N60201.AR.000002
NS MAYPORT
5090.3a

FINAL HYDROGEOLOGIC ASSESSMENT AND GROUNDWATER PLAN NS MAYPORT FL
10/25/1983
GERAGHTY & MILLER

FINAL REPORT

Hydrogeologic Assessment And Ground-Water Monitoring Plan, U.S. Naval Station, Mayport, Florida

prepared for

NAVAL FACILITIES
ENGINEERING COMMAND
Southern Division
Charleston, South Carolina

GERAGHTY & MILLER, INC.
WATER-RESOURCES CONSULTANTS

CARROLLWOOD VILLAGE EXECUTIVE CENTER
13902 North Dale Mabry Highway, Tampa, Florida 33618/ (813) 961 - 1921

Geraghty & Miller, Inc.

HYDROGEOLOGIC ASSESSMENT AND GROUND-WATER MONITORING PLAN U.S. NAVAL STATION, MAYPORT, FLORIDA

Prepared for

NAVAL FACILITIES ENGINEERING COMMAND
Southern Division
Charleston, South Carolina

October 25, 1983

GERAGHTY & MILLER, INC.
Ground-Water Consultants
13902 North Dale Mabry Highway, Suite 150
Tampa, Florida 33618

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Department of the Navy operates a Naval Station (NS) at Mayport, Florida. The NS contains an inactive sanitary landfill and a waste-oil treatment facility, the locations of which are shown in Figure 1. In accordance with Chapter 17.4, Florida Administrative Code (FAC), Section 17-4.245(6)(d), a ground-water monitoring plan must be submitted to the Florida Department of Environmental Regulation (FDER) for these sites. Presented herein is the hydrogeologic setting of the site, locations and construction details of proposed monitor wells, and a water-quality sampling and analysis plan.

BACKGROUND

Sanitary Landfill Areas

Sanitary wastes from the base have been placed in several landfills in close proximity to one another and in an area south of South Patrol Road. As shown in Figure 2, landfilling has progressed in stages; areas A and B were filled and closed in approximately 1964 and area C was closed in 1981. Area D has been used most recently, and at this time, only a portion of this area has been filled. Sanitary wastes presently generated on base are disposed of in an off-base landfill.

The sanitary landfill areas are adjacent to two large dike-enclosed areas which are used for the disposal of dredge

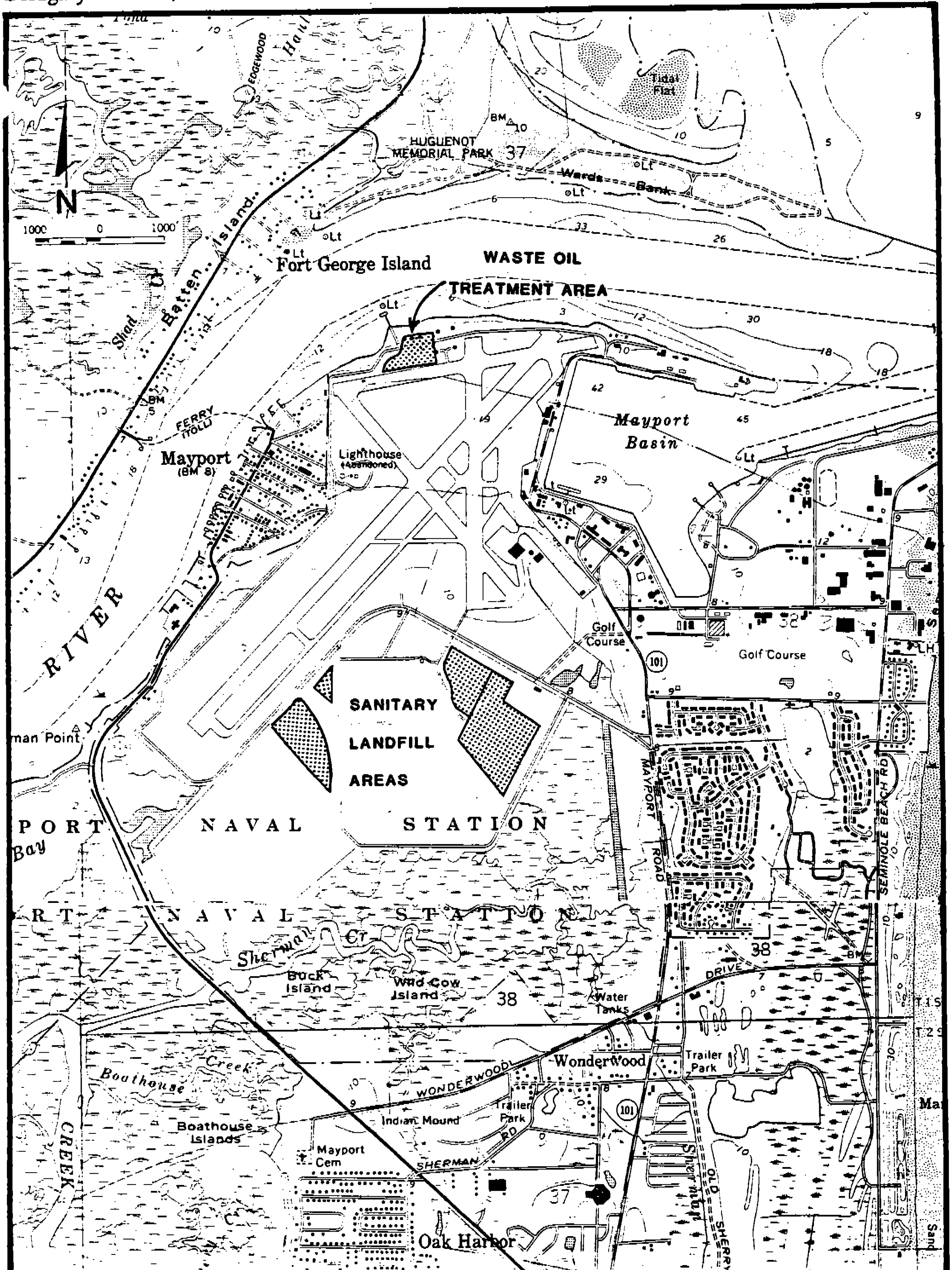


Figure 1. Locations of Sanitary Landfill and Waste Oil Treatment Areas.

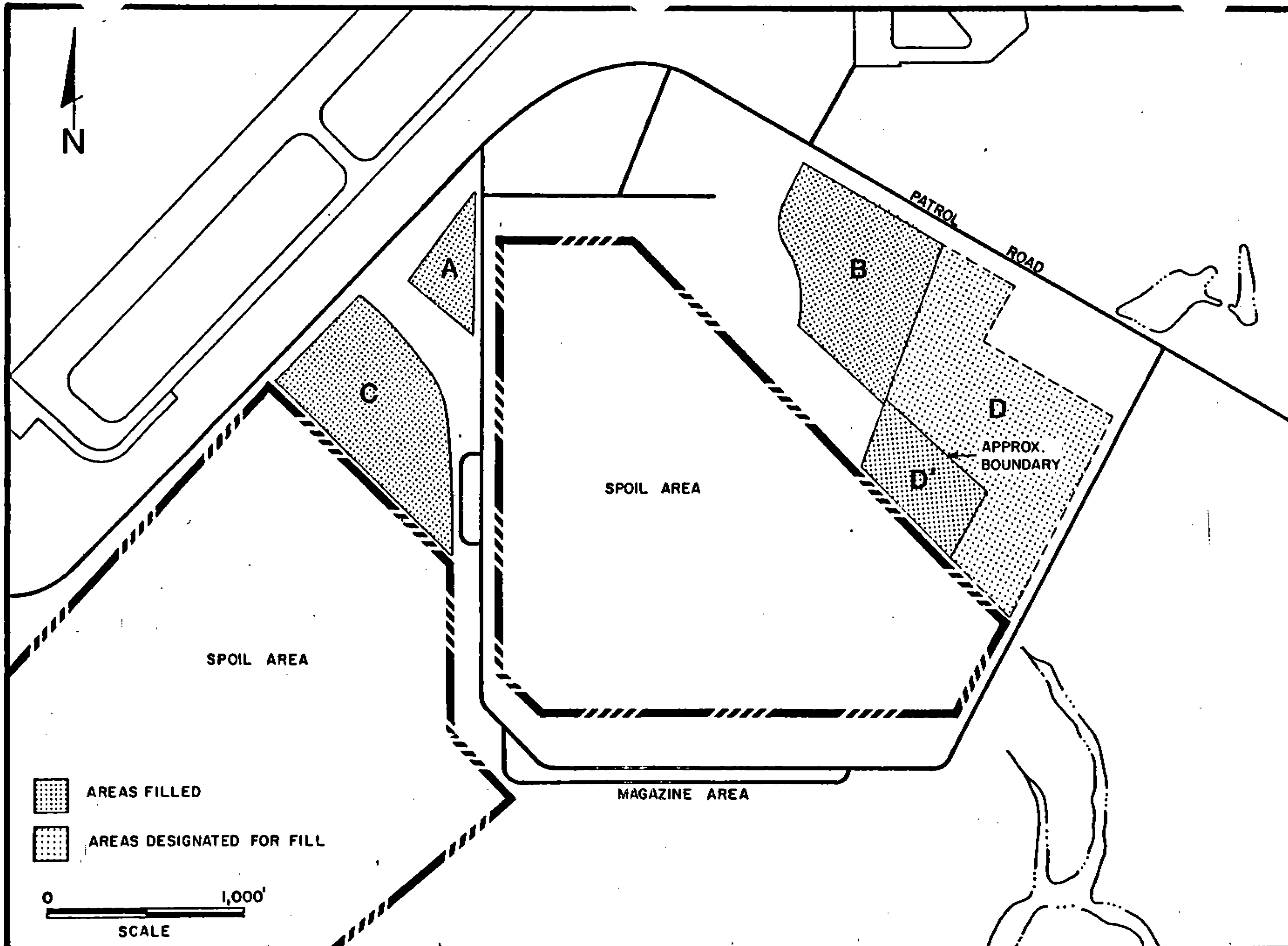


Figure 2. Areas of Sanitary Landfill.

spoil from the turning basin. The northeast spoil area has recently been filled to capacity and spoil disposal is expected to begin in the southwest area in 1983. During filling of the southwest spoil area, a plastic liner will be placed along the inside of the northeast dike in order to minimize potential seepage through the dike and into sanitary landfill Area C.

Waste Oil Treatment Facility

The components of the waste-oil treatment facility are shown in Figure 3. Bildgewater and waste oil from ships is pumped into two oil/water separator tanks (Nos. 99 and 100) where it is allowed to separate for 24 hours. The oil is then skimmed off and trucked to the boiler plant for reclamation. The oily water fraction is pumped to a flocculator where it is treated with lime, sodium hydroxide, and sulfuric acid, and pumped to a clarifier. Sludges from the flocculator and clarifier are pumped to the sludge-drying ponds while the liquid portion is pumped to the effluent leaching pond. Overflow from the leaching pond is gravity-drained by a buried pipe into the St. Johns River.

The waste-oil treatment facility has been operated during the last few years. Prior to 1978, waste oil was pumped into a pit (shown in Figure 4) and allowed to overflow into the St. Johns River. This pit was filled for construction of the new fueling pier. Waste oil was then

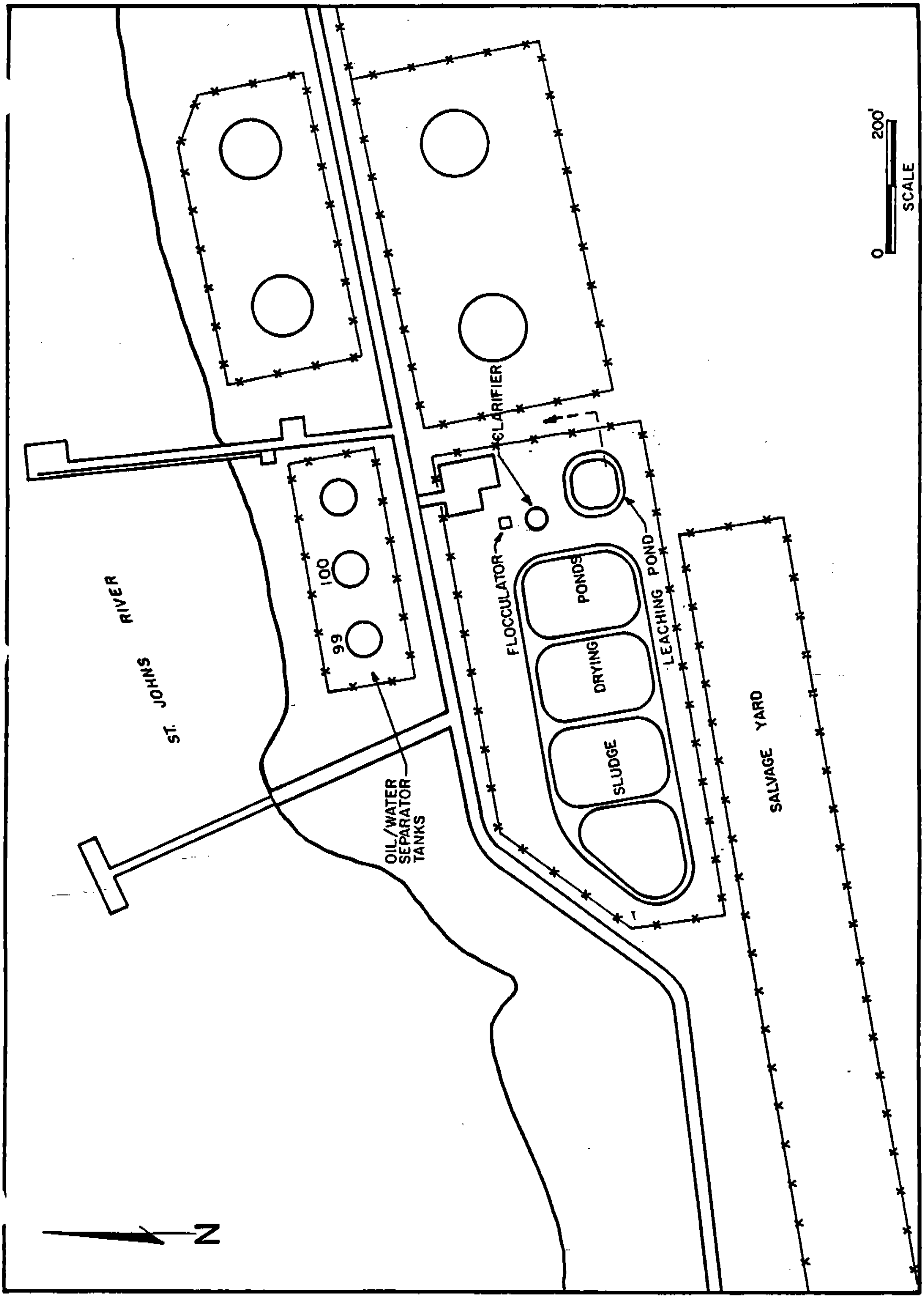


Figure 3. Components of Waste Oil Treatment Plant.

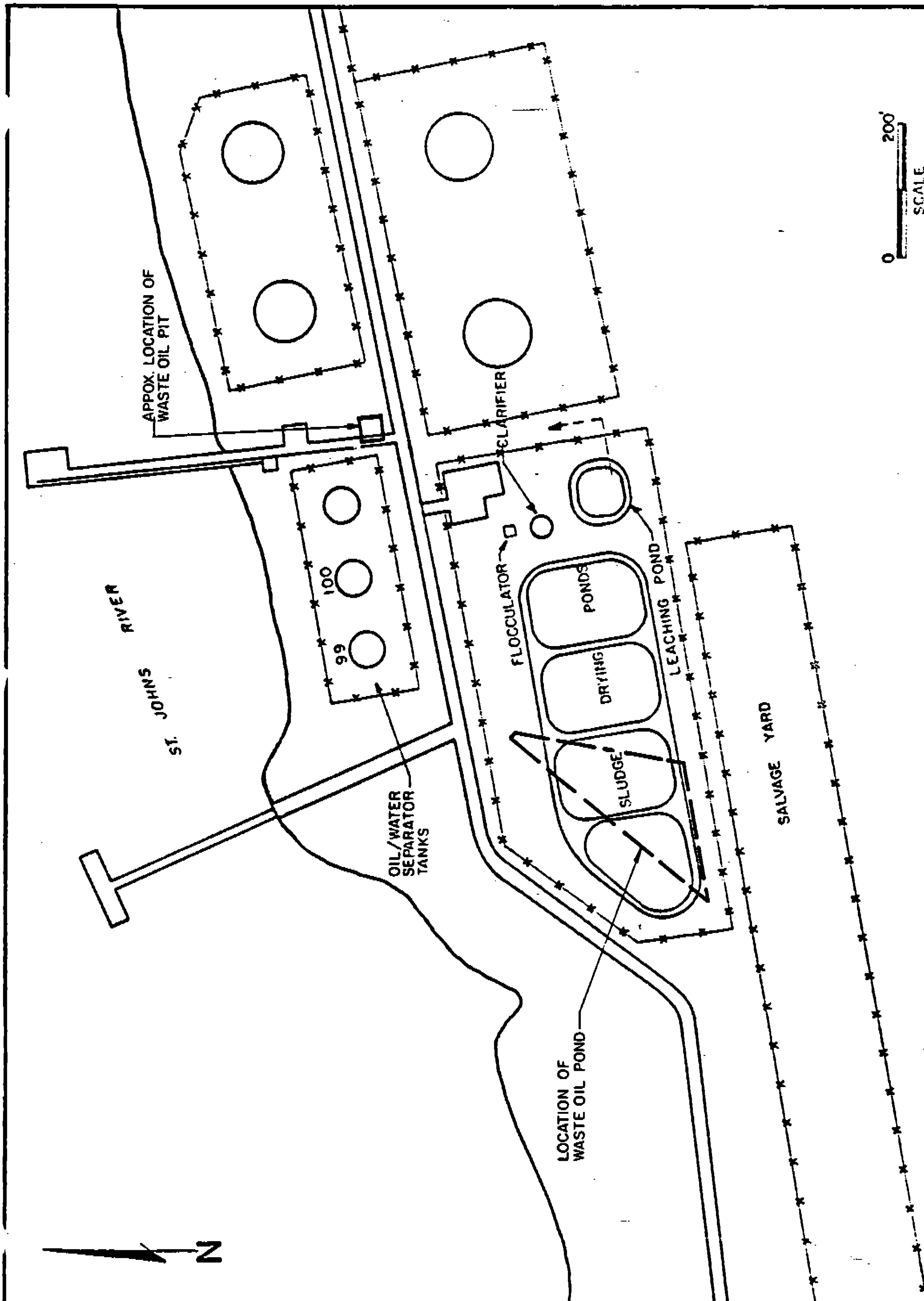


Figure 4. Previously used waste oil facilities.

disposed of into a triangular-shaped pond (Figure 4), which was replaced in 1980 by the sludge-drying ponds.

WELL INVENTORY

Essentially all potable water supplies in the vicinity of the NS Mayport are obtained from the Floridan Aquifer. The surficial sands, which form the surficial aquifer, have a relatively low permeability and because of the proximity to the coast and the St. Johns River, water in these shallow sands contains potable water only in the upper 30 to 40 feet of the aquifer.

The area within one mile of the waste-oil treatment facility and the sanitary landfill areas is shown in Figure 5 and includes most of the NS, a residential neighborhood south of Wonderwood Drive, the Village of Mayport, and a populated strip on the west bank of the St. Johns River. Potable water on base is supplied by four wells tapping the Floridan Aquifer and designated N-1, N-2, N-3, and N-4. The locations of these and other wells within the one-mile radius are shown in Figure 5. Many unused wells at the NS were sealed with grout during a well-abandonment program in 1974.

The Village of Mayport has recently installed a municipal water system supplied by two Floridan wells; however, it is believed that some residents of the Village may still use privately-owned Floridan Aquifer wells. Likewise, houses located along the west bank of the St. Johns River

Geraghty & Miller, Inc.

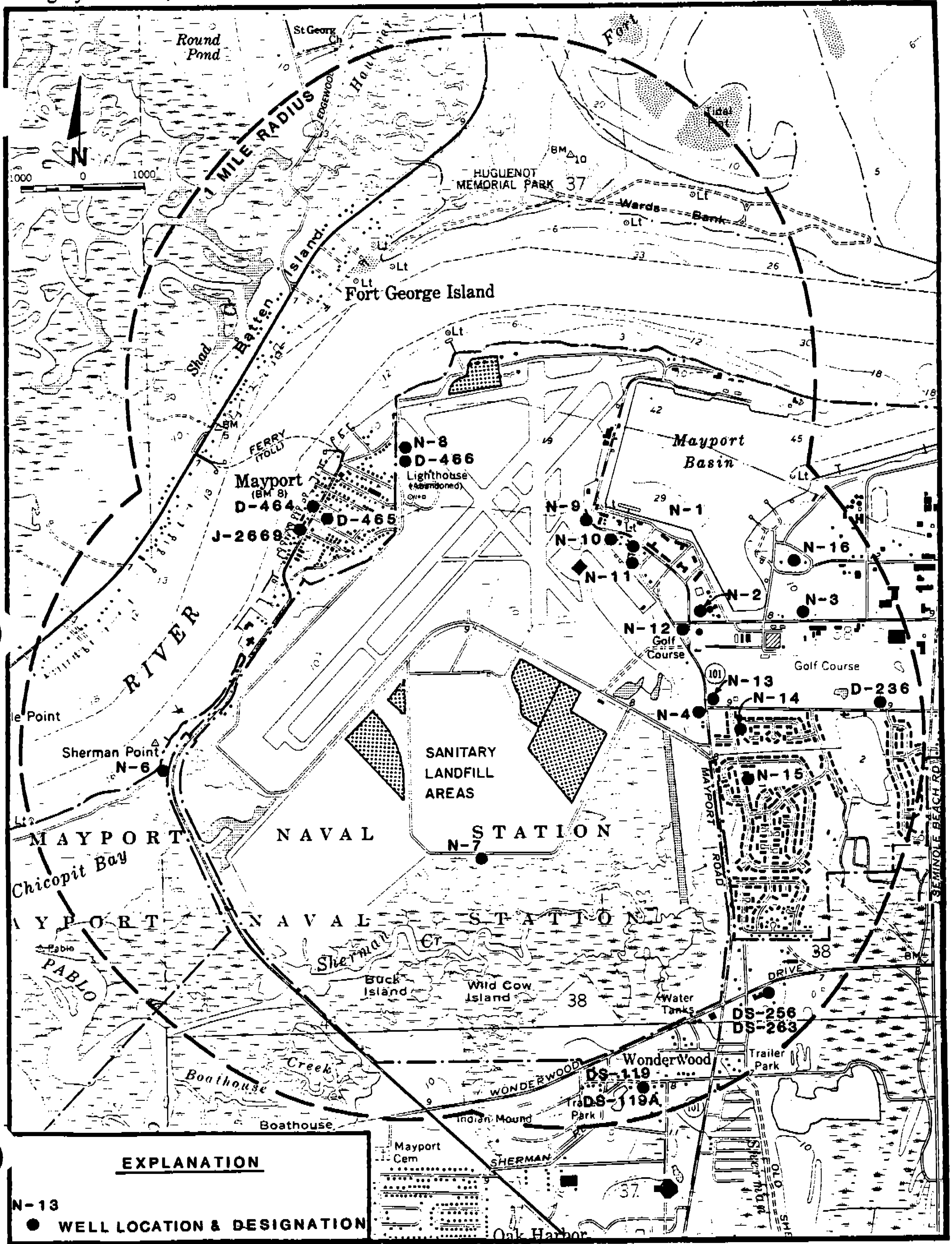


Figure 5. Locations of wells for which records are available within one mile of the sites.

have individual Floridan Aquifer wells. An inventory of wells for which records are available, within one mile of the waste facilities, is presented in Table 1.

HYDROGEOLOGIC SYSTEM

Topography and Drainage

The NS is located on remnants of the Silver Bluff and Pamlico marine terraces, modified by sand dune development, stream erosion, and especially by the dredging and filling activities associated with construction of the NS. The turning basin was constructed in the 1940s from the original Ribault Bay which extended westward as far as the waste-oil area (see Figure 6). Dredge spoil from the turning basin was pumped behind the west bulkhead to fill the old bay and to form the land underlying a portion of the runways. Subsequent maintenance dredging spoil has been used as fill in other areas, most recently in the diked areas south of the runway.

The elevation of the runways are higher than the surrounding land in order to facilitate drainage and therefore serve as a drainage divide between the northwest and southeast portions of the NS. Soils on the north edge of the base, along the St. Johns River, are very sandy and therefore a high proportion of the rainfall is drained internally into the ground. In this area there is little surface-water runoff and few surface-water drainage features.

Table 1. Inventory of Wells for Which Records Are Available Within One Mile of Sites

Well Designation	Owner	Date Installed	Casing Diameter (inches)	Surface Elevation (ft msl)	Total Depth (ft)	Interval Open to Formation (ft depth)	Status
N-1	U.S. Navy	1961	12	10	1001	435-1001	In use
N-2	U.S. Navy	1958	12	10	1000	435-1000	In use
N-3	U.S. Navy	1979	16	10	1000	433-1000	In use
N-4	U.S. Navy	1979	16	10	1000	419-1000	In use
D-466	U.S. Navy	?	?	12	?	?	Plugged
D-236	U.S. Navy	1962	6	9	814	440- 814	Used for irrigation
D-465	City of Jacksonville	?	?	10	700	?	Plugged
N-6	U.S. Navy	?	6	<10	?	?	Plugged
N-7	U.S. Navy	?	2		?	?	Plugged
N-8	U.S. Navy	?			?	?	Unknown
N-9	U.S. Navy	?	4		?	?	Plugged
N-10	U.S. Navy	?			?	?	Plugged
N-11	U.S. Navy	?	6		?	?	Plugged
N-12	U.S. Navy	?	4		?	?	Plugged
N-13	U.S. Navy	?	3		?	?	Plugged
N-14	U.S. Navy	?	3		?	?	Plugged
N-15	U.S. Navy	?	6		?	?	Plugged
N-16	U.S. Navy	?	?		?	?	Abandoned
N-17	U.S. Navy	?	?		?	?	Plugged
D-464	City of Jacksonville	1973	6	10	1219	430-1219	In use
J-2669	Private	?	3	<10	500	399- 500	Unknown
DS-256	Duval County	1976	2	9	63	51- 63	Monitor well
DS-263	Duval County	1976	2	9	14	10- 14	Monitor well
DS-119	?	?	2	10	98	?	Not used
DS-119A	?	?	2	8	162	?	Unknown

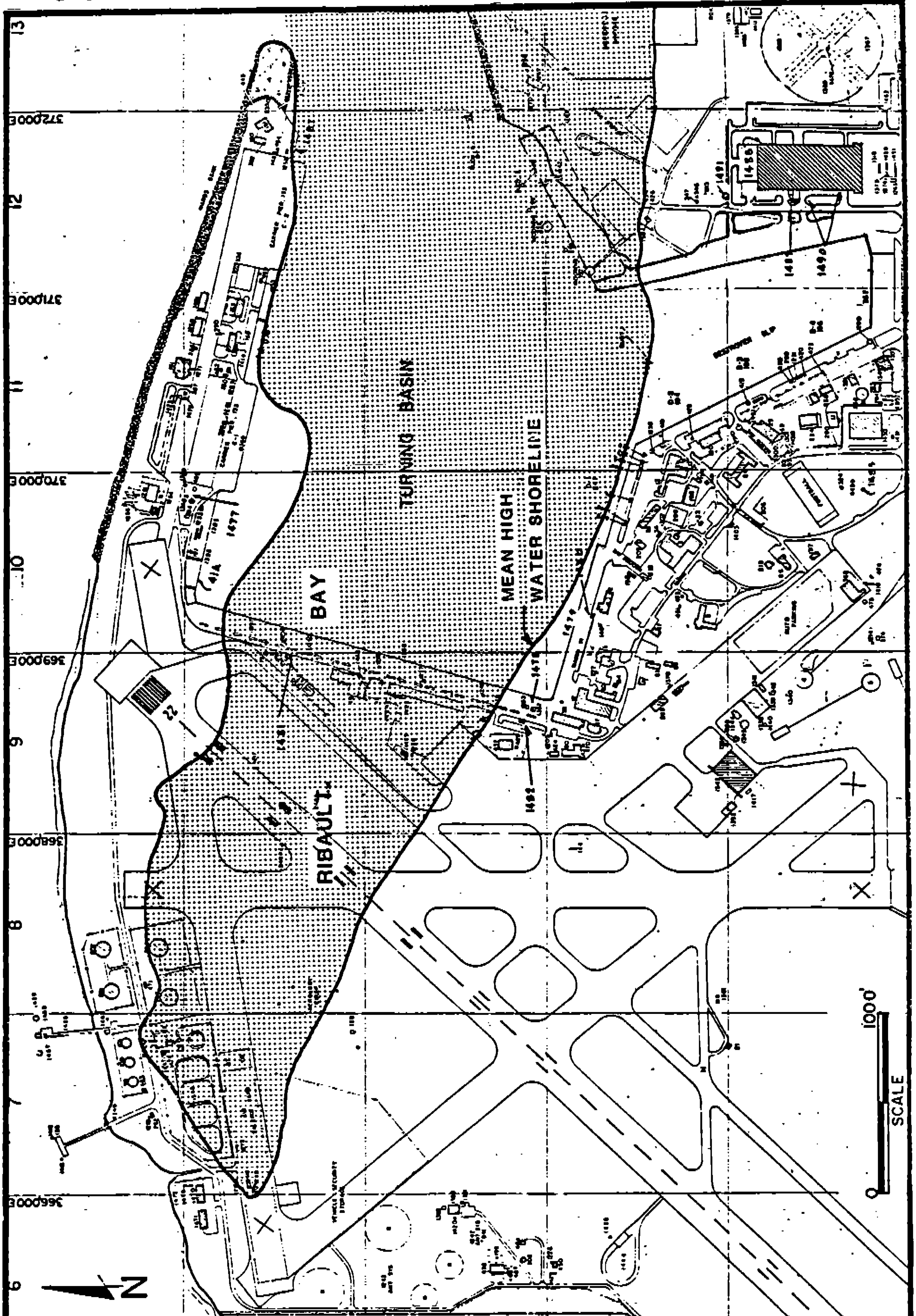


Figure 6. Extent of Former Ribault Bay.

The lower area to the south is flatter, has a larger drainage area, and is underlain by finer, less permeable soils. Drainage in this area is therefore more difficult and is accomplished by a system of ditches which drain surface-water runoff into Sherman Creek. Sherman Creek discharges into Pablo Creek, which in turn discharges into Chicopit Bay and the Intracoastal Waterway. Surface-water drainage in the area of the landfills is shown in Figure 7.

Drainage through the area between Route A1A and the southwest dike of the southwest spoil area has been blocked by slumping of the dike. As a result, surface water in the west corner of the spoil area is conveyed into the Patrol Road ditch and flows eastward around the landfill areas and into Sherman Creek.

Geologic Framework

The geologic sequence of layers underlying the NS Mayport generally consists of unconsolidated deposits of sands and clays overlying a thick sequence of marine carbonate rocks. This is illustrated in Figure 8, which is a composite geologic column constructed from well logs from the area as well as from published data. Lithologic logs of wells and borings in the Mayport area are included in Appendix A.

The uppermost sediments, extending to a depth of about 60 feet, comprise the surficial aquifer and consist of sand,

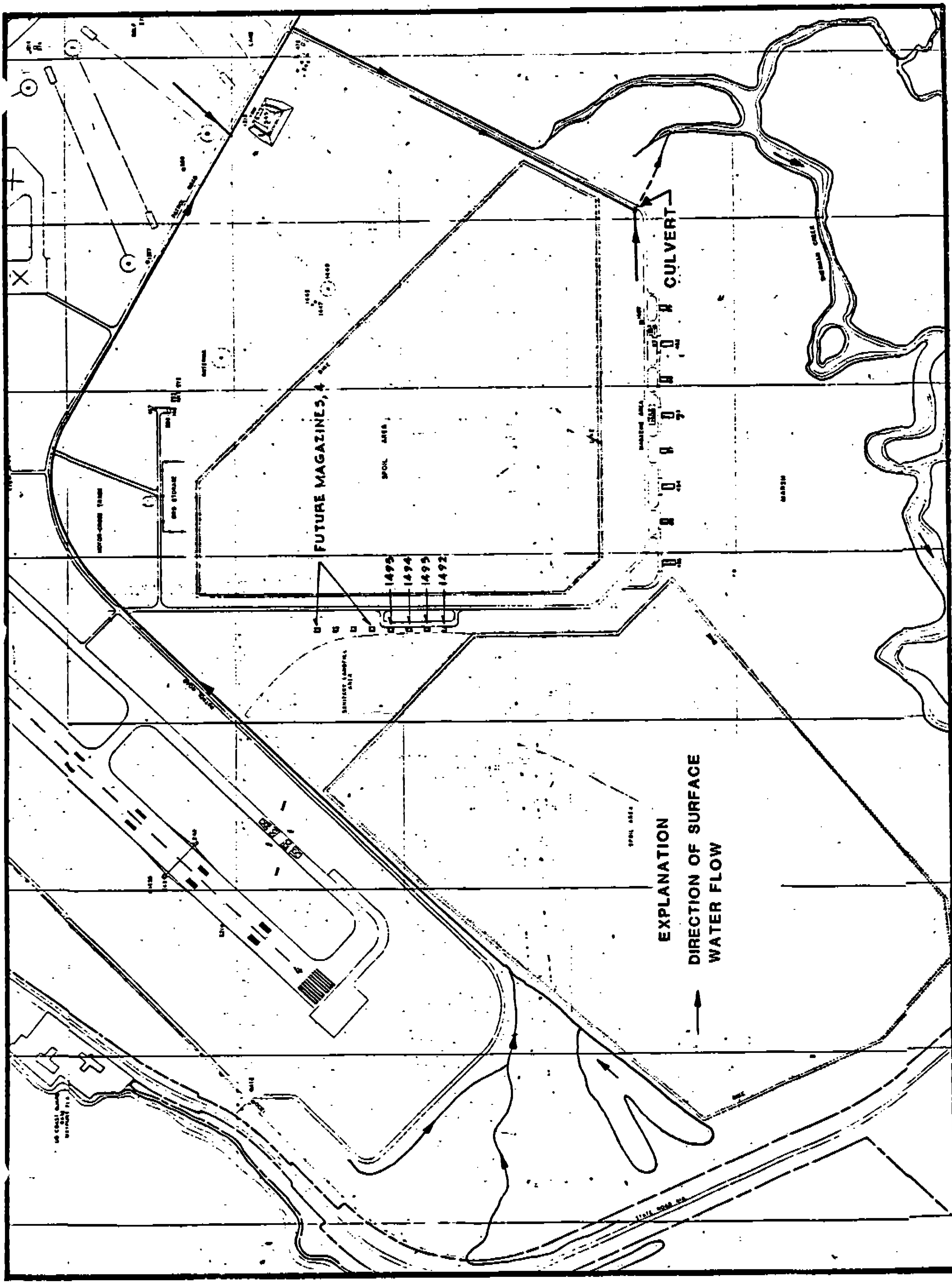


Figure 7. Surface Drainage in the Sanitary Landfill Area.

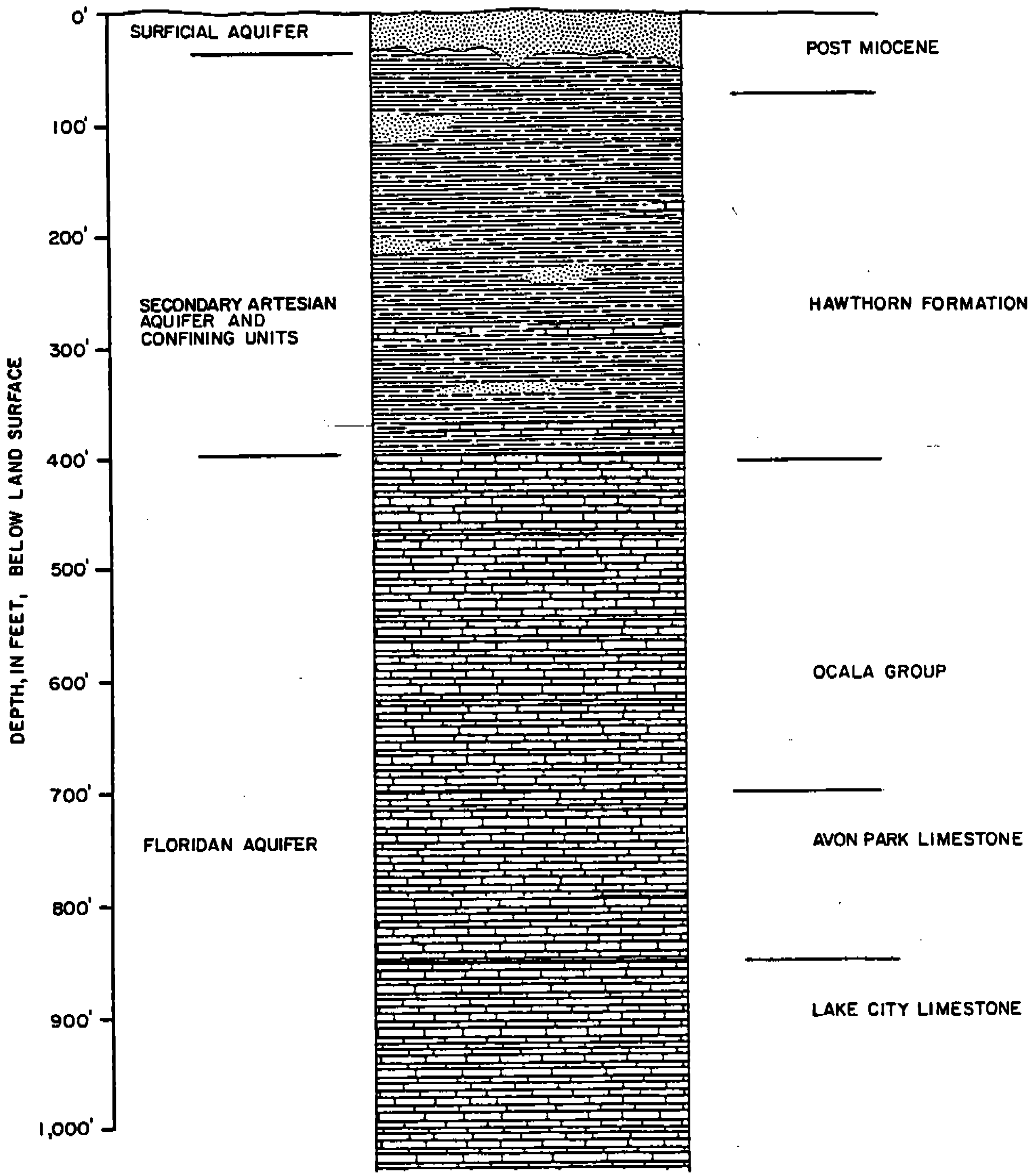


Figure 8. Generalized Geologic Column Representative of the Mayport Area.

shell, and clay. This is underlain by silty clays, clays, and clayey sands of Pliocene and upper Miocene age. Beneath these is the Hawthorn Formation which consists primarily of calcareous, phosphatic, sandy clays with occasional, thin, discontinuous lenses of sands, limestones, and dolostones. The Hawthorn Formation serves as a confining layer which separates the surficial aquifer from the underlying Floridan Aquifer, although the permeable sand and limestone layers within the confining clays form what is referred to as the secondary artesian aquifer.

The basal portion of the Hawthorn Formation generally coincides with the top of the Floridan Aquifer. The Floridan Aquifer consists, in order of increasing depth, of the Ocala Group, Avon Park Limestone, and the Lake City Limestone.

Surficial Aquifer

The surficial aquifer is comprised of the uppermost layers of sand and shell fragments. These deposits vary considerably in composition, thickness, and permeability in the area. Surficial soils of the northern portion of the base were deposited as point bar and spit sediments and are, therefore, relatively permeable. The area to the south was occupied by Ribault Bay and tidal marsh, in which finer, less permeable silts and organic sediments have accumulated. This relationship can be seen in the geologic cross-section of the upper sediments shown in Figure 9.

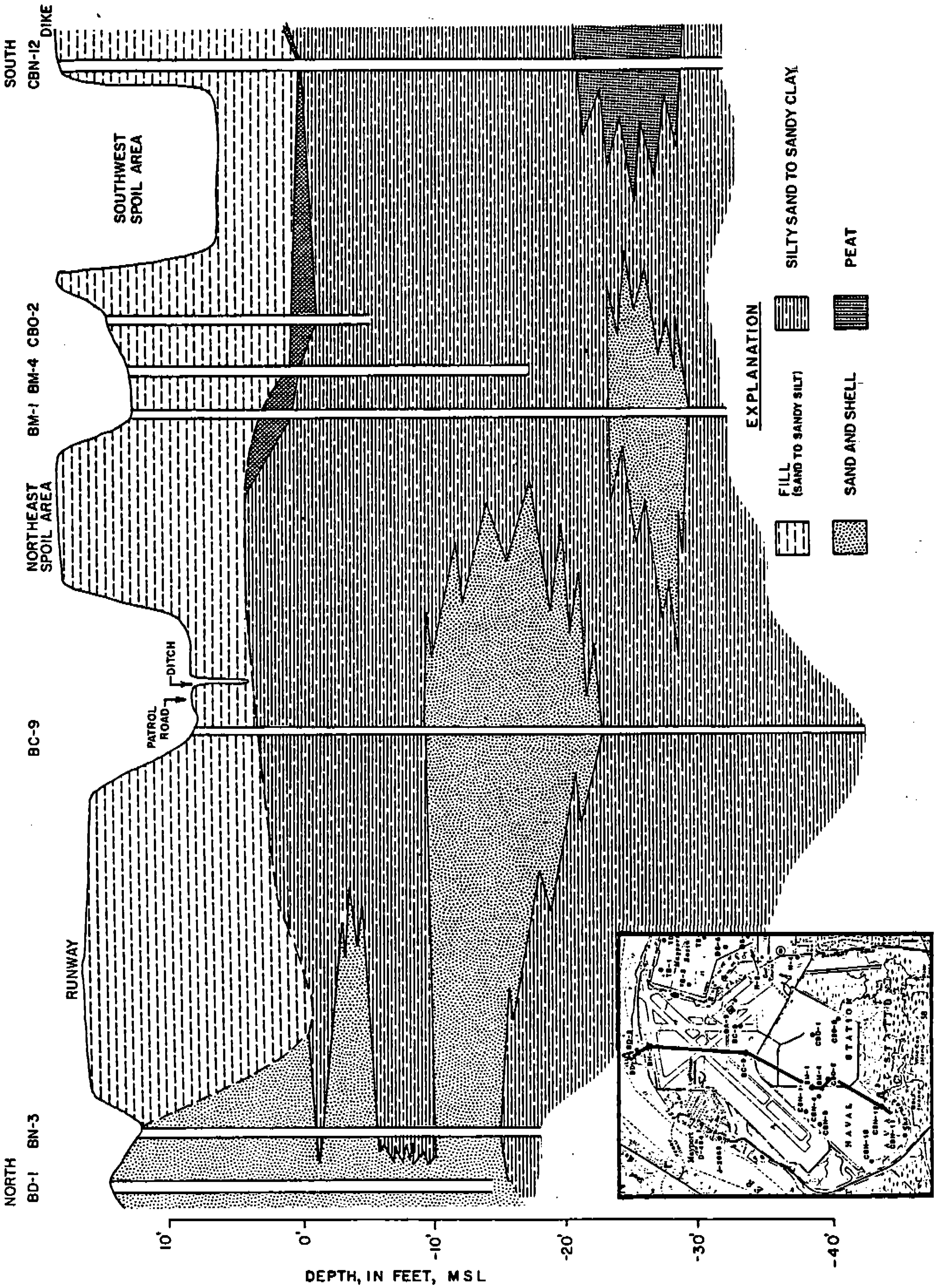


Figure 9. Geologic cross-section at NS Mayport.

The hydraulic properties of the surficial aquifer were determined in a study conducted at the NS Mayport (Franks, 1980). The transmissivity of the principal water-bearing sand and shell zone, at a depth of from 35 to 55 feet, was determined to be 320 gpd/ft (gallons per day per foot).

Ground water can move laterally or vertically depending upon the permeability of the sediments through which it is moving and the prevailing hydraulic gradients. In the study area, ground-water movement is primarily lateral through the surficial aquifer as vertical movement is impeded by underlying clayey sediments.

The major control of the lateral movement of ground water in the surficial aquifer is topography. Shallow ground water moves from topographic highs to areas of natural discharge, such as streams, ditches, or swamps. Figure 10, which was prepared from land surface topography, shows the inferred direction of shallow ground-water flow in the vicinity of the sites. In the waste-oil treatment area, shallow ground water moves relatively easily through the sand and shell and into the St. Johns River.

South of the runway, ground-water flow is more complicated because of the topographically raised spoil and landfill areas and because of the rather deep ditches. In general, the dredge spoil areas act as hydraulic barriers and shallow ground water flow would be away from these areas and toward the ditches.

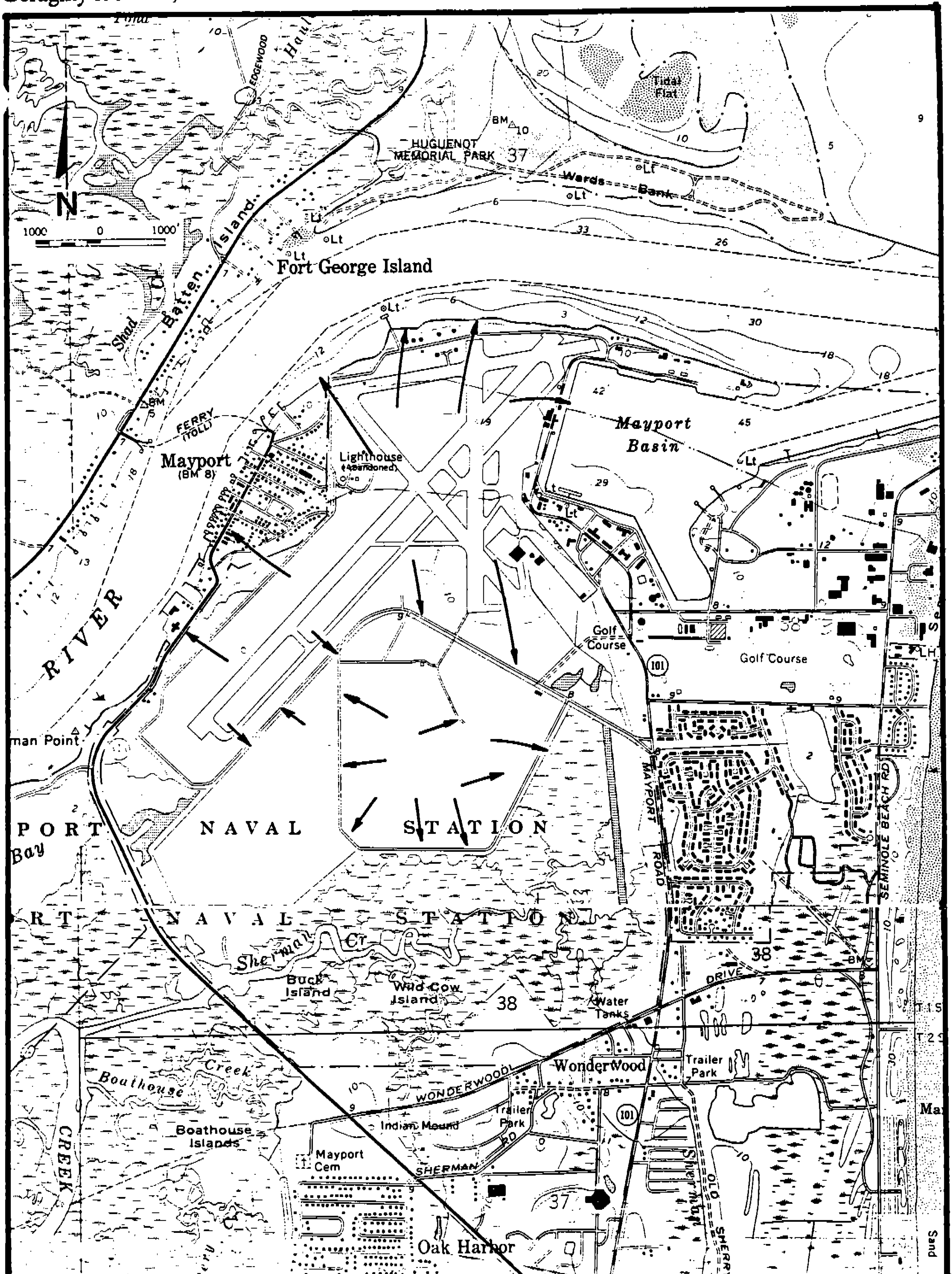


Figure 10. Inferred direction of ground-water flow in the surficial aquifer.

Water in the surficial aquifer in the Mayport area is fresh in the upper part but becomes increasingly brackish below a depth of about 40 feet. This is demonstrated in Table 2 which includes chemical analyses of water from depths of 14 feet and 51 feet. In another study conducted near Mayport (Frazee and McClaugherty, 1979), chloride concentrations of less than 250 mg/l (milligrams per liter) were found at a depth of 10 feet, and at a depth of 50 feet, the chloride concentration exceeded 4,000 mg/l. The deterioration in water quality is more pronounced near the coast and the St. Johns River.

Secondary Artesian Aquifer

The secondary artesian aquifer consists of the sand and limestone lenses which are interbedded in the clayey confining units between the surficial aquifer and the underlying Floridan aquifer. The most productive zone, a limestone layer in the upper part of the Hawthorn, is notably absent in the Mayport area (Spechler, 1982). A study of water levels in the secondary artesian aquifer in Duval County suggests that lateral ground-water flow in the aquifer in the Mayport area is toward the northeast (Fairchild, 1972).

Water quality in the secondary artesian aquifer generally meets the EPA drinking-water standards. Presented in

Table 2. Water Quality Analyses for Wells DS-256 and DS-263 in the Surficial Aquifer[1]

Well Designation	DS-256	DS-263
Well Depth (ft.)	63	14
Casing Depth (ft.)	51	10
Sampling Date	7-7-76	7-8-76
Temperature (field, ^{o}C)	22.5	23
pH (field)	7.3	6.8
Specific Conductance (umhos)	2,250	750
Chloride	452	18
Hardness, as $CaCO_3$	290	424
Iron	0.09	0.34
Calcium	74.0	-
Magnesium	21.0	-
Sodium	420.0	-
Potassium	18.0	-
Sulfate	16.0	-
Strontium	0.50	-

Note: Concentrations in mg/l

[1]Source: Causey & Phelps, 1978

Table 3 is a chemical analysis of water from a secondary artesian aquifer well just south of the base.

Floridan Aquifer

The Floridan Aquifer consists of limestone and dolostone of the Ocala Group, Avon Park Limestone and Lake City Limestone. The top of the Floridan Aquifer occurs at a depth of about 400 feet at Mayport. Published transmissivities of the Floridan Aquifer in eastern Duval County range from approximately 85,000 to 160,000 gpd/ft (Leve, 1968).

The potentiometric surface of the Floridan Aquifer for September 1982 is shown in Figure 11. This figure indicates that ground water in the Floridan Aquifer at Mayport is moving southward toward areas of heavy pumpage along the coast. It can also be seen that Floridan wells in the Mayport area are under sufficient artesian pressure to flow at the surface. Because of this, there is an upward hydraulic gradient between the Floridan and surficial aquifers.

Water quality in the Floridan Aquifer is potable in the Mayport area, as shown in the chemical analyses of Tables 4 and 5. The concentration of total dissolved solids is approximately 400 mg/l and the concentration of chlorides is around 25 mg/l.

Table 3. Water Quality Analysis from Well DS-119A in the Secondary Artesian Aquifer[1]

Well Depth (ft.)	162
Casing Depth (ft.)	?
Sampling Date	9-26-68
Silica	55
Calcium	46
Magnesium	16
Sodium	25
Potassium	4.7
Carbonate	-
Bicarbonate	228
Sulfate	14
Chloride	25
Fluoride	0.9
Nitrate	0.3
Phosphate	0
Dissolved Solids	299
Hardness (Ca,Mg)	182
Specific Conductance (umhos)	442
pH	8.1

NOTE: Concentrations in mg/l

[1]Source: Fairchild, 1972

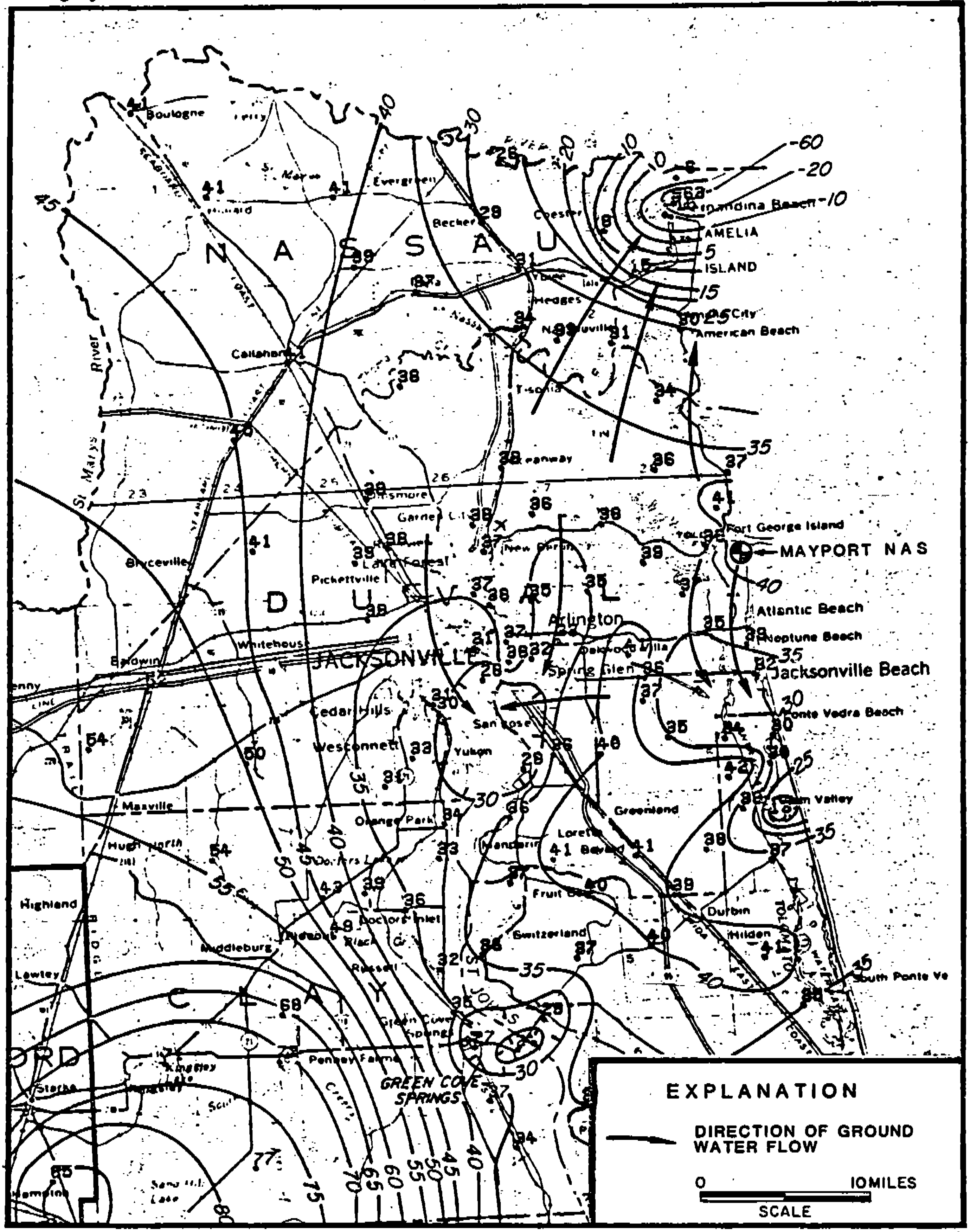


Figure 11. Contour Map of the Potentiometric Surface of the Floridan Aquifer for September, 1982.

Table 4. Water Quality Analysis From Well N-2 in the Floridan Aquifer[1]

Well Depth (ft.)	1,000
Casing Depth (ft.)	435
Sampling Date	10-12-61
Total Solids	444
Loss on Ignition	91
Fixed Solids	353
Calcium as Ca	35.3
Magnesium as Mg	26.2
Sodium and Potassium as Na	33.5
Iron as Fe	0.2
Silica as SiO_2	1.0
Sulphates as SO_4	74.2
Chlorides as Cl	21.3
Alkalinity (Methyl Orange) as $CaCO_3$	148
(Phenolphthalein) as $CaCO_3$	4
Total Hardness as $CaCO_3$	196
Carbonate Hardness as $CaCO_3$	148
Non-carbonate Hardness as $CaCO_3$	48
Free Carbon Dioxide as CO_2	None
pH Value	7.0

NOTE: Concentrations in parts per million

[1]Source: Pittsburgh Testing Laboratory, Pittsburgh, PA

Table 5. Water Quality Analysis From Well N-4 in the Floridan Aquifer[1]

Well Depth (ft.)	1,000
Casing Depth (ft.)	419
Sampling Date	5-31-79
Total Suspended Solids	11
Calcium Hardness	182
Chloride, as NaCl	22.2
Magnesium Hardness, as $CaCO_3$	98
Nitrate	0.04
Total Dissolved Solids	394
Total Hardness, as $CaCO_3$	280
Alkalinity, as $CaCO_3$	138
Non-Carbonate Hardness, as $CaCO_3$	142
Silica	22.2
Sulfate	129
Chloride	25
Calcium	72.83
Magnesium	23.71
Sodium	15.14
Iron	0.4
Potassium	2.53
Carbonate	0
Bicarbonate	138
Turbidity (NTU)	0.47
pH (laboratory)	7.6

NOTE: Concentrations in mg/l

[1]Source: Southern Analytical Laboratory, Jacksonville, Florida

PROPOSED MONITORING NETWORK

The fact that in the Mayport area the artesian head in the Floridan aquifer is well above the water table, minimizes the potential for downward movement of contaminants to aquifers below the surficial sands. Therefore, emphasis in the design of the monitoring system has been placed on monitoring the surficial aquifer and surface water.

Waste Oil Area

In the waste oil area, shallow ground-water flow is restricted to lateral movement through the surficial sands toward the St. Johns River. For this area, 3 monitor wells are proposed, one to be located upgradient from the treatment facilities and two downgradient as shown in Figure 12. It is expected that these wells will be between 10 and 30 feet deep.

Sanitary Landfill Area

Shallow ground-water movement in the landfill area is generally toward Sherman Creek, although locally it is complicated by flow away from the spoil areas and toward the Patrol Road ditch. As shown in Figure 13, four downgradient wells are proposed to monitor possible leachate migration from the landfills. These wells will be less than 20 feet in depth. The upgradient well in the waste oil area will serve to establish background water quality for the landfill area as well. Because Sherman Creek is the discharge point for

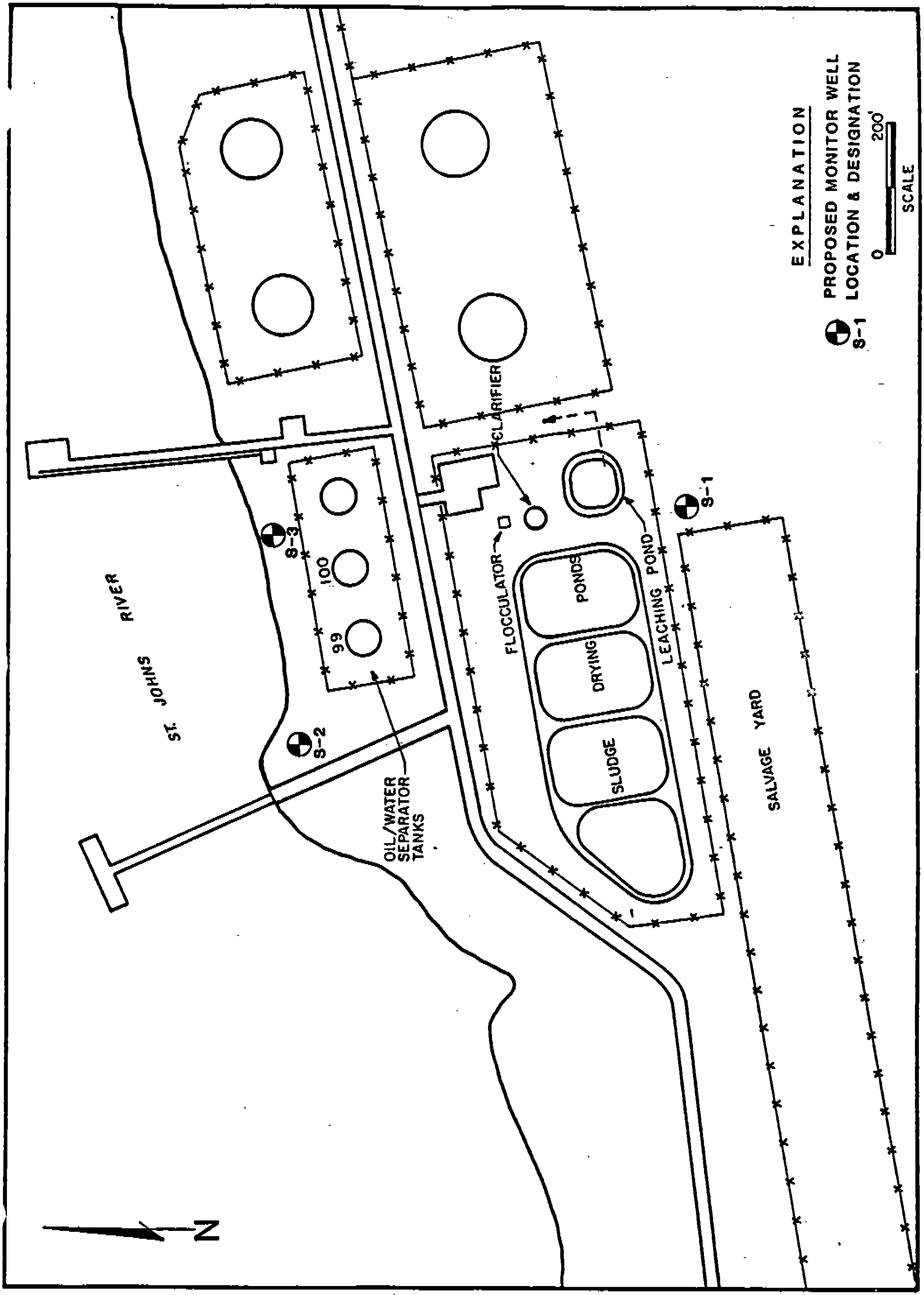


Figure 12. Proposed Monitor Wells for the Waste-Oil Area.

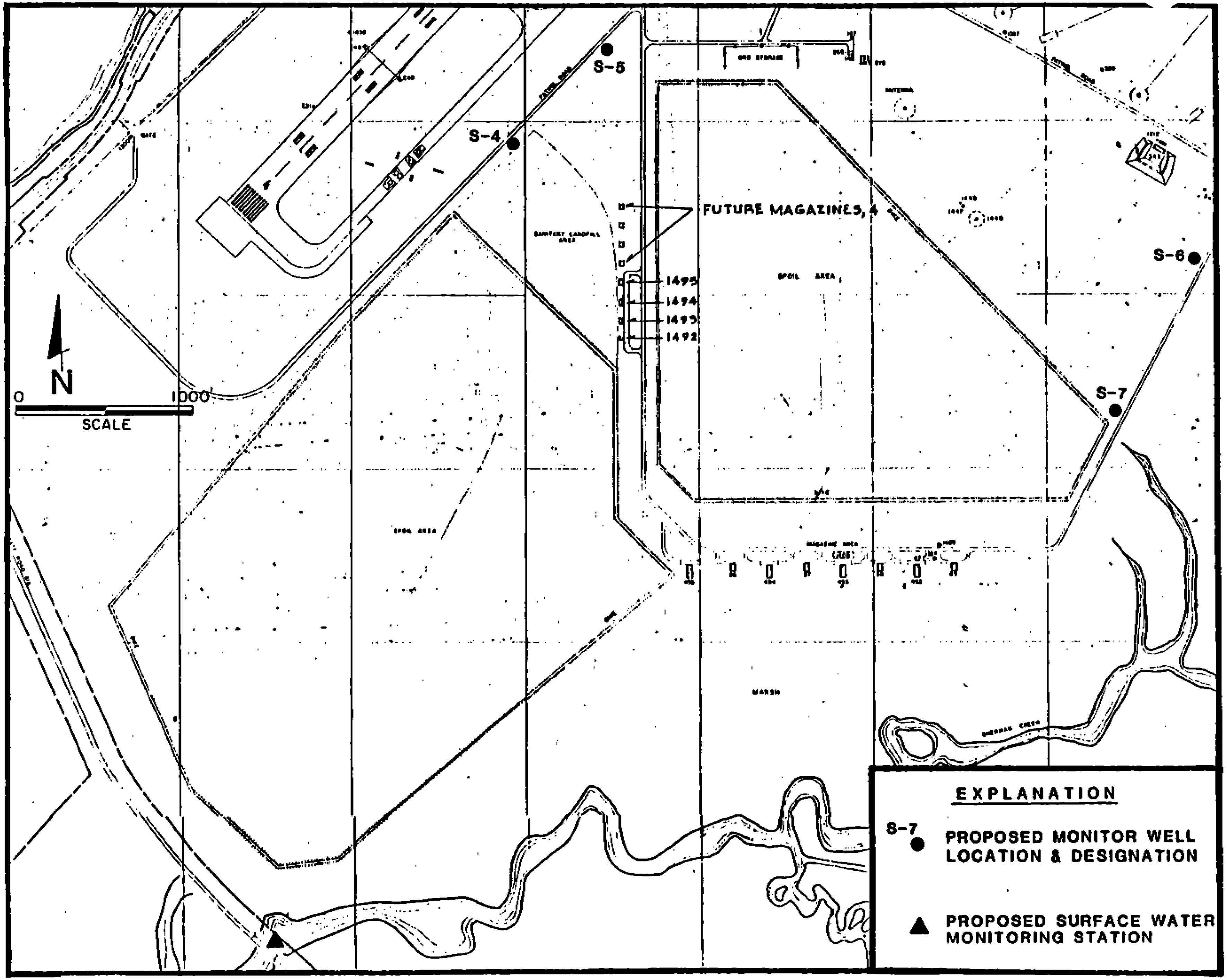
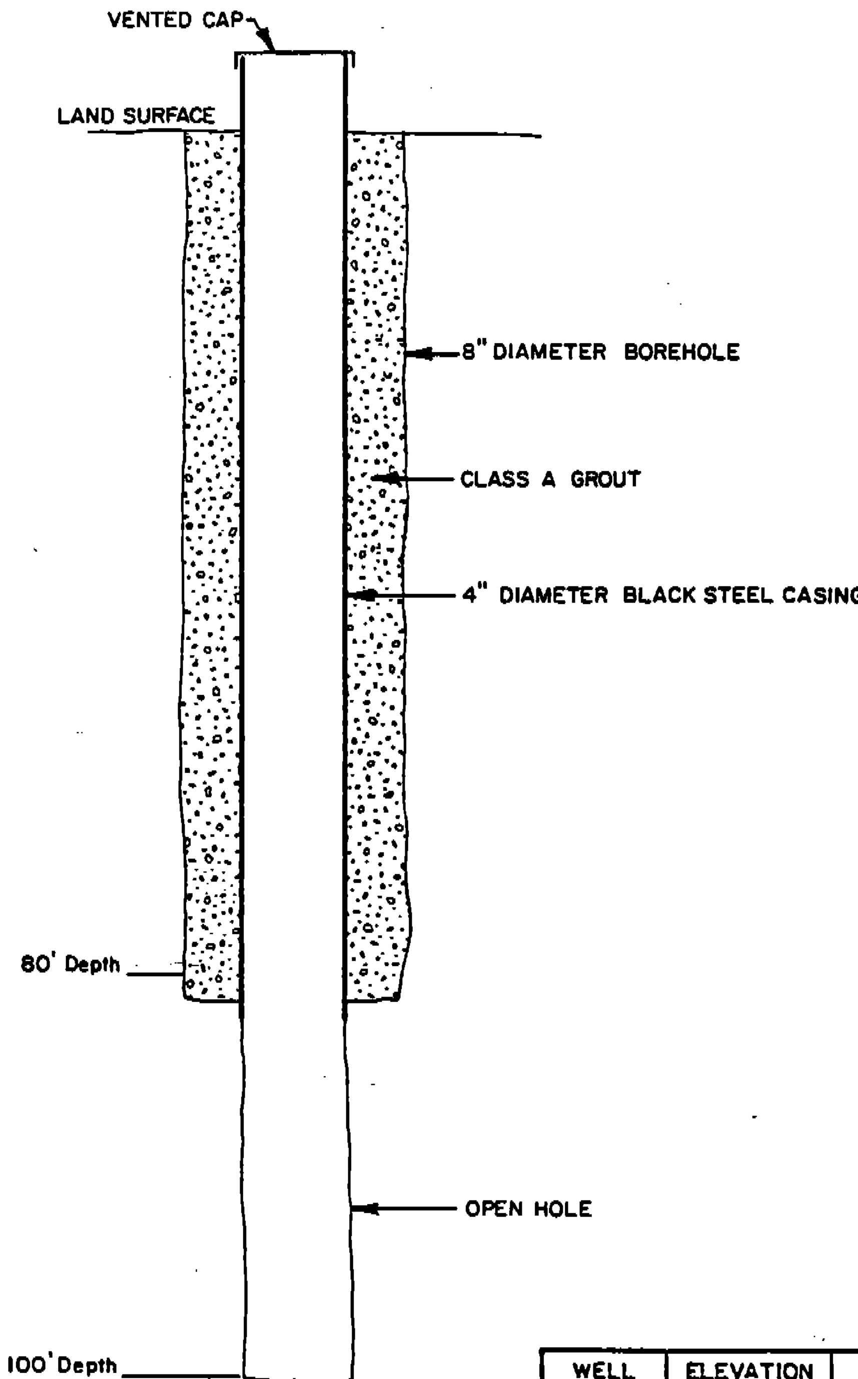


Figure 13. Proposed Surface and Ground-Water Monitoring Network for the Sanitary Landfill Area

surface and ground water from the landfill area, it is proposed that a surface-water monitoring station be established in Sherman Creek at the Route A1A bridge.

Construction details for the proposed monitor wells are illustrated in the schematic diagram of Figure 14. Sampling of the monitor wells and Sherman Creek will be done in accordance with the sampling and analysis plan included in Appendix B.



NOT TO SCALE

WELL NUMBER	ELEVATION (FT. MSL)	TOTAL DEPTH (FT.)

MEASUREMENT FROM TOP OF CASING

Figure 14. Schematic Diagram of Proposed Surficial Aquifer Monitor Well.

REFERENCES

Causey, L.V., 1975, Depth to Water Table, Recharge Areas, Drainage Basins, and Relief of Duval County, Florida: U.S. Geol. Survey, Water-Resources Investigation No. 52-75.

Causey, L.V., and G.G. Phelps, 1978, Availability and Quality of Water from Shallow Aquifers in Duval County, Florida: U.S. Geol. Survey, Water-Resources Investigation No. 78-92.

Fairchild, R.W., 1972, The Shallow Aquifer System in Duval County, Florida: Florida Bureau of Geology Report of Investigations 59.

Fairchild, R.W., and G.W. Leve, 1973, Water Quality and Related Studies, Jacksonville Area, Florida: U.S. Geol. Survey, Open-File Reeport Florida 73035.

Franks, Bernard J., 1980, The Surficial Aquifer at the US Naval Station near Mayport, Florida: U.S. Geol. Survey, Open-File Report 80-765.

Frazee, J.M., and D.R. McClaugherty, 1979, Investigation of Ground Water Resources and Salt Water Intrusion in the Coastal Areas of Northeast Florida: St. Johns River Water Management District, Technical Report No. 3.

Leve, G.W., 1966, Ground Water in Duval and Nassau Counties, Florida: Florida Geol. Survey Report of Investigations 42.

Leve, G.W., 1968, The Floridan Aquifer in Northeast Florida.

Leve, G.W., 1978, Altitude and Configuration of the Top of the Floridan Aquifer, Duval County, Florida: U.S. Geol. Survey, Water-Resources Investigation No. 77-114.

Leve, G.W., 1980, Seasonal and Annual Variations in the Potentiometric Surface of the Floridan Aquifer in Duval County, Florida, 1960-77: U.S. Geol. Survey, Water-Resources Investigations, Open-File Report 80-164.

Schiner, G.R., and E.C. Hayes, 1982, Potentiometric Surface Map of the Floridan Aquifer in the St. Johns River Water Management District and Vicinity, Florida, September 1982: U.S. Geol. Survey, Open-File Report 83-30.

Spechler, Rick M., 1982, Generalized Configuration of the Top of the Limestone Unit of the Lower Part of the Surficial Aquifer, Duval County, Florida: U.S. Geol. Survey, Water-Resources Investigations, Open-File Report 82-336.

Thompson, Thomas H., 1982, Chemical Quality of Water in the Upper Part of the Floridan Aquifer, Duval County, Florida: U.S. Geol. Survey, Water-Resources Investigations, Open-File Report 82-119.

APPENDIX A

LITHOLOGIC LOGS

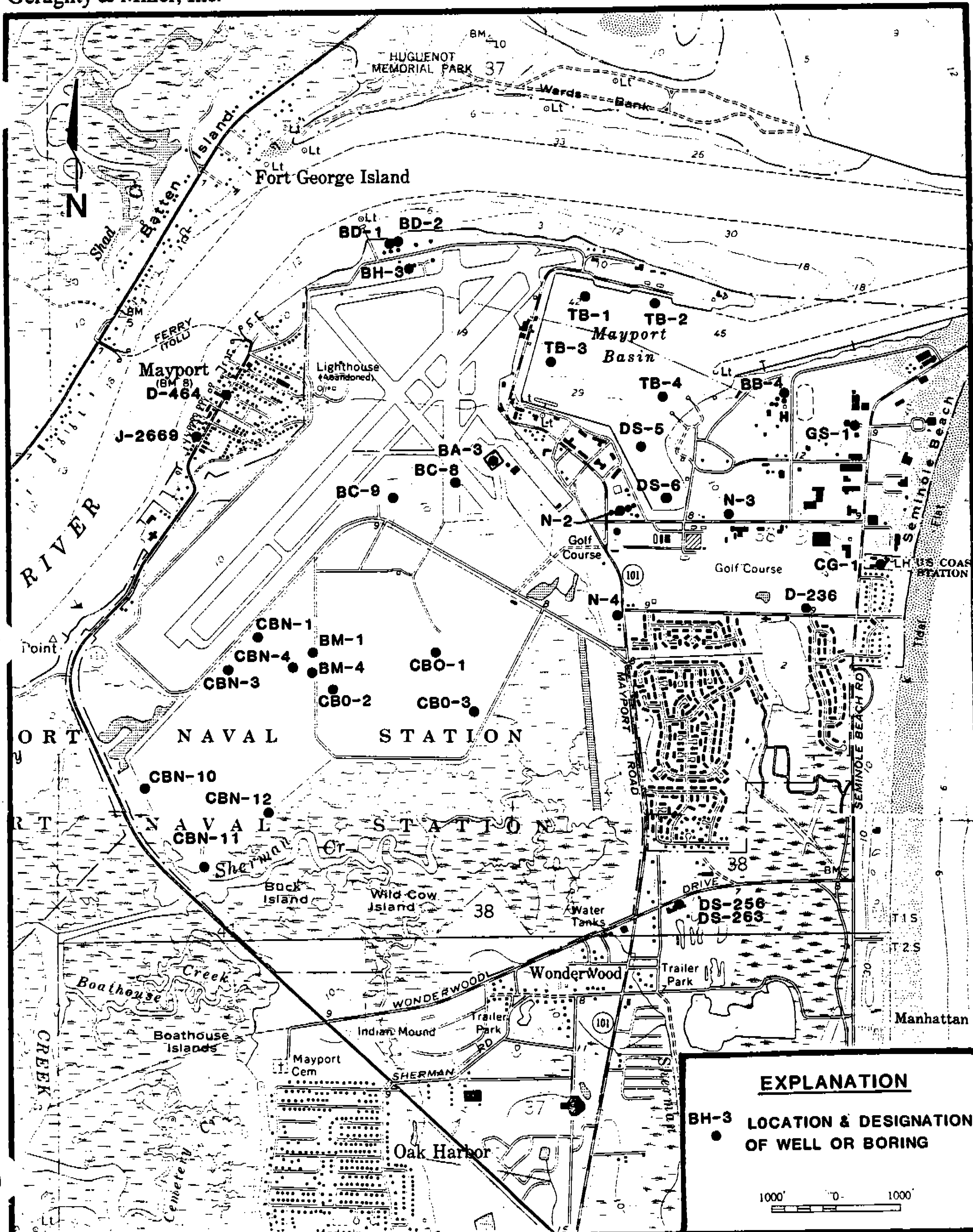


Figure A-1. Locations of wells and borings for which lithologic logs are presented.

Table A-1. Lithologic Log of Well D-464[1]

Well Designation: D-464
Surface Elevation: 10 Feet MSL

Depth (ft. below surface)	Description
0- 10	Sand
10- 20	Sand - little shell
20- 30	Sand
30- 40	Sand
40- 50	Sand and shell
50- 63	Sand and shell
63- 73	Mud
73- 83	Mud
83-120	Sand and mud
120-154	Mud
154-275	Sand and mud
275-307	Broken lime and mud
307-345	Sand and mud
345-347	Hard lime
347-375	Mud, lime and sand
375-427	Broken lime
427-460	White lime
460-665	White, grey and brown lime
665-685	Pinkish brown lime
685-800	Brown lime
800-1020	Brown lime
1020-1204	Brown lime

[1]Source: State of Florida, Department of Health and Rehabilitative Services, 1973

Table A-2. Lithologic Log of Well J-2669[1]

Well Designation: J-2669
Surface Elevation: Elevation less than 10 feet MSL

Depth (ft. below surface)	Description
0- 5	Sand and shell
5- 15	Fine sand and clay
15- 35	Sand and shell
35- 60	Clay and sand, some shell
60- 65	Light brown lime rock
65-100	Grey clay
100-105	Hard white clay
105-145	Grey clay
145-160	Sandy grey clay
160-275	Grey clay
275-280	Hard grey and brown lime rock
280-345	Grey clay with some shell
345-360	Hard grey - brown lime
360-370	Sandy green clay
370-380	Medium hard brown lime
380-390	Hard brown and grey lime
390-399	Soft white lime
399-500	Soft white limestone

[1]Source: State of Florida, Department of Health and Rehabilitative Services

Table A-3. Lithologic Logs of Borings BD-1 and BD-2 at Fuel Tanks[1]

Boring: BD-1
Surface Elevation: 14.2 Feet MSL

Depth (ft.)	Description
0--3.7	Loose oyster shell and tan sand
3.7--9.0	Fine Shell and tan sand
9.0-19.5	Coquina shell and a little white sand

Boring: BD-2
Surface Elevation: 12.8 Feet MSL

Depth (ft.)	Description
0--9.0	Coquina shell and tan sand
9.0-17.5	Fine shell and a little sand

[1]Source: NS Mayport, 1952

Table A-4. Lithologic Log of Boring BH-3

Boring: BH-3
Surface Elevation: 10± Feet MSL

JACKSONVILLE ENGINEERING & TESTING CO

LOG OF BORING

PROJECT: Hazardous Waste Storage Facility, U. S. Naval Station, Mayport, Florida
JOB NO.: 82-170
DATE: 4-3-82
CLIENT: McCully & Parker, Architects
GROUND ELEV:
BORING NO: B-3
FIELD CREW: F. L. Green & Crew
WATER LEVEL: 6.3'

SAMPLE NO	SAMPLE DEPTH - FEET FROM	SAMPLE DEPTH - FEET TO	STRATUM DEPTH - FEET FROM	STRATUM DEPTH - FEET TO	BLOWS PER FOOT	VISUAL SOIL CLASSIFICATION
						Ground Surface
1	0.5	1.5	0.0	2.0	17	Very Dense Tan Fine Sand and Shell (SP - Sh)
2	2.5	3.5	2.0	6.0	19	Very Dense Tan Fine Sand With Shell (SP - Sh)
3	4.5	5.5	2.0	6.0	19	
4	6.5	7.5	6.0	8.0	7	Firm Tan Fine Sand (SP)
5	9.0	10.0	8.0	13.0	7	Firm Tan Fine Sand and Shell (SP - Sh)
			13.0	14.0		Soft Greenish-Gray Clay (CL)
6	14.0	15.0	14.0	17.5	8	Firm Gray Fine Sand With Some Shell (SP)
7	19.0	20.0	17.5	22.0	5	Loose Gray Clayey Sand and Shell (SC - Sh)
8	24.0	25.0	22.0	27.0	4	Loose Gray Fine Sand With Some Shell (SP)
9	29.0	30.0	27.0	32.5	4	Medium Stiff Gray Clay With Thin Sand Lenses (CL)

Table A-5. Lithologic Log of Boring BB-4[1]

Boring: BB-4
Surface Elevation: Elevation 10± Feet MSL

Depth (ft.)	Description
0-12.0	Very firm to loose grey fine sand with shell (possible fill)
12.0-18.0	Very dense grey fine sand with shell
18.0-22.5	Very firm grey fine sand with shell
22.5-32.5	Soft dark grey silt
32.5-36.0	Loose grey fine sand with silt seams and shell
36.0-40.0	Firm grey fine sand with shell and silt seams
40.0	Boring terminated

[1]Source: Law Engineering Testing Company

Table A-6. Lithologic Log of Boring BA-3[1]

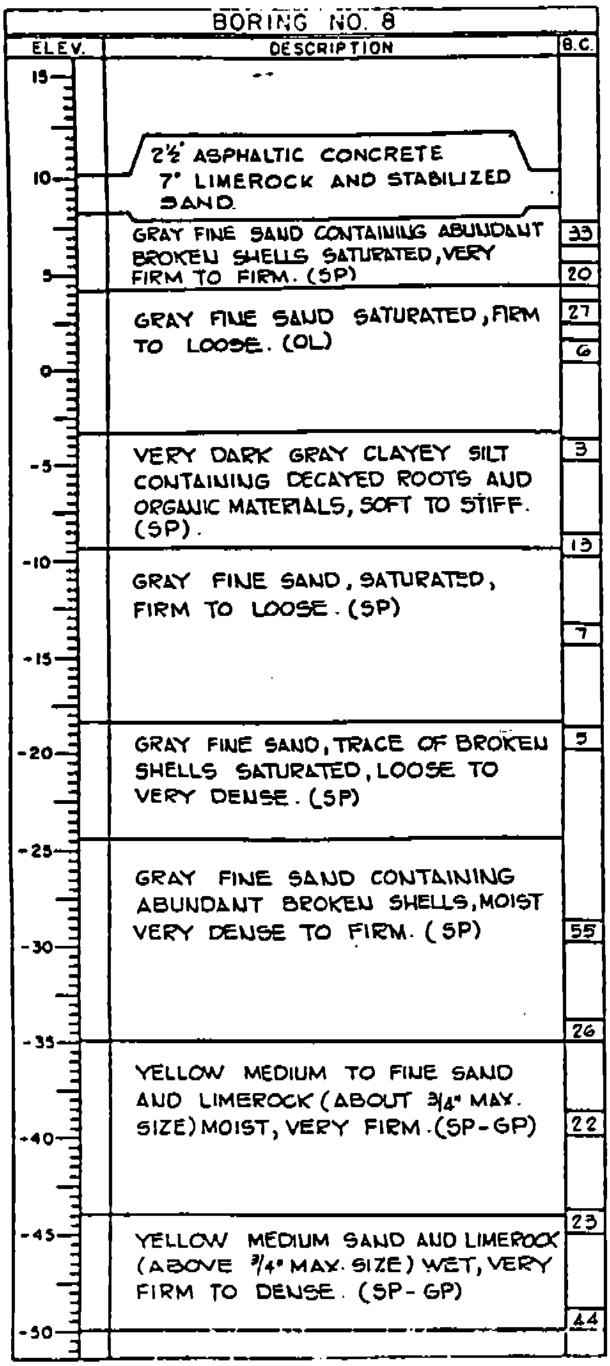
Boring: BA-3
Surface Elevation: Elevation 10± Feet MSL

Depth (ft.)	Description
0--9.5	Firm to loose grey fine sand and shell with trace of clay (SP)
9.5-16.0	Very soft grey slightly clayey silt (MH)
16.0-26.0	Very loose grey slightly organic silty fine sand with some shell (SM)
26.0-40.0	Dense to very firm grey fine sand and shell (SW)
40.0-42.5	Dense to very firm grey fine sand and shell (SW)
42.5-51.0	Firm to loose grey fine sand with silt seams (SW-SM)
51.0-72.0	Loose grey fine sand with limestone and shell fragments (SP)
72.0-80.0	Very firm to loose grey slightly clayey silty fine sand (SM-SC)
80.0-88.5	Very firm to loose grey slightly clayey silty fine sand (SM-SC)
88.5-90.0	Firm grey silty clayey fine sand (SM-SC)
90.0	Boring terminated

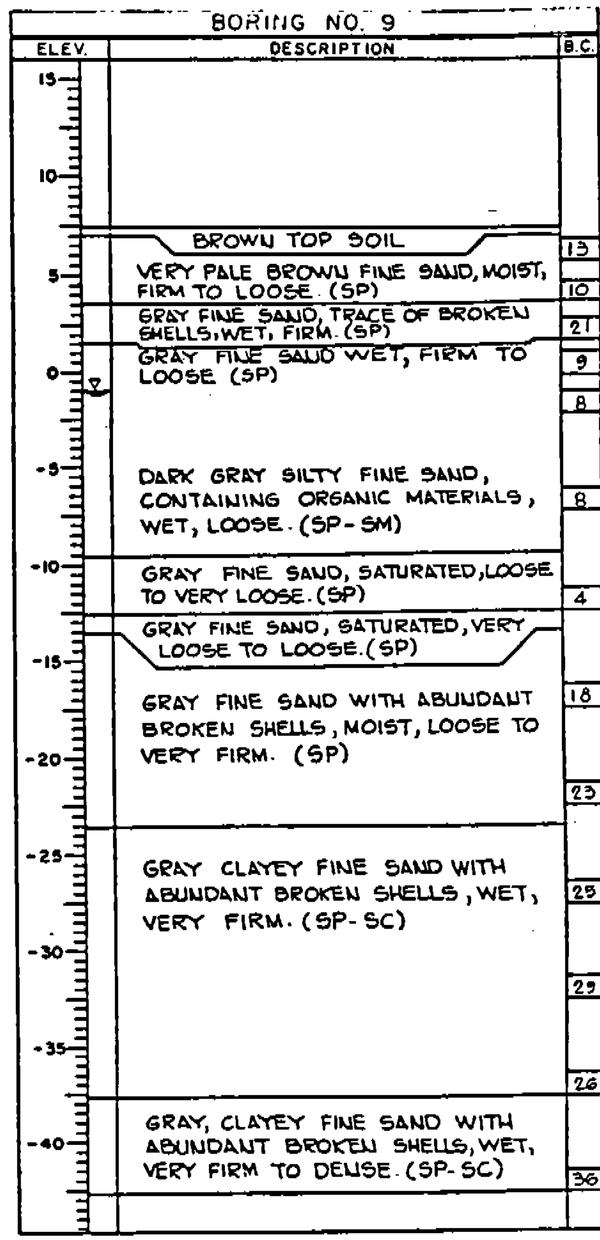
[1]Source: Law Engineering Testing Company, 1973

Table A-7. Lithologic Logs of Borings BC-8 and BC-9[1]

BC-8



BC-9



[1]Source: NS Mayport

Table A-8. Lithologic Log of Boring CBN-1

CBN-1

Hole No. CB-0/A-N-1

DRILLING LOG	Division: South Atlantic
Installation: Jacksonville District	Sheet 1 of 1 sheets
1. Project: MAYPORT BASIN	10. Size and type of bit: See Remarks
2. Location: STA: 18+00 RGE: 360	11. Datum for elevation shown: MLW
3. Drilling agency: Corps of Engineers	12. Manufacturer's designation of drill: Acker
4. Hole No.: CB-0/A-N-1	13. Total no. of overburden samples taken:
5. Name of driller: R. GORDON	14. Total number core boxes: 1
6. Direction of hole: ☒ Vertical ☐ Inclined	15. Elevation ground water: NOT OBSERVED
7. Thickness of overburden:	16. Date hole: Started 3-21-79 – Completed 3-21-79
8. Depth drilled into rock:	17. Elevation top of hole: +17.7
9. Total depth of hole: 20.0'	18. Total core recovery for boring: 36 %
	19. GEOLOGIST: D. ROSEN

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
+17.2	0.5					BIT OR BARREL +17.7
+5.2	12.5		FILL, sand, fine to medium, quartz, tan, slightly silty, layer at 4.5 ft. depth, dark gray (SP)	28	1	2" SAMPLER +12.7
			slightly sandy, (SP) very shelly from 5.0' to 10.0' depth - brown black organic layer at 9.0' depth	30	2	+7.7
+3.2	14.5		FILL, sand, fine to medium, quartz, silty, gray (SM)	56	3	
+1.7	16.0		0.3 ft. thick black, fat, silt (MH) at 14.5 ft. depth			+2.7
00.3	18.0		SILT, stiff, gray (MH)	30	4	
-2.3	20.0		PEAT, dark brown, silty (PT)		5	-2.3
			Note: Natural ground surface at 16.0 ft. depth			

[1]Source: NS Mayport

Table A-9. Lithologic Log of Boring CBN-3[1]

CBN-3

Hole No. CB-0/A-N-3

DRILLING LOG	South Atlantic	Jacksonville District	SHEET 1 of 1 SHEETS
MAYPORT BASIN		See Remarks	
STA: 25+00 RGE: 360		MLW	
Corps of Engineers		Acker	
CB-0/A-N-3			
C. MASON		1	
Vertical		NOT OBSERVED	
		3-23-79	3-23-79
		+22.0	
		31 %	
20.0'		GEOLOGIST: D. ROSEN	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
						BIT OR BARREL
+22.0	0.0					+22.0
			FILL, sand, fine to medium, quartz, slightly silty, tan (SP)	30	1	2" SAMPLER
+17.5	4.5		silty sand, brown, bed at 4.5 ft. depth			+17.0
				40		
+12.0	10.0					+12.0
			FILL, sand, fine to medium, quartz, silty, grey, shelly (SM)			
+8.5	13.5		black, silt layer at 13.5 ft. depth brown calcareous layer at 15.0 feet depth	30	2	+7.0
+6.0	15.0		SILT, black, stiff (MH)	26	3	
+2.0	20.0					+2.0

[1]Source: NS Mayport

Table A-10. Lithologic Log of Boring CBN-4[1]

CBN-4

Hole No. CB-D/A-N-4

DRILLING LOG	South Atlantic	Jacksonville District	Sheet 1 of 1 sheets
MAYPORT BASIN		See Remarks	
STA: 18+00 RGE: 1060		MLW	
Corps of Engineers		Acker	
CB-D/A-N-4			
D. GORDON		1	
Vertical		NOT OBSERVED	
		Started 3-21-79	Completed 3-21-79
		+16.0	
		32 %	
15.0'		GEOLOGIST: D. ROSEN	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
						BIT OR BARREL
+16.0	0.0					+16.0
			FILL, SAND, fine to medium, quartz, slightly silty, slightly shelly (SP)	10	1	2" SAMPLER
+11.0	5.0					+11.0
			FILL, SAND, silty, gray (SM) very silty layer at 5.0 depth to 5.5 depth, black stiff silt layer at 9.0 depth	46	2, 3, 4	
			very shelly, silty, gray sand to 10.3' depth		5	+6.0
+5.7	10.3		VERY SILTY, dark gray and buff 10.0' to 10.3' depth	40	6	
+4.2	11.8		SILT, very stiff, black (MH)			
			PEAT, very silty, dark brown (PT)		7	
+1.0	15.0					+1.0

[1] Source: NS Mayport

Table A-11. Lithologic Log of Boring CBN-10[1]

CBN-10

Hole No. CB-D/A-N-10

DRILLING LOG	DIVISION: South Atlantic	INSTALLATION: Jacksonville District	SHEET 1 OF 3 SHEETS
1. PROJECT: MAYPORT BASIN		10. SIZE AND TYPE OF BIT: See Remarks	
2. LOCATION: STA: 45+00 FSE: 400 CD/A-N ℄ of Dike		11. DATUM FOR ELEVATION SHOWN: MLW	
3. DRILLING AGENCY: Corps of Engineers		12. MANUFACTURER'S DESIGNATION OF DRILL: Acker	
4. HOLE NO.: CB-D/A-N-10		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN:	
5. NAME OF DRILLER: R. GORDON		14. TOTAL NUMBER CORE BOXES: 1	
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: NOT OBSERVED	
7. THICKNESS OF OVERBURDEN:		16. DATE HOLE: STARTED 3-26-79; COMPLETED 3-27-79	
8. DEPTH DRILLED INTO ROCK:		17. ELEVATION TOP OF HOLE: +16.8	
9. TOTAL DEPTH OF HOLE: 65.0'		18. TOTAL CORE RECOVERY FOR BORING: 47%	
		19. GEOLOGIST: D. ROSEN	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
+16.3	0.0					BIT OR BARREL +16.8
			FILL, sand - fine to medium, quartz, slightly silty, slightly shelly, light brown (SP)	40	1	2" SAMPLER +11.8
			Darker brown from 10.0 to 11.0 ft. depth	36		+6.8
				32		+1.8
			Shelly 15.0 to 16.0 ft. depth	34		-3.2

[1] Source: NS Mayport

Table A-11. (Continued)

Geraghty & Miller, Inc. CBN-10

DRILLING LOG (Cont Sheet) | Elevation top of hole: +16.8 | Hole No. CB-0/A-N-10

Project: MAYPORT BASIN | Installation: Jacksonville District | Sheet 2 of 3 sheets

Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (g)
	2?.?					
				18	2	2" SAMPLER -6.2
				40	3	-13.2
			Shelly 30.0 to 35.0 ft. depth	4		-18.2
			Shelly 40.0 to 43.0 ft. depth	40		-23.2
-26.2	43.0		Brown, silty, 43.0' to 45.0' depth Sand, very silty, dark gray 45.5' to 46.0' depth	80	4	-28.2
-29.2	46.0		SILT, black, stiff, contains yellow leafy matter and wood chips in early stages of decomposition, organic (OL)	52	5 6	
-32.9	49.7		SAND, fine to medium, quartz slightly shelly, very silty, black (SM)		7	-33.2 BIS/0.5 ft
-33.2	50.0					SPLIT SPOON 1 1 6
				13	8	-34.7
			SILT, dark gray, plastic (MH) contains some yellow leafy material shelly from 50.0 to 51.5 ft. depth medium plasticity from 56.0 to 57.5 ft. depth	10		SETTLED -36.2
				8		SETTLED -37.7
				12"		PUSHED -39.2
				10		PUSHED -40.7
			SAND, fine to medium, quartz, very silty, slightly shelly, dark brown (SM)	59		PUSHED 3 3 -42.2
-42.5	59.3			60	9 10	9 11 10 -43.7
-43.4	60.2					
-43.7	60.5		SILT, medium plasticity, shelly, dark gray (ML)	62		18 18 19 -45.2
			SAND, fine to medium, quartz, slightly shelly, very silty (SM) dark brown	60	11	21 20 21 -46.7
				58	12	32 34 35 -48.2
-47.8	64.6					
-48.2	65.0		SAND, fine to medium quartz, slightly shelly, light gray, slightly greenish-organic odor (SP) slightly silty			

[1]Source: NS Mayport

Table A-12. Lithologic Log of Boring CBN-11[1]

CBN-11

Hole No. CB-D/A-N-11

DRILLING LOG	South Atlantic	Jacksonville District	Sheet 1 of 1 sheets
1. Project: MAYPORT BASIN		10. Size and type of bit: See Remarks	
2. Location: STA: 43+00 PSE: 2000		11. Datum for elevation shown: MLW	
3. Drilling agency: Corps of Engineers		12. Manufacturer's designation of drill: Acker	
4. Hole No.: CB-D/A-N-11		13. Total no. of overburden samples taken:	
5. Name of driller: R. GARDON		14. Total number core boxes: 1	
6. Direction of hole: [X] Vertical [ ] Inclined ___ deg. from vert.		15. Elevation ground water: NOT OBSERVED	
7. Thickness of overburden:		16. Date hole: Started 3-27-79; Completed 3-27-79	
8. Depth drilled into rock:		17. Elevation top of hole: +19.2	
9. Total depth of hole: 25.0'		18. Total core recovery for boring: 37%	
		19. GEOLOGIST: D. ROSEN	

Elevation	Depth	Legend	Classification of materials (Description)	% Core recovery	Sample No.	Remarks
+19.2	0.0					BIT OR BARREL +19.2 BLS/FT
			FILL, sand, fine to medium, quartz, shelly, slightly silty (SP) tan	30	1	2" SAMPLER +14.2
			Light brown, buff silt balls, some limestone and phosphatized gravel 5.0 to 7.0 ft. depth	38	2	+9.2
+5.2	14			0	3	+4.2
+4.2	15		SAND, fine to medium, quartz very silty, dark brown (SM) with thin layers clean sand			
+2.2	17		PEAT, very silty, (PT) brown-yellow leafy material, grades into stiff silt (MH) at 16.0 depth	64	4	
-0.8	20.0		SAND, dark brown, fine to medium, quartz, very silty-interbedded layers of silt, clean sand (SM)			-0.8
-5.8	25.0		SILT-STIFF 19.8' to 20.0' DEPTH	54	5	-5.8

[1]Source: NS Mayport

Table A-13. Lithologic Log of Boring CBN-12[1]

CBN-12

DRILLING LOG — Division: South Atlantic — Installation: Jacksonville District — Sheet 1 of 1 sheets — Hole No. CB-D/A-N-12

1. Project	MAYPORT BASIN
2. Location (Coordinates or Station)	STA: 38+80 RGE: 219.0
3. Drilling Agency	Corps of Engineers
4. Hole No. (As shown on drawing title and file number)	CB-D/A-N-12
5. Name of Driller	3. GORDON
6. Direction of Hole	☒ Vertical ☐ Inclined ___ Deg. from vert.
7. Thickness of Overburden	
8. Depth Drilled into Rock	
9. Total Depth of Hole	50.0'
10. Size and Type of Bit	See Remarks
11. Datum for Elevation Shown (TBM or MSL)	MLW
12. Manufacturer's Designation of Drill	Acker
13. Total No. of Overburden Samples Taken	Disturbed / Undisturbed
14. Total Number Core Boxes	1
15. Elevation Ground Water	NOT OBSERVED
16. Date Hole	Started 3-28-79 / Completed 3-28-79
17. Elevation Top of Hole	+17.7
18. Total Core Recovery for Boring	%
19. Geologist	D. ROSEN

Elevation	Depth	Classification of Materials (Description)	% Core Recovery	Sample No.	Remarks (Drilling time, water loss, depth of weathering, etc., if significant)
+17.7	0.0				BIT OR BARREL +17.7
		FILL, sand, fine to medium, quartz, slightly silty, shelly, tan (SP) Some limestone gravel and silt balls 0.0 to 8.0 ft. depth	36	1	2" SAMPLER +12.7
			40	2	+7.7
+3.7	14.0	Interbedded brown silty layers with some silt balls and quartz gravel 5.0 to 10.0 ft. depth Some limestone gravel-silty 10.0 to 14.0 ft. (SP-SM)	10	3	+2.7
-0.3	18.0	FILL-SAND, fine to medium, quartz, silty, shelly, gray (SM)			
		SILT, medium plasticity, dark brown (ML) slightly shelly. Shell layer at 23.0 ft. depth	40	4	-2.3
			50	5	2" SAMPLER -7.3
			80		-12.3
			75		-17.3
-21.3	39.0	Isolated layers organic material - no shell 30.0 to 35.0. dark gray no shell 35.0 to 39.0 ft.	80	6	-22.3
-27.3	45.0	PEAT, dark brown, very silty (PT)	50	7	-27.3
-29.3	47.0				
-31.3	49.0	SAND, fine to medium, quartz, very silty, dark brown (SM)	60	8	2" SAMPLER -32.3
-32.3	50.0	SAND, fine to medium, quartz, very silty, very shelly, calcareous-light gray, dense (SM)			

[1]Source: NS Mayport

Table A-14. Lithologic Log of Boring CBO-1[1]

CBO-1

Hole No. CB-0/A-0-1

DRILLING LOG	South Atlantic	Jacksonville District	SHEET 1 OF 1 SHEETS
MAYPORT BASIN		See Remarks	
STA: 15+00 PGE: 1600		MLW	
Corps of Engineers		Acker	
	CB-0/A-0-1		
		1	
R. GORDON		NOT OBSERVED	
VERTICAL		3-29-79	3-29-79
		+16.0	
		51 %	
20.0'		GEOLOGIST: D. ROSEN	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
+16.0	0.0					BIT OR BARREL +16.0
+13.0	3.0		SILT, dark brown, dried, brittle (MH)	30	1	2" SAMPLER
+5.5	10.5		SAND, fine to medium, quartz, silty, brown, shelly (SM) gray 5.0 to 10.5 ft. depth silt layers 10.0 to 10.5	20	2	+11.0 / +6.0
+2.0	14.0		SILT, dark gray, sandy, stiff (MH) sand layers at 11.5, 11.0 and 12.0 ft. depth	74	3	
+0.2	15.8		PEAT, dark brown, very silty (PT) silt layers and sand at 15.5 to 15.8		4	+1.0
-0.5	16.5		SILT, dark gray, stiff, sandy (MH) organic matter		5	
-3.8	19.8		SAND, fine to medium, quartz, slightly shelly, organic matter, very silty, brown (SM)	78	6, 7	
			PEAT, dark brown, very silty (PT)			-4.0

[1] Source: NS Mayport

Table A-15. Lithologic Log of Boring CBO-2[1]

CBO-2

Hole No. CB-D/A-0-2

DRILLING LOG	DIVISION South Atlantic	INSTALLATION Jacksonville District	SHEET 1 of 1 SHEETS
1. PROJECT MAYPORT BASIN		10. SIZE AND TYPE OF BIT See Remarks	
2. LOCATION STA: 9+70 RGE: 130		11. DATUM FOR ELEVATION SHOWN MLW	
3. DRILLING AGENCY Corps of Engineers		12. MANUFACTURER'S DESIGNATION OF DRILL Acker	
4. HOLE NO. CB-D/A-0-2		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	
5. NAME OF DRILLER P. GORDON		14. TOTAL NUMBER CORE BOXES 1	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED		15. ELEVATION GROUND WATER NOT OBSERVED	
		16. DATE HOLE STARTED 3-29-79 COMPLETED 3-29-79	
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE +14.4	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING 55%	
9. TOTAL DEPTH OF HOLE 20.0'		19. GEOLOGIST: D. ROSEN	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
+14.4	0.0					BIT OR BARREL +14.4
+9.6	4.8		SILT, stiff, dark gray (MH) brown and dried at surface sand layers at 2.0 and 2.8 feet depth	54	1	2" SAMPLER +9.4
+7.4	7.0		SAND, fine to medium, quartz, silty, shelly, gray (SM) grades into silt below	28	2	
+0.4	14.0		SILT, stiff, dark gray (MH) less stiff 10.5 to 14.0 feet depth light gray layer 11.5 to 12.0 ft. depth		3	+4.4
				70	4	-0.6
-1.6	16.0		PEAT, dark brown, very silty (PT)			
-5.6	20.0		SAND, fine to medium, quartz, very silty (SM) grades from dark brown to light brown from 16.0 to 20.0 ft. depth	68	5	-5.6

[1]Source: NS Mayport

Geraghty & Miller, Inc.

Table A-16. Lithologic Log of Boring CBO-3[1]

CBO-3

Hole No. CB-D/A-0-3

DRILLING LOG	Division: South Atlantic
Installation	Jacksonville District
Sheet	1 of 1 sheets
1. Project	MAYPORT BASIN
2. Location	STA: 6+30 PGE: 2540
3. Drilling agency	Corps of Engineers
4. Hole No.	CB-D/A-0-3
5. Name of driller	D. GORDON
6. Direction of hole	Vertical
7. Thickness of overburden	
8. Depth drilled into rock	
9. Total depth of hole	20.0'
10. Size and type of bit	See Remarks
11. Datum for elevation shown	MLW
12. Manufacturer's designation of drill	Acker
13. Total no. of overburden samples taken	
14. Total number core boxes	1
15. Elevation ground water	NOT OBSERVED
16. Date hole	Started 3-29-79. Completed 3-29-79
17. Elevation top of hole	+11.5
18. Total core recovery for boring	%
19.	GEOLOGIST: D. ROSEN

Elevation	Depth	Legend	Classification of materials	% Core recovery	Sample No.	Remarks
+11.5	0.0					BIT OR BARREL +11.5
+10.5	1.0		SILT, dried, brittle, dark brown (MH)		1	2" SAMPLER
+7.7	3.8		SAND, fine to medium, quartz, silty, shelly, tan (SM)	30	2, 3	+6.5
+3.3	8.2		SILT, stiff, black, sandy (MH) dried and brittle 3.8 to 5.0 feet depth	66	4	
+1.5	10.0		SAND, fine to medium, quartz, silty, gray (SM)			+1.5
-1.5	13.[illegible]		SILT, stiff, dark brown to gray, sandy (MH) very sandy 10.7 to 11.2 feet depth	72	5	
-2.5	14.[illegible]		PEAT, very silty, dark brown-grades into silt, dark brown with organic matter at 14.0 ft. depth (PT)		6	-3.5
-6.7	18.2		SILT, stiff, dark brown, some organic matter (MH)	84	7	
-8.5	20.0		SAND, fine to medium, quartz, very silty, brown (SM)			-8.5

[1]Source: NS Mayport

Table A-17. Lithologic Logs of Borings BM-1 and BM-4 at Magazine Structures[1]

Boring: BM-1
Surface Elevation: 12.4 Feet MSL

Depth (ft.)	Description
0--2.2	Very loose to loose tan sand with some shell (SP)
2.2--7.0	Very loose to medium dense grey sand with some shell (SP)
7.0--9.5	Very soft grey silty clay (ML-CL)
9.5-11.0	Peat (OL)
11.0-14.5	Very soft to soft grey sandy silty clay (SP-CL)
14.5-31.0	Very loose to medium dense green silty fine sand (SM)
31.0-36.5	Loose grey silty fine sand (SM)
36.5-42.0	Dense grey fine sand with some shell (SP)
42.0-45.0	Medium dense grey silty fine sand (SM)
45.0	Boring terminated

Boring: BM-4
Surface Elevation: 12.3 Feet MSL

Depth (ft.)	Description
0--3.0	Very loose to medium dense grey fine sand with some shell (SP)
3.0--4.5	Dense grey silty fine sand (SM)
4.5--7.3	Very loose to medium dense grey sand with some shell (SP)
7.3-11.5	Very soft to soft grey clay (CL)
11.5-12.0	Peat (OL)
12.0-13.0	Very soft grey silty clay (ML-CL)
13.0-16.5	Soft to stiff grey silty clay with layers of sandy shell (SP-CL)
16.5-30.0	Very loose to medium dense grey silty fine sand (SM)
30.0	Boring terminated

[1]Source: Pittsburgh Testing Laboratory

Table A-18. Lithologic Log of Well N-2[1]

Well Designation: N-2
Surface Elevation: 10 Feet MSL

Depth (ft. below surface)	Description
0- 20	Sand and shell
20- 40	Sand and shell
40- 65	Sand and shell
65- 85	Sand and shell
85-110	Grey marl
110-130	Grey marl with white rock
130-150	Grey marl with white rock strata
150-175	Sandy marl with rock strata
175-198	Sandy marl
198-218	Green marl
218-238	Stiff green marl
238-258	Stiff green marl
258-278	Stiff green marl
278-285	Stiff green marl
285-290	Mud rock
290-298	Sandy marl
298-318	Sandy marl
318-338	Sandy marl
338-358	Sandy marl
358-378	Green marl
378-398	Stiff green marl
398-401	Rock
401-412	Green marl
412-435	Ocala lime
435-455	Soft lime rock
455-475	Soft lime rock
475-495	Soft lime rock
495-505	Hard lime
505-535	Soft lime
535-555	Water bearing soft rock
555-575	Soft water bearing rock
575-595	Very soft water bearing rock
595-615	Soft lime rock
615-635	Soft lime rock
635-655	Soft lime rock
655-675	Soft lime rock
675-695	Hard and soft lime
695-715	Hard limestone brown
715-730	Hard brown lime
730-755	Soft lime
755-775	Soft brown lime
775-795	Soft brown lime
795-815	Very hard lime rock brown

Table A-18. (Continued)

Depth (ft. below surface	Description
815-835	Hard brown lime
835-855	Hard brown lime
855-875	Extra hard brown lime
875-895	Hard brown lime
895-915	Brown lime hard
915-935	Brown lime softer
935-955	Soft white lime
955-975	Porous brown limestone, water bearing
975-995	Soft porous white rock, water bearing
1001	Soft white rock

[1]Source: Duval Drilling Co., 1958

Table A-19. Lithologic Log of Well N-3[1]

Well Designation: N-3
Surface Elevation: 10 Feet MSL

Depth (ft. below surface)	Description
0- 15	Sand and shell (fill)
15- 25	Sand and shell (fill)
25- 35	Sand, clay and shell
35- 40	Clay
40- 60	Shell and sand
60- 80	Sandy clay
80-103	Sandy clay
103-104	Soft rock
104-142	Gray marl
142-144	Rock
144-231	Gray marl
231-252	Stiff gray clay
252-273	Stiff gray clay
273-294	Stiff gray clay
294-297	Rock
297-315	Sandy clay
315-336	Sandy clay
336-342	Sand
342-357	Clay
357-366	Clay
366-367	Rock
367-375	Rock and clay
375-378	Hard rock
378-380	Soft rock
380-399	Clay
399-421	Dark rock - seal on top of lime
421-436	Lime rock
436-441	Lime rock
441-462	Lime rock
462-483	Lime rock
483-504	Medium hard fractured lime rock
504-525	Lime rock
525-546	Soft lime rock
546-567	Soft lime rock
567-588	" " "
588-609	" " "
609-630	" " "
630-651	" " "
651-672	" " "
672-693	" " "
693-714	Hard and soft strata of lime rock

Table A-19. (Continued)

Depth (ft. below surface)	Description
714-735	Hard brown lime rock
735-756	Soft brown limestone
756-777	" " "
777-798	" " "
798-819	" " "
819-840	Medium hard brown limestone
840-861	Dense and hard lime rock
861-882	" " " " "
882-903	" " " " "
903-924	" " " " "
924-945	Medium hard and soft strata of limestone
945-966	Soft limestone
966-987	Hard and soft strata of limestone
987-1000	Hard and soft strata of limestone

[1]Source: W. Earl Floyd & Son, Well Drilling, 1979

Table A-20. Lithologic Log of Well N-4[1]

Well Designation: N-4
Surface Elevation: 10 Feet MSL

Depth (ft. below surface)	Description
0- 20	Sand and shell
20- 40	Sand and shell
40- 60	Shell mixed in clay
60- 80	Clay and rock strata
80-107	Sandy clay
107-128	Sandy clay and soft rock
128-149	Sandy and rock strata
149-160	Grey clay
160-186	Grey clay
186-212	Stiff grey clay
212-233	Stiff grey clay
233-254	Stiff grey clay
254-275	Stiff grey clay
275-296	Stiff grey clay with rock
296-317	Stiff grey clay
317-327	Sandy clay
327-338	Soft rock
338-350	Stiff clay
350-352	Hard rock
352-359	Clay
359-380	Stiff dense clay
380-390	Stiff dense clay
390-408	Stiff clay with rock strata
408-422	Lime rock
422-443	Lime rock
443-464	Lime rock
464-485	Lime rock
485-506	Medium hard lime rock
506-527	Soft lime rock
527-548	Soft lime rock
548-569	Soft lime rock
569-590	Soft lime rock
590-611	Soft lime rock
611-632	Soft lime rock
632-653	Soft lime rock
653-674	Soft lime rock
674-695	Medium hard lime rock
695-716	Medium hard lime rock
716-737	Brown limestone

Table A-20. (Continued)

Depth (ft. below surface)	Description
737-758	Soft limestone
758-779	Hard strata brown limestone
779-800	Hard strata brown limestone
800-821	Hard strata brown limestone
821-842	Hard strata brown limestone
842-863	Very hard dense brown limestone
863-884	Brown limestone
884-905	Hard and soft strata brown limestone
905-926	Hard and soft strata brown limestone
926-947	Hard and soft strata brown limestone
947-968	Hard and soft strata brown limestone
968-989	Soft limestone
989-1000	Medium hard lime rock

[1]Source: W. Earl Floyd & Son, Well Drilling, 1979

Table A-21. Lithologic Logs of Borings TB-1 and TB-2[1]

TB-1

Hole No. CB-MTB-1

DRILLING LOG — South Atlantic — Jacksonville District — Sheet 1 of 1 sheets

- MAYPORT TURNING BASIN
- STA: 18+00 RGE: 600
- Corps of Engineers
- CB-MTB-1
- R. GORDON
- See Remarks
- MLW
- Acker
- 1
- Tidal
- 3-16-79 / 3-16-79
- -47.8'
- 90 %
- 5.0'
- GEOLOGIST: D. ROSEN

Elevation	Depth	Legend	Classification of materials	% Core recovery	Sample no.	Remarks
-47.8	0.0					BIT OR BARREL -47.8
			CLAY, black, very soft, slightly sandy, (CH) oily	90	1	2" SAMPLER
-50.8	3.0					
			SAND, Clayey, fine to medium, quartz, brown, slightly shelly (SC) (OL) layer at -51.3		2	
-52.8	5.0					-52.8
			CONFORMS TO SAO LABORATORY CLASSIFICATION 5/17/79			

TB-2

Hole No. CB-MTB-2

DRILLING LOG — South Atlantic — Jacksonville District — Sheet 1 of 1 sheets

- MAYPORT TURNING BASIN
- STA: 19+00 RGE: 1500
- Corps of Engineers
- CB-MTB-2
- R. GORDON
- See Remarks
- MLW
- Acker
- 1
- Tidal
- 3-16-79 / 3-16-79
- -4.6'
- 100
- 4.8'
- GEOLOGIST: D. ROSEN

Elevation	Depth	Legend	Classification of materials	% Core recovery	Sample no.	Remarks
-46.0	0.0					BIT OR BARREL -46.0
-47.0	1.0		CLAY, black, very soft, oily (CH)		1	2" SAMPLER
			Slightly sandy, slightly shelly -47.0 to -49.8 sandy layer -48.0 to -48.5	100	2	
-49.8	3.8					
			SAND, clayey, silty, slightly shelly, brown (SC)		3	
-50.8	4.8					-50.8
			CONFORMST TO SAO LABORATORY CLASSIFICATION 5-17-79			

[1]Source: NS Mayport

Table A-22. Lithologic Logs of Borings TB-3 and TB-4[1]

TB-3

Hole No. CB-MTB-3

DRILLING LOG	Division: South Atlantic
Installation	Jacksonville District
Sheet	1 of 1 sheets
1. Project	MAYPORT TURNING BASIN
2. Location	STA: 8+00 RGE: 450
3. Drilling agency	Corps of Engineers
4. Hole No.	CB-MTB-3
5. Name of driller	R. GORDON
6. Direction of hole	[X] Vertical [ ] Inclined
7. Thickness of overburden	
8. Depth drilled into rock	
9. Total depth of hole	6.0'
10. Size and type of bit	See Remarks
11. Datum for elevation shown	MLW
12. Manufacturer's designation of drill	Acker
13. Total no. of overburden samples taken	
14. Total number core boxes	1
15. Elevation ground water	Tidal
16. Date hole	Started 3-16-79; Completed 3-16-79
17. Elevation top of hole	-45.2'
18. Total core recovery for boring	90 %
19. Geologist	D. ROSEN

Elevation	Depth	Legend	Classification of materials	% Core recovery	Sample no.	Remarks
-45.2	0.0					BIT OR BARREL -45.2
-47.7	2.5		CLAY, slightly sandy, black, oily (CH)		1	2" SAMPLER
-51.2	6.0		SAND, fine to medium, quartz, silty, clayey (SC) soft to -49.7 (OL) layer at -48.7	90	2, 3	-51.2
			CONFORMS TO SAD LABORATORY CLASSIFICATION 5-17-79			

TB-4

Hole No. CB-MTB-4

DRILLING LOG	Division: South Atlantic
Installation	Jacksonville District
Sheet	1 of 1 sheets
1. Project	Mayport Turning Basin
2. Location	STA 8+00 RGE 1900
3. Drilling agency	Corps of Engineers
4. Hole No.	CB-MTB-4
5. Name of driller	R. Gordon
6. Direction of hole	[ ] Vertical [ ] Inclined
7. Thickness of overburden	
8. Depth drilled into rock	
9. Total depth of hole	10.0'
10. Size and type of bit	See remarks
11. Datum for elevation shown	MLW
12. Manufacturer's designation of drill	Acker
13. Total no. of overburden samples taken	
14. Total number core boxes	1
15. Elevation ground water	Tidal
16. Date hole	Started 16 Mar 79; Completed 16 Mar 79
17. Elevation top of hole	-39.0
18. Total core recovery for boring	60
19. Geologist	D. ROSEN

Elevation	Depth	Legend	Classification of materials	% Core recovery	Sample no.	Remarks
-39.0	0.0					BIT OR BARREL -39.0
-46.5	7.5		SILT, sandy, clayey, soupy, oily (OL) Layer of clayey sand (SC) from -47.5 to -48.0	60	1	2" SAMPLER
-47.5	8.5		Black, slightly plastic, oily -46.5 to -48.5		2	
-48.5	9.5		Shell, sandy, silty (SM)		3	
-49.0	10.0				4	-49.0
			CONFORMS TO SAD LABORATORY CLASSIFICATION 5-17-79			

[1]Source: NS Mayport

Geraghty & Miller, Inc.

Table A-23. Lithologic Logs of Borings DS-5 and DS-6[1]

DS-5

Hole No. CB-MDS-5

DRILLING LOG	South Atlantic
Installation	Jacksonville District
Sheet	1 of 1 sheets
Project	Maypport Basin
Location	STA 3+50 RGE 250 Destroyer Slip
Drilling agency	Corps of Engineers
Hole No.	CB-MDS-5
Name of driller	R. Gordon
Direction of hole	[X] Vertical
Thickness of overburden	
Depth drilled into rock	
Total depth of hole	17.0'
Size and type of bit	See remarks
Datum for elevation shown	MLW
Manufacturer's designation of drill	Acker
Total no. of overburden samples taken	
Total number core boxes	
Elevation ground water	Tidal
Date hole	Started 14 Mar 79; Completed 19 Mar 79
Elevation top of hole	-30.0
Total core recovery for boring	35
Remarks	GEOLOGIST: D. Rosen

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
-30.0	0.0					BIT OR BARREL -30.0
			SILT, black, very soft (OL)	4		2" SAMPLER
-37.0	7.0		SILT, firm, gray-sandy (MH)		1	-38.0
-38.0	8.0		SAND, fine to medium, quartz, silty, very shelly, gray (SP-SM)		2	
-41.0	11.0		SAND, fine to medium, quartz and broken shell, clayey, calcareous, buff (SC)	66	3	
			CONFORMS TO SAD LABORATORY CLASSIFICATION 5/17/79			
-47.0	17.0					-47.0

DS-6

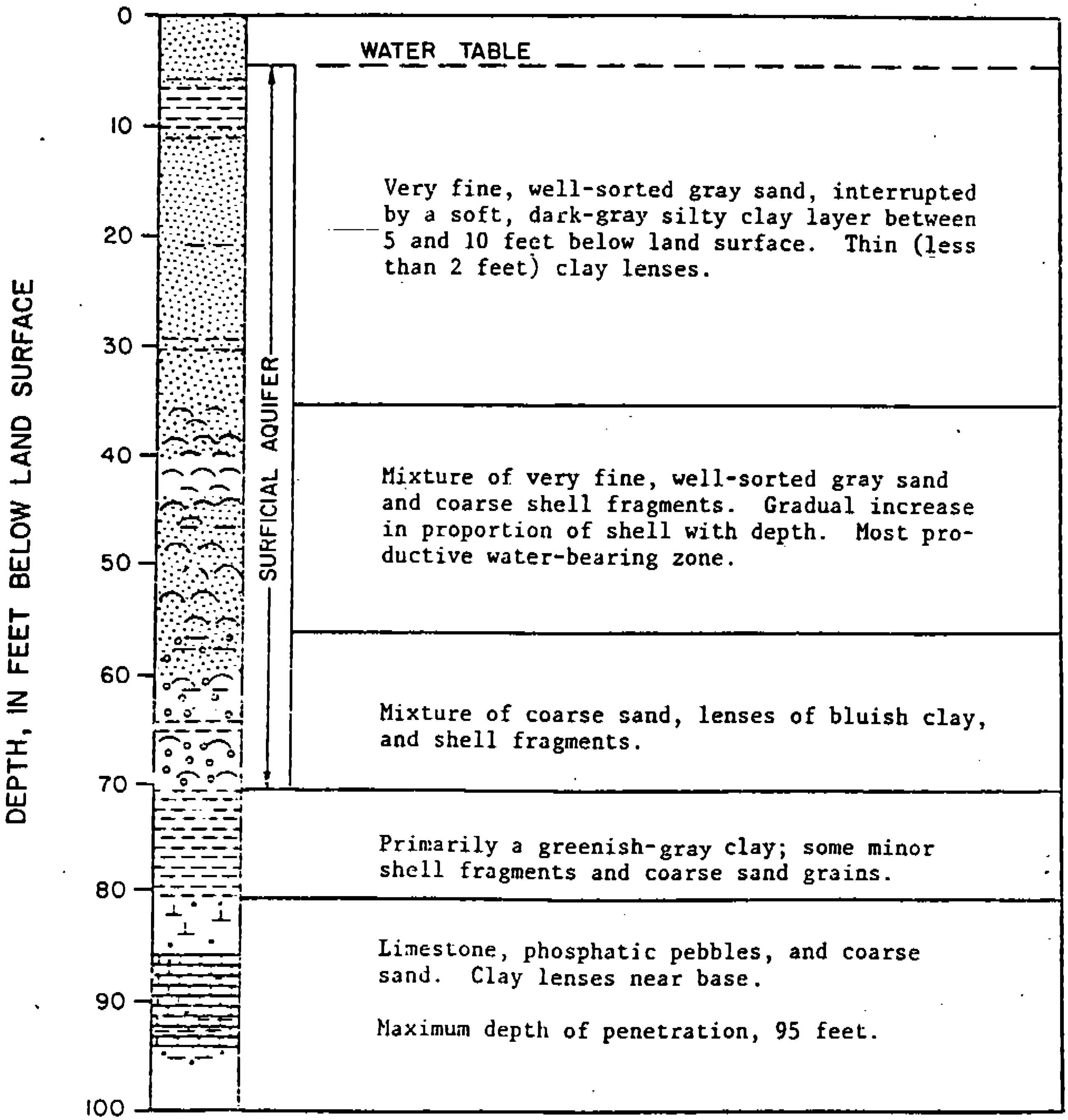
Hole No. CB-MDS-6

DRILLING LOG	South Atlantic
Installation	Jacksonville District
Sheet	1 of 1 sheets
Project	MAYPORT BASIN DESTROYER SLIP
Location	STA: 13+50 RGE: 250
Drilling agency	Corps of Engineers
Hole No.	CB-MDS-6
Name of driller	R. GORDON
Direction of hole	[X] Vertical
Thickness of overburden	
Depth drilled into rock	
Total depth of hole	17.5'
Size and type of bit	See Remarks
Datum for elevation shown	MLW
Manufacturer's designation of drill	Acker
Total no. of overburden samples taken	
Total number core boxes	1
Elevation ground water	Tidal
Date hole	Started 3-19-79; Completed 3-19-79
Elevation top of hole	-29.5
Total core recovery for boring	
Remarks	GEOLOGIST: D. ROSEN

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	SAMPLE NO.	REMARKS
-29.5	0.0					BIT OR BARREL -29.5
			SILT, black, very soft, sandy (OL)			2" Sampler
-30.5	1.0		SAND, fine to medium, quartz, silty, slightly shelly, saturated and loose, gray (SM)	52	1	
-38.5	9.0		hard packed -38.5 to -41.5		2	-41.0
-41.5	12.0		SAND, fine to coarse - quartz and limestone sand, buff to yellow, silty (SP-SM)	65	3	
			CONFORMS TO SAD LABORATORY CLASSIFICATION 5-17-79			
-47.0	17.5					-47.0

[1]Source: NS Mayport

Table A-24. Composite Lithologic Log of Wells and Test Borings Drilled at GS-1[1]



[1]Source: Franks, 1980

Table A-25. Lithologic Log of Well D-236[1]

Well Designation: D-236
Surface Elevation: 9 Feet MSL

Depth (ft. below surface)	Description
0- 15	Sand
15- 40	Sandy grey marl and shell
40- 50	Shell
50- 70	Green sandy marl
70-140	Grey marl
140-200	Sandy grey marl
200-275	Stiff grey marl
275-335	Green sandy marl
335-351	Stiff green marl
351-353	Dark green shale
353-361	Green marl
361-365	Limestone
365-385	Green marl
385-390	Limestone
390-402	Green marl
402-406	Hard dark green limestone
406-416	Green marl
416-700	White Ocala limestone
700-814	Brown limestone

[1]Source: Duval Drilling Company, 1962

Table A-26. Lithologic Log of Well CG-1[1]

Well Designation: CG-1
Surface Elevation: 10 Feet MSL

Depth (ft. below surface)	Description
0- 65	Grey sand
65- 70	Grey marl
70- 90	Sandy grey marl and shell
90-105	Sandy green marl
105-140	Grey marl
140-170	Grey sandy marl
170-190	Sand with light grey marl
190-240	Sandy grey marl
240-310	Green marl
310-320	Green sandy marl
320-327	Sand
327-360	Green sand
360-390	Green marl
390-393	Limestone
393-437	Green marl
437-465	Sand and limestone
465-700	White limestone

[1]Source: Duval Drilling Company, 1953

APPENDIX B

PROPOSED
GROUND-WATER SAMPLING AND
ANALYSIS PLAN FOR
U.S. NAVAL STATION, MAYPORT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Chapter 17-4.6(d) of the Florida Administrative Code requires owners and operators of facilities that discharge into the ground water to obtain and analyze samples from a ground-water monitoring system. The requirement includes the development and implementation of a ground-water sampling and analysis plan which must include procedures and techniques for sample collection.

To comply with these requirements at the U.S. Naval Station, Mayport, Florida, the following "Sampling and Analysis Plan" has been prepared.

2.0 SAMPLE COLLECTION AND SHIPMENT

2.1 Frequency of Sample Collection

Table 2.1 presents water quality parameters which should be monitored at NS Mayport on a quarterly basis during the first year of monitoring and semi-annually in succeeding years. Maps showing locations of the proposed monitor wells and a surface-water sampling station are presented in Figures B-1 and B-2.

2.2 Equipment

Sampling equipment needed for collecting representative samples of ground water are presented below.

(1) 100-ft fiberglass or plastic measuring tape with weighted bottom (or) water-level indicator ("m-scope") consisting of an ammeter, electrode, and 100-ft cable;
(2) Several gallons of distilled water and wash bottle;
(3) Clean rags;
(4) Plastic sheeting or large size garbage bags;
(5) Bottom filling PVC bailer and 120-ft nautical rope, peristaltic pump, or submersible pump;
(6) Graduated bucket;
(7) Sample bottles;
(8) Sample bottle labels, waterproof marking pen;
(9) pH meter;
(10) Thermometer;
(11) Specific conductivity meter;

Table 2.1: Water Quality Parameters

Parameter	Monitor Wells S-2 and S-3 (waste oil area)	Monitor Wells S-1 (upgradient) and S-4, S-5, S-6 & S-7 (landfill area)	Surface-water Sampling Station (Sherman Creek)
Temperature (field)	x	x	x
pH	x	x	x
Specific Conductance (field)	x	x	x
Total Dissolved Solids	x	x	x
Chloride		x	x
Sulfate		x	x
Nitrate		x	x
Arsenic		x	x
Barium		x	x
Cadmium		x	x
Chromium		x	x
Fluoride		x	x
Lead		x	x
Mercury		x	x
Selenium		x	x
Silver		x	x
Volatile Organic Carbon Scan	x	x	
Turbidity			x

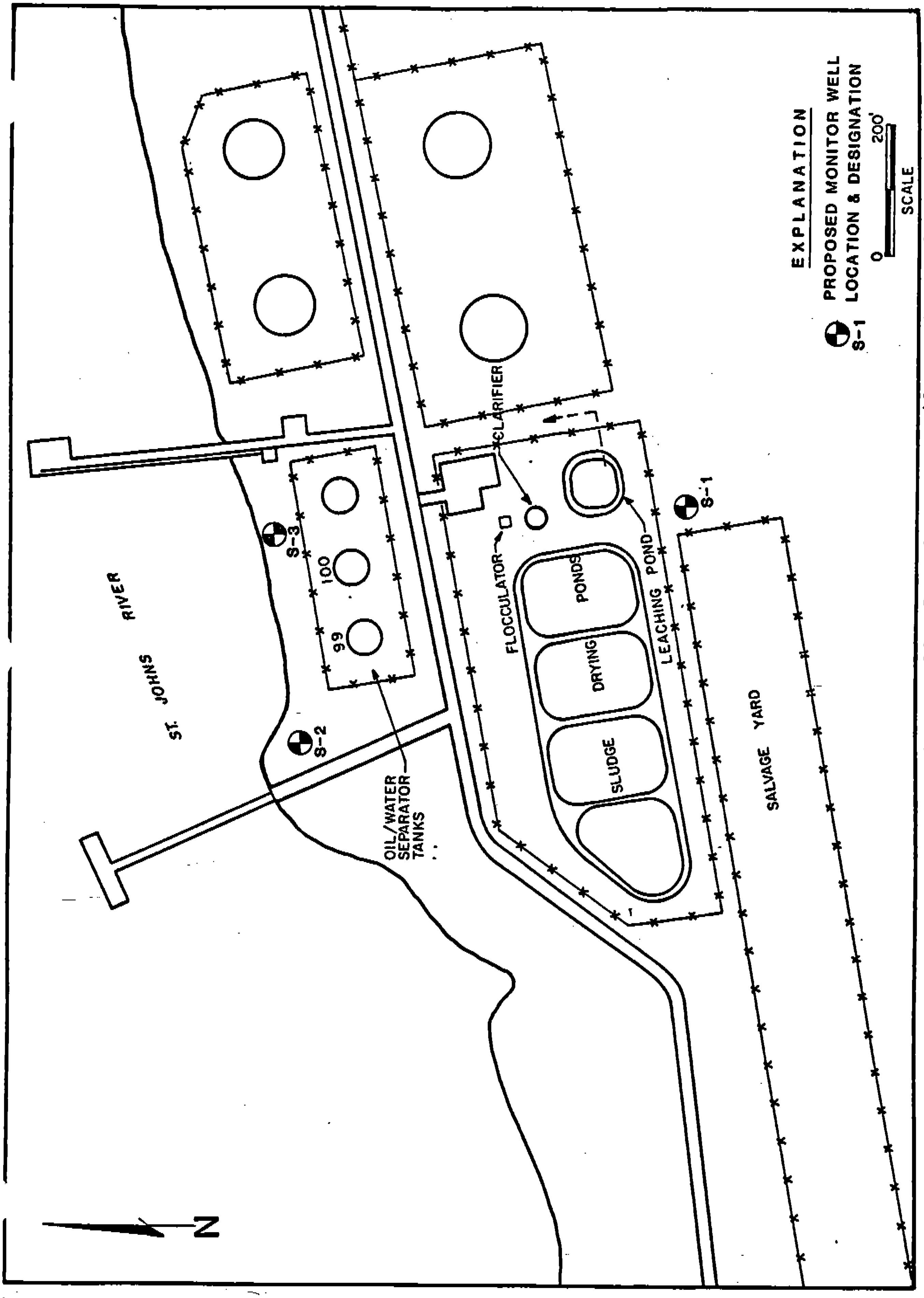


Figure B-1. Proposed Locations of Monitor Wells for the Waste Oil Treatment Area.

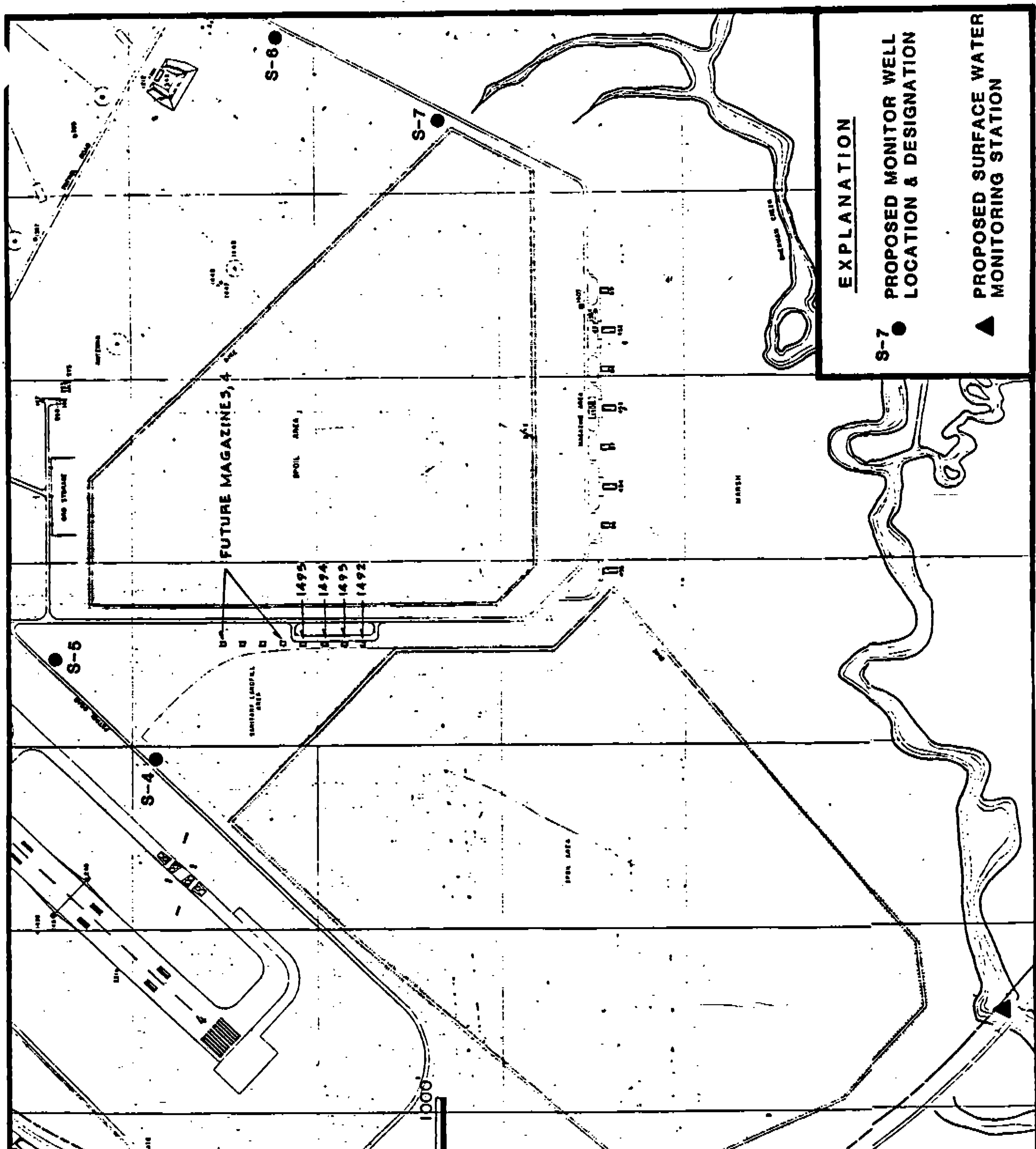


Figure B-2. Proposed Surface and Ground-Water Monitoring Network for the Sanitary Landfill Area.

(12) Preservatives for water samples;
(13) Field data forms, clipboard, pen; and
(14) Optional: ice chest and ice or freezer packs.

2.3 Sample Collection Method

2.3.1 Procedures for Measuring Water Levels

(a) Place plastic sheeting around well to protect sampling equipment from potential contamination.

(b) After unscrewing outer casing cap, measure the depth to water in the well. <u>All measurements are made from top of PVC casing</u>.

- Using the M-scope, drop the probe down the center of the casing and allow cord to go untangled down the well. When ammeter indicates a closed electrical circuit, determine depth to water from top of PVC casing. Record depth to water on field data form (Figure B-3). Subtract this value from elevation at top of PVC casing to find elevation of water level (see Figure B-4 for elevation of top of casing),

(or)

- Using a fiberglass or plastic 100-ft tape with sandpaper backing on first five feet, drop weighted tape down center of casing. After water is encountered in well, record measurement of tape at top of casing, wind up tape and record the measurement where tape is wet. Subtract the "wet" measurement from the "held" measurement to determine the depth to water. Subtract this value from the elevation at top of PVC casing to find elevation of water level.

- The water-level measurements must be obtained at each sampling point every time water samples are collected.

Geraghty & Miller, Inc.

FIGURE B-3: GROUND-WATER SAMPLING DATA FORM

Date: ______________________

Spring/Well Number: ______________ Time: __________ to __________

Sampled by: ______________________ Weather: ______________________

GROUND-WATER ELEVATION

A. (1) Length of Tape Held at Top of Outer Casing: __________ (or) m-scope reading: __________

(2) Length of Tape Wet: __________

(3) Depth to Water (1 minus 2): __________

Water Level Elevation - Subtract Depth to Water from Elevation of Outer Casing: ______________________

Depth to Well Bottom: ______________________

Height of Water Column (h) = ______________________

'R SAMPLING DATA

Volume of water in well:

$\pi r^2 h$ ______________________

____

Amount of water removed from well: ______________________

Method of water removal: ______________________

Was well pumped dry? ______________________

FIELD ANALYSES AND REMARKS

Temperature: ______________________

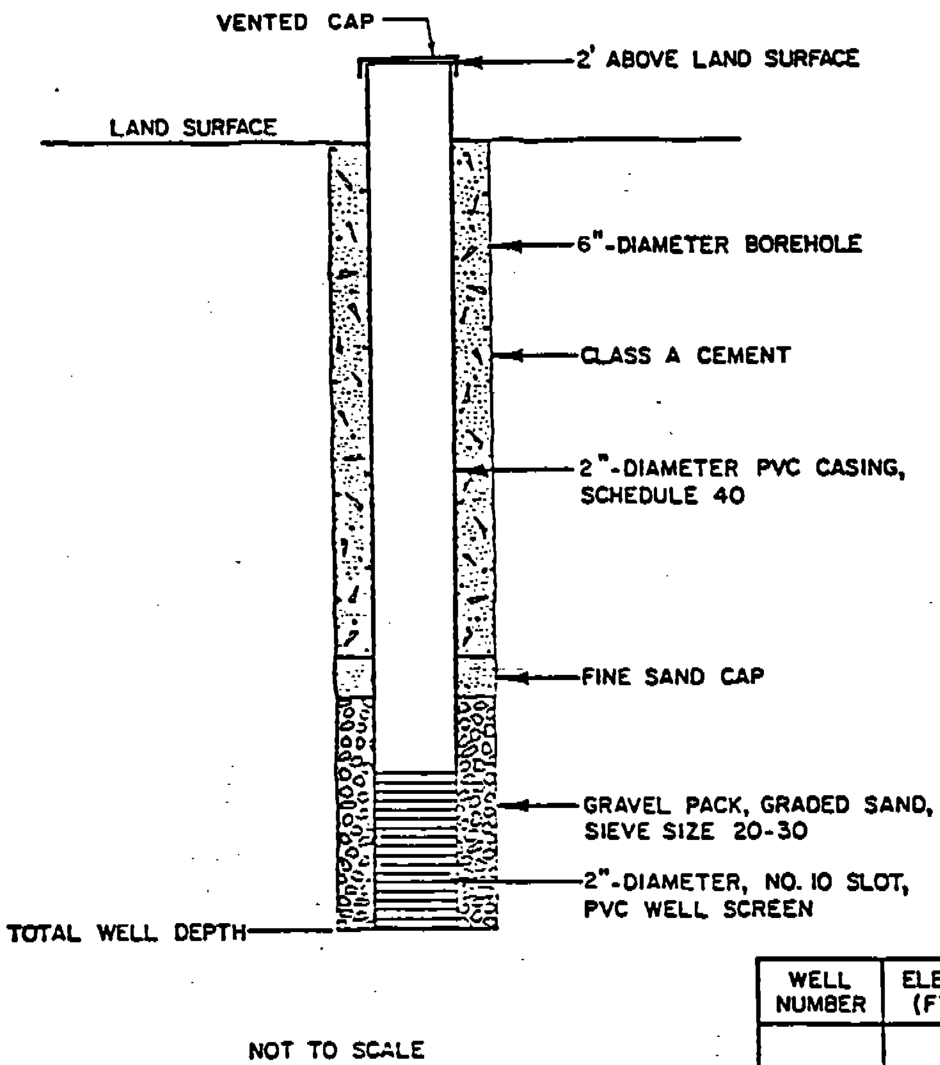
Specific Conductance: ______________________

pH: ______________________

Physical Appearance: ______________________

'er & Type of Samples Collected: ______________________

____



WELL NUMBER	ELEVATION (FT. MSL)	TOTAL DEPTH (FT.)

MEASUREMENT FROM TOP OF CASING

Figure B-4. Schematic Diagram of Surficial Aquifer Monitor Well.

(c) Clean M-scope or tape bottom with distilled water and wipe dry with clean rag.

2.3.2 Procedures for Removing Standing Water in Wells

(a) Remove at least one well volume of standing water using either the peristaltic pump, submersible pump, or a hand bailer.

- To find the volume of standing water in the well, use the following calculation:

$$V = 3.14\ r^2h$$

where V = volume (ft^3)

r = radius of monitor well casing (ft)

h = height of standing water in well (ft)

- The height of standing water in the well is found by subtracting the depth to water measurement from the total depth of the well (refer to Figure B-4 for depth of monitor wells).

- It is generally recommended to remove three to five well volumes of water from the well to insure an accurate sample of ground-water quality but this may not be possible if the wells are low yielding. At the least, the well should be pumped or bailed to dryness before sampling. Use graduated bucket to measure volume of water removed from the well.

- The "Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities," pp 220 to 270, should be consulted for further information concerning the amount of water to evacuate from the well, types of pumps or bailers to use in sampling ground water, and procedures to follow for using pumps or bailers. Another reference source is the U.S. Geological Survey (USGS) publication, "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," pp 3 to 9.

(b) Clean bailer or pump with distilled water before use in other wells to prevent possible cross contamination of ground water in the monitor wells.

2.3.3 Procedures for Sample Collection and Field Analyses

(a) Allow well to recharge sufficiently to obtain samples. In some wells, this may require waiting a few minutes to a few hours; in other wells recovery time may be extremely slow and sampling may not be possible until after 24 hours. If the well is incapable of producing sufficient water required for analyses, composite sampling may be necessary where small quantities of samples are taken several days in a row.

(b) Analyses of pH, temperature, and specific conductance should be made in the field at the time of sampling because these parameters change rapidly and a laboratory analysis might not be representative of the true ground-water quality. Remove enough water from well to determine temperature of water, specific conductivity, and pH. Record values on field data sheet and discard water in a manner so as to avoid potential contamination.

(c) Rinse sample bottle with sampled ground water except when bottle is fixed with a preservative.

(d) Transfer water from well sampling device to sample bottles provided by the laboratory. Care should be taken not to agitate sample in order to limit amount of added oxygen to water sample. Minimize the number of containers used in order to limit the addition of outside contaminants. Sample bottles should be prepared as specified by the 1974 and 1979 EPA "Manual of Methods for Chemical Analysis of Water and Wastes" (EPA 625/6-74-003 and EPA 600/4-79-020).

(e) If there is insufficient water in the well to supply the necessary volumes for samples specified above, the sample collector should fill up as many bottles as possible, preserve and label as required, and continue sampling daily until the remaining bottles are filled.

2.3.4 Surface Water Sampling Procedure

The collection of water samples from the sampling station on Sherman Creek will be done in accordance with EPA, 1980, Standard Operating Procedures and Quality Assurance Manual. At each sampling period, the water level from the staff gage will be recorded and stream discharge will be estimated. Because the water level in Sherman Creek is influenced by tidal fluctuuations, sampling of the creek should be done only during outgoing tidal currents.

3.0 ANALYTICAL PROCEDURES

Analyses of water samples collected from monitor wells will be performed by an approved laboratory.

Bibliography

Johnson, Thomas M., and Keras Cartwright, 1980, Monitoring of Leachate Migration in the Unsaturated Zone in the Vicinity of Sanitary Landfills, Illinois State Geological Survey Circular 514, 82 p.

Moser, J.H., and K.R. Huibregtse, 1976, Handbook for Sampling and Sample Preservation of Water and Wastewater, EPA-600/4-76-049, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio, 257 p.

Scalf, Marion R., James F. McNabb, William J. Dunlap, Roger L. Cosby, and John S. Fryberger, 1981, Manual of Ground-Water Sampling Procedures, NWWA/EPA Series, National Water Well Association, Worthington, Ohio, 93 p.

Taras, Michael J., Arnold E. Greenberg, R.D. Hoak, and M.C. Rand, 1971, Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Washington, D.C., 874 p.

Todd, David K., et al., 1976, Monitoring Groundwater Quality: Monitoring Methodology, EPA 600/4-76-026, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada, 172 p.

U.S. Environmental Protection Agency, 1979, Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio 460 p.

U.S. Environmental Protection Agency, 1980, Federal Register, Volume 45, No. 98, Monday, May 19, 1980, 33154 Part VII, Subpart F, 265.90-265.94, "Ground-Water Monitoring."

U.S. Environmental Protection Agency, 1980, Standard Operating Procedures and Quality Assurance Manual, EPA Region IV, Surveillance and Analysis Division, Athens, Georgia.

Wood, Warren W., 1976, Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents, U.S. Department of the Interior, U.S. Geological Survey, 24 p.