Site Suitability Review of the Bottineau Municipal Landfill

by
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Prepared by the
North Dakota State Water Commission
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ND Landfill Site Investigation No. 24

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Bismarck, North Dakota
1994

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INTRODUCTION

Purpose

The North Dakota State Engineer and the North Dakota State Geologist were instructed by the 52nd State Legislative Assembly to conduct site-suitability reviews of the solid waste landfills in the state of North Dakota. These reviews are to be completed by July 1, 1995 (North Dakota Century Code 23-29-07.7). The purpose of this program is to evaluate site suitability of each landfill for disposal of solid waste based on geologic and hydrologic characteristics. Reports will be provided to the North Dakota State Department of Health and Consolidated Laboratories (NDSDHCL) for use in site improvement, site remediation, or landfill closure. A one time ground-water sampling event was performed at each site thus, additional studies may be necessary to meet the requirements of the NDSDHCL for continued operation of solid waste landfills. The Bottineau municipal solid waste landfill is one of the landfills being evaluated.

Location of the Bottineau Landfill

The Bottineau municipal solid waste landfill is located one mile north of the City of Bottineau in Township 162 North, Range 76 West, SE 1/4 Section 24 (Fig. 1). The landfill site encompasses approximately 30 acres.

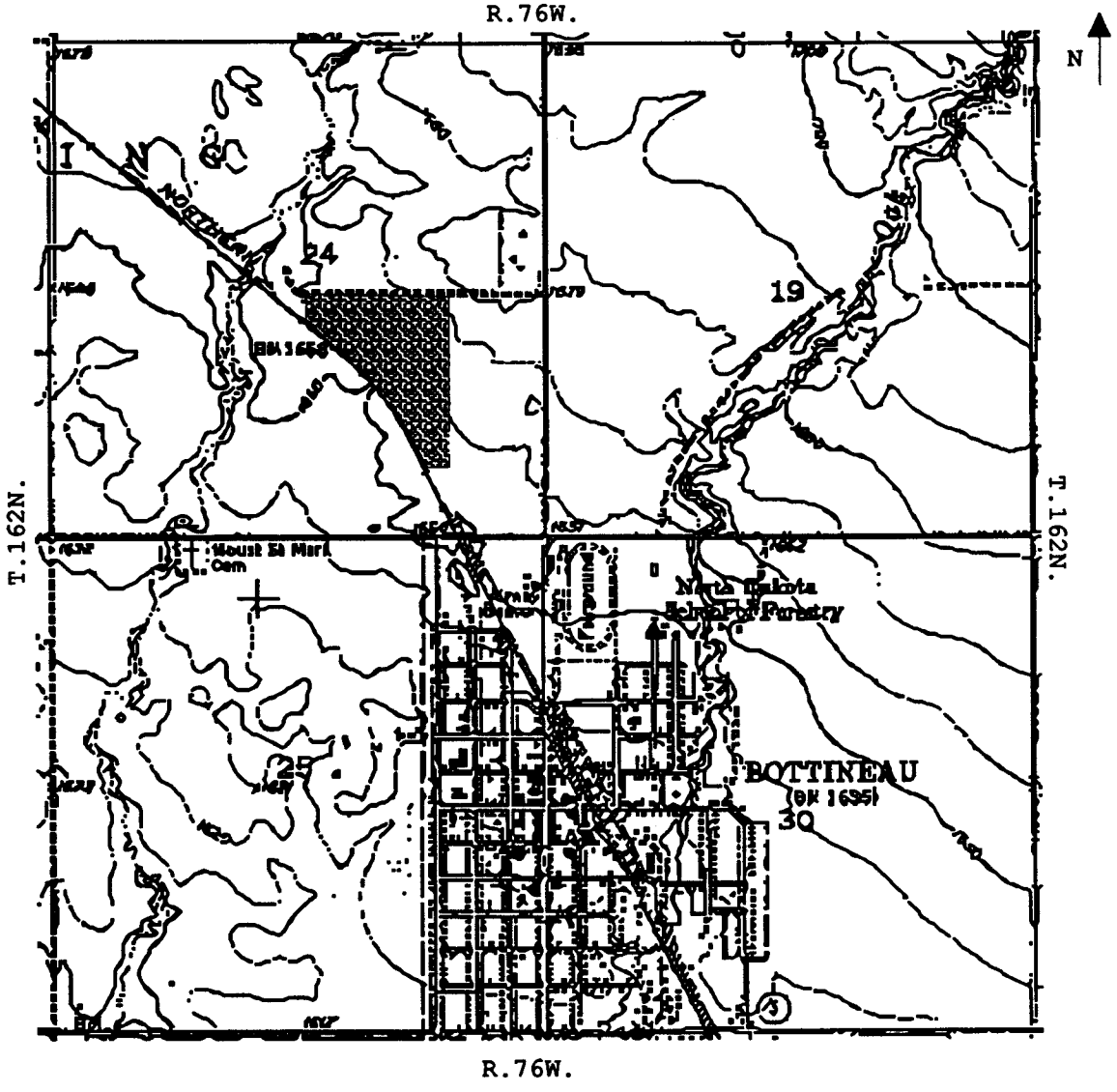

Figure 1. Location of the Bottineau Municipal landfill in the SE 1/4 of section 24, T162N, R76W.

Previous Site Investigations

A subsurface soil investigation was conducted in 1978 by Soil Exploration Company. Five test holes were drilled to a depth of 51 feet at the site (Appendix C). The subsurface was described as a silty clay till or sandy clay till at the surface and underlain by thin layers of alluvial clay. The investigation indicates that the depth to bedrock was 50 to 70 feet and consists of either the Hell Creek or Cannonball Formation. The locations and elevations of these test holes were not available. Water-level measurements were not obtained during this investigation. The report indicated the water level to be at a depth of greater than 20 feet based on the color of the drill cuttings.

Methods of Investigation

The Bottineau study was accomplished by means of: 1) drilling test holes; 2) constructing and developing monitoring wells; 3) collecting and analyzing water samples; and 4) measuring water levels.

Test-Drilling Procedure

The drilling method at the Bottineau landfill was based on the site's geology and depth to ground water, as determined by the preliminary evaluation. A hollow-stem

auger was used at the Bottineau landfill because the sediments were poorly consolidated and because the depth to the water table was expected to be less than 70 feet. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Six test holes were drilled at the Bottineau landfill, and monitoring wells were installed in five of the test holes. Five existing test holes installed by Soil Exploration were also used in this study. The number of wells installed at the Bottineau landfill was based on the geologic and topographic characteristics of the site. The depth and intake interval of each well was selected to monitor the water level at the top of the uppermost aquifer. The wells were located within the active area of the landfill.

Wells were constructed following a standard design (Fig. 2) intended to comply with the construction regulations of the NDSDHCL and the North Dakota Board of Water Well Contractors (North Dakota Department of Health, 1986). The wells were constructed using a 2-inch diameter, SDR21, polyvinyl chloride (PVC) well casing and a PVC screen, either 5 or 10 feet long, with a slot-opening size of 0.012 or 0.013 inches. The screen was fastened to the casing with stainless steel screws (no solvent weld cement was used). After the

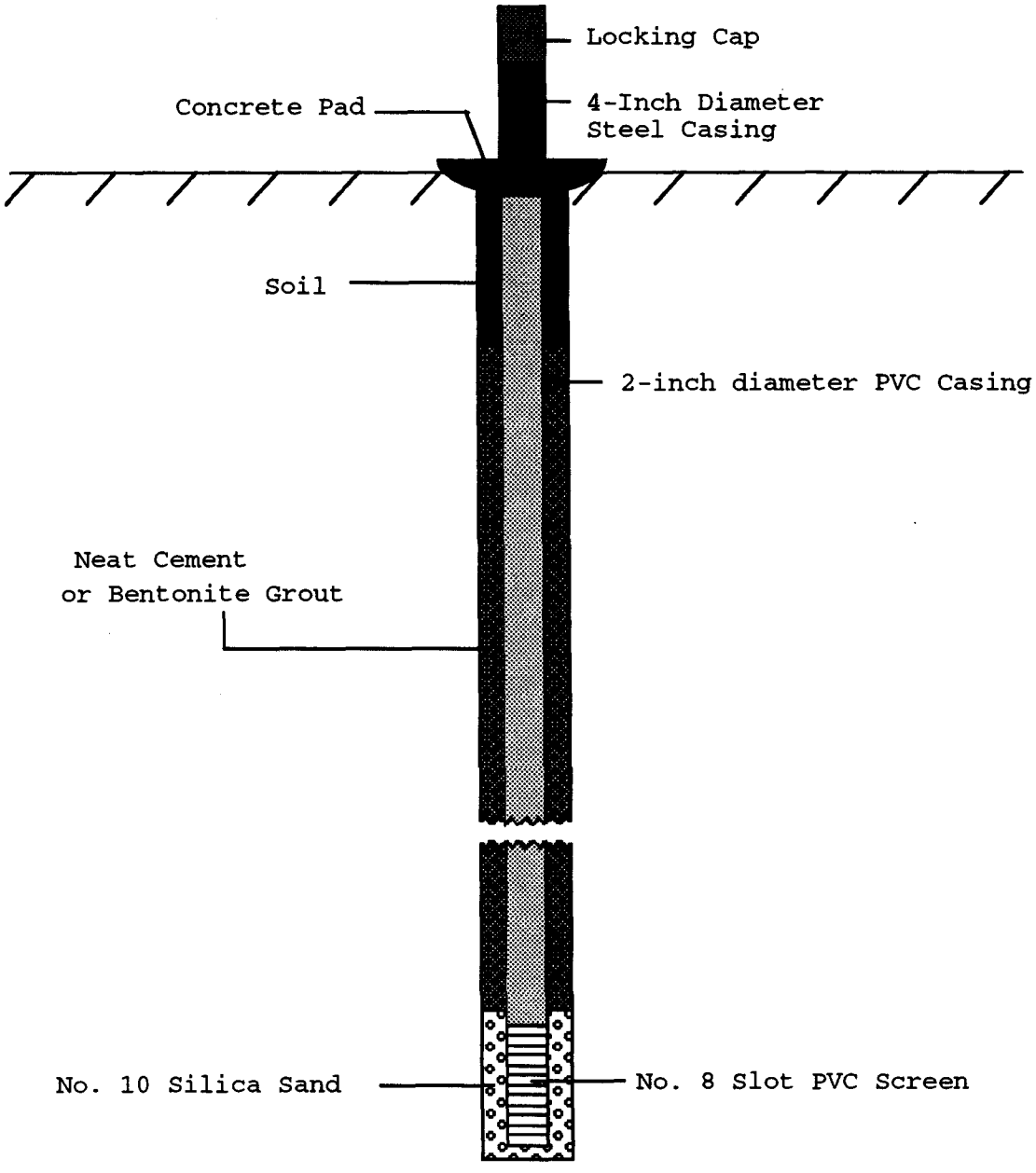

Figure 2. Construction design used for monitoring wells installed at the Bottineau Municipal landfill.

casing and screen were installed into the drill hole, the annulus around the screen was filled with No. 10 (grain-size diameter) silica sand to a height of two feet above the top of the screen. High-solids bentonite grout and/or neat cement was placed above the silica sand to seal the annulus to approximately five feet below land surface. The remaining annulus was filled with drill cuttings. The permanent wells were secured with a protective steel casing and a locking cover protected by a two-foot-square concrete pad.

All monitoring wells were developed using a stainless steel bladder pump or a teflon bailer. Any drilling fluid and fine materials present near the well were removed to insure movement of formation water through the screen.

The Mean Sea Level (MSL) elevation was established for each well by differential leveling to Third Order accuracy. The surveys established the MSL elevation at the top of the casing and the elevation of the land surface next to each well.

Collecting and Analyzing Water Samples

Water-quality analyses were used to determine if leachate is migrating from the landfill into the underlying ground-water system. Selected field parameters, major ions, and trace elements were measured for each water sample. These field parameters and analytes are listed in Appendix A with their Maximum Contaminant Levels (MCL). MCLs are

enforcable drinking water standards that represent the maximum permissible level of a contaminant as stipulated by the U.S. Environmental Protection Agency (EPA).

Water samples were collected using a bladder pump constructed of stainless steel with a teflon bladder. A teflon bailer was used in monitoring wells with limited transmitting capacity. Before sample collection, three to four well volumes were extracted to insure that unadulterated formation water was sampled. Four samples from each well were collected in high density polyethylene plastic bottles as follows:

1) Raw (500 ml)
2) Filtered (500 ml)
3) Filtered and acidified (500 ml)
4) Filtered and double acidified (500 ml)

The following parameters were determined for each sample. Specific conductance, pH, bicarbonate, and carbonate were analyzed using the raw sample. Sulfate, chloride, nitrate*, and dissolved solids were analyzed using the filtered sample. Calcium, magnesium, sodium, potassium, iron, and manganese were analyzed from the filtered, acidified sample. Cadmium, lead, arsenic, and mercury were analyzed using the filtered double-acidified samples.

One well was sampled for Volatile Organic Compounds (VOC) analysis. This sample was collected at a different time than the standard water-quality sample. The procedure

* No special preservative techniques were applied to nitrate samples and as a result reported nitrate concentrations may be lower than actual.

used for collecting the VOC sample is described in Appendix B. Each sample was collected with a plastic throw-away bailer and kept chilled. These samples were analyzed within the permitted 14-day holding period. The standard water-quality analyses were performed at the North Dakota State Water Commission (NDSWC) Laboratory and VOC analyses were performed by the NDSDHCL.

Water-Level Measurements

Water-level measurements were taken at least three times at a minimum of two-week intervals. The measurements were taken using a chalked-steel tape or an electronic (Solnist 10078) water-level indicator. These measurements were used to determine the shape and configuration of the water table.

Location-Numbering System

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township north and Range west of the 5th Principle Meridian and baseline (Fig. 3). The third number indicates the section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section (160-acre tract), quarter-quarter section (40-acre tract), and quarter-quarter-quarter section

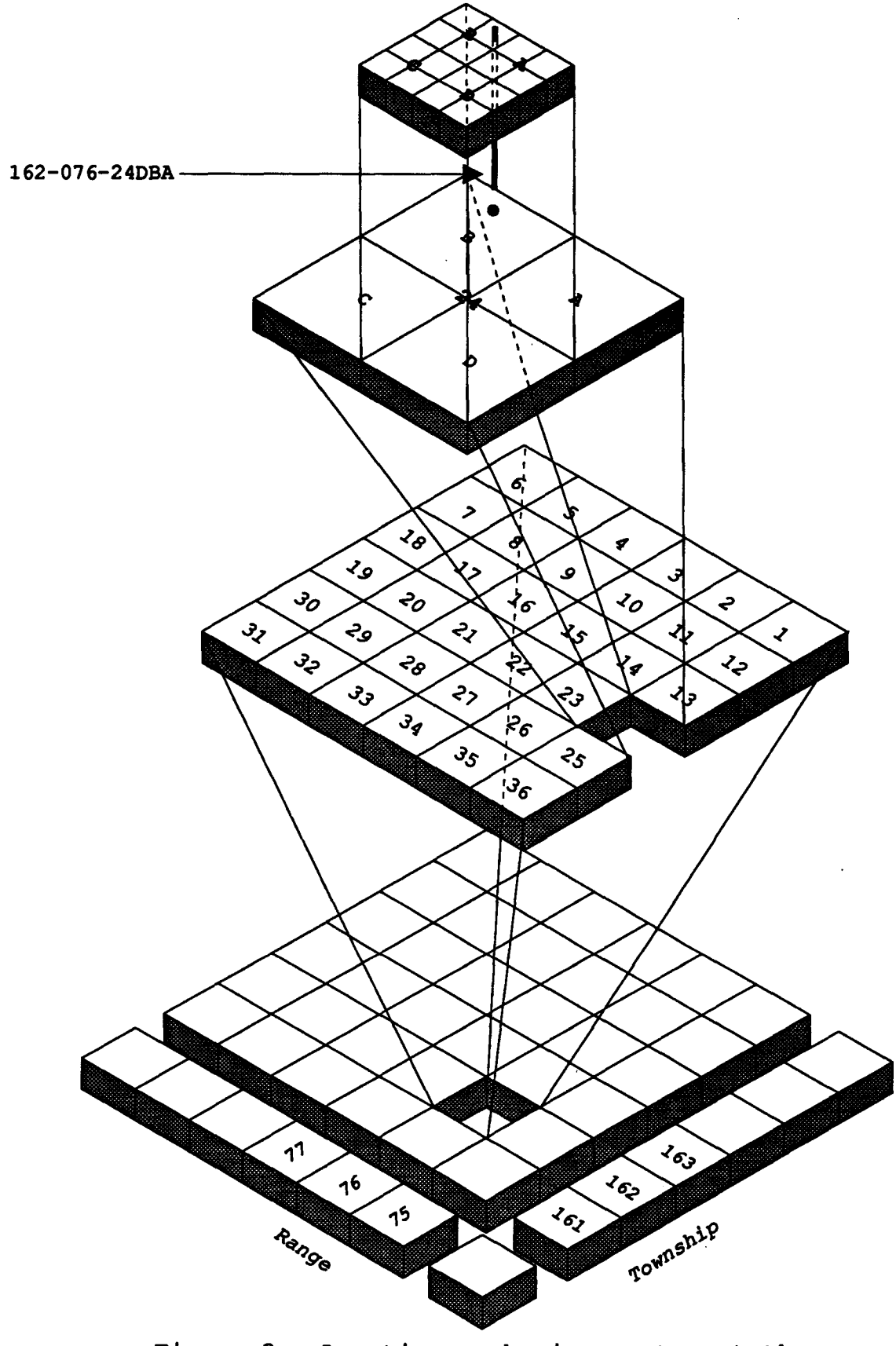

Figure 3. Location-numbering system at the Bottineau Municipal landfill.

(10-acre tract). Therefore, a well denoted by 162-076-24DBA would be located in the NE1/4, NW1/4, SE1/4, Section 24, Township 162 North, Range 76 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 162-076-24DBA1 and 162-076-24DBA2.

GEOLOGY

The Bottineau landfill is located in an area of gentle relief, with a gradual slope to the southwest. The Turtle Mountains are located about three miles northeast of the landfill. Surface elevations at the landfill range from 1,655 feet in the southwest corner of the landfill to 1,680 feet in the northeast corner (Fig. 4).

The sediments at the landfill consist of sandy clay till with a few thin (2 to 5 feet thick) layers of interbedded glaciofluvial sand. Test holes 162-076-24ADC1, 24ADC2, and 24ACD encountered a layer of silt and sand at the surface, while the other three test holes encountered till at the surface. Test hole 162-076-24ADC1 penetrated two more thin layers of fine-grained sand at depths of 31 feet and 42 feet (Fig. 5). Layers of sand were also encountered at depths of about 30 feet in test holes 162-076-24DAB and 24DBA1 (lithologic logs in Appendix C).

Soil Exploration Company drilled five test borings at the landfill in 1978. Four of their borings penetrated sand

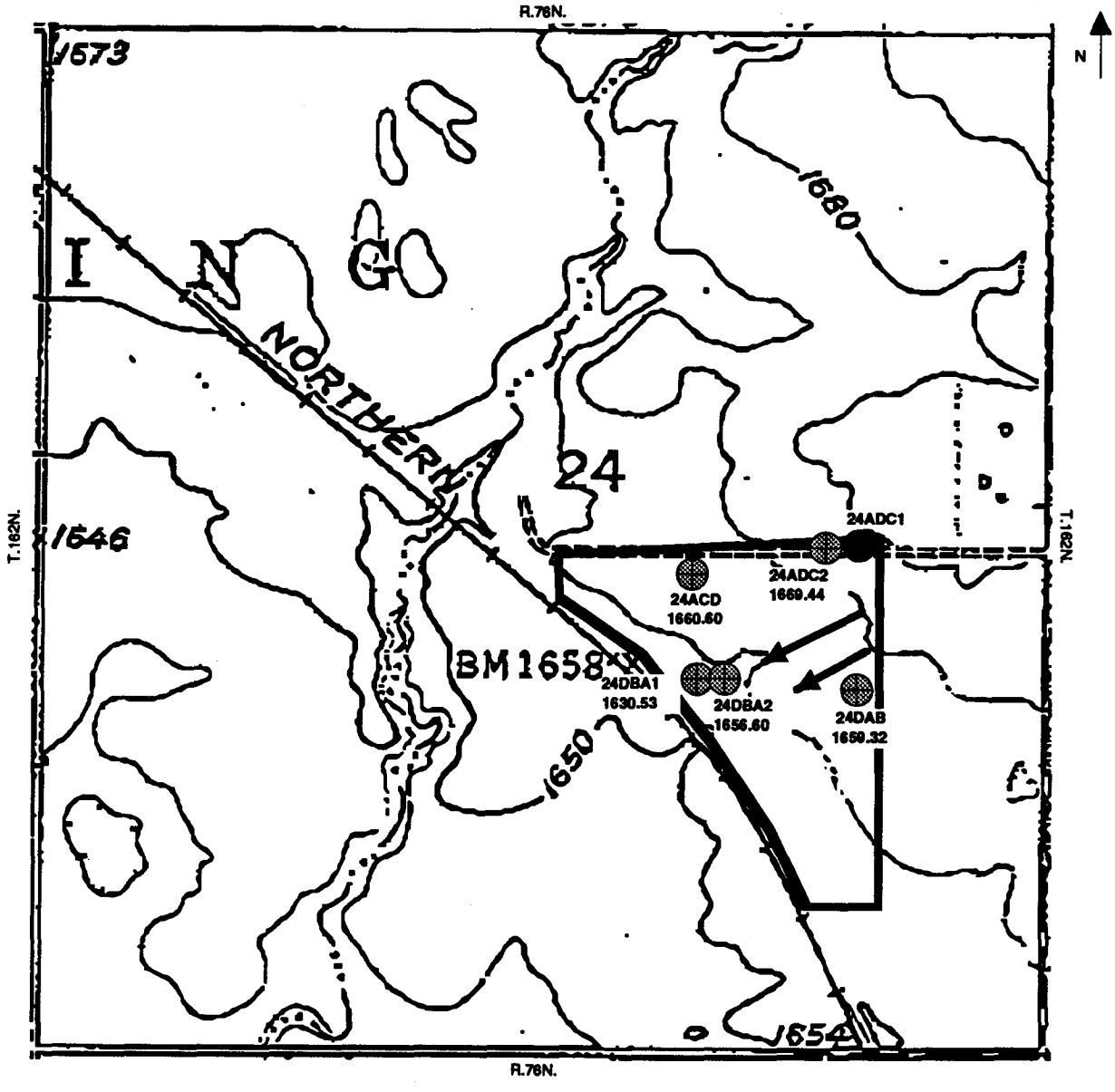

Figure 4. Location of monitoring wells and test holes at the Bottineau Municipal landfill.

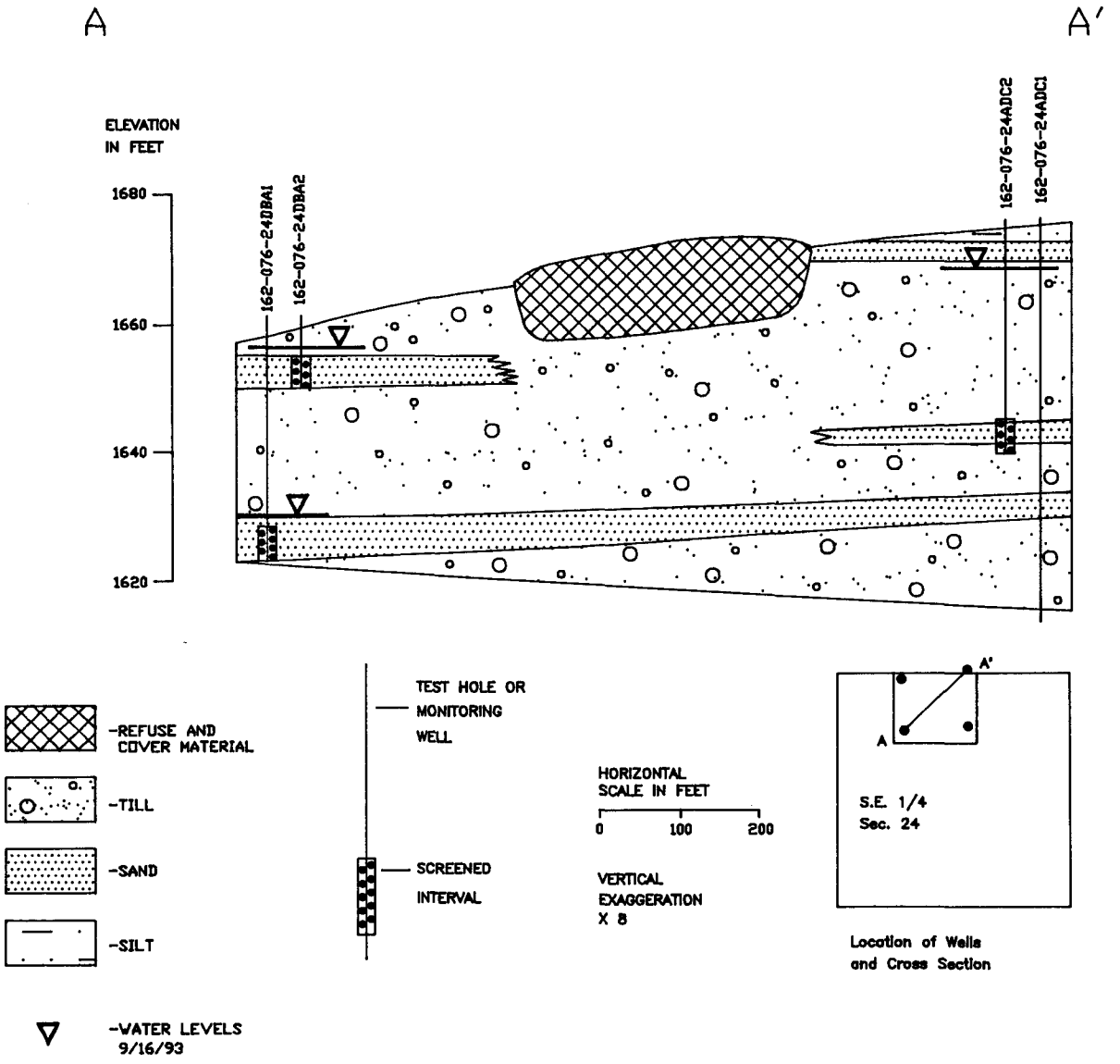

Figure 5. Geohydrologic section A-A' in the Bottineau Landfill.

at depths of about 48 feet and one boring penetrated sand at a depth of 33 feet. The deeper sand in their borings may correlate with the deepest sand in Figure 5. Exact locations and elevations for the Soil Exploration Company test holes are not available.

The glacial sediments are underlain by the Fox Hills Formation. The top of this formation occurs at an elevation of approximately 1,600 feet in the area of the landfill (Randich and Kuzniar, 1984, Plate 2). This would correspond to a depth of about 60 to 80 feet. The Fox Hills Formation is about 200 feet thick in this area and is composed of sandstone, siltstone, claystone, and shale (Bluemle, 1985). The Fox Hills Formation is underlain by the Pierre Formation. The Pierre Formation consists predominantly of clay and shale.

HYDROLOGY

Surface-Water Hydrology

The surface water in the area of the Bottineau municipal landfill consists of an intermittent stream west of the landfill in the SW quarter of section 24. This stream flows south into Stone Creek and may be susceptible to contaminant migration from the landfill because of its down-gradient location.

Stone Creek is located about 1 mile west of the landfill. Stone Creek flows to the south and does not appear to be susceptible to contaminant migration due to its distance from the landfill.

Oak Creek is located about 3/4 mile east and up-gradient from the landfill. Oak Creek flows south through the City of Bottineau. Oak Creek does not appear to be susceptible to contaminant migration because of its up-gradient location.

There are a few wetlands located within a 2-mile radius of the landfill. These wetlands do not appear to be susceptible to contaminant migration because of their distance from the landfill.

Regional Ground-Water Hydrology

Regional aquifers consist of both glacial and bedrock lithologies. The uppermost bedrock aquifer is the Fox Hills Formation located about 60 to 70 feet below land surface (Randich and Kuzniar, 1984). The Fox Hills aquifer is characterized by a sodium-mixed anion (chloride, bicarbonate, sulfate) type water. The Fox Hills aquifer may be susceptible to contaminant migration from the landfill because of its shallow depth and the occurrence of sand layers in the overlying glacial drift that may facilitate rapid downward ground-water flow.

The Pierre Formation underlies the Fox Hills Formation and is a source of ground water in areas of extensive fracturing. Well yields from this aquifer are usually small.

There are no major glacial aquifers within a three-mile radius of the landfill. Undifferentiated glacial aquifers are found throughout the area. These aquifers are not extensive and small quantities of water are usually found with slow recharge potential. These aquifers are usually characterized by a mixed cation-bicarbonate, sulfate type water.

An undifferentiated aquifer is located about one-mile north of the Bottineau landfill. Randich and Kuzniar (1984) interpreted this aquifer to extend toward the southwest and may underlie the landfill. This aquifer occurs at depths ranging from 10 to 90 feet and may be hydraulically connected to the underlying Fox Hills aquifer. The undifferentiated aquifer may be susceptible to contaminant migration due to its shallow depth and its down-gradient location from the landfill.

Local Ground-Water Hydrology

Five monitoring wells were installed at the Bottineau landfill with the screens placed in the uppermost undifferentiated glacial aquifer. Five water-level

measurements were taken over about a ten-week period (Appendix D).

Three undifferentiated sand aquifers were identified beneath the site. The lower-sand aquifer (24ACD1) and the middle sand aquifer in test hole 24ADC2 appear to be separated by about 10 feet of till (Fig. 5). The upper sand aquifer (24DBA2) and the deep sand aquifer (24DBA1) are seperated by about 20 feet of till. It is not known if a hydraulic connection exists between the upper and middle aquifers. A 20-foot water level difference in wells 24DBA1 and 24DBA2 indicates a poor hydraulic connection between the two sands. Water-level measurements indicate that the ground water occurs under confined conditions in the three undifferentiated sand aquifers. The direction of ground-water flow appears to be to the southwest (Fig. 4).

Water Quality

Chemical analyses of water samples are shown in Appendix E. The major ion analysis indicated the ground water in four of the wells is characterized by a sodium-sulfate type. The water in well 24DBA2 is characterized by a calcium-sulfate type. Well 24DBA2 also indicated a chloride concentration of 230 mg/L which is near the MCL of 250 mg/L. The water level in this well is shallow (4 feet below land surface) and is located down-gradient of the buried refuse (Fig. 4). The

high chloride concentration may be indicative of leachate migration from the landfill. The elevated calcium concentration (550 mg/L) at this site may also indicate leachate migration from the landfill. Trace element analyses did not indicate any concentration exceeding the MCL's.

The results of the VOC analysis, from well 24DBA2, is shown in Appendix F. The analysis did not detect any VOC compounds.

CONCLUSIONS

The Bottineau landfill is located in an area of gentle relief, with a gradual slope to the southwest. The glacial sediments at the landfill consist of sandy clay till with a few thin layers of glaciofluvial sand. The Fox Hills Formation that consists of sandstone, siltstone, claystone, and shale underlies the till. The depth of the Fox Hills Formation is about 60 to 80 feet. The Fox Hills Formation is underlain by the Pierre Formation. The Pierre Formation consists predominantly of clay and shale.

Stone Creek and Oak Creek are located within one mile of the landfill. An intermittent stream that originates about one-quarter mile west of the landfill drains south into Stone Creek. Oak Creek is located east of the landfill. Oak Creek flows to the south through the City of Bottineau. Very few wetlands are located within a two-mile radius of the

landfill. The two creeks and the wetlands do not appear to be susceptible to contaminant migration from the landfill.

There are no major glacial aquifers within a three-mile radius of the landfill. Undifferentiated glacial aquifers were identified in the landfill study area. An undifferentiated aquifer is located about one mile north of the landfill. This aquifer extends to the southwest and may underlie the landfill. The depth of this aquifer ranges from 10 to 90 feet. This aquifer may be susceptible to contaminant migration from the landfill.

Three undifferentiated sand aquifers were identified beneath the Bottineau landfill. Water-level measurements indicate these aquifers are confined and the direction of ground-water flow in the upper-sand aquifer is to the southwest. This aquifer may be susceptible to contaminant migration from the landfill.

The direction of ground-water flow in the middle-sand aquifer and the lower sand aquifer were not determined. These aquifers should not be susceptible to contaminant migration from the landfill.

The Fox Hills aquifer is the uppermost bedrock aquifer beneath the landfill. The depth of this aquifer is about 60 to 70 feet. This aquifer may be hydraulically connected to the undifferentiated aquifer near the landfill. The Fox Hills aquifer may be susceptible to contaminant migration from the landfill because of its shallow depth and the

occurrence of sand layers in the overlying glacial drift that may facilitate rapid downward ground-water flow.

The Pierre Formation underlies the Fox Hills Formation and and is a source of ground water. The depth of the Pierre aquifer is greater than 250 feet. This aquifer should not be susceptible to contaminant migration from the landfill.

Water-quality analyses indicated a chloride concentration in well 24DBA2 of 230 mg/L which is close to the MCL of 250 mg/L. This well also indicated a calcium concentration of 550 mg/L, which is eleven times higher than the recommended concentration of 50 mg/L. The water-quality results may be indicative of contaminant migration from the landfill. No trace elements were detected from the analyses. A VOC analysis from well 24DBA2 did not detect any VOC compounds.

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APPENDIX A

WATER QUALITY STANDARDS
AND
CONTAMINANT LEVELS

Water Quality Standards and Contaminant Levels

Field Parameters	
appearance	color/odor
pH	6-9 (optimum)
specific conductance	-----
temperature	-----

Constituent	MCL (µg/L)
Arsenic	50
Cadmium	10
Lead	50
Molybdenum	100
Mercury	2
Selenium	10
Strontium	*

*EPA has not set an MCL for strontium. The median concentration for most U.S. water supplies is 100 µg/L (Hem, 1989).

	SMCL (mg/L)
Chloride	250
Iron	>0.3
Nitrate	50
Sodium	20-170
Sulfate	300-1000
Total Dissolved Solids	>1000

	Recommended Concentration Limits (mg/L)
Bicarbonate	150-200
Calcium	25-50
Carbonate	150-200
Magnesium	25-50
Hardness	>121 (hard to very hard)

APPENDIX B

SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

1. Three samples must be collected in the 40ml bottles that are provided by the lab. One is the sample and the others are duplicates.

2. A blank will be sent along. Do Not open this blank and turn it in with the other three samples.

3. Adjust the flow so that no air bubbles pass through the sample as the bottle is being filled. No air should be trapped in the sample when the bottle is sealed. Make sure that you do not wash the ascorbic acid out of the bottle when taking the sample.

4. The meniscus of the water is the curved upper surface of the liquid. The meniscus should be convex (as shown) so that when the cover to the bottle is put on, no air bubbles will be allowed in the sample.

convex meniscus

5. Add the small vial of concentrated HCL to the bottle.

6. Screw the cover on with the white Teflon side down. Shake vigorously, turn the bottle upside down, and tap gently to check if air bubbles are in the sample.

7. If air bubbles are present, take the cover off the bottle and add more water. Continue this process until there are no air bubbles in the sample.

8. The sample must be iced after collection and delivered to the laboratory as soon as possible.

9. The 40 ml bottles contain ascorbic acid as a preservative and care must be taken not to wash it out of the bottles. The concentrated acid must be added after collection as an additional preservative.

APPENDIX C

LITHOLOGIC LOGS OF WELLS AND TEST HOLES

162-076-24ACD
NDSWC

Date Completed:	7/19/93	Purpose:	Observation Well
L.S. Elevation (ft):	1662.02	Well Type:	2" PVC
Depth Drilled (ft):	10	Aquifer:	UND
Screened Interval (ft):	5-10	Source:	
		Owner:	Bottineau

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Sandy, dark gray.	1-3
SAND	Silty, moderate yellowish brown 10YR5/4.	3-5
CLAY	Sandy, moderate yellowish brown 10YR5/4.	5-10

162-076-24ADC1
NDSWC

Date Completed:	7/14/93	Purpose:	Test Hole
L.S. Elevation (ft):	1675	Well Type:	
Depth Drilled (ft):	60		
		Source:	
		Owner:	Bottineau

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	With very fine sand, moderate yellowish brown 10YR5/4.	1-5
SAND	Medium grained, clayey, trace gravel.	5-7
CLAY	Trace sand and gravel moderate yellowish brown 10YR5/4 (till).	7-19
SILT	Clayey, trace gravel, moderate yellowish brown 10YR5/4 (till).	19-24
CLAY	Sandy, trace gravel, moderate yellowish brown 10YR5/4 (till).	24-31
SAND	Fine grained, clayey bluish gray 5B5/1.	31-33
CLAY	Sandy, trace gravel, olive gray 5Y4/1 (till).	33-42
SAND	Very fine grained, silty, olive gray 5Y4/1.	42-44
CLAY	Sandy, trace gravel olive gray 5Y4/1 (till).	44-49
CLAY	trace sand and gravel, olive gray 5Y4/1 (till).	49-60

162-076-24ADC2

NDSWC

Date Completed:	7/14/93	Purpose:	Observation Well
L.S. Elevation (ft):	1675.55	Well Type:	2" PVC
Depth Drilled (ft):	35	Aquifer:	UND
Screened Interval (ft):	30-35	Source:	
		Owner:	Bottineau

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	Sandy, moderate yellowish brown 10YR5/4.	1-4
SAND	Medium to coarse grained, moderate yellowish brown 10YR5/4.	4-8
CLAY	Silty, trace of sand and gravel, moderate yellowish brown 10YR5/4 (till).	8-12
CLAY	Trace gravel, moderate yellowish brown 10YR5/4 (till).	12-18
SAND	Fine grained, silty, trace gravel, moderate yellowish brown 10YR5/4.	18-22
CLAY	Sandy, trace gravel, moderate yellowish brown 10YR5/4 (till).	22-25
SAND	Very fine grained, bluish gray 5B5/1.	25-31
CLAY	Sandy, olive gray 5Y4/1	31-35

162-076-24DAB

NDSWC

Date Completed:	7/19/93	Purpose:	Observation Well
L.S. Elevation (ft):	1664.82	Well Type:	2" PVC
Depth Drilled (ft):	32	Aquifer:	UND
Screened Interval (ft):	22-32	Source:	
		Owner:	Bottineau

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Trace sand and gravel, moderate yellowish brown 10Y5/4. (till).	1-24
CLAY	Sandy, trace gravel, olive gray 5Y4/1 (till).	24-27
SAND	Very fine grained, silty, bluish gray 5B5/1.	27-28
SAND	Very fine grained, clayey, bluish gray 5B5/1.	28-30
CLAY	Sandy, olive gray 5Y4/1.	30-32

162-076-24DBA1

NDSWC

Date Completed:	7/19/93	Purpose:	Observation Well
L.S. Elevation (ft):	1658.26	Well Type:	2" PVC
Depth Drilled (ft):	35	Aquifer:	UND
Screened Interval (ft):	30-35	Source:	
		Owner:	Bottineau

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Sandy, trace gravel, moderate yellowish brown 10YR5/4 (till).	1-3
SAND	Clayey, trace gravel, moderate yellowish brown 10YR5/4 (till).	3-9
CLAY	Sandy, trace gravel, moderate yellowish brown 10YR5/4 (till).	9-16
CLAY	Trace Sand and gravel, moderate yellowish brown 10YR5/4 (till).	16-28
SAND	Fine to coarse grained, silty, gravelly, olive gray 5Y4/1.	28-35

162-076-24DBA2

NDSWC

Date Completed:	7/19/93	Purpose:	Observation Well
L.S. Elevation (ft):	1658.63	Well Type:	2" PVC
Depth Drilled (ft):	9	Aquifer:	UND
Screened Interval (ft):	4-9	Source:	
		Owner:	Bottineau

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Sandy, trace gravel, moderate yellowish brown 10YR5/4 (till).	1-4
SAND	Medium grained, silty, trace gravel, moderate yellowish brown 10YR5/4.	4-9

APPENDIX D

WATER-LEVEL TABLES

Bottineau Water Levels
7/29/93 to 10/4/93

162-076-24ACD LS Elev (msl,ft)=1662.02
UND Aquifer SI (ft.)=5-10

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/29/93	0.52	1661.50	09/16/93	1.42	1660.60
08/19/93	1.53	1660.49	10/04/93	2.70	1659.32
08/31/93	0.69	1661.33			

162-076-24ADC2 LS Elev (msl,ft)=1675.55
UND Aquifer SI (ft.)=30-35

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/29/93	6.13	1669.42	09/16/93	6.11	1669.44
08/19/93	6.37	1669.18	10/04/93	6.28	1669.27
08/31/93	6.14	1669.41			

162-076-24DAB LS Elev (msl,ft)=1664.82
UND Aquifer SI (ft.)=22-32

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/29/93	1.61	1663.21	09/16/93	5.50	1659.32
08/19/93	4.88	1659.94	10/04/93	2.90	1661.92
08/31/93	2.26	1662.56			

162-076-24DBA1 LS Elev (msl,ft)=1658.26
UND Aquifer SI (ft.)=30-35

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/29/93	2.98	1655.28	08/31/93	22.59	1635.67
07/30/93	30.43	1627.83	09/16/93	27.73	1630.53
08/19/93	25.91	1632.35	10/04/93	23.36	1634.90

162-076-24DBA2 LS Elev (msl,ft)=1658.63
UND Aquifer SI (ft.)=4-9

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/29/93	0.82	1657.81	09/16/93	2.03	1656.60
08/19/93	2.59	1656.04	10/04/93	2.85	1655.78
08/31/93	0.82	1657.81			

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Bottineau Water Quality
Major Ions

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness $CaCO_3$	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (∞C)	pH
			←(milligrams per liter)→																					
162-076-24ACD	5-10	07/29/93	25	0.24	0.07	150	180	900	4.9	777	0	2300	100	0.7	0.1	0.78	4040	1100	480	64	12	4900	13	
162-076-24ADC2	30-35	07/29/93	19	0.03	1.6	150	53	520	14	535	0	1300	100	0.3	5.3	0.94	2430	590	150	65	9.3	3250	14	
162-076-24DAB	22-32	07/29/93	18	0.01	0.36	140	63	270	12	501	0	730	54	1	4.1	0.64	1540	610	200	48	4.8	2150	11	
162-076-24DBA1	30-35	07/30/93	13	0.18	0.41	290	93	400	18	330	0	1600	120	0.5	6.6	0.49	2710	1100	840	44	5.2	3280	7	
162-076-24DBA2	4-9	07/29/93	32	0.04	0.05	550	230	210	18	555	0	1800	230	0.2	0.8	0.46	3340	2300	1900	16	1.9	3840	13	

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
162-076-24ACD	7/29/93	6	0	0	0	0	13	1100
162-076-24ADC2	7/29/93	1	0	0	0.1	5	9	1300
162-076-24DAB	7/29/93	1	0	0	0	1	13	910
162-076-24DBA1	7/29/93	2	0	0	0	0	33	1600
162-076-24DBA2	7/29/93	4	0	0	0.1	1	5	2400

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 162-076-24DBA2

Volatile Organic Compounds
and
Minimum Concentrations

Concentrations are based only on detection limits. Anything over the detection limit indicates possible contamination.

Constituent	Chemical Analysis µg/L
Benzene	<2
Vinyl Chloride	<1
Carbon Tetrachloride	<2
1,2-Dichlorethane	<2
Trichloroethylene	<2
1,1-Dichloroethylene	<2
1,1,1-Trichloroethane	<2
para-Dichlorobenzene	<2
Acetone	<50
2-Butanone (MEK)	<50
2-Hexanone	<50
4-Methyl-2-pentanone	<50
Chloroform	<5
Bromodichloromethane	<5
Chlorodibromomethane	<5
Bromoform	<5
trans1,2-Dichloroethylene	<2
Chlorobenzene	<2
m-Dichlorobenzene	<5
Dichloromethane	<5
cis-1,2-Dichloroethylene	<2
o-Dichlorobenzene	<2
Dibromomethane	<5
1,1-Dichloropropene	<5
Tetrachlorethylene	<2
Toluene	<2
Xylene(s)	<2
1,1-Dichloroethane	<5
1,2-Dichloropropane	<2
1,1,2,2-Tetrachloroethane	<5
Ethyl Benzene	<2
1,3-Dichloropropane	<5
Styrene	<2
Chloromethane	<5
Bromomethane	<5
1,2,3-Trichloropropane	<5
1,1,1,2-Tetrachloroethane	<5
Chloroethane	<5
1,1,2-Trichloroethane	<5

* Constituent Detection

VOC Constituents cont.

2,2-Dichloropropane	<5
o-Chloroluene	<5
p-Chlorotoluene	<5
Bromobenzene	<5
1,3-Dichloropropene	<5
1,2,4-Trimethylbenzene	<5
1,2,4-Trichlorobenzene	<5
1,2,3-Trichlorobenzene	<5
n-Propylbenzene	<5
n-Butylbenzene	<5
Naphthalene	<5
Hexachlorobutadiene	<5
1,3,5-Trimethylbenzene	<5
p-Isopropyltoluene	<5
Isopropylbenzene	<5
Tert-butylbenzene	<5
Sec-butylbenzene	<5
Fluorotrichloromethane	<5
Dichlorodifluoromethane	<5
Bromochloromethane	<5
Allylchloride	<5
2,3-Dichloro-1-propane	<5
Tetrahydrofuran	<50
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection