16-24					Green-Brown Sandy Clay, Medium to Fine grain
24-27					Brown Sandy-clay, 1/4"-3/8" gravel mixed
27-32					GREEN-BROWN Sandy Clay, Fine grain
32'-33.5'		1	SS	46/18"	FINE-MEDIUM Sand w/ clay matrix - saturated.
32-37					GREEN BROWN Sandy Clay, Medium to Fine grain.
37-45					Blue-Gray clay with little Fine Sand

* ASTM D1586

SHEET ___ OF ___

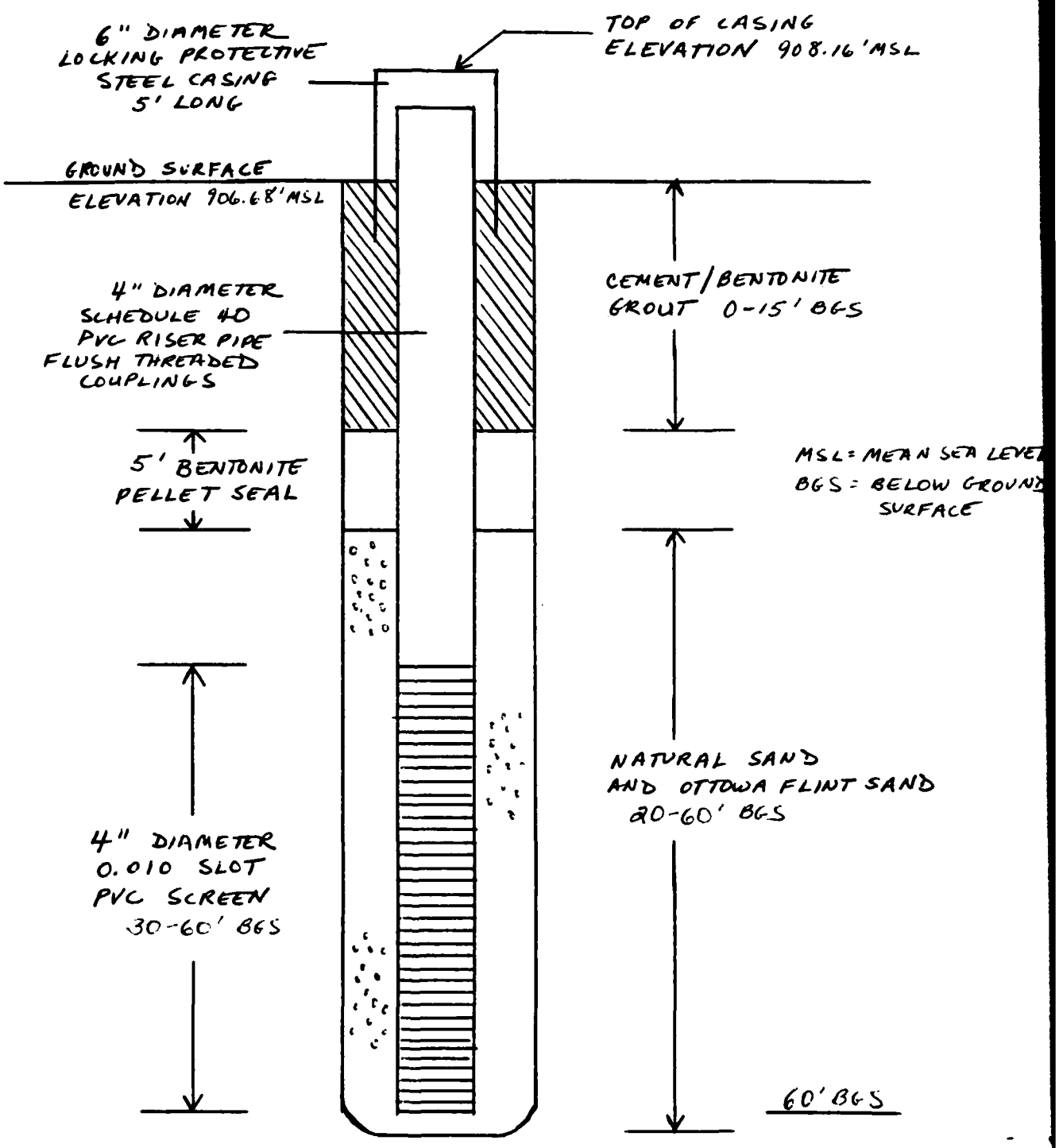
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-2

WESTON DESIGNERS & CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-2 OWNER: _____

LOCATION: _____ ADDRESS: _____

TOTAL DEPTH 60.0'

SURFACE ELEVATION: _____ WATER LEVEL: _____

DRILLING COMPANY: S.C. Patterson DRILLING METHOD: Cable Tool DATE DRILLED: 9 DEC 1983

DRILLER: S.C. Patterson HELPER: J. Patterson

LOG BY: D Epps

SKETCH MAP

NOTES:
Approx. 9.0' splinters of lumber were brought out of bore hole

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-12					Green-Brown clay with 3/8" gravel
12-16					Yellow-Brown Fine grain Sandy Clay, some gravel
16-27					Yellow-Brown Medium to Fine grained Sandy Clay
27-37					Gray Clay with small amounts of Fine grain sand. * First water
37-40					Gray Sandy Clay, Fine to Medium grain
40-44					Brownish-Gray sandy Clay, Fine to Medium grain
44-55					GREENISH-Brown Sandy Clay, Medium to Coarse grain
55-58					GREENISH Brown Sandy Clay, Medium to Coarse grain
58-60					Gray Sandy Clay, Fine to Medium grain

* ASTM D1586

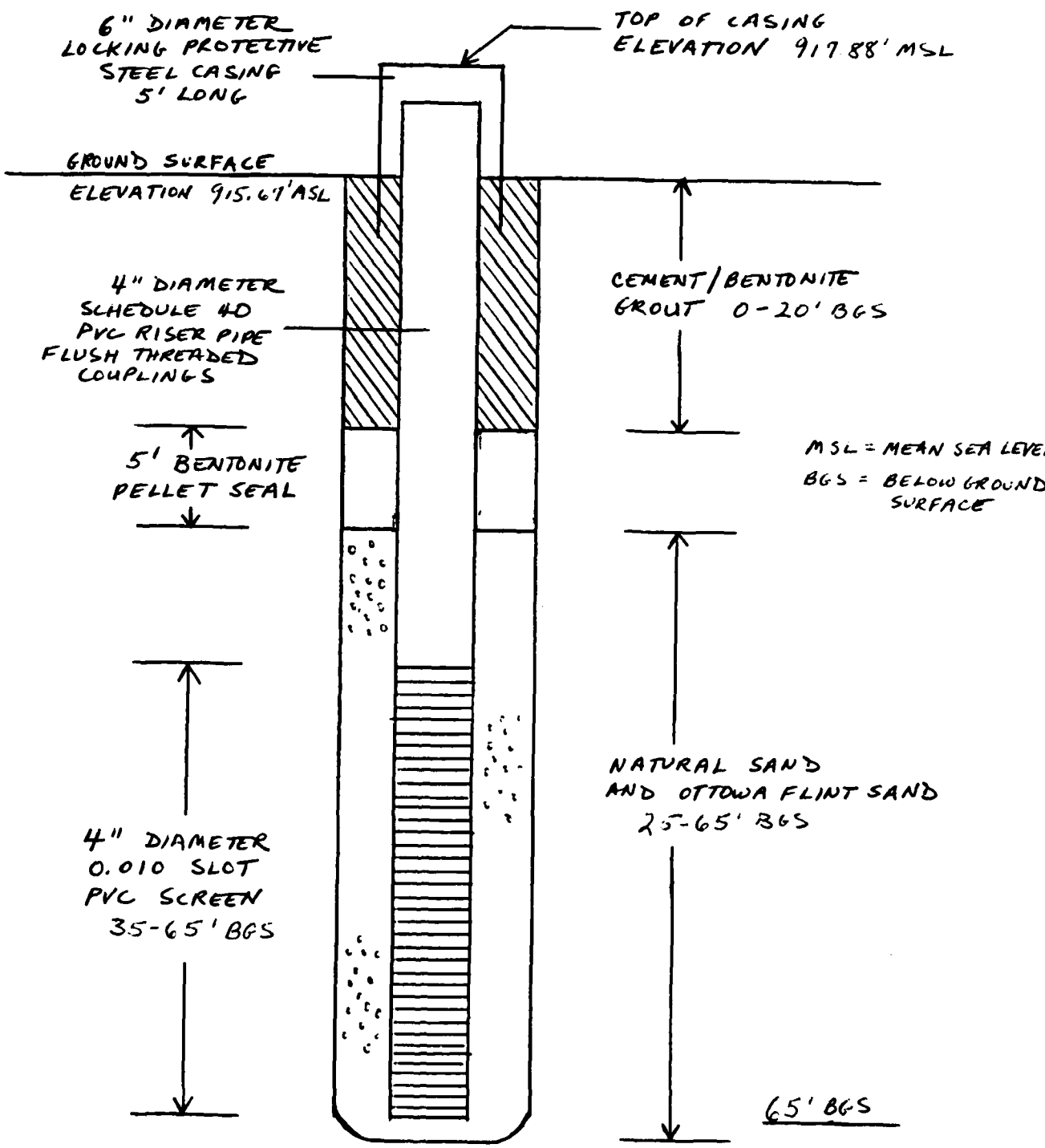
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-1

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-8 OWNER: USAF
LOCATION: _____ ADDRESS: Wright Patterson
TOTAL DEPTH 23
SURFACE ELEVATION: _____ WATER LEVEL: 8
DRILLING COMPANY: S.C. Patterson DRILLING METHOD: Cable Tool DATE DRILLED: 2/5 DEC 83
DRILLER: S.C. Patterson HELPER: J Patterson
LOG BY: Bonser Manor.

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1					Topsoil and fill material
1-5					Clay mixed with sand and gravel
5-10					Clay mixed with sand and gravel
10-23					Clay mixed with sand and gravel

* A.S.T.M D1586

SHEET ___ OF ___

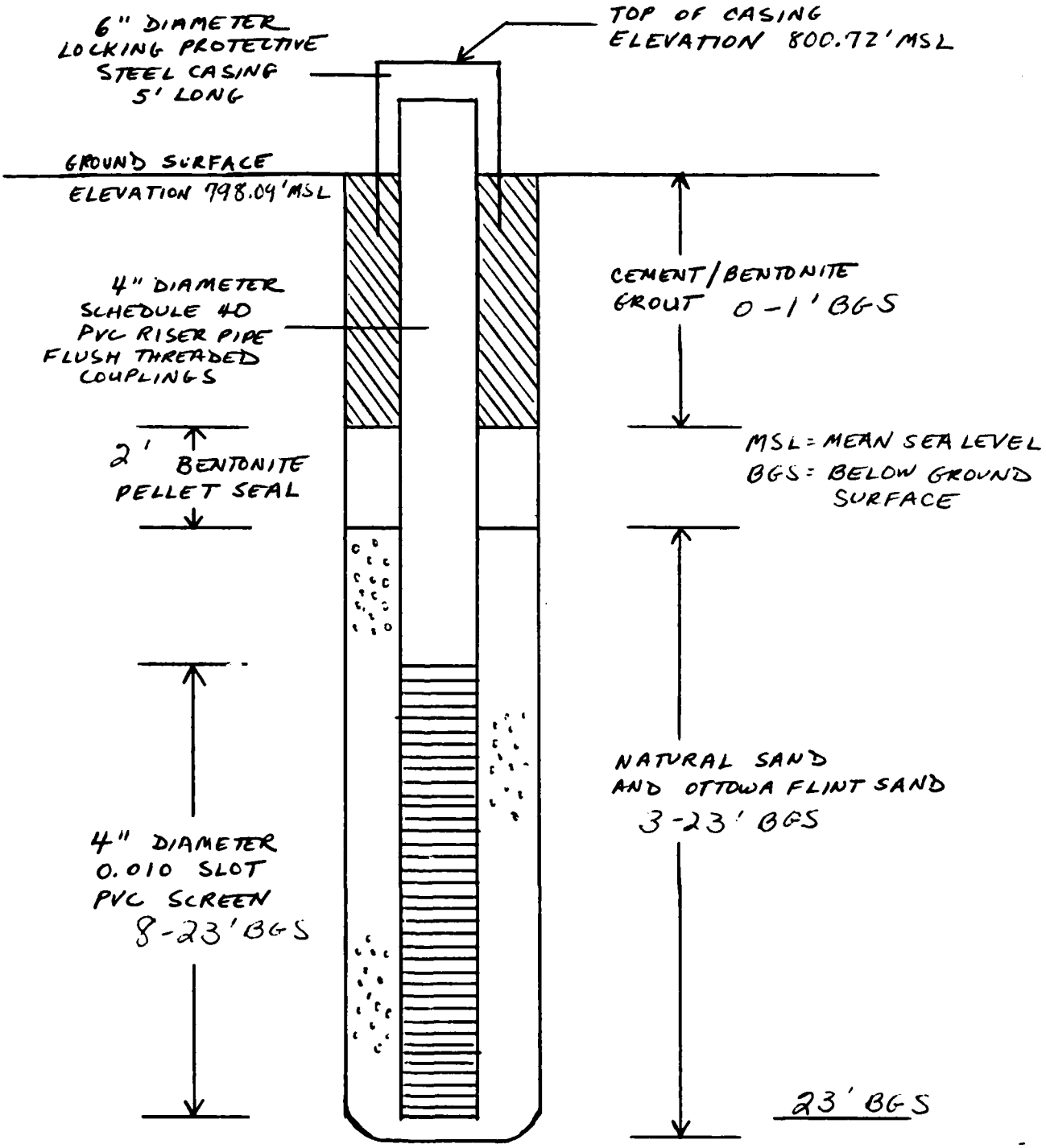
WESTON DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB

WELL NUMBER MW-8

WESTON
DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-9 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH 23.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C. PATTERSON DRILLING METHOD: CABLE TOOL DATE DRILLED: 2 DEC 1983
DRILLER: S.C. PATTERSON HELPER: J. PATTERSON
LOG BY: J. Williams

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0 - 2					Soil mixed with 3/8" gravel and Fine to medium Sand.
2 - 23					Brown Medium to Very Coarse Sand mixed with 3/8" - 3/4" gravel, minor clay.

* ASTM D1586

SHEET ___ OF ___

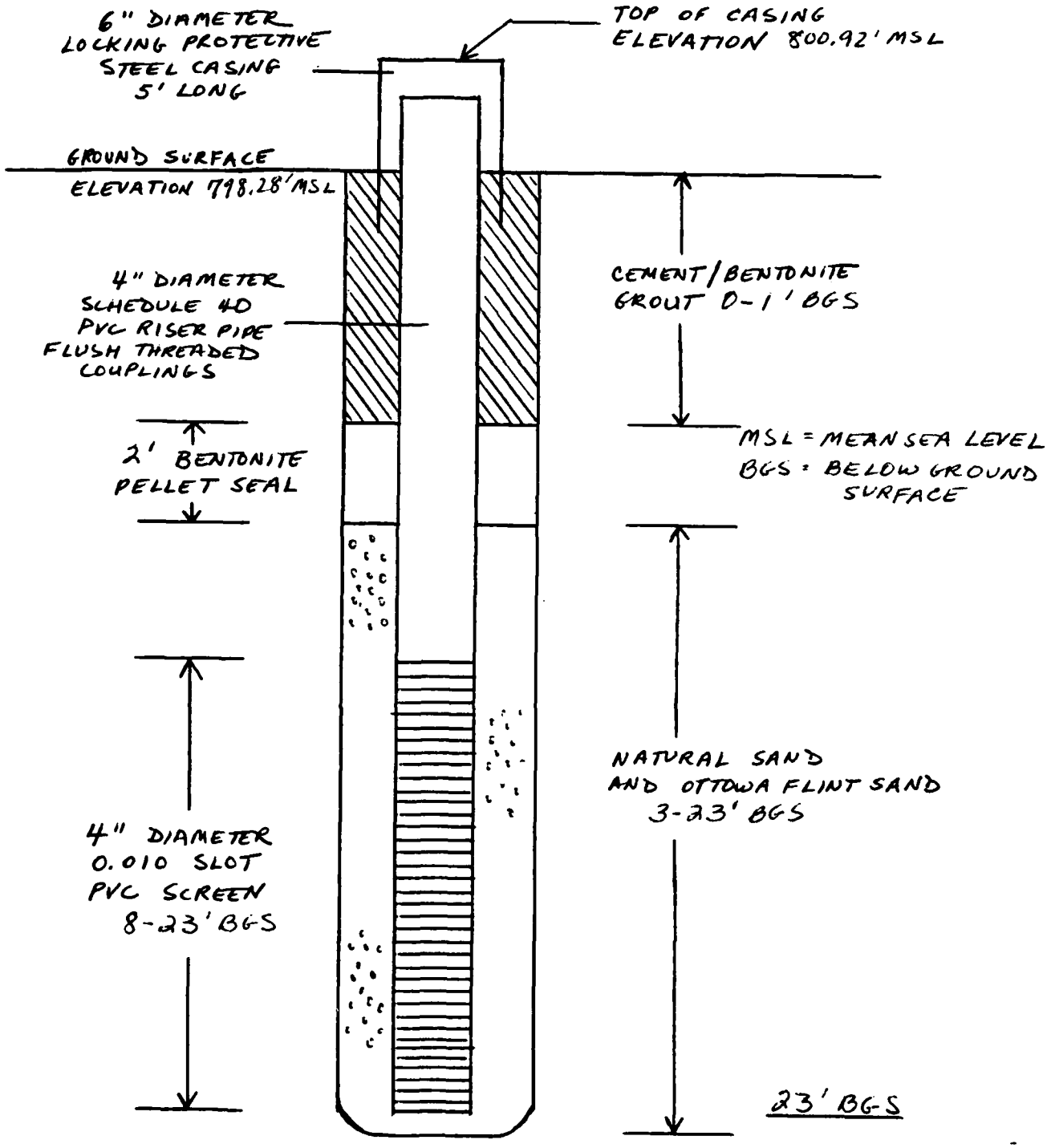
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-9

RFW 338-5-81

WESTON
DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-10 OWNER: _____
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH 39
SURFACE ELEVATION: _____ WATER LEVEL: 7.0
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: _____ DATE DRILLED: 12-1-83 12-2-83
DRILLER: BL HELPER: RH
LOG BY: Bowser-Morner

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2.0					Black silt, some clay, trace of sand moist
2-26					Brown sand and gravel (6"), trace silt wet
26-27					Br clay seam, moist
27-39					Brown Sand and gravel, trace silt. wet

* ASTM D1586

SHEET ___ OF ___

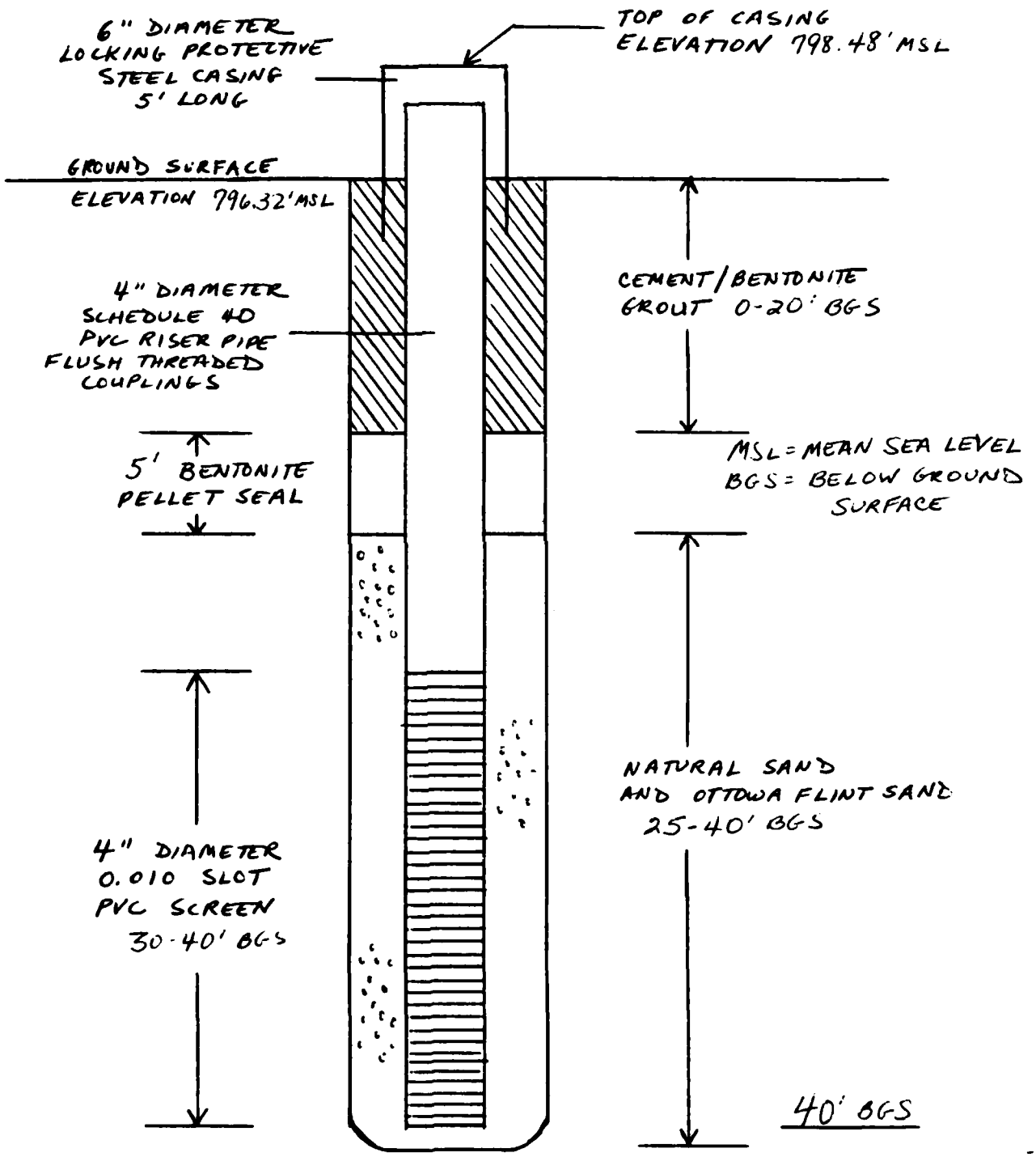
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-10

WESTON
DESIGNERS & CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-11 OWNER: USAF
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH 29
SURFACE ELEVATION: _____ WATER LEVEL: 12
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: HSA DATE DRILLED: 11-29-83 / 11-30-83
DRILLER: BC HELPER: RH
LOG BY: Bowser-Morner

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1					Black sand and gravel, mixed with fill material ie. concrete, brick, wire
1-7					Brown clay, some silt moist
7-29					Brown sand and gravel, trace silt wet @ 12'

* ASTM D1586

SHEET ___ OF ___

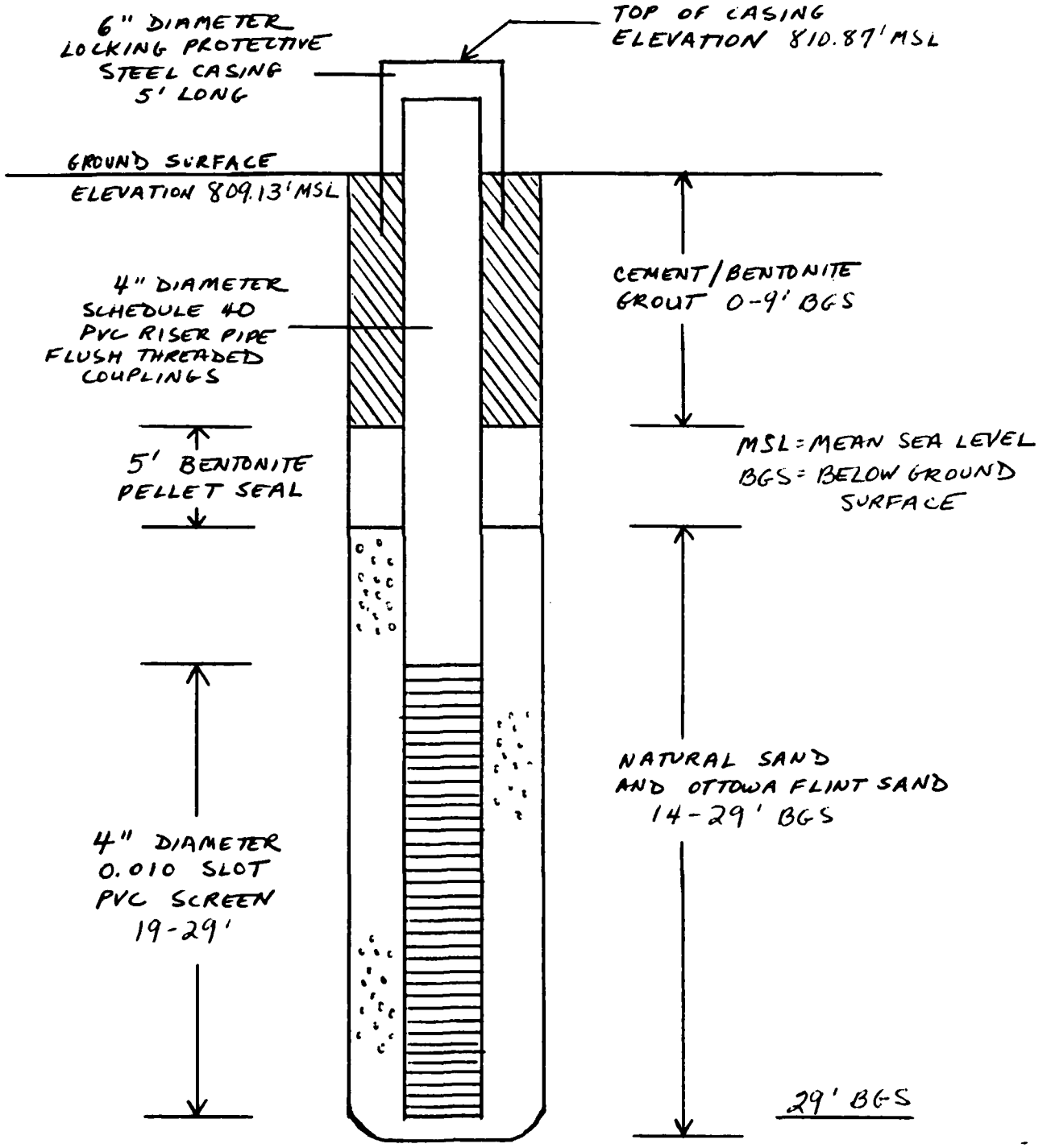
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-11

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-12 OWNER: _____

LOCATION: _____ ADDRESS: _____

_____ _____

_____ TOTAL DEPTH 40.0'

SURFACE ELEVATION: _____ WATER LEVEL: 13.0' 30 NOV. 1983

DRILLING COMPANY: S.C. PATTERSON DRILLING METHOD: Cable Tool DATE DRILLED: 29 Nov. 1983

DRILLER: S.C. PATTERSON HELPER: J. Patterson

LOG BY: J. Williams

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1					Brown Sandy Top Soil
1-12					Brown Sandy Clay, Fine grain
12-18					Brown Clay Sand, Fine grain
18-22					Medium to Coarse Sand, minor clay
22-28					Coarse Brown Sand, little to NONE clay
28-40					Coarse to Very Coarse Sand, mixed with 1/4" - 3/8" gravel

* ASTM D1586

SHEET ___ OF ___

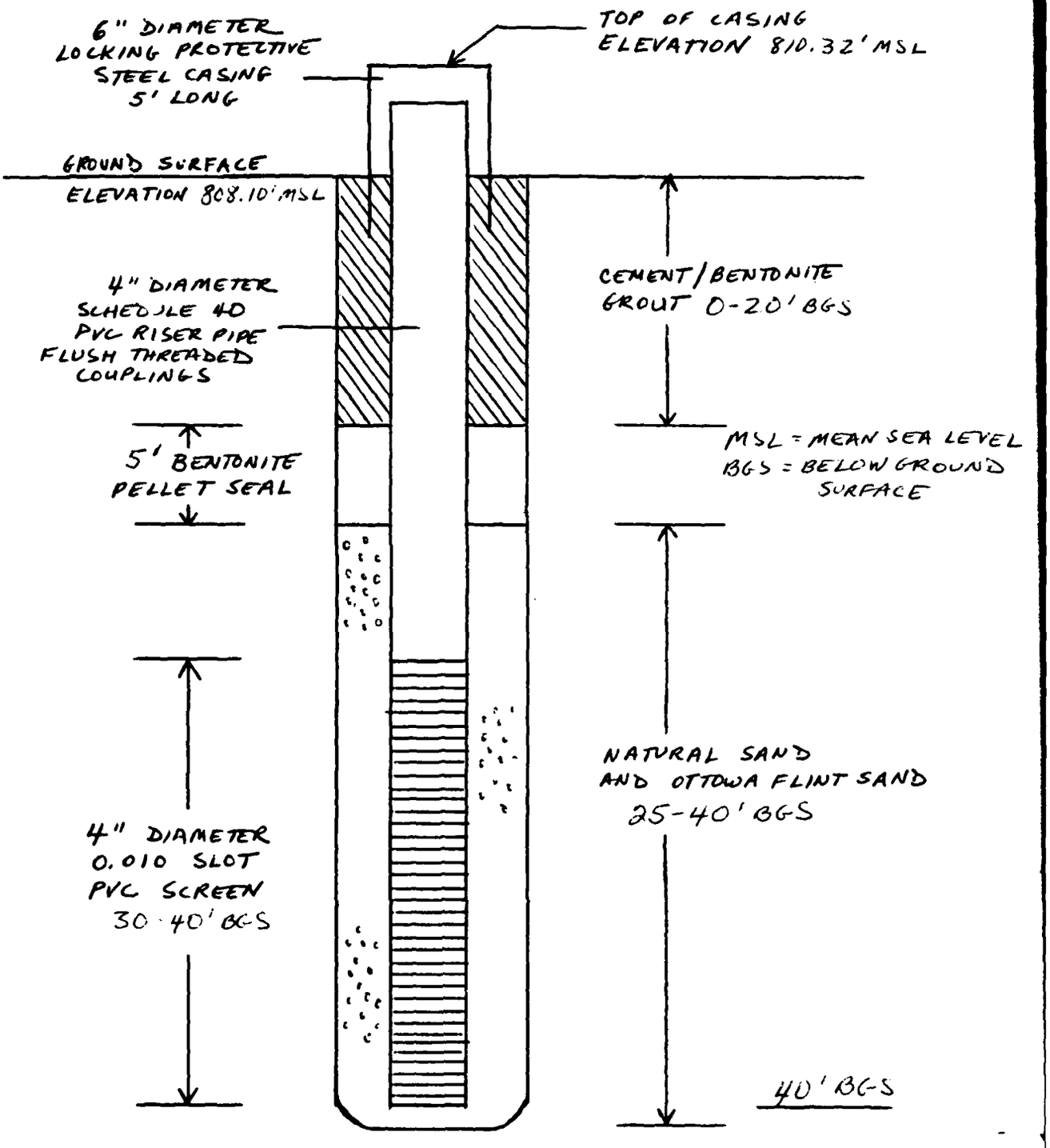
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-12

RFW 338-5-81

WESTON DESIGNERS & CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-13 OWNER: _____

LOCATION: _____ ADDRESS: _____

TOTAL DEPTH 27.0'

SURFACE ELEVATION: _____ WATER LEVEL: 10.0' 29 NOV 1983

DRILLING COMPANY: Bowser-Morner DRILLING METHOD: Auger DATE DRILLED: 28 NOV. 1983

DRILLER: Bill Chastie HELPER: Rob

LOG BY: John. Williams
M. Dzeday

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-6'					Brown Sandy Clay, Fine grain
4-5.5		1A	SS	8 11 14	
6-10'					Brown Clay Sand, Fine grain, trace of gravel
9-10.5		2A	SS	0.5 Rec 6 8 8	3½" Gravelly Silt, 7" light Brown fine-medium grain sand (moist)
10-18'					Coarse to Very Coarse sand mixed with ½" to 1" Gravel.
14 15.5'		3A	SS	7 14 22	brownish Gray Sandy gravel, 3/4" - 1¼" saturated
18-27'					Brownish-Gray Coarse to Very Coarse Sand mixed with ½" - 1¼" Gravel
19-20.5'		4A	SS	0.67 Rec	Brown Gray rounded Gravel, fine to Coarse Sand.
24 25.5'		5A	SS	1.0 Rec 90	Fine to Very Coarse brown sand, minor clay

* ASTM D1586

SHEET ___ OF ___

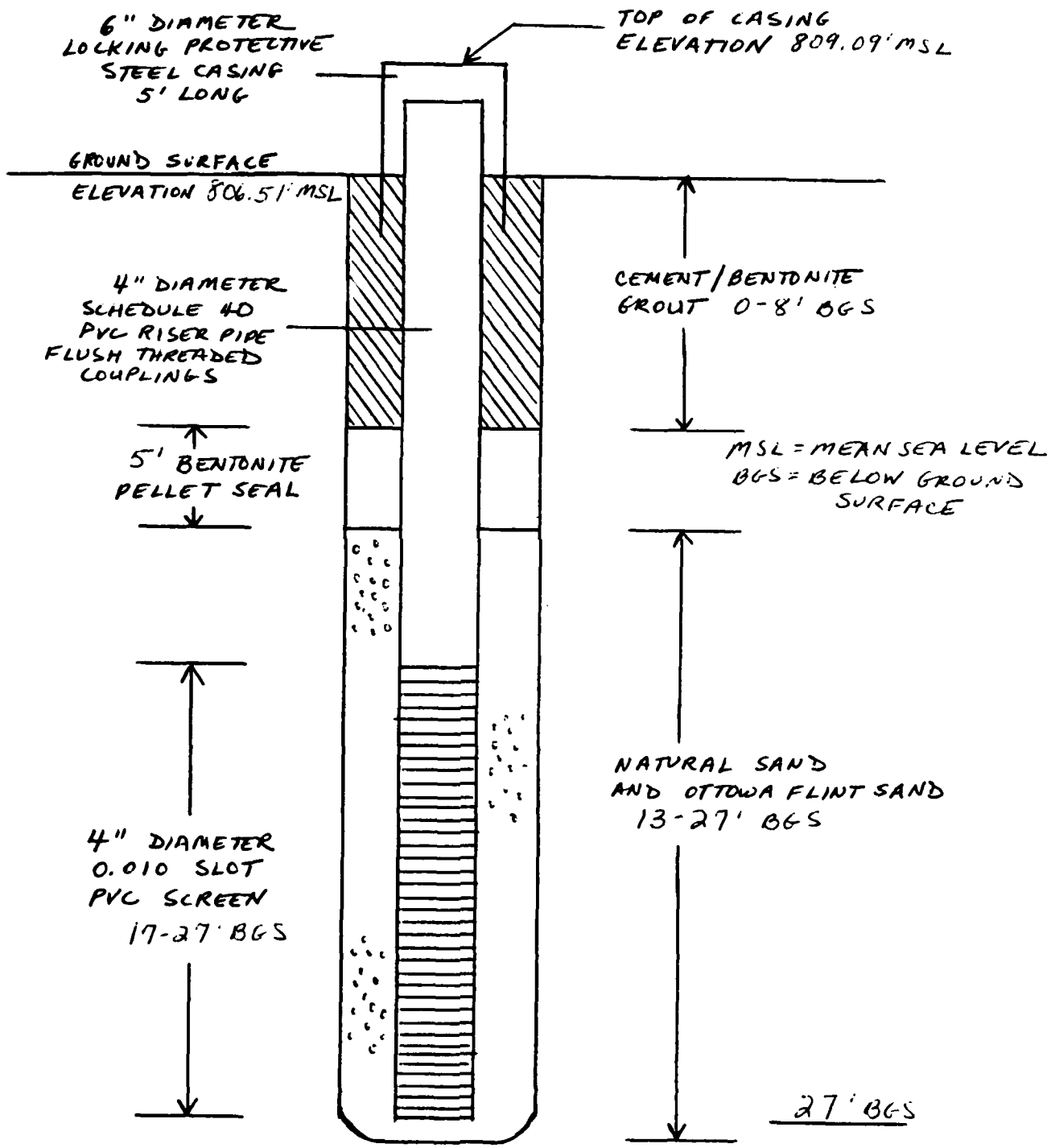
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

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SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-13

RFW 338-5-81

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-14 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH 50
SURFACE ELEVATION: WATER LEVEL: 7.0
DRILLING COMPANY: Brasser-Mervin DRILLING METHOD: HSA DATE DRILLED: 11-30-83 / 12-1-83
DRILLER: B.C HELPER: RH
LOG BY: Brasser-Mervin

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0.5					Top soil
2					Brown sand, some silt, moist
2-7					Brown clay, some silt, moist-wet
19					Brown sand and gravel, some silt, wet
7-22					Brown clay, some silt, wet
28					Brown sand and gravel, wet
35					Brown clay, some silt, wet
50					Brown sand and gravel, trace silt with several 1" to 2" clay layers interbedded.

* ASTM D1586

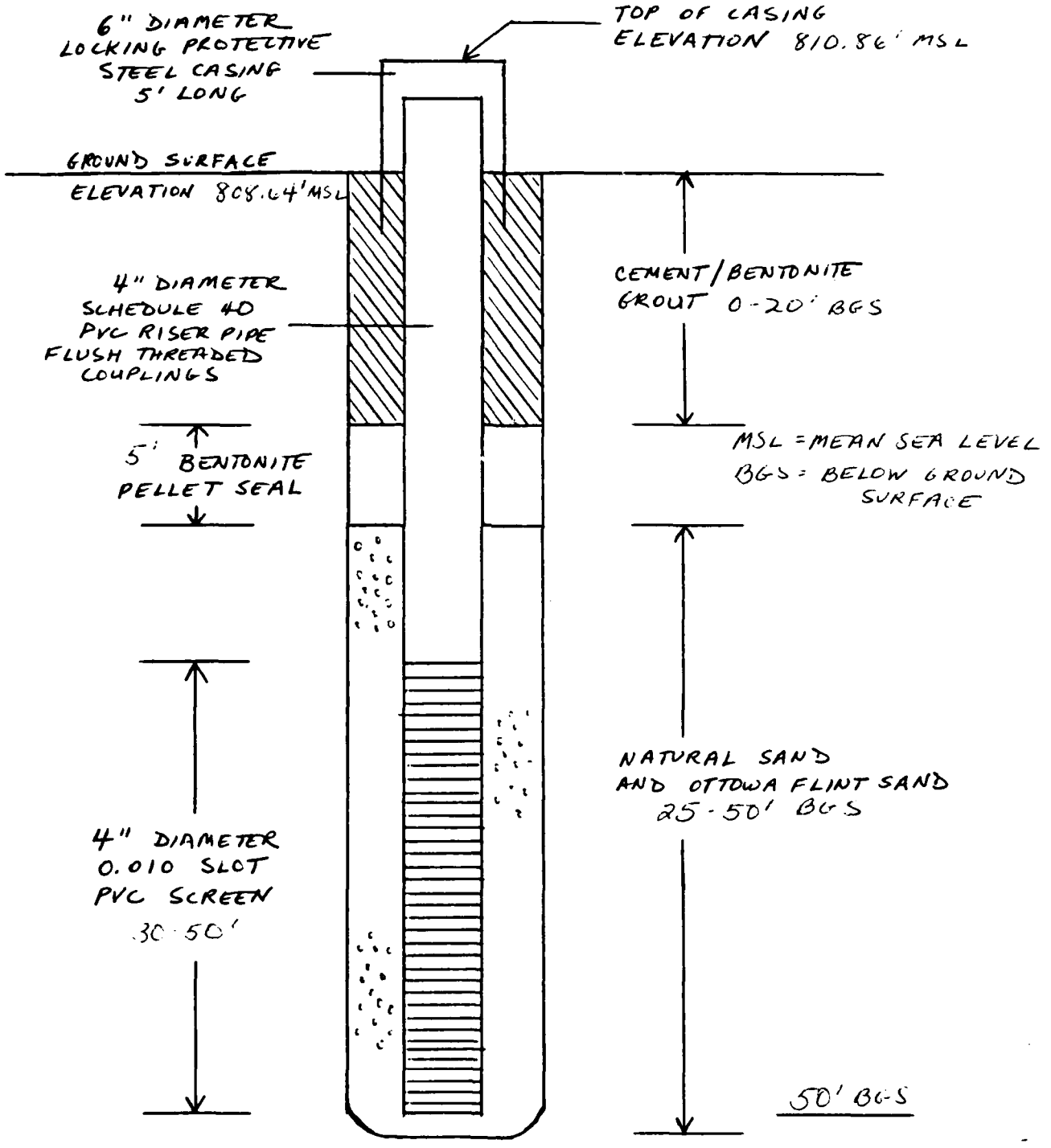
WESTON
DESIGNERS CONSULTANTS

_____ DATE _____ DIV _____ SHEET _____ OF _____

KD BY _____ DATE _____ DEPT _____ W.O. NO. _____

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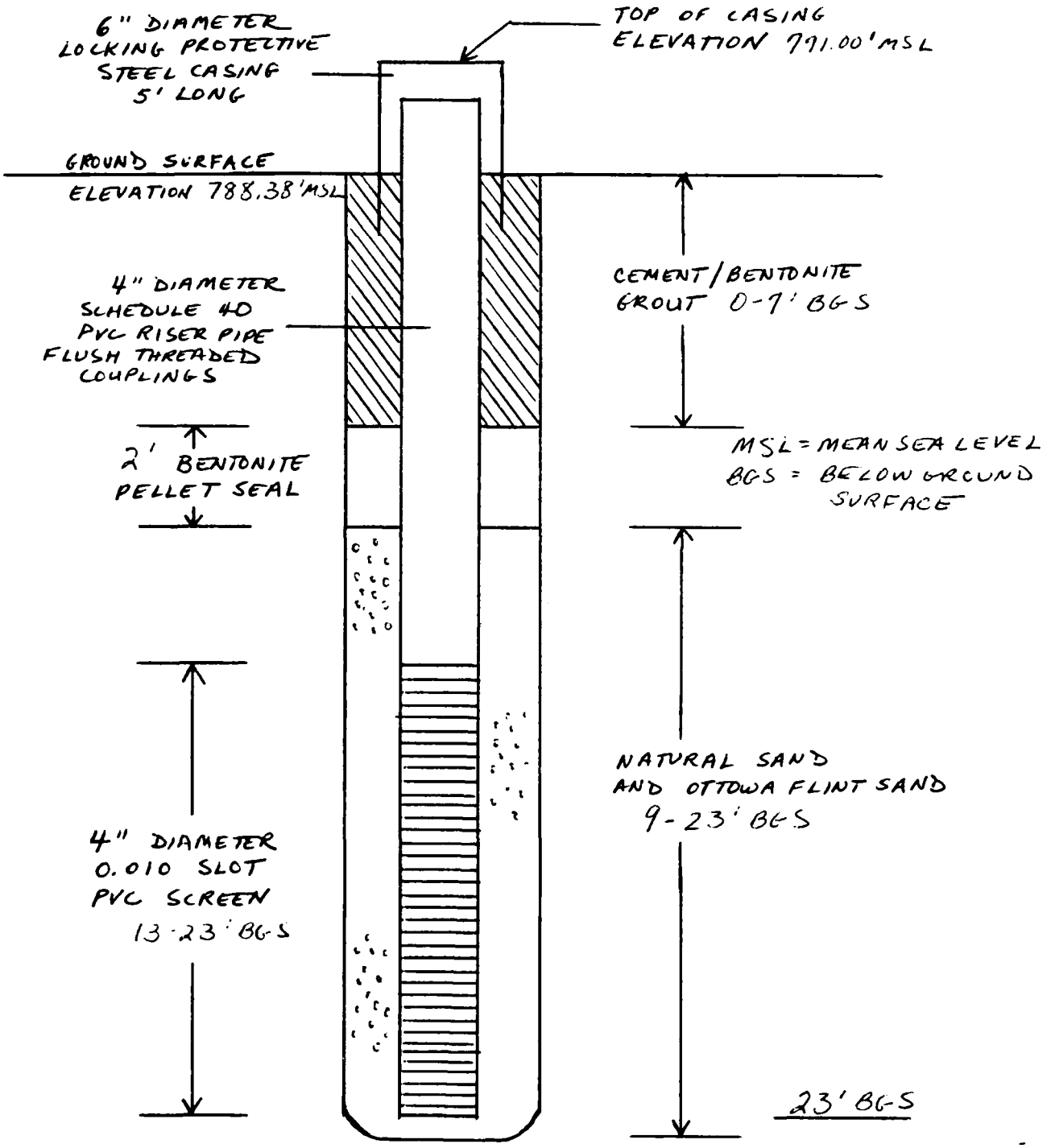


WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-14

REW 338-5-81

WESTON
DESIGNERS CONSULTANTS

Y_____ DATE_____ DIV_____ SHEET_____ OF_____
HKD BY_____ DATE_____ DEPT_____ W.O. NO._____
ROJECT_____
UBJECT_____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-21

RFW 338-5-81

WESTON

DRILLING LOG

WELL NUMBER: MW-21 OWNER: USAF
LOCATION: Landfill 5, along Runnymede Rd., Southern Tip of Landfill ADDRESS: WRIGHT-PATTERSON A.F.B. FAIRBORN, OHIO
TOTAL DEPTH 25.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: Hollow stem Auger DATE DRILLED: 7 FEB. 1984
DRILLER: Bill Whitaker HELPER: Ralph East.

LOG BY: M. DZEDZY

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
2.0'					Black organic silt, sand and minor gravel
4.0					Brown sand and gravel, minor silt
9.0					Brown sand and gravel, minor silt
12.0					Brown Sand, and gravel, cobbles moist
15.0					Brown sand and gravel, cobbles, wet
18.5'		1	SS	9,10 14	rec. 18.0" - Saturated, Sand and gravel.
23.0					Brown Sand and gravel, Cobbles, minor silt
-25.0					Brown Sand and gravel, Cobbles

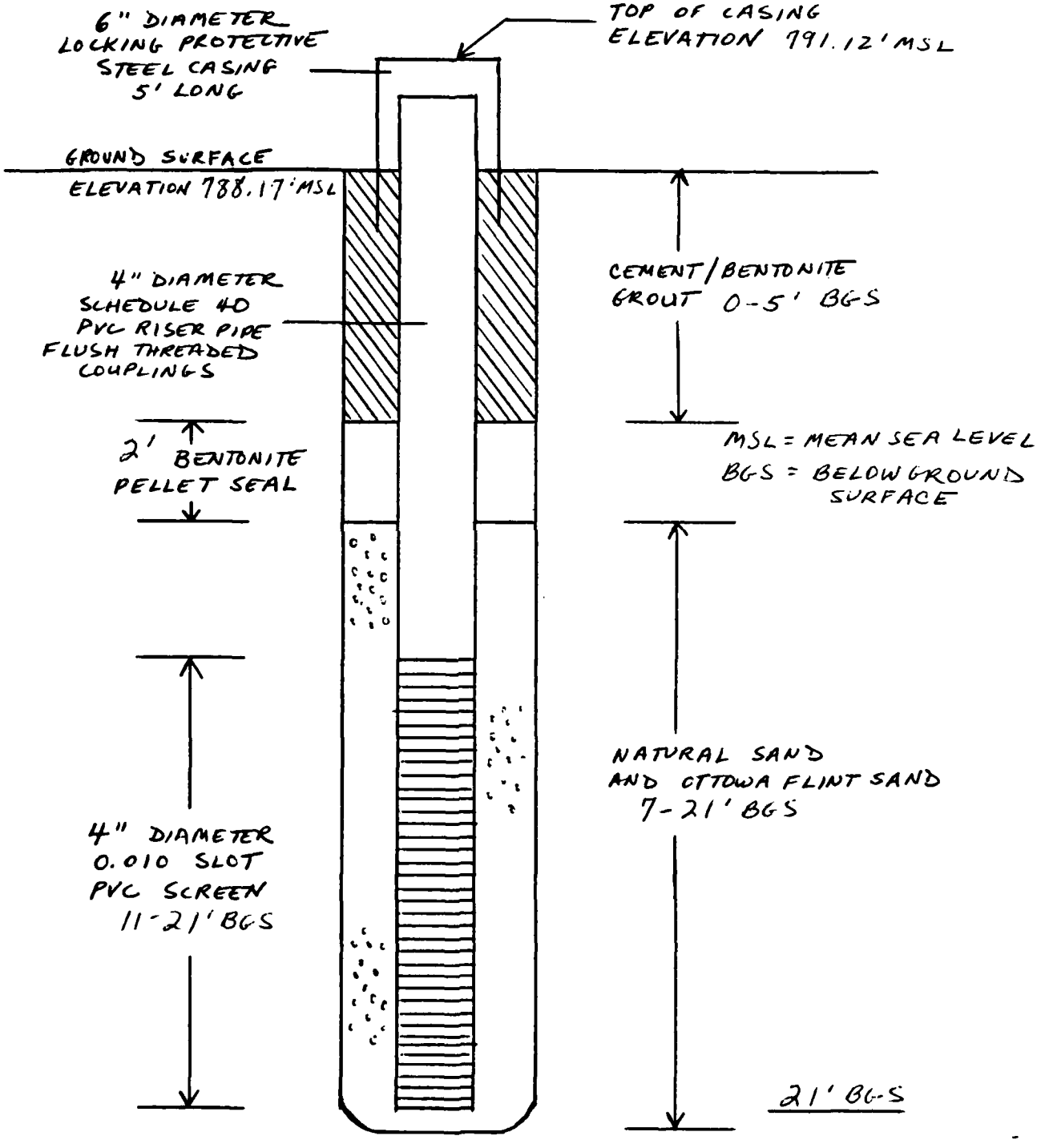
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-20

RFW 338-5-81

WESTON

DRILLING LOG

WELL NUMBER: MW 20 OWNER: USAF
LOCATION: Landfill 5, Along Riverview Rd, Northern Part of Landfill ADDRESS: WRIGHT-PATTERSON A.F.B., FAIRBORN, OHIO
SURFACE ELEVATION: _____ TOTAL DEPTH 25.0
DRILLING COMPANY: Bowser-Morner WATER LEVEL: _____
DRILLING METHOD: Hollow Stem Auger DATE DRILLED: 9 FEB 1984
DRILLER: Bill Whitaker HELPER: Jeff Akers
LOG BY: B. Whitaker

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
-1.0					Topsoil
-3.5					Brown Silt and clay, minor sand and gravel
-5.5					Brown Medium sand and gravel, minor silt
5-8.5					Sand and gravel mixed with cobbles, minor silt moist
5-12.5					Sand and gravel mixed with cobbles, minor silt, clay wet @ 12.5'
5-15.0					Sand and gravel mixed with cobbles, minor silt & clay
5-16.5		1	S.S.	10,13 12	16.0' Rec. Saturated
0-19.0					Sand and gravel mixed with cobbles, minor silt & clay
0-25.0					Sand and gravel mixed with cobbles, minor silt & clay

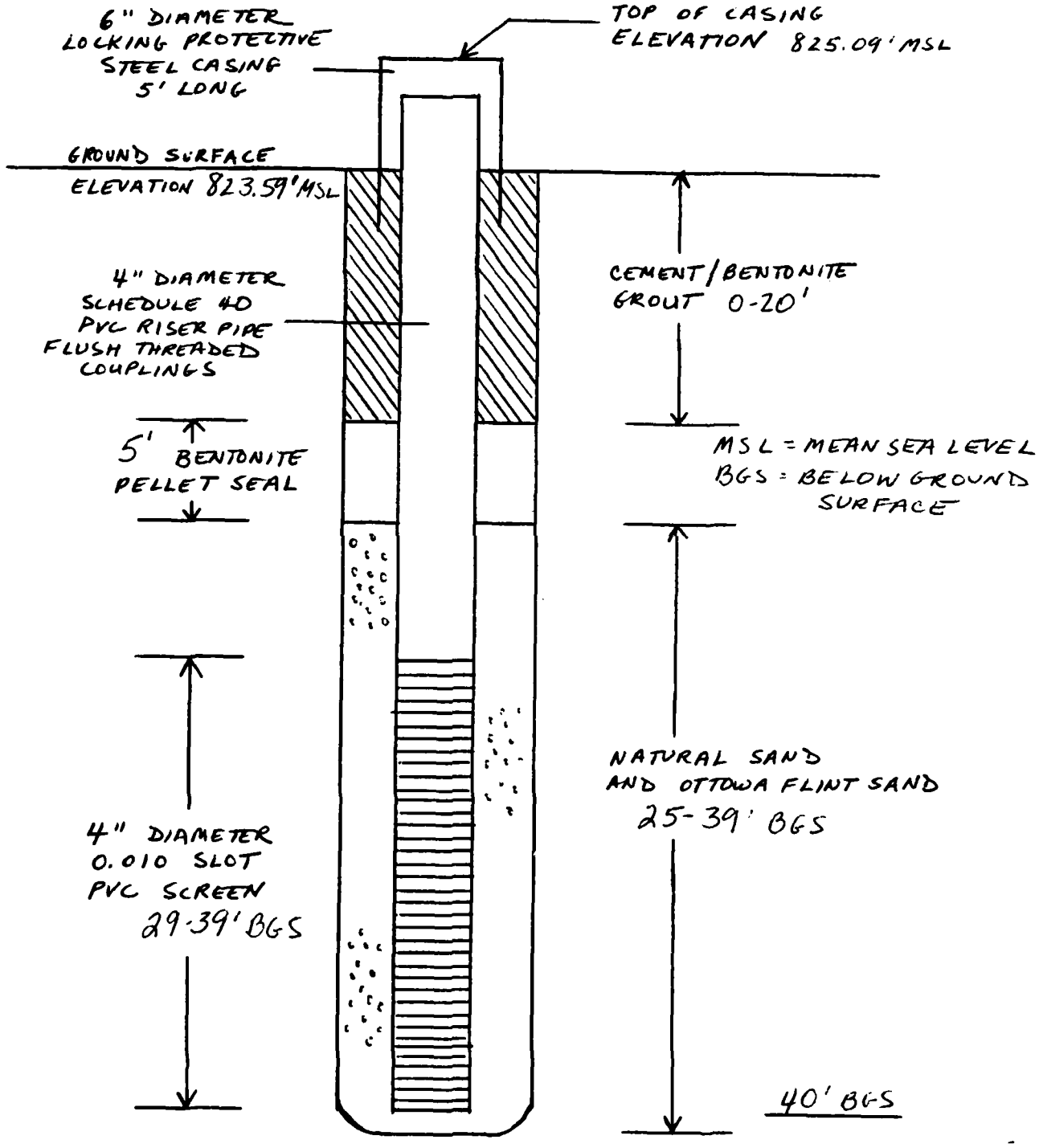
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-19

RFW 338-5-81

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-19 OWNER: USAF
LOCATION: _____ ADDRESS: _____
TOTAL DEPTH 40
SURFACE ELEVATION: _____ WATER LEVEL: 22
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: HSA DATE DRILLED: 12-5-83
DRILLER: B.C. HELPER: R.H
LOG BY: Bowser-Morner

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1					Topsoil
1-2					Brown clay
2-12					Brown Sand and gravel (5")
12-22					Hard Green silt and clay layers interbedded with 1" sand layers, ~~damp~~, trace rock fragments, damp.
22-40					Green-Brown Sand and gravel, dense wet @ 22'

* ASTM D1586

SHEET ___ OF ___

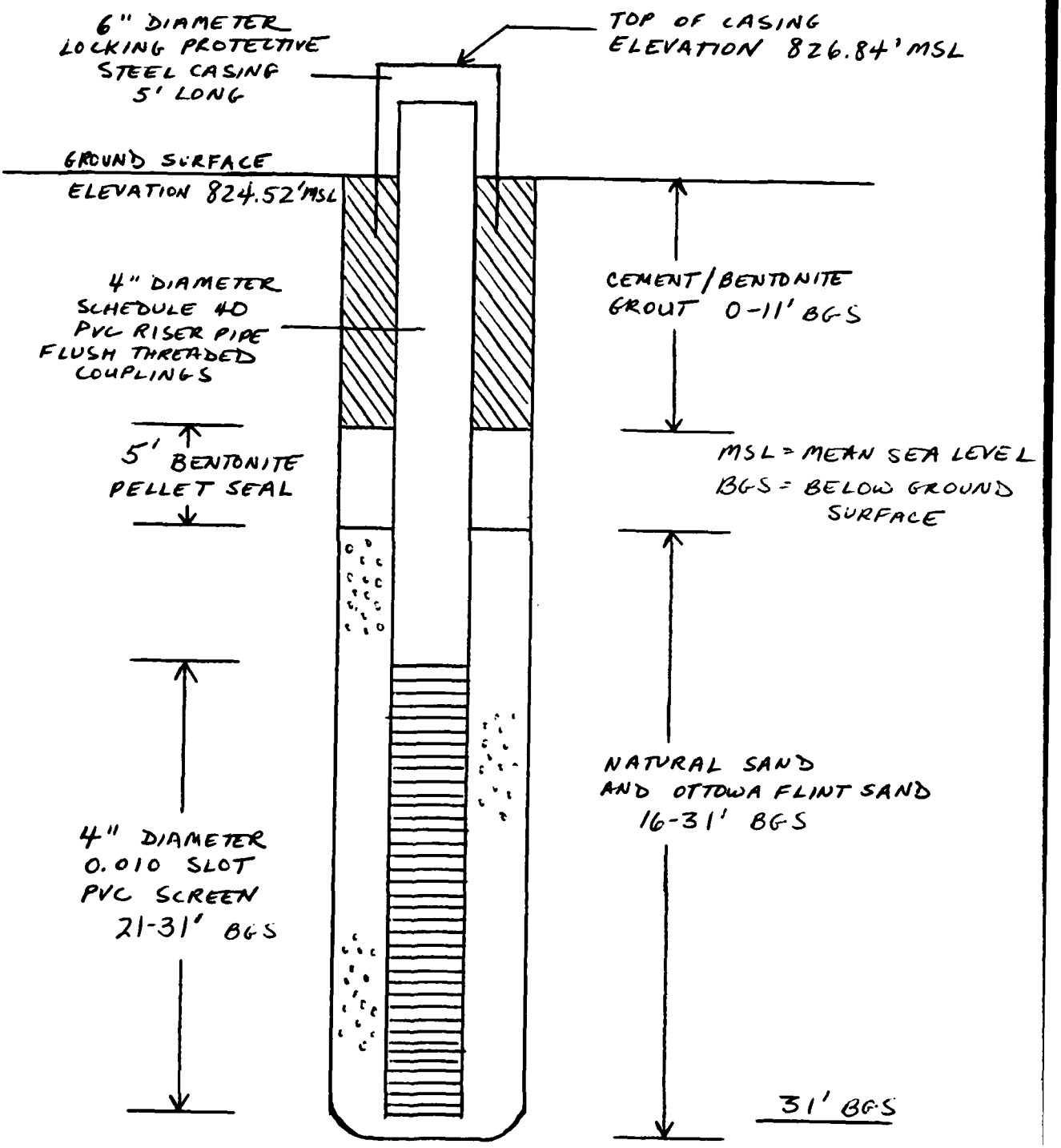
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-18

WESTON

DRILLING LOG

WELL NUMBER: MW-18 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH 31.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C Patterson DRILLING METHOD: Cable Tool DATE DRILLED: 30 Nov 1983
DRILLER: S C Patterson HELPER: J. Patterson
LOG BY: J. Williams

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2					So.l mixed with Medium grain Sand.
2-6					Greenish-Brown Clay, minor Fine Sand
6-13					Brown Fine to Medium Sand, minor Clay * First water ≈ 12.0'
13-20					Brown Clayey Sand Medium to Coarse.
20-31					Coarse to Very Coarse Sand mixed with 3/8" gravel, minor clay.

* ASTM D1586

SHEET ___ OF ___

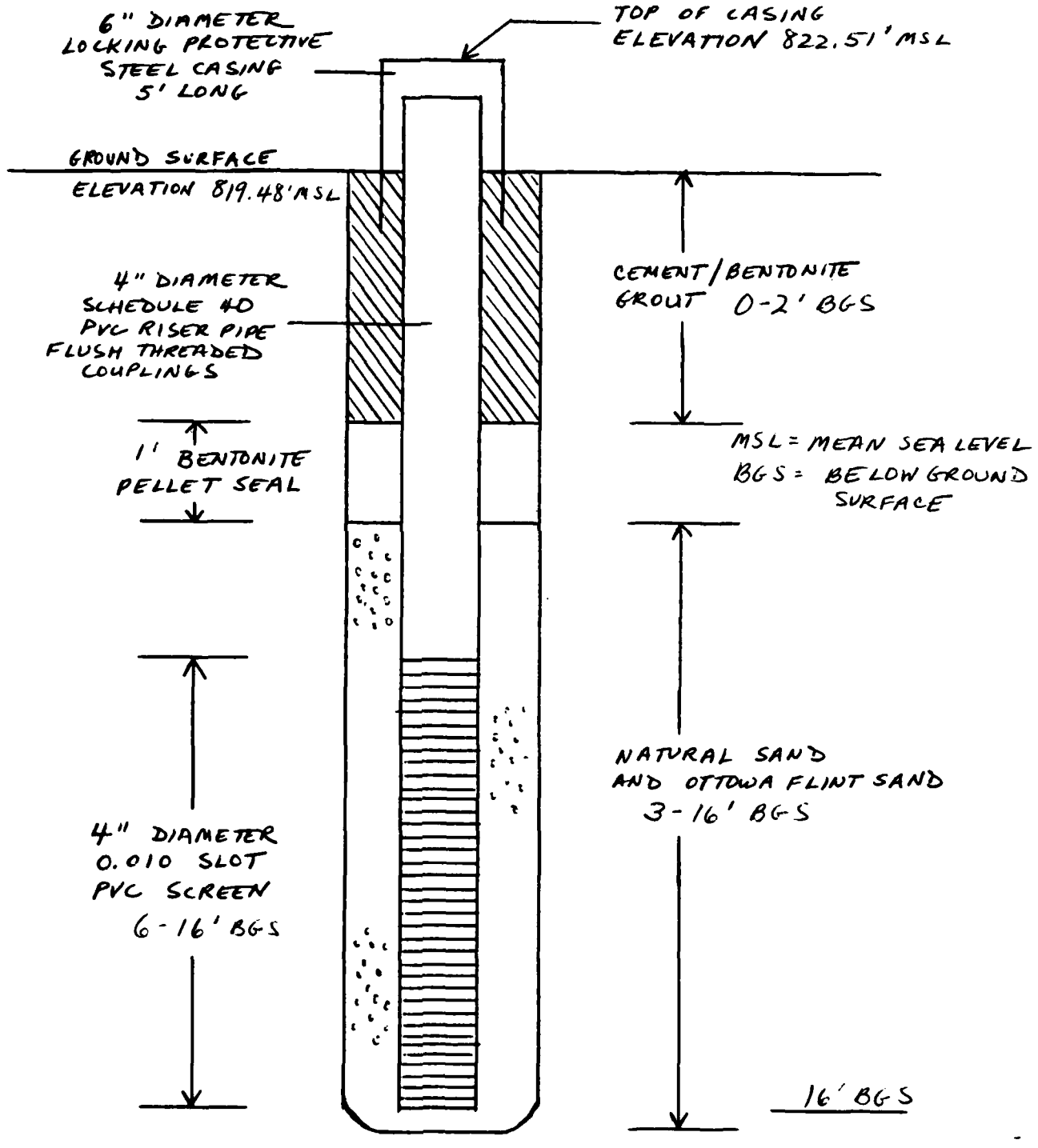
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

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SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-17

RFW 338 5-8'

WESTON
DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW 17 OWNER: _____
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH 116.0'
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: Boyer Mercer DRILLING METHOD: AUGER DATE DRILLED: 8 DEC 1983
DRILLER: Bill Christie HELPER: _____
LOG BY: J. Williams

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-3					Brown Soil, minor clay and sand.
3-13					Greenish-Brown dense clay, little gravel and sand present.

* ASTM D1586

SHEET ___ OF ___

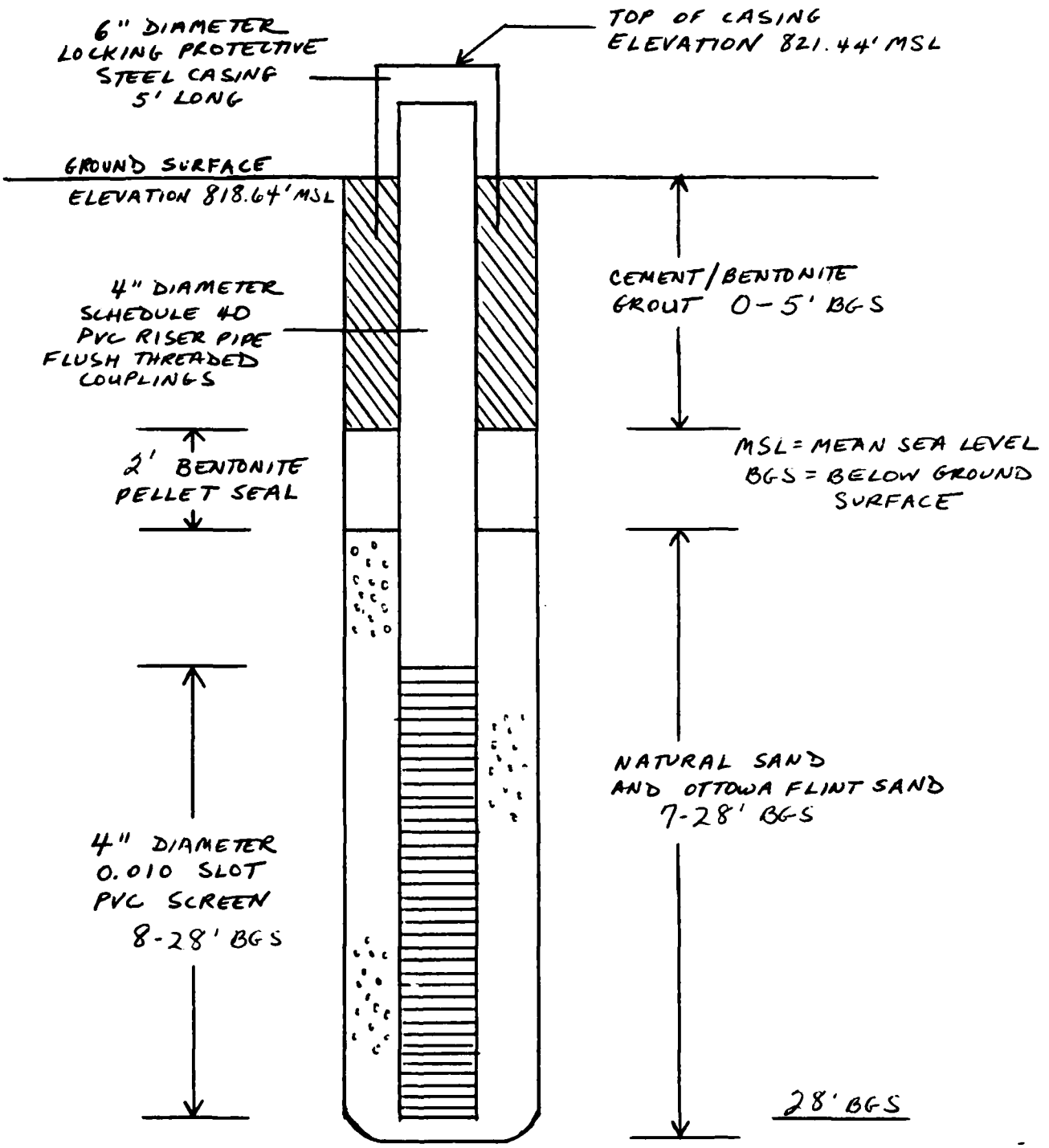
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-16

WESTON DESIGNERS & CONSULTANTS

DRILLING LOG

WELL NUMBER: MW #16 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH 28.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 6 DEC 1983
DRILLER: Bill Christie HELPER: Kerry
LOG BY: J. Williams

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1					Coal
1-5					Brown Clay with Very Fine Sandy matrix
5-17					Brown Sand mixed with gravel and cobble
					* First water at 12.0'
		1	SS	10 30 46	15'-16.5' Gravel, Medium to Very Coarse Sand.
17-20					GREENISH-GRAY Clay
20-28					Gravel, Cobble Sub rounded to Rounded
					minor amounts of clay and sand.

* ASTM D1586

SHEET ___ OF ___

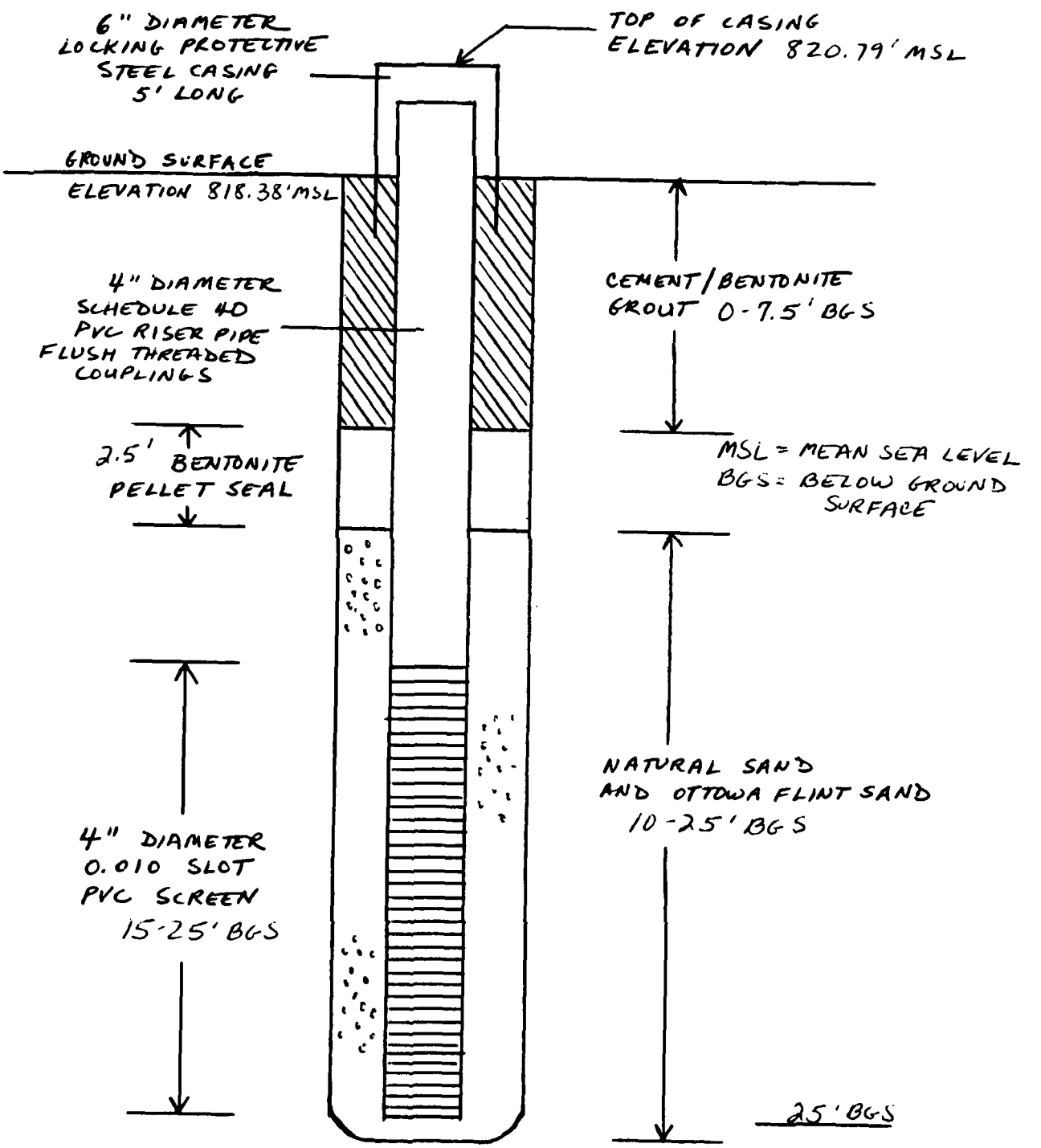
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-15

RFW 338-5-81

WESTON
DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-15 OWNER: _____
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH 27'
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 5 DEC 1983
DRILLER: Bill Christie HELPER: Rob
LOG BY: M. Deeley

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-3'					dark brown to black clay
3'-9'					brown Sandy clay with cobbles 1-2"
9'-12'					brown Sandy clay with cobbles 2"-4" * Moist - Hydrocarbon odor.
12'-19'					brown Sand, minor clay, cobbles 2"-4", saturated.
19-24'					brown, minor clay, 3/4" gravel, 2"-4" cobbles rounded * Hydrocarbon smell
24'-26'					3/8" - 3/4" gravel, brown sand, 2" cobble rounded.
26'-27'					gravel, cobbles 2", minor clay, saturated.

* A.S.T.M D1586

SHEET ___ OF ___

WESTON

DRILLING LOG

WELL NUMBER: MW 22 OWNER: USAF
LOCATION: SE. LANDFILL 5 Between Prairie Rd. and the Twin Lakes ADDRESS: WRIGHT-PATTERSON A.F.B., FAIRBORD, OHIO
TOTAL DEPTH 36.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C. Patterson DRILLING METHOD: CABLE TOOL DATE DRILLED: 6 FEB 1984
DRILLER: BILL HELPER: JEFF

LOG BY: D. EPPS

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-5.0'					Brown Clayey Silt
5.0-17.0					Very Dark gray Fine Sandy Clay
17.0-24.0					Greenish Fine Sandy Clay
25.0-36.0					Light Brown Fine to Coarse sand and gravel up to 1", minor silt

* A.S.T.M. D1586

SHEET 1 OF 1

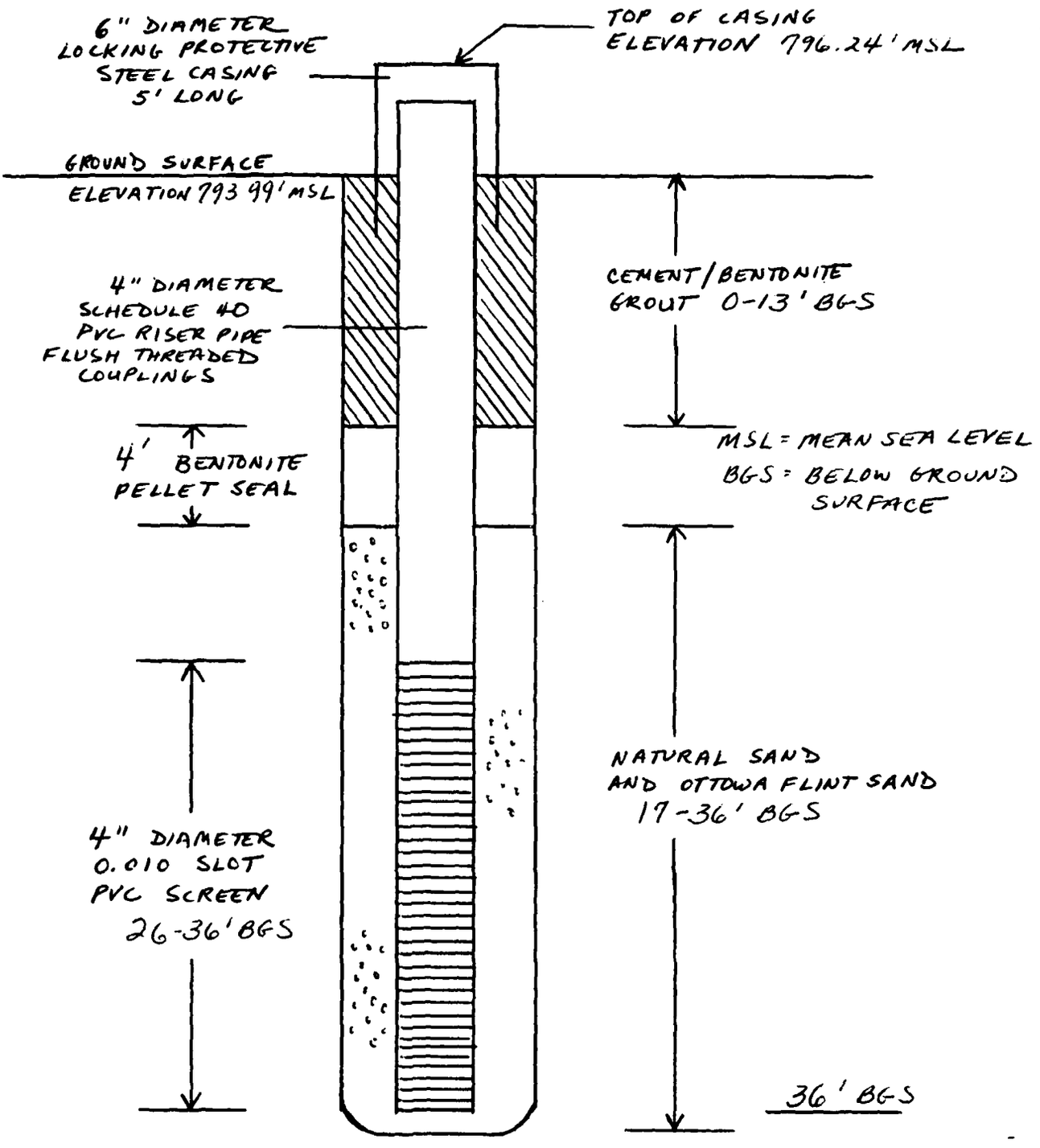
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. O. _____

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SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-22

RFW 338-5-81

WESTON

DRILLING LOG

WELL NUMBER: MW-23 OWNER: USAF
LOCATION: LANDFILL 5 ADDRESS: WRIGHT-PATTERSON AFB., FAIRBORN, OHIO
TOTAL DEPTH 34.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: SC. PATTERSON DRILLING METHOD: Cable Tool DATE DRILLED: 7 FEB. 1984
DRILLER: SC. PATTERSON HELPER: JOE PATTERSON
LOG BY: D. EPPS

SKETCH MAP

NOTES:
SLIGHT ODOR Coming from well

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2.0					DARK BROWN SANDY CLAY
2.0-8.0					BROWN FINE to MEDIUM SAND
8.0-20.0					BROWN FINE to Coarse sand mixed with 1/4" - 3/8" gravel
20.0-23.0					BROWN FINE to Very Coarse Sand mixed WITH 1/4" - 3/4" gravel, moist
23.0-25.0					1/4" - 3/4" gravel with minor amount of Fine to very coarse sand
25.0-30.0					1/4" - 3/4" gravel, minor sand
30.0-35.0					1/4" - 3/4" gravel, minor sand

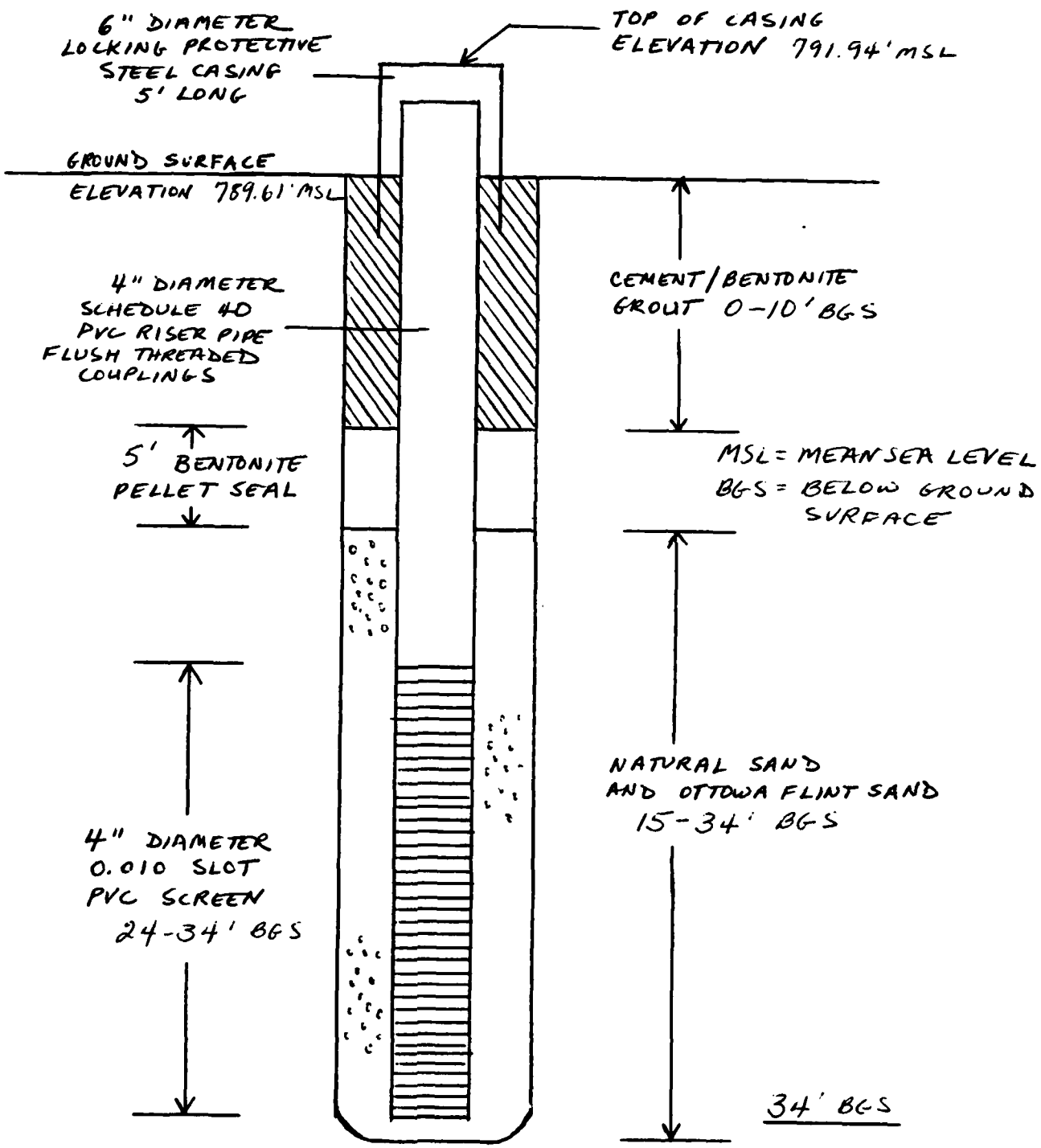
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-23

RFW 338-5-81

WESTON

DRILLING LOG

WELL NUMBER: MW-24 OWNER: USAF
LOCATION: FIRE TRAINING AREA 1 ADDRESS: WRIGHT-PATTERSON A.F.B., FAIRBORN, OHIO
TOTAL DEPTH 12.5'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: Hollow STEM Auger DATE DRILLED: 8 FEB. 1984
DRILLER: Bill Whitaker HELPER: Roger Shivadecker
LOG BY: M. DZEDZY

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2.0'					Dark Brown silt Loam, topsoil
2.0-6.0'					Brown sandy clay, minor gravel, moist
6.0-10.0'					Light Brown clayey sand, gravel and cobbles up to 3", wet.
10.0-12.5					Gravel, Sand, minor silt, saturated.
10-11.0		1	SS	24,83	Recovered 7.0" gray and brown sand, gravel 3/4" to 2.0"
11.0-12.0		2	SS	100	Refusal

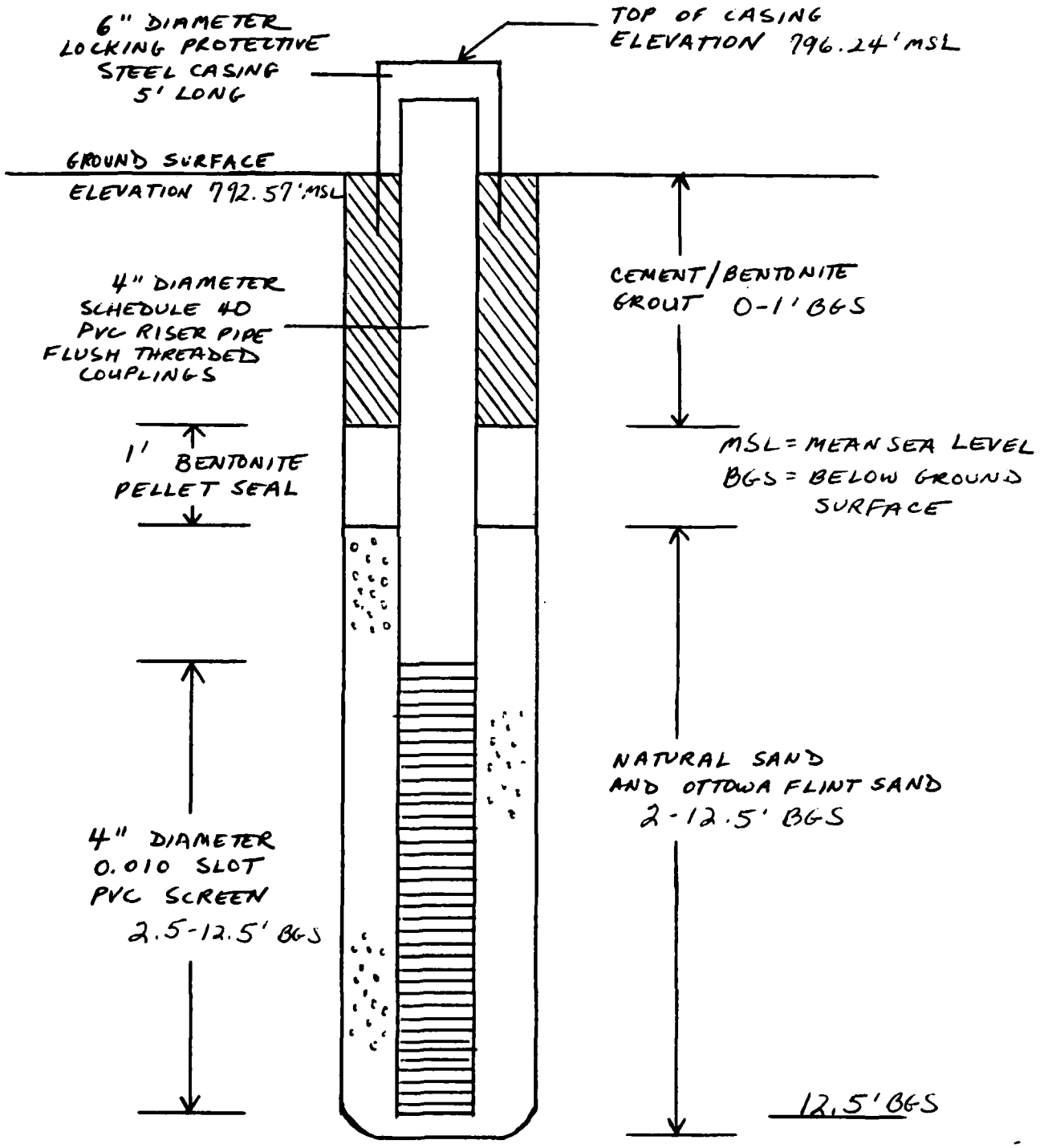
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

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WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-24

RFW 338-5-81

WESTON DESIGNERS & CONSULTANTS

DRILLING LOG

WELL NUMBER: MW-25 OWNER: USAF
LOCATION: Landfill 2 Along Creek ADDRESS: WRIGHT-PATTERSON A.F.B. Fairborn, Ohio
TOTAL DEPTH 30.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser-Morner DRILLING METHOD: Hollow Stem Auger DATE DRILLED: 9 FEB. 1984
DRILLER: Bill Whitaker HELPER: Jeff Ackers
LOG BY: B. Whitaker

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-2.0					Top soil
2.0-6.0					Brown Fine to Medium Sand mixed with gravel minor silt, and cobbles
6.0-10.0					Brown Fine to Coarse Sand and gravel, cobbles minor silt and clay, moist.
10.0-15.5					Brown Sand and gravel, cobbles, minor silt and clay, wet.
15.5-20.0					Brown Sand and gravel, cobbles, minor silt and clay.
20-21.5		1	S.S.	15, 30 21	Recovered 10.0" Saturated.
20.0-26.0					Brown Sand and gravel, cobbles, minor Silt and clay
26.0-30.0					Brown Sand and gravel, cobbles, minor Silt and clay

* A.S.T.M. D1586

SHEET ___ OF ___

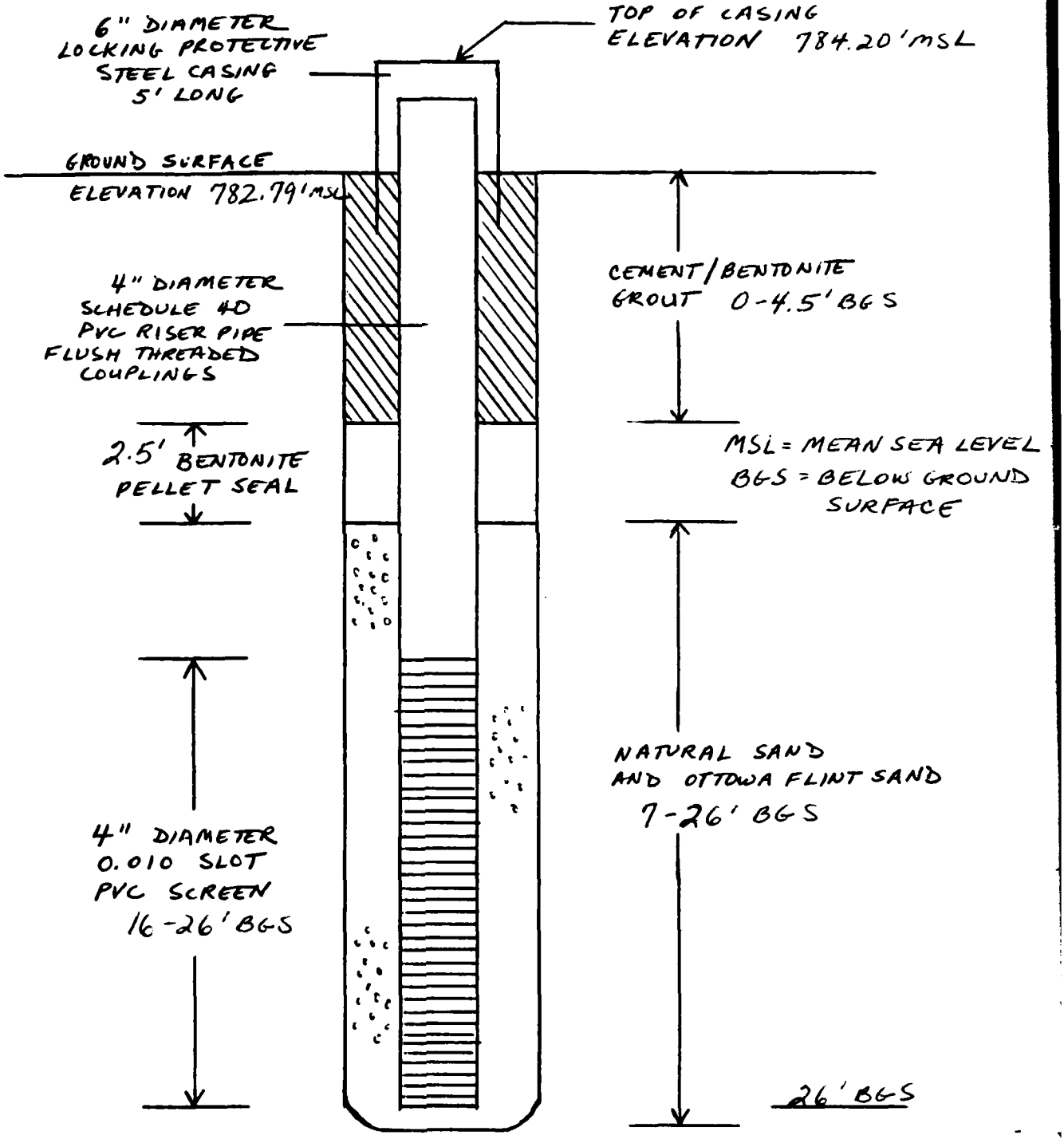
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

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SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-25

RFW 338-5-81

WESTON

DRILLING LOG

WELL NUMBER: MW-26 OWNER: USAF
LOCATION: SANDHILL LANDFILL ADDRESS: WRIGHT-PATTERSON AFB, FAIRBORN, OHIO
TOTAL DEPTH 42.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C. PATTERSON DRILLING METHOD: CABLE TOOL DATE DRILLED: 8 FEB 1984
DRILLER: S.C. PATTERSON HELPER: JOE PATTERSON
LOG BY: D. EPPS

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-7.0					LIGHT BROWN FINE SANDY CLAY
7.0-10.0					DARK BROWN CLAY
10.0-22.0					GREEN-GRAY FINE SANDY CLAY
22.0-26.0					GRAY FINE to MEDIUM SANDY CLAY
26.0-29.0					GRAY FINE to MEDIUM SANDY clay grading to 1/4" - 1.0" sandy gravel, moist
29.0-34.0					FINE to very coarse sand mixed with 1/4"-1.0" gravel, water at 32.0'
34.0-42.0					FINE to VERY COARSE SAND mixed with 1/4"-1.0" gravel

* A.S.T.M. D1586

SHEET ___ OF ___

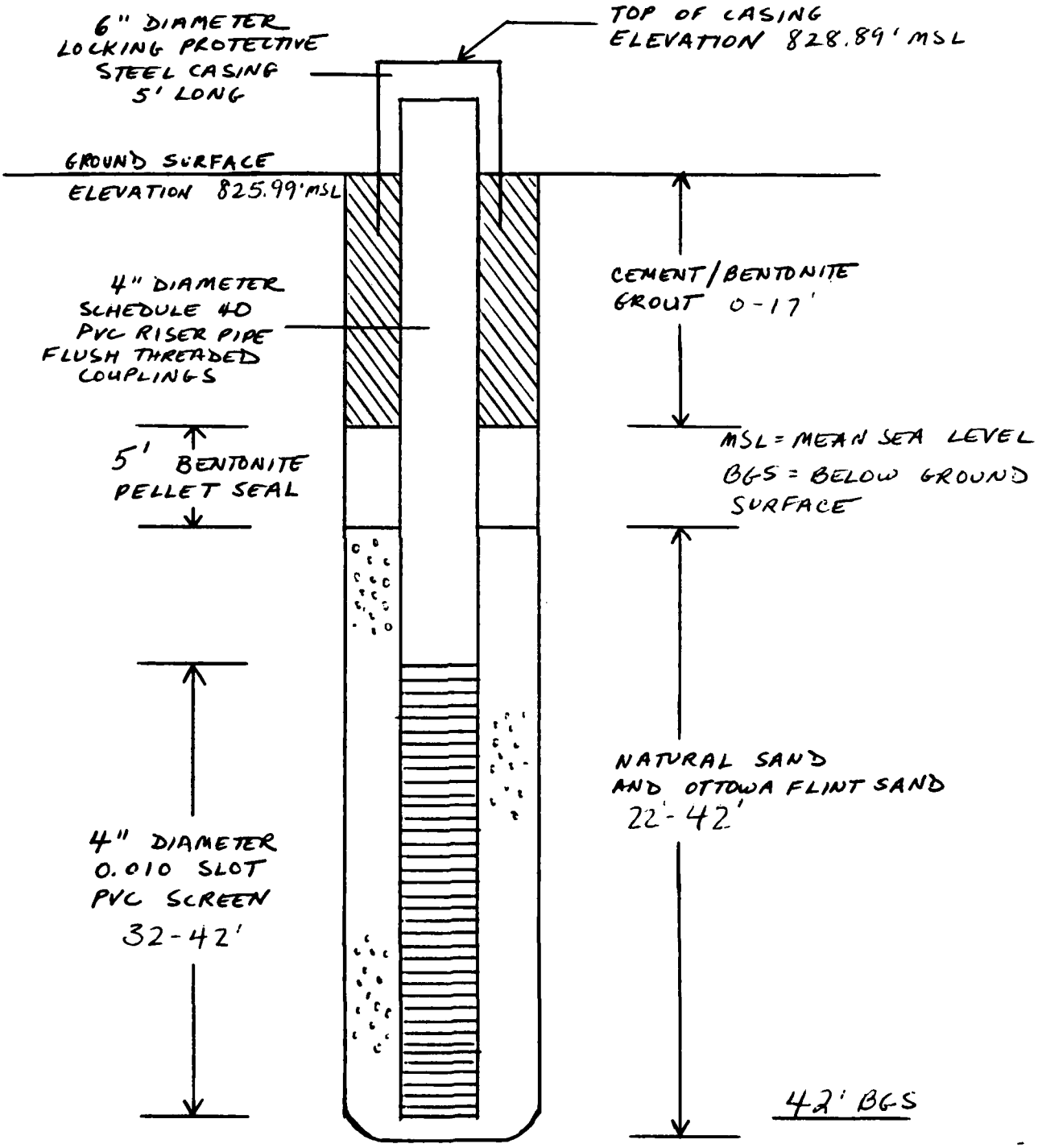
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-26

RFW 338-5-81

WESTON

DRILLING LOG

WELL NUMBER: MW-27 OWNER: USAF
LOCATION: FIRE TRAINING AREA # 2 ADDRESS: WRIGHT-PATTERSON AFB, FAIRBORN, OHIO
TOTAL DEPTH 35.0'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: S.C. PATTERSON DRILLING METHOD: CABLE TOOL DATE DRILLED: 9 FEB. 1984
DRILLER: S.C. PATTERSON HELPER: JOE PATTERSON
LOG BY: D. EPPS

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-9.0					DARK GREEN FINE to Coarse Sandy Clay very strong oily odor. @ 9.0'
9.0-13.0					GRAY-GREEN clay mixed with 1/4"-3/8" gravel and minor Fine sand.
13-15.0					BROWNISH-GREEN clay mixed with 1/4"-3/8" gravel and minor Fine to medium sand
15.0-20.0					BROWNISH-GREEN clay mixed with 1/4"-3/8" gravel moist
20.0-25.0					BROWNISH-GREEN clay mixed with 1/4"-3/8" gravel
25.0-26.5		1	SS.	22,25 35	FINE TO Coarse sand, 1/4"-3/8" gravel grading to Fine sandy clay
30-32.0					GRAY Fine Sandy clay
32-35.0					GRAY Fine Sandy clay, increase in Sand content
35-36.5		2.	SS.	4,9, 12	GRAY Fine Sandy clay grading to a Fine to Medium Brown Sand.

* A.S.T.M. D1586

SHEET ___ OF ___

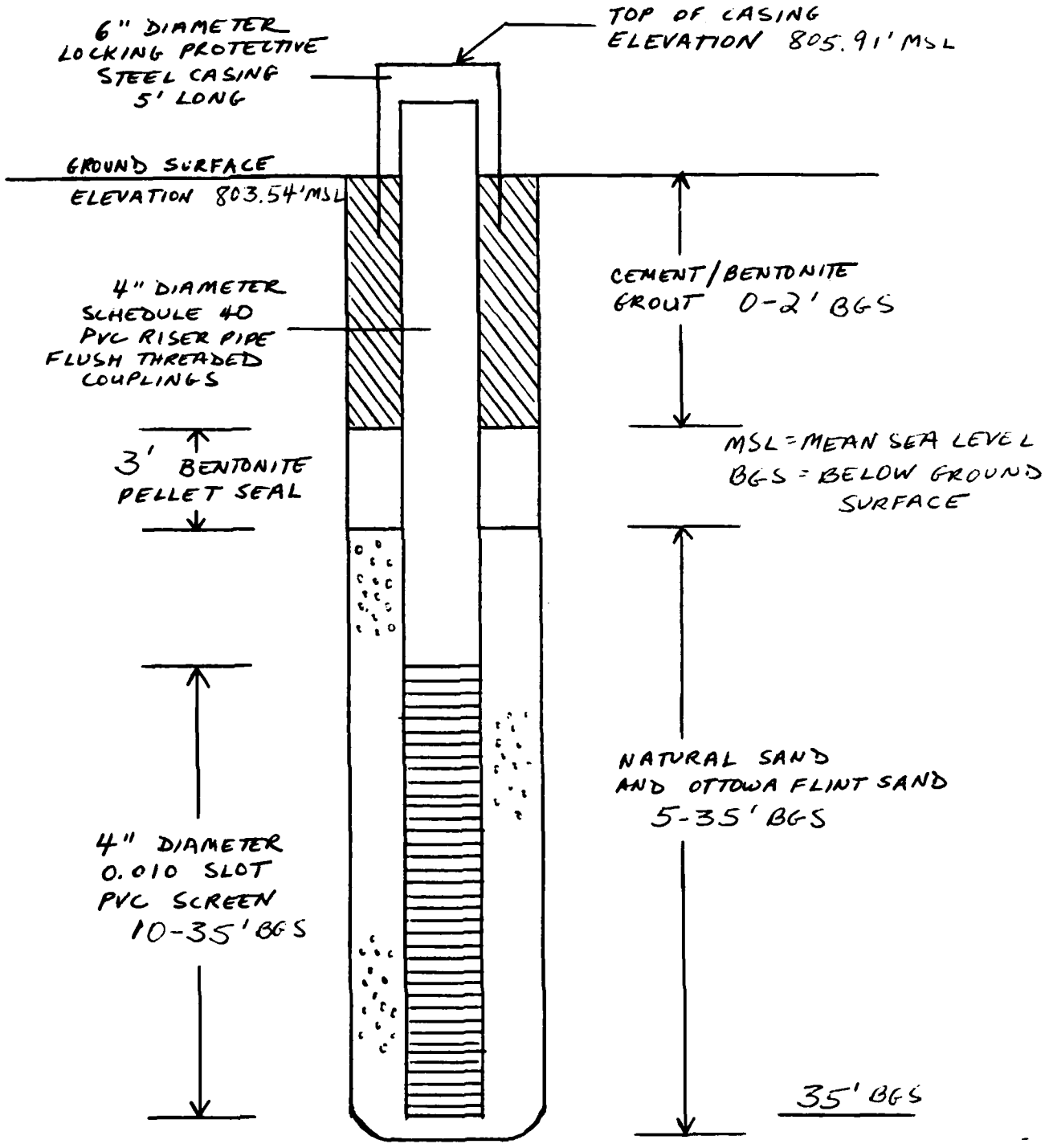
WESTON
DESIGNERS CONSULTANTS

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER MW-27

RFW 338-5-81

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: GW-1 OWNER: WPAFB
LOCATION: Hadden Park WPAFB ADDRESS:
TOTAL DEPTH 25.5' (ss)
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 8-27-84
DRILLER: D. Hoop HELPER: Gary
LOG BY: M. Dzedzy

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
3'					Light brown dry loam
4'					Concrete rubble fragments Exp = 0
8'					Moist, dark brown sandy clay loam mixed with trash: wood, paper, metal, concrete frags.
		1	SS		8-9.5' Dark brown-black moist fill, tarry smell Exp = 0 Rec = 2/18"
14.5'					Dark brown-black moist fill Exp (in borehole) = 8% LEL
		2	SS	5 4 7	14.5-16' Fill Damp fibrous material, Looks like straw or coarse wood fibers; White crumbly material; red coloration on remaining soil. Rec = 3/18" Exp (in borehole) = 18 % LEL

* A.S.T.M. D1586

SHEET 1 OF 2

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: GW-1 OWNER: WPAFB
LOCATION: Hadden Park WPAFB ADDRESS:
TOTAL DEPTH 24' Auger (25.5' SS)
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 8-27-84
DRILLER: D. Hoop HELPER: Gary
LOG BY: M. Dzedzy

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
16'					Auger pulled up old fire hose.
		3	SS	2/4	20-21.5' Moist black sandy clay loam and wood fibers. Rec = 6/18"
					Exp (in borehole) = 72% LEL
					Monotox for H_2S < 10 ppm: No alarm
		4	SS		24-25.5' 9" Moist black sandy clay loam fill over 3" yellowish gray silty clay loam. Rec = 12/18"
					Exp (in borehole) = 16% LEL
					Monotox for H_2S < 10 ppm.

* ASTM D1586

SHEET 2 OF 2

$$D = \frac{ct}{2\ Er} = \frac{Vmt}{2}$$

Where:

D = Depth in feet

C = Velocity of light

t = Pulse travel time in nanoseconds

Er = Relative dielectric constant of material

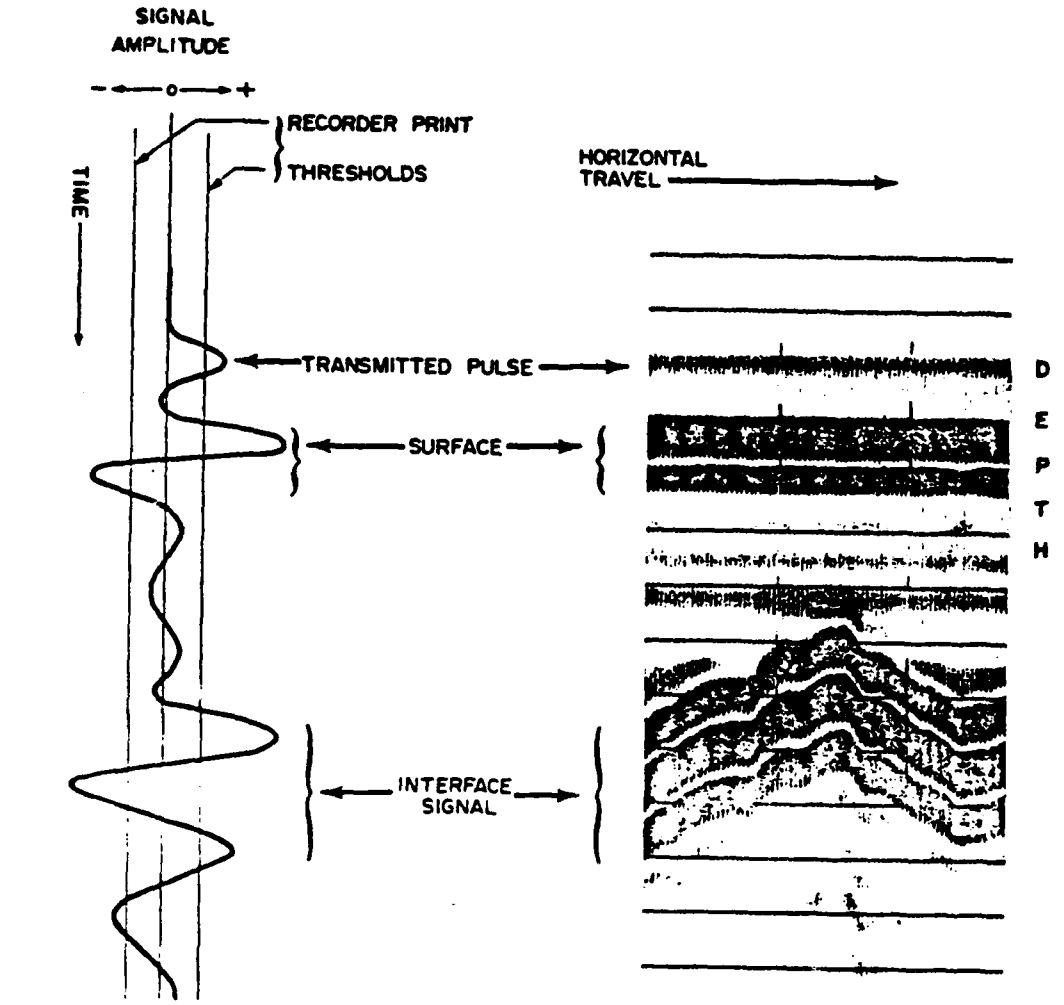
Vm = Velocity of propagation in material = $\frac{C}{Er}$

The conductivities and dielectric constants of various materials are presented in Table A-1. The presence of water and the chemical state of the water has the greatest effect on the dielectric constant and conductivity.

The penetration depth of the GPR system is dependent upon the effective conductivity of the material being probed. In highly conductive materials, the GPR signal is rapidly attenuated, severely limiting the penetration depths. For example, penetration through wet clay is only about five feet, and penetration in sea water deteriorates to less than a foot. This is in contrast to penetration depths through low conductivity materials, such as dry sand or rock, which can reach depths of perhaps as much as 100 feet. The depth of penetration of the signal is also dependent upon the frequency content of the pulse. Generally, lower frequency components propagate to the greatest depths, but higher frequency components provide to better resolution. Therefore, selection of the antenna with the proper frequency response is important to achieving the desired results.

Interpretation of GPR Data

The graphic recorder produces a profile by printing strong signals (amplitudes higher than print threshold) as black and weak signals as white (see Figure A-2). The result is the display of dark bands that extend throughout the



Sketch of a Single GPR Pulse and its Reflections as Seen by the Receiver.

Example of Profile Information as Displayed by the Graphic Recorder.

Figure A-2: Example of Ground Penetrating Radar Profile Data.

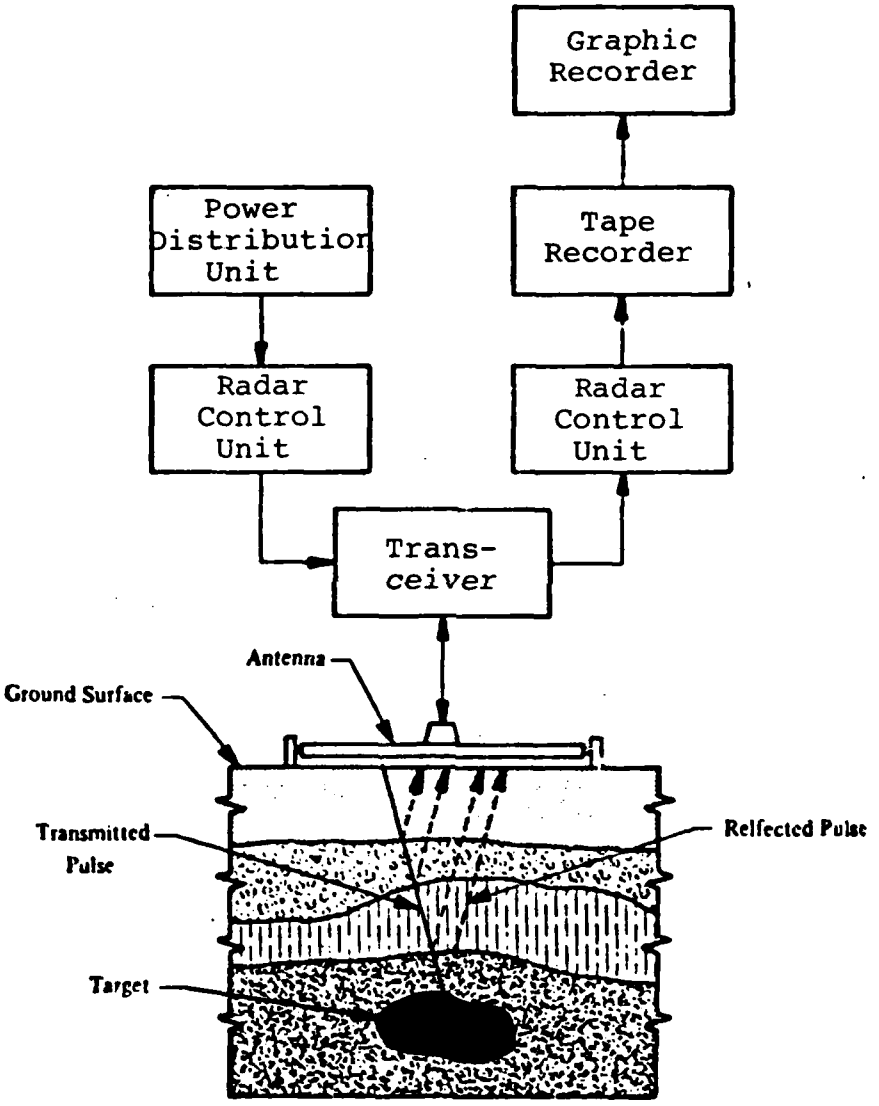


Figure A-1: Block Diagram of the Ground Penetrating Radar (GPR) Unit.

portion of the signal is reflected and the remaining portion continues through the interface. The reflected pulse is collected by the antenna transceiver, and it is this signal which is recorded as data. (See Figure A-1)

The reflected signals received by the antenna receiver are converted to the audio frequency range which is processed by the radar control unit. Processing is an operator-initiated procedure which selects and enhances that portion of the data which is of greatest importance to the objective of the survey. The processed data is then sent to the graphic recorder which produces a permanent chart or profile of the subsurface interfaces. The processed data may also be sent to the tape recorder, thereby providing a data log which can be reprocessed or printed at a later date. The primary advantage of tape recording data is that its use allows data to be taken as much as 16 times faster than with the graphic recorder.

Signal Structure and Resulting Profile

An example of GPR signal structure and the resulting profile is shown in Figure A-2. The received signal consists of three components:

- Transmitted pulse
- Surface reflection
- Interface reflections

A continuous stream of received pulses is fed into the graphic recorder and a profile is produced. The horizontal scale is dependent upon the traverse speed of the antenna across the ground. The vertical scale is dependent upon the travel time of the GPR pulse. The travel time may be converted into a depth scale if either the dielectric constant of the medium being probed or the depth to a specific interface is known. Depth would be calculated by the following relationship:

GROUND PENETRATING RADAR

Introduction

GPR is used on land surveys to map interfaces such as changes in soil types, bedrock and other soil and geological characteristics. It is also used to locate artifacts such as pipes, barrels, cables, and conduits. When GPR is used in over-water surveys, it is capable of mapping the same interfaces as on land. It can also be used to measure ice thickness and to profile the bottom of rivers and lakes.

Components

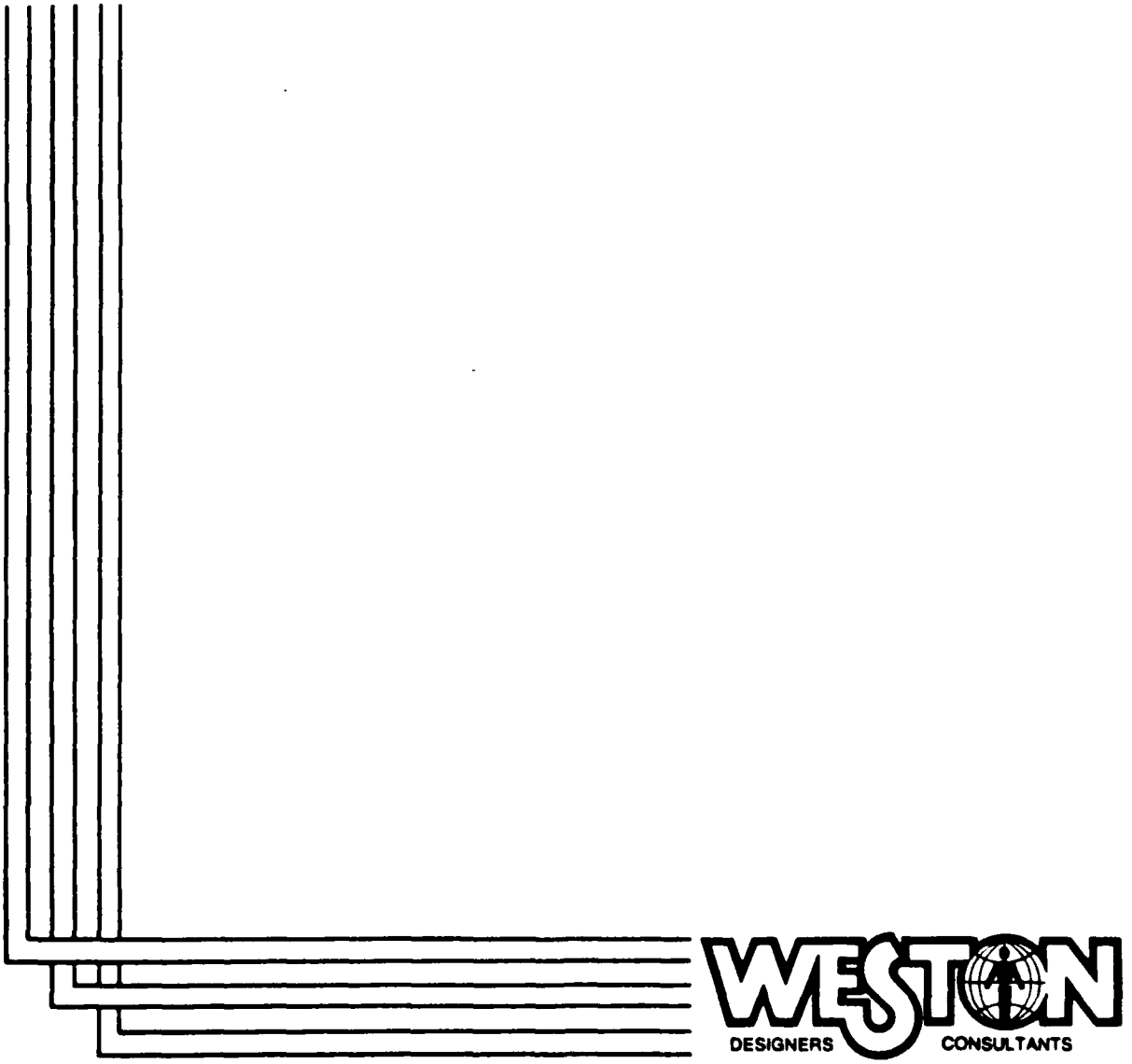
GPR is an impulse radar system that provides a continuous profile of subsurface conditions by radiating electromagnetic pulses into the earth (or water) and displaying the reflections from surface and subsurface interfaces on a strip-chart recorder. The system is composed of five major components:

- Power distribution unit - provides proper AC/DC voltages to all GPR equipment
- Radar Control Unit - Triggers antenna transmitter and processes received data
- Antenna Transceiver - Radiates electromagnetic pulses into the earth and receives reflections
- Graphic Recorder - Produces chart of the subsurface profile
- Tape Recorder - Records data on the tape for future processing

The radar control unit triggers the antenna transmitter to produce the electromagnetic pulse, which it shapes into Quasi-Gaussian form and radiates it through the broad-band antenna. The transmitted pulse travels through the subsurface until it encounters an interface (i.e. a change or discontinuity in electrical properties such as a soil or geological boundary or an imbedded object such as a drum, boulder, etc.). Once the pulse reaches the interface, a

Ground Penetrating Radar

Summary of Capabilities



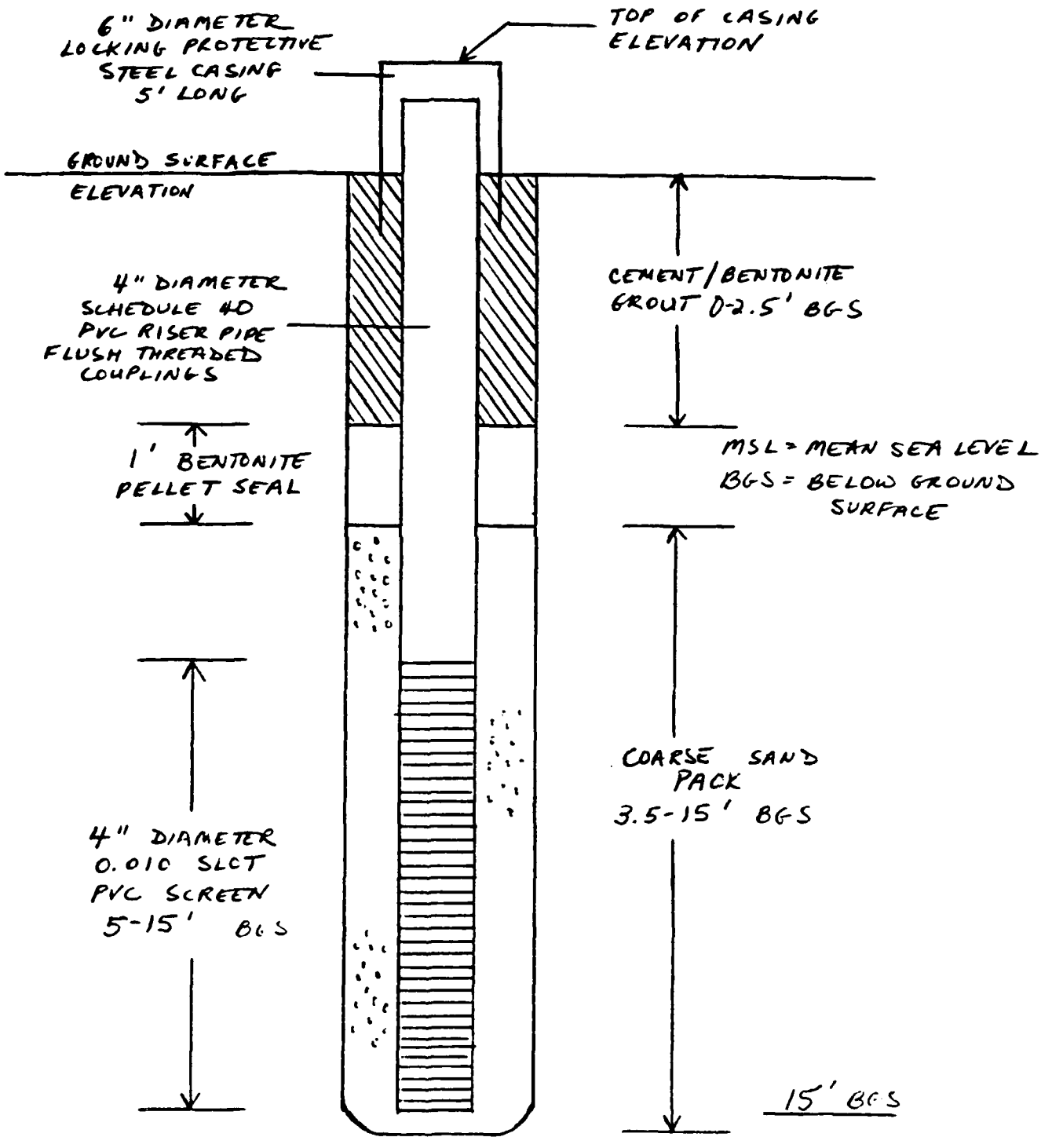
WESTON

BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB

WELL NUMBER GW-4

WESTON
DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: GW-4 OWNER: WPAFB
LOCATION: Woodland Hills WPAFB ADDRESS:
TOTAL DEPTH 15'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 8-28-84
DRILLER: D. Hoop HELPER: Gary
LOG BY: M. Dzedzy

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
8-11'					General refuse: (paper, wire, metal) mixed with dark gray fill soil. saturated at 11'
		2	SS	7/10	12-13.5' Saturated compressed paper. Rec 9/18"
13-15'					Saturated dark gray clayey fill.

* A.S.T.M. D1586

SHEET 2 OF 2

WESTON

DRILLING LOG

WELL NUMBER: GW-4 OWNER: WPAFB
LOCATION: Woodland Hills WPAFB ADDRESS:
TOTAL DEPTH 15'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 8-28-84
DRILLER: D. Heop HELPER: Gary
LOG BY: M. Dzedzy

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-1'					Brown sandy clay loam.
1-5'					Dark grayish brown sandy clay loam fill mixed with trash: wood, cement pieces, wire, rags. Exp (in borehole) = 36% LEL
5-8'					Dry refuse (landfill contents): paper, plastic, aluminum, wood -- very little soil.
		1	SS	19 19 11	8-9.5' Compressed paper (parts still readable) refuse, moist; "garbage" odor Rec=19/18" Exp (in borehole) = 72% LEL Monotox for H_2S <10 ppm Left borehole to vent gases: elapsed time 8 mins: Exp = 40% LEL " " 13 mins: Exp = 44% LEL " " 15 mins: Exp = 48% LEL Resumed drilling after 20 mins when %LEL stabilized around 40% LEL

* A.S.T.M. D1586

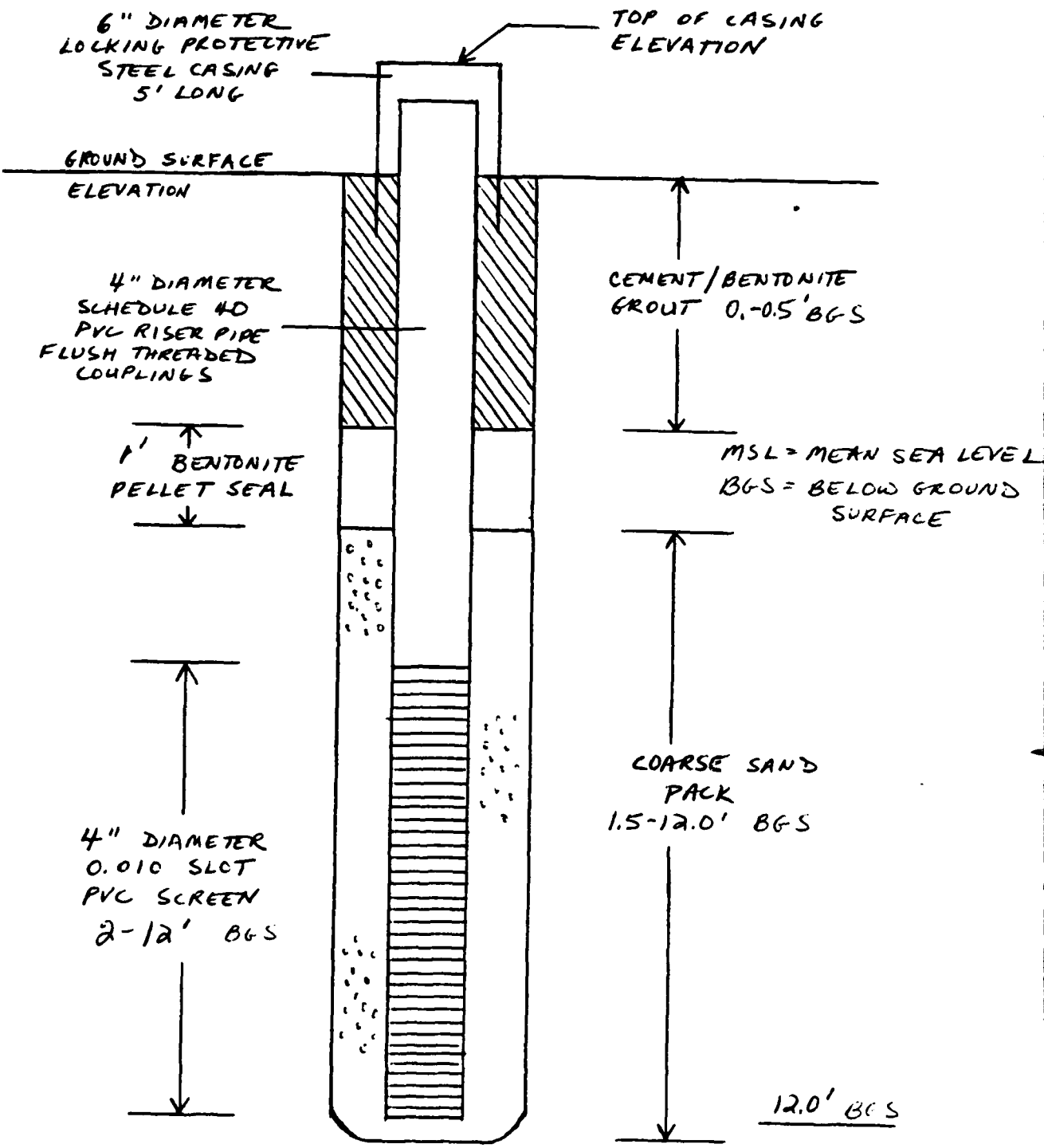
SHEET 1 OF 2

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WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER GW-3

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: GW-3 OWNER: WPAFB
LOCATION: Woodland Hills WPAFB ADDRESS:
TOTAL DEPTH 13'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Bowser Morner DRILLING METHOD: Auger DATE DRILLED: 8-28-84
DRILLER: D. Hoop HELPER: Gary
LOG BY: M. Dzedzy

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-3'					Dark brown sandy loam
3-8'					Moist, very dark gray sandy clay loam fill, pieces wire, metal, concrete
					Exp (in borehole) = 6% LEL
		1	SS	7/9	8-9.5' 3" Saturated dark gray sand (fill)
					with some clay over 5" dark gray/black
					moist sandy clay. (fill) Rec = 8/18"
					Exp (in borehole) = 4% LEL
9.5-13'					Saturated dark gray sandy clay fill.

* A.S.T.M. D1586

SHEET 1 OF 1

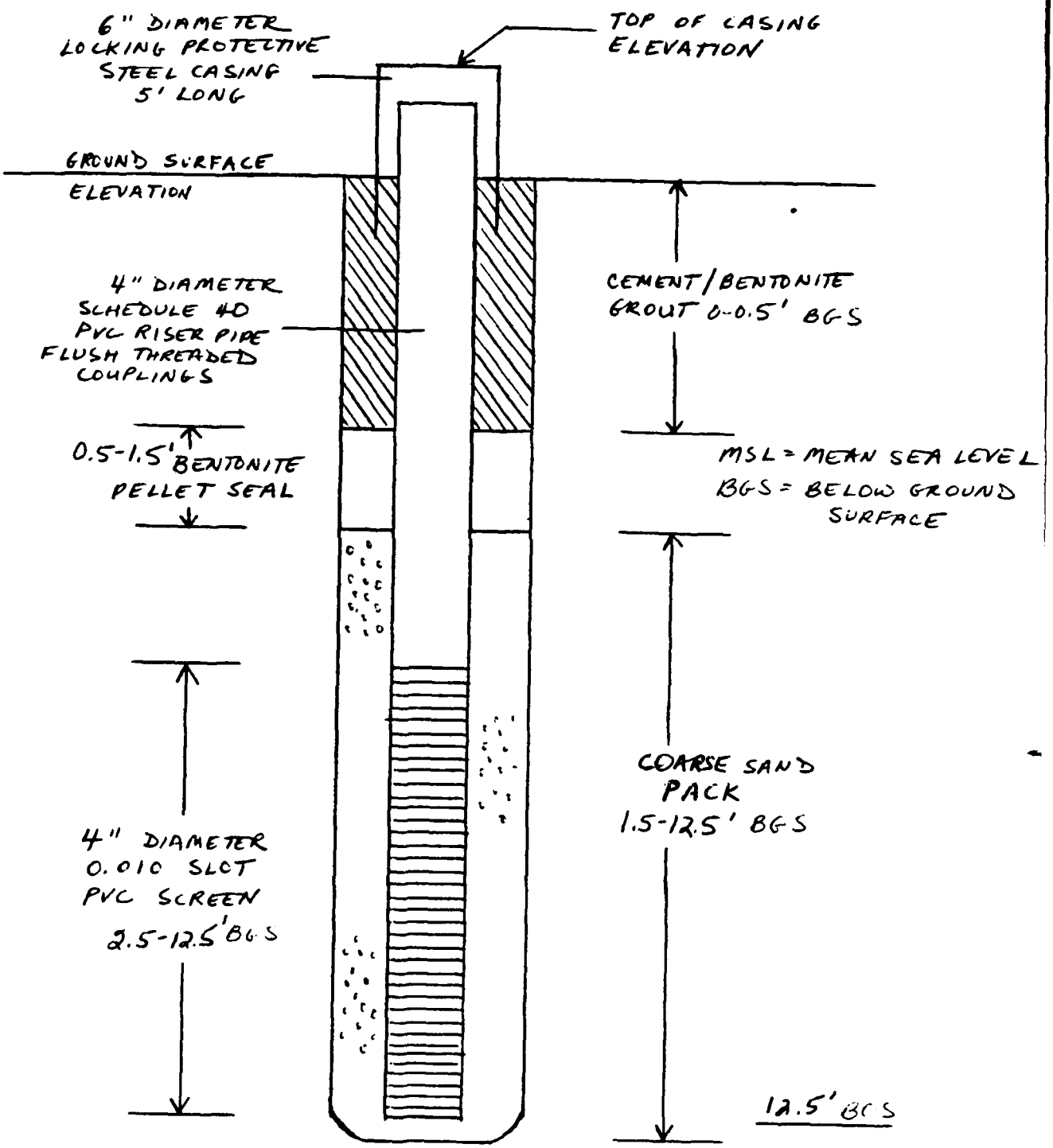
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BY _____ DATE _____ DIV _____ SHEET _____ OF _____

CHKD BY _____ DATE _____ DEPT _____ W.O. NO. _____

PROJECT _____

SUBJECT _____



WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER GW-2

WESTON DESIGNERS CONSULTANTS

DRILLING LOG

WELL NUMBER: GW-2 OWNER: WPAFB
LOCATION: HADDEN PARK WPAFB ADDRESS:
TOTAL DEPTH 12.5'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: BOWSER MORNER DRILLING METHOD: AUGER DATE DRILLED: 8-27-84
DRILLER: D. Hoop HELPER: Gary
LOG BY: M. DZEDZY

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0-7.5'					Dark grayish brown sandy clay loam Exp = 0
		1	SS		8-9.5' Black fill (clayey fine sand), moist
7.5-11.5					Black fill (clayey fine sand), moist
11.5-12.5'					Saturated black fill

* ASTM D1586

SHEET 1 OF 1

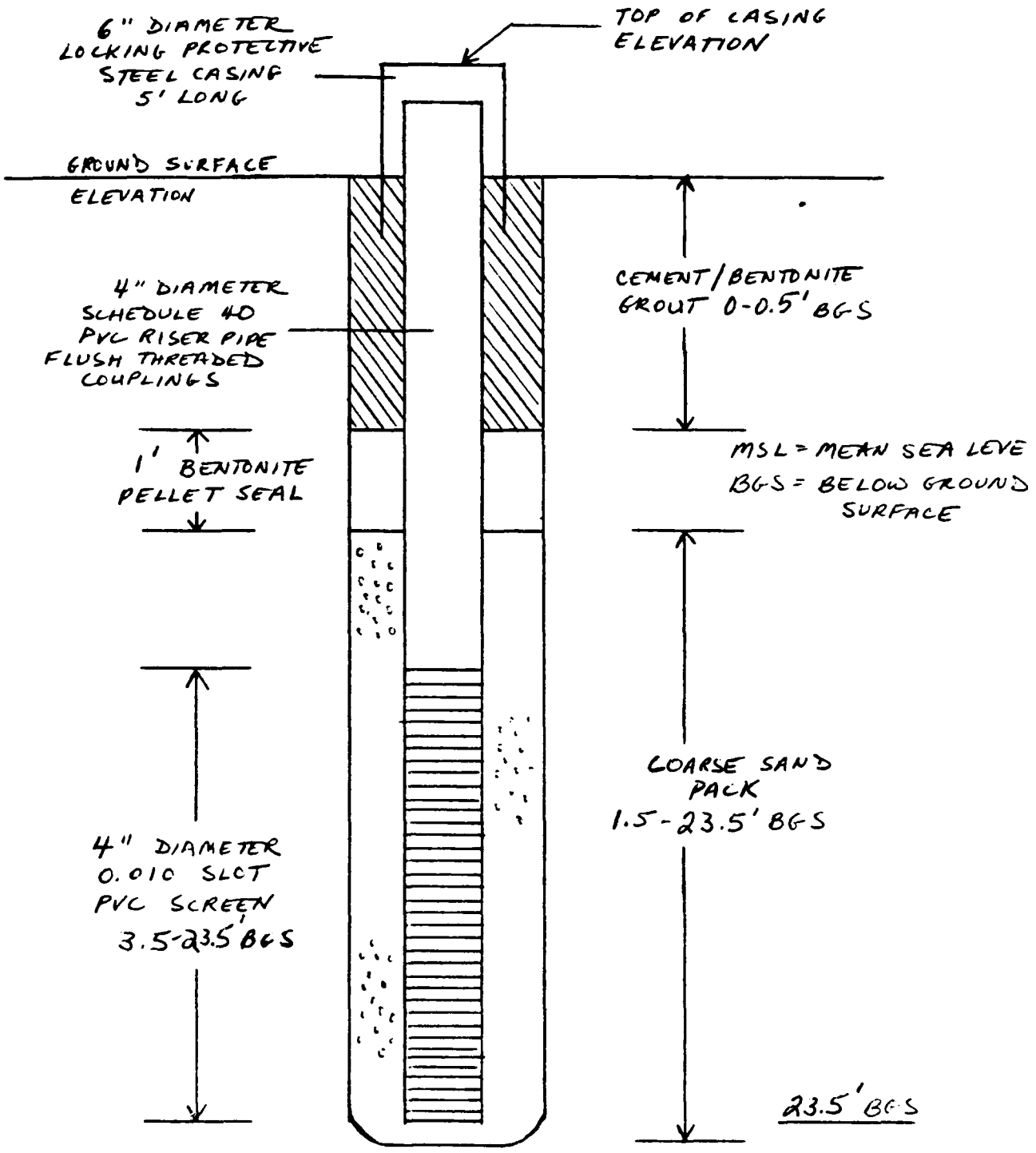
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WELL CONSTRUCTION LOG - WRIGHT PATTERSON AFB
WELL NUMBER GW-1

Table A-1: Conductivities and Dielectric Constants of Various Earth Materials.

Material	Approximate Conductivity, σ (mho/m)	Approximate Dielectric Constant, ϵ_r
Air	0	1
Fresh Water	10^{-4} to 3 x 10^{-2}	81
Sea Water	4 to 5	81 to 88
Fresh Water Ice	10^{-4} to 10^{-2}	4
Sea Water Ice	10^{-2} to 10^{-1}	4 to 8
Ice (Glacial)	10^{-6} to 10^{-4}	3.2
Permafrost	10^{-5} to 10^{-2}	4 to 5
Snow Firn	10^{-6} to 10^{-5}	1.4
Granite	10^{-9} to 10^{-3}	8
Sand, Dry	10^{-7} to 10^{-3}	4 to 6
Sand, Saturated (Fresh Water)	10^{-4} to 10^{-2}	30
Silt, Saturated (Fresh Water)	10^{-3} to 10^{-2}	10
Clay, Saturated (Fresh Water)	10^{-1} to 1	8 to 12
Average "Dirt"	10^{-4} to 10^{-2}	16

profile at varying depths. These bands represent the reflection from an interface between two materials.

The antenna has a fairly broad radiation pattern within the ground. The radiation pattern is conical in shape with the apex at the center of the antenna and an included angle of approximately 90°. For flat reflecting surfaces, such as soil interfaces, it is the energy that is directed straight down and reflected that the antenna receives. However, for round objects such as pipes and barrels, there are many surfaces which are normal to the antenna pattern as it passes over the object at right angles. The result is a unique signature as shown in Figure A-3.

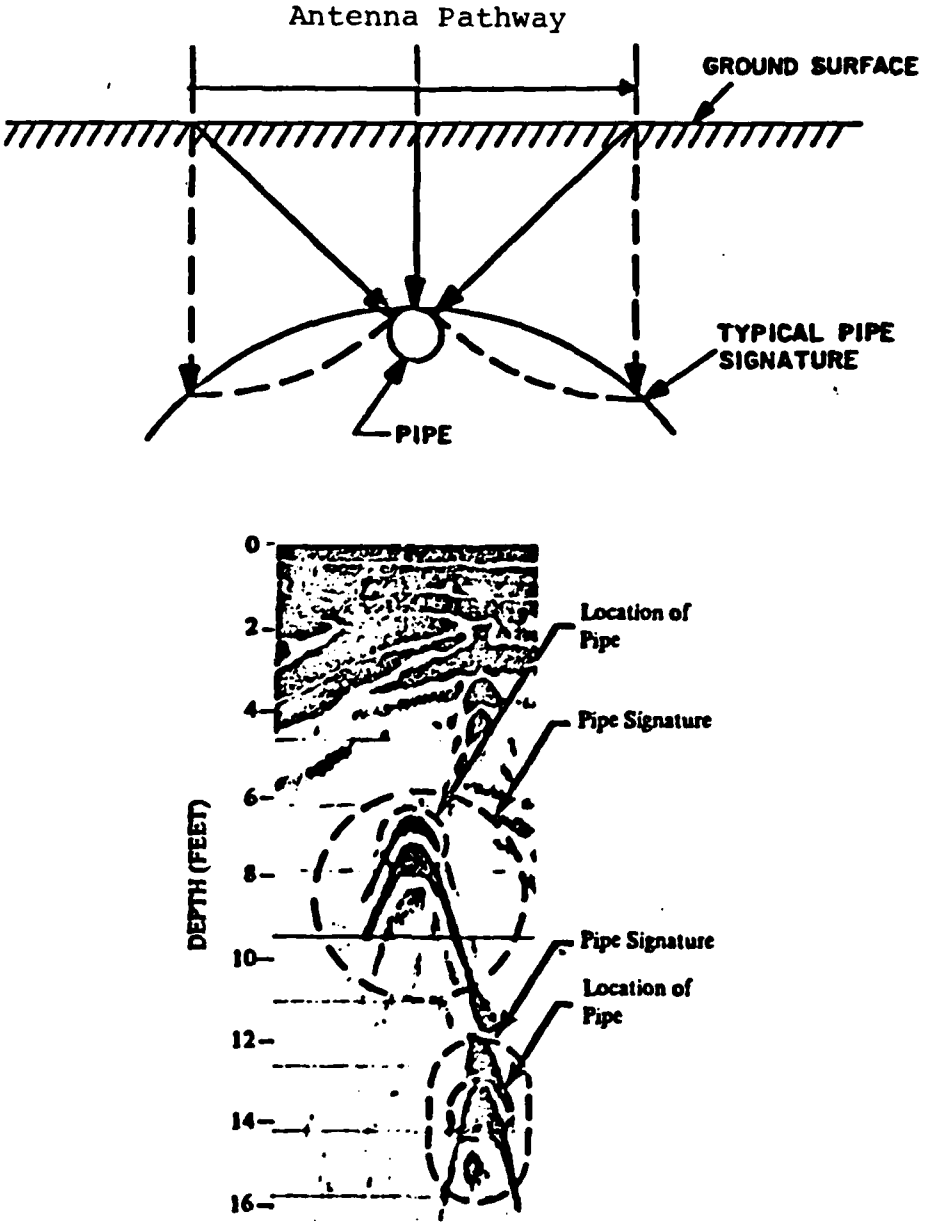


Figure A-3: Typical Signature of a Buried Pipe.

GPR TRAVERSES

W.P. AFB

1 November 1983

Zone #1

Landfill #8

Wright-Patterson AFB - USAF

01 Nov. 83 J. Williams

Zone #1 M. Dzedzy

Landfill #8

Adj - 27.8
Mult - 2X
Gain - 8.2
Time Time - 2.0
Sens. - 66.6
Filter - M
Program - 3-6

CALIBRATION
Calibration over Culvert
12" dia 1'-1½" Dep
on Island Br. by Maitland Ave
11/11/83

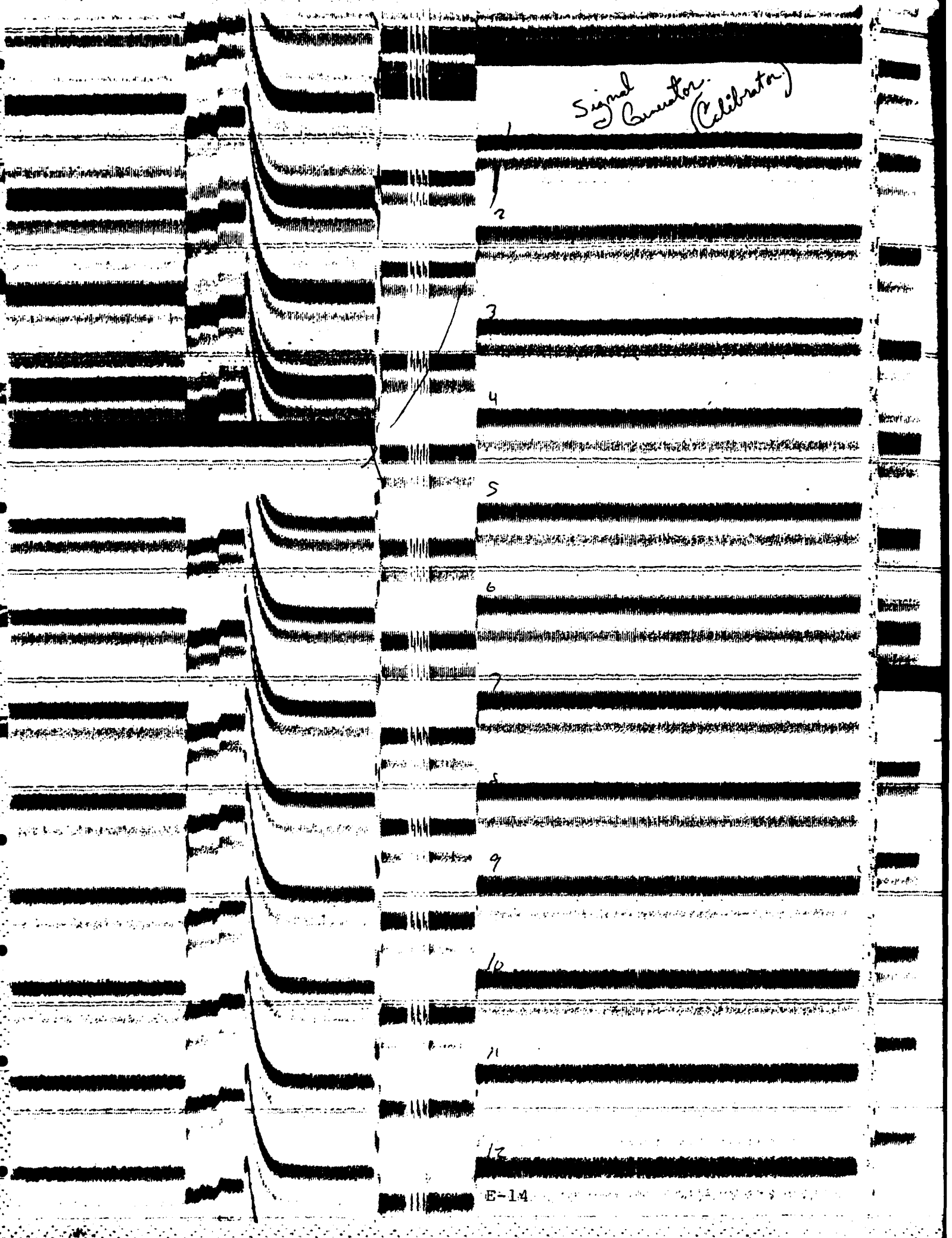
D = Desired Depth of Penetration = 20'

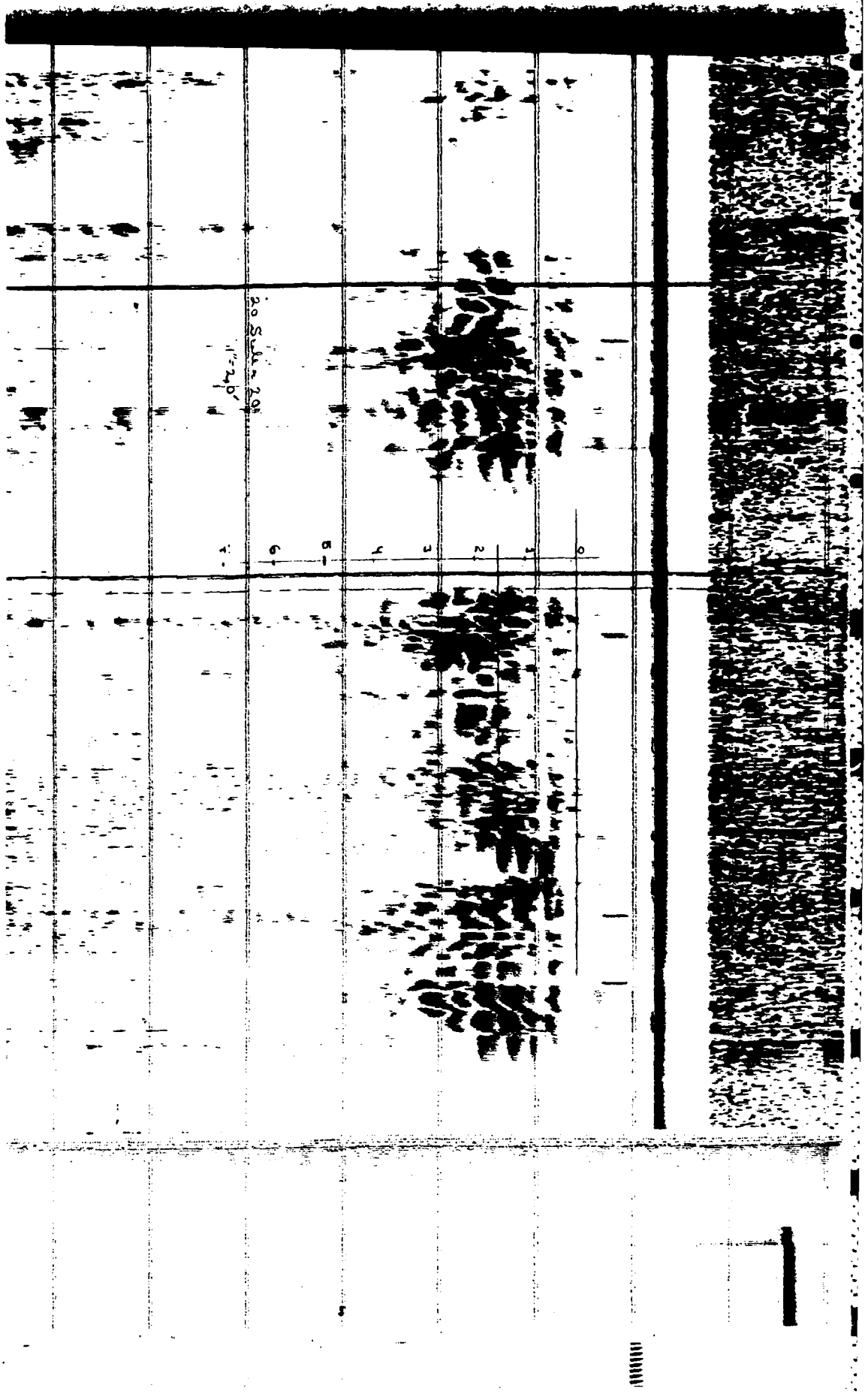
ϵ_r = Dielectric Constant (moist sand) = 16

T =

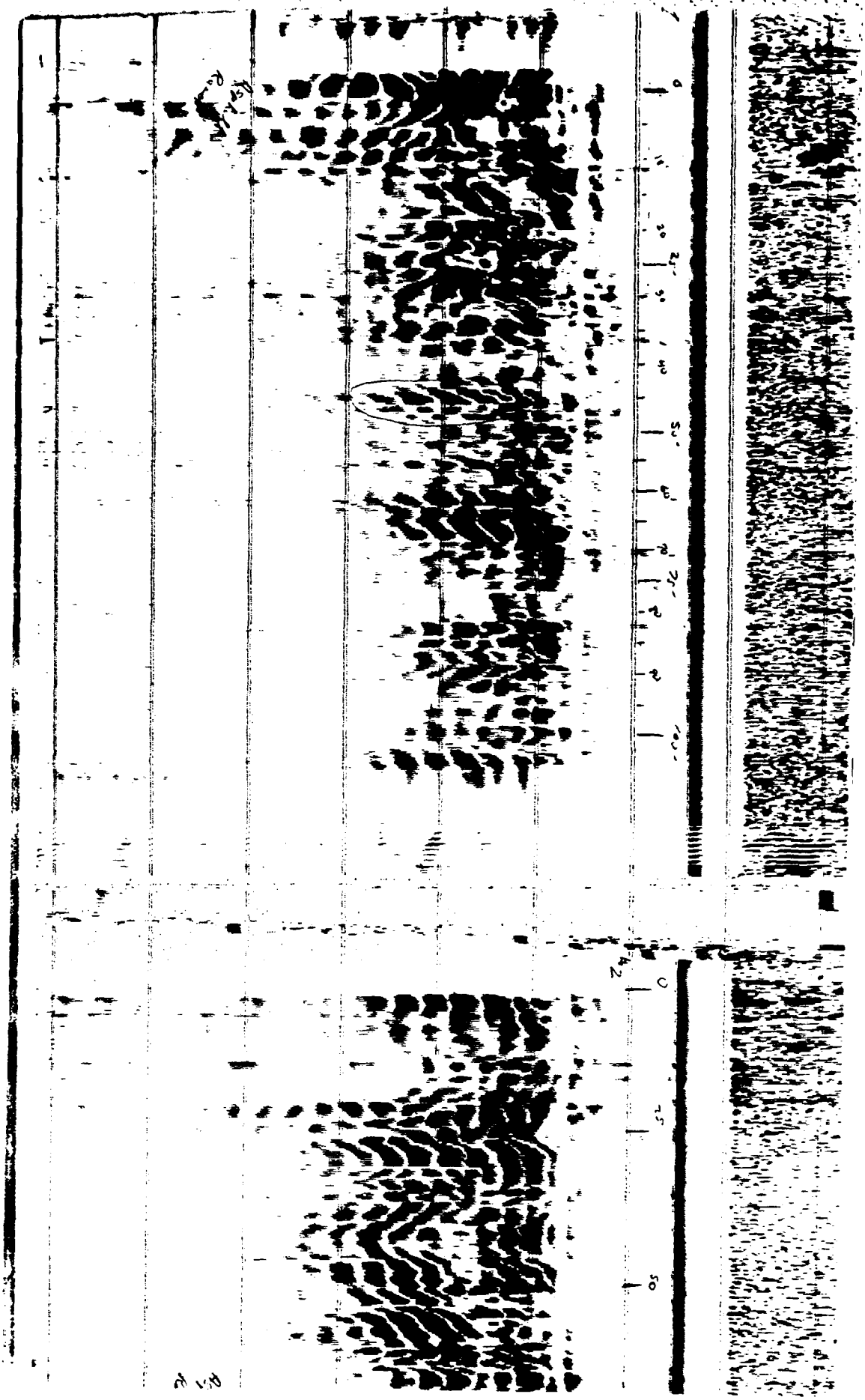
$$T = \frac{2 D \sqrt{\epsilon_R}}{10}$$

$$T = \frac{2 \cdot 20 \sqrt{16}}{10} = \frac{160}{10} = 16$$

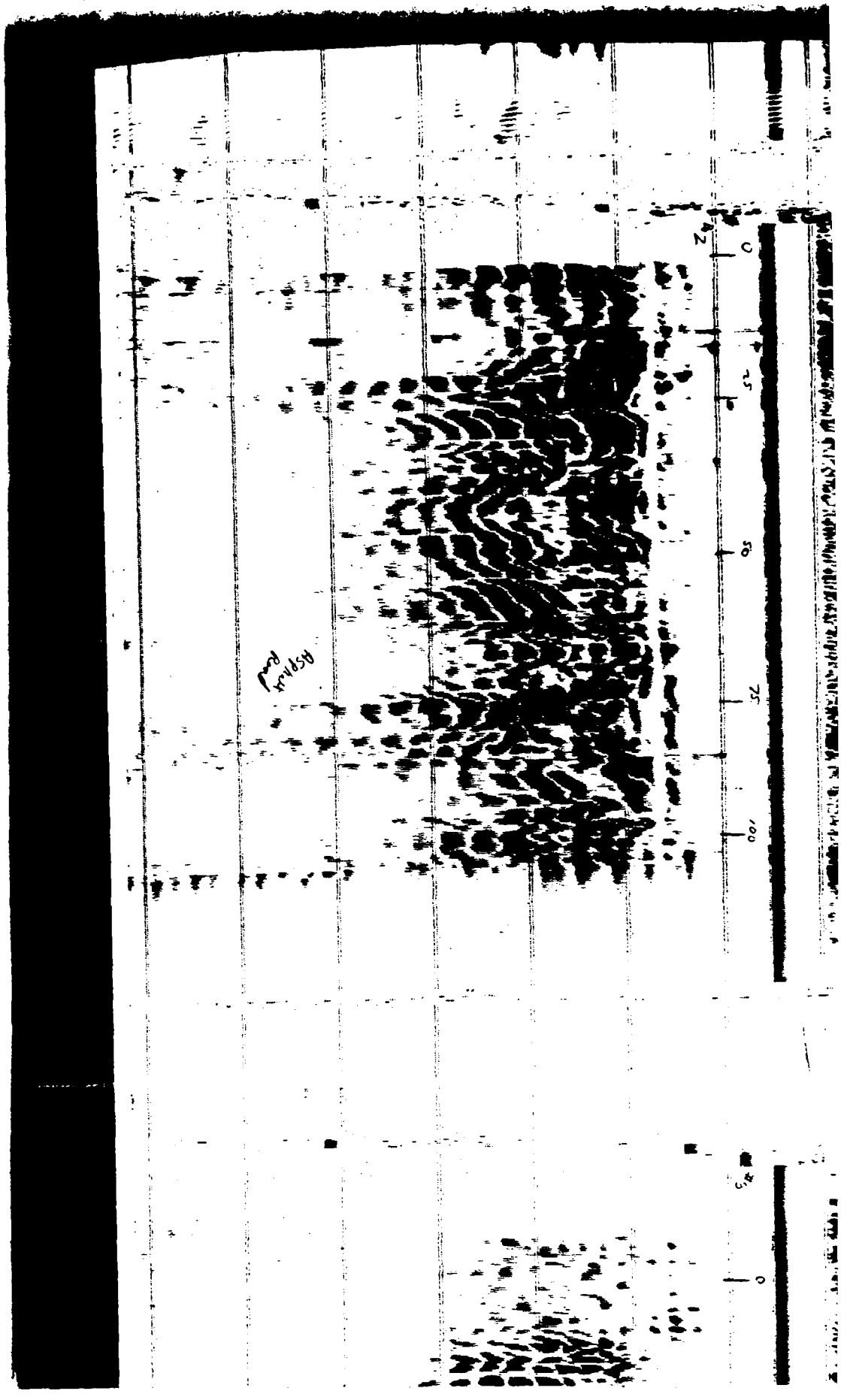

Signal Generator (Calibrator)
1
2
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11
12



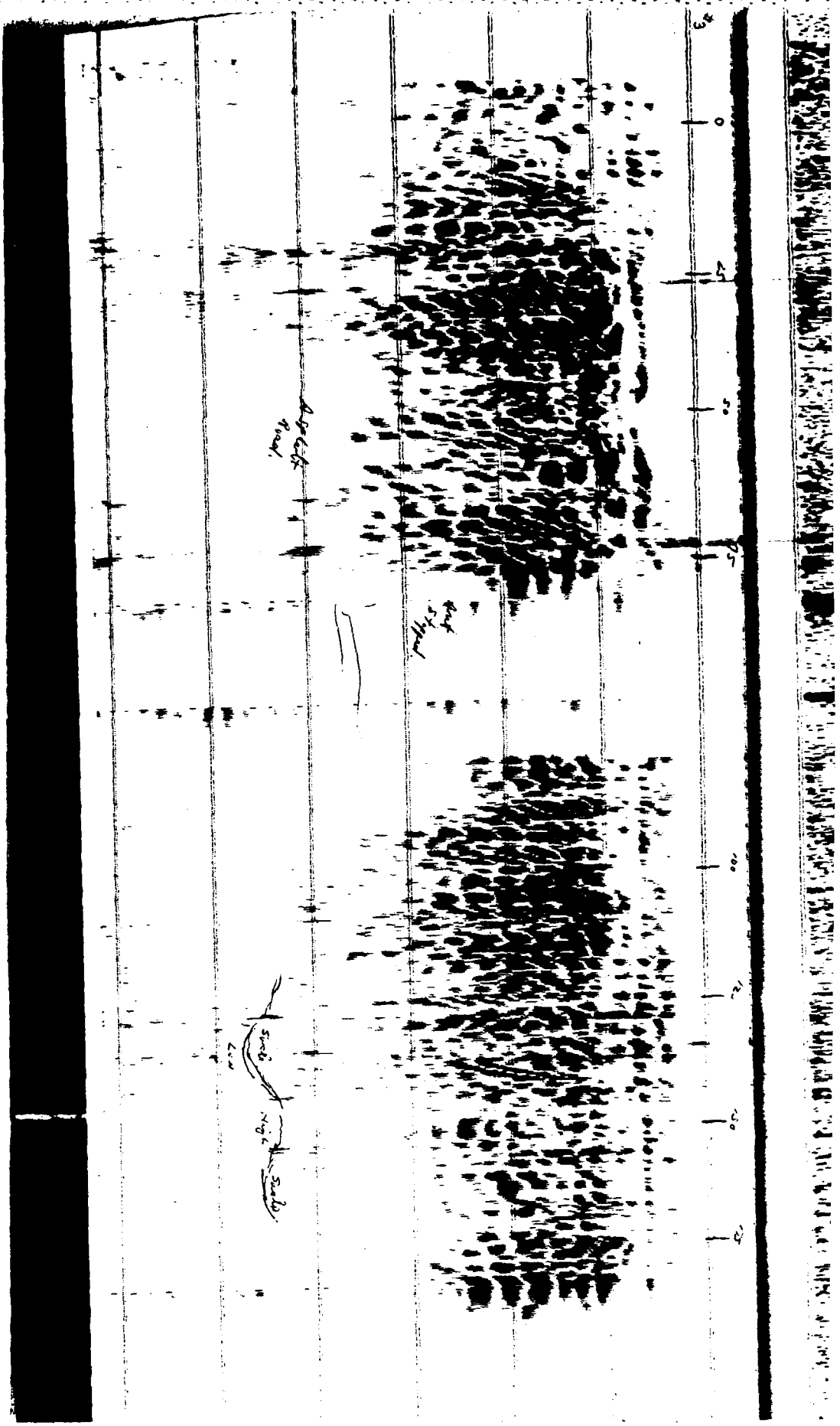
CALIBRATION



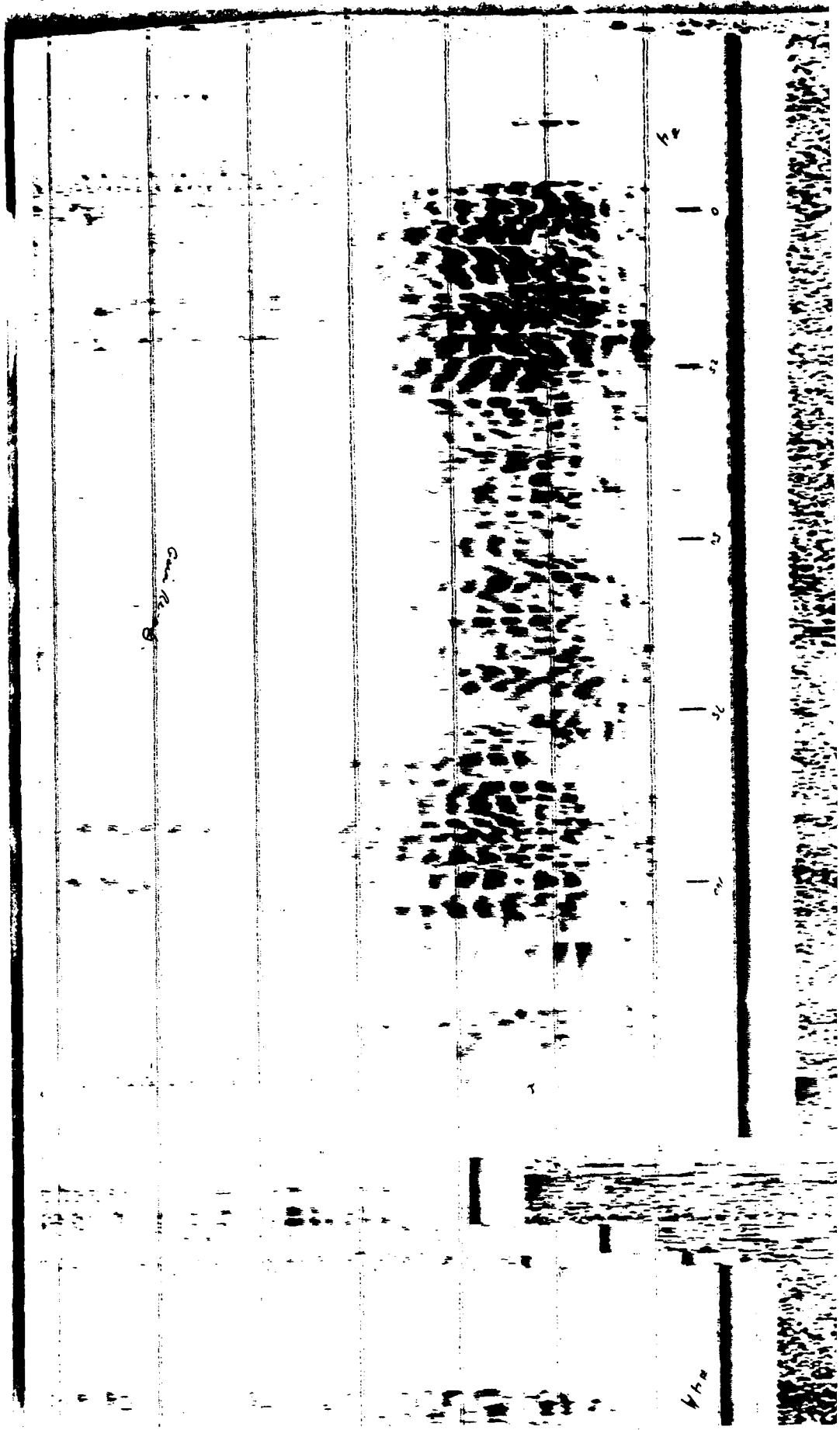
LANDFILL 8 11-1-83 TRAVERSE 1



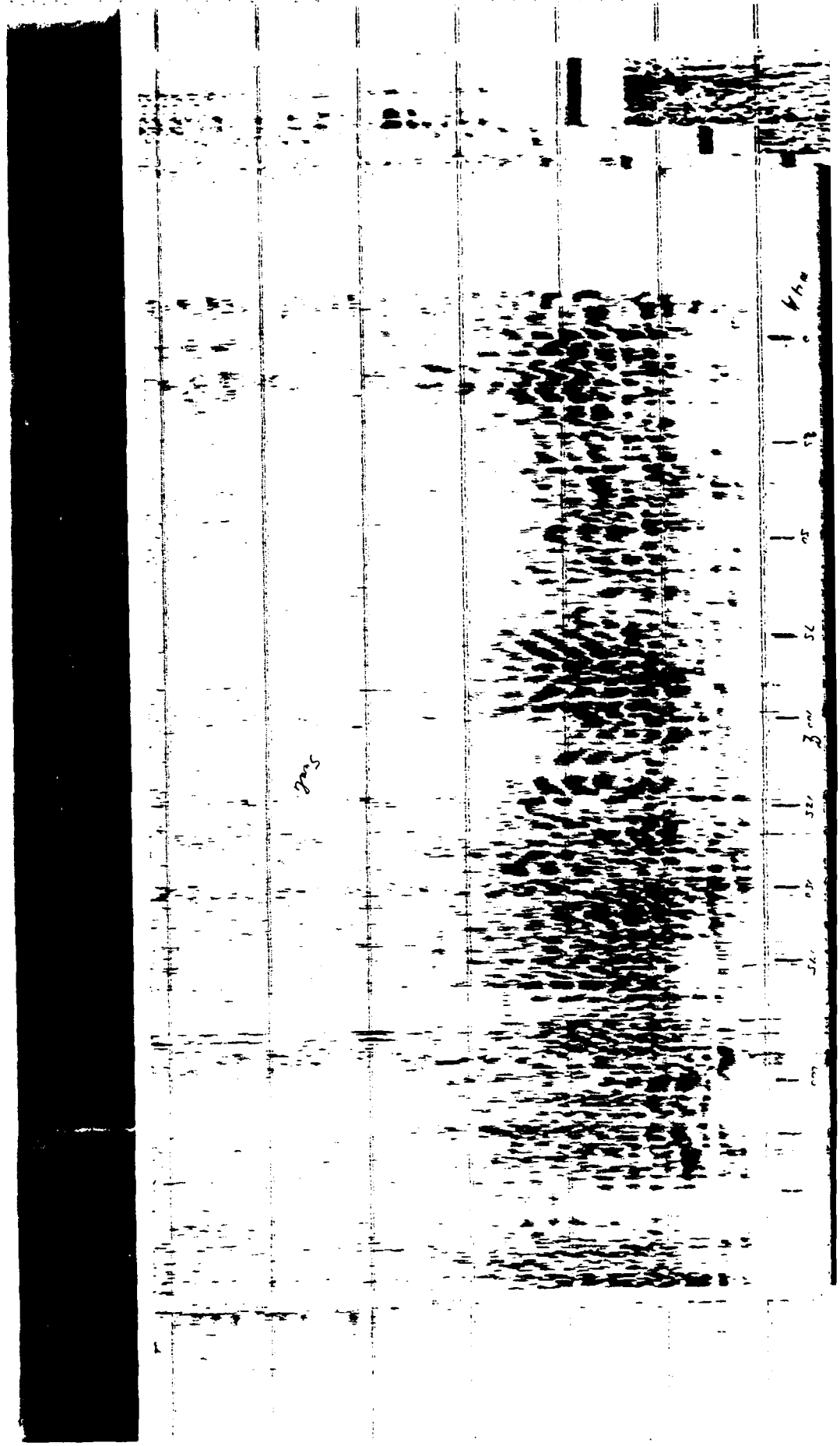
LANDFILL 8 11-1-83 TRAVERSE 2



LANDFILL 8 11-1-83 TRAVERSE 3



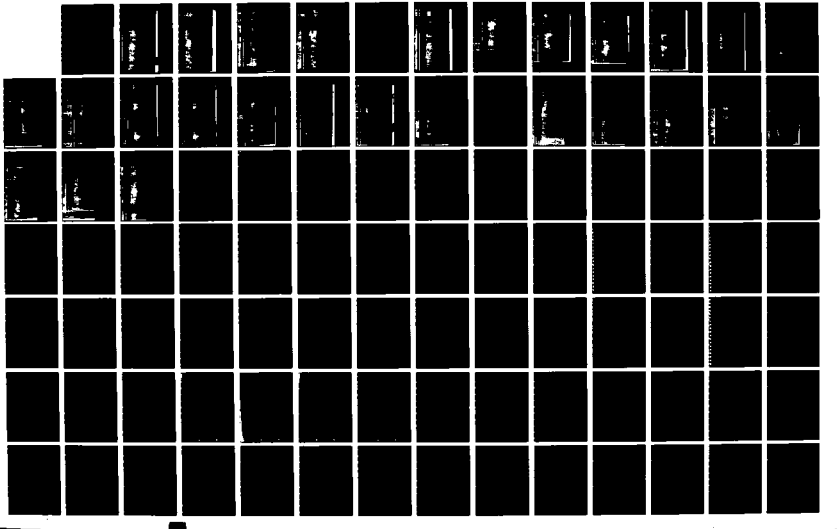
LANDFILL 8 11-1-83 TRAVERSE 4

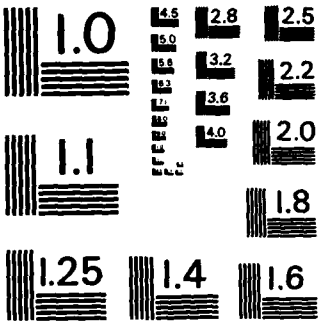


LANDFILL 8 11-1-83 TRAVERSE 4 REVERSE

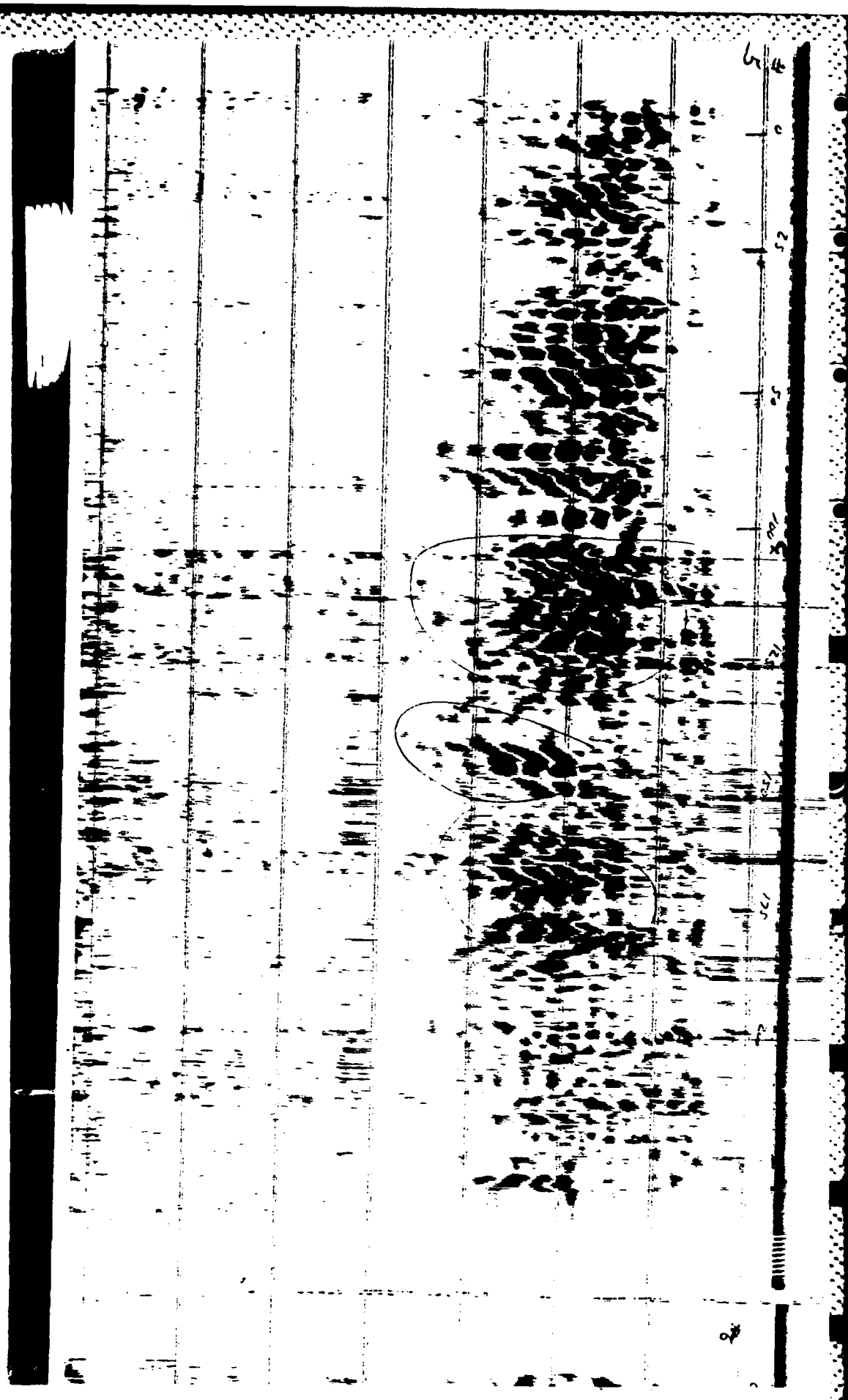
AD-A159 573 INSTALLATION RESTORATION PROGRAM PHASE II 4/5
CONFIRMATION/QUANTIFICATION STA..(U) WESTON (ROY F) INC
WEST CHESTER PA SEP 85 F33615-80-D-4006

UNCLASSIFIED F/G 13/2 NL

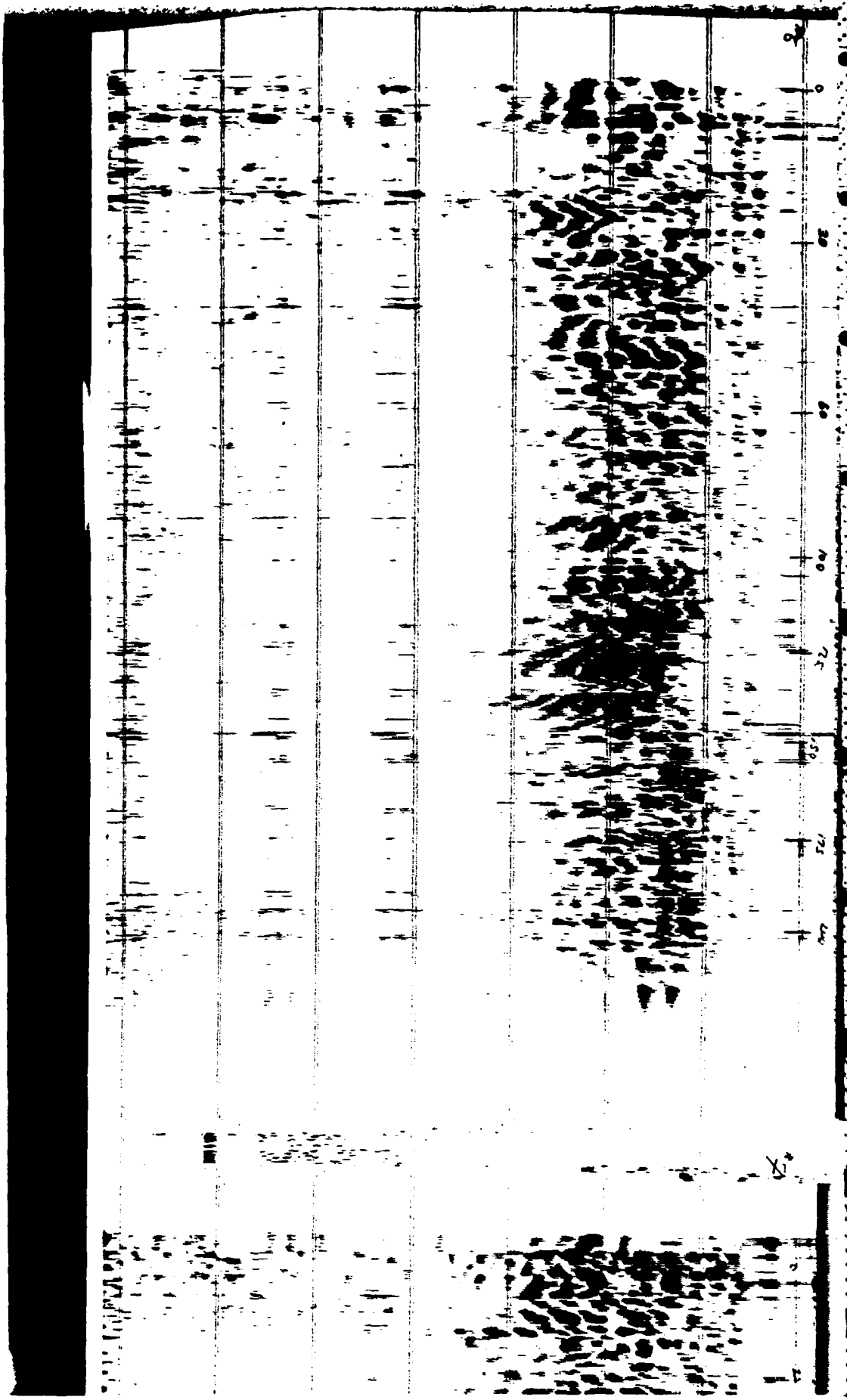




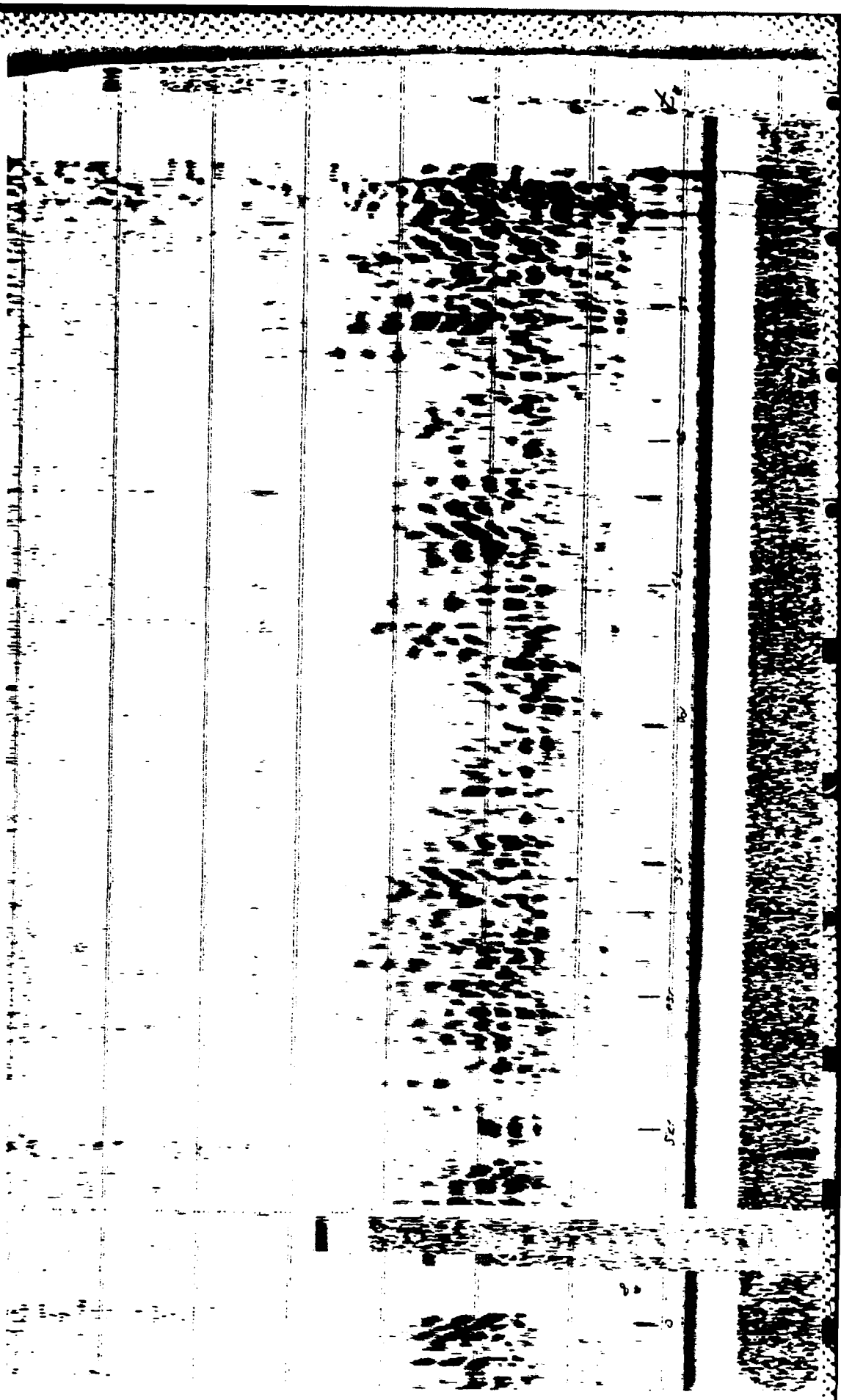
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



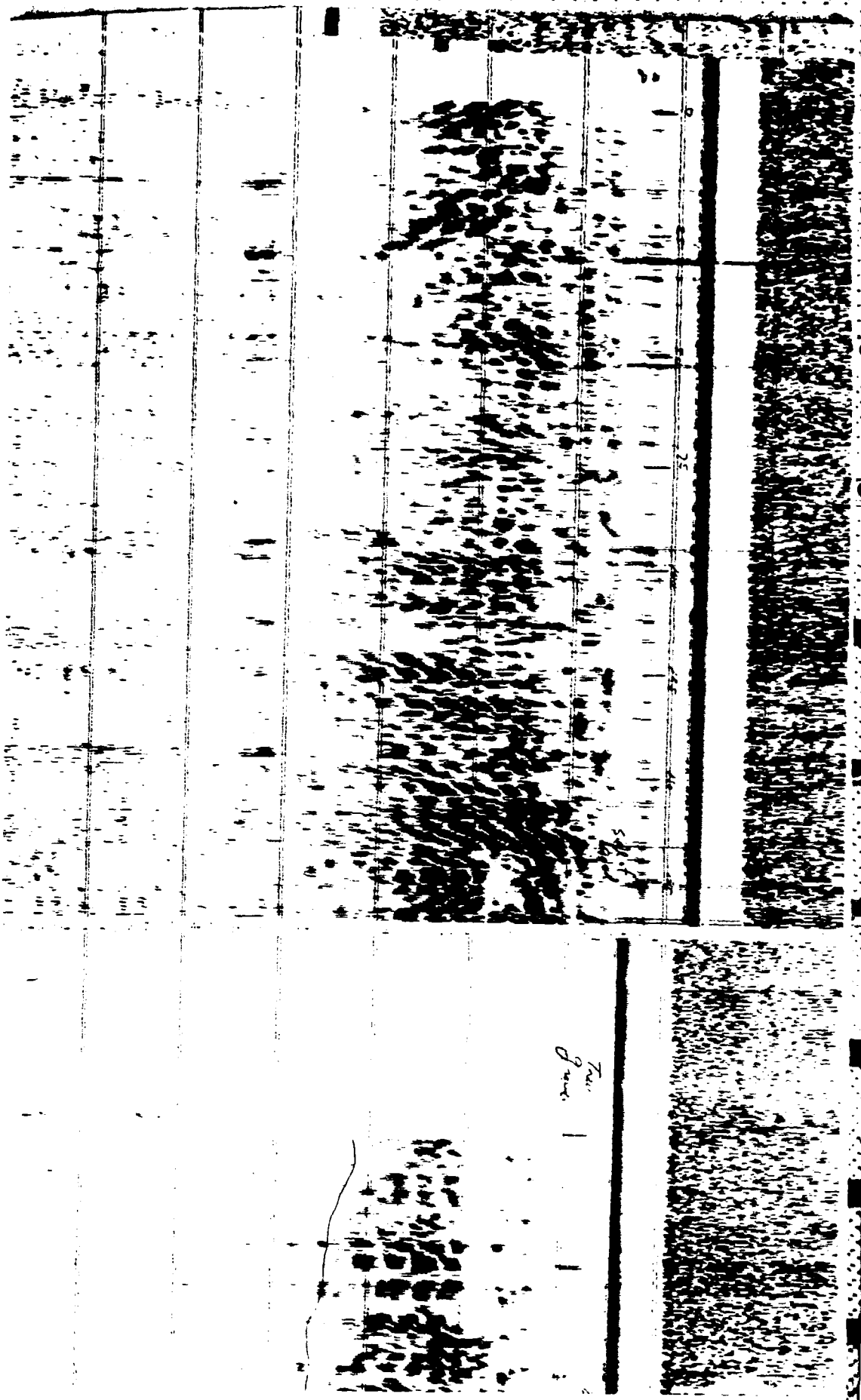
LANDFILL 8 11-1-83 TRAVERSE 5



LANDFILL 8 11-1-83 TRAVERSE 6



LANDFILL 8 11-1-83 TRAVERSE 7



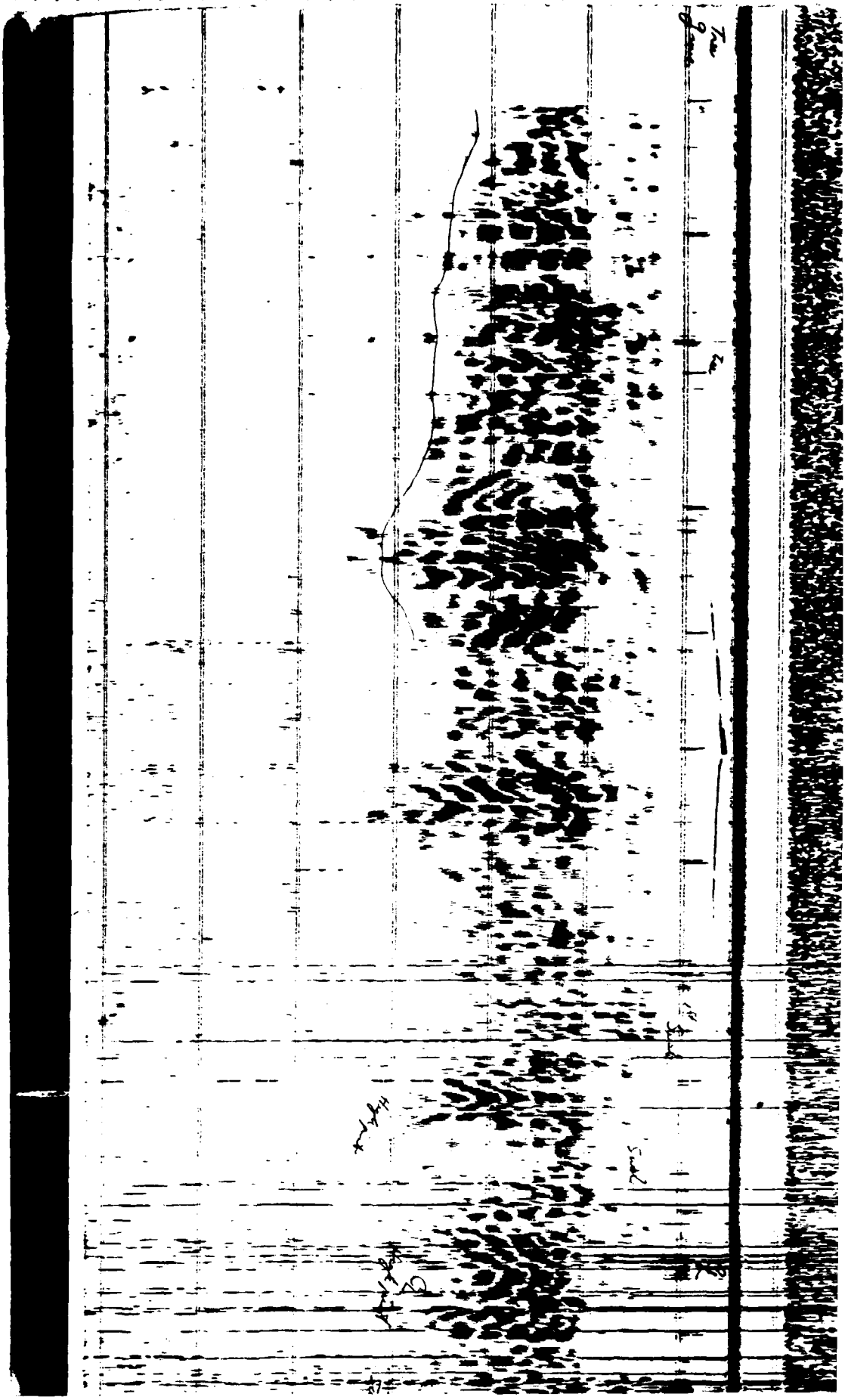
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WRIGHT PATTERSON AFB

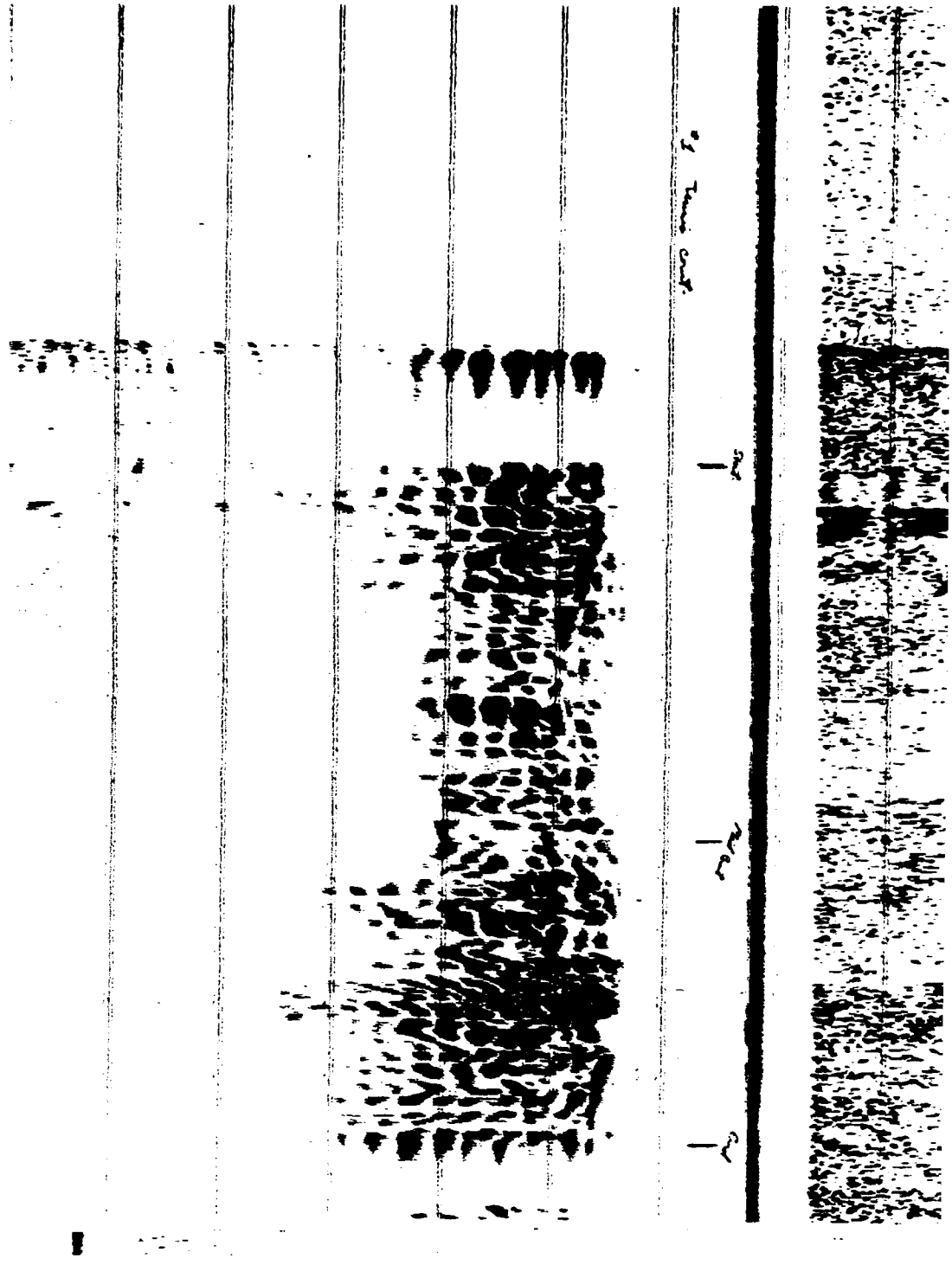
2 NOVEMBER 1983

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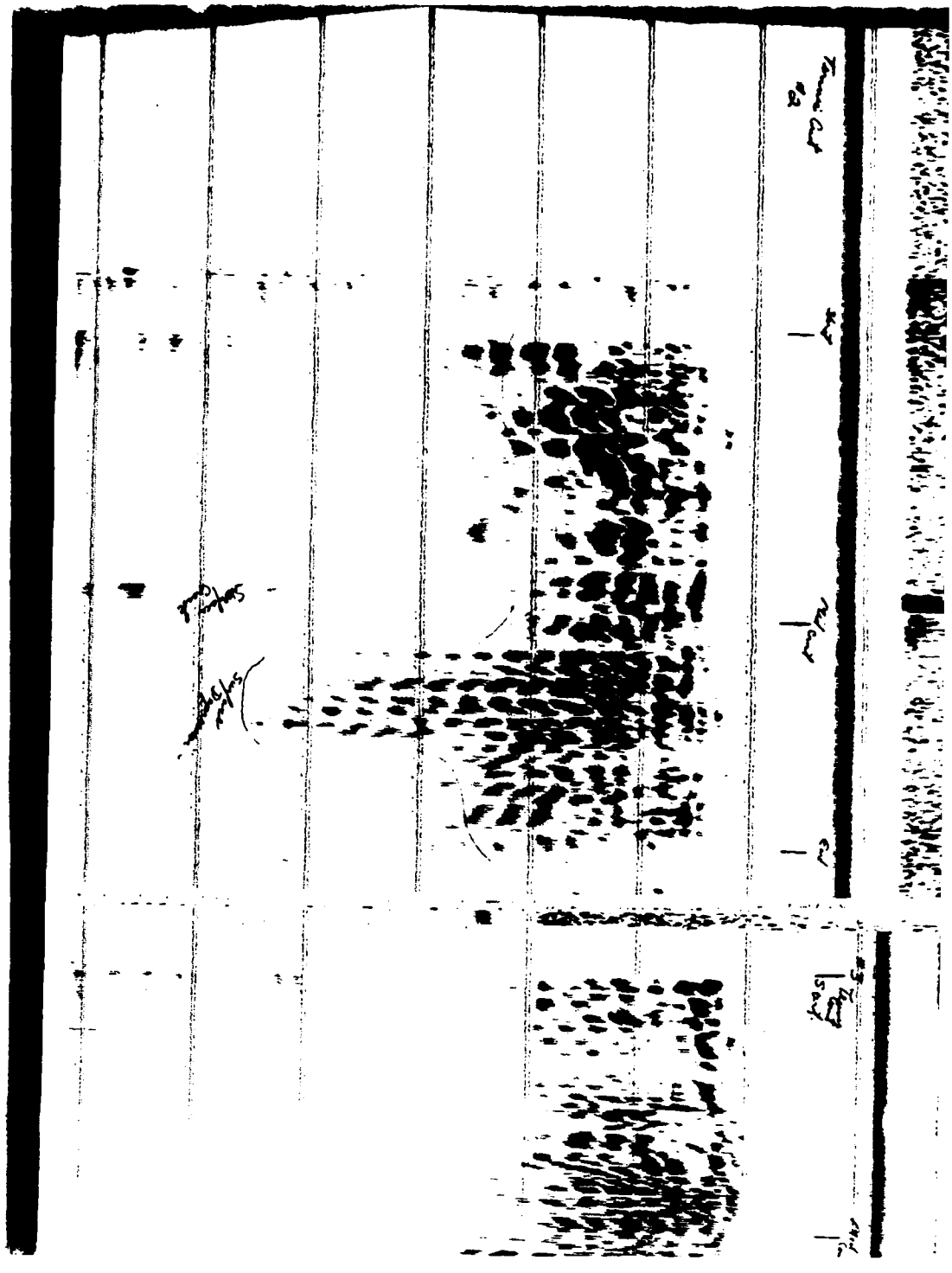
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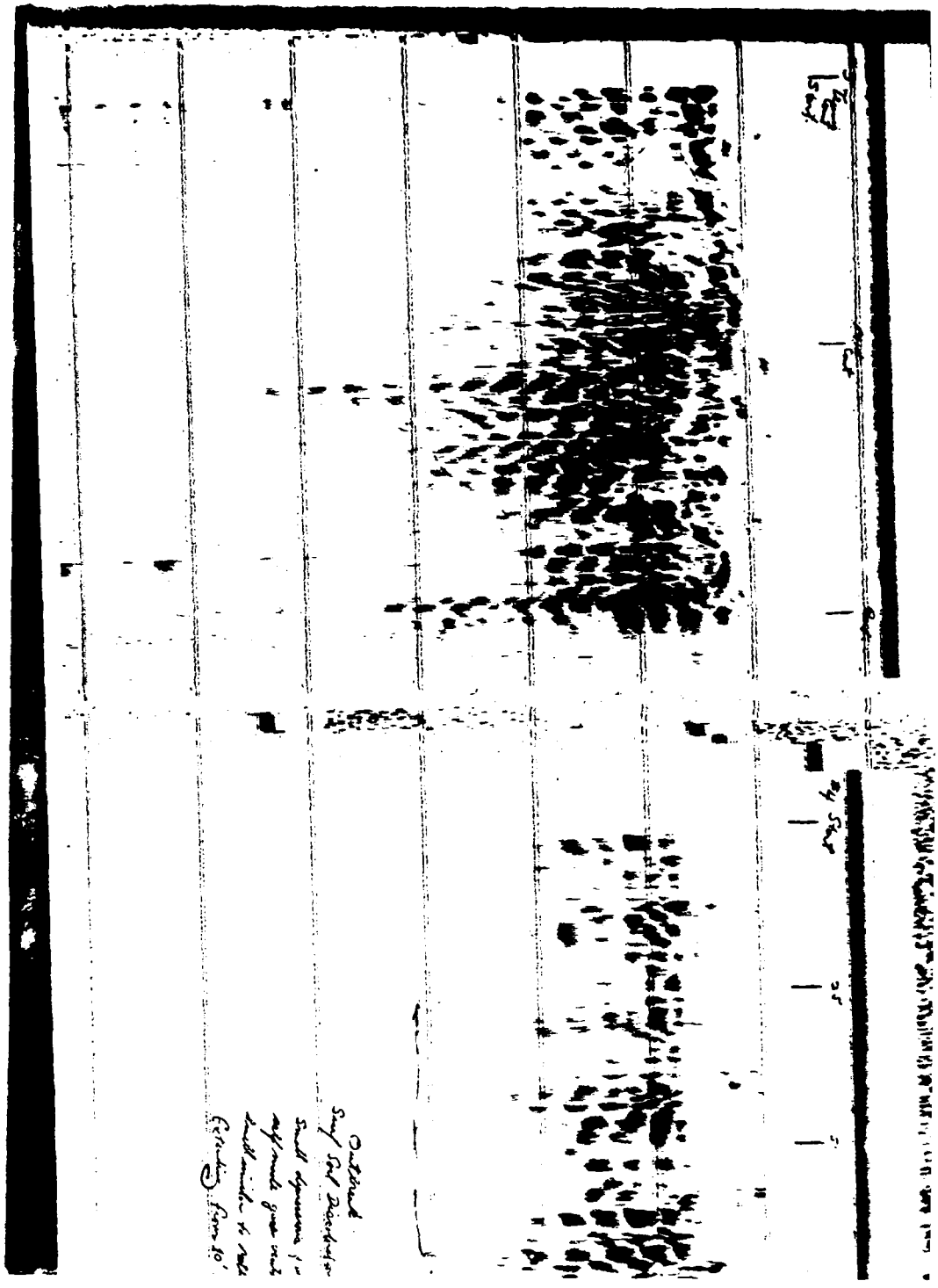
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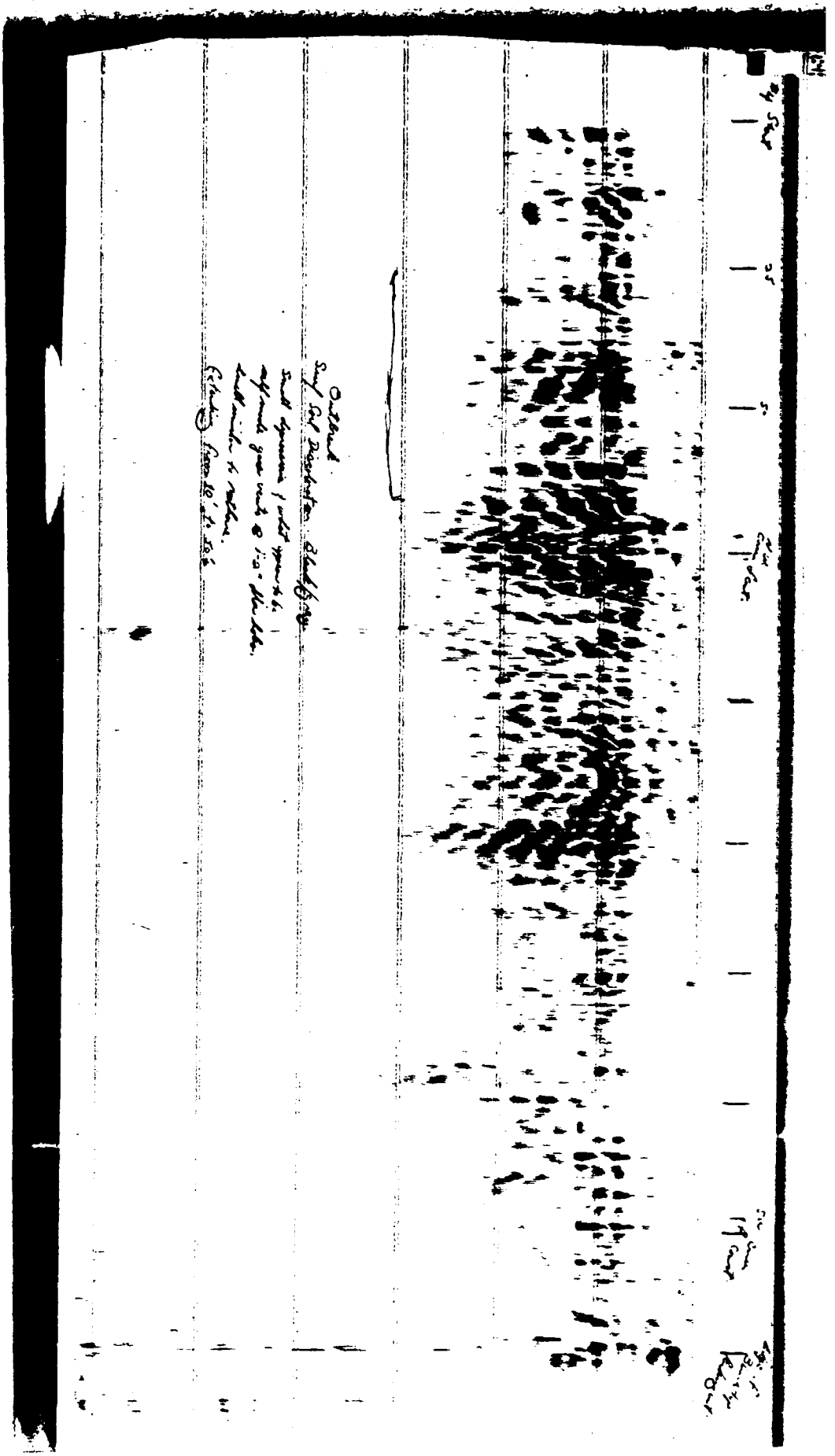
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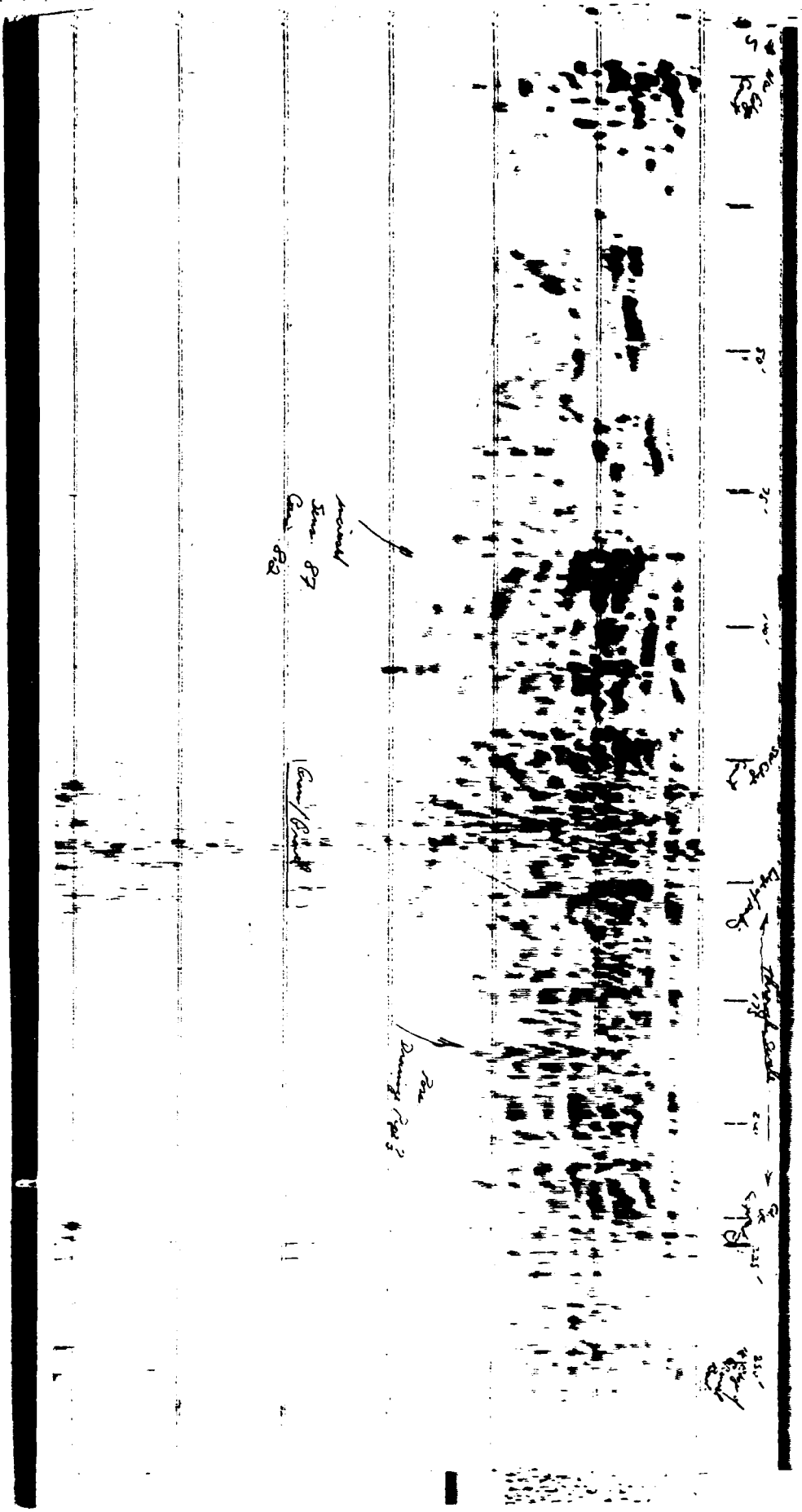
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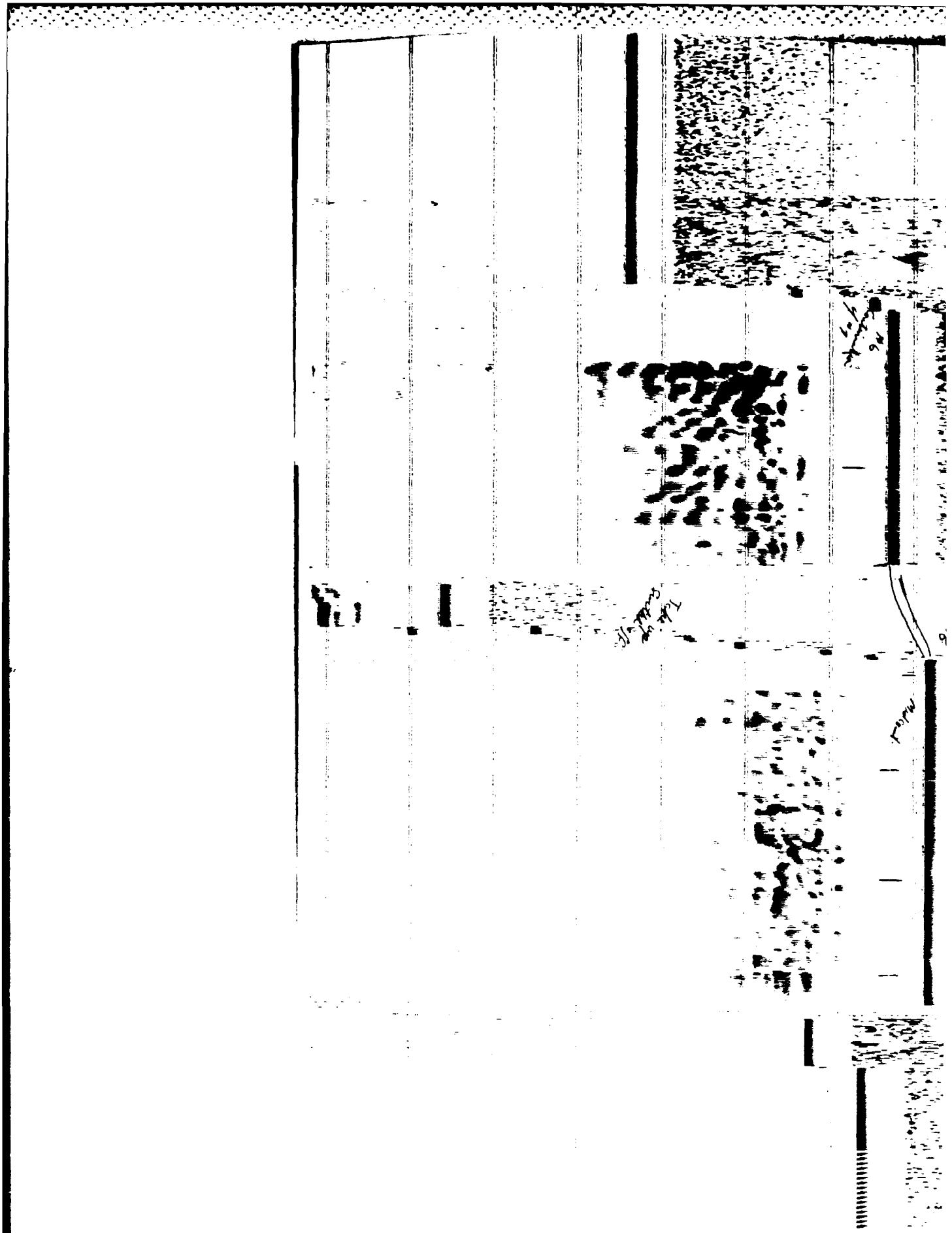
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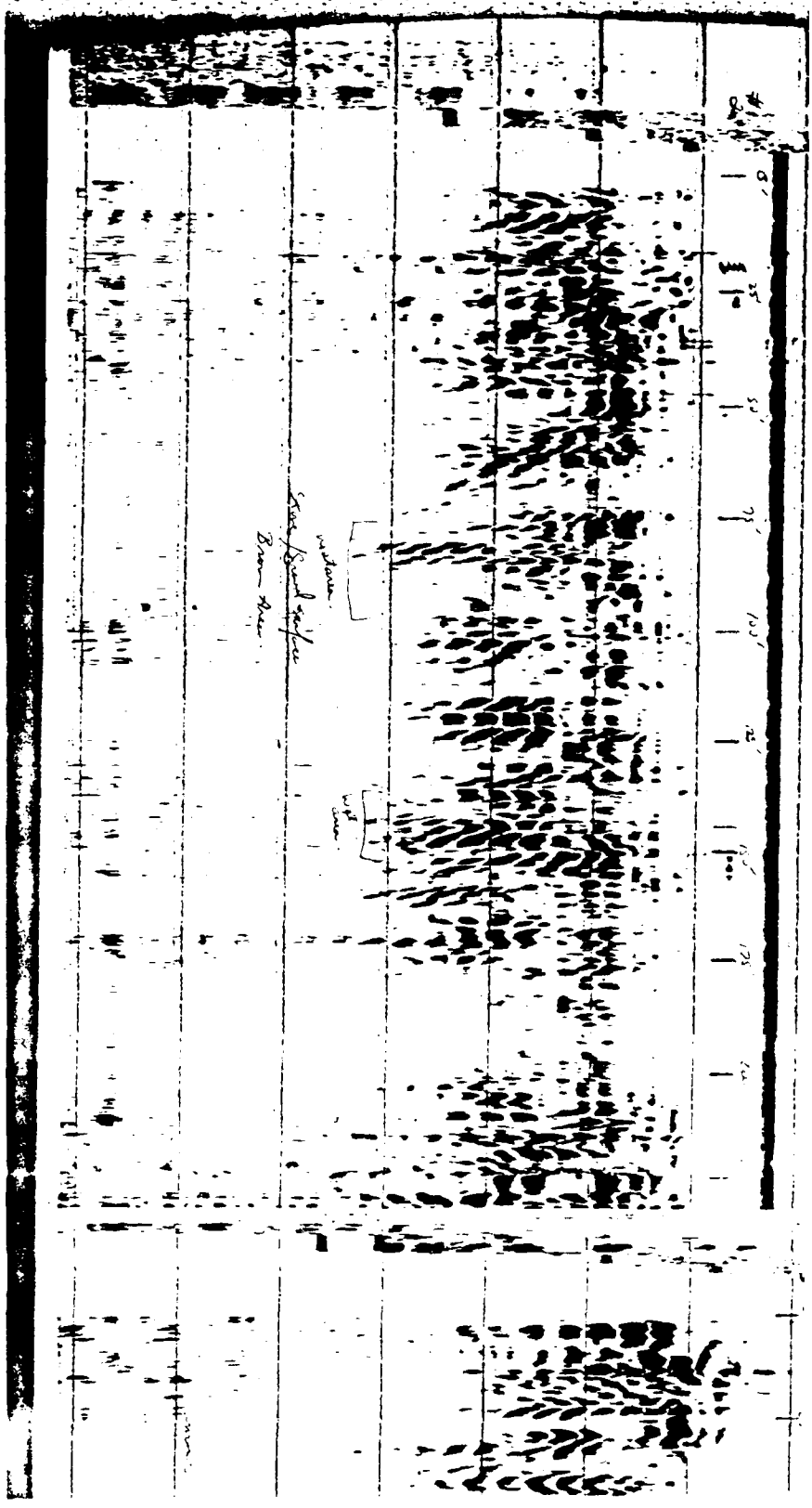
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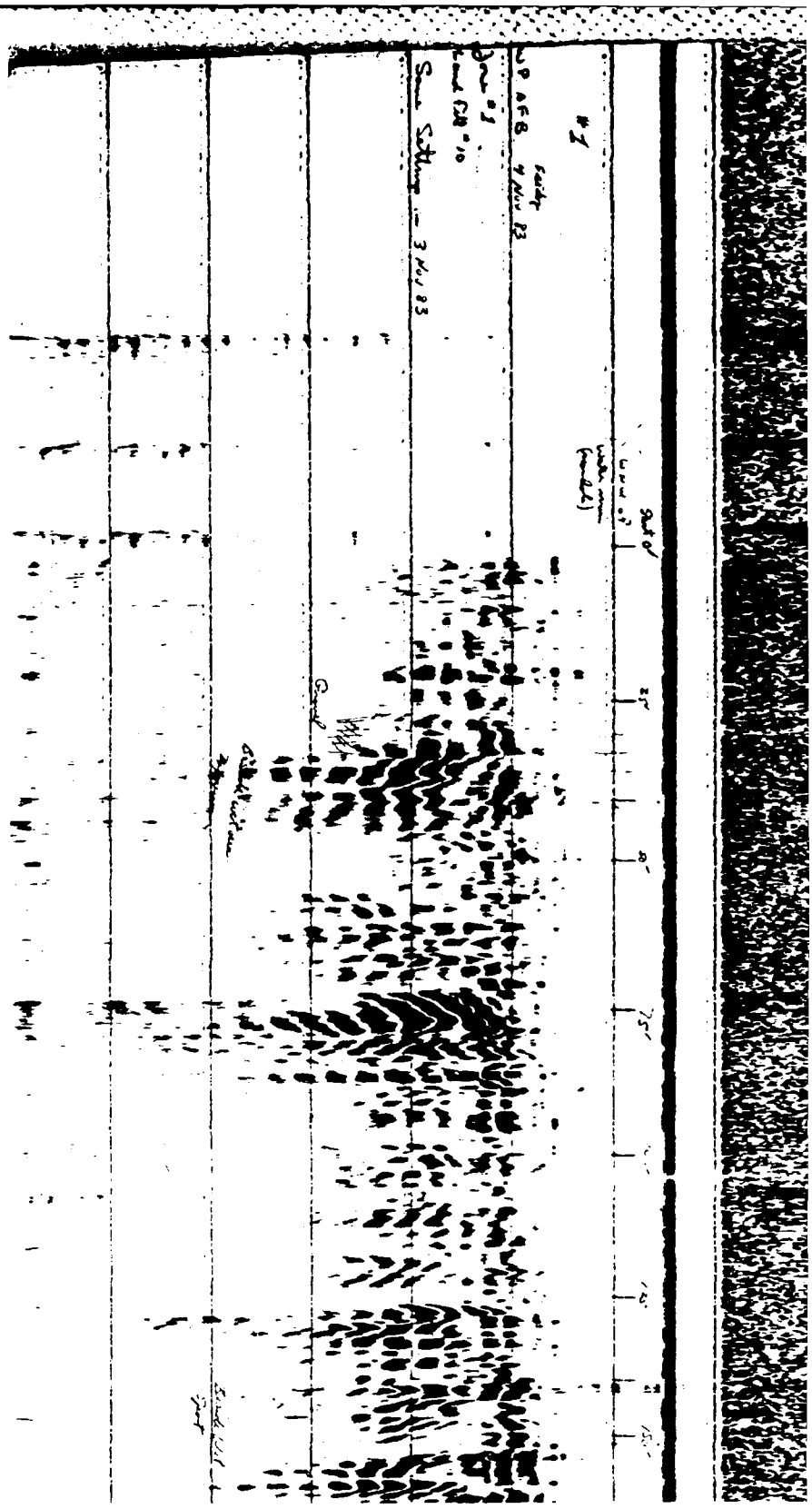
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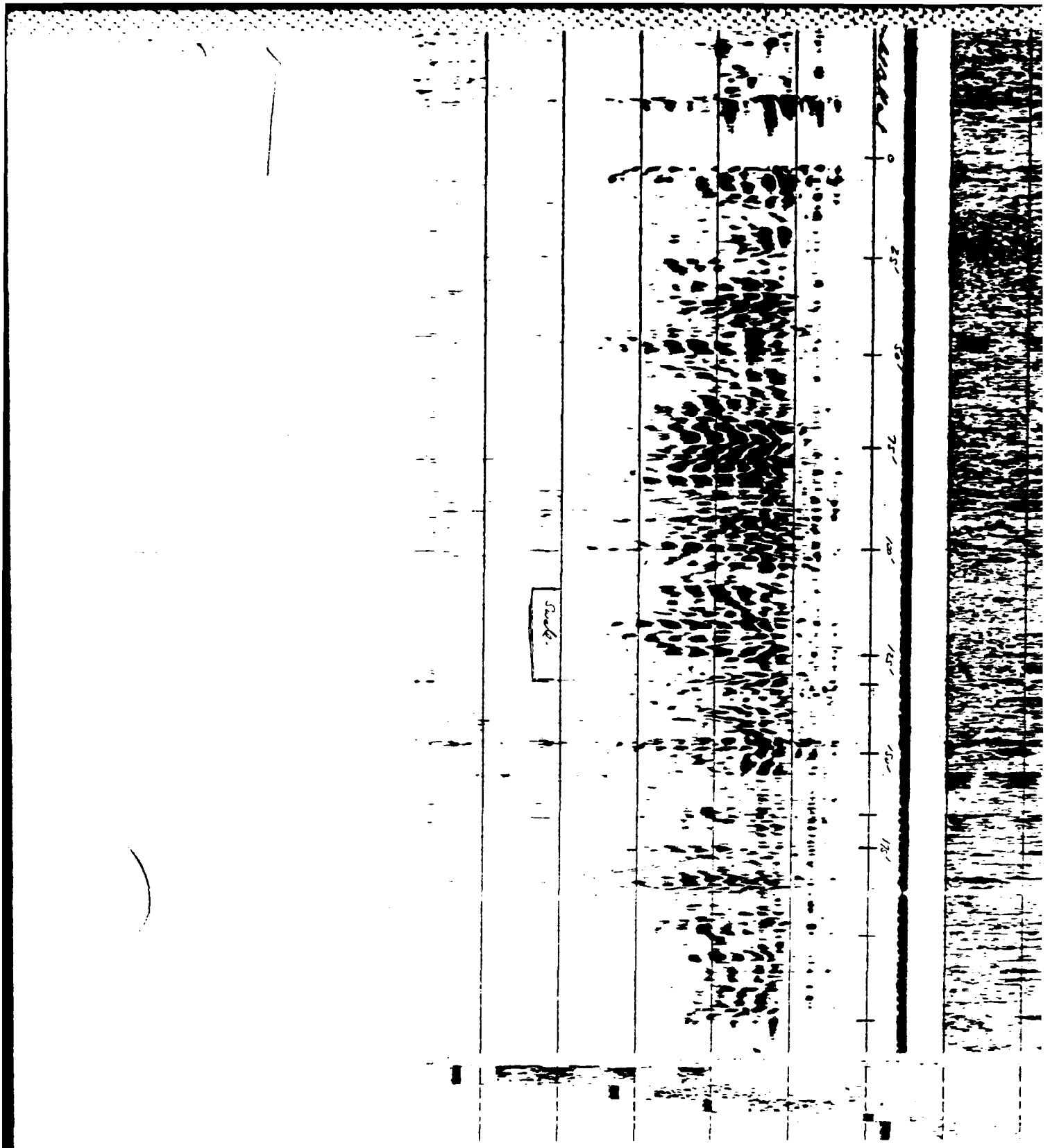
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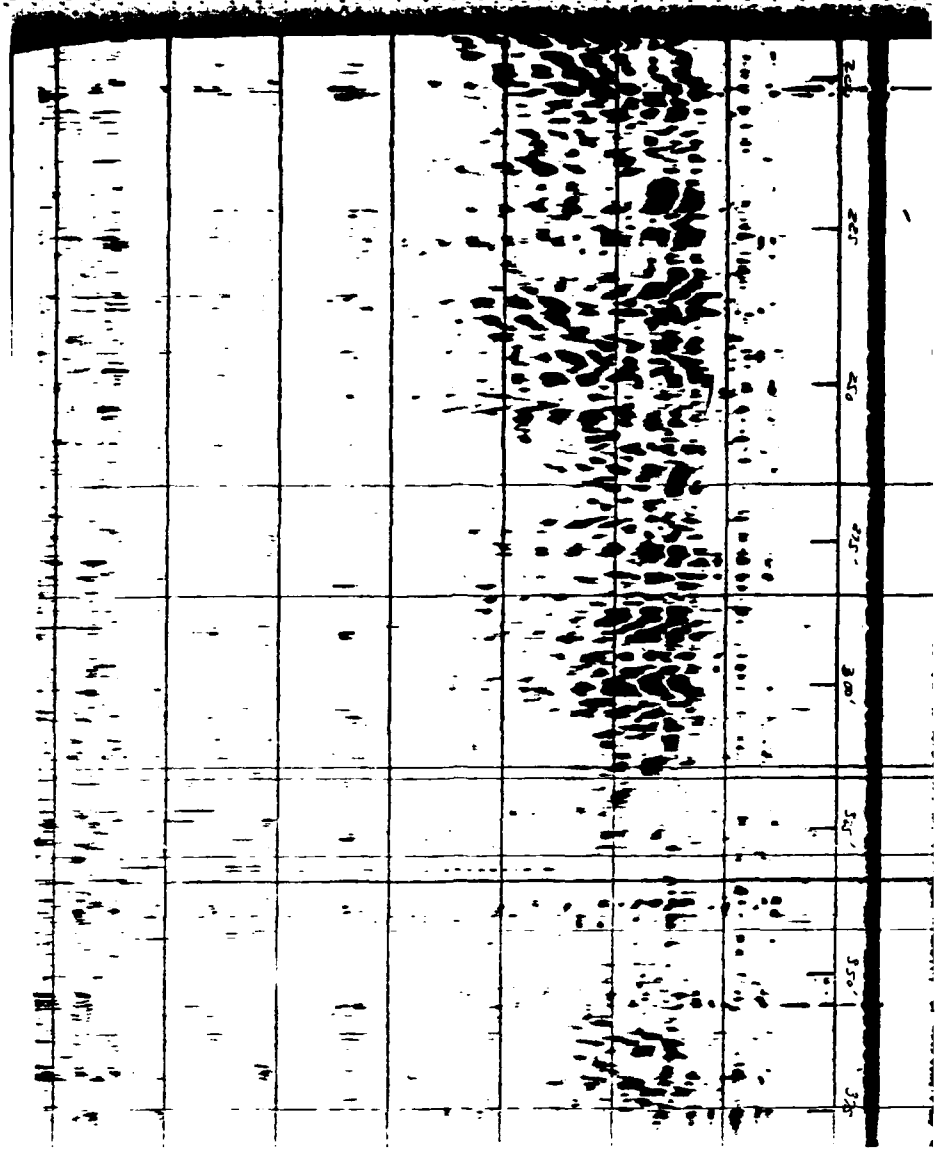
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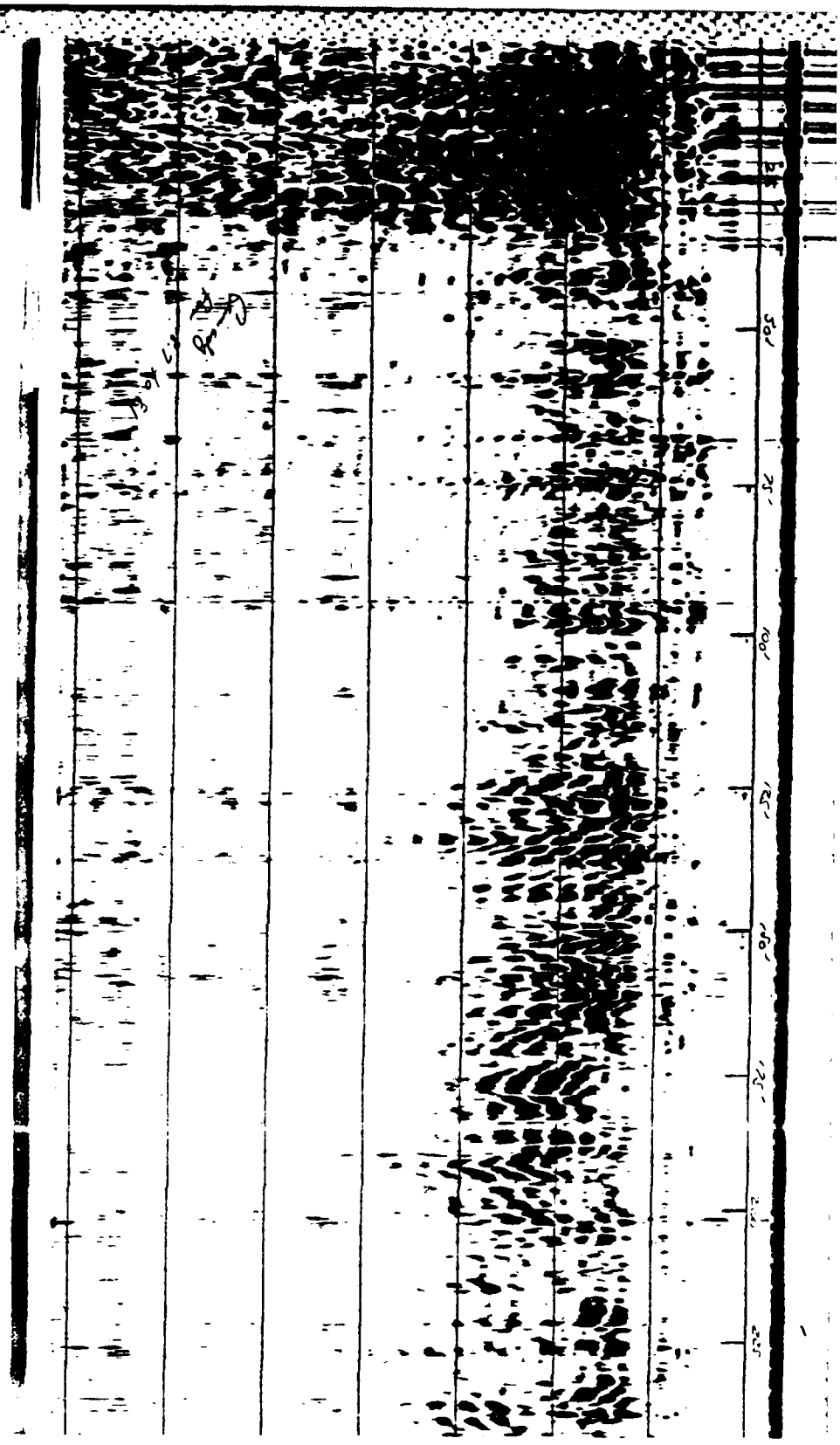
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CALIBRATION



CALIBRATION



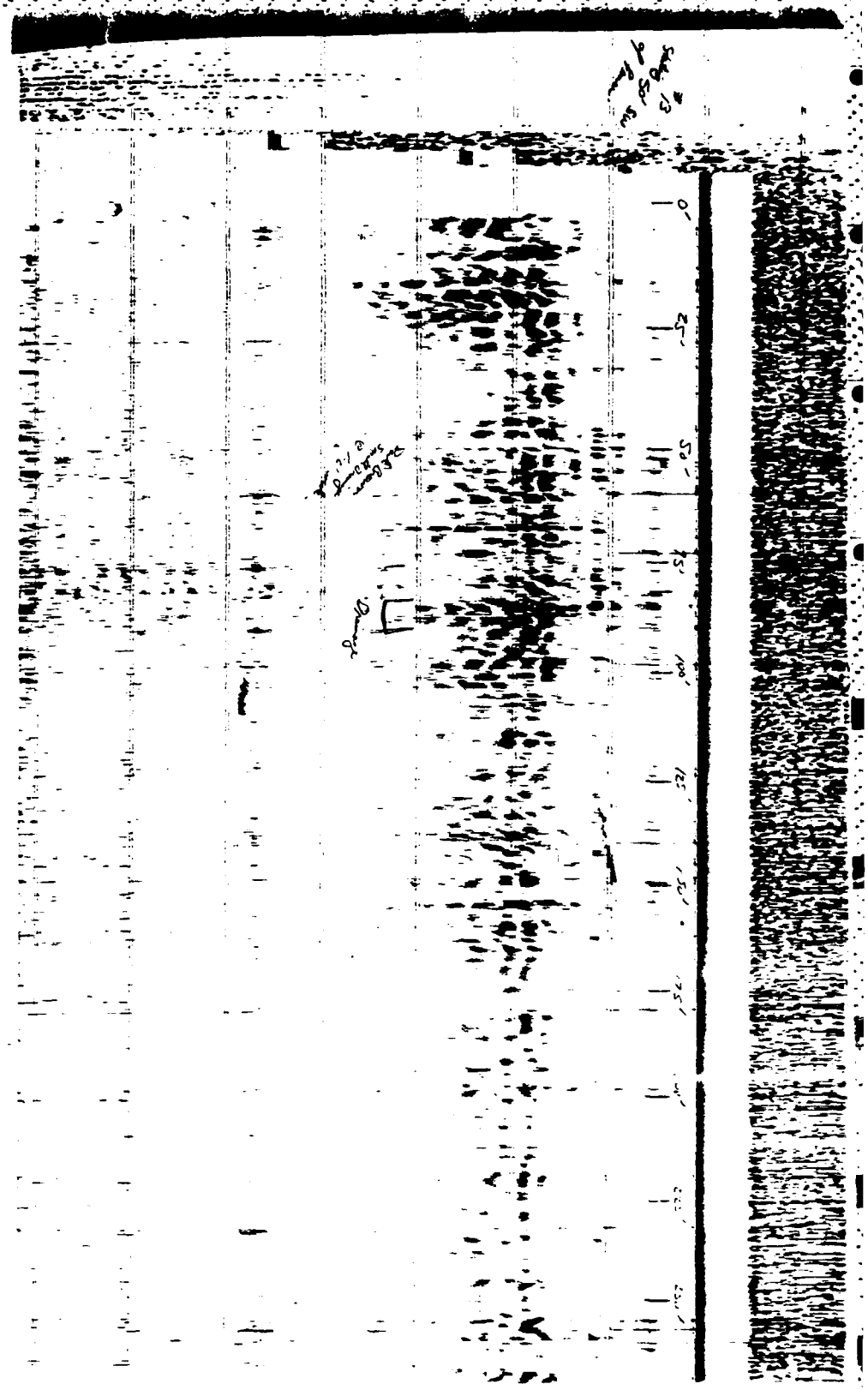
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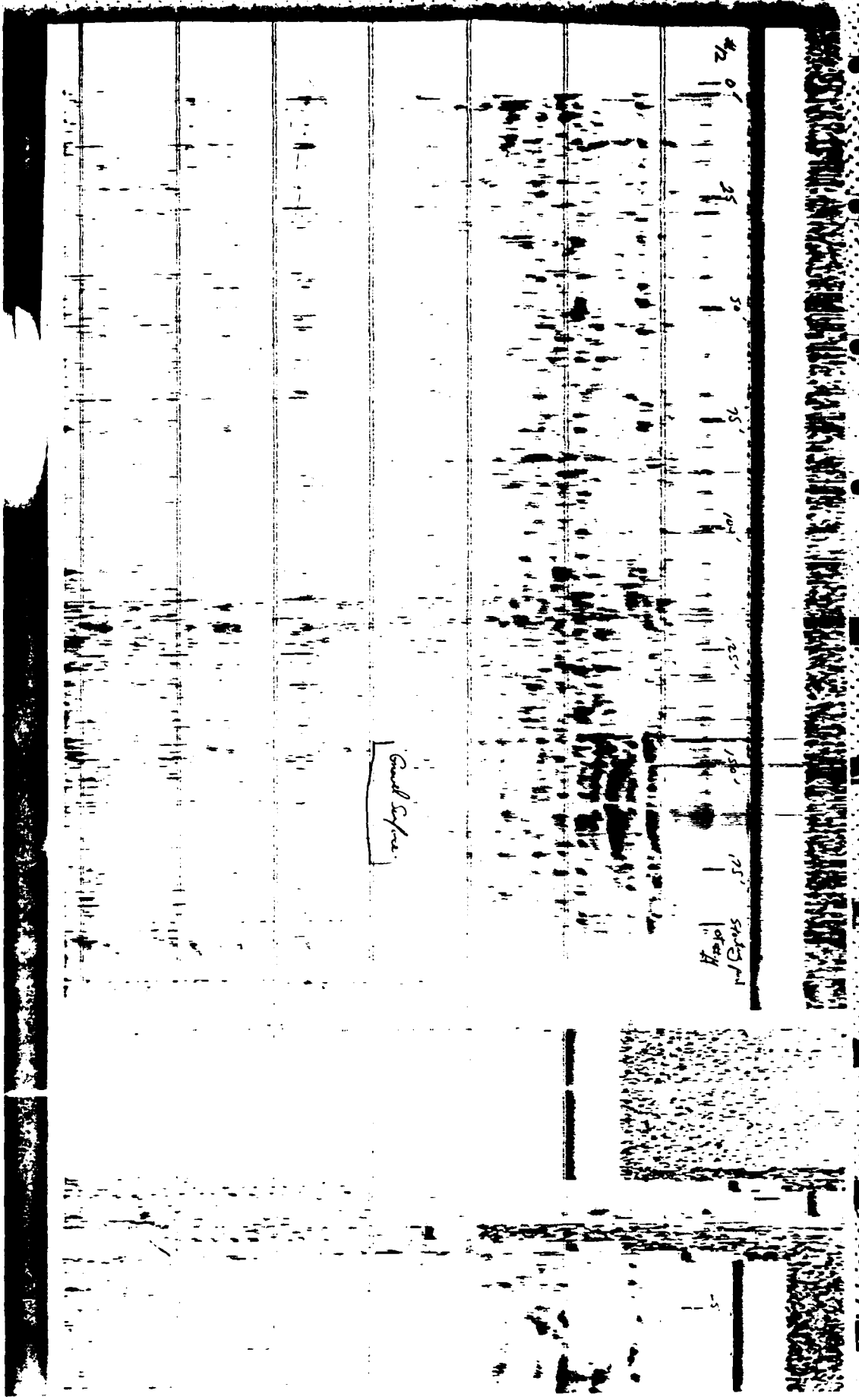
3 NOVEMBER 1983

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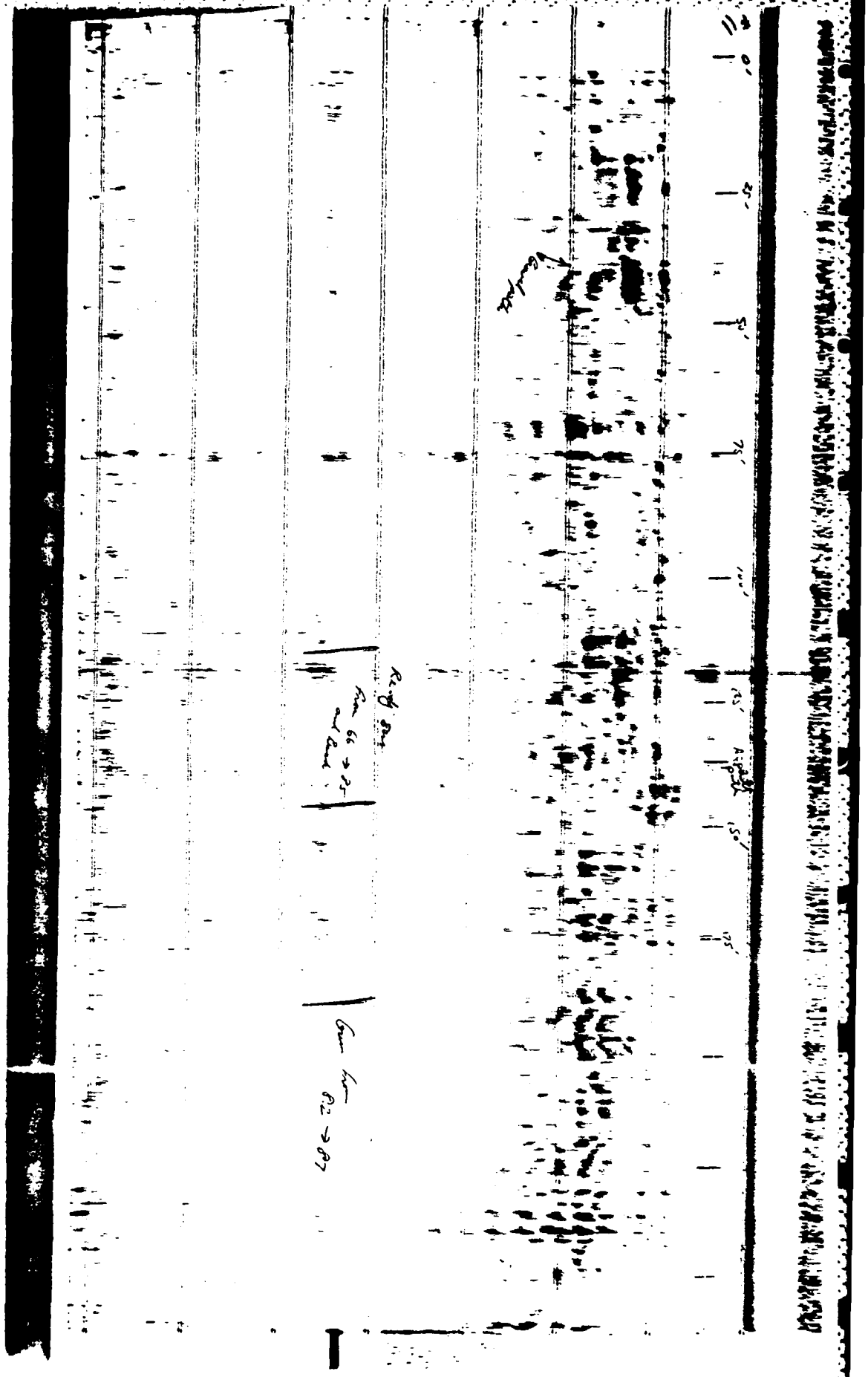
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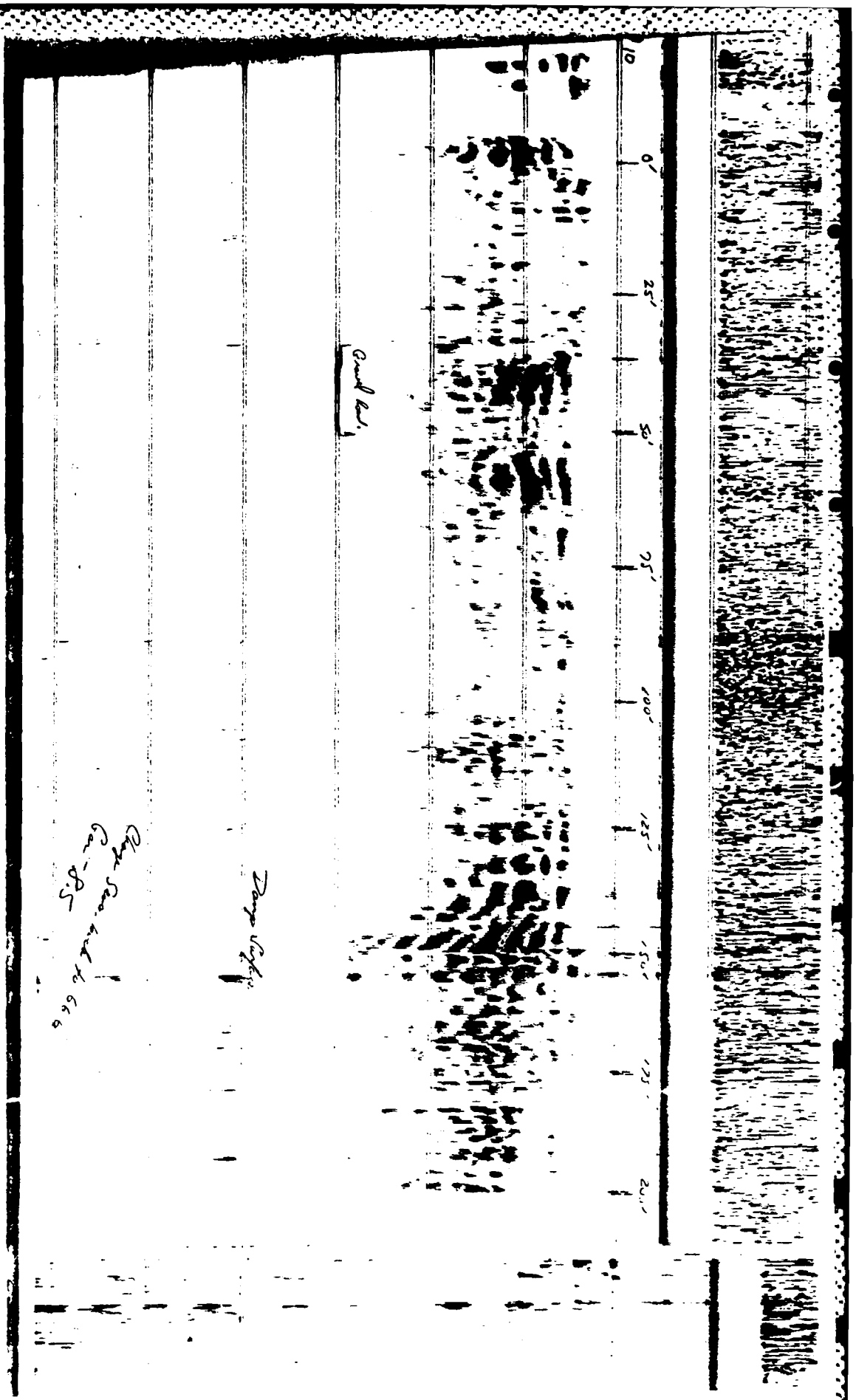
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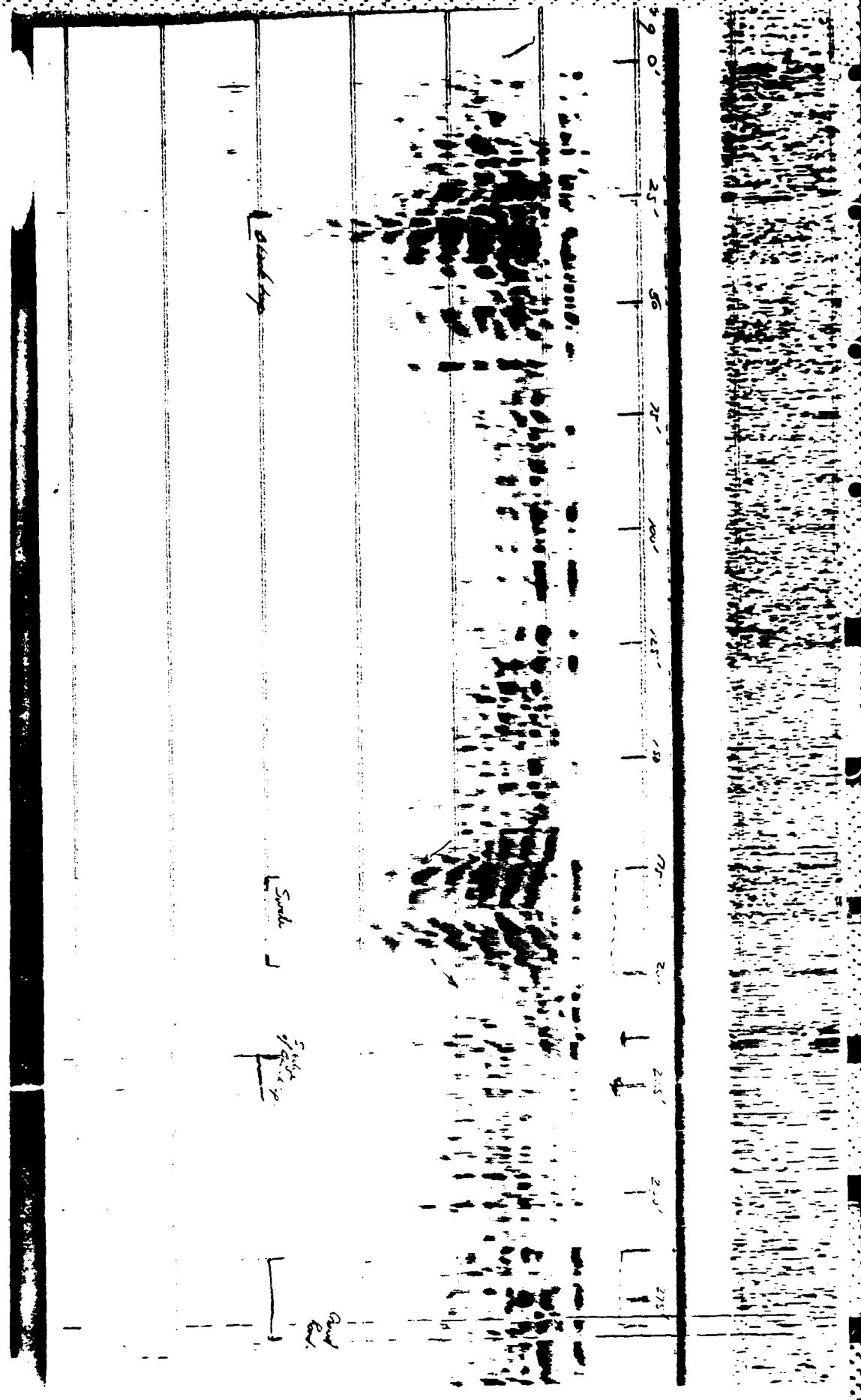
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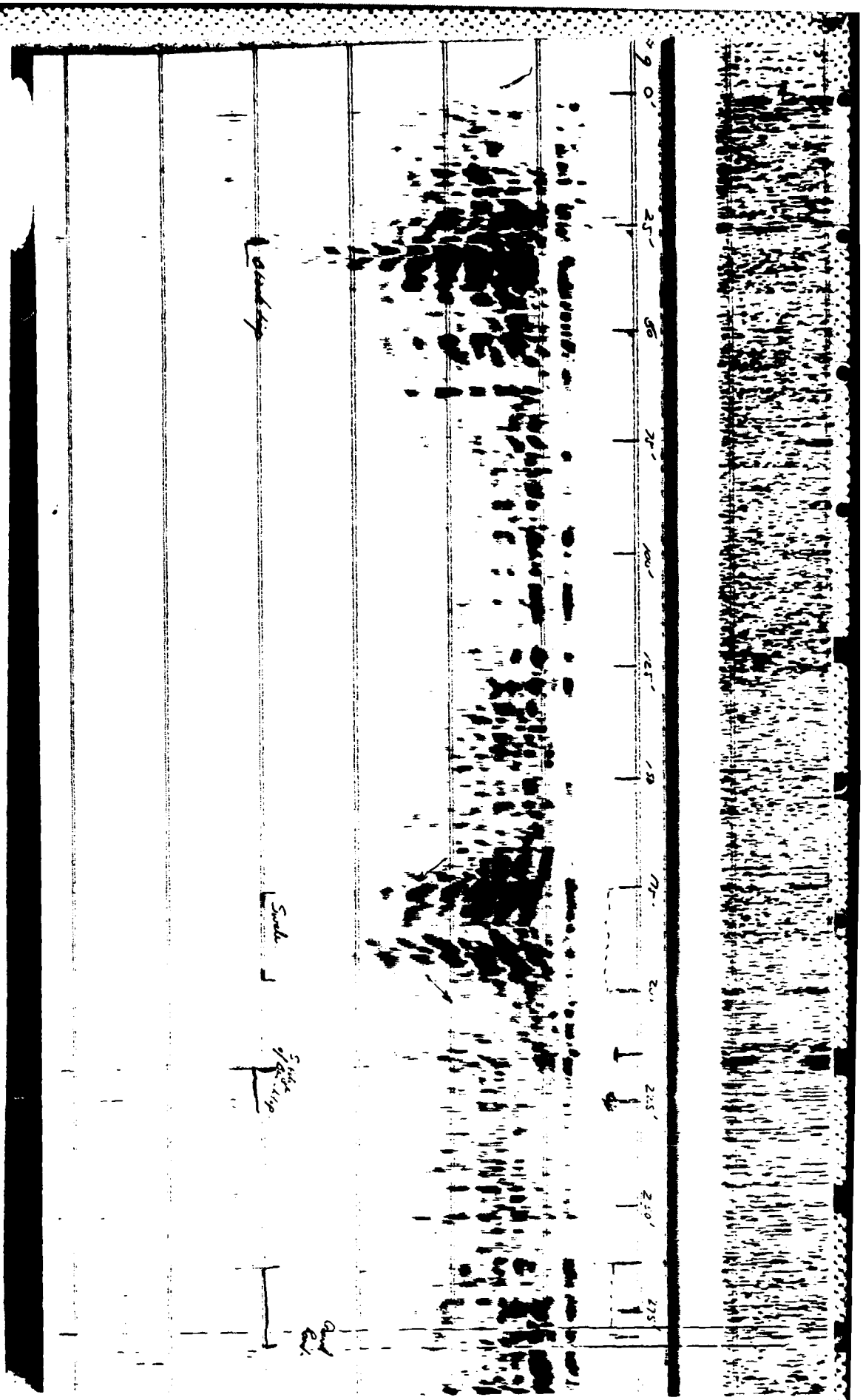
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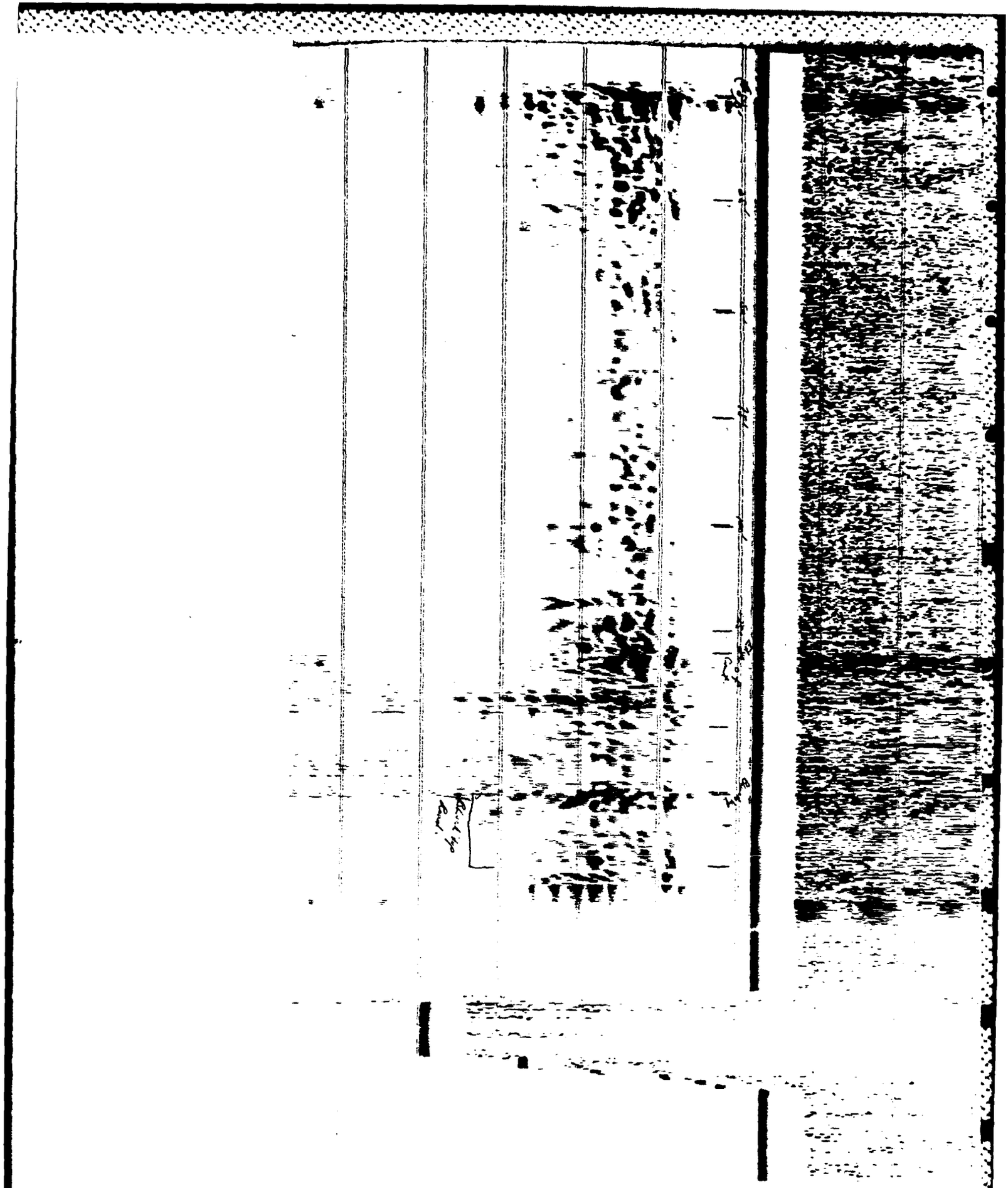
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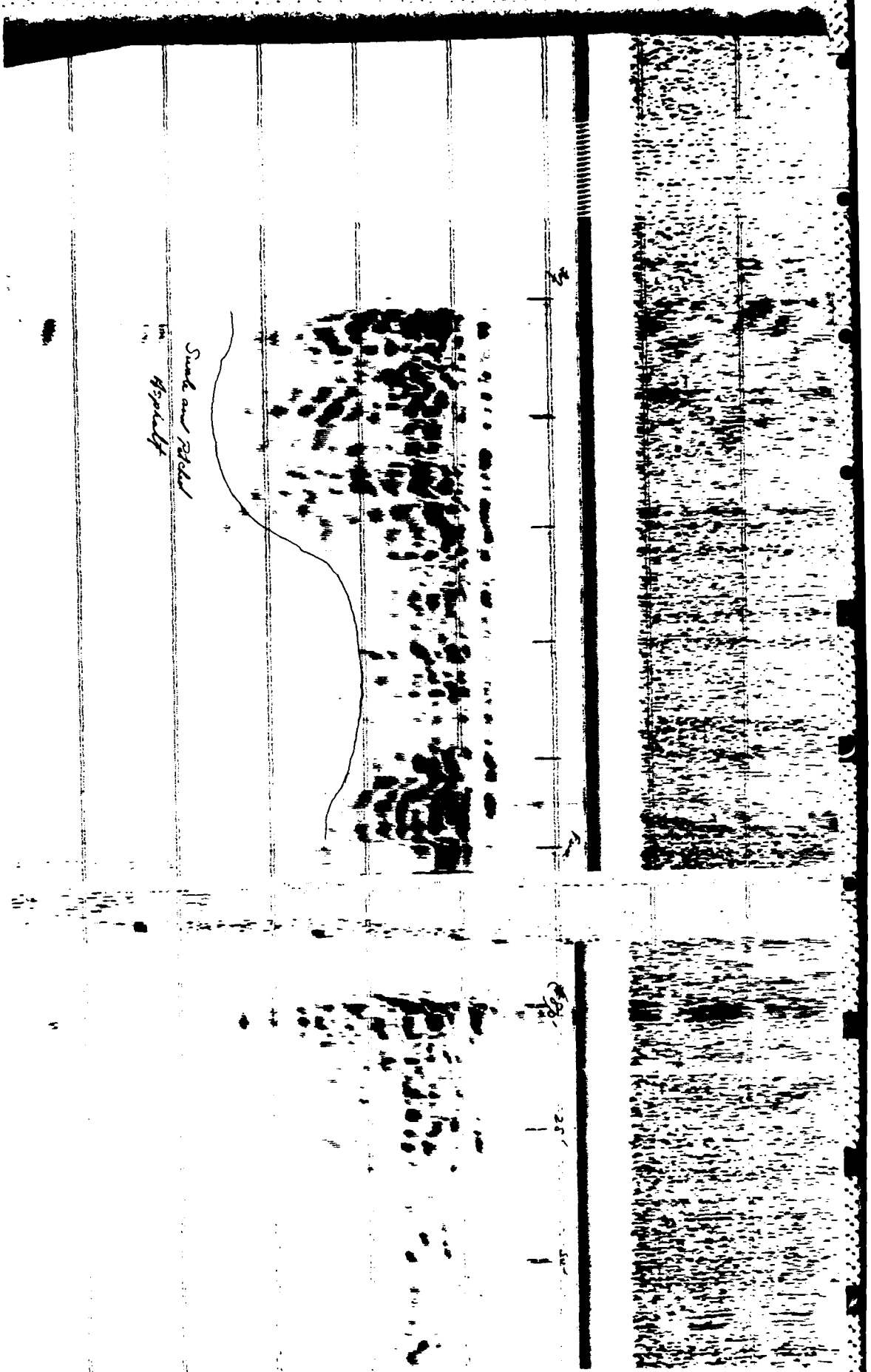
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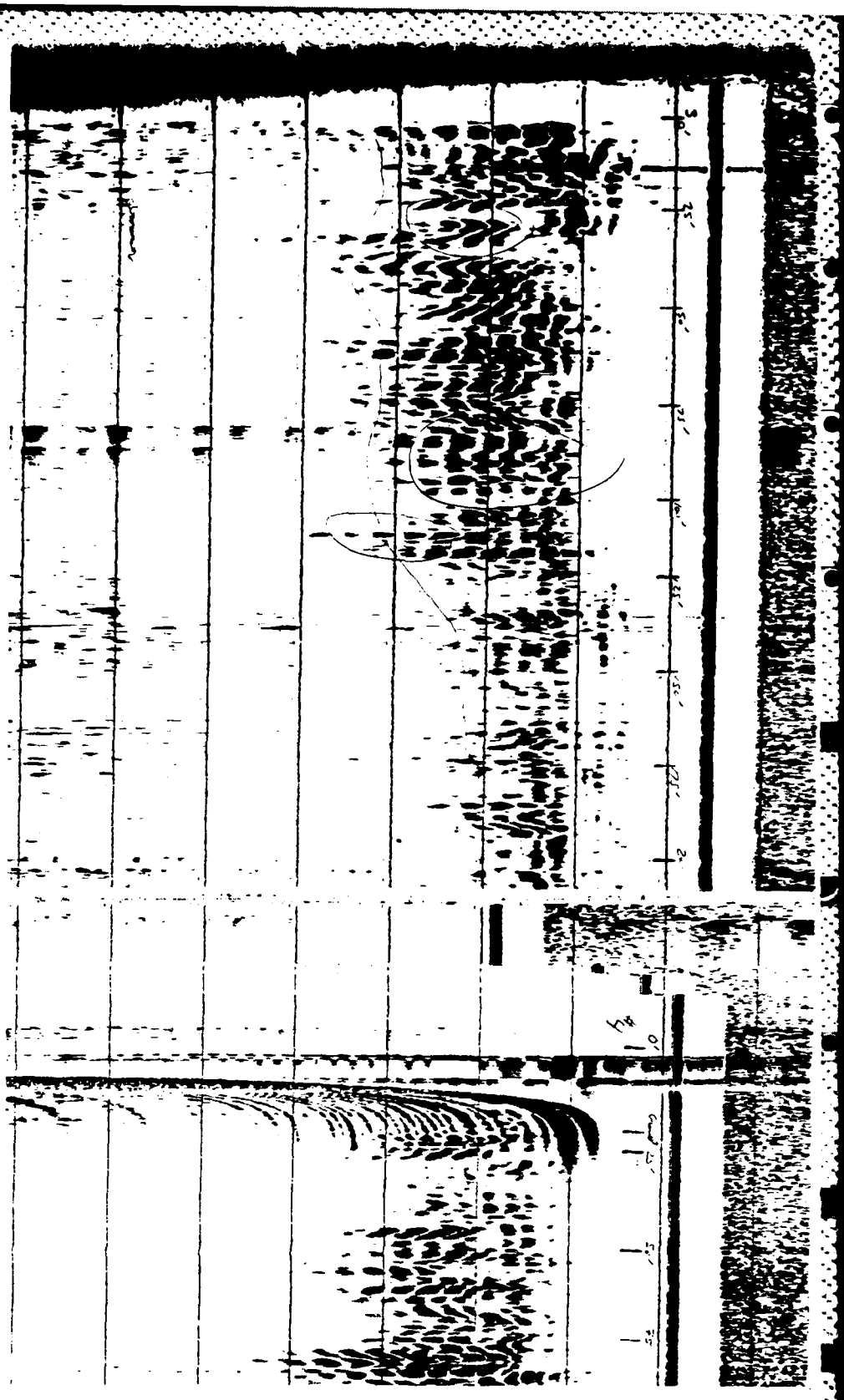
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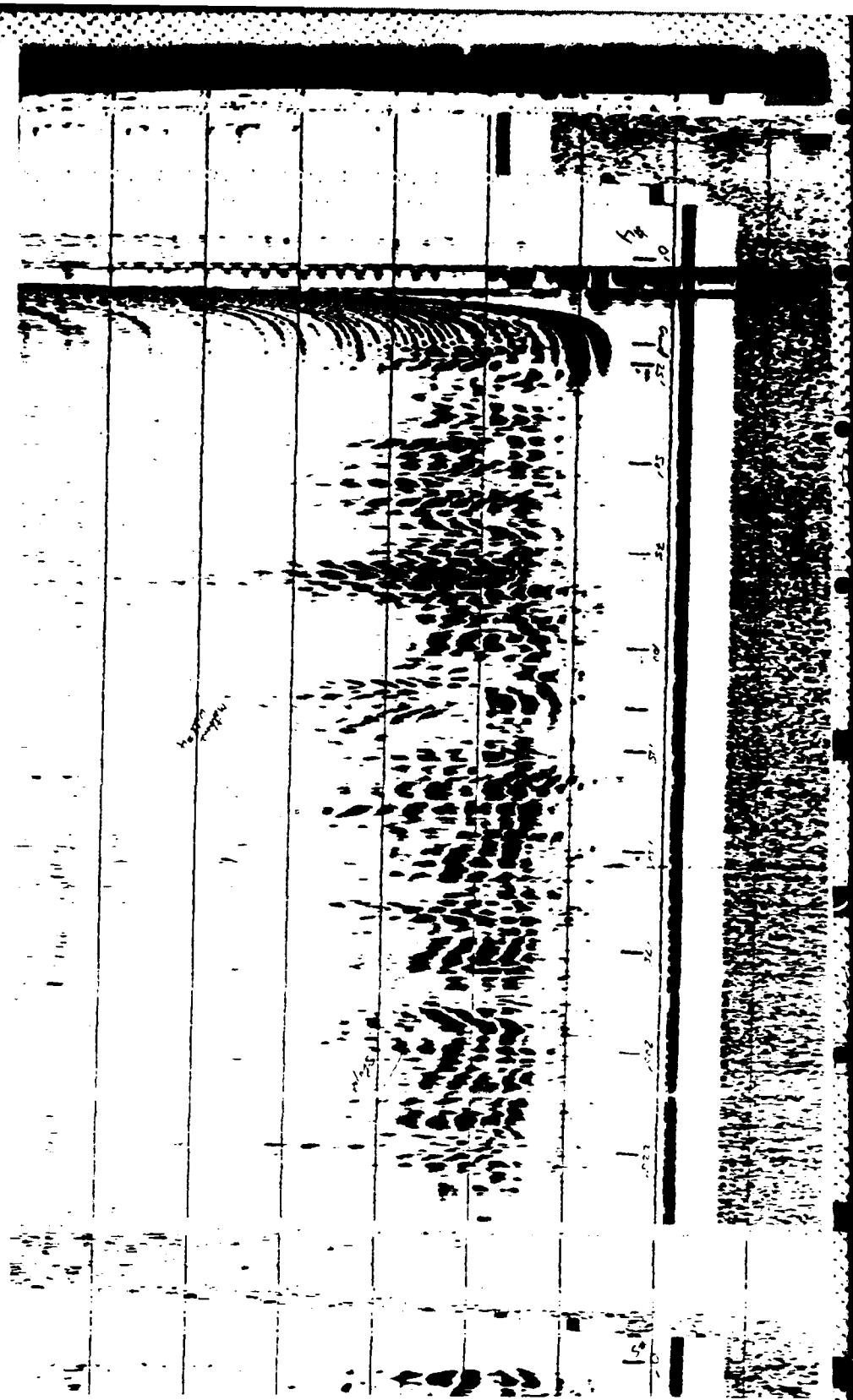
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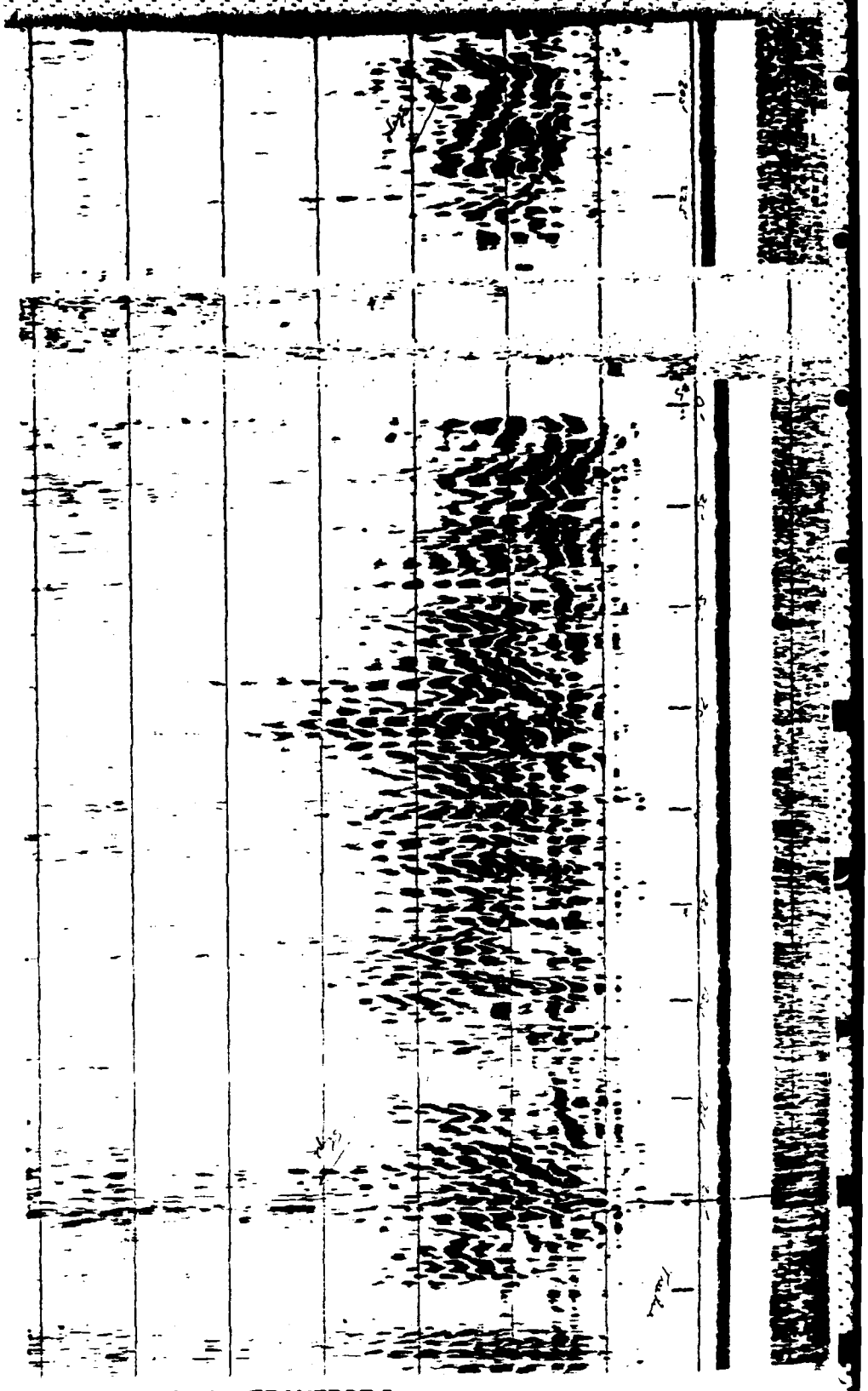
LANDFILL 8 11-2-83 TRAVERSE 7A



LANDFILL 10 11-3-83 TRAVERSE 3



LANDFILL 10 11-3-83 TRAVERSE 4



LANDFILL 10 11-3-83 TRAVERSE 5

APPENDIX E

GEOPHYSICAL SURVEY PROCEDURES

AND

RAW GPR DATA

MF-2-100

Portable Fluxgate Magnetometer

753 010

1/80

1.0 General Information

1.1 The Magnetic Environment

Figure 1 is a map of the total intensity of the earth's magnetic field in kilogammas (kγ). Comparison of the magnitude of these values with those on the Range Switch of the MF-2-100 indicates that the instrument has a world wide range. The contours on Figure 1 are, however, undisturbed background values which might be altered considerably by localized magnetic bodies. This should be considered when selecting the proper Range Switch setting after entering an unknown area.

Superimposed on the map are two dashed horizontal lines marked $\pm 45^{o}$. These are the contours of 45^{o} inclination of the total field. It should be remembered that toward the poles the strongest component of the earth's field is vertical, while between the lines, in equatorial regions, the horizontal component is most important. These facts will be of importance when setting up the instrument as outlined in Section 3.4.

For accurate measurements, the sensor has to be exposed to a "clean" magnetic environment. Objects carried by the operator such as metal parts on clothing, knives, or pencils are frequently magnetic and can severely affect the results.

To establish if an object is magnetic, the sensor is set up in a stationary position and the readings compared first with the object removed and then with the object in the position with respect to the sensor in which it is to be carried. Various orientations of the object should be tried as certain positions may not affect the reading. Small objects such as a screwdriver, file etc. can give anomalies ranging between 5 and 150 gammas when they are placed within 1 m of the sensor. Large objects such as an automobile or an iron fence could give anomalies between 40 and 2000 gammas when within 10m of the sensor.

During magnetic storms the intensity of the field is subject to rapid fluctuations, which are usually immediately apparent even in relatively short measuring periods. If these fluctuations are of sufficiently large amplitude, the measurements may be severely impaired and have to be suspended for the duration of the disturbance.

1.2 The Magnetic Method

The magnetic method of applied geophysics consists of measuring

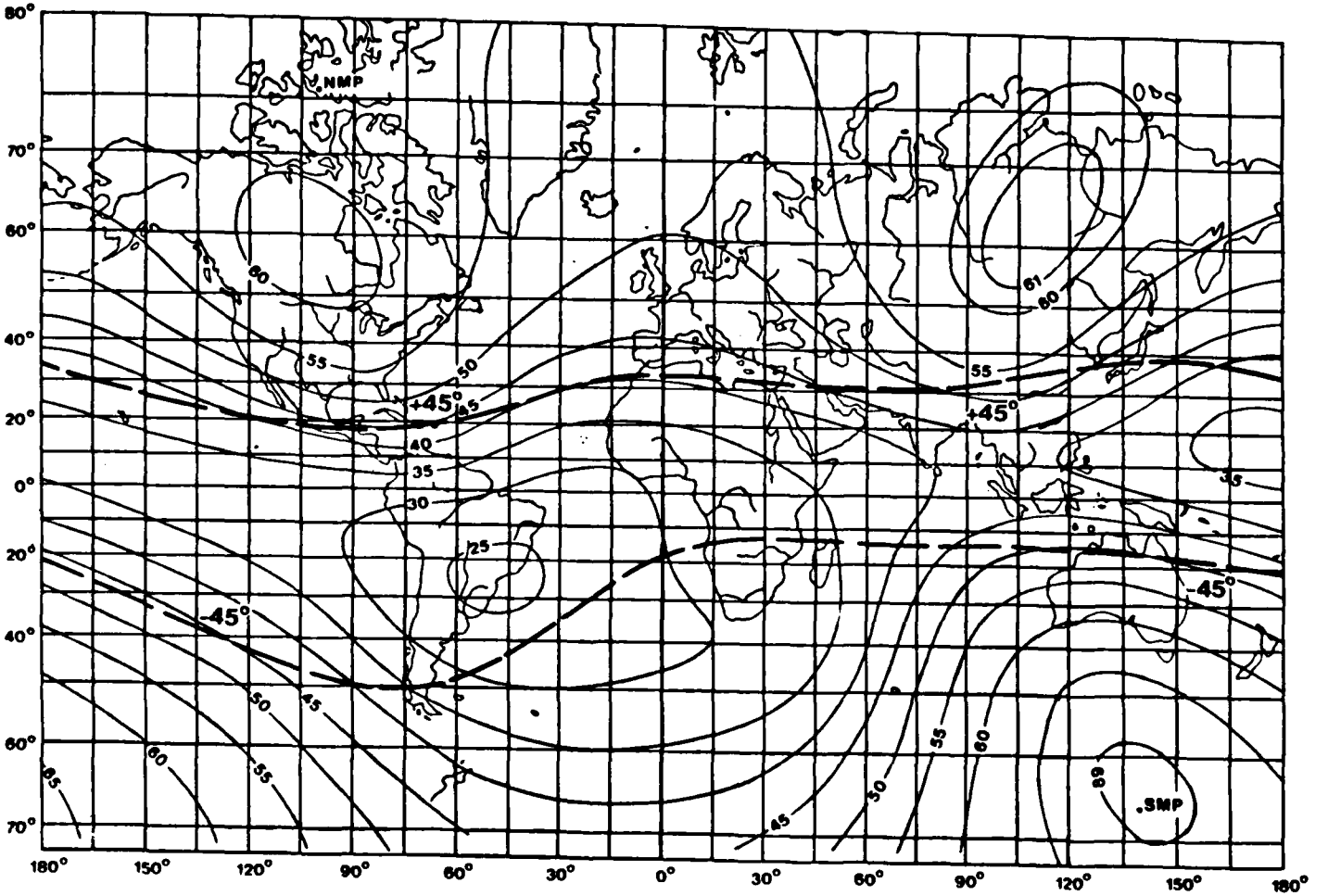


Figure 1
Total magnetic intensity in kilogammas with contours of 45° inclination. In the northern hemisphere, the total field direction is considered to be downwards (positive) and in the southern hemisphere, to be upwards (negative).

accurately the resultant magnetic field of the earth's magnetism acting on rock formations having different magnetic properties and configurations. The resultant field is the vector sum of induced and remanent magnetism. Thus, there are three factors, excluding geometrical factors, which determine the magnetic field at any particular locality. These are: 1) the strength of the earth's magnetic field; 2) the magnetic susceptibilities of the rocks present and; 3) their remanent magnetism.

The earth's magnetic field can be represented to a close approximation as the field due to a bar magnet situated near the center of the earth. Both the polarity and the orientation of this bar magnet are variable. At the present time, the general orientation of this imaginary magnet is NNW.

The flux lines of the geomagnetic field are vertical at the north and south magnetic poles where the strength is approximately 60,000 γ. At the equator, the field is horizontal and its strength is approximately 30,000 γ. The geomagnetic field is variable in both space and time. The spatial variation has magnitude and direction components and these must be taken into account when magnetic measurements are taken over large areas.

The temporal variation is perhaps more troublesome. Significant time variations may occur within periods of seconds, minutes and hours. There are also long term variations extending over months, years and millions of years, but this secular variation can be neglected in magnetic surveys. The magnitude of the short term variations is extremely variable and in the case of sudden magnetic storms may reach several hundred gammas. This means that in magnetically active areas, it may be necessary to take continuous readings of the geomagnetic field with a base station magnetometer, such as an MF-2-100 or MBS-2 equipped with a recorder, while the magnetic survey is being done. An alternative field procedure is to make periodic repeat measurements at convenient traverse points.

The intensity of magnetization induced in rocks by the total geomagnetic field F is given by:

$$I_i = kF$$

where
I_i is the induced magnetization in cgs units
k is the volume magnetic susceptibility
F is the strength of the geomagnetic field

For most materials, k is very much less than 1. If k is negative, the body is said to be diamagnetic. Examples are quartz, marble, graphite and rock salt. If k is positive, but very small, the body is said to be paramagnetic, examples of which are gneiss, pegmatite, dolomite and syenite. If k is positive and the body is strongly magnetic, it is said to be ferromagnetic, for example, magnetite, for which $k \approx 0.3$.

The susceptibility of a rock is mostly determined by its magnetite content since this mineral is so strongly magnetic and so widely distributed. Other magnetic minerals include titanomagnetite, ilmenite and pyrrhotite.

The remanent magnetization of a rock depends both on its composition and previous history. Whereas the induced magnetization is always parallel (rarely anti-parallel) to the direction of the geomagnetic field, the natural remanent magnetization may bear no relation whatsoever to the present direction and intensity of the earth's field. The remanent magnetization is related to the direction of the earth's field at the time the rock was last magnetized. Movement of the body through tectonic activity and the chemical history since the previous magnetization are additional factors which affect the magnitude and direction of the remanent magnetic vector.

Thus, the resultant magnetization M of a rock is given by:

$$M = M_n + kF$$

where M_n is the natural remanent magnetization. F is a vector which can be completely specified by its horizontal (H) and vertical (Z) components and by the declination (D) from true north. Similarly, M_n is specified when its magnitude and direction are known.

Thus, considerable simplification results if $M_n = 0$, whereupon M merely reduces to kF. In the early years of magnetic prospecting, it was usually assumed that there was no remanent magnetization. However, it has now been established that both igneous and sedimentary rocks possess remanent magnetization, and that the phenomena is a widespread one.

1.3 Description of the MF-2-100

The MF-2-100 is a rugged, lightweight and easy to operate magnetometer which is used for magnetic surveys and for base station magnetic field recording.

The standard MF-2-100 measures relative values of the vertical magnetic field intensity (ΔZ). When attached with the external sensor it is capable of measuring the relative values of other components such as the total field (F) or the horizontal magnetic field intensity (ΔH). Thus, it is an extremely versatile instrument which can give all the components necessary to specify the relative value and direction of F. It can also be used to measure the remanent magnetization (M) and the magnetic susceptibility (K) of rock samples.

The instrument is of the fluxgate type. It will give readings of the magnetic field with a precision of 1 γ when used with a tripod, otherwise with a precision of about 5 γ, if hand held. Its accuracy is not impaired even in the presence of steep magnetic gradients. Its measuring range is 200,000 γ, so that it can be used in any region from the north to south pole. A simple adjustment converts the polarity setting from the northern to the southern hemisphere or vice versa. The construction of the instrument allows it to be used under any temperature that the operator can tolerate.

The readings are displayed on an analog meter and can be recorded for base station use by connecting the magnetometer to an analog recorder. The instrument is powered either by a non-rechargeable external battery pack or by rechargeable batteries inserted internally; which brings the total weight to less than 3 kg., making the magnetometer extremely portable.

Standard Items for the MF-2-100
1 Instrument
1 Strap
1 Case
1 External Battery Pack
16 "C" Cell Batteries
1 Non-Magnetic Belt
1 Manual

Optional
3 Rechargeable Batteries
1 Battery Charger
1 Charger Cable
1 Recorder Cable - External Batteries
1 Recorder Cable - Internal Batteries
1 Single Channel Recorder
1 External Sensor

Tripod
1 Carrying Case (for instrument and tripod)
1 Major Spare Parts Kit

1.4 Applications of the MF-2-100

Geological Mapping
Readings taken with the MF-2-100 are normally presented as profiles and as contoured maps. These are now routinely used as integral parts of geological mapping programs. Qualitative interpretation of these maps and profiles assists in the identification of surface rocks, in mapping their distribution, in indicating sub-surface plutons and in revealing structural features. Quantitative interpretation provides depth, dip and strike of magnetic rock types, linear features and estimates of magnetic susceptibility.

For most geophysical surveys only the vertical component of the magnetic field is measured with a fluxgate magnetometer. Special projects, generally for research purposes, measure the horizontal component to gain more detail about geologic structure.

Exploration for Iron and Associated Minerals
Certain types of iron deposits are strongly ferromagnetic. The MF-2-100 is an excellent instrument to use in exploring for such deposits. It can be used in the extremely high magnetic gradients that would be associated with this type of deposit. Under some circumstances, the grade and tonnage of the deposit may be estimated.

In other cases, the strong magnetic field is a guide not to iron, but to associated metals such as nickel, chrome and asbestos.

Iron Objects
Iron objects hidden from view will have an associated magnetic field, the strength of which will depend on the size of the object and the depth of burial. A lightweight, sensitive instrument such as the MF-2-100 can be used to find such objects.

Archaeological Exploration
This is an extension of the use of the MF-2-100 to find iron objects. At some archaeological sites the contrast in magnetic properties between cultural features (iron tools, bricks, pottery, etc) and the surrounding medium is sufficient to produce a magnetic effect that is detectable with a sensitive magnetometer. Such features as buried walls, pathways, entrances, fire-pits, etc. have all been detected and mapped by portable magnetometers.

2.0 Specifications

The MF-2-100 conforms to the following technical specifications:

Meter Ranges
From 100 gammas to 100,000 gammas full scale in seven switch selectable steps, reversible in polarity.

Measuring Range
-100,000 +100,000 gammas relative to a given zero field level.

Latitude Bucking (zero gamma level adjustment)
Range is 100,000 gammas in 9 steps of 10,000 gammas plus fine control of 0 to 10,000 gammas by ten turn potentiometer. Northern Hemisphere -20,000 to +80,000 gammas absolute. Southern Hemisphere -20,000 to +80,000 gammas absolute.

Operating Temperature Range
-40^{o} to $+50^{o}C$.

Resolution
±0.5% of full scale on all meter ranges.

Perming
Less than 1 gamma/oersted.

Meter
Taut band suspension.
100 scale is 53 mm long with 50 divisions.
300 scale is 48 mm long with 60 divisions.

Noise Level
Less than 1 gamma peak to peak from DC to 3 Hz.

Temperature Coefficient
Less than 1 gamma/^{o}C.

Electrical Response
3 db down from DC to 3 Hz on most sensitive range.

Recording Output
Standard: For high impedance recorder (1 megohm).
Optional: For low impedance recorder.

Batteries
Standard: Remote battery pack containing 16 "C" cells and with a 1 meter cable, designed to be carried on a belt.
Optional: Internal rechargeable batteries. Three 6 volt, lamp-

hour Centralab GC 6101 sealed lead acid cells. 8 hour recharge time.

Battery Test
Readable on meter.

Battery Charger
110V to 220V AC, 50/60 Hz or 24 to 28V DC supply. Automatic charge rate and cutoff preset for Centralab GC 6101 batteries.

Power Consumption
60 milliamperes. GC 6101 batteries rated for 16 hours continuous use. 30 hours of operation with Leclanche type C cells.

Tripod
Aluminum. Single shaft with 3 collapsible legs and swivel head which screws easily into base of magnetometer.

Optional Remote Sensor
Sensor assembly is installed in a small tube on an 8 meter cable. Internal sensor is automatically eliminated when remote sensor is connected to console.

Weights & Dimensions
Standard console 1.7 kg; 160 x 70 x 255 mm.
Standard battery pack 1.2 kg; 38 x 140 x 259 mm.
Console with rechargeable batteries 2.5 kg; 160 x 70 x 255 mm.
Battery charger 1.1 kg; 155 x 65 x 65 mm.
Tripod 1.9 kg; approx 1 m high.

Standard Accessories
Battery pack and cable, batteries, carrying case, carrying strap, manual.

Shipping Weight
Approximately 9.5 kg.

APPENDIX F

Sampling and Quality Assurance Plans

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	_____
1000 ml	_____
Total	_____

3. Sampled by: Althouse / Deedy

4. Samples preserved and prepared according to S.O.P.: _____ Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
M. Dyedyg	[illegible]	1000	3584	Analysis

COMMENTS: _____

of 2

ENT Wright Patterson AFB — PRIORITY/HAZARD _____

/PO# 0628-05-22 — SUBMITTED BY Marian Dzedzy

E RECEIVED _____ — MISC: _____

#	SAMPLE DESCRIPTION		DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
26C	MW-26	☆								
1?0	MW-27	Ⓐ	3-1-84							
?1EC	Leachate 1	☒	☒	Cl	SO_4	Sp. cond.	Total B	Total Fe	TOC	TOX	pheno
)29C	Leachate 2	☒								
)2C	Leachate 3	☒								
(:10	Leachate 4	☒								
:2D	Leachate 5	☒								
	Leachate 6	☒								
	Comp. Leachate LF-8			VOA	VOH					
	Comp. Leachate LF-10			VOA	VOH					
~~0351~~	MW-22D	☆	3-1-84							
~~0352~~	MW-6D	☆	3-1-84							
~~0353~~	MW-2D	☆								
~~0354~~	MW-15D	Ⓐ								
~~0357~~	MW-DW	☆	3-1-84	VOA	VOH					
~~0355~~	MW-BW	~~too, nuts~~ ☆	3-1-84							
0340	Lost Blank	ⓐⒹ								

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet: - 40 ml _____
   100 ml _____
   250 ml _____
   500 ml _____
   1000 ml _____
   Total _____

3. Sampled by: Dzedzy / Althouse

4. Samples preserved and prepared according to S.O.P.: _____ Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
M. Dzedzy	[illegible]	1000	3-5-84	Analysis

COMMENTS: _____

CLIENT Wright Patterson AFB

PRIORITY/HAZARD

WO#/PO# 0628-05-22

SUBMITTED BY Marian Dzedzy

DATE RECEIVED

MISC: 8403-909

RFW#	SAMPLE DESCRIPTION		DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1. 0010	MW-1	☆		☆ Cl	SO_4	B / Sol. Fe	Sol. Mn / Na	TOC	TOX	pheno
2. 0020	MW-2	☆								
3. 0030	MW-3	☆								
4. 0040	MW-4	☆								
5. 0050	MW-5	☆								
6. [illegible]	MW-6	☆	3-1-84							
7. [illegible]	MW-7	☆	3-1-84							
8. [illegible]	MW-8	Ⓐ	3-1-84	Ⓐ oil + grease	VOA	VOH				
9. [illegible]	MW-9	Ⓐ	3-1-84							
10. 0100	MW-10	☆	3-1-84							
11. 0110	MW-11	☆	2-29-84							
12. 0120	MW-12	☆	2-29-84							
13. 0130	MW-13	☆	2-29-84							
14. 0140	MW-14	☆	2-29-84							
15. 0150	MW-15	Ⓐ								
16. 0160	MW-16	Ⓐ								
17. 0170	MW-17	☆								
18. 0180	MW-18	☆								
19. 0190	MW-19	☆								
20. 0200	MW-20	☆	3-1-84							
21. 0210	MW-21	☆	3-1-84							
22. 0220	MW-22	☆	3-1-84							
23. 0230	MW-23	☆	3-1-84							
24. 0240	MW-24	Ⓐ ☆	3-1-84							
25. 0250	MW-25	☆								

APPENDIX G

CHAIN OF CUSTODY DOCUMENTATION

F.2.7 CHAIN-OF-CUSTODY

Since they document the history of samples, chain-of-custody procedures are a crucial part of a sampling/analysis program. Chain-of-custody documentation enables identification and tracking of a sample from collection to analysis to reporting.

WESTON's chain-of-custody program necessitates the use of EPA-approved sample labels, secure custody, and attendant recordkeeping. Depending on the client's requirements, WESTON also offers container sealing during unattended transportation of samples.

In essence, WESTON considers a sample in custody if it: is in a WESTON employee's physical possession; it is in view of that WESTON employee; is secured by that WESTON employee to prevent tampering; or is secured by that WESTON employee in an area that is restricted to authorized personnel.

Each time a sample is relinquished from one analyst to another or from one major location to another, WESTON's analytical personnel are required to make appropriate entries. Personnel-specific initials are used as identifiers of analysts, as are location codes for various locations (refrigerators, extraction areas, analytical areas, etc.) within the laboratory. Each transaction for each sample is accompanied by a specific reason for transfer. Chain-of-custody documentation is given in Appendix G.

F.2.8 QA/QC OFFICER

Toward maintenance of a rigid, credible QA/QC regimen, WESTON Analytical Services maintains a full-time, in-house QA/QC officer who retains independent authority to declare out-of-control situations, thereby precluding reporting of unacceptable data. The QA/QC officer has been available, as needed, on the project.

F.2.5 SAMPLE PLAN/LOG

Normal protocol demands client-and /or site-specific logging of all sample batches delivered to WESTON. Basic information -- such as client name, address, etc.; client phone number; reporting/invoicing instructions; site descriptions; and parameter-specifications and total requirements -- is initiated here. Additionally, sample storage/disposal instructions as well as turnaround requirements and sample collection requirements are addressed at this point.

The appropriate number of method blanks is also logged at this point, and in-house chain-of-custody documentation is initiated here.

F.2.6 SAMPLE RESULTS

WESTON's analytical protocols generally require five-point calibration curve plus a reagent blank s the basis for quantification analytes from a linear calibration curve. (A three-point plus blank curve vs. the original five point one is acceptable if it falls within the QA/QC requirements of ± 3 standard deviation of the original curve.) Linear regression analysis is then performed. Method- and detection limit-specific data are accessed for quantitation and report-writing from each such data set. For reporting accuracy, the algorithm

$$\frac{\text{Linear-Regressed Raw Concentration from Calibration Curve} \times \text{Solid Sample Extract Volume If Solid}}{\text{Solid Sample Mass If Solid} \times \text{Fraction Solids If Solid}} \times \text{Concentration or Dilution Factor} = \text{Final Concentration}$$

is used for all quantitations. (All such algorithm input data are archived for long-term storage.) Detection limits for solids are generated on a per-sample basis and calculated by replacing "LINEAR-REGRESSED RAW CONCENTRATION FROM CALIBRATION CURVE" with "DETECTION LIMIT OF ANALYTE IN LIQUID MATRIX" in the above equation.

E.2.4 DATA HANDLING - LABORATORY

Use of any analytical data should be preceded by an assessment of its quality. The assessment should be based on accuracy, precision, completeness, representativeness, and comparability. These criteria are, in turn, assessed as follows:

- o Accuracy - Is it acceptable for the planned use? QA/QC shall measure the accuracy of all data.
- o Precision - Is it acceptable for the planned use? QA/QC shall reflect the reproducibility of the measurements.
- o Completeness - Are the data sufficient for the planned use? QA/QC shall identify the quantity of data needed to match the goals.
- o Representativeness -Do the data accurately reflect actual site conditions, sampling procedures, and analytical method? QA/QC shall ensure this.
- o Comparability - Is the report self-consistent in format, units, and standardization of methods used to generate it? QA/QC shall ensure this.

Additionally, statistical methods outlined in the QA/QC program have been applicable to data evaluation.

The Laboratory Supervisor and the Laboratory QA/QC Officer have been responsible for the evaluation of the above criteria and for enforcement of analytical protocols that will necessarily lead to acceptable data quality. The signature of the Supervisor and QA/QC Officer accompany each laboratory analytical report and serve to ensure the overall validity of the reported data.

F.2.2 CONTAINER PREPARATION

Another consideration in this, or any, analytical project is that of sample container preparation. Accordingly, all appropriate sample bottles shall be cleaned in a manner mandated by the U.S. EPA to insure maximal cleanliness (and minimal contamination) before the containers go to the field. Sufficient bottles to accommodate both laboratory and field blank requirements will be prepared in a single batch mode for each sampling requirement.

F 2.3 VERIFICATION/VALIDATION

In the laboratory, the analytical scheme begins with initial verification, which is comprised of:

- Lab Blanks - To insure that no background level of specific analytes is introduced by laboratory procedures.
- Standard Analytical Reference Materials (SARMS) - To determine the accuracy and precision of procedures.
- Spikes - To determine the percent recovery of analyte(s).

If the laboratory QA/QC program is extended to the field, it includes a fifth item:

- Field Blanks - To provide a check on contamination of containers and/or preservatives and to establish "practical" detection limits.

WESTON has used all of the above in this project. All data resulting from these verification media have been archived for future reference, retrieval, or processing.

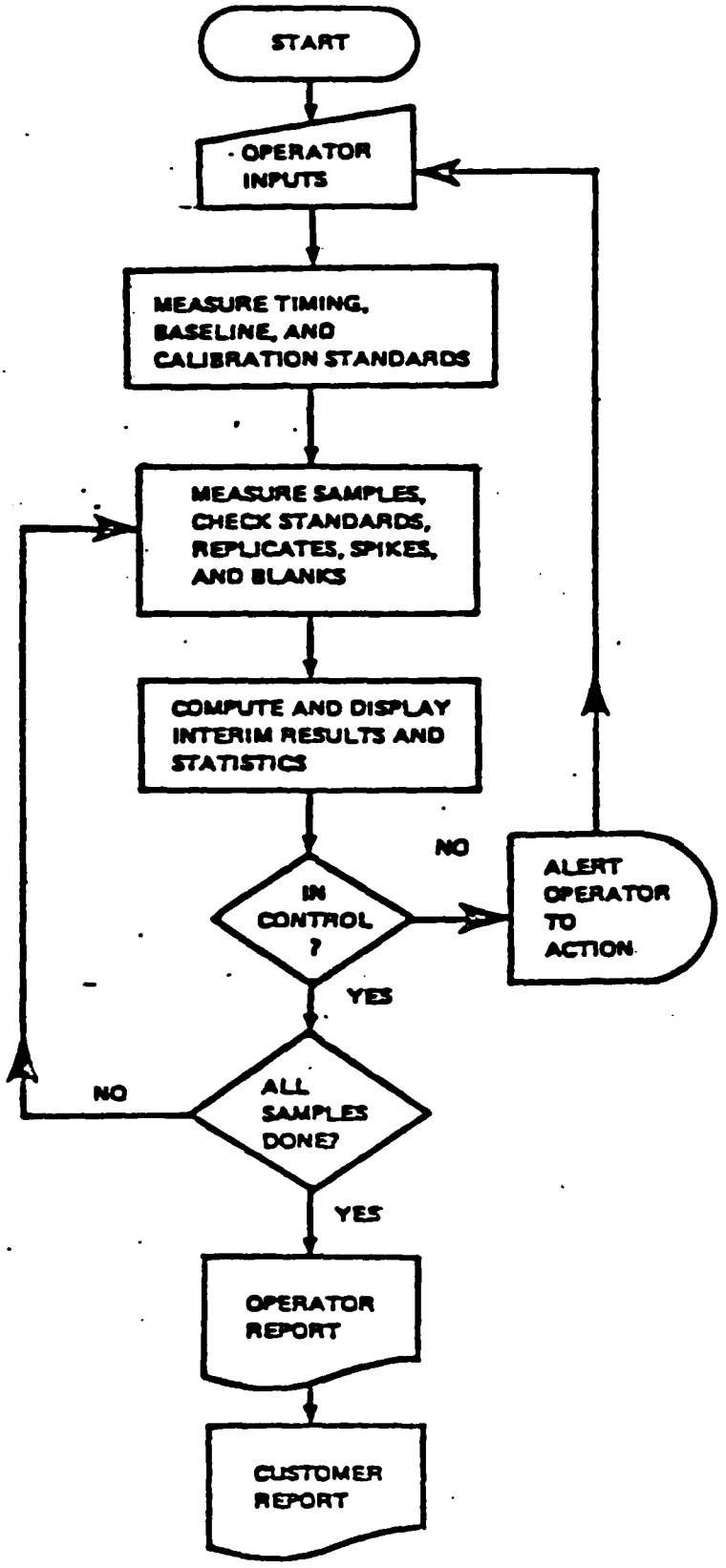


Figure E-1 Flow Chart of the Sequence of Events during a Controlled Series of Laboratory Measurements.

F -2.1 QUALITY ASSURANCE PLAN

WESTON Analytical Services enforces a rigid QA/QC program toward maintenance of validity and reliability of all analytical data. The Laboratory QA/QC Manual (Table of Contents thereof is Attachment No. 1 to this appendix) outlines the specifics of the QA/QC plan. This plan is patterned after the EPA Handbook for Analytical Quality Control in Water and Wastewater Laboratories (EPA-600/4-79-019, March 1979), augmented by general applicable experience and interaction with the QA/QC plan of the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). All methods and procedures followed by WESTOn are either USEPA or ASTM-approved. Any variations from such procedures, regardless of cause, are documented by the responsible analyst(s) and are documentable, and, literature-traceable. A general review of this QA/QC plan is in the following paragraphs.

Although specific QA/QC measures for each method are designated in WESTON's Laboratory Quality Assurance Manual, the general QA/QC program normally includes:

- o EPA-acceptable sample preparation and analytical methods.
- o Instrument calibration via use of Standard Analytical Reference Materials (SARMS).
- o Regular equipment maintenance and servicing.
- o Use of SARMS and QA/QC samples (spikes, laboratory blanks, replicates, and splits) to ascertain overall precision.
- o Statistical evaluation of data to delineate acceptable limits.
- o Documentation of system/operator performance.
- o Suitable chain-of-custody procedures.
- o Maintenance and archiving of all records, charts, and logs generated in the above.
- o Proper reporting.

Acceptable analyses at WESTON's Analytical Laboratory Services include, but are not limited to, the above.

In general, WESTON's QA/QC sequence follows the following diagram (Figure E-1). Documentation (as available from instrument recordings and technicians' notebooks) is sufficient to validate each step in the sequence.

3. Grab samples were taken for immediate analyses in the field for pH, temperature and specific conductance.

4. The sample containers were wrapped in packaging material and placed in a thermal chest packed with enough ice to insure cooling to 4°C.

5. Nitrate samples, due to a 24 hour holding time requirement, were transported in daily batches to Howard Laboratories, a local laboratory, in Dayton, Ohio. The remaining samples were taken to WESTON's laboratory in WestChester, Pennsylvania after sampling was completed.

F-1.3 Leachate Sample Collection

The method used to sample leachate seeps is described in the text (Section 3.2.6.2 Leachate Seep Sampling). Sample handling and preservation procedures were the same as those used for groundwater samples.

The seeps were analyzed for:

1. Specific conductance
2. Chloride
3. Sulfate
4. Boron
5. Iron
6. Total Organic Carbon (TOC)
7. Total Organic Halogen (TOX)
8. Phenol
9. Volatile Organic Compounds (VOA).

3. Sulfate
4. Boron
5. Iron
6. Manganese
7. Sodium
8. Phenol
9. Total Organic Carbon (TOC)
10. Total Organic Halogen (TOX)
11. Oil and Grease
12. Volatile Organics (VOA)

All required sample containers were prepared by WESTON laboratories in accordance with standard EPA procedures and protocols.

After the wells were purged, sampling consisted of the following steps:

1. Sample containers for inorganic parameters (metals, chloride, sulfate, nitrate) were filled from the pump line. Samples for organic parameters were bailed from the well using a teflon bailer to avoid aeration and excessive turbulence in the sample water.

2. Appropriate containers were filled according to analytical parameter. The containers used were:

   - o Nitrate: 1 liter plastic bottles (24 hour holding time)
   - o Metals (Boron, Iron, Manganese, Sodium): sample was first filtered a 0.45 micron filter, then poured into 1 liter plastic bottles preserved with nitric acid.
   - o Chloride and Sulfate: 1 liter plastic bottles
   - o Phenol: 1 liter amber glass bottles preserved with phosphoric acid and copper sulfate.
   - o TOC: 40 ml septum seal glass vials preserved with hydrochloric acid.
   - o TOX: 250 ml septum seal amber glass bottles.
   - o VOA: 40 ml septum seal glass vials
   - o Oil and Grease: 1 liter amber glass bottles preserved with sulfuric acid

   All glass containers have Teflon-lined caps.

WESTON

APPENDIX F

SAMPLING AND QA/QC PLANS

F-1.1 MONITORING WELL PURGING

All groundwater sampling was accomplished after the installed monitoring wells were properly developed and had stabilized for a period of at least two weeks. Prior to collecting samples, each well was purged by pumping a minimum of three volumes of standing water in the well using a Johnson-Keck submersible pump[1]. This ensured that a representative sample of the aquifer is collected during the sampling process. The field procedures used for monitoring well purging included the following guidelines:

1. Prior to placing any equipment into the well, the equipment was scrubbed with Alconox (detergent) solution and rinsed with distilled water.

2. Before purging, the depth to water from the referenced measuring point on the top of the well casing was measured and recorded.

3. The volume of water to be purged based on the amount of standing water in the well casing was calculated.

4. The well was purged by pumping, removing at least three times the calculated volume of standing water in the well casing.

5. The pump was disconnected and removed from the well. The equipment was decontaminated by scrubbing with Alconox and flushing with deionized water.

6. The protective caps were secured.

F-1.2 MONITOR WELL SAMPLE COLLECTION

Groundwater sampling was directed toward the detection of:

1. Nitrates
2. Chloride

---

[1] A 1.5-inch diameter stainless steel, screw-lift type pump. Capable of a steady flow of around one gpm. Teflon or polypropylene discharge hose was used.

John C. Heemer
Data Management Coordinator

ORIGINAL

WESTON
DESIGNERS & CONSULTANTS
WESTON WAY
WEST CHESTER, PA 19380
PHONE (215) 692-3030
TELEX 83-5348

labs

Date: 3/13/84

P.O. NO: 29302

Coordinator
INC.

1 Weston Way
West Chester, PA 19380

PHONE: (215)-692-3030 Ext. 498

Please analyze the following samples RFW No.:

909 - 0320, 0310, 0270, 0240, 0160
0150, 0090, 0080

for the following parameters: VOA (GC/MS)

Bill to Accounts Payable at the above address using the Purchase Order Number at the top of this page.

Please send the results to:

John Heemer

Century Labs
Environmental Testing Lab
1501 Grandview Ave
Mid Atlantic Ave
P.O. Box 248
Thorofare, N.J. 08086

Thank you, John Heemer

609-848-3939

CLIENT: U PAFB

PRIORITY/HAZARD: _____

WO#/PO#: _____

SUBMITTED BY: _____

DATE RECEIVED: _____

MISC.: _____

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1.	909-0320 (2)	2	VOA		40ml				
2.	909-0310 (2)	2							
3.	909-0270 (2)	2							
4.	909-0240 (2)	2							
5.	909-0160 (2)	2							
6.	909-0150 (2)	2							
7.	909-0090 (2)	2							
8.	909-0080 (2)	2	↓						
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									

Roy F. Weston Inc.

CLIENT Wright Patterson Air Force Base

PRIORITY/HAZARD _____

WO#/PO# 0628-05-22 (WO#) / 24136 (PO#)

SUBMITTED BY Marian R Dudney

DATE RECEIVED 2-29-84

MISC: 24 hr holding time

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1.	MW-11	2-29-84	Nitrate						
2.	MW-12	"	"						
3.	MW-13	"	"						
4.	MW-14	"	"						
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	4
1000 ml	_____
Total	_____

3. Sampled by: M. Dredzy

4. Samples preserved and prepared according to S.O.P.: No pres. Cool.
Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
M R Dydzy	J Howard	6:23 PM	2-29-84	entering lab

COMMENTS: _____

Roy F. Weston Inc

CLIENT Wright Patterson AFB

PRIORITY/HAZARD

WO#/PO# WO# 0628-05-22

SUBMITTED BY Marian Dzadzy

DATE RECEIVED 3-1-84

MISC. 24 hr holding time

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1.	MW-6	3-1-84	Nitrate						
2.	MW-6D								
3.	MW-7								
4.	MW-10								
5.	MW-20								
6.	MW-21								
7.	MW-22								
8.	MW-22D								
9.	MW-23								
10.	MW-24								
11.	MW-DW								
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	11
1000 ml	_____
Total	11

3. Sampled by: M. Dzedzy / R. AHhouse

4. Samples preserved and prepared according to S.O.P.: no preservative MRD
(Initials)

Relinquished	Received by	Time	Date	Reason for Change of Custody
M.R. Dzedzy	Joyce Rose	6:42 PM	3-1-84	entering laboratory

COMMENTS: _____

CLIENT Roy F. Weston Inc Wright Patt AFB

PRIORITY/HAZARD

WO#/PO# WO# 0628-05-22

SUBMITTED BY R. Althouse

DATE RECEIVED 3.2.84

MISC: 24 hr. holding time

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1.	MW-1	3.2.84	Nitrate						
2.	MW-2								
3.	MW-2D								
4.	MW-3								
5.	MW-4								
6.	MW-5								
7.	MW-25								
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	_____
1000 ml	_____
Total	_____

3. Sampled by: _____

4. Samples preserved and prepared according to S.O.P.: No Preservative
Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
[signature]	J. Howard	5:50 P	3-2-84	entering lab

COMMENTS: _____

CLIENT Roy F. Weston Inc (Wright Patterson AFB)

PRIORITY/HAZARD

WO#/PO# 0629-05-22

SUBMITTED BY Ron Abbruzzo

DATE RECEIVED 3/3/64

MISC.

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1.	MW-17	3/3/64	NITRATE						
2.	MW-18								
3.	MW-19								
4.	MW-26								
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	____
100 ml	____
250 ml	____
500 ml	4
1000 ml	____
Total	____

3. Sampled by: _____

4. Samples preserved and prepared according to S.O.P.: _____
Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
	Patti Miller	3:30P	3/3/84	Standard Delivery

COMMENTS: _____

LIENT Wright Patterson Air Force Base — PRIORITY/HAZARD leachate seeps unknown content bad smell

O#/PO# 0628-05-22 — SUBMITTED BY Marian Dzedzy

(002)

ATE RECEIVED 5-7-84 — MISC. 8905-178

FW#	SAMPLE DESCRIPTION		DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
0010	Leachate 1		5-3-84	Bo	Fe	total				
0020	2									
0030	3									
0040	4									
0050	5	*				(priority)				*
0060	6									
0070	BE-W									
0080	Leachate 1			Sulfate		PSULFT				
0090	2									
0100	3									
0110	4									
0120	5	*								
0130	6									
0140	BE-W									
0150	Leachate 1			Cl		PCHLOR				
0160	2									
0170	3									
0180	4									
0190	5	*								
0200	6									
0210	BE-W									
0220	Leachate 1			SPCD		PSPCD				
0230	2									
0240	3									
0250	4									

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	_____
1000 ml	_____
Total	_____

3. Sampled by: Marian Dredzy | Richard Johnson

4. Samples preserved and prepared according to S.O.P.: MRD (Initials)

Relinquished	Received by	Time	Date	Reason for Change of Custody
MR Dredzy	JC Heeman	12:06 P	5-7-84	entering lab

COMMENTS: _____

IENT Wright Patterson AFB PRIORITY/HAZARD leachate seeps unknown Conc.

#/PO# 0628-05-22 SUBMITTED BY Marian Dzedzy

TE RECEIVED 5-7-89 MISC.

WH	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
0260	Leachate 5 *		SPCD						
0270	6								
0280	BE-W								
0290	Leachate 1		TOX		PT.O.K				
0300	2								
0310	3								
0320	4								
0330	5 *								
0340	6								
0350	BE-W								
0360	Leachate 1		phenol		PPhenl				
0370	2								
0380	3								
0390	4								
0400	5 *								
0410	6								
0420	BE-W								

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	_____
1000 ml	_____
Total	_____

3. Sampled by: _____

4. Samples preserved and prepared according to S.O.P.: _____
Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
M R. Dadey	[signature]	12:06 P.	5-7-84	entry lab

COMMENTS: _____

6. Reagents

6.1 Hydrochloric acid, 1:1. Mix equal volumes of conc. HCl and distilled water.

6.2 Fluorocarbon-113, (1,1,2-trichloro-1,2,2-trifluoroethane), b. p. 48°C.

6.3 Sodium sulfate, anhydrous crystal.

6.4 Calibration mixtures:

6.4.1 Reference oil: Pipet 15.0 ml n-hexadecane, 15.0 ml isooctane, and 10.0 ml chlorobenzene into a 50 ml glass stoppered bottle. Maintain the integrity of the mixture by keeping stoppered except when withdrawing aliquots.

6.4.2 Stock standard: Pipet 1.0 ml reference oil (6.4.1) into a tared 200 ml volumetric flask and immediately stopper. Weigh and dilute to volume with fluorocarbon-113.

6.4.3 Working standards: Pipet appropriate volumes of stock standard (6.4.2) into 100 ml volumetric flasks according to the cell pathlength to be used. Dilute to volume with fluorocarbon-113. Calculate concentration of standards from the stock standard.

7. Procedure

7.1 Mark the sample bottle at the water meniscus for later determination of sample volume. If the sample was not acidified at time of collection, add 5 ml hydrochloric acid (6.1) to the sample bottle. After mixing the sample, check the pH by touching pH-sensitive paper to the cap to insure that the pH is 2 or lower. Add more acid if necessary.

7.2 Pour the sample into a separatory funnel.

7.3 Add 30 ml fluorocarbon-113 (6.2) to the sample bottle and rotate the bottle to rinse the sides. Transfer the solvent into the separatory funnel. Extract by shaking vigorously for 2 minutes. Allow the layers to separate.

7.4 Filter the solvent layer into a 100 ml volumetric flask through a funnel containing solvent-moistened filter paper.

NOTE: An emulsion that fails to dissipate can be broken by pouring about 1 g sodium sulfate (6.3) into the filter paper cone and slowly draining the emulsion through the salt. Additional 1 g portions can be added to the cone as required.

7.5 Repeat (7.3 and 7.4) twice more with 30 ml portions of fresh solvent, combining all solvent in the volumetric flask.

7.6 Rinse the tip of the separatory funnel, filter paper, and the funnel with a total of 5–10 ml fluorocarbon-113 and collect the rinsings in the flask. Dilute the extract to 100 ml, and stopper the flask.

7.7 Select appropriate working standards and cell pathlength according to the following table of approximate working ranges:

Pathlength	Range
10 mm	2–40 mg
50 mm	0.4–8 mg
100 mm	0.1–4 mg

7.8 Scan standards and samples from 3200 cm^{-1} to 2700 cm^{-1} with fluorocarbon-113 in the reference beam and record the results on absorbance paper. The absorbances of samples

OIL AND GREASE, TOTAL RECOVERABLE

Method 413.2 (Spectrophotometric, Infrared)

STORET NO. 00560

1. Scope and Application
   1.1 This method includes the measurement of fluorocarbon-113 extractable matter from surface and saline waters, industrial and domestic wastes. It is applicable to the determination of hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and related matter.
   1.2 The method is applicable to measurement of most light petroleum fuels, although loss of about half of any gasoline present during the extraction manipulations can be expected.
   1.3 The method covers the range from 0.2 to 1000 mg/l of extractable material.
   1.4 While this method can be used to obtain an estimate of the oil and grease that would be measured gravimetrically, in many cases the estimate more accurately describes the parameter, as it will measure volatiles more effectively and is not susceptible to interferences such as extractable sulfur. It can be used with the Petroleum Hydrocarbon procedure to obtain an oil and grease value and a petroleum hydrocarbon value on the same sample.
2. Summary of Method
   2.1 The sample is acidified to a low pH (< 2) and extracted with fluorocarbon-113. The oil and grease is determined by comparison of the infrared absorbance of the sample extract with standards.
3. Definitions
   3.1 The definition of oil and grease is based on the procedure used. The source of the oil and/or grease, and the presence of extractable non-oily matter will influence the material measured and interpretation of results.
4. Sampling and Storage
   4.1 A representative sample of 1 liter volume should be collected in a glass bottle. If analyss is to be delayed for more than a few hours, the sample is preserved by the addition of 5 ml HCl (6.1) at the time of collection and refrigerated at 4°C.
   4.2 Because losses of grease will occur on sampling equipment, the collection of a composite sample is impractical. Individual portions collected at prescribed time intervals must be analyzed separately to obtain the average concentration over an extended period.
5. Apparatus
   5.1 Separatory funnel, 2000 ml, with Teflon stopcock.
   5.2 Infrared spectrophotometer, scanning. Non-scanning instruments may also be used but can be subject to positive interferences in complex chemical wastewaters.
   5.3 Cells, 10 mm, 50 mm, and 100 mm path length, sodium chloride or infrared grade glass.
   5.4 Filter paper, Whatman No. 40, 11 cm.

Issued 1974
Editorial revision 1978

7.5 Carbonate-bicarbonate, standard solution: Prepare a series of standards similar to step 7.3.

NOTE 3: This standard is not required by some instruments.

7.6 Blank solution: Use the same distilled water (or similar quality water) used for the preparation of the standard solutions.

8. Procedure

8.1 Follow instrument manufacturer's instructions for calibration, procedure, and calculations.

8.2 For calibration of the instrument, it is recommended that a series of standards encompassing the expected concentration range of the samples be used.

9. Precision and Accuracy

9.1 Twenty-eight analysts in twenty-one laboratories analyzed distilled water solutions containing exact increments of oxidizable organic compounds, with the following results:

Increment as TOC mg/liter	Precision as Standard Deviation TOC, mg/liter	Accuracy as Bias, %	Accuracy as Bias, mg/liter
4.9	3.93	+15.27	+0.75
107	8.32	+ 1.01	+1.08

(FWPCA Method Study 3, Demand Analyses)

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D 2574–79, p 469 (1976).
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 532, Method 505, (1975).

4. Sample Handling and Preservation

4.1 Sampling and storage of samples in glass bottles is preferable. Sampling and storage in plastic bottles such as conventional polyethylene and cubitainers is permissible if it is established that the containers do not contribute contaminating organics to the samples. **NOTE 1:** A brief study performed in the EPA Laboratory indicated that distilled water stored in new, one quart cubitainers did not show any increase in organic carbon after two weeks exposure.

4.2 Because of the possibility of oxidation or bacterial decomposition of some components of aqueous samples, the lapse of time between collection of samples and start of analysis should be kept to a minimum. Also, samples should be kept cool (4°C) and protected from sunlight and atmospheric oxygen.

4.3 In instances where analysis cannot be performed within two hours (2 hours) from time of sampling, the sample is acidified ($pH \leq 2$) with HCl or H_2SO_4.

5. Interferences

5.1 Carbonate and bicarbonate carbon represent an interference under the terms of this test and must be removed or accounted for in the final calculation.

5.2 This procedure is applicable only to homogeneous samples which can be injected into the apparatus reproducibly by means of a microliter type syringe or pipette. The openings of the syringe or pipette limit the maximum size of particles which may be included in the sample.

6. Apparatus

6.1 Apparatus for blending or homogenizing samples: Generally, a Waring-type blender is satisfactory.

6.2 Apparatus for total and dissolved organic carbon:

6.2.1 A number of companies manufacture systems for measuring carbonaceous material in liquid samples. Considerations should be made as to the types of samples to be analyzed, the expected concentration range, and forms of carbon to be measured.

6.2.2 No specific analyzer is recommended as superior.

7. Reagents

7.1 Distilled water used in preparation of standards and for dilution of samples should be ultra pure to reduce the carbon concentration of the blank. Carbon dioxide-free, double distilled water is recommended. Ion exchanged waters are not recommended because of the possibilities of contamination with organic materials from the resins.

7.2 Potassium hydrogen phthalate, stock solution, 1000 mg carbon/liter: Dissolve 0.2128 g of potassium hydrogen phthalate (Primary Standard Grade) in distilled water and dilute to 100.0 ml.

NOTE 2: Sodium oxalate and acetic acid are not recommended as stock solutions.

7.3 Potassium hydrogen phthalate, standard solutions: Prepare standard solutions from the stock solution by dilution with distilled water.

7.4 Carbonate-bicarbonate, stock solution, 1000 mg carbon/liter: Weigh 0.3500 g of sodium bicarbonate and 0.4418 g of sodium carbonate and transfer both to the same 100 ml volumetric flask. Dissolve with distilled water.

ORGANIC CARBON, TOTAL

Method 415.1 (Combustion or Oxidation)

STORET NO. Total 00680
Dissolved 00681

1. Scope and Application
   1.1 This method includes the measurement of organic carbon in drinking, surface and saline waters, domestic and industrial wastes. Exclusions are noted under Definitions and Interferences.
   1.2 The method is most applicable to measurement of organic carbon above 1 mg/l.
2. Summary of Method
   2.1 Organic carbon in a sample is converted to carbon dioxide (CO_2) by catalytic combustion or wet chemical oxidation. The CO_2 formed can be measured directly by an infrared detector or converted to methane (CH_4) and measured by a flame ionization detector. The amount of CO_2 or CH_4 is directly proportional to the concentration of carbonaceous material in the sample.
3. Definitions
   3.1 The carbonaceous analyzer measures all of the carbon in a sample. Because of various properties of carbon-containing compounds in liquid samples, preliminary treatment of the sample prior to analysis dictates the definition of the carbon as it is measured. Forms of carbon that are measured by the method are:
      A) soluble, nonvolatile organic carbon; for instance, natural sugars.
      B) soluble, volatile organic carbon; for instance, mercaptans.
      C) insoluble, partially volatile carbon; for instance, oils.
      D) insoluble, particulate carbonaceous materials, for instance; cellulose fibers.
      E) soluble or insoluble carbonaceous materials adsorbed or entrapped on insoluble inorganic suspended matter; for instance, oily matter adsorbed on silt particles.
   3.2 The final usefulness of the carbon measurement is in assessing the potential oxygen-demanding load of organic material on a receiving stream. This statement applies whether the carbon measurement is made on a sewage plant effluent, industrial waste, or on water taken directly from the stream. In this light, carbonate and bicarbonate carbon are not a part of the oxygen demand in the stream and therefore should be discounted in the final calculation or removed prior to analysis. The manner of preliminary treatment of the sample and instrument settings defines the types of carbon which are measured. Instrument manufacturer's instructions should be followed.

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Issued 1971
Editorial revision 1974

APPENDIX H

STANDARD LABORATORY ANALYTICAL PROTOCOLS

WESTON
CONSULTANTS
WESTON WAY
WEST CHESTER, PA. 19380
PHONE: (215) 692-3030
TELEX: 83-5348

CHAIN OF CUSTODY RECORD

PROJ NO. | PROJECT NAME: WPAFB

SAMPLERS: *(Signature)*

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	Mary Brune	REMARKS
					349-0060	3.0		
					0180	41.0		
					0280	45.0		
					0320	35.0		
					Blank	1.0		

G-26

Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*
Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*
Relinquished by: *(Signature)*	Date / Time	Received for Laboratory by: *(Signature)*	Date / Time	Remarks	

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	_____
1000 ml	_____
Total	_____

3. Sampled by: _____

4. Samples preserved and prepared according to S.O.P.: _____ Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody

COMMENTS: _____

CLIENT: WRIGHT PATTERSON AFB

PRIORITY/HAZARD: _____

WO#/PO#: 0628-05-22-02

SUBMITTED BY: [signature]

DATE RECEIVED: _____

MISC.: _____

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1. 0260	WELL 16	6/15/84	TOC	X					
2. 0270	WELL 23	6/15/84	TOC						
3. 0290	WELL 26	6/15/84	TOC	X					
4. 0280	WELL 4	6/15/84	TOC						
5. 0300	BASE WELL B-4	6/14/84	TOC	X					
6. 0310	BASE WELL B-5	6/14/84	TOC	X					
7. 0320	BASE WELL A-E	6/14/84	TOC	X					
8. 0330	BASE WELL A-C	6/14/84	TOC	X					
9. 0340	BASE WELL C-2-171	6/14/84	TOC	X					
10. 0350	BASE WELL C-3-203	6/14/84	TOC	X					
11. 0360	Blank								
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									

CHAIN OF CUSTODY

1. RFW # _____

2. No. of bottles on this sheet:

40 ml	_____
100 ml	_____
250 ml	_____
500 ml	_____
1000 ml	_____
Total	_____

3. Sampled by: JRG

4. Samples preserved and prepared according to S.O.P.: JRG
Initials

Relinquished	Received by	Time	Date	Reason for Change of Custody
Ron Watkins	Victoria Parker	0800	6/19/84	Analysis

COMMENTS: _____

CLIENT WRIGHT PATTERSON AFB

PRIORITY/HAZARD

WO#/PO# 0628-05-22-02 DQ3

SUBMITTED BY

DATE RECEIVED

MISC. 2406.379

(X) TWO BLANK GLASS BOTTLES OF SAMPLE

RFW#	SAMPLE DESCRIPTION	DATE COLLECTED	PA	PA	PA	PA	PA	PA	PA
1. 0010	WELL # 1	6/12/84	TOC						
2. 0020	WELL # 3	6/12/84	TOC						
3. 0030	WELL # 2	6/12/84	TOC	X					
4. 0040	WELL # S-	6/12/84	TOC						
5. 0050	WELL # 17	6/13/84	TOC						
6. 0060	WELL # 18	6/13/84	TOC	X					
7. 0070	WELL # 19	6/13/84	TOC						
8. 0080	WELL # 24	6/13/84	TOC						
9. 0090	WELL # 24-A	6/13/84	TOC						
10. 0100	WELL # 20	6/13/84	TOC	X					
11. 0110	WELL # 22	6/13/84	TOC						
12. 0120	WELL # 21	6/13/84	TOC	X					
13. 0130	WELL # 12	6/13/84	TOC	X					
14. 0140	WELL # 13	6/13/84	TOC	X					
15. 0150	WELL # 13-B	6/13/84	TOC						
16. 0160	WELL # 11	6/13/84	TOC	X					
17. 0170	WELL # 9	6/13/84	TOC	X					
18. 0180	WELL # 8	6/14/84	TOC	X					
19. 0190	WELL # 7	6/14/84	TOC						
20. 0200	WELL # 6	6/14/84	TOC						
21. 0210	WELL # 10	6/14/84	TOC						
22. 0220	WELL # 25	6/14/84	TOC	X					
23. 0230	WELL # 14	6/15/84	TOC	X					
24. 0240	WELL # 27	6/15/84	TOC	X					
25. 0250	WELL # 15	6/15/84	TOC	X					

WESTON
THE ENGINEERS CONSULTANTS

WESTON WAY
WEST CHESTER, PA. 19380
PHONE: (215) 692-3030
TELEX: 83-5348

CHAIN OF CUSTODY RECORD

PROJ NO.: 0628
PROJECT NAME: WPAFB
SAMPLERS: (Signature)

A NO	DATE	TIME	COMP.	GRAB	[redacted]	NO. OF CONTAINERS								REMARKS
					8905-178-0290	1								Analyze for TOX
					0300	1								EPA method 9020
					0310	1								
					0320	1								
					0330	1								
					0340	1								
					0350	1								

G-21

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
John C. Heeme	5-8-89 1437				
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks	

WESTON

TO: Century Labs. Date: 5/8/84

FROM: John Heemer
Data Managment Coordinator
ROY F. WESTON, INC.
1 Weston Way
West Chester, PA 19380

P.O. NO: 24849

PHONE: (215)-692-3030 Ext. 498

Please analyze the following samples RFW No.:

8405-178-0290, 0300, 0310, 0320
0330, 0390, 0350

for the following parameters: TOX method
EPA 9020

Bill to Accounts Payable at the above address using the Purchase Order Number at the top of this page.

Please send the results to:

Above address

Thank you,

John C Heemer

WESTON
DESIGNERS CONSULTANTS

MATERIALS AND EQUIPMENT REQUISITION

TO: Purchasing

PURCHASE ORDER ASSIGNED: 29899

FROM: Heemer

DATE: 5-8-89

Request that we obtain: ____Purchase ____Repair ____Rent ____Price Quotation X 01

FROM: (Vendor name if preference)
Century Labs

New Jersey

SHIP TO: _____

SHIP VIA: _____

FOB _____ TERMS _____

DELIVERY REQUIRED BY: _____

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	TOTA
1	7	TOY analysis	35.00	245
				245

Is this purchase within your budget? Yes(x) No ( ) TOTAL COST

Charge above item to: Work Order No. 1541 Division/Dept. No. _____

Project Director/Manager or
Responsible Head Approval _____ V.P. QA/Finance _____

Purchasing Approval _____

RFW-152-10-82 COMPLETE REVERSE SIDE FOR ALL CAPITAL EQUIPMENT REQUISITIONS G-1

and standards are measured by constructing a straight baseline over the range of the scan and measuring the absorbance of the peak maximum at 2930 cm^{-1} and subtracting the baseline absorbance at that point. For an example of a typical oil spectrum and baseline construction, see Gruenfeld[3]. Non-scanning instruments should be operated according to manufacturer's instructions, although calibration must be performed using the standards described above (6.4). If the absorbance exceeds 0.8 for a sample, select a shorter pathlength or dilute as required.

7.9 Use a calibration plot of absorbance vs. mg oil prepared from the standards to determine the mg oil in the sample solution.

8. Calculation

8.1 $$\text{mg/l total oil and grease} = \frac{R \times D}{V}$$

where:

R = oil in solution, determined from calibration plot, in milligrams.
D = extract dilution factor, if used.
V = volume of sample, determined by refilling sample bottle to calibration line and correcting for acid addition if necessary, in liters.

9. Precision and Accuracy

9.1 The two oil and grease methods in this manual were tested by a single laboratory (EMSL) on sewage. This method determined the oil and grease level in the sewage to be 17.5 mg/l. When 1 liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 99% with a standard deviation of ±1.4 mg/l.

Bibliography

1. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 556, Method 502B, (1975).
2. American Petroleum Institute, "Manual on Disposal of Refinery Wastes", Vol. IV, Method 733-58 (1958).
3. Gruenfeld, M., "Extraction of Dispersed Oils from Water for Quantitative Analysis by Infrared Spectroscopy", Environ. Sci. Technol. 7, 636 (1973).

PHENOLICS, TOTAL RECOVERABLE

Method 420.1 (Spectrophotometric, Manual 4-AAP with Distillation)

STORET NO. 32730

1. Scope and Application
   1.1 This method is applicable to the analysis of drinking, surface and saline waters, domesti and industrial wastes.
   1.2 The method is capable of measuring phenolic materials at the 5 ug/1 level when th colored end product is extracted and concentrated in a solvent phase using phenol as a standard.
   1.3 The method is capable of measuring phenolic materials that contain more than 50 ug/ in the aqueous phase (without solvent extraction) using phenol as a standard.
   1.4 It is not possible to use this method to differentiate between different kinds of phenols.
2. Summary of Method
   2.1 Phenolic materials react with 4-aminoantipyrine in the presence of potassiun ferricyanide at a pH of 10 to form a stable reddish-brown colored antipyrine dye. Th amount of color produced is a function of the concentration of phenolic material.
3. Comments
   3.1 For most samples a preliminary distillation is required to remove interfering materials.
   3.2 Color response of phenolic materials with 4-amino antipyrine is not the same for al compounds. Because phenolic type wastes usually contain a variety of phenols, it is no possible to duplicate a mixture of phenols to be used as a standard. For this reason pheno has been selected as a standard and any color produced by the reaction of other phenolic compounds is reported as phenol. This value will represent the minimum concentratio of phenolic compounds present in the sample.
4. Sample Handling and Preservation
   4.1 Biological degradation is inhibited by the addition of 1 g/1 of copper sulfate to th sample and acidification to a pH of less than 4 with phosphoric acid. The sample shoul be kept at 4°C and analyzed within 24 hours after collection.
5. Interference
   5.1 Interferences from sulfur compounds are eliminated by acidifying the sample to a pH o less than 4 with H_3PO_4 and aerating briefly by stirring and adding $CuSO_4$.
   5.2 Oxidizing agents such as chlorine, detected by the liberation of iodine upon acidification in the presence of potassium iodide, are removed immediately after sampling by th addition of an excess of ferrous ammonium sulfate (~~6.5~~ 7.5). If chlorine is not removed, th phenolic compounds may be partially oxidized and the results may be low.

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6. Apparatus
   - 6.1 Distillation apparatus, all glass consisting of a 1 liter pyrex distilling apparatus with Graham condenser.
   - 6.2 pH meter.
   - 6.3 Spectrophotometer, for use at 460 or 510 nm.
   - 6.4 Funnels.
   - 6.5 Filter paper.
   - 6.6 Membrane filters.
   - 6.7 Separatory funnels, 500 or 1,000 ml.
   - 6.8 Nessler tubes, short or long form.
7. Reagents
   - 7.1 Phosphoric acid solution, 1 + 9: Dilute 10 ml of 85% H_3PO_4 to 100 ml with distilled water.
   - 7.2 Copper sulfate solution: Dissolve 100 g $CuSO_4 \cdot 5H_2O$ in distilled water and dilute to 1 liter.
   - 7.3 Buffer solution: Dissolve 16.9 g NH_4Cl in 143 ml conc. NH_4OH and dilute to 250 ml with distilled water. Two ml should adjust 100 ml of distillate to pH 10.
   - 7.4 Aminoantipyrine solution: Dissolve 2 g of 4AAP in distilled water and dilute to 100 ml.
   - 7.5 Potassium ferricyanide solution: Dissolve 8 g of $K_3Fe(CN)_6$ in distilled water and dilute to 100 ml.
   - 7.6 Stock phenol solution: Dissolve ~~1.0 g~~ 1.00g phenol in freshly boiled and cooled distilled water and dilute to 1 liter. 1 ml = 1 mg phenol.
   - 7.7 Working solution A: Dilute 10 ml stock phenol solution to 1 liter with distilled water. 1 ml = 10 *u*g phenol.
   - 7.8 Working solution B: Dilute 100 ml of working solution A to 1000 ml with distilled water. 1 ml = 1 *u*g phenol.
   - 7.9 Chloroform
8. Procedure
   - 8.1 Distillation
     - 8.1.1 Measure 500 ml sample into a beaker. Lower the pH to approximately 4 with 1 + 9 H_3PO_4 (7.1), add 5 ml $CuSO_4$ solution (7.2) and transfer to the distillation apparatus. Omit adding H_3PO_4 and $CuSO_4$ if sample was preserved as described in 4.1.
     - 8.1.2 Distill 450 ml of sample, stop the distillation, and when boiling ceases add 50 ml of warm distilled water to the flask and resume distillation until 500 ml have been collected.
     - 8.1.3 If the distillate is turbid, filter through a prewashed membrane filter.
   - 8.2 Direct photometric method
     - 8.2.1 Using working solution A (7.7), prepare the following standards in 100 ml volumetric flasks.

ml of working solution A	Conc. ug/l
0	0.0
0.5	50.0
1.0	100.0
2.0	200.0
5.0	500.0
8.0	800.0
10.0	1000.0

8.2.2 To 100 ml of distillate or an aliquot diluted to 100 ml and/or standards, add 2 ml of buffer solution (7.3) and mix. The pH of the sample and standards should be 10 ±0.2.

8.2.3 Add 2.0 ml aminoantipyrine solution (7.4) and mix.

8.2.4 Add 2.0 ml potassium ferricyanide solution (7.5) and mix.

8.2.5 After 15 minutes read absorbance at 510 nm.

8.3 Chloroform extraction method

8.3.1 Using working solution B (7.8), prepare the following standards. Standards may be prepared by pipetting the required volumes into the separatory funnels and diluting to 500 ml with distilled water.

ml of working solution B	Conc. ug/l
0.0	0.0
3.0	6.0
5.0	10.0
10.0	20.0
20.0	40.0
25.0	50.0

8.3.2 Pla 500 ml of distillate or an aliquot diluted to 500 ml in a separatory funnel. The sample should not contain more than 25 ug phenol.

8.3.3 To sample and standards add 10 ml of buffer solution (7.3) and mix. The pH should be 10 ±0.2.

8.3.4 Add 3.0 ml aminoantipyrine solution (7.4) and mix.

8.3.5 Add 3.0 ml potassium ferricyanide solution (7.5) and mix.

8.3.6 After three minutes, extract with 25 ml of chloroform (7.9). Shake the separatory funnel at least 10 times, let $CHCl_3$ settle, shake again 10 times and let chloroform settle again.

8.3.7 Filter chloroform extracts through filter paper. Do not add more chloroform.

8.3.8 Read the absorbance of the samples and standards against the blank at 460 nm.

9. Calculation

9.1 Prepare a standard curve by plotting the absorbance value of standards versus the corresponding phenol concentrations.

9.2 Obtain concentration value of sample directly from standard curve.

10. Precision and Accuracy

10.1 Using the extraction procedure for concentration of color, six laboratories analyzed samples at concentrations of 9.6, 48.3, and 93.5 *ug*/1. Standard deviations were ±0.99, ±3.1 and ±4.2 *ug*/1, respectively.

10.2 Using the direct photometric procedure, six laboratories analyzed samples at concentrations of 4.7, 48.2 and 97.0 mg/1. Standard deviations were ±0.18, ±0.48 and ±1.58 mg/1, respectively.

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D1783–70, p553 (1970).
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p574–581, Method 510 through 510C, (1975).

Appendix IV.—Inductively Coupled Plasma Optical Emission Spectrometric Method (ICP) for Trace Element Analysis of Water and Wastes

Inductively Coupled Plasma (ICP) Optical Emission Spectrometric Method for Trace Element Analysis of Water and Wastes

Interim

U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268

October 1979.

Foreword

This method has been prepared by the staff of the Environmental Monitoring and Support Laboratory—Cincinnati, with the cooperation of the EPA–ICP Users Group. Their cooperation and support is gratefully acknowledged.

This method represents the current state-of-the-art, but as time progresses, improvements are anticipated. Users are encouraged to identify problems and assist in updating the method by contacting the Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268.

Inductively Coupled Plasma (ICP) Optical Emission Spectrometric Method for Trace Element Analysis of Water and Wastes

1. Scope and Application.

1.1 This method may be used for the determination of dissolved, suspended, or total elements in surface water, drinking water, and domestic and industrial wastewaters.

1.2 Dissolved elements are determined in filtered and acidified samples. Appropriate steps must be taken to ensure that potential interference are taken into account when dissolved solids exceed 1500 mg/l. (See 4.2)

1.3 Total elements are determined after appropriate digestion procedures are performed. Since digestion techniques increase the dissolved solids content of the samples, appropriate steps *must* be taken to correct for potential interference effects.

1.4 Table 1 lists elements for which this method applies along with recommended wavelengths and typical estimated instrumental detection limits. Actual working detection limits are sample dependent and as the sample matrix varies, these concentrations may also vary. In time, other elements may be added as more information becomes available.

1.5 Because of the differences between various makes and models of satisfactory instruments, no detailed instrumental operating instructions can be provided. Instead, the analyst is referred to the instructions provided by the manufacturer of the particular instrument.

Table 1—*Recommended Wavelengths* [1] and Estimated Instrumental Detection Limits

Element	Wavelength, nm	Estimated detection limit, µg/l [2]
Aluminum	308.2	45
Arsenic	193.7	53
Barium	455.5	2
Beryllium	313.0	0.3
Boron	249.8	5
Cadmium	226.5	4
Calcium	317.9	10
Chromium	267.7	7
Cobalt	228.6	7
Copper	324.7	8
Iron	259.9	7
Lead	220.3	42
Lithium	670.7	4
Magnesium	279.1	30
Manganese	257.6	2
Molybdenum	202.0	8
Nickel	231.6	15
Potassium	766.4	see [3]
Selenium	196.0	75
Silica (SiO_2)	288.1	27
Silver	328.0	7
Sodium	589.0	29
Strontium	407.7	0.5
Vanadium	292.4	8
Zinc	213.8	2

[1] The wavelengths listed are recommended because of their sensitivity and overall acceptance. Other wavelengths may be substituted if they can proved the needed sensitivity and are treated with the same corrective techniques for spectral interference. (See 4.1.1).

[2] The estimated instrumental detection limit as shown are taken from "Inductively Coupled Plasma-Optical Emission Spectroscopy Prominent Lines," EPA-600/4-79-017. Detection limits are sample dependent and as the sample matrix varies, these concentration values may also vary.

[3] Highly dependent on operating conditions and plasma position.

2. Summary of Method.

2.1 The method describes a technique for the simultaneous or sequential multielement determination of trace elements in solution. The basis of the method is the measurement of atomic emission by an optical spectroscopic technique. Samples are nebulized and the aerosol that is produced is transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio-frequency inductively coupled plasma (ICP). The spectra are dispersed by a grating spectrometer and the intensities of the lines are monitored by photomultiplier tubes. The photocurrents from the photomultiplier tubes are processed and controled by a computer system. A background correction technique is required to compensate for variable background contribution to the determination of trace elements. Background must be measured adjacent to analyte lines on samples during analysis. Additional interferences named in 4.1 shoud also be recognized and appropriate corrections made.

3. Definitions.

3.1 *Dissolved*—Those elements which will pass through a 0.45 µm membrane filter.

3.2 *Suspended*—Those elements which are retained by a 0.45 µm membrane filter.

3.3 *Total*—The concentration determined on an unfiltered sample following vigorous digestion (Section 8.3), or the sum of the dissolved plus suspended concentrations (Section 8.1 plus 8.2).

3.4 *Total recoverable*—The concentration determined on an

unfiltered sample following treatment with hot, dilute mineral acid (Section 8.4).

3.5 *Instrumental detection limit*—The concentration equivalent to a signal, due to the analyte, which is equal to three times the standard deviation of a series of ten replicate measurements of a reagent blank signal at the same wavelength.

3.6 *Sensitivity*—The slope of the analytical curve, i.e. funtional relationship between emission intensity and concentration.

3.7 *Instrument check standard*—A multielement standard of known concentrations prepared by the analyst. Should be included in the analytical scheme with a frequency of 10%. (See 6.6.1.)

3.8 *Reference standard*—A solution obtained from an outside source having known, verified values. Must be used initially to verify the calibration standards and analyzed thereafter as a blind sample on a weekly frequency. (See 6.6.2.)

3.9 *Calibration standards*—A series of known standard solutions used by the analyst for calibration of the instrument (i.e., preparation of the analytical curve). (See 6.4.)

3.10 *Linear dynamic range*—The concentration range over which the analytical curve remains linear.

3.11 *Reagent blank*—A volume of deionized, distilled water containing the same acid matrix as the calibration standards carried through the entire analytical scheme. (See 6.5.2.)

3.12 *Calibration blank*—A volume of deionized, distilled water acidified with HNO_3 and HCl. (See 6.5.1.)

3.13 *Method of standard addition*—The standard addition technique involves the use of the unknown and the unknown plus a known amount of standard. (See 9.6.1.)

4. Interferences.

4.1 Several types of interference effects may contribute to inaccuracies in the determination of trace elements. They can be summarized as follows:

4.1.1 *Spectral interferences* can be categorized as (1) overlap of a spectral line from another element; (2) unresolved overlap of molecular band spectra; (3) background contribution from continuous or recombination phenomena; and (4) background contribution from stray light from the line emission of high concentration elements. The first of these effects can be compensated by utilizing a computer correction of the raw data, requiring measurement of the interfering element. The second effect may require selection of an alternate wavelength. The third and fourth effects can usually be compensated by a background correction adjacent to the analyte line.

4.1.2 *Physical interferences* are generally considered to be effects associated with the sample nebulization and transport processes. Such properties as change in viscosity and surface tension can cause significant inaccuracies especially in samples which may contain high dissolved solids and/or acid concentrations. (See Note 1.) If these types of interferences are operative, they must be reduced by dilution of the sample and/or utilization of standard addition techniques.

Note 1.—The use of a peristaltic pump may lessen these interferences.

4.1.3 *Chemical interferences* are characterized by molecular compound formation, ionization effects and solute vaporization effects. Normally these effects are not pronounced with the ICP technique, however, if observed they can be minimized by careful selection of operating conditions (that is, incident power, observation position, and so forth), by buffering of the sample, by matrix matching, and by standard addition procedures. These types of interferences can be highly dependent on matrix type and the specific analyte element.

4.2 It is recommended that whenever a new or unusual sample matrix is encountered, a series of tests be performed prior to reporting concentration data for analyte elements. These tests, as outlined in 4.2.1 through 4.2.4, will ensure the analyst that neither positive nor negative interference effects are operative on any of the analyte elements thereby distorting the accuracy of the reported values.

4.2.1 *Serial dilution*—If the analyte concentration is sufficiently high (minimally a factor of 10 above the instrumental detection limit after dilution), an analysis of a dilution should agree within 5 percent of the original determination (or within some acceptable control limit (13.3) that has been established for that matrix). If not, a chemical or physical interference effect should be suspected.

4.2.2 *Spike addition*—The recovery of a spike addition added at a minimum level of 10X the instrumental detection limit (maximum 100X) to the original determination should be recovered to within 90 to 110 percent or within the established control limit for that matrix. If not, a matrix effect should be suspected. The use of a standard addition analysis procedure can usually compensate for this effect.

Caution.—The standard addition technique does not detect coincident spectral overlap. If suspected, use of an alternate wavelength or comparison with an alternate method recommended (See 4.2.3).

4.2.3 *Comparison with alternate method of analysis*—When investigating a new sample matrix, comparison tests may be performed with other analytical techniques such as atomic absorption spectrometry, or other approved methodology.

4.2.4 *Wavelength scanning of analyte line region*—If the appropriate equipment is available, wavelength scanning can be performed to detect potential spectral interferences.

5. Apparatus.

5.1 Inductively Coupled Plasma (ICP) Optical Emission Spectrometer.

5.1.1 Computer controlled atomic emission spectrometer with background correction.

5.1.2 Radiofrequency generator.

5.1.3 Argon gas supply, welding grade or better.

5.2 Operating conditions—Because of the differences between various makes and models of satisfactory instruments, no detailed operating instructions can be provided. Instead, the analyst should follow the instructions provided by the manufacturer of the particular instrument. Sensitivity, instrumental detection limit, precision, linear dynamic range, and interference effects must be investigated and established for each individual analyte line on that particular instrument.

6. Reagents and standards.

6.1 Acids used in the preparation of standards and for sample processing must be ultra-high purity grade or equivalent. Redistilled acids are acceptable.

6.1.1 *Acetic acid*, conc. (sp gr 1.00).

6.1.2 *Aqua regia*: Mix cautiously: 3 parts conc. HCl (sp gr 1.19) and 1 part conc. HNO_3 (sp gr 1.41) just before use.

6.1.3 *Hydrochloric acid*, conc. (sp gr 1.19).

6.1.4 *Hydrochloric acid*, (1+1): Add 500 ml conc. HCl (sp gr 1.19) to 400 ml deionized, distilled water and dilute to 1 liter.

6.1.5 *Nitric acid*, conc. (sp gr 1.41).

6.1.6 *Nitric acid*, (1+1): Add 500 ml conc. HNO_3 (sp gr 1.41) to 400 ml deionized, distilled water and dilute to 1 liter.

6.2 *Deionized, distilled water*: Prepare by passing distilled water through a mixed bed of cation and anion exchange resins. Use deionized, distilled water for the preparation of all reagents, calibration standards and as dilution water.

6.3 *Standard stock solutions* may be purchased or prepared from ultra high purity grade chemicals or metals

(Caution: See Note 2). All salts must be dried for 1 h at 105° C unless otherwise specified.

Note 2.—Many metal salts are extremely toxic and may be fatal if swallowed. Wash hands thoroughly after handling.

Typical stock solution preparation procedures follow:

6.3.1 *Aluminum solution, stock,* 1 ml = 100 μg Al: Dissolve 0.100 g of aluminum metal in an acid mixture of 4 ml of (1+1) HCl and 1 ml of conc. HNO_3 in a beaker. Warm gently to effect solution. When solution is complete, transfer quantitatively to a liter flask, add an additional 10 ml of (1+1) HCl and dilute to 1,000 ml with deionized, distilled water.

6.3.2 *Arsenic solution, stock,* 1 ml = 100 μg As: Dissolve 0.1320 g of As_2O_3 in 100 ml of deionized, distilled water containing 0.4 g NaOH. Acidify the solution with 2 ml conc. NHO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.3 *Barium solution, stock,* 1 ml = 100 μg Ba: Dissolve 0.1516 g $BaCl_2$ in 10 ml deionized, distilled water with 1 ml (1+1) HCl. Add 10.0 ml (1+1) HCl and dilute to 1,000 ml with deionized, distilled water.

6.3.4 *Beryllium solution, stock,* 1 ml = 100 μg Be: Dissolve 1.127 g $Be_4O(C_2H_3O_2)_6$, beryllium acetate basic, in a minimum amount of conc. acetic acid. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.5 *Boron solution, stock,* 1 ml = 100 μg B: Dissolve 0.5716 g anhydrous H_3BO_3 in deionized, distilled water and dilute to 1,000 ml. Because H_3BO_3 loses weight on drying at 105° C, use a reagent meeting ACS specifications and keep the bottle tightly stoppered to prevent the entrance of atmospheric moisture.

6.3.6 *Cadmium solution, stock,* 1 ml = 100 μg Cd: Dissolve 0.1142 g CdO in a minimum amount of (1+1) HNO_3. Heat to increase rate of dissolution. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.7 *Calcium solution, stock,* 1 ml = 100 μg Ca: Suspend 0.2498 g $CaCO_3$, dried at 180° C for 1 h before weighing in deionized, distilled water and dissolve cautiously with a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.8 *Chromium solution, stock,* 1 ml = 100 μg Cr: Dissolve 0.1923 g of CrO_3 in deionized, distilled water. When solution is complete, acidify with 10 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.9 *Cobalt solution, stock,* 1 ml = 100 μg Co: Dissolve 0.1407 g Co_3O_4 in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.10 *Copper solution, stock,* 1 ml = 100 μg Cu: Dissolve 0.1252 g CuO in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.11 *Iron solution, stock,* 1 ml = 100 μg Fe: Dissolve 0.1430 g Fe_2O_3 in 10 ml deionized, distilled water with 1 ml (1+1) HCl. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.12 *Lead solution, stock,* 1 ml = 100 μg Pb: Dissolve 0.1599 g $Pb(NO_3)_2$ in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.13 *Lithium solution, stock,* 1 ml = 100 μg Li: Dissolve 0.5323 g Li_2CO_3 slowly in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.14 *Magnesium solution, stock,* 1 ml = 100 μg Mg: Dissolve 0.1658 g MgO in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.15 *Manganese solution, stock,* 1 ml = 100 μg Mn: Dissolve 0.5225 g $Mn(NO_3)_2 \cdot 6H_2O$ (do not dry) in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.16 *Molybdenum solution, stock,* 1 ml = 100 μg Mo: Dissolve 0.2043 g $(NH_4)_2MoO_4$ in deionized, distilled water and dilute to 1,000 ml.

6.3.17 *Nickel solution, stock,* 1 ml = 100 μg Ni: Dissolve 0.4953 g $Ni(NO_3)_2 \cdot 6H_2O$ in deionized, distilled water. Add 10 ml of conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.18 *Potassium solution, stock,* 1 ml = 100 μg K: Dissolve 0.1907 g KCl, dried at 110° C, in deionized, distilled water dilute to 1,000 ml.

6.3.19 *Selenium solution, stock,* 1 ml = 100 μg Se: Dissolve 0.1727 g H_2SeO_3 in deionized, distilled water and dilute to 1,000 ml.

6.3.20 *Silica solution, stock,* 1 ml = 100 μg SiO_2: *Do not dry.* Dissolve 0.4730 g $Na_2SiO_3 \cdot 9H_2O$ in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.21 *Silver solution, stock,* 1 ml = 1 μg Ag: Dissolve 0.1575 g $AgNO_3$ in 100 ml of deionized, distilled water and 10 ml conc. HNO_3. Dilute to 1,000 ml with deionized, distilled water.

6.3.22 *Sodium solution, stock,* 1 ml = 100 μg Na: Dissolve 0.2542 g NaCl in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.23 *Strontium solution, stock,* 1 ml = 100 μg Sr: Dissolve 0.2416 g $Sr(NO_3)_2$ in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,00 ml with deionized, distilled water.

6.3.24 *Vanadium solution, stock,* 1 ml = 100 μg V: Dissolve 0.2297 NH_4VO_3 in a minimum amount of conc. HNO_3. Heat to increase rate of dissolution. Add 10.0 ml conc. HNO_3 and dilute to 1,00 ml with deionized, distilled water.

6.3.25 *Zinc solution, stock,* 1 ml = 100 μg Zn: Dissolve 0.1245 g ZnO in a minimum amount of dilute HNO. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.4 *Mixed calibration standard solutions*—Prepared mixed calibration standard solutions by combining appropriate volumes of the stock solutions in volumetric flasks. (See 6.4.1 thru 6.4.6) Add 2 ml of (1+1) HNO_3 and 2 ml of (1+1) HCl and dilute to 100 ml with deionized, distilled water. Prior to preparing the mixed standards, each stock solution should be analyzed separately to determine possible spectral interference. Care shoud be taken when preparing the mixed standards that the elements are compatible and stable. Transfer the mixed standard solutions to a FEP fluorocarbon bottle for storage. Fresh mixed standards should be prepared weekly. Some typical combinations follow:

6.4.1 *Mixed standard solution I*—Iron, manganese, cadmium, lead, and zinc.

6.4.2 *Mixed standard solution II*—Beryllium, copper, strontium, vanadium, and cobalt.

6.4.3 *Mixed standard solution III*—Molybdenum, silica, lithium, and barium.

6.4.4 *Mixed standard solution IV*—Calcium, magnesium, sodium, and potassium.

6.4.5 *Mixed standard solution V*—Aluminum, arsenic, boron, chromium, nickel, and selenium.

6.4.6 *Mixed standard solution VI*—Silver.

6.5 Two types of blanks are required for the analysis. The calibration blank (3.12) is used in establishing the analytical curve while the reagent blank (3.11) is used to correct for possible contamination resulting from varying amounts of the acids used in the sample processing.

6.5.1 *The calibration blank* is prepared by diluting 2 ml of (1 + 1) HNO_3 and 2 ml of (1 + 1) HCl to 100 ml with deionized, distilled water. Prepare a sufficient quantity to be used to flush the system between standards and samples.

6.5.2 *The reagent blank* must contain all the reagents and in the same volumes as used in the processing of the samples. The reagent blank must be carried through the complete procedure and contain the same acid concentration in the final solution as the sample solution used for analysis.

6.6 In addition to the calibration standards, an instrument check standard (3.7) and a reference standard (3.8) are also required for the analyses.

6.6.1 *The instrument check standard* is prepared by the analyst by combining compatible elements at a concentration equivalent to the midpoint of their respective calibration curves. This standard should be included in the analytical scheme with a frequency of 10%.

6.6.2 *The reference standard* should be prepared according to the instructions provided by the supplier. Following initial verification of the calibration standards, analyze weekly.

7. Sample handling and preservation.

7.1 For the determination of trace elements, contamination and loss are of prime concern. Dust in the laboratory environment, impurities in reagents and impurities on laboratory apparatus which the sample contacts are all sources of potential contamination. Sample containers can introduce either positive or negative errors in the measurement of trace elements by (a) contributing contaminants through leaching or surface desorption and (b) by depleting concentrations through adsorption. Thus the collection and treatment of the sample prior to analysis requires particular attention. Laboratory glassware including the sample bottle (whether linear polyethylene, polyproplyene or TFE-fluorocarbon) should be thoroughly washed with detergent and tap water; rinsed with (1+1) nitric acid, tap water, (1+1) hydrochloric acid, tap and finally deionized, distilled water in that order. (See Notes 3 and 4).

Note 3.—*Chromic acid may be useful to remove organic deposits from glassware; however, the analyst should be cautioned that the glassware must be thoroughly rinsed with water to remove the last traces of chromium. This is especially important if chromium is to be included in the analytical scheme. A commercial product, NOCHROMIX, available from Godax Laboratories, 6 Varick St., New York, NY 10013, may be used in place of chromic acid. Chromic acid should not be used with plastic bottles.*

Note 4.—If it can be documented through an active analytical quality control program using spiked samples and reagent blanks, that certain steps in the cleaning procedure are not required for routine samples, those steps may be eliminated from the procedure.

7.2 Before collection of the sample a decision must be made as to the type of data desired, that is dissolved, suspended or total, so that the appropriate preservation and pretreatment steps may be accomplished. Filtration, acid preservation, etc., are to be performed at the time the sample is collected or as soon as possible thereafter.

7.2.1 For the determination of dissolved elements the sample must be filtered through a 0.45-μm membrane filter as soon as practical after collection. (Glass or plastic filtering apparatus is recommended to avoid possible contamination.) Use the first 50–100 ml to rinse the filter flask. Discard this portion and collect the required volume of filtrate. Acidify the filtrate with (1+1) HNO_3 to a pH of 2 or less. Normally, 3 ml of (1+1) acid per liter should be sufficient to preserve the sample.

7.2.2 For the determination of suspended elements a measured volume of unpreserved sample must be filtered through a 0.45-μm membrane filter as soon as practical after collection. The filter plus suspended material should be transferred to a suitable container for storage and/or shipment. No preservative is required.

7.2.3 For the determinaion of total or total recoverable elements, the sample is acidified with 5 ml conc. HNO_3 per liter (pH 2) as soon as possible, preferably at the time of collection. The sample is not filtered before processing.

8. Sample Preparation.

8.1 For the determinations of dissolved elements, the filtered, preserved sample may often be analyzed as received. The acid matrix and concentration of the samples and calibration standards must be the same. If a precipitate formed upon acidification of the sample or during transit or storage, it must be redissolved before the analysis by adding additional acid and/or by heat as described in 8.3.

8.2 For the determinaton of suspended elements, transfer the membrane filter containing the insoluble material to a 250-ml Griffin beaker and add 3 ml conc. HNO_3. Cover the beaker with a watch glass and heat gently. The warm acid will soon dissolve the membrane. Increase the temperature of the hot plate and digest the material. When the acid has nearly evaporated, cool the beaker and watch glass and add another 3 ml of conc. HNO_3. Cover and continue heating until the digestion is complete, generally indicated by a light colored digestate. Evaporate to near dryness (DO NOT BAKE), cool, add 2 ml of (1+1) HNO_3 and 2 ml HCl (1+1) per 100 ml dilution and warm the beaker gently to dissolve any soluble material. Wash down the watch glass and beaker walls with deionized distilled water and filter the sample to remove insoluble material that could clog the nebulizer. Adjust the volume based on the expected concentrations of elements present. This volume will vary depending on the elements to be determined. The sample is now ready for analysis. Concentrations so determined shall be reported as "suspended."

8.3 For the determination of total elements, choose a measured, volume of *the well mixed acid preserved sample* appropriate for the expected level of elements and transfer to a Griffin beaker. (See Note 5.) Add 3 ml of conc. HNO_3. Place the beaker on a hot plate and evaporate to near dryness cautiously, making certain that the sample does not boil. (DO NOT BAKE.) Cool the beaker and add another 3 ml portion of conc. HNO_3. Cover the beaker with a watch glass and return to the hot plate. Increase the temperature of the hot plate so that a gentle reflux action occurs. Continue heating, adding additional acid as necessary, until the digestion is complete (generally indicated when the digestate is ligh in color or does not change in appearance with continued refluxing.) Again, evaporate to near dryness and cool the beaker. Add 2 ml of 1+1 HNO_3 and 2 ml of 1+1 HCl per 100 ml of final solution and warm the beaker to dissolve any precipitate or residue resulting from evaporation. Wash down the beaker walls and watch glass with deionized distilled water and filter the sample to remove insoluble material that could clog the nebulizer. Adjust the volume based on the expected concentrations of elements present. The sample is now ready for analysis. Concentrations so determined shall be reported as "total."

Note 5.—If low determinations of boron are critical, quartz glassware should be used.

8.4 For the determination of total recoverable elements, choose a measured volume of a well mixed, acid preserved sample appropriate for the expected level of elements and transfer to a Griffin beaker. (See Note 5.) Add 1 ml of HNO_3 (1+1) and 2 ml of HCl (1+1) to the sample and heat on a steam bath or hot plate until the volume has been reduced to 15–20 ml making certain the sample does not boil. After this treatment the sample is filtered to remove insoluble material that could clog the nebulizer, and the volume adjusted to 100 ml. The sample is then ready for analysis. Concentrations so determined shall be reported as "total."

9. Procedure.

9.1 Set up instrument with proper operating parameters established in Section 5.2. Instrument must be allowed to stabilize for at least 30 min prior to operations.

9.2 Initiate appropriaate operating configuration of computer.

9.3 Profile and calibrate instrument according to instrument manufacturer's recommended procedures, using the typical mixed calibration standard solutions described in Section 6.4. Flush the system with the calibration blank (6.5.1) between each standard. (See note 6.) (The use of the average intensity of multiple exposures for both standardization and sample analysis has been found to reduce random error.)

NOTE 6.—For boron concentrations greater than 500 μg/l extended flush times of 1 to 2 minutes may be required.

9.4 Before beginning the sample run, reanalyze the highest mixed calibration standard as if it were a sample. Concentration values obtained should not deviate from the actual values by more than 2 percent (or the established control limits). If they do, follow the recommendations of the instrument manufacturer to correct for this condition.

9.5 Begin the sample run flushing the system with the calibration blank (6.5.1) between each sample. (See Note 6.) Analyze an instrument check standard (6.6.1) each 10 samples.

9.6 If it has been found that methods of standard addition are required, the following procedure is recommended.

9.6.1 The standard addition technique (13.2) involves preparing new standards in the sample matrix by adding known amounts of standard to one or more aliquots of the processed sample solution. This technique compensates for a sample constituent that enhances or depresses the analyte signal thus producing a different slope from that of the calibration standards. It will not correct for additive intererence which causes a baseline shift. The simplest version of this technique is the single-addition method. The procedure is as follows. Two identical aliquots of the sample solution, each of volume V_s, are taken. To the first (labeled A) is added a small volume V_a of a standared analyte solution of concentration c_a. To the second (labeled B) is added the same volume V_a of the solvent. The analytical signals of A and B are measured and corrected for nonanalyte signals. The unknown sample concentration c_s is calculated:

$$C_s = \frac{S_B V_a c_a}{(S_A - S_B) V_s}$$

where S_A and S_B are the analytical signals (corrected for the blank) of solutions A and B, respectively. V_a and c_a should be chosen so that S_A is roughly twice S_B on the average. It is best if V_a is made much less than V_s, and thus c_a is much greater than c_s, to avoid excess dilution of the sample matrix. If a separation or concentration step is used, the additions are best made first and carried through the entire procedure. For the results from this technique to be valid, the following limitations must be taken into consideration:

1. The analytical curve must be linear.
2. The chemical form of the analyte added must respond the same as the analyte in the sample.
3. The interference effect must be constant over the working range of concern.
4. The signal must be corrected for any additive interference.

10. Calculation.

10.1 Reagent blanks (6.5.2) should be subtracted from all samples. This is particularly important for digested samples requiring large quantities of acids to complete the digestion.

10.2 If dilutions were performed, the appropriate factor must be applied to sample values.

10.3 Results should be reported to the nearest μg/l, up to three significant figures, except calcium, magnesium, sodium, and potassium which are reported to the nearest 0.1 mg/l.

11. Quality Control (Instrumental).

11.1 Check the instrument standardization by analyzing appropriate quality control check standards as follow:

11.1.1 Analyze the instrument check standard (6.6.1) made up of all the elements of interest at a frequency of 10%. This check standard is used to determine instrument drift. If agreement is not within ± 2% of the expected values or within the established control limits, the analysis is out of control.

11.1.2 For the purpose of verifying interelement and/or background correction factors, analyze a second check standard, prepared in the following manner. Select a representative sample which contains minimal concentrations of the elements of interest. Spike this sample with the analytes of interest at or near 20 μg/l. (For effluent samples of expected high concentrations, spike at an appropriate level.) Values should fall within the established control levels of 1. times the standard deviation of the mean value of the check standard. If not, repeat the standardization.

11.1.3 A reference standard (6.6.2) from an outside source, but having known concentration values, should be analyzed as a blind sample on a weekly frequency. Values should be within the established quality control limits. If not, prepare new stock standards.

12. *Precision and Accuracy.*

12.1 In an EPA round phase I study, seven laboratories applied the ICP technique to acid-distilled water matrices that had been dosed with various metal concentrates. Table II lists the true value, the mean reported value and the mean % relative standard deviation.

Table II.—*ICP Precision and Accuracy Data*

Element	Sample No. 1			Sample No. 2			Sample No. 3		
	True value μg/l	Mean reported value μg/l	Mean percent RSD	True value μg/l	Mean reported value μg/l	Mean percent RSD	True value μg/l	Mean reported value μg/l	Mean percent RSD
Be	750	733	0.2	20	20	9.8	180	178	5.2
Mn	350	345	2.7	15	15	8.7	100	95	3.3
V	750	749	1.8	70	68	2.9	170	169	1.1
As	200	208	7.5	22	19	23	80	83	17
Cr	150	149	3.8	10	10	18	50	50	3.3
Cu	250	235	5.1	11	11	40	70	67	7.9
Fe	600	594	3.0	20	19	15	180	178	8.0
Al	700	696	5.6	60	62	33	160	161	13
Cd	50	48	12	2.5	2.9	18	14	13	18
Co	500	512	10	20	20	4.1	120	108	21
Ni	250	245	5.8	30	28	11	80	55	14
Pb	250	236	16	24	30	32	80	85	14
Zn	200	201	5.6	16	19	45	80	87	9.4
Se	40	32	21.9	8	8.5	42	10	8.1	8.3

Not all elements were analyzed by all laboratories.

13. References.

13.1 Winge, R. K., V. J. Peterson, and V. A. Fassel. "Inductively Coupled Plasma-Optical Emission Spectroscopy: Prominent Lines. EPA-600/4-79-017.

13.2 Winefordner, J. D., "Trace Analysis: Spectroscopic Methods for Elements." *Chemical Analysis*, Vol. 46, pp. 41-42.

13.3 Handbook for Analytical Quality Control in Water and Wastewater Laboratories. EPA-600/4-79-019.

13.4 Carbarino, J. R. and Taylor, H. E., "An Inductively-Coupled Plasma Optical Emission Spectrometric Method for Routine Water Quality Testing," Applied Spectroscopy 33, No. 3 (1979).

13.5 "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020.

METHOD 9020

TOTAL ORGANIC HALIDES (TOX)

1.0 Scope and Application

1.1 Method 9020 determines Total Organic Halides (TOX) as Cl^- in drinking and ground waters. The method uses carbon adsorption with a microcoulometric-titration detector. It requires that all samples be run in duplicate. Under conditions of duplicate analysis, the reliable limit of sensitivity is 5 µg/l.

1.2 Method 9020 detects all organic halides containing chlorine, bromine and iodine that are adsorbed by granular activated carbon under the conditions of the method. Fluorine-containing species are not determined by this method.

1.3 Method 9020 is applicable to samples whose inorganic-halide concentration does not exceed the organic-halide concentration by more than 20,000 times.

1.4 Method 9020 is restricted to use by, or under the supervision of, analysts experienced in the operation of a pyrolysis/microcoulometer and in the interpretation of the results.

1.5 This method is provided as a recommended procedure. It may be used as a reference for comparing the suitability of other methods thought to be appropriate for measurement of TOX (i.e., by comparison of sensitivity, accuracy, and precision data).

2.0 Summary of Method

2.1 A sample of water that has been protected against the loss of volatiles by the elimination of headspace in the sampling container, and that is free of undissolved solids, is passed through a column containing 40 mg of activated carbon. The column is washed to remove any trapped inorganic halides, and is then analyzed to convert the adsorbed organohalides to a titratable species that can be measured by a microcoulometric detector.

3.0 Interferences

3.1 Method interferences may be caused by contaminants, reagents, glassware, and other sample processing hardware. All these materials must be

routinely demonstrated to be free from interferences under the conditions of the analysis by running method blanks.

3.1.1 Glassware must be scrupulously cleaned. Clean all glassware as soon as possible after use by treating with chromate cleaning solution. This should be followed by detergent washing in hot water. Rinse with tap water and distilled water, drain dry, and heat in a muffle furnace at 400° C for 15 to 30 min. Volumetric ware should not be heated in a muffle furnace. Glassware should be sealed and stored in a clean environment after drying and cooling to prevent any accumulation of dust or other contaminants.

3.1.2 The use of high purity reagents and gases helps to minimize interference problems.

3.2 Purity of the activated carbon must be verified before use. Only carbon samples that register less than 1000 ng/40 mg should be used. The stock of activated carbon should be stored in its granular form in a glass container with a Teflon seal. Exposure to the air must be minimized, especially during and after milling and sieving the activated carbon. No more than a two-week supply should be prepared in advance. Protect carbon at all times from all sources of halogenated organic vapors. Store prepared carbon and packed columns in glass containers with Teflon seals.

4.0 Apparatus and Materials

4.1 Adsorption system

4.1.1 Dohrmann adsorption module (AD-2), or equivalent, pressurized, sample and nitrate-wash reservoirs.

4.1.2 Adsorption columns: Pyrex, 5-cm-long x 6-mm-O.D. x 2-mm-I.D.

4.2.3 Granular activated carbon (GAC): Filtrasorb-400, Calgon-APC or equivalent, ground or milled, and screened to a 100/200 mesh range. Upon combustion of 40 mg of GAC, the apparent-halide background should be 1000 mg Cl^- equivalent or less.

4.1.4 Cerafelt (available from Johns-Manville), or equivalent: Form this material into plugs using a 2-mm-I.D. stainless-steel borer with ejection rod (available from Dohrmann) to hold 40 mg of GAC in the adsorption columns. CAUTION: Do not touch this material with your fingers.

4.1.5 Column holders (available from Dohrmann).

4.1.6 Volumetric flasks: 100-ml, 50-ml. A general schematic of the adsorption system is shown in Figure 1.

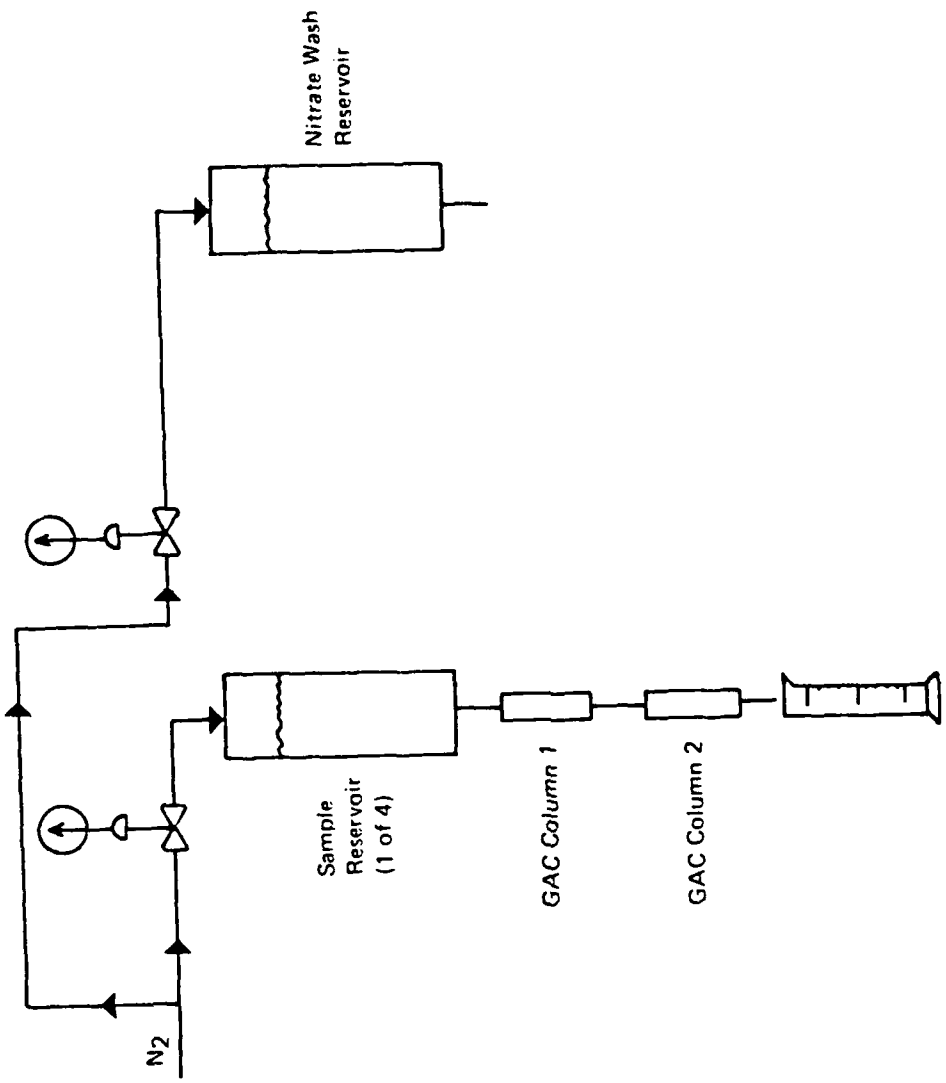
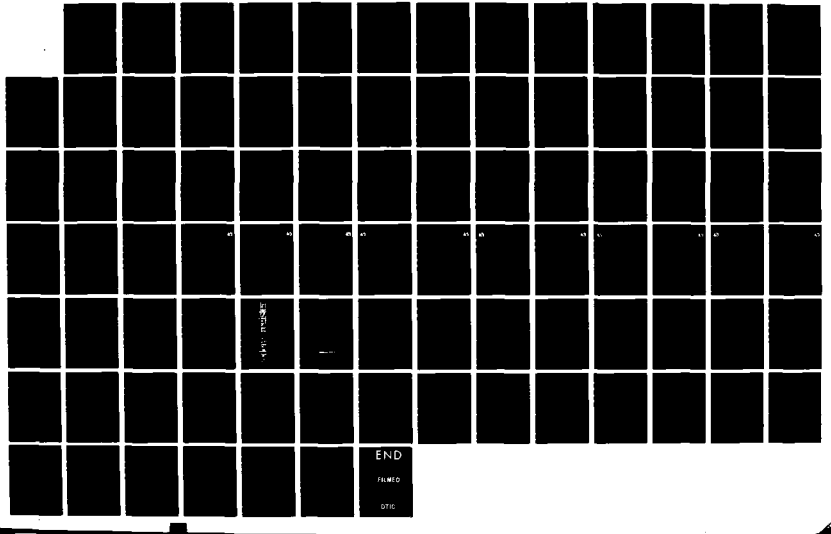
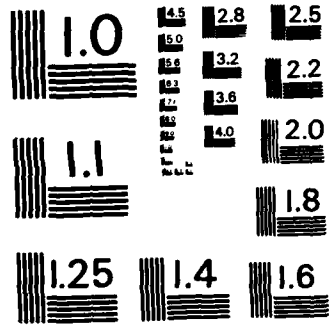


Figure 1. Schematic of Adsorption System.

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NATIONAL BUREAU OF STANDARDS - 1963 - A

4.2 Dohrmann microcoulometric-titration system (MCTS-20 or DX-20), or equivalent, containing the following components:

4.2.1 Boat sampler.

4.2.2 Pyrolysis furnace.

4.2.3 Microcoulometer with integrator.

4.2.4 Titration cell: A general description of the analytical system is shown in Figure 2.

4.3 Strip chart recorder.

5.0 Reagents

5.1 Sodium sulfite: 0.1 M, ACS reagent grade (12.6 g/liter).

5.2 Nitric acid: Concentrated.

5.3 Nitrate-wash solution (5000 mg NO_3^-/l): Prepare a nitrate-wash solution by transferring approximately 8.2 g of potassium nitrate into a 1-liter volumetric flask and diluting to volume with reagent water.

5.4 Carbon dioxide: Gas, 99.9% purity.

5.5 Oxygen: 99.9% purity.

5.6 Nitrogen: Prepurified.

5.7 70% acetic acid in water: Dilute 7 volumes of acetic acid with 3 volumes of water.

5.8 Trichlorophenol solution, stock (1 µl = 10 µg Cl^-): Prepare a stock solution by weighing accurately 1.856 g of trichlorophenol into a 100-ml volumetric flask. Dilute to volume with methanol.

5.9 Trichlorophenol solution, calibration (1 µl = 500 ng Cl^-): Dilute 5 ml of the trichlorophenol stock solution to 100 ml with methanol.

5.10 Trichlorophenol standard, instrument-calibration: First, nitrate-wash a single column packed with 40 mg of activated carbon as instructed for sample analysis, and then inject the column with 10 µl of the calibration solution.

5.11 Trichlorophenol standard, adsorption-efficiency (100 µg Cl^-/liter): Prepare an adsorption-efficiency standard by injecting 10 µl of stock solution into 1 liter of reagent water.

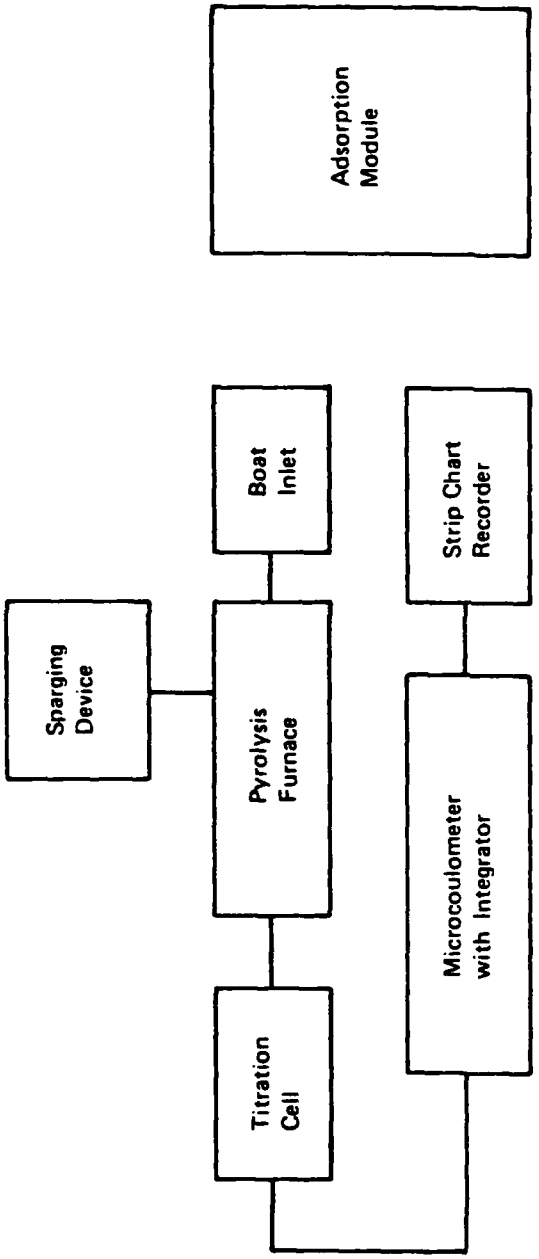


Figure 2. Schematic diagram of CAOX analysis system.

5.12 Reagent water: Reagent water is defined as a water in which an interferent is not observed at the method detection limit of each parameter of interest.

5.13 Blank standard: The reagent water used to prepare the calibration standard should be used as the blank standard.

6.0 Sample Collection, Preservation, and Handling

6.1 All samples must have been collected using a sampling plan that addresses the considerations discussed in Section One of this manual.

6.2 All samples should be collected in bottles with teflon septa (e.g., Pierce #12722 or equivalent) and be protected from light. If this is not possible, use amber glass, 250-ml, fitted with teflon-lined caps. Foil may be substituted for teflon if the sample is not corrosive. Samples must be protected against loss of volatiles by eliminating headspace in the container. If amber bottles are not available, protect samples from light. The container must be washed and muffled at 400° C before use, to minimize contamination.

6.3 All glassware must be dried prior to use according to the method discussed in 3.1.1.

7.0 Procedure

7.1 Sample preparation

7.1.1 Special care should be taken in handling the sample in order to minimize the loss of volatile organohalides. The adsorption procedure should be performed simultaneously on duplicates.

7.1.2 Reduce residual chlorine by adding sulfite (1 ml of 0.1 M per liter of sample). Sulfite should be added at the time of sampling if the analysis is meant to determine the TOX concentration at the time of sampling. It should be recognized that TOX may increase on storage of the sample. Samples should be stored at 4° C without headspace.

7.1.3 Adjust the pH of the sample to approximately 2 with concentrated HNO_3 just prior to adding the sample to the reservoir.

7.2 Calibration

7.2.1 Check the adsorption efficiency of each newly-prepared batch of carbon by analyzing 100 ml of the adsorption-efficiency standard, in duplicate, along with duplicates of the blank standard. The net recovery should be within 5% of the standard value.

7.2.2 Nitrate-wash blanks (method blanks): Establish the repeatability of the method background each day by first analyzing several nitrate-wash blanks. Monitor this background by spacing nitrate-wash blanks between each group of eight pyrolysis determinations. The nitrate-wash blank values are obtained on single columns packed with 40 mg of activated carbon. Wash with the nitrate solution as instructed for sample analysis, and then pyrolyze the carbon.

7.2.3 Pyrolyze duplicate instrument-calibration standards and the blank standard each day before beginning sample analysis. The net response to the calibration-standard should be within 3% of the calibration-standard value. Repeat analysis of the instrument-calibration standard after each group of eight pyrolysis determinations, and before resuming sample analysis after cleaning or reconditioning the titration cell or pyrolysis system.

7.3 Adsorption procedure

7.3.1 Connect two columns in series, each containing 40 mg of 100/200-mesh activated carbon.

7.3.2 Fill the sample reservoir, and pass a metered amount of sample through the activated-carbon columns at a rate of approximately 3 ml/min. NOTE: 100 ml of sample is the preferred volume for concentrations of TOX between 5 and 500 µg/l; 50 ml for 501 to 1000 µg/l, and 25 ml for 1001 to 2000 µg/l.

7.3.3 Wash the columns-in-series with 2 ml of the 5000-mg/l nitrate solution at a rate of approximately 2 ml/min to displace inorganic chloride ions.

7.4 Pyrolysis procedure

7.4.1 The contents of each column are pyrolyzed separately. After rinsing with the nitrate solution, the columns should be protected from the atmosphere and other sources of contamination until ready for further analysis.

7.4.2 Pyrolysis of the sample is accomplished in two stages. The volatile components are pyrolyzed in a CO_2-rich atmosphere at a low temperature to ensure the conversion of brominated trihalomethanes to a titratable species. The less volatile components are then pyrolyzed at a high temperature in an O_2-rich atmosphere. NOTE: The quartz sampling boat should have been previously muffled at 800° C for at least 2 to 4 min as in a previous analysis, and should be cleaned of any residue by vacuuming.

7.4.3 Transfer the contents of each column to the quartz boat for individual analysis.

7.4.4 If the Dohrmann MC-1 is used for pyrolysis, manual instructions are followed for gas flow regulation. If the MCTS-20 is used, the information on the diagram in Figure 3 is used for gas flow regulation.

7.4.5 Position the sample for 2 min in the 200° C zone of the pyrolysis tube. For the MCTS-20, the boat is positioned just outside the furnace entrance.

7.4.6 After 2 min, advance the boat into the 800° C zone (center) of the pyrolysis furnace. This second and final stage of pyrolysis may require from 6 to 10 min to complete.

7.5 Detection: The effluent gases are directly analyzed in the micro-coulometric-titration cell. Carefully follow manual instructions for optimizing cell performance.

7.6 Breakthrough. The unpredictable nature of the background bias makes it especially difficult to recognize the extent of breakthrough of organohalides from one column to another. All second-column measurements for a properly operating system should not exceed 10% of the two-column total measurement. If the 10% figure is exceeded, one of three events can be happening. Either (1) the first column was overloaded and a legitimate measure of breakthrough was obtained, in which case taking a smaller sample may be necessary; or (2) channeling or some other failure occurred, in which case the sample may need to be rerun; or (3) a high random bias occurred and the result should be rejected and the sample rerun. Because it may not be possible to determine which event occurred, a sample analysis should be repeated often enough to gain confidence in results. As a general rule, any analysis that is rejected should be repeated whenever sample is available. If the second-column measurement is equal to or less than the nitrate-wash blank value, the second-column value should be disregarded.

7.7 Calculations: TOX as Cl^- is calculated using the following formula:

$$\frac{(C_1 - C_3) + (C_2 - C_3)}{V} = \mu g/l \text{ Total Organic Halide}$$

where:

C_1 = µg Cl^- on the first column in series

C_2 = µg Cl^- on the second column in series

C_3 = predetermined, daily, average, method-blank value (nitrate-wash blank for a 40-mg carbon column)

V = the sample volume in liters.

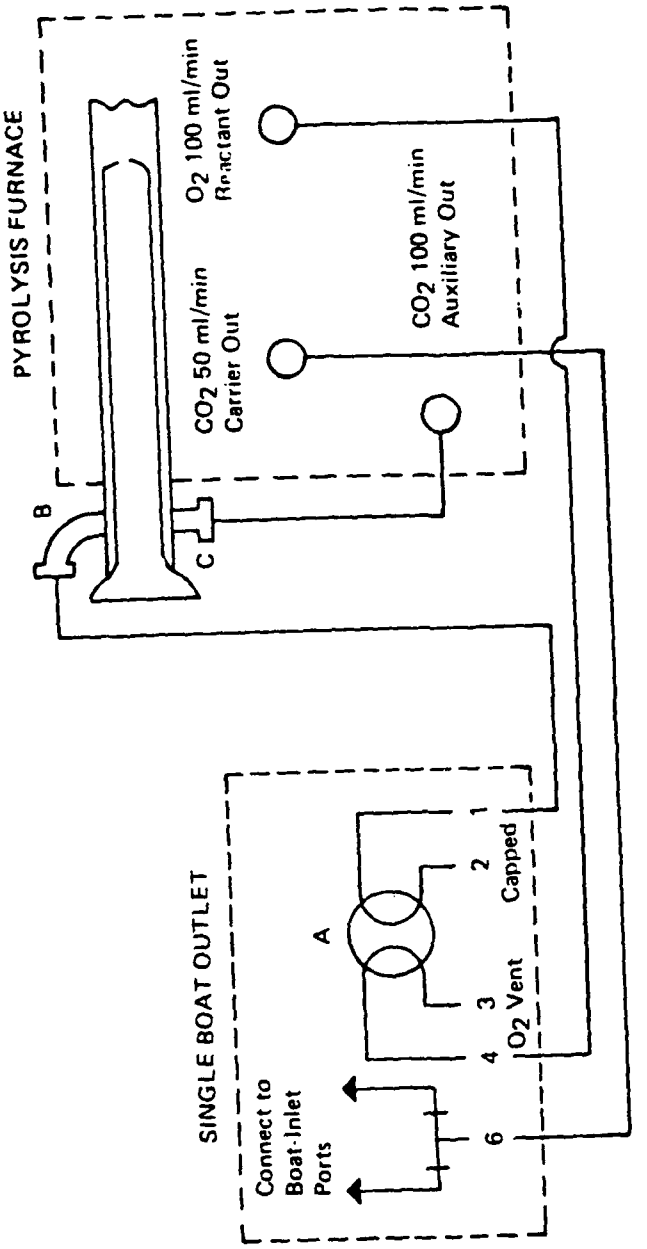


Figure 3. Rear-view plumbing schematic for MCTS–20 System. Valve A is set for first-stage combustion, O_2 venting (push/pull valve out). Port B enters inner combustion tube; Port C enters outer combustion tube.

8.0 Quality Control

8.1 All quality control data should be maintained and available for easy reference or inspection.

8.2 Before performing any analyses, the analyst must demonstrate the ability to generate acceptable accuracy and precision with this procedure by analyzing appropriate quality-control check samples.

8.3 The laboratory must develop and maintain a statement of method accuracy for their laboratory. The laboratory should update the accuracy statement regularly as new recovery measurements are made.

8.4 Employ a minimum of one blank per sample batch to determine if contamination or any memory effects are occurring.

8.5 Run check standard after approximately every 15 samples.

8.6 Run one duplicate sample for every 10 samples. A duplicate sample is a sample brought through the whole sample preparations process.

8.7 It is recommended that the laboratory adopt additional quality-assurance practices for use with this method. The specific practices that would be most productive will depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to monitor the precision of the sampling technique. Whenever possible, the laboratory should perform analysis of standard reference materials and participate in relevant performance-evaluation studies.

CHLORIDE

Method 325.3 (Titrimetric, Mercuric Nitrate)

STORET NO. 00940

1. Scope and Application
   - 1.1 This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes.
   - 1.2 The method is suitable for all concentration ranges of chloride content; however, in order to avoid large titration volume, a sample aliquot containing not more than 10 to 20 mg Cl per 50 ml is used.
   - 1.3 Automated titration may be used.
2. Summary of Method
   - 2.1 An acidified sample is titrated with mercuric nitrate in the presence of mixed diphenylcarbazone-bromophenol blue indicator. The end point of the titration is the formation of the blue-violet mercury diphenylcarbazone complex.
3. Comments
   - 3.1 Anions and cations at concentrations normally found in surface waters do not interfere.
   - 3.2 Sulfite interference can be eliminated by oxidizing the 50 ml of sample solution with 0.5 to 1 ml of H_2O_2.
4. Apparatus
   - 4.1 Standard laboratory titrimetric equipment including a 1 ml or 5 ml microburet with 0.01 ml graduations.
5. Reagents
   - 5.1 Standard sodium chloride, 0.025 N: Dissolve 1.4613 ±0.0002 g (dried at 600°C for 1 hour) in chloride-free water in a 1 liter volumetric flask and dilute to the mark.
   - 5.2 Nitric acid, HNO_3 solution (3 + 997)
   - 5.3 Sodium hydroxide solution, NaOH, (10 g/1)
   - 5.4 Hydrogen peroxide (30%), H_2O_2
   - 5.5 Hydroquinone solution (10 g/liter): Dissolve 1 g of purified hydroquinone in water in a 100 ml volumetric and dilute to the mark.
   - 5.6 Mercuric nitrate titrant (0.141 N): Dissolve 25 g $Hg(NO_3)_2 \cdot H_2O$ in 900 ml of distilled water acidified with 5.0 ml conc. HNO_3 in a 1 liter volumetric flask and dilute to the mark with distilled water. Filter if necessary. Standardize against standard sodium chloride solution (5.1) using procedure 6. Adjust to exactly 0.141 N and check. Store in a dark bottle. A 1.00 ml aliquot is equivalent to 5.00 mg of chloride.
   - 5.7 Mercuric nitrate titrant (0.025 N): Dissolve 4.2830 g $Hg(NO_3)_2 \cdot H_2O$ in 50 ml of distilled water acidified with 0.5 ml conc. HNO_3 (sp. gr. 1.42) in a 1 liter volumetric flask and dilute to the mark with distilled water. Filter if necessary. Standardize against standard

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sodium chloride solution (5.1) using procedure 6. Adjust to exactly 0.025 N and check. Store in a dark bottle.

5.8 Mercuric nitrate titrant (0.0141 N): Dissolve 2.4200 g $Hg(NO_3)_2 \cdot H_2O$ in 25 ml of distilled water acidified with 0.25 ml of conc. HNO_3 (sp. gr. 1.42) in a 1 liter volumetric flask and dilute to the mark with distilled water. Filter if necessary. Standardize against standard sodium chloride solution (5.1) using procedure 6. Adjust to exactly 0.0141 N and check. Store in a dark bottle. A 1 ml aliquot is equivalent to 500 ug of chloride.

5.9 Mixed indicator reagent: Dissolve 0.5 g crystalline diphenylcarbazone and 0.05 g bromophenol blue powder in 75 ml 95% ethanol in a 100 ml volumetric flask and dilute to the mark with 95% ethanol. Store in brown bottle and discard after 6 months.

5.10 Alphazurine indicator solution: Dissolve 0.005 g of alphazurine blue-green dye in 95% ethanol or isopropanol in a 100 ml volumetric and dilute to the mark with 95% ethanol or isopropanol.

6. Procedure

6.1 Place 50 ml of sample in a vessel for titration. If the concentration is greater than 20 mg/1 chloride, use 0.141 N mercuric nitrate titrant (5.6) in step 6.6 or dilute. If the concentration is less than 2.5 mg/1 of chloride, use 0.0141 N mercuric nitrate titrant (5.8) in step 6.6, a 1 ml or 5 ml microburet, and determine an indicator blank on 50 ml chloride-free water using procedure 6.6. If the concentration is less than 0.1 mg/1 of chloride concentrate an appropriate volume to 50 ml.

6.2 Add 5 to 10 drops of mixed indicator reagent (5.9), shake or swirl solution.

6.3 If a blue-violet or red color appears add HNO_3 solution (5.2) dropwise until the color changes to yellow.

6.4 If a yellow or orange color forms immediately on addition of the mixed indicator, add NaOH solution (5.3) dropwise until the color changes to blue-violet; then add HNO_3 solution (5.2) dropwise until the color changes to yellow.

6.5 Add 1 ml excess HNO_3 solution (5.2).

6.6 Titrate with 0.025 N mercuric nitrate titrant (5.7) until a blue-violet color persists throughout the solution. See 6.1 for choice of titrant normality. Alphazurine indicator solution (5.10) may be added with the indicator to sharpen the end point. This will change color shades. Practice runs should be made.

6.7 Additional steps to eliminate particular interferences:

6.7.1 If chromate is present at < 100 mg/1 and iron is not present, add some alphazurine indicator solution (5.10) and acidify to pH 3 (indicating paper). End point will then be an olive-purple color.

6.7.2 If chromate is present at > 100 mg/1 and iron is not present, add 2 ml of fresh hydroquinone solution (5.5).

6.7.3 If ferric ion is present use volume containing no more than 2.5 mg of ferric ion or ferric ion plus chromate ion. Add 2 ml fresh hydroquinone solution (5.5).

6.7.4 If sulfite ion is present, add 0.5 ml of H_2O_2 solution (5.4) to 50 ml sample and mix for 1 minute.

7. Calculation

$$\text{mg chloride/l} = \frac{(A - B)N \times 35{,}450}{\text{ml of sample}}$$

where:
A = ml titrant for sample
B = ml titrant for blank
N = normality mercuric nitrate titrant

mg NaCl/l = mg chloride/l x 1.65

8. Precision and Accuracy

8.1 Forty two analysts in eighteen laboratories analyzed synthetic water samples containing exact increments of chloride, with the following results:

Increment as Chloride mg/liter	Precision as Standard Deviation mg/liter	Accuracy as Bias, %	Accuracy as Bias, mg/liter
17	1.54	+2.16	+0.4
18	1.32	+3.50	+0.6
91	2.92	+0.11	+0.1
97	3.16	-0.51	-0.5
382	11.70	-0.61	-2.3
398	11.80	-1.19	-4.7

(FWPCA Method Study 1, Mineral and Physical Analyses)

8.2 In a single laboratory (EMSL), using surface water samples at an average concentration of 34 mg Cl/1, the standard deviation was ±1.0.

8.3 A synthetic unknown sample containing 241 mg/1 chloride, 108 mg/1 Ca, 82 mg/1 Mg, 3.1 mg/1 K, 19.9 mg/1 Na, 1.1 mg/1 nitrate N, 0.25 mg/1 nitrite N, 259 mg/1 sulfate and 42.5 mg/1 total alkalinity (contributed by $NaHCO_3$) in distilled water was analyzed in 10 laboratories by the mercurimetric method, with a relative standard deviation of 3.3% and a relative error of 2.9%.

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D512-67, Method A, p 270 (1976).

SULFATE

Method 375.4 (Turbidimetric)

STORET NO. Total 00945

1. Scope and Application
   - 1.1 This method is applicable to drinking and surface waters, domestic and industrial wastes.
   - 1.2 The method is suitable for all concentration ranges of sulfate; however, in order to obtain reliable readings, use a sample aliquot containing not more than 40 mg SO_4/1.
   - 1.3 The minimum detectable limit is approximately 1 mg/1 sulfate.
2. Summary of Method
   - 2.1 Sulfate ion is converted to a barium sulfate suspension under controlled conditions. The resulting turbidity is determined by a nephelometer, filter photometer or spectrophotometer and compared to a curve prepared from standard sulfate solutions.
   - 2.2 Suspended matter and color interfere. Correct by running blanks from which the barium chloride has been omitted.
   - 2.3 Silica in concentrations over 500 mg/1 will interfere.
3. Comments
   - 3.1 Proprietary reagents, such as Hach Sulfaver or equivalent, are acceptable.
   - 3.2 Preserve by refrigeration at 4°C.
4. Apparatus
   - 4.1 Magnetic stirrer, variable speed so that it can be held constant just below splashing. Use identical shape and size magnetic stirring bars.
   - 4.2 Photometer: one of the following which are given in order of preference.
     - 4.2.1 Nephelometer
     - 4.2.2 Spectrophotometer for use at 420 nm with light path of 4 to 5 cm.
     - 4.2.3 Filter photometer with a violet filter having a maximum near 420 nm and a light path of 4 to 5 cm.
   - 4.3 Stopwatch, if the magnetic stirrer is not equipped with an accurate timer.
   - 4.4 Measuring spoon, capacity 0.2 to 0.3 ml.
5. Reagents
   - 5.1 Conditioning reagent: Place 30 ml conc. HCl, 300 ml distilled water, 100 ml 95% ethanol or isopropanol and 75 g NaCl in solution in a container. Add 50 ml glycerol and mix.
   - 5.2 Barium chloride, $BaCl_2$, crystals, 20 to 30 mesh.
   - 5.3 Sodium carbonate solution (approximately 0.05N): Dry 3 to 5 g primary standard Na_2CO_3 at 250°C for 4 hours and cool in a desiccator. Weigh 2.5 ±0.2 g (to the nearest mg), transfer to a 1 liter volumetric flask and fill to the mark with distilled water.

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5.4 Standard sulfate solution (1.00 ml = 100 μg SO_4): Prepare by either 5.4.1 or 5.4.2.

5.4.1 Standard sulfate solution from H_2SO_4

5.4.1.1 Standard sulfuric acid, 0.1N: dilute 3.0 ml conc. H_2SO_4 to 1 liter with distilled water. Standardize versus 40.00 ml of 0.05 N Na_2CO_3 solution (5.3) with about 60 ml distilled water by titrating potentiometrically to pH about 5. Lift electrodes and rinse into beaker. Boil gently for 3–5 minutes under a watch glass cover. Cool to room temperature. Rinse cover glass into beaker. Continue titration to the pH inflection point. Calculate normality using

$$N = \frac{A \times B}{53.00 \times C}$$

where:

A = g Na_2CO_3 weighed into 1 liter
B = ml Na_2CO_3 solution
C = ml acid used to inflection point

5.4.1.2 Standard acid, 0.02 N: Dilute appropriate amount of standard acid, 0.1 N (5.4.1.1) to 1 liter (200.00 ml if 0.1000 N). Check by standardization versus 15 ml of 0.05 N Na_2CO_3 solution (5.3).

5.4.1.3 Place 10.41 ml standard sulfuric acid, 0.02 N (5.4.1.2) in a 100 ml volumetric and dilute to the mark.

5.4.2 Standard sulfate solution from Na_2SO_4: Dissolve 147.9 mg anhydrous Na_2SO_4 in distilled water in a 1 liter volumetric flask and dilute to the mark with distilled water.

6. Procedure

6.1 Formation of barium sulfate turbidity

6.1.1 Place 100 ml sample, or a suitable portion diluted to 100 ml, into a 250 Erlenmeyer flask.

6.1.2 Add exactly 5.0 ml conditioning reagent (5.1).

6.1.3 Mix in the stirring apparatus.

6.1.4 While the solution is being stirred, add a measuring spoonful of $BaCl_2$ crystals (5.2) and begin timing immediately.

6.1.5 Stir exactly 1.0 minutes at constant speed.

6.2 Measurement of barium sulfate turbidity

6.2.1 Immediately after the stirring period has ended, pour solution into absorbance cell.

6.2.2 Measure turbidity at 30 second intervals for 4 minutes.

6.2.3 Record the maximum reading obtained in the 4 minute period.

6.3 Preparation of calibration curve.

6.3.1 Prepare calibration curve using standard sulfate solution (5.4).

6.3.2 Space standards at 5 mg/1 increments in the 0–40 mg/1 sulfate range.

...ng is completed, the trap is heated ...backflushed with the inert gas to ...ute the aromatics onto a gas ...matographic column. The gas ...matograph is temperature pro...med to separate the aromatics ...ch are then detected with a photo...zation detector[2,3].

...The method provides an optional ...chromatographic column that may ...helpful in resolving the compounds ...interest from interferences that may ...cur.

Interferences

...1 Impurities in the purge gas and ...ganic compounds out-gassing from ...e plumbing ahead of the trap account ...the majority of contamination ...oblems. The analytical system must ...e demonstrated to be free from ...ontamination under the conditions of ...e analysis by running laboratory ...eagent blanks as described in Section ...5. The use of non-TFE plastic tubing, ...on-TFE thread sealants, or flow ...ontrollers with rubber components in ...e purging device should be avoided.

...2 Samples can be contaminated by ...diffusion of volatile organics through ...he septum seal into the sample during ...hipment and storage. A field reagent ...blank prepared from reagent water and ...carried through the sampling and ...handling protocol can serve as a check ...on such contamination.

...3 Contamination by carry-over can ...occur whenever high level and low ...level samples are sequentially ...analyzed. To reduce carry-over, the ...purging device and sample syringe ...must be rinsed with reagent water ...between sample analyses. Whenever ...an unusually concentrated sample is ...encountered, it should be followed by ...an analysis of reagent water to check ...for cross contamination. For samples ...containing large amounts of water-soluble materials, suspended solids, ...high boiling compounds or high ...aromatic levels, it may be necessary to ...wash out the purging device with a ...detergent solution, rinse it with distilled ...water, and then dry it in an oven at ...105 °C between analyses. The trap ...and other parts of the system are also ...subject to contamination; therefore, ...frequent bakeout and purging of the ...entire system may be required.

4. Safety

...4.1 The toxicity or carcinogenicity of ...each reagent used in this method has ...not been precisely defined; however, ...each chemical compound should be ...treated as a potential health hazard. ...From this viewpoint, exposure to these ...chemicals must be reduced to the ...lowest possible level by whatever ...means available. The laboratory is ...responsible for maintaining a current ...awareness file of OSHA regulations ...regarding the safe handling of the ...chemicals specified in this method. A ...reference file of material data handling ...sheets should also be made available to ...all personnel involved in the chemical ...analysis. Additional references to ...laboratory safety are available and ...have been identified[4-6] for the ...information of the analyst.

4.2 The following parameters covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: benzene and 1,4-dichlorobenzene. Primary standards of these toxic compounds should be prepared in a hood. An NIOSH/MESA approved toxic gas respirator should be worn when the analyst handles high concentrations of these toxic compounds.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete sampling.

5.1.1 Vial—25-mL capacity or larger, equipped with a screw cap with hole in center (Pierce #13075 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C before use.

5.1.2 Septum—Teflon-faced silicone (Pierce #12722 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C for one hour before use.

5.2 Purge and trap device—The purge and trap device consists of three separate pieces of equipment: the sample purger, trap, and the desorber. Several complete devices are now commercially available.

5.2.1 The sample purger must be designed to accept 5-mL samples with a water column at least 3 cm deep. The gaseous head space between the water column and the trap must have a total volume of less than 15 mL. The purge gas must pass through the water column as finely divided bubbles with a diameter of less than 3 mm at the origin. The purge gas must be introduced no more than 5 mm from the base of the water column. The sample purger, illustrated in Figure 1, meets these design criteria.

5.2.2 The trap must be at least 25 cm long and have an inside diameter of at least 0.105 inch.

5.2.2.1 The trap is packed with 1 cm of methyl silicone and 23 cm 2,6-diphenylene oxide polymer as shown in Figure 2. This trap was used to develop the method performance statements in Section 12.

5.2.2.2 Alternatively, either of the two traps described in Method 601 may be used, although water vapor will preclude the measurement of low concentrations of benzene.

5.2.3 The desorber must be capable of rapidly heating the trap to 180 °C. The polymer section of the trap should not be heated higher than 180 °C and the remaining sections should not exceed 200 °C. The desorber design, illustrated in Figure 2, meets these criteria.

5.2.4 The purge and trap device may be assembled as a separate unit or be coupled to a gas chromatograph as illustrated in Figures 3, 4, and 5.

5.3 Gas chromatograph—Analytical system complete with a temperature programmable gas chromatograph suitable for on-column injection and all required accessories including syringes, analytical columns, gases, detector, and stripchart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1—6 ft long × 0.082 in ID stainless steel or glass, packed with 5% SP-1200 and 1.75% Bentone-34 on Supelcoport (100/120 mesh) or equivalent. This column was used to develop the method performance statements and the MDLs listed in Tables 1 and 2. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2—8 ft long × 0.1 in ID stainless steel or glass, packed with 5% 1,2,3-Tris(2-cyanoethoxy)propane on Chromosorb W-AW (60/80 mesh) or equivalent.

5.3.3 Detector—Photoionization detector (*h-nu* Systems, Inc. Model PI-51-02 or equivalent). This type of detector has been proven effective in the analysis of wastewaters for the parameters listed in the scope, and was used to develop the performance statements in Section 12. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes—5-mL glass hypodermic with Luerlok tip (two each), if applicable to the purge device.

United States
Environmental Protection
Agency

Environmental Monitoring and
Support Laboratory
Cincinnati OH 45268

Research and Development

EPA

Test Method

Purgeable Aromatics—Method 602

1. Scope and Application

1.1 This method covers the determination of various purgeable aromatics. The following parameters may be determined by this method:

Parameter	STORET No.	CAS No.
Benzene	34030	71-43-2
Chlorobenzene	34301	108-90-7
1,2-Dichlorobenzene	34536	95-50-1
1,3-Dichlorobenzene	34566	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Ethylbenzene	34371	100-41-4
Toluene	34010	108-88-3

1.2 This is a purge and trap gas chromatographic method applicable to the determination of the compounds listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for any or all of the compounds above, compound identifications should be supported by at least one additional qualitative technique. This method describes analytical conditions for a second gas chromatographic column that can be used to confirm measurements made with the primary column. Method 624 provides gas chromatograph/mass spectrometer (GC/MS) conditions appropriate for the qualitative and quantitative confirmation of results for all of the parameters listed above.

1.3 The method detection limit (MDL, defined in Section 12.1[1]) for each parameter is listed in Table 1. The MDL for a specific wastewater may differ from these listed depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method, beyond those expressly permitted, shall be considered as major modifications subject to application and approval for alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the operation of a purge and trap system and a gas chromatograph and in the interpretation of chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

2. Summary of Method

2.1 An inert gas is bubbled through a 5-mL water sample contained in a specially-designed purging chamber at ambient temperature. The aromatics are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent trap where the aromatics are trapped. After

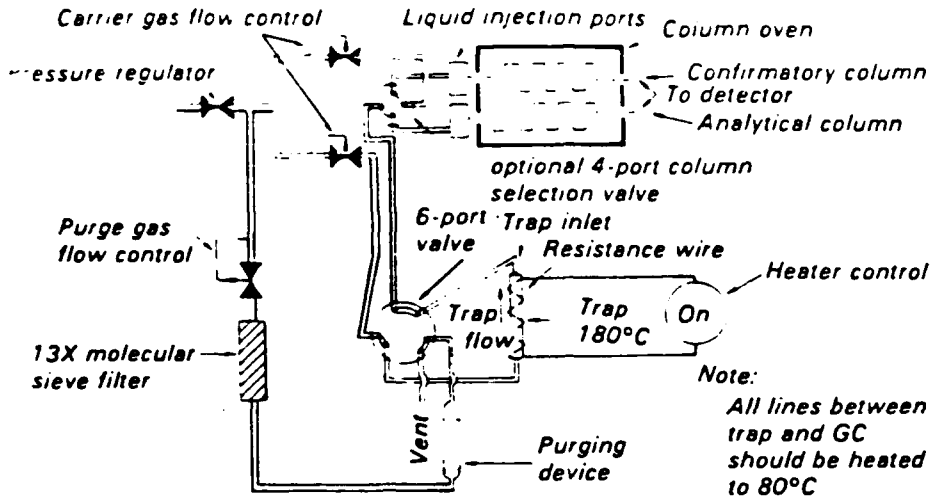


Figure 4. *Schematic of purge and trap device — desorb mode*

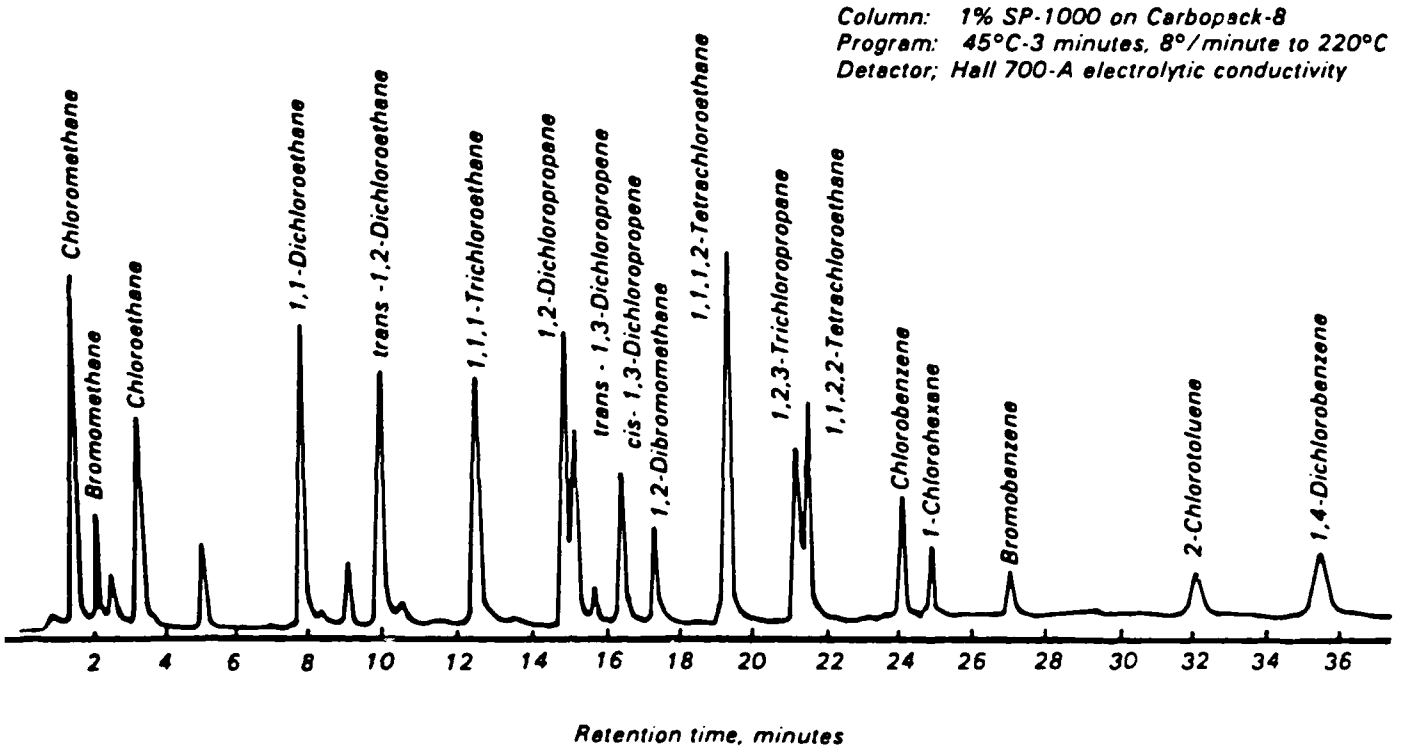
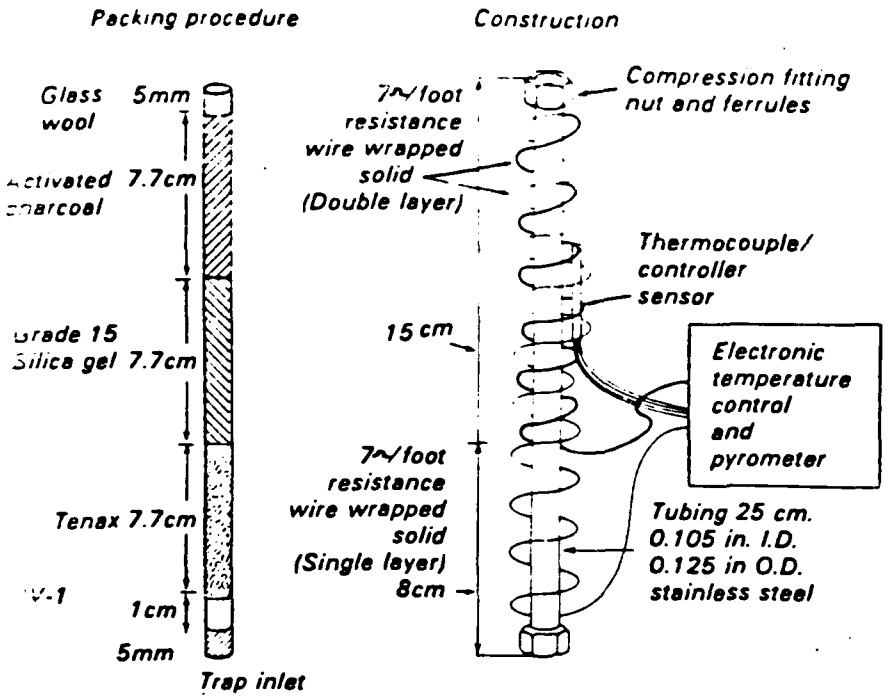


Figure 5. *Gas chromatogram of purgeable halocarbons*



2. *Trap packings and construction to include desorb capability*

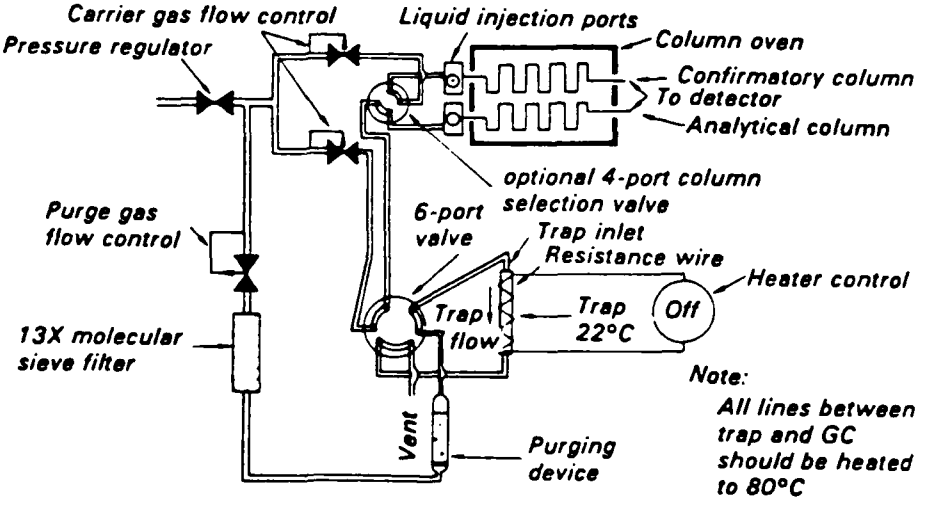


Figure 3. *Schematic of purge and trap device — purge mode*

Single Operator Accuracy and Precision

Parameter	Average Percent Recovery	Standard Deviation %	Spike Range (µg/L)	Number of Analyses	Matrix Types
[illegible]chloromethane	100.9	5.0	0.43-46.7	21	3
[illegible]orm	89.5	9.0	1.45-50	20	3
[illegible]methane	105.0	17.3	3.39-49.2	21	3
[illegible] tetrachloride	82.5	25.6	0.55-50	19	3
[illegible]benzene	93.9	8.9	2.21-50	20	3
[illegible]ethane	91.5	22.4	3.95-50	21	3
[illegible]roethylvinyl ether	96.3	9.9	4.39-133	20	3
[illegible]orm	101.7	20.6	0.44-50	20	3
[illegible]omethane	91.4	13.4	0.55-23.9	21	3
[illegible]mochloromethane	98.3	6.5	0.75-93.0	21	3
[illegible]ichlorobenzene	10.20	2.0	4.89-154	21	3
[illegible]ichlorobenzene	91.6	4.3	2.94-46.7	21	3
[illegible]ichlorobenzene	97.5	9.3	2.99-51.6	21	3
[illegible]rodifluoromethane	87.8	18.0	2.18-43.4	21	3
[illegible]ichloroethane	102.3	5.5	0.44-46.7	21	3
[illegible]ichloroethane	97.8	4.8	0.44-46.7	21	3
[illegible]ichloroethene	101.1	21.7	0.37-50	19	3
[illegible]1,2-Dichloroethene	91.0	19.3	0.44-98.0	20	3
[illegible]ichloropropane	97.7	8.8	0.29-39.0	21	3
[illegible]3-Dichloropropene	86.7	6.0	0.44-46.7	21	3
[illegible]1,3-Dichloropropene	73.5	17.2	0.43-50	20	3
[illegible]ylene chloride	97.9	2.6	0.73-46.7	21	3
[illegible]2-Tetrachloroethane	91.9	15.0	0.46-46.7	21	3
[illegible]chloroethene	94.1	18.1	0.50-35.0	21	3
[illegible]Trichloroethane	75.1	12.5	0.37-29.0	21	3
[illegible]Trichloroethane	91.0	25.1	0.45-50	21	3
[illegible]oroethene	106.1	7.4	0.38-46.7	21	3
[illegible]orofluoromethane	89.3	13.9	149	14	2
[illegible]chloride	101.9	11.4	0.82-32.3	21	3

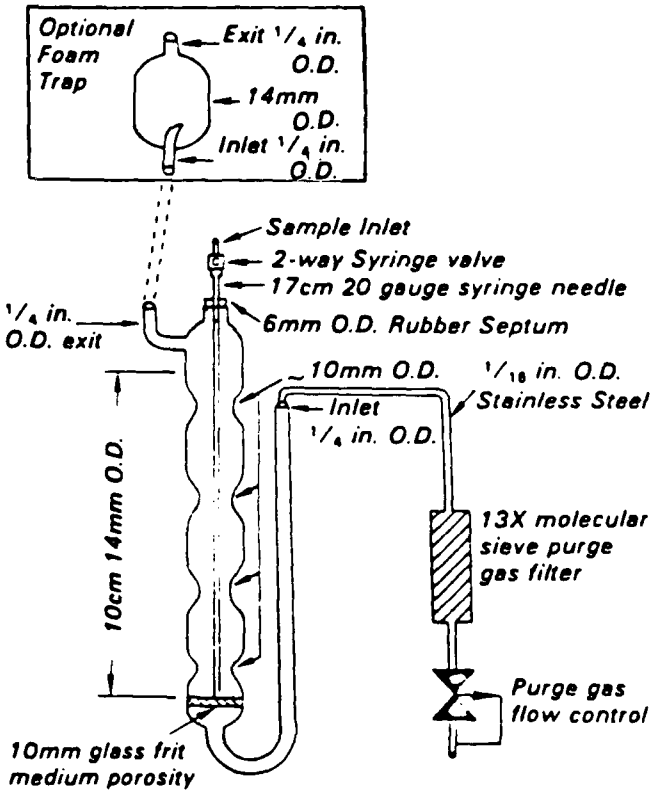


Figure 1. *Purging device*

...ntal Monitoring and Support
...– Cincinnati, Ohio 45268.
...79.
...Method Validation Study 23,
...1 (Purgeable Halocarbons),"
... EPA Contract 68-03-2856
...ration).

Table 1. Chromatographic Conditions and Method Detection Limits

Parameter	Retention Time (min.) Column 1	Retention Time (min.) Column 2	Method Detection Limit µg/L
Chloromethane	1.50	5.28	0.08
Bromomethane	2.17	7.05	1.18
Dichlorodifluoromethane	2.62	nd	1.81
Vinyl chloride	2.67	5.28	0.18
Chloroethane	3.33	8.68	0.52
Methylene chloride	5.25	10.1	0.25
Trichlorofluoromethane	7.18	nd	nd
1,1-Dichloroethene	7.93	7.72	0.13
1,1-Dichloroethane	9.30	12.6	0.07
trans-1,2-Dichloroethene	10.1	9.38	0.10
Chloroform	10.7	12.1	0.05
1,2-Dichloroethane	11.4	15.4	0.03
1,1,1-Trichloroethane	12.6	13.1	0.03
Carbon tetrachloride	13.0	14.4	0.12
Bromodichloromethane	13.7	14.6	0.10
1,2-Dichloropropane	14.9	16.6	0.04
trans-1,3-Dichloropropene	15.2	16.6	0.34
Trichloroethene	15.8	13.1	0.12
Dibromochloromethane	16.5	16.6	0.09
1,1,2-Trichloroethane	16.5	18.1	0.02
cis-1,3-Dichloropropene	16.5	18.0	0.20
2-Chloroethylvinyl ether	18.0	nd	0.13
Bromoform	19.2	19.2	0.20
1,1,2,2-Tetrachloroethane	21.6	nd	0.03
Tetrachloroethene	21.7	15.0	0.03
Chlorobenzene	24.2	18.8	0.25
1,3-Dichlorobenzene	34.0	22.4	0.32
1,2-Dichlorobenzene	34.9	23.5	0.15
1,4-Dichlorobenzene	35.4	22.3	0.24

nd = not determined

Column 1 conditions: Carbopack B 60/80 mesh coated with 1% SP-1000 packed in an 8 ft × 0.1 in ID stainless steel or glass column with helium carrier gas at 40 mL/min flow rate. Column temperature held at 45°C for 3 min. then programmed at 8°C/min. to 220° and held for 15 min.

Column 2 conditions: Porasil-C 100/120 mesh coated with n-octane packed in a 6 ft × 0.1 in ID stainless steel or glass column with helium carrier gas at 40 mL/min flow rate. Column temperature held at 50°C for 3 min then programmed at 6°C/min to 170° and held for 4 min.

syringe plunger and compress the sample. Open the syringe valve and vent any residual air while adjusting sample volume to 5.0 mL. Since this process of taking an aliquot destroys the validity of the sample for future analysis, the analyst should fill a second syringe at this time to protect against possible loss of data. Add 10.0 µL of the surrogate spiking solution (8.7) and 10.0 µL of the internal standard spiking solution (Section 7.4.2), if applicable, through the valve bore, then close the valve.

10.5 Attach the syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject the sample into the purging chamber.

10.6 Close both valves and purge the sample for 11.0 ± .1 minutes at ambient temperature.

10.7 After the 11-minute purge time, attach the trap to the chromatograph, adjust the device to the desorb mode, and begin to temperature program the gas chromatograph. Introduce the trapped materials to the GC column by rapidly heating the trap to 180 °C while backflushing the trap with an inert gas between 20 and 60 mL/min for four minutes. If rapid heating of the trap cannot be achieved, the gas chromatographic column must be used as a secondary trap by cooling it to 30 °C (subambient temperature, if poor peak geometry or random retention time problems persist) instead of the initial program temperature of 45 °C.

10.8 While the trap is being desorbed into the gas chromatograph, empty the purging chamber using the sample introduction syringe. Wash the chamber with two 5-mL flushes of reagent water.

10.9 After desorbing the sample for four minutes recondition the trap by returning the purge and trap device to the purge mode. Wait 15 seconds then close the syringe valve on the purging device to begin gas flow through the trap. The trap temperature should be maintained at 180 °C. After approximately seven minutes turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When cool the trap is ready for the next sample.

10.10 The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time for a compound can be used to calculate a suggested window size, however, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

10.11 If the response for the peak exceeds the working range of the system, prepare a dilution of the sample with reagent water from the aliquot in the second syringe and reanalyze.

11. Calculations

11.1 Determine the concentration of individual compounds in the sample.

11.1.1 If the external standard calibration procedure is used, calculate the concentration of material from the peak response using the calibration curve or calibration factor determined in Section 7.3.2.

11.1.2 If the internal standard calibration procedure was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and equation 2.

Eq. 2.

Concentration $\mu g/L = (A_s C_{is})/(A_{is})(RF)$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_s = Concentration of the internal standard.

11.2 Report results in micrograms per liter. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

11.3 For samples processed as part of a set where the spiked sample recovery falls outside of the control limits which were established according to Section 8.3, data for the affected parameters must be labeled as suspect.

12. Method Performance

12.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.[1] The MDL concentrations listed in Table 1 were obtained using reagent water.[9] Similar results were achieved using representative wastewaters. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and matrix effects.

12.2 This method is recommended for use in the concentration range from the MDL up to 1000 × MDL. Direct aqueous injection techniques should be used to measure concentration levels above 1000 × MDL.

12.3 In a single laboratory (Monsanto Research), using reagent water and wastewaters spiked at or near background levels, the average recoveries presented in Table 2 were obtained.[9] The standard deviation of the measurement in percent recovery is also included in Table 2.[9]

12.4 The U.S. Environmental Protection Agency is in the process of conducting an interlaboratory method study to fully define the performance of this method.

References

1. See Appendix A.
2. Bellar, T.A., and Lichtenberg, J.J. *Journal American Water Works Association, 66,* 739, (1974).
3. Bellar, T.A., and Lichtenberg, J.J. "Semi-Automated Headspace Analysis of Drinking Waters and Industrial Waters for Purgeable Volatile Organic Compounds," Proceedings from *Symposium on Measurement of* Organic Pollutants in Water and Wastewater, American Society for Testing and Materials, STP 686, C.E. Van Hall, editor, 1978.
4. "Carcinogens—Working With Carcinogens," Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Publication No. 77-206, Aug. 1977.
5. "OSHA Safety and Health Standards, General Industry," (29 CFR 1910), Occupational Safety and Health Administration, OSHA 2206, (Revised, January 1976).
6. "Safety in Academic Chemistry Laboratories," American Chemical Society Publication, Committee on Chemical Safety, 3rd Edition, 1979.
7. "Handbook for Analytical Quality Control in Water and Wastewater Laboratories," EPA-600/4-79-019, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory—Cincinnati, Ohio 45268, March 1979.
8. "Methods 330.4 (Titrimetric, DPD-FAS) and 330.5 (Spectrophotometric, DPD) for Chlorine, Total Residual," Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, U.S. Environmental Protection Agency,

water may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery, (R), and the standard deviation of the percent recovery (s), for the results. Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Using Table 2, note the average recovery (X) and standard deviation (p) expected for each method parameter. Compare these to the calculated values for R and s. If $s > 2p$ or $|X - R| > 2p$, review potential problem areas and repeat the test.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.2.5 The U.S. Environmental Protection Agency plans to establish performance criteria for R and s based upon the results of interlaboratory testing. When they become available, these criteria must be met before any samples may be analyzed.

8.3.1 Calculate upper and lower control limts for method performance:

$$\text{Upper Control Limit (UCL)} = R + 3s$$
$$\text{Lower Control Limit (LCL)} = R - 3s$$

where R and s are calculated as in Section 8.2.3. The UCL and LCL can be used to construct control charts[7] that are useful in observing trends in performance. The control limits above must be replaced by method performance criteria as they become available from the U.S. Environmental Protection Agency.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as $R \pm s$. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternately, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in Section 8.4. The accuracy statements should be updated regularly.[7]

8.4 The laboratory is required to collect a portion of their samples in duplicate to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the recovery for a particular parameter does not fall within the control limits for method performance, the results reported for that parameter in all samples processed as part of the same set must be qualified as described in Section 11.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Each day, the analyst must demonstrate through the analysis of reagent water, that interferences from the analytical system are under control.

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to monitor the precision of the sampling technique. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should perform analysis of standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should maintain constant surveillance of both the performance of the analytical system and the effectiveness of the method in dealing with each sample matrix by spiking each sample, standard and blank with surrogate halocarbons. A combination of bromochloromethane, 2-bromo-1-chloropropane, and 1,4-dichlorobutane is recommended to encompass the range of the temperature program used in this method. From stock standard solutions prepared as above, add a volume to give 7500 μg of each surrogate to 45 mL of reagent water contained in a 50-mL volumetric flask, mix and dilute to volume (15 ng/μL). If the internal standard calibration procedure is being used, the surrogate compounds may be added directly to the internal standard spiking solution (Section 7.4.2). Add 10 μL of this surrogate spiking solution directly into the 5-mL syringe with every sample and reference standard analyzed. Prepare a fresh surrogate spiking solution on a weekly basis.

9. Sample Collection, Preservation, and Handling

9.1 All samples must be iced or refrigerated from the time of collection until extraction. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl_2) to the empty sample bottle just prior to shipping to the sampling site. USEPA methods 330.4 and 330.5 may be used for measurement of residual chlorine.[8] Field test kits are available for this purpose.

9.2 Grab samples must be collected in glass containers having a total volume of at least 25 mL. Fill the sample bottle just to overflowing in such a manner that no air bubbles pass through the sample as the bottle is being filled. Seal the bottle so that no air bubbles are entrapped in it. If preservative has been added, shake vigorously for one minute. Maintain the hermetic seal on the sample bottle until time of analysis.

9.3 All samples must be analyzed within 14 days of collection.

10. Sample Extraction and Gas Chromatography

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this Table are estimated retention times and method detection limits that can be achieved by this method. An example of the separations achieved by Column 1 is shown in Figure 5. Other packed columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

10.2 Calibrate the system daily as described in Section 7.

10.3 Adjust the purge gas (nitrogen or helium) flow rate to 40 mL/min. Attach the trap inlet to the purging device, and set the device to purge. Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow sample to come to ambient temperature prior to introducing it to the syringe. Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample bottle (or standard) and carefully pour the sample into the syringe barrel to just short of overflowing. Replace the

7. Calibration

7.1 Assemble a purge and trap device that meets the specifications in Section 5.2. Condition the trap overnight at 180 °C by backflushing with an inert gas flow of at least 20 mL/min. Prior to use, daily condition traps 10 minutes while backflushing at 180 °C.

7.2 Connect the purge and trap device to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate parameters equivalent to those in Table 1. Calibrate the purge and trap-gas chromatographic system using either the external standard technique (Section 7.3) or the internal standard technique (Section 7.4).

7.3 External standard calibration procedure:

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter by carefully adding 20.0 µL of one or more secondary dilution standards to 100, 500, or 1000 mL of reagent water. A 25-µL syringe with a 0.006 inch ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the method detection limit (See Table 1) and the other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector. These aqueous standards can be stored up to 24 hours, if held in sealed vials with zero headspace as described in Section 9.2. If not so stored, they must be discarded after one hour.

7.3.2 Analyze each calibration standard according to Section 10, and tabulate peak height or area responses versus the concentration in the standard. The results can be used to prepare a calibration curve for each compound. Alternatively, if the ratio of response to concentration (calibration factor) is a constant over the working range (≤10% relative standard deviation, RSD), linearity through the origin can be assumed and the average ratio or calibration factor can be used in place of a calibration curve.

7.3.3 The working calibration curve or calibration factor must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ± 10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared for that parameter.

7.4 Internal standard calibration procedure. To use this approach, the analyst must select one or more internal standards that are similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Because of these limitations, no internal standard can be suggested that is applicable to all samples. The compounds recommended for use as surrogate spikes in Section 8.7 have been used successfully as internal standards, because of their generally unique retention times.

7.4.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest as described in Section 7.3.1.

7.4.2 Prepare a spiking solution containing each of the internal standards using the procedures described in Sections 6.5 and 6.6. It is recommended that the secondary dilution standard be prepared at a concentration of 15 µg/mL of each internal standard compound. The addition of 10 µL of this standard to 5.0 mL of sample or calibration standard would be equivalent to 30 µg/L.

7.4.3 Analyze each calibration standard, according to Section 10, adding 10 µL of internal standard spiking solution directly to the syringe (Section 10.4). Tabulate peak height or area responses against concentration for each compound and internal standard, and calculate response factors (RF) for each compound using equation 1.

$$\text{Eq. 1 } RF = (A_s C_{is})/(A_{is} C_s)$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
C_{is} = Concentration of the internal standard.
C_s = Concentration of the parameter to be measured.

If the RF value over the working range is a constant (≤10% RSD), the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios, A_s/A_{is}, vs. RF.

7.4.4 The working calibration curve or RF must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ± 10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared for that compound.

8. Quality Control

8.1 Each laboratory that uses this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated. Ongoing performance checks must be compared with established performance criteria to determine if the results of analyses are within accuracy and precision limits expected of the method.

8.1.1 Before performing any analyses, the analyst must demonstrate the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of the rapid advances that are occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications are made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in methyl alcohol 500 times more concentrated than the selected concentrations. Quality control check sample concentrates, appropriate for use with this method, will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268

8.2.2 Using a syringe, add 10 µL of the check sample concentrate to each of a minimum of four 5-mL aliquots of reagent water. A representative waste-

not be heated higher than 180 °C and the remaining sections should not exceed 220 °C. The desorber design, illustrated in Figure 2, meets these criteria.

5.2.4 The purge and trap device may be assembled as a separate unit or be coupled to a gas chromatograph as illustrated in Figures 3 and 4.

5.3 Gas chromatograph—An analytical system complete with a temperature programmable gas chromatograph suitable for on-column injection and all required accessories including syringes, analytical columns, gases, detector, and strip-chart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1—8 ft long × 0.1 in ID stainless steel or glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh) or equivalent. This column was used to develop the method performance statements in Section 12. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2—6 ft long × 0.1 in ID stainless steel or glass, packed with chemically bonded n-octane on Porasil-C (100/120) mesh or equivalent.

5.3.3 Detector—Electrolytic conductivity or microcoulometric. These types of detectors have proven effective in the analysis of wastewaters for the parameters listed in the scope. The electrolytic conductivity detector was used to develop the method performance statements and MDL listed in Tables 1 and 2. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes—5-mL glass hypodermic with Luerlok tip (two each), if applicable to the purging device.

5.5 Micro syringes—25 μL, 0.006 in ID needle.

5.6 Syringe valve—2-way, with Luer ends (three each).

5.7 Syringe—5-mL, gas-tight with shut-off valve.

5.8 Bottle—15-mL, screw cap, with Teflon cap liner.

5.9 Balance—Analytical, capable of accurately weighing 0.0001 g.

6. Reagents

6.1 Reagent water—Reagent water is defined as a water in which an interferent is not observed at the MDL of the parameters of interest.

6.1.1 Reagent water can be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon (Filtrasorb-300 or equivalent (Calgon Corp.)).

6.1.2 A water purification system (Millipore Super-Q or equivalent) may be used to generate reagent water.

6.1.3 Reagent water may also be prepared by boiling water for 15 minutes. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for one hour. While still hot, transfer the water to a narrow mouth screw-cap bottle and seal with a Teflon-lined septum and cap.

6.2 Sodium thiosulfate—(ACS) Granular.

6.3 Trap Materials

6.3.1 Coconut charcoal (6/10 mesh sieved to 26 mesh), (Barnaby Chaney, CA-580-26 lot # M-2649 or equivalent).

6.3.2 2,6-Diphenylene oxide polymer—Tenax, (60/80 mesh), chromatographic grade or equivalent.

6.3.3 Methyl silicone packing—3% OV-1 on 60/80 mesh Chromosorb-W or equivalent.

6.3.4 Silica gel—35/60 mesh, Davison, grade-15 or equivalent.

6.4 Methyl Alcohol—Pesticide quality or equivalent.

6.5 Stock standard solutions—Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions. Prepare stock standard solutions in methyl alcohol using assayed liquids or gas cylinders as appropriate. Because of the toxicity of some of the organohalides, primary dilutions of these materials should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be used when the analyst handles high concentrations of such materials.

6.5.1 Place about 9.8 mL of methyl alcohol into a 10-mL ground glass stoppered volumetric flask. Allow the flask to stand, unstoppered, for about 10 minutes or until all alcohol wetted surfaces have dried. Weigh the flask to the nearest 0.1 mg.

6.5.2 Add the assayed reference material:

6.5.2.1 Liquids—Using a 100-μL syringe, immediately add two or more drops of assayed reference material to the flask, then reweigh. Be sure that the drops fall directly into the alcohol without contacting the neck of the flask.

6.5.2.2 Gases—To prepare standards for any of the six halocarbons that boil below 30 °C (bromomethane, chloroethane, chloromethane, dichlorodifluoromethane, trichlorofluoromethane, vinyl chloride), fill a 5-mL valved gas-tight syringe with the reference standard to the 5.0-mL mark. Lower the needle to 5 mm above the methyl alcohol meniscus. Slowly introduce the reference standard above the surface of the liquid (the heavy gas will rapidly dissolve into the methyl alcohol).

6.5.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in micrograms per microliter from the net gain in weight. When compound purity is assayed to be 96% or greater, the weight can be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards can be used at any concentration if they are certified by the manufacturer or by an independent source.

6.5.4 Transfer the stock standard solution into a Teflon-sealed screw-cap bottle. Store, with minimal headspace, at −10 to −20 °C and protect from light.

6.5.5 Prepare fresh standards weekly for the six gases and 2-chloroethylvinyl ether. All other standards must be replaced after one month, or sooner if comparison with check standards indicate a problem.

6.6 Secondary dilution standards—Using stock standard solutions, prepare secondary dilution standards in methyl alcohol that contain the compounds of interest, either singly or mixed together. The secondary dilution standards should be prepared at concentrations such that the aqueous calibration standards prepared in Sections 7.3.1 or 7.4.1 will bracket the working range of the analytical system. Secondary dilution standards should be stored with minimal headspace and should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them. Quality control check standards that can be used to determine the accuracy of calibration standards will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, in Cincinnati, Ohio.

technique. This method describes analytical conditions for a second gas chromatographic column that can be used to confirm measurements made with the primary column. Method 624 provides gas chromatograph/mass spectrometer (GC/MS) conditions appropriate for the qualitative and quantitative confirmation of results for most of the parameters listed above.

1.3 The method detection limit (MDL, defined in Section 12.1)[1] for each parameter is listed in Table 1. The MDL for a specific wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method, beyond those expressly permitted, shall be considered as major modifications subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the operation of a purge and trap system and a gas chromatograph and in the interpretation of chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

2. Summary of Method

2.1 An inert gas is bubbled through a 5-mL water sample contained in a specially-designed purging chamber at ambient temperature. The halocarbons are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent trap where the halocarbons are trapped. After purging is completed, the trap is heated and backflushed with the inert gas to desorb the halocarbons onto a gas chromatographic column. The gas chromatograph is temperature programmed to separate the halocarbons which are then detected with a halide-specific detector.[2,3]

2.2 The method provides an optional gas chromatographic column that may be helpful in resolving the compounds of interest from interferences that may occur.

3. Interferences

3.1 Impurities in the purge gas and organic compounds out-gassing from the plumbing ahead of the trap account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.5. The use of non-TFE plastic tubing, non-TFE thread sealants, or flow controllers with rubber components in the purging device should be avoided.

3.2 Samples can be contaminated by diffusion of volatile organics (particularly fluorocarbons and methylene chloride) through the septum seal into the sample during shipment and storage. A field reagent blank prepared from reagent water and carried through the sampling and handling protocol can serve as a check on such contamination.

3.3 Contamination by carry-over can occur whenever high level and low level samples are sequentially analyzed. To reduce carry-over, the purging device and sample syringe must be rinsed with reagent water between sample analyses. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of reagent water to check for cross contamination. For samples containing large amounts of water-soluble materials, suspended solids, high boiling compounds or high organohalide levels, it may be necessary to wash out the purging device with a detergent solution, rinse it with distilled water, and then dry it in a 105 °C oven between analyses. The trap and other parts of the system are also subject to contamination; therefore, frequent bakeout and purging of the entire system may be required.

4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified[4-6] for the information of the analyst.

4.2 The following parameters covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: carbon tetrachloride, chloroform, 1,4-dichlorobenzene, and vinyl chloride. Primary standards of these toxic compounds should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be worn when the analyst handles high concentrations of these toxic compounds.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete sampling.

5.1.1 Vial—25-mL capacity or larger, equipped with a screw cap with hole in center (Pierce #13075 or equivalent). Detergent wash, rinse cap with tap and distilled water, and dry at 105 °C before use.

5.1.2 Septum—Teflon-faced silicone (Pierce #12722 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C for one hour before use.

5.2 Purge and trap device—The purge and trap device consists of three separate pieces of equipment: the sample purger, trap, and the desorber. Several complete devices are now commercially available.

5.2.1 The sample purger must be designed to accept 5-mL samples with a water column at least 3 cm deep. The gaseous head space between the water column and the trap must have a total volume of less than 15-mL. The purge gas must pass through the water column as finely divided bubbles with a diameter of less than 3 mm at the origin. The purge gas must be introduced no more than 5 mm from the base of the water column. The sample purger, illustrated in Figure 1, meets these design criteria.

5.2.2 The trap must be at least 25 cm long and have an inside diameter of at least 0.105 inch. The trap must be packed to contain the following minimum lengths of adsorbents: 1.0 cm of methyl silicone coated backing (Section 6.3.3), 7.7 cm of 2,6-diphenylene oxide polymer (Section 6.3.2), 7.7 cm of silica gel, 7.7 gm of coconut charcoal (Section 6.3.1). If it is not necessary to analyze for dichlorodifluoromethane, the charcoal can be eliminated, and the polymer section lengthened to 15 cm. The minimum specifications for the trap are illustrated in Figure 2.

5.2.3 The desorber must be capable of rapidly heating the trap to 180 °C. The polymer section of the trap should

United States
Environmental Protection
Agency

Environmental Monitoring and
Support Laboratory
Cincinnati OH 45268

Research and Development

EPA

Test Method

Purgeable Halocarbons—Method 601

1. Scope and Application

1.1 This method covers the determination of 29 purgeable halocarbons. The following parameters may be determined by this method:

Parameter	STORET No.	CAS No.
Bromodichloromethane	32101	75-27-4
Bromoform	32104	75-25-2
Bromomethane	34413	74-83-9
Carbon tetrachloride	32102	56-23-5
Chlorobenzene	34301	108-90-7
Chloroethane	34311	75-00-3
2-Chloroethylvinyl ether	34576	100-75-8
Chloroform	32106	67-66-3
Chloromethane	34418	74-87-3
Dibromochloromethane	32105	124-48-1
1,2-Dichlorobenzene	34536	95-50-1
1,3-Dichlorobenzene	34566	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Dichlorodifluoromethane	34668	75-71-8
1,1-Dichloroethane	34496	75-34-3
1,2-Dichloroethane	34531	107-06-2
1,1-Dichloroethene	34501	75-35-4
trans-1,2-Dichloroethene	34546	156-60-5
1,2-Dichloropropane	34541	78-87-5
cis-1,3-Dichloropropene	34704	10061-01-5
trans-1,3-Dichloropropene	34699	10061-02-6
Methylene chloride	34423	75-09-2
1,1,2,2-Tetrachloroethane	34516	79-34-5
Tetrachloroethene	34475	127-18-4
1,1,1-Trichloroethane	34506	71-55-6
1,1,2-Trichloroethane	34511	79-00-5
Trichloroethene	39180	79-01-6
Trichlorofluoromethane	34488	75-69-4
Vinyl chloride	39175	75-01-4

1.2 This is a purge and trap gas chromatographic method applicable to the determination of the compounds listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for any or all of the compounds above, compound identification should be supported by at least one additional qualitative

418 B. Nitrate Electrode Screening Method

1. General Discussion

a. Principle: The NO_3^- ion electrode is a selective sensor that develops a potential across a thin, porous, inert membrane that holds in place a water-immiscible liquid ion exchanger. The electrode responds only to NO_3^- ion activity between about 10^{-5} and 10^{-1} *M* (0.14 to 1,400 mg NO_3^--N/L). The lower limit of detection is determined by the small but finite solubility of the liquid ion exchanger.

b. Interferences: Chloride and bicarbonate ions interfere when their ratios to NO_3^--N are >10 or >5, respectively. Ions that are potential interferences but do not normally occur at significant levels in potable waters are NO_2^-, CN^-, S^{2-}, Br^-, I^-, ClO_3^-, and ClO_4^-. Although the electrodes function satisfactorily in buffers over the range pH 3 to 9, erratic responses have been noted where pH is not held constant. Because the electrode responds to NO_3^- activity rather than concentration, ionic strength must be constant in all samples and standards. Minimize these problems by using a buffer solution containing Ag_2SO_4, to remove Cl^-, Br^-, I^-, S^{2-}, and CN^-, sulfamic acid to remove NO_2^-, a buffer at pH 3 to eliminate HCO_3^- and to maintain a constant pH and ionic strength, and $Al_2(SO_4)_3$ to complex organic acids.

2. Apparatus

a. pH meter, expanded-scale or digital, capable of reading 0.1 mV.

*b. Single-junction reference electrode.** Fill chamber with saturated K_2SO_4.

c. Nitrate ion electrode:† (NOTE: Carefully follow manufacturer's instructions regarding care, storage, and recharge of electrode.)

d. Magnetic stirrer: TFE-coated stirring bar.

3. Reagents

a. Nitrate-free water: Prepare as described in Section 418A.3*a*. Use for all solutions and dilutions.

b. Stock nitrate solution: Prepare as described in Section 418A.3*b*.

c. Standard nitrate solutions: Dilute 1.0, 10, and 50 mL stock nitrate solution to 100 mL with water to obtain standards solutions of 1.0, 10, and 50 mg NO_3^--N/L, respectively.

d. Buffer solution: Dissolve 6.66 g $Al_2(SO_4)_3 \cdot 18H_2O$, 3.12 g Ag_2SO_4, 1.24 g H_3BO_3, and 1.94 g sulfamic acid (H_2NSO_3H), in about 400 mL water. Adjust to pH 3.0 by slowly adding 0.10 *N* NaOH. Dilute to 1,000 mL.

e. Sodium hydroxide, NaOH, 0.1 *N*.

4. Procedure

a. No major adjustment of any instrument normally is required to use the electrodes in the concentration range of 1.0 to 50 mg NO_3^--N/L.

b. Preparation of calibration curve: Transfer 10 mL of 1 mg NO_3^--N/L standard to a 50-mL beaker, add 10 mL buffer, and stir for a constant time (2 or 3 min) with a magnetic stirrer. Immerse tips of electrodes and record millivolt reading after 1 min. Remove electrodes, rinse, and blot dry. Repeat for 10 mg NO_3^--N/L and 50 mg NO_3^--N/L standards. Plot potential measurements against NO_3^--N concentration on two-cycle semilogarithmic graph paper, with NO_3^--N concentration on the logarithmic axis (abscissa) and potential (in millivolts) on the linear axis (ordinate). A straight line with a slope of +59 (+58 to +59 for solutions at 24 to 26 C) mV/decade should result. Recalibrate electrodes several times daily by checking potential reading of the 10 mg NO_3^--N standard and adjusting the calibration control on the meter until the reading plotted on the calibration curve is displayed again.

c. Measurement of sample: Transfer 10 mL sample to a 50-mL beaker, add 10 mL buffer solution, and stir with a magnetic stirrer for a constant time (2 or 3 min). Immerse electrode tips in sample and record potential reading after 1 min. Read concentration from calibration curve.

*Orion Model 90-01, Radiometer Model 601, or equivalent.

†Orion Model 92-07, Corning Model 476134, or equivalent.

from Standard Methods for the Examination of Water & Wastewater
15th Edition, pp. 369-370 .

6.3.3 Above 50 mg/l the accuracy decreases and the suspensions lose stability.

6.3.4 Check reliability of calibration curve by running a standard with every 3 or 4 samples.

6.4 Correction for sample color and turbidity.

6.4.1 Run a sample blank using the procedure 6.1 and 6.2 without the addition of barium chloride (6.1.4).

7. Calculations

7.1 Read mg SO_4 from calibration curve

$$\text{mg } SO_4/l = \frac{\text{mg } SO_4 \times 1{,}000}{\text{ml sample}}$$

8. Precision and Accuracy

8.1 Thirty-four analysts in 16 laboratories analyzed six synthetic water samples containing exact increments of inorganic sulfate with the following results:

Increment as Sulfate mg/liter	Precision as Standard Deviation mg/liter	Accuracy as Bias, %	Accuracy as Bias mg/liter
8.6	2.30	-3.72	-0.3
9.2	1.78	-8.26	-0.8
110	7.86	-3.01	-3.3
122	7.50	-3.37	-4.1
188	9.58	+0.04	+0.1
199	11.8	-1.70	-3.4

(FWPCA Method Study 1, Mineral and Physical Analyses).

8.2 A synthetic unknown sample containing 259 mg/l sulfate, 108 mg/l Ca, 82 mg/l Mg, 3.1 mg/l K, 19.9 mg/l Na, 241 mg/l chloride, 0.250 mg/l nitrite N, 1.1 mg/l nitrate N, and 42.5 mg/l total alkalinity (contributed by $NaHCO_3$) was analyzed in 19 laboratories by the turbidimetric method, with a relative standard deviation of 9.1% and a relative error of 1.2%.

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D516–68, Method B, p 430 (1976).
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 496, Method 427C, (1975).

5.5 Micro syringes—25 µL, 0.006 in ID needle.

5.6 Syringe valve—2-way, with Luer ends (three each).

5.7 Bottle—15-mL screw-cap with Teflon cap liner.

5.8 Balance—Analytical, capable of accurately weighing 0.0001 g.

6. Reagents

6.1 Reagent water—Reagent water is defined as a water in which an interferent is not observed at the MDL of the parameters of interest.

6.1.1 Reagent water can be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon. (Filtrasorb-300 or equivalent (Calgon Corp.)).

6.1.2 A water purification system (Millipore Super-Q or equivalent) may be used to generate reagent water.

6.1.3 Reagent water may also be prepared by boiling water for 15 minutes. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for one hour. While still hot, transfer the water to a narrow mouth screw-cap bottle and seal with a Teflon-lined septum and cap.

6.2 Sodium thiosulfate—(ACS) Granular.

6.3 Hydrochloric acid (1 + 1)—Add 50 mL of concentrated HCl to 50 mL of reagent water.

6.4 Trap Materials

6.4.1 2,6-Diphenylene oxide polymer-Tenax, (60/80 mesh) chromatographic grade or equivalent.

6.4.2 Methyl silicone—3% OV-1 on Chromosorb-W (60/80 mesh) or equivalent.

6.5 Methyl alcohol—Pesticide quality or equivalent.

6.6 Stock standard solutions—Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions. Prepare stock standard solutions in methyl alcohol using assayed liquids. Because benzene and 1,4-dichlorobenzene are suspected carcinogens, primary dilutions of these materials should be prepared in a hood.

6.6.1 Place about 9.8 mL of methyl alcohol into a 10-mL ground glass stoppered volumetric flask. Allow the flask to stand, unstoppered, for about 10 minutes or until all alcohol wetted surfaces have dried. Weigh the flask to the nearest 0.1 mg.

6.6.2 Using a 100-µL syringe, immediately add two or more drops of assayed reference material to the flask, then reweigh. Be sure that the drops fall directly into the alcohol without contacting the neck of the flask.

6.6.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in micrograms per microliter from the net gain in weight. When compound purity is certified at 96% or greater, the weight can be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards can be used, at any concentration, if they are certified by the manufacturer or by an independent source.

6.6.4 Transfer the stock standard solution into a Teflon-sealed screw-cap bottle. Store at 4 °C and protect from light.

6.6.5 All standards must be replaced after one month, or sooner if comparison with check standards indicate a problem.

6.7 Secondary dilution standards—Using stock standard solutions, prepare secondary dilution standards in methyl alcohol that contain the compounds of interest, either singly or mixed together. The secondary dilution standards should be prepared at concentrations such that the aqueous calibration standards prepared in Sections 7.3.1 or 7.4.1 will bracket the working range of the analytical system. Secondary solution standards must be stored with zero headspace and should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them. Quality control check standards that can be used to determine the accuracy of calibration standards will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, in Cincinnati, Ohio.

7. Calibration

7.1 Assemble a purge and trap device that meets the specifications in Section 5.2. Condition the trap overnight at 180 °C by backflushing with an inert gas flow of at least 20 mL/min. Prior to use, daily condition traps 10 minutes while backflushing at 180 °C.

7.2 Connect the purge and trap device to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate parameters equivalent to those in Table 1. Calibrate the purge and trap-gas chromatographic system using either the external standard technique (Section 7.3) or the internal standard technique (Section 7.4.).

7.3 External standard calibration procedure:

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter by carefully adding 20.0 µL of one or more secondary dilution standards to 100, 500, or 1000 mL of reagent water. A 25-µL syringe with a 0.006 inch ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the MDL (see Table 1) and the other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector. These aqueous standards must be prepared fresh daily.

7.3.2 Analyze each calibration standard according to Section 10, and tabulate peak height or area responses versus the concentration in the standard. The results can be used to prepare a calibration curve for each compound. Alternatively, if the ratio of response to concentration (calibration factor) is a constant over the working range ($\leq$10% relative standard deviation, RSD), linearity through the origin can be assumed and the average ratio or calibration factor can be used in place of a calibration curve.

7.3.3 The working calibration curve or calibration factor must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ± 10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared for that parameter.

7.4 Internal standard calibration procedure. To use this approach, the analyst must select one or more internal standards that are similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Because of these limitations, no internal standard can be suggested that

is applicable to all samples. The compound, α,α,α-trifluorotoluene, recommended as a surrogate spiking compound in Section 8.7 has been used successfully as an internal standard.

7.4.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest as described in Section 7.3.1.

7.4.2 Prepare a spiking solution containing each of the internal standards using the procedures described in Sections 6.6 and 6.7. It is recommended that the secondary dilution standard be prepared at a concentration of 15 μg/mL of each internal standard compound. The addition of 10 μL of this standard to 5.0 mL of sample or calibration standard would be equivalent to 30 μg/L.

7.4.3 Analyze each calibration standard, according to Section 10, adding 10 μL of internal standard spiking solution directly to the syringe as indicated in Section 10.4. Tabulate peak height or area responses against concentration for each compound and internal standard, and calculate response factors (RF) for each compound using equation 1.

$$\text{Eq. 1 } RF = (A_s C_{is})/(A_{is} C_s)$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
C_{is} = Concentration of the internal standard.
C_s = Concentration of the parameter to be measured.

If the RF value over the working range is a constant (<10% RSD), the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios, A_s/A_{is}, vs. RF.

7.4.4 The working calibration curve or RF must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared for that compound.

8. Quality Control

8.1 Each laboratory that uses this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated. Ongoing performance checks must be compared with established performance criteria to determine if the results of analyses are within accuracy and precision limits expected of the method.

8.1.1 Before performing any analyses, the analyst must demonstrate the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of the rapid advances that are occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications are made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in methyl alcohol 500 times more concentrated than the selected concentrations. Quality control check sample concentrates, appropriate for use with this method, will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268.

8.2.2 Using a syringe, add 10 μL of the check sample concentrate to each of a minimum of four 5-mL aliquots of reagent water. A representative wastewater may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery, (R), and the standard deviation of the percent recovery (s), for the results. Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Using Table 2, note the average recovery (X) and standard deviation (p) expected for each method parameter. Compare these to the calculated values for R and s. If $s > 2p$ or $|X - R| > 2p$, review potential problem areas and repeat the test.

8.2.5 The U.S. Environmental Protection Agency plans to establish performance criteria for R and s based upon the results of interlaboratory testing. When they become available, these criteria must be met before any samples may be analyzed.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.3.1 Calculate upper and lower control limits for method performance:

Upper Control Limit (UCL) = R + 3s
Lower Control Limit (LCL) = R − 3s

where R and s are calculated as in Section 8.2.3

The UCL and LCL can be used to construct control charts[7] that are useful in observing trends in performance. The control limits above must be replaced by method performance criteria as they become available from the U.S. Environmental Protection Agency.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as R ± s. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternately, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in Section 8.4. The accuracy statements should be updated regularly[7].

8.4 The laboratory is required to collect a portion of their samples in duplicate to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the recovery for a particular parameter does not fall within the control limits for method performance, the results

reported for that parameter in all samples processed as part of the same set must be qualified as described in Section 11.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Each day, the analyst must demonstrate through the analysis of reagent water, that interferences from the analytical system are under control.

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to monitor the precision of the sampling technique. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should perform analysis of standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should maintain constant surveillance of both the performance of the analytical system and the effectiveness of the method in dealing with each sample matrix by spiking each sample, standard and blank with surrogate compounds (e.g. α,α,α-trifluorotoluene). From stock standard solutions prepared as above, add a volume to give 7500 μg of each surrogate to 45 mL of organic-free water contained in a 50-mL volumetric flask, mix and dilute to volume (15 ng/μL). If the internal standard calibration procedure is being used, the surrogate compounds may be added directly to the internal standard spiking solution (Section 7.4.2). Dose 10 μL of this surrogate spiking solution directly into the 5-mL syringe with every sample and reference standard analyzed. Prepare a fresh surrogate spiking solution on a weekly basis.

9. Sample Collection, Preservation, and Handling

9.1 The samples must be iced or refrigerated from the time of collection until extraction. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl_2) to the empty sample bottles just prior to shipping to the sampling site. USEPA Methods 330.4 or 330.5 may be used to measure residual chlorine.[3] Field Test Kits are available for this purpose.

9.2 Collect about 500 mL sample in a clean container. Adjust the pH of the sample to about 2 by adding 1 + 1 HCl while stirring gently. Fill the sample bottle in such a manner that no air bubbles pass through the sample as the bottle is being filled. Seal the bottle so that no air bubbles are entrapped in it. Maintain the hermetic seal on the sample bottle until time of analysis.

9.3 All samples must be analyzed within 14 days of collection.[3]

10. Sample Extraction and Gas Chromatography

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and method detection limits that can be achieved by this method. An example of the separations achieved by Column 1 is shown in Figure 6. Other packed columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

10.2 Calibrate the system daily as described in Section 7.

10.3 Adjust the purge gas (nitrogen or helium) flow rate to 40 mL/min. Attach the trap inlet to the purging device, and set the device to purge. Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow sample to come to ambient temperature prior to introducing it into the syringe. Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample bottle (or standard) and carefully pour the sample into the syringe barrel to just short of overflowing. Replace the syringe plunger and compress the sample. Open the syringe valve and vent any residual air while adjusting the sample volume to 5.0 mL. Since this process of taking an aliquot destroys the validity of the sample for future analysis, the analyst should fill a second syringe at this time to protect against possible loss of data. Add 10.0 μL of the surrogate spiking solution (Section 8.7) and 10.0 μL of the internal standard spiking solution (Section 7.4.2), if applicable, through the valve bore, then close the valve.

10.5 Attach the syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject the sample into the purging chamber.

10.6 Close both valves and purge the sample for 12.0 ± 0.1 minutes at ambient temperature.

10.7 After the 12-minute purge time, disconnect the purge chamber from the trap. Dry the trap by maintaining a flow of 40 mL/min of dry purge gas through it for six minutes. See Figure 4. A dry purger should be inserted into the device to minimize moisture in the gas. Attach the trap to the chromatograph, adjust the device to the desorb mode, and begin to temperature program the gas chromatograph. Introduce the trapped materials to the GC column by rapidly heating the trap to 180 °C while backflushing the trap with an inert gas between 20 and 60 mL/min for four minutes. If rapid heating cannot be achieved, the gas chromatographic column must be used as a secondary trap by cooling it to 30 °C (subambient temperature, if poor peak geometry and random retention time problems persist) instead of the initial program temperature of 50 °C.

10.8 While the trap is being desorbed onto the GC column, empty the purging chamber using the sample introduction syringe. Wash the chamber with two 5-mL flushes of reagent water.

10.9 After desorbing the sample for four minutes, recondition the trap by returning the purge and trap device to the purge mode. Wait 15 seconds then close the syringe valve on the purging device to begin gas flow through the trap. The trap temperature should be maintained at 180 °C. After approximately seven minutes, turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When cool, the trap is ready for the next sample.

10.10 The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time for a compound can be used to calculate a suggested window size; however, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

10.11 If the response for the peak exceeds the working range of the system, prepare a dilution of the sample with reagent water from the aliquot in the second syringe and reanalyze.

11. Calculations

11.1 Determine the concentration of individual compounds in the sample.

11.1.1 If the external standard calibration procedure is used, calculate the concentration of material from the peak response using the calibration curve or calibration factor determined in Section 7.3.2.

11.1.2 If the internal standard calibration procedure was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and equation 2.

Eq. 2.

Concentration $\mu g/L = (A_s C_{is})/(A_{is})(RF)$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

11.2 Report results in micrograms per liter. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

11.3 For samples processed as part of a set where the spiked sample recovery falls outside of the control limits which were described in Section 8.3, data for the affected parameters must be labeled as suspect.

12. Method Performance

12.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero[1]. The MDL concentrations listed in Table 1 were obtained using reagent water[9]. Similar results were achieved using representative wastewaters.

12.2 This method has been demonstrated to be applicable for the concentration range from the MDL up to 1000 x MDL[9]. Direct aqueous injection techniques should be used to measure concentration levels above 1000 x MDL.

12.3 In a single laboratory (Monsanto Research), using reagent water and wastewaters spiked at or near background levels, the average recoveries presented in Table 2 were obtained[9]. The standard deviation of the measurement in percent recovery is also included in Table 2.

12.4 The Environmental Protection Agency is in the process of conducting an interlaboratory method study to fully define the performance of this method.

References

1 See Appendix A

2. Bellar, T.A., and Lichtenberg, J.J. *Journal American Water Works Association, 66,* 739, (1974).

3. Bellar, T.A., and Lichtenberg, J.J. "Semi-Automated Headspace Analysis of Drinking Waters and Industrial Waters for Purgeable Volatile Organic Compunds," Proceedings of Symposium on Measurement of Organic Pollutants in Water and Wastewater. American Society for Testing and Materials, STP 686, C.E. Van Hall, editor, 1978.

4. "Carcinogens—Working with Carcinogens," Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health. Publication No. 77-206, August 1977.

5. "OSHA Safety and Health Standards, General Industry," (29 CFR 1910), Occupational Safety and Health Administration, OSHA 2206, (Revised January 1976).

6. "Safety in Academic Chemistry Laboratories," American Chemical Society Publication, Committee on Safety, 3rd Edition, 1979.

7. "Handbook for Analytical Quality Control in Water and Wastewater Laboratories," EPA-600/4-79-019, U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. March 1979.

8. "Methods 330.4 (Titrimetric, DPD-FAS) and 330.5 (Spectrophotometric, DPD) for Chlorine, Total Residual," Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. March 1979.

9. "EPA Method Validation Study 24, Method 602 (Purgeable Aromatics)," Report for EPA Contract 68-03-2856 (In preparation).

Table 1. *Chromatographic Conditions and Method Detection Limits*

Parameter	Retention Time (min.) Column 1	Retention Time (min.) Column 2	Method Detection Limit µg/L
Benzene	3.33	2.75	0.2
Toluene	5.75	4.25	0.2
Ethylbenzene	8.25	6.25	0.2
Chlorobenzene	9.17	8.02	0.2
1,4-Dichlorobenzene	16.8	16.2	0.3
1,3-Dichlorobenzene	18.2	15.0	0.4
1,2-Dichlorobenzene	25.9	19.4	0.4

Column 1 conditions: Supelcoport 100/120 mesh coated with 5% SP-1200 and 1.75% Bentone-34 packed in a 6 ft. × 0.085 in ID stainless steel column with helium carrier gas at 36 cc/min flow rate. Column temperature held at 50°C for 2 min. then programmed at 6°C/min to 90°C for a final hold.

Column 2 conditions: Chromosorb W-AW 60/80 mesh coated with 5% 1,2,3-Tris(2-cyanoethyoxy)propane packed in a 6 ft. × 0.085 in ID stainless steel column with helium carrier gas at 30 cc/min flow rate. Column temperature held at 40°C for 2 min then programmed at 2°C/min to 100°C for a final hold.

Table 2. *Single Operator Accuracy and Precision*

Parameter	Average Percent Recovery	Standard Deviation %	Spike Range (µg/L)	Number of Analyses	Matrix Types
Benzene	91	10.0	0.5-9.7	21	3
Chlorobenzene	97	9.4	0.5-100	21	3
1,2-Dichlorobenzene	104	27.7	0.5-10.0	21	3
1,3-Dichlorobenzene	97	20.0	0.5-4.8	21	3
1,4-Dichlorobenzene	120	20.4	0.5-10.0	21	3
Ethylbenzene	98	12.4	0.5-9.9	21	3
Toluene	77	12.1	0.5-100	21	3

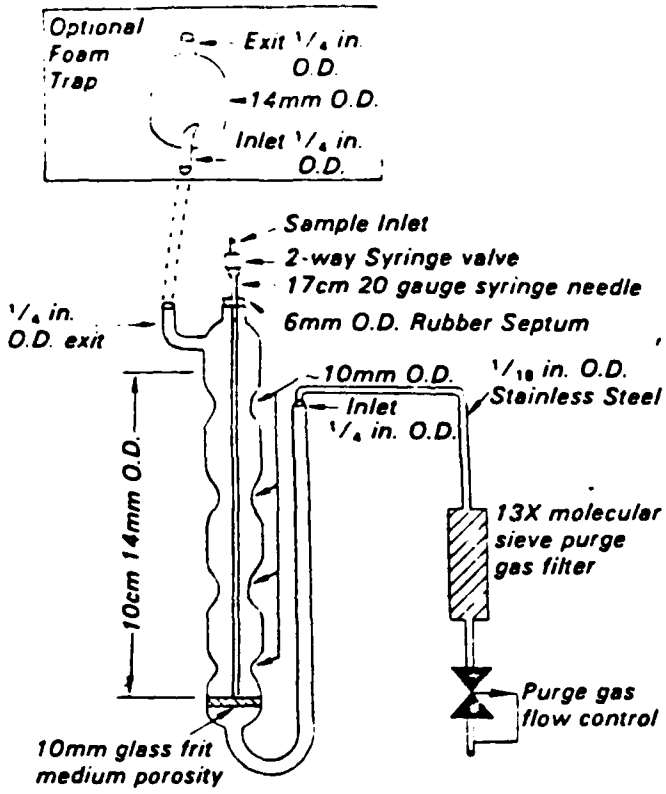


Figure 1. *Purging device*

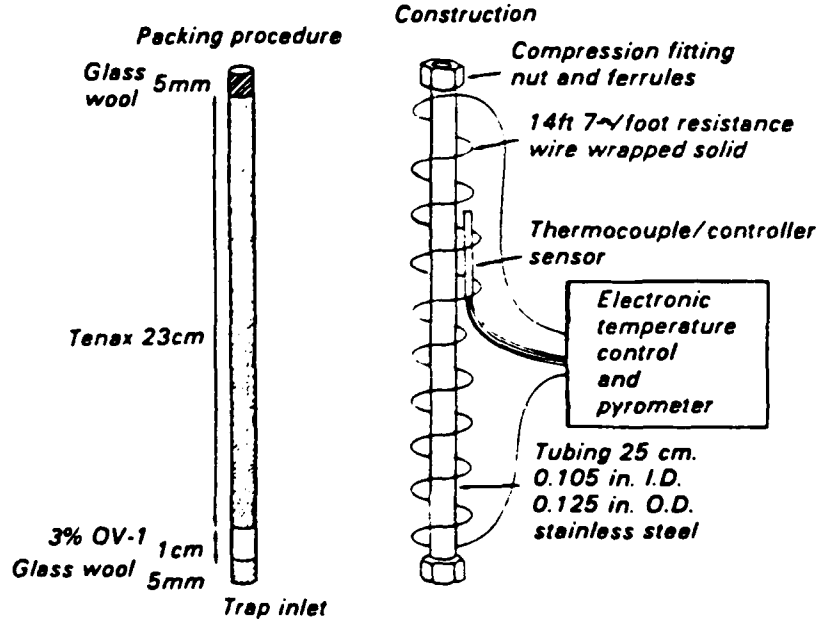


Figure 2. *Trap packings and construction to include desorb capability*

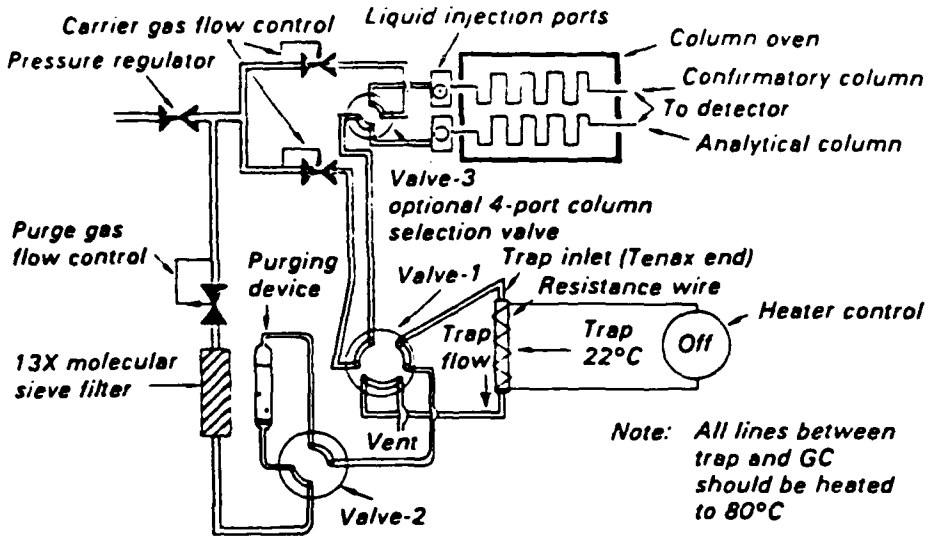


Figure 3. *Purge-trap system (Purge-sorb Mode)*

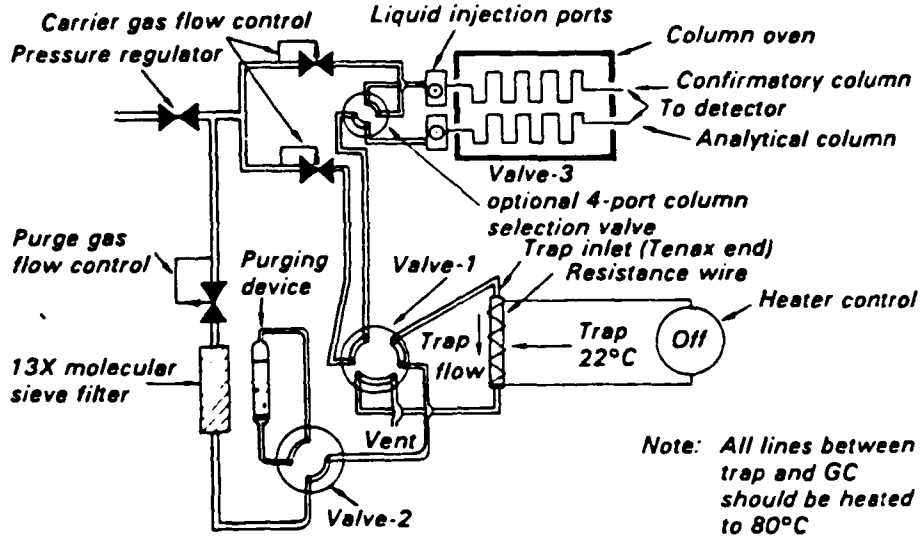


Figure 4. *Purge-trap system (Trap-dry Mode).*

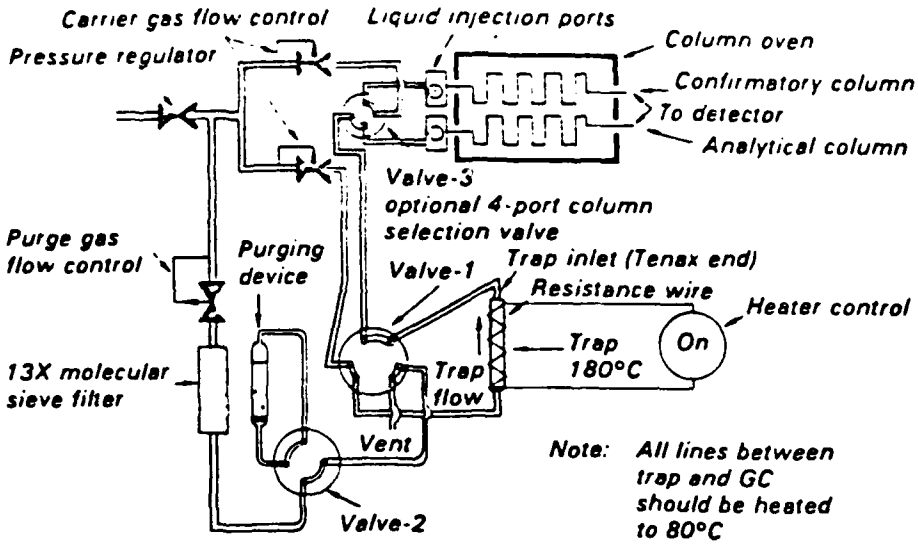


Figure 5. *Purge-trap system (Desorb Mode).*

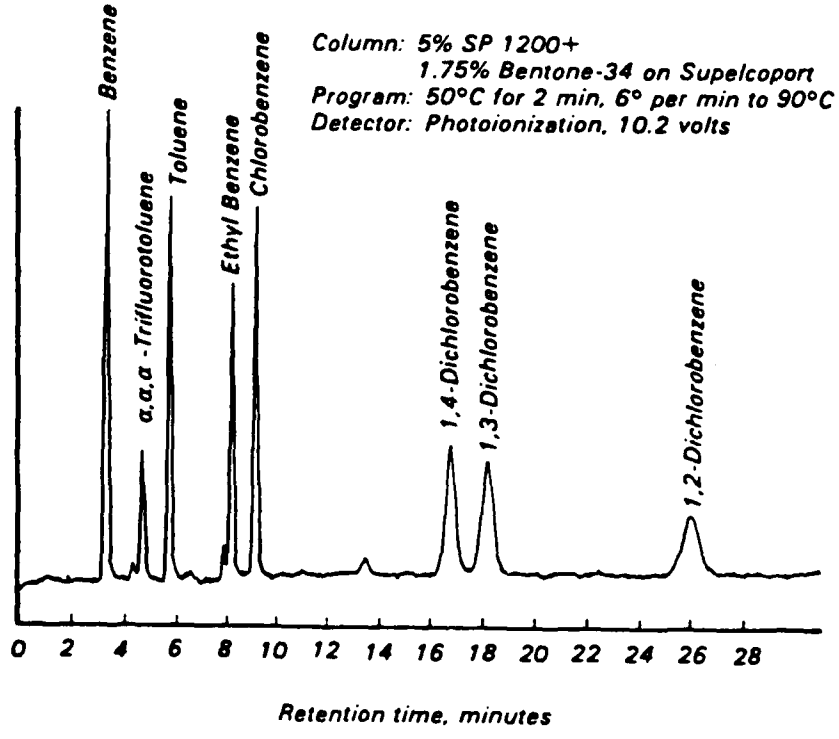


Figure 6. *Gas chromatogram of purgeable aromatics.*

APPENDIX I

RAW WATER QUALITY DATA

SUMMARY OF GROUND WATER ANALYSES
WRIGHT-PATTERSON AFB

Well Number	Location Monitored	Nitrate (mg/L)	Cl (mg/L)	SO_4 (mg/L)	B (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	TOC (mg/L)	TOX (ug/L)	Phenol (mg/L)	Oil & Grease (mg/L)
1	Upgradient Landfill 8	0.1	41.2	15.3	0.20	0.1	0.05	11.0	1.0	5	0.011	NR
2	Landfill 8	0.1	8.6	35.8	0.25	0.1	0.05	10.0	3.9	5	0.01	NR
3	Landfill 8	0.1	15.4	1.0	0.11	0.1	0.11	15.0	1.0	5	0.01	NR
4	Landfill 10	0.1	34.8	104	0.1	0.1	0.12	10.0	7.9	5	0.01	NR
5	Landfill 10	0.1	36.0	56.6	0.1	0.1	0.05	27	1.0	5	0.01	NR
6	Landfill 11	0.1	115.0	73.3	0.1	0.34	0.05	24	1.0	5	0.01	NR
7	Landfill 11	0.82	97.0	67.3	0.1	0.1	0.40	24	1.0	5		NR
8	Fire Training Area	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
9	Fire Training Area	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
10	Landfill 12	0.1	64.5	73.3	0.1	0.45	0.05	27	1.2	5	0.01	NR
	Detection Limit											

SUMMARY OF GROUND WATER ANALYSES
WRIGHT-PATTERSON AFB

Well Number	Location Monitored	Nitrate (mg/L)	Cl (mg/L)	SO_4 (mg/L)	B (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	TOC (mg/L)	TOX (ug/L)	Phenol (mg/L)	Oil & Grease (mg/L)
11	Landfill 3 (golf course)	2.05	126.5	52.1	0.1	0.1	0.05	36	1.0	5	0.01	NR
12	Landfill 4	0.14	250.0	79.4	0.05	0.1	0.05	90	3.2	18.8	0.01	NR
13	Landfill 6	0.1	113.5	77.5	0.14	9.5	0.17	30	3.8	7.0	0.01	NR
14	Landfill 7 (horse barn)	0.1	120.0	44.3	0.27	19.0	0.43	39	6.4	65.0	0.01	NR
15	Tank Farm (Tank 256)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.24
16	Tank Farm (Tank 272)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1.03
17	Coal Storage Pile	2.20	85.0	114.0	0.1	0.1	0.05	35	1.0	5	0.007	NR
18	Chemical Burial Area	1.80	75.0	134.0	0.1	0.1	0.05	31	1.0	5.2	0.01	NR
19	Chemical Burial Area	1.82	71.0	150.0	0.1	0.1	0.05	28	1.0	5	0.01	NR
	Detection Limit											

SUMMARY OF GROUNDWATER ANALYSES
WRIGHT-PATTERSON AFB

Well Number	Location Monitored	Nitrate (mg/L)	Cl (mg/L)	SO_4 (mg/L)	B (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	TOC (mg/L)	TOX (ug/L)	Phenol (mg/L)	Oil & Grease (mg/L)
20	Landfill 5	0.1	65.5	250.0	0.1	0.1	0.71	12	12.1	6.8	0.014	NR
21	Landfill 5	0.1	99.5	260	0.17	0.90	1.89	19	3.7	94.0	0.011	NR
22	Landfill 5	0.1	108.5	65	0.1	0.60	0.04	12	5.3	5.4	0.007	NR
23	Landfill 5	0.1	92.5	210	0.1	1.25	0.16	11	4.0	5	0.007	NR
24	Fire Training Area 1 (near garden plots)	0.1	54.0	65	0.1	0.1	NF	9	3.0	5	0.020	0.21
25	Landfill 2 (Woodman Rd)	0.1	78.0	75	0.1	0.15	0.06	26	3.3	5	0.010	NR
26	Landfill 9 (Sand Hill)	0.30	9	105	0.1	0.1	0.05	14	3.4	5	0.01	NR
27	Fire Training Area 2 (near present F.T. area)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.71
	Detection Limit	0.1	1.0	1.0	0.1	0.1	.05	1.0	1.0	5	.01	0.1

NR indicates not required by the Task Order

Summary of Groundwater Analyses for
USEPA Priority Pollutant VOA Compounds
(Methods 601 and 602)

Analyte	Detection Limit	MW-8	MW-9	MW-15	MW-16	MW-24	MW-27
Benzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromoform	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromomethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorobenzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorodibromomethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2-Chloroethyl vinyl ether	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloroform	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Choromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichlorobenzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3-Dichlorobenzene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,4-Dichlorobenzene	1.0	<1.0	<1.0	<1.0	10.0	<1.0	<1.0
Dichlorodifluoromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,2-Dichloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2-Dichloropropane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
cis-1,3-Dichloropropene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
trans-1,3-Dichloropropene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ethylbenzene	1.0	<1.0	<1.0	<1.0	2.0	<1.0	<1.0
Fluorotrichloromethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tetrachloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Trichloroethene	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Toluene	1.0	<1.0	<1.0	<1.0	4.0	<1.0	<1.0
Vinyl Chloride	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Summary of Leachate Analyses

Sample Number	Location	Specific Conductance (μmhos-cm)	Cl (mg/l)	SO_4 (mg/l)	B (mg/l)	Fe (mg/l)	TOX (ug/l)	TOC (mg/l)	Phenol (mg/l)
L1	Landfill 8	1760	50.2	550.0	0.56	9.9	44	14.1	< 0.01
L2	Landfill 8	1370	46.2	340.0	0.77	1.5	45	*	< 0.01
L3	Landfill 8	660	11.8	44.0	< 0.10	125.0	12	2.33	< 0.01
L4	Landfill 10	1880	118.5	44.0	0.61	143.0	940	24.8	0.16
L5	Landfill 10	12100	1030.0	90.0	5.71	694.0	900	1780.0	2.06
L6	Landfill 10	1890	144.0	30.0	0.69	56.0	400	352.0	0.32
Detection Limit	-	1.0	1.0	1.0	0.10	0.1	5.0	2.0	0.01

* TOC Samples were collected 7/31/84. At that time, the site of L-2 was dry.

WESTON



Contacts–

Mr. Russel Stein, Manager
Ground-Water Section
Division of Public Water Supply
Ohio Environmental Protection Agency
361 E. Broad St.
Columbus, OH 43215
614-466-8307

Revisions provided by Mr. Russel Stein in a letter dated 15 April 1983.



OHIO

Classification–Within the Ohio Revised Code "Waters of the State" are defined to include underground water "regardless of the depth of the strata in which underground water is located." Ground water has not been classified, although within the state ground-water protection strategy, 28 major aquifer systems have been identified for possible future designation as underground sources of drinking water.

Quality Standards–Ohio has not adopted quality standards that are applied specifically to ground water, although it is informally recognized that most geographic areas of the state are underlain by ground water that will generally meet all NIPDWR standards without treatment.

Drinking Water Standards–The Ohio EPA has adopted drinking water standards that are applicable to public water supplies and are the same as the federal primary drinking water standards.

Appropriation–Ground-water use is governed by common law. There are no statutory provisions governing the allocation of ground water.

Controlled Use Areas–There are no such areas designated in Ohio.

Well Construction–Plan approvals are required by the Ohio Environmental Protection Agency for all public water supply wells. OEPA has adopted construction standards applicable to all wells, and the Department of Health has standards applicable to private drinking water supply wells. The Department of Health is currently developing regulations to require the registration of drilling contractors.

Underground Injection Control–Ohio has developed a state UIC program that has been submitted for EPA approval, expected spring 1983. OEPA and the Division of Oil and Gas within the Department of Natural Resources have participated in the development of the program. Class I injection is and will be permitted by OEPA. Class IV injection will be prohibited. Class V injection will be regulated by rule for the specific purpose. Class II and III injections are and will be permitted by the Division of Oil and Gas. Current regulations for Class II permit annual injection and may ultimately require modification to comply with EPA requirements.

Waste Management Facilities–

Solid Waste–The Division of Land Pollution Control, within OEPA, administers the program. The Ohio Solid Waste Disposal Regulations provide minimum geologic siting criteria for landfills, and set forth parameters which must be used to determine existing ground-water quality for facility siting, to stipulate minimum monitoring parameters for facility monitoring, and to provide that sampling for additional parameters be required as determined on a case-by-case basis.

Hazardous Waste–Ohio has received interim status authorization for RCRA Phase I and is seeking Phase II authority. The Division of Hazardous Material Management within OEPA administers the program. The Ohio Hazardous Waste Management Regulations provide ground-water monitoring requirements identical to EPA requirements for TSD facilities (40 CFR 265 Subpart F).

Sole Source Aquifers–There are none at this time.

Geological Surveys–

Division of Geological Survey
Department of Natural Resources
Fountain Square
Columbus, OH 43224
614-265-6575
State Geologist:
Mr. Horace R. Collins

Water Resources Division
U.S. Geological Survey
975 W. Third Ave.
Columbus, OH 43212
614-469-5553
District Chief:
S.M. Hindall

References–

Ohio Water Pollution Control Act
(Ohio Revised Code, Title 61, Ch. 11)

Ohio Solid Waste Disposal Regulations
(Ohio Administrative Code, Regulations 3745-27)

Ohio Hazardous Waste Management Regulations
(Ohio Administrative Code, Title 3745, Ch. 50-58)

Ground Water Program Activities, Bi-Annual Report, Section 305(b), Ohio Environmental Protection Agency



3. Run-on and runoff control systems
   - Requirement: design to control flow during at least 25-year storm
   - Applicability: landfills, waste piles, land treatment
4. Wind dispersal controls
   - Requirement: cover waste or otherwise manage unit to control wind dispersal
   - Applicability: landfills, waste piles, and land treatment units that contain particulate matter
5. Overtopping controls
   - Requirement: prevent overtopping or overfilling
   - Applicability: surface impoundments
6. Disposal unit closure
   - Requirement: final cover (cap) over waste unit designed to minimize infiltration of precipitation
   - Applicability: landfills and surface impoundments (if used for disposal)
7. Storage unit closure
   - Requirement: remove waste and decontaminate
   - Applicability: surface impoundments used for treatment or storage and waste piles
8. Postclosure Care
   - Maintain effectiveness of final cover
   - Operate leachate collection and removal system
   - Maintain ground-water monitoring system (and leak detection system where double liner is used)
   - Continue 30 years after closure

The goal of the ground-water monitoring and response program is to detect and correct any ground-water contamination. There are four main elements:

1. A detection monitoring program which requires the permittee to install a system to monitor ground water in the uppermost aquifer to determine if a leachate plume has reached the edge of the waste management area.
2. A ground-water protection standard is set when a hazardous constituent is detected. The standard specifies concentration limits, compliance point, and compliance period.
3. A compliance monitoring program determines if the facility is complying with its ground-water protection standard.
4. Corrective action is required when the ground-water protection standard is violated. The permittee must either remove the contamination or treat it in place to restore ground-water quality.

Until hazardous waste management facilities are issued permits, existing facilities will continue to operate under interim status standards. Facilities operating under interim status will be required to file Part B applications for final permits.

Under Subtitle C of RCRA, EPA approves state hazardous waste management programs in two phases. Phase I authorization gives states the right to control transportation and generation of hazardous wastes within their borders and to regulate existing treatment, storage, and disposal facilities. Phase II authorization includes the permitting of new facilities.

3.7 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

This statute (CERCLA), commonly referred to as Superfund, authorizes EPA to respond to releases or threatened releases into the environment, including ground water, of any hazardous substance which may present an imminent and substantial danger to public health. The act provides funds for emergency action and has cost recovery provisions.



3.6 RESOURCE CONSERVATION AND RECOVERY ACT

The Solid Waste Disposal Act and the Resource Recovery Act of 1970, as amended by the Resource Conservation and Recovery Act of 1976 (RCRA), require EPA to establish a national program to regulate the management of waste materials.

3.6.1 Solid Waste

Subtitle D of RCRA established a broad-based national program to improve solid waste management through the development of state and regional solid waste management plans. The act offered federal financial assistance to states interested in developing and implementing a solid waste management plan. The state plans, under federal guidelines, identify respective responsibilities of local, state, and regional authorities, and encourage resource recovery and conservations and the application and enforcement of environmentally sound disposal practices.

A major element of the Subtitle D program is the open dump inventory. Section 4005 of RCRA prohibits open dumping. Federal criteria for classifying solid waste management facilities are provided in 40 CFR 257. EPA cannot approve a state solid waste management program with less stringent criteria. Solid waste management facilities failing to satisfy the criteria are considered open dumps. In order to satisfy these criteria, a facility or practice (in addition to other environmental considerations) shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary established by the state or in court persuant to the stipulations of 40 CFR 257.3-4. The federal criteria define contamination as an exceedence of the MCLs provided in the National Interim Primary Drinking Water Regulations or an increase in concentration of any parameter for which the ambient concentration exceed the MCL.

3.6.2 Hazardous Waste

EPA has issued a series of hazardous waste regulations under Subtitle C of RCRA (40 CFR 260 to 267 and 122 to 124). On 19 May 1980, EPA issued a comprehensive set of standards for generators and transporters of hazardous waste and "interim status" standards for facilities in existence on 19 November 1980, that treat, store, or dispose of hazardous waste. Such facilities were allowed to operate under interim status until they received an RCRA permit. Subsequently, EPA issued standards for granting RCRA permits to treatment and storage facilities. Standards for land disposal facilities were issued on 26 July 1982—virtually completing the program for controlling hazardous waste under RCRA.

The standards for permitting land disposal facilities were issued after a wide range of regulatory options were considered. Over a period of several years, EPA proposed two different sets of land disposal standards and solicited comments on various issues. On 13 February 1981, EPA issued temporary standards for new land disposal facilities. The 26 July regulations replace those temporary standards except for Class I underground injection wells. These will remain subject to the temporary standards until final standards are issued.

The regulations consist primarily of two complementary sets of performance standards:

1. A set of design and operating standards tailored to each of four types of facilities
2. Ground-water monitoring and response regulations applicable to all land disposal facilities

The design and operating standards implement a liquids management strategy that has two goals:

1. Minimize leachate generated at the facility
2. Remove leachate generated to minimize its chance of reaching ground water

The major requirements include

1. Liner
   - Requirement: design to prevent migration of waste out of the facility during its active life
   - Applicability: landfills, surface impoundments, and waste piles
2. Leachate collection and removal
   - Requirement: collect and remove leachate from the facility and ensure that leachate depth over the liner does not exceed 30 centimeters (1 foot)
   - Applicability: landfills and waste piles



3.3.4 Underground Injection Control

The Underground Injection Control (UIC) program regulates the uses of underground injection wells to protect an underground source of drinking water (USDW). USDW means an aquifer or its portion which

1. supplies any public water system or contains a sufficient quantity of ground water to supply a public water system;
2. currently supplies drinking water for human consumption or contains less than 10,000 mg/liter total dissolved solids; and
3. is not an exempted aquifer (40 CFR 146.04 provides criteria for exemption).

SDWA requires any state designated by EPA as requiring a UIC program to develop and submit a state UIC program for EPA approval. EPA has designated each of the fifty states.

The federal program classifies injection wells as follows:

Class I—Wells used to inject hazardous waste, or other industrial and municipal disposal wells which inject fluids beneath the lower-most formation containing a USDW within one-quarter mile of the well bore.

Class II—Wells that inject fluids

1. which are brought to the surface as part of conventional oil or natural gas production and may be mixed with production waste waters from gas plants, unless those waters are classified as a hazardous waste at the time of injection;
2. for enhanced recovery of oil or natural gas; and
3. for storage of hydrocarbons which are liquid at standard temperature and pressure.

Class III—Wells that inject for extraction of minerals including

1. mining of sulfur by the Frasch process;
2. in situ production of uranium or other metals. This category includes only in situ production from ore bodies which have not been conventionally mined. Solution mining of conventional mines such as stopes leaching is included in Class V; and
3. solution mining of salts or potash.

Class IV—Wells used to dispose of hazardous or radioactive waste into or above a formation which contains a USDW within one-quarter mile of the well. Also, wells used to inject hazardous waste that cannot be classified as Class I or Class IV under the above criteria are Class IV wells.

Class V—All other injection wells (40 CFR 146.05(e) and 146.51 provide specific information and exemptions).

Underground injection is controlled through the permitting process. Construction, operation, monitoring and reporting activities are controlled. Individual state programs are based upon, and must be essentially equivalent to, the federal criteria and standards (40 CFR 146).

3.4 TOXIC SUBSTANCE CONTROL ACT

This statute (TSCA) authorizes EPA to restrict or prohibit the manufacture, distribution, and use of products which may result in unreasonable risk to health and the environment. Although ground water is not specifically named in the Act, EPA has taken the position that the protection of health and the environment includes the protection of ground water.

3.5 FEDERAL INSECTICIDE, FUNGICIDE, RODENTICIDE ACT

This statute (FIFRA) gives EPA the responsibility to control the sale and use of all pesticides to prevent unreasonable adverse environmental and health effects. The use and disposal of pesticide packages and containers is also regulated. In deciding whether to register, cancel, suspend, or change the classification of a pesticide, EPA considers a broad range of environmental impacts including those affecting ground water.



3.3.1 National Interim Primary Drinking Water Regulations

EPA initiated a detailed study of the health effects of various contaminants in water soon after the Safe Drinking Act (SDWA) was signed into law. So that the regulations could include the findings of this and other studies, the primary drinking water regulations were to be developed in two stages: an interim version and a final version. The interim version of the regulation became effective 24 June 1977. SDWA provides for delegation of authority to the states. State Primary Drinking Water Regulations must be at least as stringent as the federal regulations.

The National Interim Primary Drinking Water Regulations define Maximum Contaminant Level as the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system, except in the case of turbidity (applicable to surface water only) where the maximum permissible level is measured at the point of entry to the distribution system. The MCLs are provided with the state summaries.

3.3.2 National Secondary Drinking Water Regulations

These regulations control contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water. At considerably higher concentrations of these contaminants, health implications may also exist as well as aesthetic degradation. The National Secondary Drinking Water Regulations are not federally enforceable but are intended as guidelines for the states.

Secondary Maximum Contaminant Levels (SMCLs) are defined as the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. Federal and state SMCLs are provided in the state summaries. The states may establish higher or lower levels which may be appropriate depending upon local conditions such as unavailability of alternate sources of water or other compelling factors, provided the public health and welfare are not adversely affected.

3.3.3 Sole Source Aquifer

The Sole Source Aquifer provisions of SDWA allow EPA to designate an aquifer as the sole source of drinking water for an area thereby guaranteeing protection from contamination by federally assisted activities. Local, regional, or state agencies can petition EPA for sole source designation. The EPA Administrator may designate an aquifer which is a sole or principal drinking water source if its contamination would create a significant hazard to public health. If the designation is made, no federal money or financial commitment may be made for any project which the Administrator determines may contaminate the designated aquifer through its recharge zone.

At this writing, February 1983, EPA has designated the following ten sole source aquifers:

Biscayne Aquifer - Florida
Buried Valley Aquifer - New Jersey
Edwards Aquifer - Texas
Camano Island—Whidbey Island Aquifer - Washington
Spokane-Rathdrum Aquifer - Washington and Idaho
Nassau and Suffolk counties - New York
Cape Cod - Massachusetts
Fresno - California
Ten Mile Creek - Maryland
Northern Guam Lens - Guam

The following eighteen are under consideration:

Arizona
- Santa Cruz, Upper Santa Cruz, Aura-Altar Basins

California
- Scotts Valley

Delaware
- New Castle County

Florida
- Volusia - Floridan Aquifer

Idaho
- Snake River Plain

Louisiana
- Baton Rouge
- DeSota Parish

New Jersey
- Coastal Plain
- Ridgewood
- Upper Rockaway

New York
- Kings and Queens counties
- Sardinia
- Schenectady
- Vestal

Pennsylvania
- Seven Valleys

Texas
- Carrizo-Wilcox Aquifer

Texas and New Mexico
- Delaware Basin

Wisconsin
- Niagara Aquifer

3. FEDERAL PROTECTION OF GROUND-WATER QUALITY



The federal programs dealing with the protection of ground-water quality are administered largely by the Environmental Protection Agency (EPA). The federal programs which provide the framework for state regulations are summarized in this section.

3.1 GROUND-WATER PROTECTION POLICY

At this writing, February 1983, U.S. EPA's final policy on ground-water protection, scheduled for September 1982 release, has not been published. Based on the proposed strategy published by EPA in November 1980 and recent press releases, it appears that EPA will be implementing a policy that would give the states lead responsibility in the protection of ground-water quality. EPA's efforts apparently will be focused in three major areas:

1 Development of an internally consistent federal approach to ground-water protection

2 Monitoring, research and development efforts directed toward more comprehensive problem definition and new detection, controls, and clean-up technology development

3 Guidance, coordination, and assistance to states in the development of state policies

A significant component of EPA's policy is expected to be a ground-water classification system which could be used to determine the degree of protection needed for various types of ground water. Ground-water classification is discussed in Chapter 4.

3.2 CLEAN WATER ACT

This statute refers to ground-water protection in municipal waste water treatment, planning, and research programs. Its principal regulatory programs, however, focus on surface water. Section 303 empowers EPA to approve states' water quality standards which are based on the states' classification of rivers and streams. Many states have included ground water in their definition of "waters of the state" for purposes of this act (state summaries). On this basis the National (state) Pollutant Discharge Elimination System (NPDES SPDES) permitting process may be invocable for purposes of ground-water protection. In addition the act empowers EPA to

1. Develop a comprehensive program for ground-water pollution control [Section 102(a)]
2. In cooperation with states, equip and maintain a surveillance system for monitoring ground-water quality [Section 104(a)(5)]
3. Provide grants to states and area-wide agencies to develop ground-water quality management plans to identify salt water intrusion and control disposal of pollutants in subsurface excavations, and control disposition of wastes. (May include authority for comprehensive ground-water management plans, including conjunctive use with surface water) [Section 102(c), 208(b)]
4. Require development of Best Management Practices (BMP) to control nonpoint source pollution problems to ground-water quality [Section 208(b)]
5. Develop criteria for ground-water quality considering kind and extent of effects on health and welfare from the presence of pollutants [Section 304(a)]
6. Determine information necessary to restore and maintain chemical, physical, and biological integrity of ground water [Section 304(a)]
7. Issue information on the factors necessary to restore and maintain chemical, physical, and biological integrity of ground water [Sections 304(a)(2)]

3.3 SAFE DRINKING WATER ACT

This statute authorizes EPA to set maximum contaminant levels (MCLs) and monitoring requirements for public water systems and provides for the protection of underground sources of drinking water. The MCLs regulate the quality of "finished" water, i.e., water as delivered, not the quality of the source water. As discussed below, the MCLs have been utilized by EPA and the states as the basis for other regulations dealing with ground-water quality and protection.



Geologic units that are capable of delivering useable quantities of water to wells are called aquifers. In general, the "best" aquifers are those that are highly permeable and porous. Examples of these aquifers are unconsolidated sediment, sand and gravel deposits, sandstones and conglomerates, and some carbonate and volcanic rocks. Geologic units that are unable to supply wells are commonly called confining beds and formally referred to as aquitards or aquicludes. These are generally clay beds, shales and siltstones, or dense, crystalline rocks that have low porosity or permeability.

Porosity which results from grain size distribution and degree of compaction or cementation is called primary porosity. Secondary porosity can result from features, joints, and bedding planes. When mineral matter in the rock becomes dissolved and leaves open spaces (common in carbonate rocks), solution porosity results. During the cooling of volcanic rock, particularly basalt, open fractures and channels can form. Secondary porosity can permit an aquitard, such as shale, to become highly saturated with water. However, this feature is often localized and highly variable. Permeability, i.e., interconnection of secondary porosity, must also be high to allow movement of water into wells.

Aquifers and aquitards are commonly interlayered in a stratigraphic sequence. When an aquitard overlies an aquifer, the aquifer is confined and is generally recharged in upgradient areas where the aquitard is absent. In unconfined aquifers, also called water table aquifers, water infiltrates and recharges the aquifer directly from the surface. For both types of aquifers, water in a well will rise up to a point where the hydrostatic pressure is equal to atmospheric pressure. For confined aquifers, this water level is referred to as the potentiometric surface. This surface is generally at a higher elevation than the base of the aquitard which defines the top of the aquifer. When the elevation of the potentiometric surface is higher than the land surface, water will flow from the well without pumping and the aquifer is referred to as artesian.

In an unconfined aquifer, the water level in a well will be at the same elevation as the top of the zone of saturation in the aquifer outside the well, i.e., the water table. The depth to the water table is variable and depends upon local topography, precipitation, and lithology. The water table generally follows surface contours, although it is usually less pronounced. Seasonal variations in rainfall will also affect the water table depth. During periods of high rainfall and recharge, the water table will rise, as it also falls during periods of low rainfall. Ground water, however, is much less susceptible to rainfall variation than surface water.

2.4 GROUND-WATER FLOW

In order to pump ground water out of a well, it must be able to flow into the well. Under natural conditions, ground-water flow is normally slow, ranging from a few feet per day to a few feet per year. Since ground water is moving through pore space or fractures in soil or rock units, the resistance to flow is very high and the flow path is tortuous. Ground-water flow itself results from gravity and pressure gradients caused by elevation differences. Below the water table, ground water flows downward and laterally, following changes in elevation and hydrostatic pressure. The direction of flow is away from high pressure, recharge areas and toward low pressure, discharge areas such as streams, lakes, oceans, or pumping wells. The residence time of ground water from recharge to discharge can be very long—hundreds and even thousands of years. In comparison, water in river channels has an average turnover time of two weeks.

Despite normally slow ambient velocities, ground water can flow quickly when being pumped. Flow rates in the vicinity of a pumping well can reach 5 feet per minute or more. As pumping begins, water flows quickly into the well because of high suction pressure, and the water table is lowered near the well. The drawdown of the water table is the difference between the static water table level and the pumping water level. At the pump a cone-shaped area (the cone of depression) is dewatered. As pumping continues, the cone of depression enlarges and the water table is lowered over a larger area. The maximum level of pumping that can be maintained without the water table dropping below the pump intake is called the well yield. If the well yield is exceeded, the pump will run dry. Each aquifer can have different well yields, depending on the aquifers' geological characteristics.

2. GROUND-WATER CONCEPTS AND TERMINOLOGY



A brief summary of ground-water concepts and terminology is presented here as a foundation for an understanding of both the regulations and the need for regulations.

2.1 THE GROUND-WATER RESOURCE

Ground water is one of our most valuable natural resources and also one of the least understood by the general population. Because ground water is a source of fresh-water for drinking water, agricultural use, and industrial processes, it is a water supply that is vital to our well being and economic development.

Ground water composes almost half of the drinking water supply in the United States. It is widely used in many parts of the country because of its high quality, abundance, availability, and relatively low cost. Ground water also accounts for over two-thirds of the water used for irrigation, primarily in the Western states, and it is also a significant water supply for industrial uses. The importance of ground water as a source of water in the United States is clearly illustrated in the overview table at the beginning of Section 5 which summarizes ground-water use on a state-by-state basis.

The basic source of ground water is considered to be precipitation in the form of rainfall and snowmelt. Ground water is an important part of the hydrologic cycle—the circulation of water from the atmosphere to the land by precipitation and back to the atmosphere through evaporation. When precipitation reaches the surface it can evaporate, flow as runoff in surface and streamflows, or infiltrate the surface to become ground water. The amount of infiltration varies from 10 to 30 percent of precipitation.

2.2 GROUND-WATER COMPOSITION

It is assumed, and even expected, that the water pumped from wells will be pure. While most well water is potable with little or no treatment, the natural quality of ground water varies. The presence and concentrations of minerals, salts, and metals can be due to natural causes and man's activities. The local geology is the most important factor in determining natural ground-water quality, i.e., the soils and rock units found in the area. From the time water reaches the land surface to the time it is pumped out of the ground, it undergoes numerous changes in composition and quality. Major changes are the addition of dissolved minerals and removal of most bacterial organisms as a result of reactions between the water and the soil or rock. The amount of change in water composition is directly related to geologic variability.

When water reaches the land surface, it infiltrates down through soil layers to the water table. During this time, most bacterial organisms are removed from the water due to natural processes. Plant roots and other biological organisms may use some mineral constituents as nutrients. These processes depend on the type of soil encountered by infiltrating water. Generally, finer grained soils act as better "filters" than coarser-grained soils.

As water percolates downward its mineral content increases. Water is the universal solvent and all minerals are to some extent water soluble. The major inorganic constituents of ground water are bicarbonate, calcium, chloride, magnesium, silicon, sodium sulfate, and carbonic acid. Most other constituents are present in minor or trace levels. The concentrations of these constituents depend upon the type of aquifer. For example, ground water in carbonate aquifers will generally have a higher pH and hardness than ground water in crystalline rock. The longer the water is in contact with the aquifer, the higher the concentration of dissolved solids may become. Some aquifers are saline due to a high solids concentration resulting from long residence times of infiltrated ground water or because the water originally deposited with the aquifer sediment was saline.

2.3 POROSITY AND PERMEABILITY, AQUIFERS AND AQUITARDS

Porosity and permeability are two geologic factors that determine whether a soil, sediment, or rock unit will become saturated with water. Porosity is the percentage of open spaces, or voids, in a geologic unit. All geologic units are porous to some extent, depending on grain size and distribution, grain packing and shape, and the amount of compaction and cementation. Permeability is a measure of the capacity of a geologic unit to transmit water, and depends on the interconnection of pores, their size and shape, and grain packing. Porosity and permeability determine if a geologic unit can store water and then transmit it to wells and pumps.

1. INTRODUCTION



Regulations concerning ground water have been greatly expanded in the past decade, both at the state and federal levels. At the federal level, ground-water quality is regulated under the Federal Water Pollution Control Act (Clean Water Act), the Toxic Substances Control Act, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), the Safe Drinking Water Act, and the Resource Conservation and Recovery Act. Such a diversity of regulations, even at the federal level, has led to numerous levels of ground-water protection, both use- and site-specific. However, regulations have not been made under a unified framework. The U.S. Environmental Protection Agency (EPA) is in the process of developing a ground-water protection policy which will provide for such a unified framework.

Currently, there exists a number of reviews of ground-water standards: *State of the States: Water Resources Planning and Management; Ground-water Supplement, May 1981*, and *Fiscal Year 1981 Update, September 1981* published by the U.S. Water Resources Council. This update provides a status report on the development of regulations within the states but does not provide specifics on the state regulations. Another document, *Groundwater Contamination in the United States*, in preparation by the Philadelphia Academy of Sciences, contains substantial information on the occurrence, use, and quality of ground water in the United States. Standards are discussed in detail for a number of states, but the information is not comprehensive for all the states. The American Petroleum Institute recognized the need for a publication which would provide specific information for every state in a readily updatable format. To this end, Ecological Analysts, Inc. was retained to develop an initial survey of the basic information on federal and state regulations concerning the use and protection of ground water.

Much of the information discussed in this guide—particularly aquifer classification and ground-water quality standards—may ultimately be impacted through EPA's finalization of the ground-water protection policy. EPA's interim final regulations for land disposal of hazardous waste have just taken effect (26 January 1983), and many states are now in the process of obtaining authorization to implement state programs. EPA has not yet finalized all requirements for the development of Underground Injection Control programs under the Safe Drinking Water Act. It is clear, therefore, that ground-water regulations will be in a state of flux for the next several years. The information provided in this guide is based on regulations effective January 1983. The current status of ground-water standards in each state should be investigated before making final environmental management decisions.

The Guide to Ground-Water Standards of the United States is comprised of two parts. The first part, Sections 1 through 4, contains an overview of technical and regulatory concepts and terminology, and a summary of the federal programs which provide the basis for the state regulations. The second part, Section 5, provides alphabetically arranged summaries for each of the states and territories.



GUIDE TO GROUND-WATER STANDARDS OF THE UNITED STATES

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Prepared by
Ecological Analysts, Inc.
15 Loveton Circle
Sparks, Maryland 21152

APPENDIX J

FEDERAL AND STATE DRINKING WATER AND HUMAN HEALTH STANDARDS, CRITERIA AND GUIDELINES APPLICABLE IN THE STATE OF OHIO

Summary of Field Tested
Water Quality Parameters

Well Number	Location Monitored	pH (pH units)	Spec. Cond. (umhos/cm)	Temp. C (°C)
1	Upgradient of Landfill 8	6.74	688	13
2	Landfill 8	7.21	602	14
3	Landfill 8	6.72	621	11
4	Landfill 10			14
5	Landfill 10	8.80	348	13.5
6	Landfill 11	6.91	1025	13
7	Landfill 11	6.60	1698	12
8	Fire Training Area 3			10
9	Fire Training Area 4	6.53	886	10
10	Landfill 12	6.98	898	12
11	Landfill 3	6.75	1088	14
12	Landfill 4	9.15	1215	13.5
13	Landfill 6	6.53	1056	12
14	Landfill 7	6.39	1195	11
15	Tank Farm (Tank 256)	7.2	1012	10
16	Tank Farm (Tank 272)	7.2	1079	11
17	Coal Storage Pile	7.0	1238	10
18	Chemical Burial Area	7.1	1223	11
19	Chemical Burial Area	7.1	1126	10
20	Landfill 5	6.70	1390	13
21	Landfill 5	6.76	1620	13
22	Landfill 5	6.81	996	16
23	Landfill 5	6.83	1272	12
24	Fire Training Area 1	6.85	898	10
25	Landfill 2			12
26	Landfill 9 (Sand Hill)	7.1	973	11
27	Fire Training Area 2	6.97	970	[illegible]

QUALITY CONTROL SAMPLES

Well Number	Location Monitored	Nitrate mg/l	Cl mg/l	SO_4 mg/l	B mg/l	Fe mg/l	Mn mg/l	Na mg/l	TOC mg/l	TOX µg/l	Phenol mg/l	Oil & Grease mg/l	VOA ug/l
2	Landfill 8	< 0.1	8.6	35.8	0.25	<0.1	<0.05	10.0	3.9	<5.0	<0.01	NR	NR
2 (D)		< 0.1	32.0	35.0	< 0.1	<0.1	<0.05	9.6	4.2	<5.0	NR	NR	NR
6	Landfill 11	<0.1	115.0	73.3	< 0.1	0.34	<0.05	24.0	<1.0	<5.0	<0.01	NR	NR
6 (D)		<0.1	65.5	67.0	0.1	0.23	<0.05	30.0	<1.0	<5.0	<0.01	NR	NR
15	Tank Farm (Tank 256)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.24	<10
15 (D)		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.27	<10
22	Landfill 5	<0.1	108.5	65	<0.1	0.60	<0.05	12	5.3	5.4	<0.01	NR	NR
22 (D)		<0.1	88.5	65	<0.1	0.57	<0.05	20	4.6	8.3	<0.01	NR	NR
MW-BW	Base Water Sup. from lab at Tank Farm	<0.1	--	48.0	<0.1	<0.1	<0.05	26.0	<1.0	<5.0	<0.01	NR	NR
MW-DW	Deionized Water Field Blank	<0.1	<1.0	<1.0	<0.1	<0.1	<0.05	<1.0	<1.0	<5.0	<0.01	<0.1	<10
	Lab Blank	<0.1	<1.0	<1.0	<0.1	<0.1	<0.05	<1.0	<1.0	<5.0	<0.01	<0.1	--
	Detection Limit	0.1	1.0	1.0	0.1	0.1	0.05	1.0	1.0	5.0	0.01	0.1	10

WESTON

OHIO

Parameter (mg/l unless noted)	Drinking Water Standards		Quality Standards	Monitoring Requirements	
	Federal	State		Solid Waste	Hazardous Waste
Arsenic	0.05	0.05			M
Barium	1.0	1.0			M
Cadmium	0.010	0.010			M
Chromium	0.05	0.05			M
Lead	0.05	0.05			M
Mercury	0.002	0.002			M
Selenium	0.01	0.01			M
Silver	0.05	0.05			M
Fluoride	1.4–2.4	1.4–2.4			M
Nitrate (as N)	10.0	10.0		S	M
Endrin	0.0002	0.0002			M
Lindane	0.004	0.004			M
Methoxychlor	0.1	0.1			M
Toxaphene	0.005	0.005			M
2,4-D	0.1	0.1			M
2,4,5-TP Silvex	0.01	0.01			M
Trihalomethanes	0.10	0.10			
Turbidity (TU)	1 or 5*	1 or 5*			
Coliform bacteria — membrane filter test (#/100 ml)	1 or 4	1			M
Gross alpha (pCi/l)	15	15			M
Combined Radium 226 and Radium 228	5	5			M
Beta and photon particle activity (mrem/yr)	4	4			M
Chloride	250			M–S	M
Color (units)	15				
Copper	1				
Corrosivity	Noncorrosive				
Foaming agents	0.5			S	M
Iron	0.3			S	M
Manganese	0.05				M
Odor (threshold no.)	3				
pH (units)	6.5–8.5			S	M
Sulfate	250			S	M
Total dissolved solids	500			M–S	
Zinc	5				
Phenol					M
Sodium				S	M
Conductivity (no units)				S	M
Total organic carbon				S	M
Total organic halogen					M
Temperature (no units)				S	
Total alkalinity				S	
Ammonia-nitrogen				S	
Total kjeldahl nitrogen				S	
Calcium				S	
Magnesium				S	
Chemical oxygen demand				M–S	
MBAS				M–S	

Note: "M" denotes monitoring requirement. See Section 4.3.
"S" denotes siting requirement. See text.
(*) Surface water only.

ENVIRONMENTAL PROTECTION AGENCY NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

(40 CFR 141; 40 FR 59565, December 24, 1975; Amended by 41 FR 28402, July 9, 1976; 44 FR 68641, November 29, 1979; Corrected by 45 FR 15542, March 11, 1980; 45 FR 57342, August 27, 1980)

Title 40—Protection of Environment
CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 141—NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

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Sec.
141.1 Applicability.
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141.3 Coverage.
141.4 Variances and exemptions.
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Subpart B—Maximum Contaminant Levels

141.11 Maximum contaminant levels for inorganic chemicals.
141.12 Maximum contaminant levels for organic chemicals.
141.13 Maximum contaminant levels for turbidity.
141.14 Maximum microbiological contaminant levels.
141.15 Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity in community water systems.
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141.21 Microbiological contaminant sampling and analytical requirements.
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Subpart D—Reporting Public Notification, and Record-keeping

141.31 Reporting requirements.
141.32 Public notification of variances, exemptions, and non-compliance with regulations.
141.33 Record maintenance.

Subpart E—Special Monitoring Regulations for Organic Chemicals

141.40 Special monitoring for organic chemicals.

Authority: Secs. 1412, 1414, 1445, and 1450 of the Public Health Service Act, 88 Stat. 1660 (42 U.S.C. 300g-1, 300g-3, 300j-4, and 300j-9).

Subpart A—General

§ 141.1 Applicability.

This part establishes primary drinking water regulations pursuant to section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93-523); and related regulations applicable to public water systems.

§ 141.2 Definitions.

As used in this part, the term:

(a) "Act" means the Public Health Service Act, as amended by the Safe Drinking Water Act, Pub. L. 93-523.

(b) "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(c) "Maximum contaminant level" means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(d) "Person" means an individual, corporation, company, association, partnership, State, municipality, or Federal agency.

(e) "Public water system" means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" community water system."

(f) "Community water syst a public water system whic least 15 service connections u round residents or regularl least 25 year-round residents

(g) "Non-community wa means a public water system a community water system.

(h) "Sanitary survey" me site review of the water so ties, equipment, operation a nance of a public water sys purpose of evaluating the s such source, facilities, equ eration and maintenance fo and distributing safe drinki

(i) "Standard sample" aliquot of finished drinking w examined for the presence bacteria.

(j) "State" means the a State government which h tion over public water syst any period when a State d primary enforcement pursuant to Section 1413 of term "State" means the R ministrator, U.S. Environme tion Agency.

(k) "Supplier of water" person who owns or opera water system.

(l) "Dose equivalent" mea uct of the absorbed dose f radiation and such factors differences in biological effe to the type of radiation and tion in the body as specifie ternational Commission on Units and Measurements (IC

(m) "Rem" means the equivalent from ionizing rad total body or any internal o system. A "millirem (mren of a rem.

(n) "Picocurie (pCi)" mean tity of radioactive materi 2.22 nuclear transformations

(o) "Gross alpha partic means the total radioacti alpha particle emission as measurements on a dry sam

(p) "Man-made beta part ton emitters" means all emitting beta particles an

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listed in Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, NBS Handbook 69, except the daughter products of thorium-232, uranium-235 and uranium-238.

(o) "Gross beta particle activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

[41 FR 28402, July 9, 1976]
[141.2 (p)-(t) added by 44 FR 68641, November 29, 1979]

(p) "Halogen" means one of the chemical elements chlorine, bromine or iodine.

(q) "Trihalomethane" (THM) means one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

(r) "Total trihalomethanes" (TTHM) means the sum of the concentration in milligrams per liter of the trihalomethane compounds [trichloromethane [chloroform], dibromochloromethane, bromodichloromethane and tribromomethane [bromoform]], rounded to two significant figures.

(s) "Maximum Total Trihalomethane Potential (MTP)" means the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25° C or above.

(t) "Disinfectant" means any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

§ 141.3 Coverage.

This part shall apply to each public water system, unless the public water system meets all of the following conditions:

(a) Consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(b) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(c) Does not sell water to any person; and

(d) Is not a carrier which conveys passengers in interstate commerce.

§ 141.4 Variances and exemptions.

Variances or exemptions from certain provisions of these regulations may be granted pursuant to Sections 1415 and 1416 of the Act by the entity with primary enforcement responsibility. Provisions under Part 142, *National Interim Primary Drinking Water Regulations Implementation*—subpart E (Variances) and subpart F (Exemptions)—apply where EPA has primary enforcement responsibility.

§ 141.5 Siting requirements.

Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase the capacity of an existing public water system, he shall notify the State, and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(b) Except for intake structures, is within the floodplain of a 100-year flood or is lower than any recorded high tide where appropriate records exist.

The U.S. Environmental Protection Agency will not seek to override land use decisions affecting public water systems siting which are made at the State or local government levels.

§ 141.6 Effective dates.

[141.6 revised by 44 FR 68641, November 29, 1979]

(a) Except as provided in paragraph (b) of this section, the regulations set forth in this part shall take effect on June 24, 1977.

(b) The regulations for total trihalomethanes set forth in § 141.12(c) shall take effect 2 years after the date of promulgation of these regulations for community water systems serving 75,000 or more individuals, and 4 years after the date of promulgation for communities serving 10,000 to 74,999 individuals.

(c) The regulations set forth in 141.11 (a), (c) and (d); 141.14(a)(1); 141.14(b)(1)(c); 141.14(b)(2)(i); 141.14(d); 141.21 (a), (c) and (i); 141.22 (a) and (e); 141.23 (a)(3) and (a)(4); 141.23(f); 141.24(a)(3); 141.24 (e) and (f); 141.25(e); 141.27(a); 141.28 (a) and (b); 141.31 (a), (c), (d) and (e); 141.32(b)(3); and 141.32(d) shall take effect immediately upon promulgation.

(d) The regulations set forth in 141.41 shall take effect 18 months from the date of promulgation. Suppliers must complete the first round of sampling and reporting within 12 months following the effective date.

(e) The regulations set forth in 141.42 shall take effect 18 months from the date of promulgation. All requirements in 141.42 must be completed within 12 months following the effective date.

[141.6 (c)-(e) added by 45 FR 57342, August 27, 1980]

Subpart B—Maximum Contaminant Levels

§ 141.11 Maximum contaminant levels for inorganic chemicals.

(a) The MCL for nitrate is applicable to both community water systems and non-community water systems except as provided by in paragraph (d). The levels for the other organic chemicals apply only to community water systems. Compliance with MCLs for inorganic chemicals is calculated pursuant to § 141.23.

[141.11(a) amended by 45 FR 57342, August 27, 1980]

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

Contaminant	Level, milligrams per liter
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

(c) When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the maximum contaminant levels for fluoride are:

Temperature Degrees Fahrenheit	Degrees Celsius	Level, milligrams per liter
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.	26.3 to 32.6	1.4

(c) Fluoride at optimum levels in drinking water has been shown to have beneficial effects in reducing the occurrence of tooth decay.

[141.11 (c) amended by 45 FR 57342, August 27, 1980]

(d) At the discretion of the State, nitrate levels not to exceed 20 mg/l may be allowed in a non-community water system if the supplier of water demonstrates to the satisfaction of the State that:

(1) Such water will not be available to children under 6 months of age; and

(2) There will be continuous posting of the fact that nitrate levels exceed 10 mg/l and the potential health effects of exposure; and

(3) Local and State public health authorities will be notified annually of nitrate levels that exceed 10 mg/l; and

(4) No adverse health effects shall result.

[141.11 (d) added by 45 FR 57342, August 27, 1980]

§ 141.12 Maximum contaminant levels for organic chemicals.

[141.12 revised by 44 FR 68641, November 29, 1979]

The following are the maximum contaminant levels for organic chemicals. The maximum contaminant levels for organic chemicals in paragraphs (a) and (b) of this section apply to all community water systems. Compliance with the maximum contaminant levels in paragraphs (a) and (b) is calculated pursuant to § 141.24. The maximum contaminant level for total trihalomethanes in paragraph (c) of this section applies only to community water systems which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in any part of the drinking water treatment process. Compliance with the maximum contaminant level for total trihalomethanes is calculated pursuant to § 141.30.

	Level, milligrams per liter
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene).	0.0002 (0.2 ppb)
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer).	0.004 (4 ppb)
Methoxychlor (1,1,1-Trichloro-2, 2-bis [p-methoxyphenyl] ethane).	0.1 (100 ppb)
Toxaphene ($C_{10}H_{10}Cl_8$, Technical chlorinated camphene, 67-69 percent chlorine).	0.005 (5 ppb)
(b) Chlorophenoxys:	
2,4-D, (2,4-Dichlorophenoxyacetic acid).	0.1 (100 ppb)
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	0.01 (10 ppb)

(c) Total trihalomethanes (the sum of the concentrations of bromodichloromethane, dibromochloromethane, tribromomethane (bromoform) and trichloromethane (chloroform) 0.10 mg/l.

[141.12(c) added by 44 FR 68641, November 29, 1979]

§ 141.13 Maximum contaminant levels for turbidity.

The maximum contaminant levels for turbidity are applicable to both community water systems and non-community water systems using surface water sources in whole or in part. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

(a) One turbidity unit (TU), as determined by a monthly average pursuant to § 141.22, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:

(1) Interfere with disinfection;

(2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or

(3) Interfere with microbiological determinations.

(b) Five turbidity units based on an average for two consecutive days pursuant to § 141.22.

§ 141.14 Maximum microbiological contaminant levels.

The maximum contaminant levels for coliform bacteria, applicable to community water systems and non-community water systems, are as follows:

(a) When the membrane filter technique pursuant to § 141.21(a) is used, the number of coliform bacteria shall not exceed any of the following:

[141.14(a)(1) revised by 45 FR 57342, August 27, 1980]

(1) One per 100 milliliters as the arithmetic mean of all samples examined per compliance period pursuant to § 141.21(b) or (c), except that, at the primacy Agency's discretion systems required to take 10 or fewer samples per month may be authorized to exclude one positive routine sample per month from the monthly calculation if: (i) as approved on a case-by-case basis the State determines and indicates in writing to the public water system that no unreasonable risk to health existed under the conditions of this modification. This determination should be based upon a number of factors not limited to the following: (A) the system provided and had maintained an active disinfectant residual in the distribution system, (B) the potential for contamination as indicated by a sanitary survey, and (C) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (ii) the supplier initiates a check sample on each of two consecutive days from the same sampling point within 24 hours after notification that the routine sample is positive, and each of these check samples is negative; and (iii) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this paragraph and a summary of the corrective action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or

(3) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

(b) (1) When the fermentation tube method and 10 milliliter standard portions pursuant to § 141.21(a) are used coliform bacteria shall not be present in any of the following:

[141.14(b)(1)(i) revised by 45 FR 57342, August 27, 1980]

(i) More than 10 percent of the portions (tubes) in any one month pursuant to § 141.21 (b) or (c) except that, at the State's discretion, systems required to take 10 or fewer samples per month may be authorized to exclude one positive routine sample resulting in one or more positive tubes per month from the monthly calculation if: (A) as approved on a case-by-case basis the State determines and indicates in writing to the public water system that no unreasonable risk to health existed under the conditions of this modification. This determination should be based upon a number of factors not limited to the following: (1) the system provided and had maintained an active disinfectant residual in the distribution system, (2) the potential for contamination as indicated by a sanitary survey, and (3) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (B) the supplier initiates a check sample on each of two consecutive days from the sampling point within 24 hours after notification that the routine sample is positive, and each of these check samples is negative; and (C) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this paragraph and report the action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(ii) three or more portions in more than one sample when less than 20 samples are examined per month; or

(iii) three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

(2) When the fermentation tube

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Part V

Environmental Protection Agency

Water Quality Criteria Documents; Availability

ENVIRONMENTAL PROTECTION AGENCY

[FRL 1623-3]

Water Quality Criteria Documents; Availability

AGENCY: Environmental Protection Agency.

ACTION: Notice of Water Quality Criteria Documents.

SUMMARY: EPA announces the availability and provides summaries of water quality criteria documents for 64 toxic pollutants or pollutant categories. These criteria are published pursuant to section 304(a)(1) of the Clean Water Act.

AVAILABILITY OF DOCUMENTS: Summaries of both aquatic-based and health-based criteria from the documents are published below. Copies of the complete documents for individual pollutants may be obtained from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, (703-487-4650). A list of the NTIS publication order numbers for all 64 criteria documents is published below. These documents are also available for public inspection and copying during normal business hours at: Public Information Reference Unit, U.S. Environmental Protection Agency, Room 2404 (rear), 401 M St., S.W., Washington, D.C. 20460. As provided in 40 CFR Part 2, a reasonable fee may be charged for copying services. Copies of these documents are also available for review in the EPA Regional Office libraries.

Copies of the documents are not available from the EPA office listed below. Requests sent to that office will be forwarded to NTIS or returned to the sender.

1. Acenaphthene, PB81-117269.
2. Acrolein, PB81-117277.
3. Acrylonitrile, PB81-117285.
4. Aldrin/Dieldrin, PB81-117301.
5. Antimony, PB81-117319.
6. Arsenic, PB81-117327.
7. Asbestos, PB81-117335.
8. Benzene, PB81-117293.
9. Benzidine, PB81-117343.
10. Beryllium, PB81-117350.
11. Cadmium, PB81-117368.
12. Carbon Tetrachloride, PB81-117376.
13. Chlordane, PB81-117384.
14. Chlorinated benzenes, PB81-117392.
15. Chlorinated ethanes, PB81-117400.
16. Chloroalkyl ethers, PB81-117418.
17. Chlorinated naphthalene, PB81-117426.
18. Chlorinated phenols, PB81-117434.
19. Chloroform, PB81-117442.
20. 2-chlorophenol, PB81-117459.
21. Chromium, PB81-117467.
22. Copper, PB81-117475.
23. Cyanides, PB81-117483.
24. DDT, PB81-117491.
25. Dichlorobenzenes, PB81-117509.
26. Dichlorobenzidine, PB81-117517.
27. Dichloroethylenes, PB81-117525.
28. 2,4-dichlorophenol, PB81-117533.
29. Dichloropropanes/propenes, PB81-117541.
30. 2,4-dimethylphenol, PB81-117558.
31. Dinitrotoluene, PB81-117566.
32. Diphenylhydrazine, PB81-117731.
33. Endosulfan, PB81-117574.
34. Endrin, PB81-117582.
35. Ethylbenzene, PB81-117590.
36. Fluoranthene, PB81-117608.
37. Haloethers, PB81-117616.
38. Halomethanes, PB81-117624.
39. Heptachlor, PB81-117632.
40. Hexachlorobutadiene, PB81-117640.
41. Hexachlorocyclohexane, PB81-117657.
42. Hexachlorocyclopentadiene, PB81-117665.
43. Isophorone, PB81-117673.
44. Lead, PB81-117681.
45. Mercury, PB81-117699.
46. Naphthalene, PB81-117707.
47. Nickel, PB81-117715.
48. Nitrobenzene, PB81-117723.
49. Nitrophenols, PB81-117749.
50. Nitrosamines, PB81-117756.
51. Pentachlorophenol, PB81-117764.
52. Phenol, PB81-117772.
53. Phthalate esters, PB81-117780.
54. Polychlorinated biphenyls (PCBs), PB81-117798.
55. Polynuclear aromatic hydrocarbons, PB81-117806.
56. Selenium, PB81-117814.
57. Silver, PB81-117822.
58. Tetrachloroethylene, PB81-117830.
59. Thallium, PB81-117848.
60. Toluene, PB81-117855.
61. Toxaphene, PB81-117863.
62. Trichloroethylene, PB81-117871.
63. Vinyl chloride, PB81-117889.
64. Zinc, PB81-117897.

FOR FURTHER INFORMATION CONTACT: Dr. Frank Gostomski, Criteria and Standards Division (WH-585), United States Environmental Protection [redacted] Washington, D.C. 20460 (202) 245-3033.

SUPPLEMENTARY INFORMATION:

Background

Pursuant to section 304(a)(1) of the Clean Water Act, 33 U.S.C. 1314(a)(1), EPA is required to periodically review and publish criteria for water quality accurately reflecting the latest scientific knowledge:

(A) on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water, including groundwater; (B) on the concentration and dispersal of pollutants, or their byproducts, through biological, physical, and chemical processes; and (C) on the effects of pollutants on biological community diversity, productivity, and stability, including information on the factors affecting rates of eutrophication and rates of organic and inorganic sedimentation for varying types of receiving waters.

EPA is today announcing the availability of criteria documents for 64 of the 65 pollutants designated as toxic under section 307(a)(1) of the Act. The document on TCDD (Dioxin) will be published within the next month after review of recent studies. Criteria for the section 307(a)(1) toxic pollutants being published today will replace the criteria for those same pollutants found in the EPA publication, *Quality Criteria for Water*, (the "Red Book.") Criteria for all other pollutants and water constituents found in the "Red Book" remain valid. The criteria published today have been derived using revised methodologies for determining pollutant concentrations that will, when not exceeded, reasonably protect human health and aquatic life. Draft criteria documents were made available for public comment (44 FR 15926, March 15, 1979, 44 FR 43660, July 25, 1979, 44 FR 56628, October 1, 1979). These final criteria have been derived after consideration of all comments received.

These criteria documents are also issued in satisfaction of the Settlement Agreement in *Natural Resources Defense Council, et al.* v. *Train*, 8 E.R.C. 2120 (1976), modified, 12 E.R.C. 1833 (D.D.C. 1979). Pursuant to paragraph 11 of that agreement, EPA is required to publish criteria documents for the 65 pollutants which Congress, in the 1977 amendments to the Act, designated as toxic under section 307(a)(1). These documents contain recommended maximum permissible pollutant concentrations consistent with the protection of aquatic organisms, human health, and some recreational activities. Although paragraph 11 imposes certain obligations on the Agency, it does not create additional authority.

The Development of Water Quality Criteria

Section 304(a)(1) criteria contain two essential types of information: (1) discussions of available scientific data on the effects of pollutants on public health and welfare, aquatic life and recreation, and (2) quantitative concentrations or qualitative assessments of the pollutants in water which will generally ensure water

quality adequate to support a specified water use. Under section 304(a)(1), these criteria are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects. Criteria values do not reflect considerations of economic or technological feasibility.

Publication of water quality criteria of this type has been an ongoing process which EPA, and its predecessor Agency, the Federal Water Pollution Control Administration, have been engaged in since 1968. At that time the first Federal compilation of water quality criteria, the so-called "Green Book" *(Water Quality Criteria)*, was published. As now, these criteria contained both narrative discussions of the environmental effects of pollutants on a range of possible uses and concentrations of pollutants necessary to support these uses. Since that time, water quality criteria have been revised and expanded with publication of the "Blue Book" *(Water Quality Criteria 1972)* in 1973 and the "Red Book" *(Quality Criteria for Water)* in 1976.

Since publication of the Red Book there have been substantial changes in EPA's approach to assessing scientific data and deriving section 304(a)(1) criteria. Previous criteria were derived from a limited data base. For many pollutants, an aquatic life criterion was derived by multiplying the lowest concentration known to have acute lethal effect on half of a test group of an aquatic species (the LC50 value) by an application factor in order to protect against chronic effects. If data showed a substance to be bioaccumulative or to have other significant long-term effects, a factor was used to reduce the indicated concentrations to a level presumed to be protective. Criteria for the protection of human health were similarly derived by considering the pollutants' acute, chronic, and bioaccumulative effects on non-human mammals and humans.

Although a continuation of the process of criteria development, the criteria published today were derived using revised methodologies (Guidelines) for calculating the impact of pollutants on human health and aquatic organisms. These Guidelines consist of systematic methods for assessing valid and appropriate data concerning acute and chronic adverse effects of pollutants on aquatic organisms, non-human mammals, and humans. By use of these data in prescribed ways, criteria are formulated to protect aquatic life and human health from exposure to the pollutants. For some pollutants, bioconcentration properties are used to formulate criteria protective of aquatic life uses. For almost all of the pollutants, bioconcentration properties are used to assess the relative extent of human exposure to the pollutant either directly through ingestion of water or indirectly through consumption of aquatic organisms. Human health criteria for carcinogens are presented as incremental risks to man associated with specific concentrations of the pollutant in ambient water. The Guidelines used to derive criteria protective of aquatic life and human health are fully described in appendices B and C, respectively, of this Notice.

The Agency believes that these Guidelines provide criteria which more accurately reflect the effects of these pollutants on human health and on aquatic organisms and their uses. They are based on a more rational and consistent approach for using scientific data. These Guidelines were developed by EPA scientists in consultation with scientists from outside the Agency and they have been subjected to intensive public comment.

Neither the Guidelines nor the criteria are considered inflexible doctrine. Even at this time, EPA is taking action to employ the resources of peer review groups, including the Science Advisory Board, to evaluate recently published data, and EPA is conducting its own evaluation of new data to determine whether revisions to the criteria documents would be warranted.

The criteria published today are based solely on the effect of a single pollutant. However, pollutants in combination may have different effects because of synergistic, additive, or antagonistic properties. It is impossible in these documents to quantify the combined effects of these pollutants, and persons using criteria should be aware that site-specific analysis of actual combinations of pollutants may be necessary to give more precise indications of the actual environmental impacts of a discharge.

Relationship of the Section 304(a)(1) Criteria to Regulatory Programs

Section 304(a)(1) criteria are not rules and they have no regulatory inpact. Rather, these criteria present scientific data and guidance on the enviromental effect of pollutants which can be useful to derive regulatory requirements based on considerations of water quality impacts. Under the Clean Water Act, these regulatory requirements may include the promulgation of water quality-based effluent limitations under section 302, water quality standards under section 303, or toxic pollutant effluent standards under section 307. States are encouraged to begin to modify or, if necessary, develop new programs necessary to support the implementation of regulatory controls for toxic pollutants. As appropriate, States may incorporate criteria for toxic pollutants, based on this guidance, into their water quality standards.

Section 304(a)(1) criteria have been most closely associated with the development of State water quality standards, and the "Red Book" values have, in the past, been the basis for EPA's assessments of the adequacy of State requirements. However, EPA is now completing a major review of its water quality standards policies and regulations. After consideration of comments received on an Advance Notice of Proposed Rulemaking (43 FR 29588, July 10, 1978) and the draft criteria documents, the Agency intends to propose, by the end of this year, a revised water quality standards regulation which will clarify the Agency's position on a number of significant standards issues.

With the publication of these criteria, however, it is appropriate to discuss EPA's current thinking on standards issues relating to their use. This discussion does not establish new regulatory requirements and is intended as guidance on the possible uses of these criteria and an indication of future rulemaking the Agency may undertake. No substantive requirements will be established without further opportunity for public comment.

Water Quality Standards

Section 303 of the Clean Water Act provides that water quality standards be developed for all surface waters. A water quality standard consists basically of two parts: (1) A "designated use" for which the water body is to be protected (such as "agricultural," "recreation" or "fish and wildlife"), and (2) "criteria" which are numerical pollutant concentration limits or narrative statements necessary to preserve or achieve the designated use. A water quality standard is developed through State or Federal rulemaking proceedings and must be translated into enforceable effluent limitations in a point source (NPDES) permit or may form the basis of best management practices applicable to nonpoint sources under section 208 of the Act.

Relationship of Section 304(a)(1) Criteria to the Criteria Component of State Water Quality Standards:

In the ANPRM, EPA announced a policy of "presumptive applicability" for

section 304(a)(1) criteria codified in the "Red Book." Presumptive applicability meant that a State had to adopt a criterion for a particular water quality parameter at least as stringent as the recommendation in the Red Book unless the State was able to justify a less stringent criterion based on: natural - background conditions, more recent scientific evidence, or local, site-specific information. EPA is rescinding the policy of presumptive applicability because it has proven to be too inflexible in actual practice.

Although the section 304(a)(1) criteria represent a reasonable estimate of pollutant concentrations consistent with the maintenance of designated water uses, States may appropriately modify these values to reflect local conditions. In certain circumstances, the criteria may not accurately reflect the toxicity of a pollutant because of the effect of local water quality characteristics or varying sensitivities of local populations. For example, in some cases, ecosystem adaptation may enable a viable, balanced aquatic population to exist in waters with high natural background levels of certain pollutants. Similarly, certain compounds may be more or less toxic in some waters because of differences in alkalinity, temperature, hardness, and other factors.

Methods for adjusting the section 304(a)(1) criteria to reflect these local differences are discussed below.

Relationship of Section 304(a)(1) Criteria to Designated Water Uses:

The criteria published today can be used to support the designated uses which are generally found in State standards. The following section discusses the relationship between the criteria and individual use classifications. Where a water body is designated for more than one use, criteria necessary to protect the most sensitive use should be applied.

1. *Recreation:* Recreational uses of water include such activities as swimming, wading, boating and fishing. Although insufficient data exist on the effects of toxic pollutants resulting from exposure through such primary contact as swimming, section 304(a)(1) criteria based on human health effects may be used to support this designated use where fishing is included in the State definition of "recreation." In this situation only the portion of the criterion based on fish consumption should be used.

2. *Protection and Propagation of Fish and Other Aquatic Life:* The section 304(a)(1) criteria based on toxicity to aquatic life may be used directly to support this designated use.

3. *Agricultural and Industrial Uses:* The section 304(a)(1) criteria were not specifically developed to reflect the impact of pollutants on agricultural and industrial uses. However, the criteria developed for human health and aquatic life are sufficiently stringent to protect these other uses. States may establish criteria specifically designed to protect these uses.

4. *Public Water Supply:* The drinking water exposure component of the human health effects criteria can apply directly to this use classification or may be appropriately modified depending upon whether the specific water supply system falls within the auspices of the Safe Drinking Water Act's (SDWA) regulatory control, and the type and level of treatment imposed upon the supply before delivery to the consumer. The SDWA controls the presence of toxic pollutants in finished ("end-of-tap") drinking water. A brief description of relevant sections of this Act is necessary to explain how the SDWA will work in conjunction with section 304(a)(1) criteria in protecting human health from the effects of toxics due to consumption of water.

Pursuant to section 1412 of the SDWA, EPA has promulgated "National Interim Primary Drinking Water Standards" for certain organic and inorganic substances. These standards establish "maximum contaminant levels" ("MCLs") which specify the maximum permissible level of a contaminant in water which may be delivered to a user of a public water system now defined as serving a minimum of 25 people. MCLs are established based on consideration of a range of factors including not only the health effects of the contaminants but also technological and economic feasibility of the contaminants' removal from the supply. EPA is required to establish revised primary drinking water regulations based on the effects of a contaminant on human health, and include treatment capability, monitoring availability, and costs. Under Section 1401(1)(D)(i) of the SDWA, EPA is also allowed to establish the minimum quality criteria for water which may be taken into a public water supply system.

Section 304(a)(1) criteria provide estimates of pollutant concentrations protective of human health, but do not consider treatment technology, costs and other feasibility factors. The section 304(a)(1) criteria also include fish bioaccumulation and consumption factors in addition to direct human drinking water intake. These numbers were not developed to serve as "end of tap" drinking water standards, and they have no regulatory significance under the SDWA. Drinking water standards are established based on considerations, including technological and economic feasibility, not relevant to section 304(a)(1) criteria. Section 304(a)(1) criteria may be analogous to the recommended maximum contaminant levels (RMCLs) under section 1412(b)(1)(B) of the SDWA in which, based upon a report from the National Academy of Sciences, the Administrator should set target levels for contaminants in drinking water at which "no known or anticipated adverse effects occur and which allows an adequate margin of safety". RMCLs do not take treatment, cost, and other feasibility factors into consideration. Section 304(a)(1) criteria are, in concept, related to the health-based goals specified in the RMCLs. Specific mandates of the SDWA such as the consideration of multi-media exposure, as well as different methods for setting maximum contaminant levels under the two Acts, may result in differences between the two numbers.

MCLs of the SDWA, where they exist, control toxic chemicals in finished drinking water. However, because of variations in treatment and the fact that only a relatively small number of MCLs have been developed, ambient water criteria may be used by the States as a supplement to SDWA regulations. States will have the option of applying MCLs, section 304(a)(1) human health effects criteria, modified section 304(a)(1) criteria or controls more stringent than these three to protect against the effects of toxic pollutants by ingestion from drinking water.

For untreated drinking water supplies, States may control toxics in the ambient water through either use of MCLs (if they exist for the pollutants of concern), section 304(a)(1) human health effects criteria, or a more strigent contaminant level than the former two options.

For treated drinking water supplies serving less than 25 people, States may choose toxics control through application of MCLs (if they exist for the pollutants of concern and are attainable by the type of treatment) in the finished drinking water. States also have the options to control toxics in the ambient water by choosing section 304(a)(1) criteria, adjusted section 304(a)(1) criteria resulting from the reduction of the direct drinking water exposure component in the criteria calculation to the extent that the treatment procedure reduces the level of pollutants, or a more stringent contaminant level than the former three options.

For treated drinking water supplies serving 25 people or greater, States *must* control toxics down to levels at least as stringent as MCLs (where they exist for

the pollutants of concern) in the finished drinking water. However, States also have the options to control toxics in the ambient water by choosing section 304(a)(1) criteria, adjusted section 304(a)(1) criteria resulting from the reduction of the direct drinking water exposure component in the criteria calculation to the extent that the treatment process reduces the level of pollutants, or a more stringent contaminant level than the former three options.

Inclusion of Specific Pollutants in State Standards:

To date, EPA has not required that a State address any specific pollutant in its standards. Although all States have established standards for most conventional pollutants, the treatment of toxic pollutants has been much less extensive. In the ANPRM, EPA suggested a policy under which States would be required to address a set of pollutants and incorporate specific toxic pollutant criteria into water quality standards. If the State failed to incorporate these criteria, EPA would promulgate the standards based upon these criteria pursuant to section 303(c)(4)(B).

In the forthcoming proposed revision to the water quality standard regulations, a significant change in policy will be proposed relating to the incorporation of certain pollutants in State water quality standards. This proposal will differ from the proposal made in the ANPRM. The ANPRM proposed an EPA-published list of pollutants for which States would have had to develop water quality standards. This list might have contained some (or all) of the 65 toxic pollutants. However, the revised water quality standards regulation will propose a process by which EPA will assist States in identifying specific toxic pollutants required for assessment for possible inclusion in State water quality standards. For these pollutants, States will have the option of adopting the published criteria or of adjusting those criteria based on site-specific analysis.

These pollutants would generally represent the greatest threat to sustaining a healthy, balanced ecosystem in water bodies or to human health due to exposure directly or indirectly from water. EPA is currently developing a process to determine which pollutants a State must assess for possible inclusion in its water quality standards. Relevant factors might include the toxicity of the pollutant, the frequency and concentration of its discharge, its geographical distribution, the breadth of data underlying the scientific assessment of its aquatic life and human health effects, and the technological and economic capacity to control the discharge of the pollutant. For some of the pollutants, all States may be required to assess them for possible inclusion in their standards. For others, assessment would be restricted to States or limited to specific water bodies where the pollutants pose a particular site-specific problem.

Criteria Modification Process

Flexibility is available in the application of these and any other valid water quality criteria to regulatory programs. Although in some cases they may be used by the States as developed, the criteria may be modified to reflect local environmental conditions and human exposure patterns before incorporation into programs such as water quality standards. If significant impacts of site-specific water quality conditions in the toxicities of pollutants can be demonstrated or significantly different exposure patterns of these pollutants to humans can be shown, section 304(a)(1) criteria may be modified to reflect these local conditions. The term "local" may refer to any appropriate geographic area where common aquatic environmental conditions or exposure patterns exist. Thus, "local" may signify a Statewide, regional, river reach, or entire river basin area. On the other hand, the criteria of some pollutants might be applicable nationwide without the need for adaptation to reflect local conditions. The degree of toxicity toward aquatic organisms and humans characteristic of these pollutants would not change significantly due to local water quality conditions.

EPA is examining a series of environmental factors or water quality parameters which might realistically be expected to affect the laboratory-derived water quality criterion recommendation for a specific pollutant. Factors such as hardness, pH, suspended solids, types of aquatic organisms present, etc. could impact on the chemical's effect in the aquatic environment. Therefore, local information can be assembled and analyzed to adjust the criterion recommendation if necessary.

The Guidelines for deriving criteria for the protection of aquatic life suggest several approaches for modifying the criteria. First, toxicity data, both acute and chronic, for local species could be substituted for some or all of the species used in deriving criteria for the water quality standard. The minimum data requirements should still be fulfilled in calculating a revised criterion. Second, criteria may be specifically tailored to a local water body by use of data from toxicity tests performed with that ambient water. A procedure such as this would account for local environmental conditions in formulating a criterion relevant to the local water body. Third, site-specific water quality characteristics resulting in either enhancement or mitigation of aquatic life toxicity for the pollutant could be factored into final formulation of the criterion. Finally, the criteria may be made more stringent to ensure protection of an individual species not otherwise adequately protected by any of the three modification procedures previously mentioned.

EPA does not intend to have States assess every local stream segment and lake in the country on an individual basis before determining if an adjustment is necessary. Rather, it is envisioned that water bodies having similar hydrological, chemical, physical, and biological properties will be grouped for the purpose of criteria adjustment. The purpose of this effort is to assist States in adapting the section 304(a) criteria to local conditions where needed, thereby precluding the setting of arbitrary and perhaps unnecessarily stringent or underprotective criteria in a water body. In all cases, EPA will still be required, pursuant to section 303(c), to determine whether the State water quality standards are consistent with the goals of the Act, including a determination of whether State-established criteria are adequate to support a designated use.

Criteria for the Protection of Aquatic Life

Interpretation of the Criteria

The aquatic life criteria issued today are summarized in Appendix A of this Federal Register notice. Criteria have been formulated by applying a set of Guidelines to a data base for each pollutant. The criteria for the protection of aquatic life specify pollutant concentrations which, if not exceeded, should protect most, but not necessarily all, aquatic life and its uses. The Guidelines specify that criteria should be based on an array of data from organisms, both plant and animal, occupying various trophic levels. Based on these data, criteria can be derived which should be adequate to protect the types of organisms necessary to support an aquatic community.

The Guidelines are not designed to derive criteria which will protect all life stages of all species under all conditions. Generally some life stage of one or more tested species, and

probably some untested species, will have sensitivities below the maximum value or the 24-hour average under some conditions and would be adversely affected if the highest allowable pollutant concentrations and the worst conditions existed for a long time. In actual practice, such a situation is not likely to occur and thus the aquatic community as a whole will normally be protected if the criteria are not exceeded. In any aquatic community there is a wide range of individual species sensitivities to the effects of toxic pollutants. A criterion adequate to protect the most susceptible life stage of the most sensitive species would in many cases be more stringent than necessary to protect the overall aquatic community.

The aquatic life criteria specify both maximum and 24-hour average values. The combination of the two values is designed to provide adequate protection of aquatic life and its uses from acute and chronic toxicity and bioconcentration without being as restrictive as a one-number criterion would have to be to provide the same amount of protection. A time period of 24 hours was chosen in order to ensure that concentrations not reach harmful levels for unacceptably long periods. Averaging for longer periods, such as a week or a month for example, could permit high concentrations to persist long enough to produce significant adverse effects. A 24-hour period was chosen instead of a slightly longer or shorter period in recognition of daily fluctuations in waste discharges and of the influence of daily cycles of sunlight and darkness and temperature on both pollutants and aquatic organisms.

The maximum value, which is derived from acute toxicity data, prevents significant risk of adverse impact to organisms exposed to concentrations above the 24-hour average. Merely specifying the average value over a specified time period is insufficient because concentrations of chemicals higher than the average value can kill or cause irreparable damage in short periods. Furthermore, for some chemicals the effect of intermittent high exposures is cumulative. It is therefore necessary to place an upper limit on pollutant concentrations to which aquatic organisms might be exposed. The two-number criterion is intended to describe the highest average ambient water concentration which will produce a water quality generally suited to the maintenance of aquatic life while restricting the extent and duration of the excursions over that average to levels which will not cause harm. The only way to assure the same degree of protection with a one-number criterion would be to use the 24-hour average as a concentration that is not to be exceeded at any time in any place.

Since some substances may be more toxic in freshwater than in saltwater, or vice versa, provision is made for deriving separate water quality criteria for freshwater and for saltwater for each substance. However, for some substances sufficient data may not be available to derive one or both of these criteria using the Guidelines.

Specific aquatic life criteria have not been developed for all of the 65 toxic pollutants. In those cases where there were insufficient data to allow the derivation of a criterion, narrative descriptions of apparent threshold levels for acute and/or chronic effects based on the available data are presented. These descriptions are intended to convey a sense of the degree of toxicity of the pollutant in the absence of a criterion recommendation.

Summary of the Aquatic Life Guidelines

The Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and its Uses were developed to describe an objective, internally consistent, and appropriate way of ensuring that water quality criteria for aquatic life would provide, on the average, a reasonable amount of protection without an unreasonable amount of overprotection or underprotection. The resulting criteria are not intended to provide 100 percent protection of all species and all uses of aquatic life all of the time, but they are intended to protect most species in a balanced, healthy aquatic community. The Guidelines are published as Appendix B of this Notice. Responses to public comments on these Guidelines are attached as Appendix D.

Minimum data requirements are identified in four areas: acute toxicity to animals (eight data points), chronic toxicity to animals (three data points), toxicity to plants, and residues. Guidance is also given for discarding poor quality data.

Data on acute toxicity are needed for a variety of fish and invertebrate species and are used to derive a Final Acute Value. By taking into account the number and relative sensitivities of the tested species, the Final Acute Value is designed to protect most, but not necessarily all, of the tested and untested species.

Data on chronic toxicity to animals can be used to derive a Final Chronic Value by two different means. If chronic values are available for a specified number and array of species, a final chronic value can be calculated directly. If not, an acute-chronic ratio is derived and then used with the Final Acute Value to obtain the Final Chronic Value.

The Final Plant Value is obtained by selecting the lowest plant toxicity value based on measured concentrations.

The Final Residue Value is intended to protect wildlife which consume aquatic organisms and the marketability of aquatic organisms. Protection of the marketability of aquatic organisms is, in actuality, protection of a use of that water body ("commercial fishery"). Two kinds of data are necessary to calculate the Final Residue Value: a bioconcentration factor (BCF) and a maximum permissible tissue concentration, which can be an FDA action level or can be the result of a chronic wildlife feeding study. For lipid soluble pollutants, the BCF is normalized for percent lipids and then the Final Residue Value is calculated by dividing the maximum permissible tissue concentration by the normalized BCF and by an appropriate percent lipid value. BCFs are normalized for percent lipids since the BCF measured for any individual aquatic species is generally proportional to the percent lipids in that species.

If sufficient data are available to demonstrate that one or more of the final values should be related to a water quality characteristic, such as salinity, hardness, or suspended solids, the final value(s) are expressed as a function of that characteristic.

After the four final values (Final Acute Value, Final Chronic Value, Final Plant Value, and Final Residue Value) have been obtained, the criterion is established with the Final Acute Value becoming the maximum value and the lowest of the other three values becoming the 24-hour average value. All of the data used to calculate the four final values and any additional pertinent information are then reviewed to determine if the criterion is reasonable. If sound scientific evidence indicates that the criterion should be raised or lowered, appropriate changes are made as necessary.

The present Guidelines have been revised from the earlier published versions (43 FR 21506, May 18, 1978; 43 FR 29028, July 5, 1978; 44 FR 15926, March 15, 1979). Details have been added in many places and the concept of a minimum data base has been incorporated. In addition, three adjustment factors and the species sensitivity factor have been deleted. These modifications were the result of the Agency's analysis of public comments and comments received from the Science Advisory Board on earlier

versions of the Guidelines. These comments and the Resultant modifications are addressed fully in Appendix D to this notice.

Criteria for the Protection of Human Health

Interpretation of the Human Health Criteria

The human health criteria issued today are summarized in Appendix A of this Federal Register notice. Criteria for the protection of human health are presented for 62 of the 65 pollutants based on their carcinogenic, toxic, or organoleptic (taste and odor) properties. The meanings and practical uses of the criteria values are distinctly different depending on the properties on which they are based.

The objective of the health assessment portions of the criteria documents is to estimate ambient water concentrations which, in the case of non-carcinogens, prevent adverse health effects in humans, and in the case of suspect or proven carcinogens, represent various levels of incremental cancer risk.

Health assessments typically contain discussions of four elements: Exposure, pharmacokinetics, toxic effects, and criterion formulation.

The exposure section summarizes information on exposure routes: ingestion directly from water, indirectly from consumption of aquatic organisms found in ambient water, other dietary sources, inhalation, and dermal contact. Exposure assumptions are used to derive human health criteria. Most criteria are based solely on exposure from consumption of water containing a specified concentration of a toxic pollutant and through consumption of aquatic organisms which are assumed to have bioconcentrated pollutants from the water in which they live. Other multimedia routes of exposure such as air, non-aquatic diet, or dermal are not factored into the criterion formulation for the vast majority of pollutants due to lack of data. The criteria are calculated using the combined aquatic exposure pathway and also using the aquatic organism ingestion exposure route alone. In criteria reflecting both the water consumption and aquatic organism ingestion routes of exposure, the relative exposure contribution varies with the propensity of a pollutant to bioconcentrate, with the consumption of aquatic organisms becoming more important as the bioconcentration factor (BCF) increases. As additional information on total exposure is assembled for pollutants for which criteria reflect only the two specified aquatic exposure routes, adjustments in water concentration values may be made. The Agency intends to publish guidance which will permit the States to identify significantly different exposure patterns for their populations. If warranted by the demonstration of significantly different exposure patterns, this will become an element of a process to adapt/modify human health-based criteria to local conditions, somewhat analogous to the aquatic life criteria modification process discussed previously. It is anticipated that States at their discretion will be able to set appropriate human health criteria based on this process.

The pharmacokinetics section reviews data on absorption, distribution, metabolism, and excretion to assess the biochemical fate of the compounds in the human and animal system. The toxic effects section reviews data on acute, subacute, and chronic toxicity, synergistic and antagonistic effects, and specific information on mutagenicity, teratogenicity, and carcinogenicity. From this review, the toxic effect to be protected against is identified taking into account the quality, quantity, and weight of evidence characteristic of the data. The criterion formulation section reviews the highlights of the text and specifies a rationale for criterion development and the mathematical derivation of the criterion number.

Within the limitations of time and resources, current published information of significance was incorporated into the human health assessments. Review articles and reports were used for data evaluation and synthesis. Scientific judgment was exercised in reviewing and evaluating the data in each criteria document and in identifying the adverse effects for which protective criteria were published.

Specific health-based criteria are developed only if a weight of evidence supports the occurrence of the toxic effect and if dose/response data exist from which criteria can be estimated.

Criteria for suspect or proven carcinogens are presented as concentrations in water associated with a range of incremental cancer risks to man. Criteria for non-carcinogens represent levels at which exposure to a single chemical is not anticipated to produce adverse effects in man. In a few cases, organoleptic (taste and odor) data form the basis for the criterion. While this type of criterion does not represent a value which directly affects human health, it is presented as an estimate of the level of a pollutant that will not produce unpleasant taste or odor either directly from water consumption or indirectly by consumption of aquatic organisms found in ambient waters. A criterion developed in this manner is judged to be as useful as other types of criteria in protecting designated water uses. In addition, where data are available, toxicity-based criteria are also presented for pollutants with derived organoleptic criteria. The choice of criteria used in water quality standards for these pollutants will depend upon the designated use to be protected. In the case of a multiple use water body, the criterion protecting the most sensitive use will be applied. Finally, for several pollutants no criteria are recommended due to a lack of information sufficient for quantitative criterion formulation.

Risk Extrapolation

Because methods do not now exist to establish the presence of a threshold for carcinogenic effects, EPA's policy is that there is no scientific basis for estimating "safe" levels for carcinogens. The criteria for carcinogens, therefore, state that the recommended concentration for maximum protection of human health is zero. In addition, the Agency has presented a range of concentrations corresponding to incremental cancer risks of 10^{-7} to 10^{-5} (one additional case of cancer in populations ranging from ten million to 100,000, respectively). Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Summary of the Human Health Guidelines

The health assessments and corresponding criteria published today were derived based on *Guidelines and Methodology Used in the Preparation of Health Effect Assessment Chapters of the Consent Decree Water Criteria Documents* (the Guidelines) developed by EPA's Office of Reserch and Development. The estimation of health risks associated with human exposure to environmental pollutants requires predicting the effect of low doses for up to a lifetime in duration. A combination of epidemiological and animal dose/response data is considered the preferred basis for quantitative criterion derivation. The complete Guidelines are presented as Appendix C. Major issues associated with these Guidelines and responses to public comments are presented as Appendix E.

No-effect (non-carcinogen) or specified risk (carcinogen) concentrations were estimated by extrapolation from animal toxicity or

human epidemiology studies using the following basic exposure assumptions: a 70-kilogram male person (*Report of the Task Group on Reference Man*, International Commission for Radiation Protection, November 23, 1957) as the exposed individual; the average daily consumption of freshwater and estuarine fish and shellfish products equal to 6.5 grams/day; and the average ingestion of two liters/day of water (*Drinking Water and Health*, National Academy of Sciences, National Research Council, 1977). Criteria based on these assumptions are estimated to be protective of an adult male who experiences average exposure conditions.

Two basic methods were used to formulate health criteria, depending on whether the prominent adverse effect was cancer or other toxic manifestations. The following sections detail these methods.

Carcinogens

Extrapolation of cancer responses from high to low doses and subsequent risk estimation from animal data is performed using a linearized multi-stage model. This procedure is flexible enough to fit all monotonically-increasing dose response data, since it incorporates several adjustable parameters. The multi-stage model is a linear non-threshold model as was the "one-hit" model originally used in the proposed criteria documents. The linearized multi-stage model and its characteristics are described fully in Appendix C. The linear non-threshold concept has been endorsed by the four agencies in the Interagency Regulatory Liaison Group and is less likely to underestimate risk at the low doses typical of environmental exposure than other models that could be used. Because of the uncertainties associated with dose response, animal-to-human extrapolation and other unknown factors, because of the use of average exposure assumptions, and because of the serious public health consequences that could result if risk were underestimated, EPA believes that it is prudent to use conservative methods to estimate risk in the water quality criteria program. The linearized multistage model is more systematic and invokes fewer arbitrary assumptions than the "one-hit" procedure previously used.

It should be noted that extrapolation models provide estimates of risk since a variety of assumptions are built into any model. Models using widely different assumptions may produce estimates ranging over several orders of magnitude. Since there is at present no way to demonstrate the scientific validity of any model, the use of risk extrapolation models is a subject of debate in the scientific community. However, risk extrapolation is generally recognized as the only tool available at this time for estimating the magnitude of health hazards associated with non-threshold toxicants and has been endorsed by numerous Federal agencies and scientific organizations, including EPA's Carcinogen Assessment Group, the National Academy of Sciences, and the Interagency Regulatory Liaison Group as a useful means of assessing the risks of exposure to various carcinogenic pollutants.

Non-Carcinogens

Health criteria based on toxic effects of pollutants other than carcinogenicity are estimates of concentrations which are not expected to produce adverse effects in humans. They are based upon Acceptable Daily Intake (ADI) levels and are generally derived using no-observed-adverse-effect-level (NOAEL) data from animal studies although human data are used wherever available. The ADI is calculated using safety factors to account for uncertainties inherent in extrapolation from animal to man. In accordance with the National Research Council recommendations (*Drinking Water and Health*, National Academy of Sciences, National Research Council, 1977), safety factors of 10, 100, or 1,000 are used depending on the quality and quantity of data. In some instances extrapolations are made from inhalation studies or limits to approximate a human response from ingestion using the Stokinger-Woodward model (Journal of American Water Works Association, 1958). Calculations of criteria from ADIs are made using the standard exposure assumptions (2 liters of water, 6.5 grams of edible aquatic products, and an average body weight of 70 kg).

Dated: October 24, 1980.

Douglas M. Costle,

Administrator.

Appendix A—Summary of Water Quality Criteria

Acenaphthene

Freshwater Aquatic Life

The available data for acenaphthene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,700 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of acenaphthene to sensitive freshwater aquatic animals but toxicity to freshwater algae occur at concentrations as low as 520 μg/l.

Saltwater Aquatic Life

The available data for acenaphthene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 970 and 710 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Toxicity to algae occurs at concentrations as low as 500 μg/l.

Human Health

Sufficient data is not available for acenaphthene to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 20 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Acrolein

Freshwater Aquatic Life

The available data for acrolein indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 68 and 21 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for acrolein indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 55 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of acrolein to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of acrolein ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 320 μg/l.

For the protection of human health from the toxic properties of acrolein ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 780 μg/l.

Acrylonitrile

Freshwater Aquatic Life

The available data for acrylonitrile indicate that acute toxicity to freshwater aquatic life occurs at concentrations as

low as 7,550 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of acrylonitrile to sensitive freshwater aquatic life but mortality occurs at concentrations as low as 2,600 μg/l with a fish species exposed for 30 days.

Saltwater Aquatic Life

Only one saltwater species has been tested with acrylonitrile and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of acrylonitrile through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .58 μg/l, .058 μg/l and .006 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 6.5 μg/l, .65 μg/l, and .065 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Aldrin-Dieldrin

Dieldrin

Freshwater Aquatic Life

For dieldrin the criterion to protect fresh water aquatic life as derived using the Guidelines is 0.0019 μg/l as a 24-hour average and the concentration should not exceed 2.5 μg/l at any time.

Saltwater Aquatic Life

For dieldrin the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0019 μg/l as a 24-hour average and the concentration should not exceed 0.71 μg/l at any time.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of dieldrin through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .71 ng/l, .071 ng/l, and .0071 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .76 ng/l, .076 ng/l, and .0076 ng/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Aldrin

Freshwater Aquatic Life

For freshwater aquatic life the concentration of aldrin should not exceed 3.0 μg/l at any time. No data are available concerning the chronic toxicity of aldrin to sensitive freshwater aquatic life.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of aldrin should not exceed 1.3 μg/l at any time. No data are available concerning the chronic toxicity of aldrin to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of aldrin through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .74 ng/l, .074 ng/l, and .0074 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .79 ng/l, .079 ng/l, and .0079 ng/l, respectively. Other concentrations respresenting different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Antimony

Freshwater Aquatic Life

The available data for antimony indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 9,000 and 1,600 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Toxicity to algae occurs at concentrations as low as 610 μg/l.

Saltwater Aquatic Life

No saltwater organisms have been adequately tested with antimony, and no statement can be made concerning acute or chronic toxicity.

Human Health

For the protection of human health from the toxic properties of antimony ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 146 μg/l.

For the protection of human health from the toxic properties of antimony ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 45,000 μg/l.

Arsenic

Freshwater Aquatic Life

For freshwater aquatic life the concentration of total recoverable trivalent inorganic arsenic should not exceed 440 μg/l at any time. Short-term effects on embryos and larvae of aquatic vertebrate species have been shown to occur at concentrations as low as 40 μg/l.

Saltwater Aquatic Life

The available data for total recoverable trivalent inorganic arsenic indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 508 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trivalent inorganic arsenic to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of arsenic through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are

estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 22 ng/l, 2.2 ng/l, and .22 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 178 ng/l, 17.5 ng/l, and 1.75 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Asbestos

Freshwater Aquatic Life

No freshwater organisms have been tested with any asbestiform mineral and no statement can be made concerning acute or chronic toxicity.

Saltwater Aquatic Life

No saltwater organisms have been tested with any asbestiform mineral and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of asbestos through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 300,000 fibers/1, 30,000 fibers/1, and 3,000 fibers/1, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Benzene

Freshwater Aquatic Life

The available data for benzene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 5,300 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of benzene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for benzene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 5,100 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of benzene to sensitive saltwater aquatic life, but adverse effects occur at concentrations as low as 700 μg/l with a fish species exposed for 168 days.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of benzene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 6.6 μg/l, .66 μg/l, and .066 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 400 μg/l, 40.0 μg/l, and 4.0 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Benzidine

Freshwater Aquatic Life

The available data for benzidine indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 2,500 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of benzidine to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with benzidine and no statement can be made concerning acute and chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of benzidine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.2 ng/1, .12 ng/1, and .01 ng/1, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5.3 ng/1, .53 ng/1, and .05 ng/1, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Beryllium

Freshwater Aquatic Life

The available data for beryllium indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 130 and 5.3 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Hardness has a substantial effect on acute toxicity.

Salt water Aquatic Life

The limited saltwater data base available for beryllium does not permit any statement concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of beryllium through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 37 ng/l, 3.7 ng/l, and .37 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 641 ng/l, 64.1 ng/l, and 6.41 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Cadmium

Freshwater Aquatic Life

For total recoverable cadmium the criterion (in μg/l) to protect freshwater aquatic life as derived using the Guidelines is the numerical value given

than those tested. No data are available concerning the chronic toxicity of inorganic selenate to sensitive freshwater aquatic life.

Saltwater Aquatic Life

For total recoverable inorganic selenite the criterion to protect saltwater aquatic life as derived using the Guidelines is 54 μg/l as a 24-hour average and the concentration should not exceed 410 μg/l at any time.

No data are available concerning the toxicity of inorganic selenate to saltwater aquatic life.

Human Health

The ambient water quality criterion for selenium is recommended to be identical to the existing drinking water standard which is 10 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Silver

Freshwater Aquatic Life

For freshwater aquatic life the concentration (in μg/l) of total recoverable silver should not exceed the numerical value given by "e[1.72(ln (hardness)-6.52)]" at any time. For example, at hardnesses of 50, 100, 200 mg/l as $CaCO_3$ the concentration of total recoverable silver should not exceed 1.2, 4.1, and 13 μg/l, respectively, at any time. The available data indicate that chronic toxicity to freshwater aquatic life may occur at concentrations as low as 0.12 μg/l.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of total recoverable silver should not exceed 2.3 μg/l at any time. No data are available concerning the chronic toxicity of silver to sensitive saltwater aquatic life.

Human Health

The ambient water quality criterion for silver is recommended to be identical to the existing drinking water standard which is 50 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Tetrachloroethylene

Freshwater Aquatic Life

The available data for tetrachloroethylene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 5,280 and 840 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for tetrachloroethylene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations low as 10,200 and 450 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of tetrachloroethylene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 8 μg/l, .8 μg/l, and .08 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 88.5 μg/l, 8.85 μg/l, and .88 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Thallium

Freshwater Aquatic Life

The available data for thallium indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 1,400 and 40 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Toxicity to one species of fish occurs at concentrations as low as 20 μg/l after 2,600 hours of exposure.

Saltwater Aquatic Life

The available data for thallium indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2,130 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of thallium to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of thallium ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 13 μg/l.

For the protection of human health from the toxic properties of thallium ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 48 μg/l.

Toluene

Freshwater Aquatic Life

The available data for toluene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 17,500 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of toluene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for toluene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 6,300 and 5,000 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the protection of human health from the toxic properties of toluene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 14.3 mg/l.

For the protection of human health from the toxic properties of toluene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 424 mg/l.

Toxaphene

Freshwater Aquatic Life

For toxaphene the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.013 μg/l as a 24-hour average and the concentration should not exceed 1.6 μg/l at any time.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of toxaphene should not exceed 0.070 μg/l at any time. No data

undesirable taste and odor quality of ambient water, the estimated level is 0.3 mg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Phthalate Esters

Freshwater Aquatic Life

The available data for phthalate esters indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 940 and 3 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for phthalate esters indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2944 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of phthalate esters to sensitive saltwater aquatic life but toxicity to one species of algae occurs at concentrations as low as 3.4 μg/l.

Human Health

For the protection of human health from the toxic properties of dimethylphthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 313 mg/l.

For the protection of human health from the toxic properties of dimethylphthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 2.9 g/l.

For the protection of human health from the toxic properties of diethylphthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 350 mg/l.

For the protection of human health from the toxic properties of diethylphthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 1.8 g/l.

For the protection of human health from the toxic properties of dibutylphthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 34 mg/l.

For the protection of human health from the toxic properties of dibutylphthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 154 mg/l.

For the protection of human health from the toxic properties of di-2-ethylhexyl-phthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 15 mg/l.

For the protection of human health from the toxic properties of di-2-ethylhexyl-phthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 50 mg/l.

Polychlorinated Biphenyls

Freshwater Aquatic Life

For polychlorinated biphenyls the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.014 μg/l as a 24-hour average. The available data indicate that acute toxicity to freshwater aquatic life probably will only occur at concentrations above 2.0 μg/l and that the 24-hour average should provide adequate protection against acute toxicity.

Saltwater Aquatic Live

For polychlorinated biphenyls the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.030 μg/l as a 24-hour average. The available data indicate that acute toxicity to saltwater aquatic life probably will only occur at concentrations above 10 μg/l and that the 24-hour average should provide adequate protection against acute toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of PCBs through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-6}, 10^{-7}, and 10^{-8}. The corresponding criteria are .79 ng/l, 0.79 ng/l, and .0079 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .79 ng/l, .079 ng/l, and .0079 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Polynuclear Aromatic Hydrocarbons (PAHs)

Freshwater Aquatic Life

The limited freshwater data base available for polynuclear aromatic hydrocarbons, mostly from short-term bioconcentration studies with two compounds, does not permit a statement concerning acute or chronic toxicity.

Saltwater Aquatic Life

The available data for polynuclear aromatic hydrocarbons indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 300 ug/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of polynuclear aromatic hydrocarbons to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of PAHs through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-6}, 10^{-7}, and 10^{-8}. The corresponding criteria are 28 ng/l, 2.8 ng/l, and .28 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 311 ng/l, 31.1 ng/l, and 3.11 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Selenium

Freshwater Aquatic Life

For total recoverable inorganic selenite the criterion to protect freshwater aquatic life as derived using the Guidelines is 35 μg/l as a 24-hour average and the concentration should not exceed 260 μg/l at any time.

The available data for inorganic selenate indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 760 μg/l and would occur at lower concentrations among species that are more sensitive

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of n-nitrosodimethylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 14 ng/l, 1.4 ng/l, and .14 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 160,000 ng/l, 16,000 ng/l, and 1,600 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of n-nitrosodiethylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 8 ng/l, 0.8 ng/l, and 0.08 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 12,400 ng/l, 1,240 ng/l, and 124 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure in n-nitrosodi-n-butylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 64 ng/l 6.4 ng/l and .064 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5,868 ng/l, 587 ng/l, and 58.7 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure in n-nitrosodiphenylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 49,000 ng/l 4,900 ng/l and 490 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 161,000 ng/l, 16,100 ng/l, and 1,610 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure in n-nitrosopyrrolidine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 160 ng/l 16.0 ng/l and 1.60 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 919,000 ng/l, 91,900 ng/l, and 9,190 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Pentachlorophenol

Freshwater Aquatic Life

The available data for pentachlorophenol indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 55 and 3.2 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for pentachlorophenol indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 53 and 34 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for pentachlorophenol. Based on available toxicity data, for the protection of public health, the derived level is 1.01 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 30 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Phenol

Freshwater Aquatic Life

The available data for phenol indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 10,200 and 2,560 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for phenol indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 5,800 ug/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of phenol to sensitive saltwater aquatic life.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for phenol. Based on available toxicity data, for the protection of public health, the derived level is 3.5 mg/l. Using available organoleptic data, for controlling

ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 144 ng/l.

For the protection of human health from the toxic properties of mercury ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 146 ng/l.

Note.—These values include the consumption of freshwater, estuarine, and marine species.

Naphthalene

Freshwater Aquatic Life

The available data to naphthalene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 2,300 and 620 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for naphthalene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2,350 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of naphthalene to sensitive saltwater aquatic life.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for naphthalene.

Nickel

Freshwater Aquatic Life

For total recoverable nickel the criterion (in μg/l) to protect freshwater aquatic life as derived using the Guidelines is the numerical value given by e(0.76 [ln (hardness)] + 1.06) as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by e(0.76[ln (hardness)] + 4.02) at any time. For example, at hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the criteria are 56, 96, and 160 μg/l, respectively, as 24-hour averages, and the concentrations should not exceed 1,100, 1,800, and 3,100 μg/l, respectively, at any time.

Saltwater Aquatic Life

For total recoverable nickel the criterion to protect saltwater aquatic life as derived using the Guidelines is 7.1 μg/l as a 24-hour average and the concentration should not exceed 140 μg/l at any time.

Human Health

For the protection of human health from the toxic properties of nickel ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 13.4 μg/l.

For the protection of human health from the toxic properties of nickel ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 100 μg/l.

Nitrobenzene

Freshwater Aquatic Life

The available data for nitrobenzene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 27,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of nitrobenzene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for nitrobenzene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 6,680 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrobenzene to sensitive saltwater aquatic life.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for nitrobenzene. Based on available toxicity data, for the protection of public health, the derived level is 19.8 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 30 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Nitrophenols

Freshwater Aquatic Life

The available data for nitrophenols indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 230 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrophenols to sensitive freshwater aquatic life but toxicity to one species of algae occurs at concentrations as low as 150 μg/l.

Saltwater Aquatic Life

The available data for nitrophenols indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 4,850 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrophenols to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of 2,4-dinitro-o-cresol ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 13.4 μg/l.

For the protection of human health from the toxic properties of 2,4-dinitro-o-cresol ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 765 μg/l.

For the protection of human health from the toxic properties of dinitrophenol ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 70 μg/l.

For the protection of human health from the toxic properties of dinitrophenol ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 14.3 mg/l.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for mononitrophenol.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for tri-nitrophenol.

Nitrosamines

Freshwater Aquatic Life

The available data for nitrosamines indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 5,850 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrosamines to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for nitrosamines indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 3,300,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrosamines to sensitive saltwater aquatic life.

represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of tech-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 123 ng/l, 12.3 ng/l, and 1.23 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 414 ng/l, 41.4 ng/l, and 4.14 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of gamma-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentrations should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 186 ng/l, 18.6 ng/l, and 1.86 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 625 ng/l, 62.5 ng/l, 6.25 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for delta-HCH.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for epsilon-HCH.

Hexachlorocyclopentadiene

Freshwater Aquatic Life

The available data for hexachlorocyclopentadiene indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 7.0 and 5.2 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data to hexachlorocyclopentadiene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 7.0 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of hexachlorocyclopentadiene to sensitive saltwater aquatic life.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for hexachlorocyclopentadiene. Based on available toxicity data, for the protection of public health, the derived level is 206 μg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1.0 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Isophorone

Freshwater Aquatic Life

The available data for isophorone indicate that acute toxicity to freshwater aquatic life ocurs at concentrations as low as 117,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of isophorone to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for isophorone indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 12,900 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of isophorone to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of isophorone ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 5.2 mg/l.

For the protection of human health from the toxic properties of isophorone ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 520 mg/l.

Lead

Freshwater Aquatic Life

For total recoverable lead the criterion (in μg/l) to protect freshwater aquatic life as derived using the Guidelines is the numerical value given by e(2.35[ln(hardness)]−9.48) as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by e(1.22[ln(hardness)]−0.47) at any time. For example, at hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the criteria are 0.75, 3.8, and 20 μg/l, respectively, as 24-hour averages, and the concentrations should not exceed 74, 170, and 400 μg/l, respectively, at any time.

Saltwater Aquatic Life

The available data for total recoverable lead indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 668 and 25 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

The ambient water quality criterion for lead is recommended to be identical to the existing drinking water standard which is 50 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective to human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Mercury

Freshwater Aquatic Life

For total recoverable mercury the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.00057 μg/l as a 24-hour average and the concentration should not exceed 0.0017 μg/l at any time.

Saltwater Aquatic Life

For total recoverable mercury the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.025 μg/l as a 24-hour average and the concentration should not exceed 3.7 μg/l at any time.

Human Health

For the protection of human health from the toxic properties of mercury

1.9 μg/l, 0.19 μg/l, and 0.019 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 157 μg/l, 15.7 μg/l, and 1.57 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Heptachlor

Freshwater Aquatic Life

For heptachlor the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0038 μg/l as a 24-hour average and the concentration should not exceed 0.52 μg/l at any time.

Saltwater Aquatic Life

For heptachlor the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0036 μg/l as a 24-hour average and the concentration should not exceed 0.053 μg/l at any time.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of heptachlor through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 2.78 ng/l, .28 ng/l, and .028 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 2.85 ng/l, .29 ng/l, and .029 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Hexachlorobutadiene

Freshwater Aquatic Life

The available data for hexachlorobutadiene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 90 and 9.3 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for hexachlorobutadiene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 32 μg/l and would occur at lower concentrations among species that are more sensitive that those tested. No data are available concerning the chronic toxicity of hexachlorobutadiene to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of hexachlorobutadiene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 4.47 μg/l, 0.45 μg/l, and 0.045 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 500 μg/l, 50 μg/l, and 5 μg/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Hexachlorocyclohexane

Lindane

Freshwater Aquatic Life

For Lindane the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.080 μg/l as a 24-hour average and the concentration should not exceed 2.0 μg/l at any time.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of lindane should not exceed 0.16 μg/l at any time. No data are available concerning the chronic toxicity of lindane to sensitive saltwater aquatic life.

BHC

Freshwater Aquatic Life

The available date for a mixture of isomers of BHC indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 100 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of a mixture of isomers of BHC to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available date for a mixture of isomers of BHC indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 0.34 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of a mixture of isomers of BHC to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of alpha-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 92 ng/l, 9.2 ng/l, and .92 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 310 ng/l, 31.0 ng/l, and 3.1 ng/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of beta-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 163 ng/l, 16.3 ng/l, and 1.63 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 547 ng/l, 54.7 ng/l, and 5.47 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not

represent an Agency judgment on an "acceptable" risk level.

Endosulfan

Freshwater Aquatic Life

For endosulfan the criterion to protect freshwater aquatic life as derived using these Guidelines is 0.056 μg/l as a 24-hour average and the concentration should not exceed 0.22 μg/l at any time.

Saltwater Aquatic Life

For endosulfan the criterion to protect saltwater aquatic life as derived using these Guidelines is 0.0087 μg/l as a 24-hour average and the concentration should not exceed 0.034 μg/l at any time.

Human Health

For the protection of human health from the toxic properties of endosulfan ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 74 μg/l.

For the protection of human health from the toxic properties of endosulfan ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 159 μg/l.

Endrin

Freshwater Aquatic Life

For endrin the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0023 μg/l as a 24-hour average and the concentration should not exceed 0.18 μg/l at any time.

Saltwater Aquatic Life

For endrin the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0023 μg/l as a 24-hour average and the concentration should not exceed 0.037 μg/l at any time.

Human Health

The ambient water quality criterion for endrin is recommended to be identical to the existing drinking water standard which is 1 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Ethylbenzene

Freshwater Aquatic Life

The available data for ethylbenzene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 32,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of ethylbenzene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for ethylbenzene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 430 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of ethylbenzene to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of ethylbenzene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 1.4 mg/l.

For the protection of human health from the toxic properties of ethylbenzene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 3.28 mg/l.

Fluoranthene

Freshwater Aquatic Life

The available data for fluoranthene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 3980 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of fluoranthene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for fluoranthene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 40 and 16 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the protection of human health from the toxic properties of fluoranthene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 42 μg/l.

For the protection of human health from the toxic properties of fluoranthene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 54 μg/l.

Haloethers

Freshwater Aquatic Life

The available data for haloethers indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 360 and 122 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

No saltwater organisms have been tested with any haloether and no statement can be made concerning acute or chronic toxicity.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for haloethers.

Halomethanes

Freshwater Aquatic Life

The available data for halomethanes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 11,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of halomethanes to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for halomethanes indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 12,000 and 6,400 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. A decrease in algal cell numbers occurs at concentrations as low as 11,500 μg/l.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of chloromethane, bromomethane, dichloromethane, bromodichloromethane, tribromomethane, dichlorodifluoromethane, trichlorofluoromethane, or combinations of these chemicals through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are

Based on available toxicity data, for the protection of public health, the derived level is 3.09 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.3 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Dichloropropanes/Dichloropropenes

Freshwater Aquatic Life

The available data for dichloropropanes indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 23,000 and 5,700 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

The available data for dichloropropenes indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 6,060 and 244 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for dichloropropanes indicate that acute and chronic toxicity to saltwater aquatic life occurs at concentrations as low as 10,300 and 3,040 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

The available data for dichloropropenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low a as 790 µg/l, and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of dichloropropenes to sensitive saltwater aquatic life.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for dichloropropanes.

For the protection of human health from the toxic properties of dichloropropenes ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 87 µg/l.

For the protection of human health from the toxic properties of dichloropropenes ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 14.1 mg/l.

2,4-Dimethylphenol

Freshwater Aquatic Life

The available data for 2,4-dimethylphenol indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 2,120 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of dimethylphenol to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with 2,4-dimethylphenol and no statement can be made concerning acute and chronic toxicity.

Human Health

Sufficient data are not available for 2,4-dimethylphenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undersirable taste and odor quality of ambient water, the estimated level is 400 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

2,4-Dinitrotoluene

Freshwater Aquatic Life

The available data for 2,4-dinitrotoluene indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 330 and 230 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for 2,4-dinitrotoluenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 590 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of 2,4-dinitrotoluenes to sensitive saltwater aquatic life but a decrease in algal cell numbers occurs at concentrations as low as 370 µg/l.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 2,4-dinitrotoluene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.1 µg/l, 0.11 µg/l, and 0.011 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 91 µg/l, 9.1 µg/l, and 0.91 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

1,2-Diphenylhydrazine

Freshwater Aquatic Life

The available data for 1,2-diphenylhydrazine indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 270 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of 1,2-diphenylhydrazine to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with 1,2-diphenylhydrazine and no statement can be made concerning acute and chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,2-diphenylhydrazine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 422 ng/l, 42 ng/l, and 4 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5.6 µg/l, 0.56 µg/l, and 0.056 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not

chronic toxicity of TDE to sensitive saltwater aquatic life.

DDE

The available data for DDE indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as .14 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of DDE to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of DDT through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .24 ng/l, .024 ng/l, and .0024 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .24 ng/l, .024 ng/l, and .0024 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment of an "acceptable" risk level.

Dichlorobenzenes

Freshwater Aquatic Life

The available data for dichlorobenzenes indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 1,120 and 763 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for dichlorobenzenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 1,970 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of dichlorobenzenes to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of dichlorobenzenes (all isomers) ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 400 μg/l.

For the protection of human health from the toxic properties of dichlorobenzenes (all isomers) ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 2.6 mg/l.

Dichlorobenzidines

Freshwater Aquatic Life

The data base available for dichlorobenzidines and freshwater organisms is limited to one test on bioconcentration of 3,3'-dichlorobenzidine and no statement can be made concerning acute or chronic toxicity.

Saltwater Aquatic Life

No saltwater organisms have been tested with any dichlorobenzidine and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of dichlorobenzidine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero base on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .103 μg/l, .0103 μg/l, and .00103 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .204 μg/l, .0204 μg/l, and .00204 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Dichloroethylenes

Freshwater Aquatic Life

The available data for dichloroethylenes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 11,600 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of dichlorethylenes to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for dichlorethylenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 224,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity dichloroethylenes to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,1-dichloroethylene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .33 μg/l, .033 μg/l, and .0033 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 18.5 μg/l, 1.85 μg/l, and .185 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficency in the available data for 1,2-dichloroethylene.

2,4-Dichlorophenol

Freshwater Aquatic Life

The available data for 2,4-dichlorophenol indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 2,020 and 365 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive that those tested. Mortality to early life stages of one species of fish occurs at concentrations as low as 70 μg/l.

Saltwater Aquatic Life

Only one test has been conducted with saltwater organisms on 2,4-dichlorophenol and no statement can be made concerning acute or chronic toxicity.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for 2,4-dichlorophenol.

demonstrated relationship to potential adverse human health effects.

Chromium

Freshwater Aquatic Life

For total recoverable hexavalent chromium the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.29 μg/l as a 24-hour average and the concentration should not exceed 21 μg/l at any time.

For freshwater aquatic life the concentration (in μg/l) of total recoverable trivalent chromium should not exceed the numerical value given by "e(1.08[ln(hardness)]+3.48)" at any time. For example, at hardnesses of 50, 100 and 200 mg/l as $CaCO_3$ the concentration of total recoverable trivalent chromium should not exceed 2,200, 4,700, and 9,900 μg/l, respectively, at any time. The available data indicate that chronic toxicity to freshwater aquatic life occurs at concentrations as low a 44 μg/l and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

For total recoverable hexavalent chromium the criterion to protect saltwater aquatic life as derived using the Guidelines is 18 μg/l as a 24-hour average and the concentration should not exceed 1,260 μg/l at any time.

For total recoverable trivalent chromium, the availabe data indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 10,300 μg/l, and would occur at lower concentrations amoung species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trivalent chromium to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of Chromium III ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 170 mg/l.

For the protection of human health from the toxic properties of Chromium III ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 3433 mg/l.

The ambient water quality criterion for total Chromium VI is recommended to be identical to the existing drinking water standard which is 50 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Copper

Freshwater Aquatic Life

For total recoverable copper the criterion to protect freshwater aquatic life as derived using the Guidelines is 5.6 μg/l as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by e(0.94[ln(hardness)]-1.23) at any time. For example, at hardnesses of 50, 100, and 200 mg/l $CaCO_3$ the concentration of total recoverable copper should not exceed 12, 22, and 43 μg/l at any time.

Saltwater Aquatic Life

For total recoverable copper the criterion to protect saltwater aquatic life as derived using the Guidelines is 4.0 μg/l as a 24-hour average and the concentration should not exceed 23 μg/l at any time.

Human Health

Sufficient data is not available for copper to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1 mg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Cyanide

Freshwater Aquatic Life

For free cyanide (sum of cyanide present as HCN and CN^-, expressed as CN) the criterion to protect freshwater aquatic life as derived using the Guidelines is 3.5 μg/l as a 24-hour average and the concentration should not exceed 52 μg/l at any time.

Saltwater Aquatic Life

The available data for free cyanide (sum of cyanide present as HCN and CN^-, expressed as CN) indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 30 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. If the acute-chronic ratio for saltwater organisms is similar to that for freshwater organisms, chronic toxicity would occur at concentrations as low as 2.0 μg/l for the tested species and at lower concentrations among species that are more sensitive than those tested.

Human Health

The ambient water quality criterion for cyanide is recommended to be identical to the existing drinking water standard which is 200 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

DDT and Metabolites

Freshwater Aquatic Life

DDT

For DDT and its metabolites the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0010 μg/l as a 24-hour average and the concentration should not exceed 1.1 μg/l at any time.

TDE

The available data for TDE indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 0.8 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of TDE to sensitive freshwater aquatic life.

DDE

The available data for DDE indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,050 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of DDE to sensitive freshwater aquatic life.

Saltwater Aquatic Life

DDT

For DDT and its metabolites the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0010 μg/l as a 24-hour average and the concentration should not exceed 0.13 μg/l at any time.

TDE

The available data for TDE indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 3.6 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the

recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 3-methyl-4-chlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 3000 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 3-methyl-6-chlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 20 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Chloroalkyl Ethers

Freshwater Aquatic Life

The available data for chloroalkyl ethers indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 238,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of chloroalkyl ethers to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with any chloroalkyl ether and no statement can be made concerning acute and chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of bis-(chloromethyl)-ether through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-6}, 10^{-7}, and 10^{-8}. The corresponding criteria are .038 ng/l, .0038 ng/l, and .00038 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 18.4 ng/l, 1.84 ng/l, and .184 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of bis (2-chloroethyl) ether through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-6}, 10^{-7}, and 10^{-8}. The corresponding criteria are .3 μg/l, .03 μg/l, and .003 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 13.6 μg/l, 1.36 μg/l, and .136 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the protection of human health from the toxic properties of bis (2-chloroisopropyl) ether ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 34.7 μg/l.

For the protection of human health from the toxic properties of bis (2-chloroisopropyl) ether ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 4.36 mg/l.

Chloroform

Freshwater Aquatic Life

The available data for choloroform indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 28,900 μg/l, and would occur at lower concentrations among species that are more sensitive than the three tested species. Twenty-seven-day LC50 values indicate that chronic toxicity occurs at concentrations as low as 1,240 μg/l, and could occur at lower concentrations among species or other life stages that are more sensitive than the earliest life cycle stage of the rainbow trout.

Saltwater Aquatic Life

The data base for saltwater species is limited to one test and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of chloroform through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.90 μg/l, .19 μg/l, and .019 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 157 μg/l, 15.7 μg/l, and 1.57 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

2-Chlorophenol

Freshwater Aquatic Life

The availabe data for 2-chlorophenol indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 4,380 μg/l and would occur at lower concentrations among species that are more sensitive that those tested. No definitive data are available concerning the chronic toxicity of 2-chlorophenol to sensitive freshwater aquatic life but flavor impairment occur in one species of fish at concentrations as low as 2,000 μg/l.

Saltwater Aquatic Life

No saltwater organisms have been tested with 2-chlorophenol and no statement can be made concerning acute and chronic toxicity.

Human Health

Sufficient data is not available for 2-chlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no

more sensitive than those tested. No data are available concerning the chronic toxicity of chlorinated naphthalenes to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for chlorinated napthalenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 7.5 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of chlorinated naphthalenes to sensitive saltwater aquatic life.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for chlorinated napthalenes.

Chlorinated Phenols

Freshwater Aquatic Life

The available freshwater data for chlorinated phenols indicate that toxicity generally increases with increasing chlorination, and that acute toxicity occurs at concentrations as low as 30 μg/l for 4-chloro-3-methylphenol to greater than 500,000 μg/l for other compounds. Chronic toxicity occurs at concentrations as low as 970 μg/l for 2,4,6-trichlorophenol. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available saltwater data for chlorinated phenols indicate that toxicity generally increases with increasing chlorination and that acute toxicity occurs at concentrations as low as 440 μg/l for 2,3,5,6-tetrachlorophenol and 29,700 μg/l for 4-chlorophenol. Acute toxicity would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of chlorinated phenols to sensitive saltwater aquatic life.

Human Health

Sufficient data is not available for 3-monochlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 4-monochlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,3-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .04 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,5-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .5 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,6-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .2 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 3,4-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .3 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,3,4,6-tetrachlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

For comparison purposes, two approaches were used to derive criterion levels for 2,4,5-trichlorophenol. Based on available toxicity data, for protection of public health, the derived level is 2.6 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 2,4,6-trichlorophenol through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6} and 10^{-7}. The corresponding criteria are 12 μg/l, 1.2 μg/l, and .12 μg/l respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 36 μg/l, 3.6 μg/l and .36 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using available organoleptic data for controlling undesirable taste and odor quality of ambient water, the estimated level is 2 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2-methyl-4-chlorophenol to derive a level which would protect against any potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1800 μg/l. It should be

at this time due to the insufficiency in the available data for trichlorobenzene.

For comparison purposes, two approaches were used to derive criterion levels for monochlorobenzene. Based on available toxicity data, for the protection of public health, the derived level is 488 μg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 20 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Chlorinated Ethanes

Freshwater Aquatic Life

The available freshwater data for chlorinated ethanes indicate that toxicity increases greatly with increasing chlorination, and that acute toxicity occurs at concentrations as low as 118,000 μg/l for 1,2-dichloroethane, 18,000 μg/l for two trichloroethanes, 9,320 μg/l for two tetrachloroethanes, 7,240 μg/l for pentachloroethane, and 980 μg/l for hexachloroethane. Chronic toxicity occurs at concentrations as low as 20,000 μg/l for 1,2-dichloroethane, 9,400 μg/l for 1,1,2-trichloroethane, 2,400 μg/l for 1,1,2,2,-tetrachloroethane, 1,100 μg/l for pentachloroethane, and 540 μg/l for hexachloroethane. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available saltwater data for chlorinated ethanes indicate that toxicity increases greatly with increasing chlorination and that acute toxicity to fish and invertebrate species occurs at concentrations as low as 113,000 μg/l for 1,2-dichloroethane, 31,200 μg/l for 1,1,1-trichloroethane, 9,020 μg/l for 1,1,2,2-tetrachloroethane, 390 μg/l for pentachloroethane, and 940 μg/l for hexachloroethane. Chronic toxicity occurs at concentrations as low as 281 μg/l for pentachloroethane. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,2-dichloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 9.4 μg/l, .94 μg/l, and .094 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 2,430 μg/l, 243 μg/l, and 24.3 μg/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the protection of human health from the toxic properties of 1,1,1-trichloroethane ingested through water and contaminated aquatic organism, the ambient water criterion is determined to be 18.4 mg/l.

For the protection of human health from the toxic properties of 1,1,1,-trichloroethane ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 1.03 g/l.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,1,2-trichloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 6.0 μg/l, .6 μg/l, and .06 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 418 μg/l, 41.8 μg/l, and 4.18 μg/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,1,2,2-tetrachloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.7 μg/l, .17 μg/l, and .017 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 107 μg/l, 10.7 μg/l, and 1.07 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of hexachloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 19 μg/l, 1.9 μg/l, and .19 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 87.4 μg/l, 8.74 μg/l, and .87 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for monochloroethane.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for 1,1,-dichloroethane.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for 1,1,1,2-tetrachloroethane.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for pentachloroethane.

Chlorinated Naphthalenes

Freshwater Aquatic Life

The available data for chlorinated naphthalenes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,600 μg/l and would occur at lower concentrations among species that are

by $e^{(1.00\ [\ln(\text{hardness})]-3.53}$ as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by $e^{(1.00\ [\ln(\text{hardness})]-2.73}$ at any time. For example, a hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the criteria are 0.012, 0.025, and 0.051 μg/l, respectively, and the concentration of total recoverable cadmium should not exceed 1.5, 3.0 and 6.3 μg/l, respectively, at any time.

Saltwater Aquatic Life

For total recoverable cadmium the criterion to protect saltwater aquatic life as derived using the Guidelines is 4.5 μg/l as a 24-hour average and the concentration should not exceed 59 μg/l at any time.

Human Health

The ambient water quality criterion for cadmium is recommended to be identical to the existing drinking water standard which is 10 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Carbon Tetrachloride

Freshwater Aquatic Life

The available date for carbon tetrachloride indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 35,200 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of carbon tetrachloride to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for carbon tetrachloride indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 50,000 μg/l and would occur at lower concentrations among species that are more sensitive that those tested. No data are available concerning the chronic toxicity of carbon tetrachloride to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of carbon tetrachloride through ingestion of contaminated water and contaminated aquatic organisms the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 4.0μg/l, .40 μg/l, and .04 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 69.4 μg/l, 6.94 μg/l, and .69 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Chlordane

Freshwater Aquatic Life

For chlordane the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0043 μg/l as a 24-hour average and the concentration should not exceed 2.4 μg/l at any time.

Saltwater Aquatic Life

For chlordane the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0040 μg/l as a 24-hour average and the concentration should not exceed 0.09 μg/l at any time.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of chlordane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 4.6 ng/l, .46 ng/l, and .046 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 4.6 ng/l, .46 ng/l, and .046 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Chlorinated Benzenes

Freshwater Aquatic Life

The available data for chlorinated benzenes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 250 μg/l would occur at lower concentrat among species that are more sen than those tested. No data are a concerning the chronic toxicity o more toxic of the chlorinated be to sensitive freshwater aquatic li toxicity occurs at concentrations as 50 μg/l for a fish species expo 7.5 days.

Saltwater Aquatic Life

The available data for chlorin benzenes indicate that acute and chronic toxicity to saltwater aqu occur at concentrations as low a and 129 μg/l, respectively, and w occur at lower concentrations an species that are more sensitive t those tested.

Human Health

For the maximum protection o health from the potential carcino effects due to exposure of hexachlorobenzene through inge contaminated water and contam aquatic organisms, the ambient w concentration should be zero bas the non-threshold assumption fo chemical. However, zero level m be attainable at the present time. Therefore, the levels which may incremental increase of cancer ri the lifetime are estimated at 10^{-5} and 10^{-7}. The corresponding recommended criteria are 7.2 ng/ ng/l, and .072 ng/l, respectively. above estimates are made for consumption of aquatic organism excluding consumption of water, levels are 7.4 ng/l, .74 ng/l, and .0 l, respectively.

For the protection of human he from the toxic properties of 1,2,4, tetrachlorobenzene ingested thro water and contaminated aquatic organisms, the ambient water cri is determined to be 38 μg/l.

For the protection of human he from the toxic properties of 1,2,4, tetrachlorobenzene ingested thro contaminated aquatic organisms the ambient water criterion is determined to be 48 μg/l.

For the protection of human he from the toxic properties of pentachlorobenzene ingested thr water and contaminated aquatic organisms, the ambient water cri is determined to be 74 μg/l.

For the protection of human he from the toxic properties of pentachlorobenzene ingested thr contaminated aquatic organisms the ambient water criterion is determined to be 85 μg/l.

Using the present guidelines, a satisfactory criterion cannot be d

are available concerning the chronic toxicity of toxaphene to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of toxaphene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 7.1 ng/l, .71 ng/l, and .07 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 7.3 ng/l, .73 ng/l, and .07 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Trichloroethylene

Freshwater Aquatic Life

The available data for trichloroethylene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 45,000 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trichloroethylene to sensitive freshwater aquatic life but adverse behavioral effects occurs to one species at concentrations as low as 21,900 µg/l.

Saltwater Aquatic Life

The available data for trichloroethylene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2,000 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trichloroethylene to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of trichloroethylene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 27 µg/l, 2.7 µg/l, and .27 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 807 µg/l, 80.7 µg/l, and 8.07 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Vinyl Chloride

Freshwater Aquatic Life

No freshwater organisms have been tested with vinyl chloride and no statement can be made concerning acute or chronic toxicity.

Saltwater Aquatic Life

No saltwater organisms have been tested with vinyl chloride and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of vinyl chloride through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 20 µg/l, 2.0 µg/l, and .2 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5,246 µg/l, 525 µg/l, and 52.5 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Zinc

Freshwater Aquatic Life

For total recoverable zinc the criterion to protect freshwater aquatic life as derived using the Guidelines is 47 µg/l as a 24-hour average and the concentration (in µg/l) should not exceed the numerical value gi
$e^{(0.83\ln(\text{hardness}))+1.95}$ at any ti
example, at hardnesses of 50, 200 mg/l as $CaCO_3$ the concen
total recoverable zinc should
180, 320, and 570 µg/l at any t

Saltwater Aquatic Life

For total recoverable zinc t
to protect saltwater aquatic li
derived using the Guidelines i
as a 24-hour average and the
concentration should not exce
l at any time.

Human Health

Sufficient data is not availa
zinc to derive a level which w
protect against the potential t
this compound. Using availab
organoleptic data, for controll
undesirable taste and odor qu
ambient water, the estimated
mg/l. It should be recognized
organoleptic data as a basis f
establishing a water quality c
have limitations and have not
demonstrated relationship to
adverse human health effects.

Appendix B—Guidelines for D
Water Quality Criteria for the
of Aquatic Life and Its Uses

Introduction

This version of the Guidelin
provides clarifications, additi
details, and technical and edi
changes in the last version pu
the Federal Register [44 FR 15
15, 1979)]. This version incorp
changes resulting from comm
previous versions and from e
gained during U.S. EPA's use
previous versions. Future ver
Guidelines will incorporate n
and data as their usefulness i
demonstrated.

Criteria may be expressed
forms. The numerical form is
used, but descriptive and pro
forms can be used if numeric
are not possible or desirable.
purpose of these Guidelines i
describe an objective, interna
consistent and appropriate w
deriving numerical water qua
for the protection of the uses
as the presence of, aquatic o

A numerical criterion migh
thought of as an estimate of
concentration of a substance
which does not present a sig
to the aquatic organisms in t
and their uses. Thus the Gui
intended to derive criteria w
protect aquatic communities
protecting most of the specie
uses most of the time, but no

Summary of the Environmental Protection Agency
Suggested No Adverse Response Level
(SNARL) for Trichloroethylene

In the absence of a formal drinking water standard for trichloroethylene (TCE), the Office Drinking Water, the Environmental Protection Agency (EPA) has estimated a "suggested no advers response level" (SNARL) following the concepts in toxicology for noncarcinogenic risk for shor and long-term exposures. EPA also has estimated risks of carcinogenic effects resulting from lifetime exposures, using a model from the National Academy of Sciences Report titled Drinkin Water and Health (1977). However, SNARLs are given on a case-by-case basis in emergency situations such as spills and accidents. The SNARL calculations for short-term and chronic exposur do not reflect the possible carcinogenic risk that may result from those exposures. In additi SNARLs usually do not consider the health risk resulting from possible synergistic effects of other chemicals in drinking water, food, and air.

If the lung/whole body ratios for humans (adults) and rats (adults) are roughly equivalent the total lifetime dose of TCE can be determined and a long-term SNARL can be calculated to be approximately 75 ug/l (rounding upward) when the principal source of TCE is assumed to be from drinking water. The calculations are:

$$\frac{(300\ mg/m^3)\ \ 8\ m^3/day\ \ (5)\ \ (1)\ \ (0.30)}{(1\ liter/day)\qquad\quad (7)\ \ (7)\ \ (1000)} = 73.5\ ug/l$$

Where:

300 mg/m^3	= minimum effect level of TCE
8 m^3/day	= amount of air inhaled per day
5/7	= fraction converting from 5- to 7-day exposure
1/7	= child/adult body weight ratio
0.30	= fraction of TCE absorbed from ingestion
1 liter/day	= water consumption per day by a child
1000	= uncertainty factor due to animal study where minimal effect was reported

In cases where drinking water is assumed to account for only a portion of the total exposu say 20%, of the TCE intake, then the SNARL value would become 15 ug/l; however, the 75-ug/l SN would ordinarily be appropriate.

A chronic SNARL approximately equivalent to 75 ug/l can be justified on the basis that the long-term exposure to low doses of TCE probably does not bioaccumulate any more over a lifeti than it does in 3-6 months. The SNARL was calculated for children, not adults, thus providing somewhat larger safety margin.

Since TCE is a carcinogen, at least for mice, by using the risk estimates generated by the National Academy of Sciences (NAS), EPA has estimated that consuming 2 liters of water/day wit TCE concentration of 4.5 ug/l during a lifetime would increase the incidence of cancer by one million persons exposed. This is the same range of risks as determined for other carcinogens.

These risk extrapolations were based on the assumption that there is no threshold level fo carcinogens. At the present time, there are no experimental tools that can accurately define absolute numbers of excess cancer deaths attributable to TCE in drinking water.

The EPA concluded that, based on noncarcinogenic health effects at 2,000 ppb TCE in drinki water, the SNARL should be protective for children. The 10-day value of 200 ppb should provic at least equal protection for a longer period of time.

A chronic SNARL of 75 ppb would appear to be most appropriate from the data available. Th SNARL values do not address the possibility that an acute exposure may induce or promote carcinogenesis, since the knowledge required to make that decision is not known and the data t is not available. The estimates by NAS for incremental cancer risk for lifetime (70 years) exposure range from 4.5 ug/l to 45 ug/l as equivalent to 1 in 1,000,000 and 1 in 100,000 risk, respectively. The equivalent excess risk of 75 ug/l for a lifetime would be a[illegible] 2 per 100,0

Environmental Protection Agency; 10 December 1980

SUMMARY

SNARLS

Assumptions:

1. Looking at sensitive population.
2. Using a child weighing 10 kg. who drinks one liter of water per day.
3. Considering only toxic effects. Health. Unlike those from carcinogenic

Compound	Length of Exposure				
	1 day	7 days	10 days	1 month	life-time
trichloroethylene	2 mg/l		200 ug/l		75 ug/l
tetrachloroethylene	2.3 mg/l		180 ug/l		40 ug/l
1,1,1-trichloroethane					1 mg/l
benzene		350 ug/l			
polynuclear aromatic hydrocarbons		25 ug/l			

Cancer Risks

Assumptions:

1. There is some risk at any level of exposure, and the risk increases as lifetime exposure increases.
2. Using 70 kg. adult living 70 years who drinks two liters of water per day.

Compound	Excess Risk			
	One in 10^{-6}	One in 10^{-5}	Two in 10^{-5}	Six in 10^{-6}
trichloroethylene	4.5 ug/l	45 ug/l	75 ug/l	
tetrachloroethylene	3.5 ug/l	35 ug/l		20 ug/l

Draft SNARLS (not to be released)

Assumptions:

1. Looking at sensitive population.
2. Using a child weighing 10 kg. who drinks one liter of water per day.
3. Considering only toxic effects.

Compound	Length of Exposure				
	1 day	7 days	10 days	1 month	life-time
methylene chloride	13 mg/l		1.3-1.5 mg/l		150 ug/l
carbon tetrachloride	200 ug/l		20 ug/l		
toluene			1 mg/l		
methyl ethyl ketone			1 mg/l		
acrylonitrile			35 ug/l	3 ug/l	
polychlorinated biphenyls				1 ug/l	0.3 ug/l
dibromochloropropane					0.05 ug/l
1,4-dioxane			20 ug/l		
xylenes	12 mg/l		1.4 mg/l		620 ug/l
chlordane	63 ug/l		63 ug/l		8 ug/l
1,1 Dichloroethylene	1.0 mg/l				70 ug/l
Trans-1,2 Dichloroethylene	2.7 mg/l		0.27 mg/l		
Cis-1,2 Dichloroethylene	4.0 mg/l		0.40 mg/l		
Ethylene Glycol	19 mg/l				5.5 mg/l

SNARL For Trichloroethylene
Health Effects Branch, Criteria and Standards Division
Office of Drinking Water
U.S. Environmental Protection Agency
Washington, D.C. 20460

The Office of Drinking Water has reviewed the current literature on the health effects of trichloroethylene. Both data from animal tests and some studies from high level exposure in humans were used as basis for extrapolating to levels in drinking water that would result in negligible risks to the general human population. When considering toxicity that does not include the risk of cancer, we generally use a child weighing 10 kg (22 pounds) and drinking one liter of water per day as the basis for calculations of short exposure (acute) toxicity and longer exposure (chronic) toxicity. These levels are derived using safety factors from classical toxicology and a logic similar to that used by the National Academy of Sciences in "Drinking Water and Health." When considering the possible cancer risk, where it is assumed that there is some risk at any level of exposure, and that the risk increases as the lifetime exposure increases, we use the 70 kg (154 pounds) adult living 70 years who drinks two liters of water as the base, and calculate the excess cancer risk above the normal background according to a mathematical model developed by the National Academy of Sciences in "Drinking Water and Health," and based on animal tests conducted by the National Cancer Institute.

The drinking water levels that we have calculated providing a margin of safety from likely toxic effects in humans (assuming that 100% of the exposure is from drinking water) were related to the length of time that water is being consumed, and range from short-term emergency levels to long-term chronic exposure. We have separately computed the potential additional cancer risk.

The computed drinking water guidance levels for effects excluding cancer risks are as follows:

Time	Concentration
1 day	2 mg/l
10 days	0.2 mg/l (200 ug/l)
Chronic (long-term)	75 ug/l

The computed excess lifetime cancer risks from the NAS model at various exposures assuming the 70 kg adult drinking two liters of water per day for 70 years at the indicated concentration are as follows:

Concentration	Excess Risk
4.5 ug/l	one in 1,000,000
45 ug/l	one in 100,000
75 ug/l	approximately two in 100,000

The development of a SNARL for trichloroethylene does not condone its presence in drinking water, but rather provides useful information to guide control priorities in cases where it is found as a contaminant. Human exposure to contaminants in drinking water such as trichloroethylene should be reduced to the extent feasible, to avoid the unnecessary risks from their presence as adulterants. The applicable treatment technologies include aeration and granular activated carbon.

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