Site Suitability Review of the Turtle Mountain Landfill

(Joe Murphy)

by
Phillip L. Greer
North Dakota Geological Survey
and
Jeffrey Olson
North Dakota State Water Commission

Prepared by the
North Dakota Geological Survey
and the
North Dakota State Water Commission

ND Landfill Site Investigation No. 23

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OF THE
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Bismarck, North Dakota
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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 Turtle Mountain solid waste landfill is one of the landfills being evaluated.

Location of the Turtle Mountain Landfill

The Turtle Mountain solid waste landfill is located about three miles north and six miles east of the City of Rolla in Township 163 North, Range 71 West, SE 1/4 Section 36 (Fig. 1). The active area of the landfill encompasses

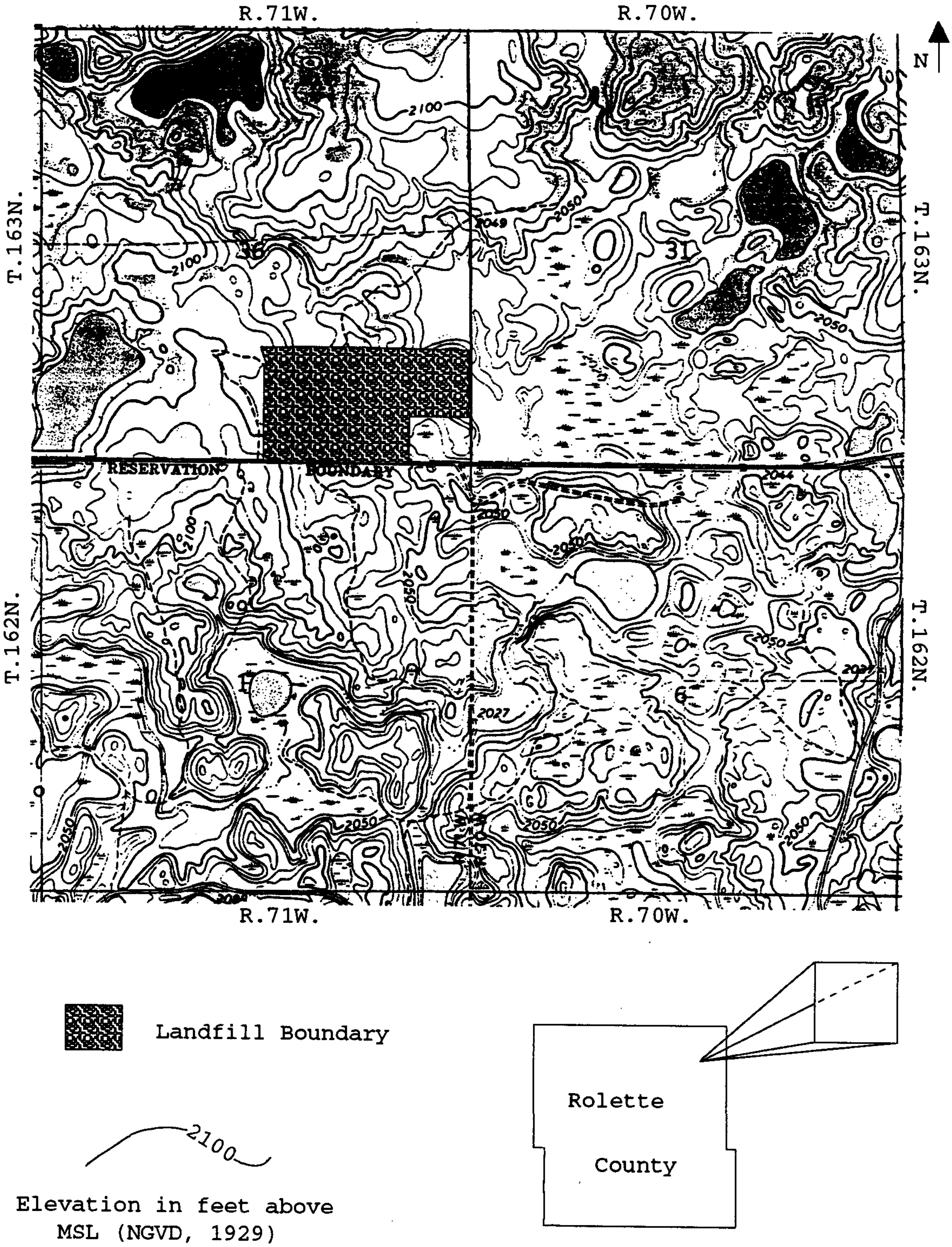

Figure 1. Location of the Turtle Mountain landfill in the SE 1/4, section 36, T.163N., R.71W.

approximately 25 acres. The landfill is owned and operated by Murphy Services, Inc.

Previous Site Investigations

Twin City Testing performed a hydrogeologic study of the Turtle Mountain landfill in 1987. This work included drilling six soil borings and installing one monitoring well. The soil borings indicated that the subsurface material was composed of clay and sandy clay to a depth of 16 feet.

Methods of Investigation

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

Test-Drilling Procedure

The drilling method used at the Turtle Mountain landfill was based on the site's geology and depth to ground water, as determined by the preliminary site evaluation. A hollow-stem auger rig was used at the Turtle Mountain landfill because the sediments were poorly consolidated and the depth to the water table was expected to be less than 70 feet. The lithologic descriptions were determined from the drill cuttings. The water used with the rig was obtained from municipal water supplies.

Monitoring Well Construction and Development

Five test holes were drilled at the Turtle Mountain landfill. Four of the holes were dry at the time of drilling and no monitoring wells were installed. A monitoring well was installed in the fifth test hole with the screen placed to monitor the top of the uppermost aquifer. All test holes were located around 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 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

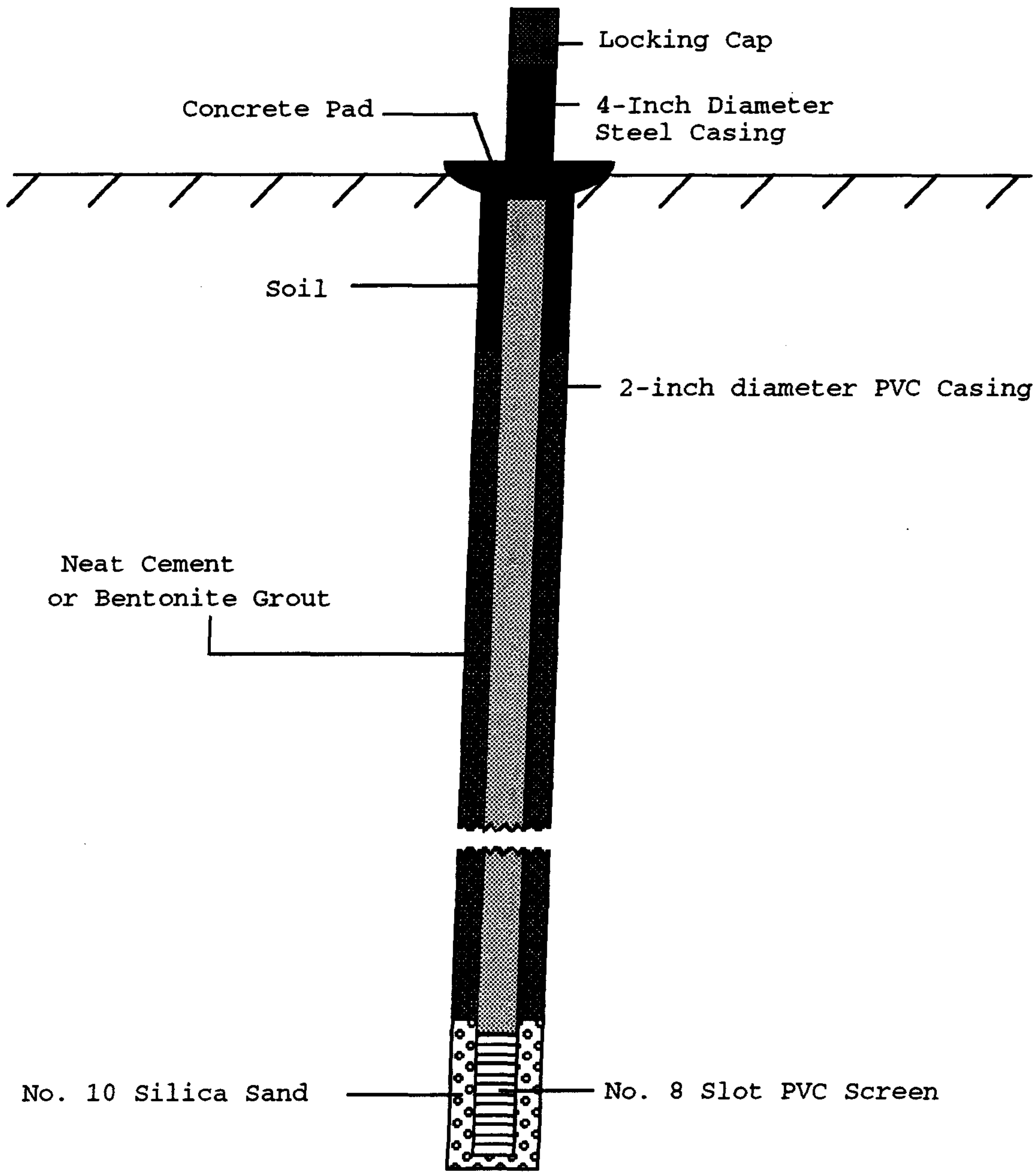

Figure 2. Construction design used for monitoring wells installed at the Turtle Mountain landfill.

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 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.

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

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 (10-acre tract). Therefore, a well denoted by 163-071-36DBD1 would be located in the SE1/4, NW1/4, SE1/4, Section 36, Township 163 North, Range 71 West. Consecutive numbers are added following the three letters if more than one well is

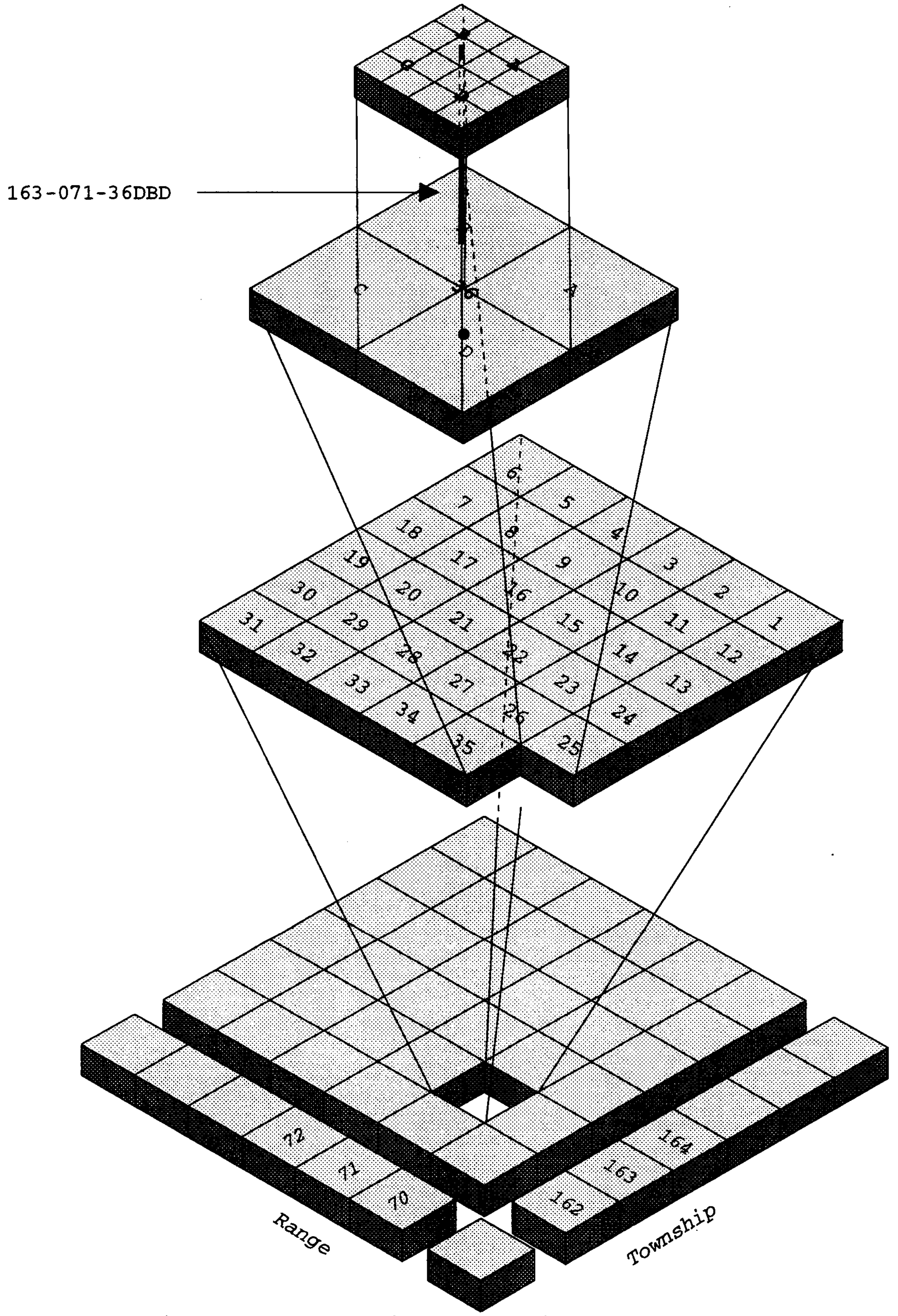

Figure 3. Location-numbering system at the Turtle Mountain landfill.

located in a 10-acre tract, e.g. 163-071-36DBD1 and 163-071-36DBD2.

GEOLOGY

Regional Geology

The Turtle Mountains originated when a previously existing plateau was overridden by glaciers. Compression and shearing within the glaciers brought large amounts of material to the surface of the ice. This supraglacial sediment insulated the ice below. Ice-walled lakes developed on top of the supraglacial sediment. When the ice eventually melted the supraglacial sediment was redeposited by mudflows (Deal, 1971; Bluemle, 1991).

The Turtle Mountains stand about 400 feet above the surrounding plain. The collapsed supraglacial sediments have produced a hummocky topography with significant local relief and numerous closed depressions. The geologic materials at or near the surface consist of glacial till, lake sediments, and outwash.

Local Geology

The active area of the Turtle Mountain landfill is on the east side of a hill (Fig. 5). At the base of the hill a circular area enclosed by a dike was used for waste disposal

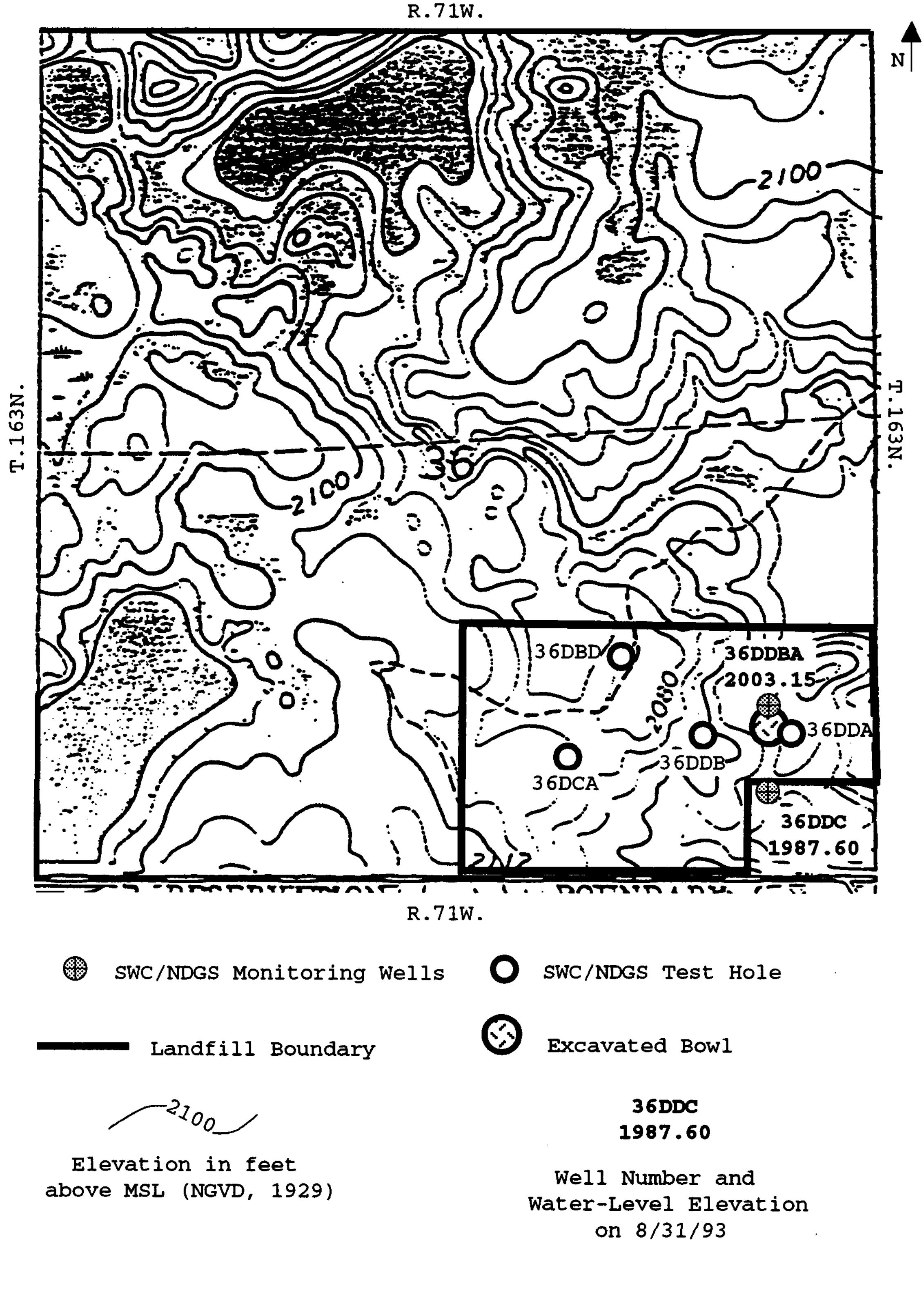

Figure 4. Location of monitoring wells at the Turtle Mountain landfill.

for a short time in the past. A small ravine on the east side of the hill intersects the diked area. Elevations on the landfill property range from 2,030 feet at the base of the hill to 2,080 feet on top of the hill.

The sediments at the landfill are dominantly till with a large clay fraction and only a trace of sand and gravel (lithologic logs in Appendix C and D, Fig. 5). The gravel portion of the till is mainly pebble-sized fragments of black shale. Few cobbles and no boulders were encountered in the drilling.

Test holes 163-071-36DBD and 163-071-36DDA penetrated intervals of clay and silt. These sediments are probably lake deposits; however, the depositional environment cannot be established conclusively because no cores were taken in this study. No layers of sand or gravel were encountered in any of the test holes.

HYDROLOGY

Surface-Water Hydrology

The Turtle Mountain landfill is located in an area of collapsed glacial sediments with a hummocky topography (Fig. 1). Several lakes, wetlands and depressions are situated around the boundaries of the landfill. Water samples were not collected from any of the surface waters.

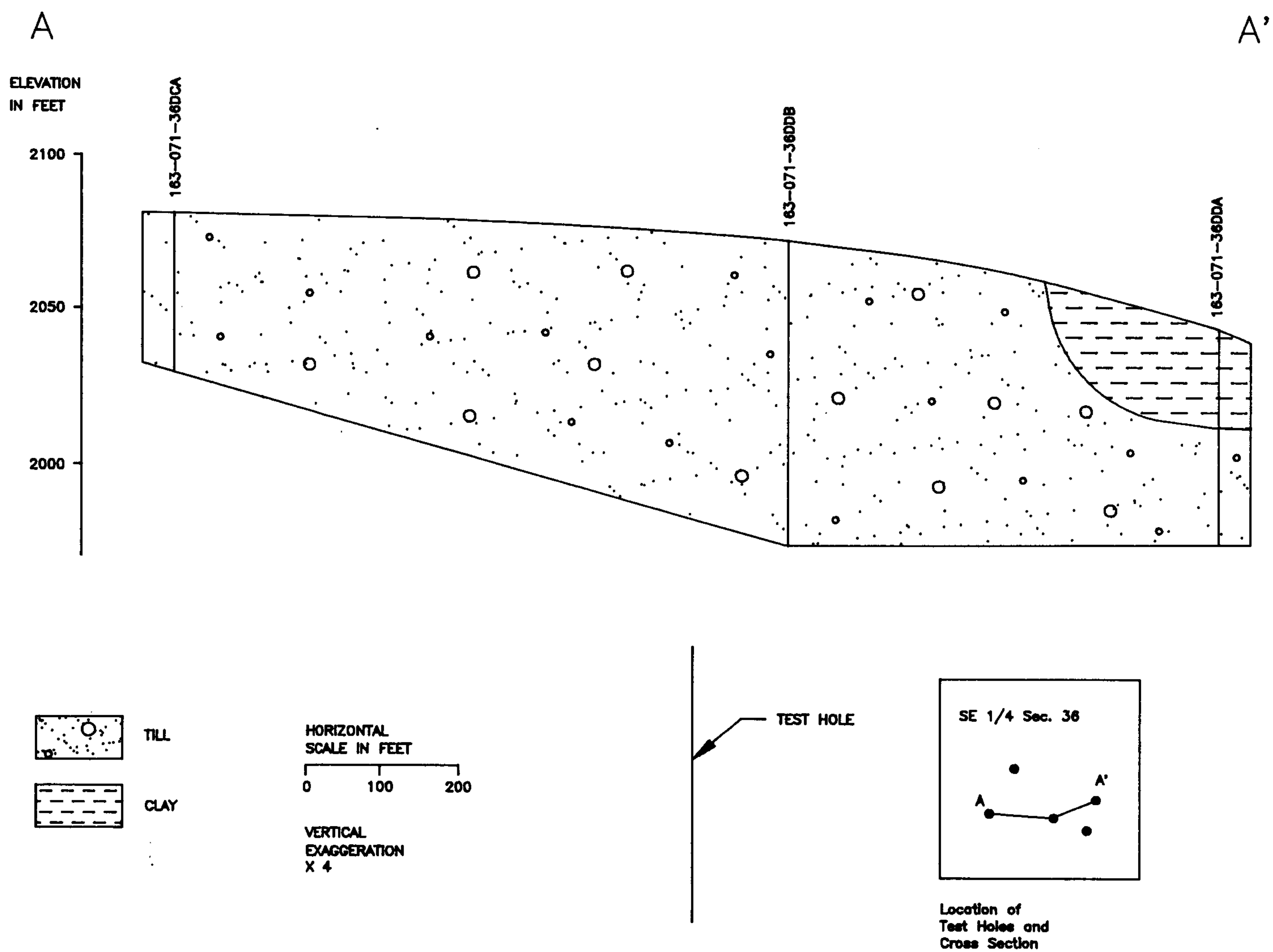

Figure 5. Geohydrologic section A–A' in the Turtle Mountain Landfill

Wetlands near the Turtle Mountain landfill are both seasonal and semi-permanent. Seasonal wetlands contain water during certain periods of the year while semi-permanent wetlands contain water throughout most of the year. Wetlands act as discharge areas for the ground water during periods of low precipitation and collection basins for surface-water runoff.

The excavation of the bowl-shaped basin, located in the SE 1/4, SE 1/4, SE 1/4, section 36, has created a surface-water runoff impoundment at the landfill. This bowl was used for disposal of a small amount of refuse and is also a discharge area for a ravine that was used for construction waste disposal. Surface-water runoff and lateral subsurface flow through the construction waste may transport contaminants into this surface-water impoundment.

Belcourt Lake is located about one mile southeast of the landfill. This lake is recharged by surface runoff and lateral ground-water flow from adjacent wetlands. Because of the distance from the landfill and the low hydraulic conductivity of lithologies at the landfill, Belcourt Lake should not be susceptible to contamination from the landfill.

Regional Ground-Water Hydrology

Regional aquifers consist of both glacial and bedrock lithologies. There are no major glacial aquifers within a two-mile radius of the Turtle Mountain landfill. The Rolla aquifer is located about eight miles east of the landfill and occupies an area of about 48 square miles (Randich and Kuzniar, 1984). This aquifer is recharged from precipitation and lateral flow from undifferentiated glacial aquifers and adjacent bedrock aquifers. Discharge is by evapotranspiration and pumpage from domestic and municipal wells including those of the City of Rolla. This aquifer is characterized by a calcium-sulfate-bicarbonate type water.

The Shell Valley aquifer is located about six miles south of the Turtle Mountain landfill and occupies an area of about 56 square miles (Randich and Kuzniar, 1984). This aquifer is recharged by precipitation. Discharge is by lateral flow into streams and potholes and pumpage from domestic, irrigation, and municipal wells. The City of Belcourt obtains its water from the Shell Valley aquifer. This aquifer is characterized by a mixed cation-bicarbonate-sulfate type water.

Undifferentiated sand and gravel aquifers are found throughout the region. These aquifers are not extensive and as a result are characterized by limited recharge. However, these aquifers commonly are a source for domestic and stock supplies. These aquifers are generally characterized by a mixed cation-bicarbonate-sulfate type water (Randich and Kuzniar, 1984).

The Fox Hills Formation directly underlies the glacial till in the area of the landfill. The Fox Hills aquifer is located in zones of sandstone with an average thickness of about 25 feet (Randich and Kuzniar, 1984). Recharge to the Fox Hills aquifer is by precipitation and lateral flow from adjacent aquifers. Discharge is by pumping or flowing wells, seeps, and lateral flow into streams, and adjacent aquifers (Randich and Kuzniar, 1984). The regional flow of the Fox Hills aquifer is towards the Souris River valley. This aquifer is characterized by a sodium-mixed anion type water (Randich and Kuzniar, 1984).

The Pierre Formation underlies the Fox Hills Formation. The Pierre aquifer is found only in areas where the formation is highly fractured.

There does not appear to be a direct hydraulic connection between the area under the landfill and the regional aquifers. Therefore, the regional aquifers probably are not susceptible to contamination from the landfill.

Local Ground-Water Hydrology

Five test holes were drilled at the Turtle Mountain landfill and a monitoring well was installed in one of the test holes. The well screen was placed near the top of the uppermost aquifer beneath the landfill. In addition, one monitoring well and five test holes from an earlier study by Twin City Testing were used in evaluating this site.

Six water-level measurements were taken over a 13-week period (Appendix E). There is not enough information from the two monitoring wells to determine the ground-water flow direction. The depth to ground water appears to be greater than 100 feet except in the immediate area of wetlands and lakes.

Water Quality

Chemical analyses of water samples are shown in Appendix F. The water in both wells is characterized by a calcium-sulfate type. The major ion analyses did not indicate contaminant migration from the landfill to the saturated zone.

The trace element analyses indicated an anomalously high molybdenum concentration (99 µg/L) in well 163-071-36DDBA. This molybdenum concentration is close to the MCL of 100 µg/L. A bowl-shaped surface-water impoundment is located near this well. The impoundment increases surface water infiltration to the water table. The magnitude of water-level fluctuations in well 36DDBA is much larger than those in well 36DDC, suggesting that the bowl-shaped impoundment operates as a point source. The large molybdenum concentration may originate from water moving through the construction waste and into the impoundment.

The results of the VOC analysis, from monitoring well 163-071-36DDBA, are shown in Appendix G. The analysis did not detect any VOC compounds in the ground water.

CONCLUSIONS

The Turtle Mountain landfill is located on the east side of a hill. Several lakes and wetlands are situated around the landfill. Belcourt Lake is located about a mile southeast of the landfill. Surface water at the landfill discharges eastward through a small ravine and into adjacent wetlands.

The geologic materials at the landfill consist of till, clay, and silt, all of which are characterized by relatively low hydraulic conductivity. The till is composed predominantly of clay and is the dominant lithology in the landfill area. Clay and silt encountered in two test holes are believed to be lake deposits. No sand or gravel layers were encountered in any of the test holes.

The water table at the landfill is relatively deep. Near a wetland east of the landfill, the water table is between 30 to 50 feet below the surface. On the hill where the active area of the landfill is located, the water-table depth appears to be more than 100 feet.

There are no major aquifers near the landfill, except for the Fox Hills aquifer, which is several hundred feet below the ground surface. The regional aquifers should not be affected by contaminant migration from the landfill.

Major ion concentrations are typical of groundwater in the region. A water sample from well 163-071-36DDBA contained a molybdenum concentration of 99 ug/L, which is near the MCL of 100 ug/L. The bowl-shaped impoundment may be a "point source" for the increased molybdenum concentration. The VOC analysis from the same well showed no detections of volatile organic compounds.

The wetlands in the area of the landfill may be susceptible to contaminant migration by surface runoff. Because of the number and location of surrounding wetlands, it is suggested that a buffer zone be maintained between the refuse cells and the wetlands. A surface-water diversion may also be appropriate around these wetlands.

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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

163-071-36DBD

NDSWC

Date Completed:	6/2/93	Purpose:	Test Hole
L.S. Elevation (ft):	2081.62	Well Type:	
Depth Drilled (ft):	100		
		Source:	NDGS
		Owner:	Joe Murphy

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	WITH TRACE OF GRAVEL, BLACK	1-3
SAND	MEDIUM GRAINED, MODERATE YELLOWISH-BROWN 10YR5/4.	3-6
SAND	CLAYEY, GRAYISH ORANGE, 10YR7/4.	6-10
CLAY	SANDY WITH A TRACE F GRAVEL, MODERATE YELLOWISH-BROWN 10YR5/4.	10-16
SILT	CLAYEY, MODERATE YELLOWISH-BROWN, 10YR5/4, DAMP, LACUSTRINE.	16-28
SILT	CLAYEY, OLIVE GRAY 5Y4/1.	28-34
CLAY	SILTY, OLIVE GRAY, 10Y4/1.	34-40
CLAY	DARK GREENISH-GRAY, 5GY4/1, LACUSTRINE.	40-46
CLAY	TRACE OF MEDIUM AND COARSE GRAINED SAND, DARK GREENISH-GRAY, 5GY4/1.	46-100

163-071-36DCA

NDSWC

Date Completed:	6/3/93	Purpose:	Test Hole
L.S. Elevation (ft):	2080.42	Well Type:	
Depth Drilled (ft):	50		
		Source:	NDGS
		Owner:	JOE MURPHY

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	STIFF, FEW SMALL GYSUM CRYSTALS, FEW PEBBLES, MODERATE YELLOWISH-BROWN (10YR5/4) WITH DARK YELLOWISH-ORANGE (10YR6/6) MOTTLES.	1-22
CLAY	TRACE OF SAND AND GRAVEL,MODERATE YELLOWISH-BROWN, 10YR5/4, TILL.	22-32
CLAY	TRACE OF SAND AND GRAVEL, OLIVE GRAY, 5Y4/1.	32-50

163-071-36DDA

NDSWC

Date Completed:	6/3/93	Purpose:	Observation Well
L.S. Elevation (ft):	2043.5	Well Type:	
Depth Drilled (ft):	70		
		Source:	NDGS
		Owner:	JOE MURPHY

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-3
CLAY	STIFF, VERY FEW SAND GRAINS, PALE YELLOWISH-BROWN, 10YR6/2, LACUSTRINE.	3-9
CLAY	STIFF, OLIVE GRAY, 5Y4/1, LACUSTRINE.	9-33
CLAY	SANDY, TRACE OF GRAVEL, OLIVE GRAY, 5Y4/1.	33-51
CLAY	SANDY, TRACE GRAVEL, OLIVE GRAY, 5Y4/1, TILL.	51-70

163-071-36DDB
NDSWC

Date Completed:	6/2/93	Purpose:	Test Hole
L.S. Elevation (ft):	2072.78	Well Type:	
Depth Drilled (ft):	100		
		Source:	NDGS
		Owner:	JOE MURPHY

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	TRACE OF SAND, PALE BROWN (5YR5/2) WITH FEW MODERATE YELLOWISH-BROWN (10YR5/4) MOTTLED STREAKS.	2-8
CLAY	TRACE OF SAND AND GRAVEL, DARK YELLOWISH-BROWN, 10YR4/2, TILL.	8-49
CLAY	TRACE OF SAND AND GRAVEL, OLIVE GRAY, 5Y4/1, LACUSTRINE.	49-58
CLAY	TRACE OF SAND AND GRAVEL, DARK GREENISH-GRAY, 5GY4/1, LACUSTRINE.	58-100

163-071-36DDBA

NDSWC

Date Completed:	1/27/87	Purpose:	Observation Well
L.S. Elevation (ft):	2038.5	Well Type:	1.75" PVC
Depth Drilled (ft):	51	Aquifer:	UND
Screened Interval (ft):		Source:	Braun Intertec
		Owner:	JOE MUROHY

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	ORGANIC LEAN CLAY, DARK BROWN, VERY STIFF, (POSSIBLY FROZEN).	0-1.5
FAT CLAY / LACUSTRINE	GRAYISH BROWN, VERY STIFF TO STIFF.	1.5-6.5
SANDY FAT CLAY / GLACIAL TILL	GRAYISH BROWN MOTTLED, STIFF.	6.5-10
FAT CLAY / LACUSTRINE	BROWN AND GRAY MOTTLED, STIFF.	10-11.5
CLAY	SANDY LEAN CLAY WITH A LITTLE GRAVEL, BROWN AND GRAY MOTTLED, STIFF, TILL.	11.5-25
CLAY	GRAY, STIFF, LACUSTRINE.	25-28
CLAY	SANDY LEAN CLAY WITH A LITTLE GRAVEL, GRAY, STIFF, TILL.	28-30
CLAY	SANDY LEAN CLAY CONTINUED, TILL.	30-51

163-071-36DDC

NDSWC

Date Completed:	6/3/93	Purpose:	Observation Well
L.S. Elevation (ft):	2036.49	Well Type:	2" PVC
Depth Drilled (ft):	55	Aquifer:	Undefined
Screened Interval (ft):	45-55	Source:	NDGS
		Owner:	JOE MURPHY

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-3
CLAY	DARK YELLOWISH BROWN (10YR4/2) WITH LIGHT GRAY (N7), MOTTLE STREAKS.	3-6
CLAY	TRACE OF SAND AND GRAVEL, MODERATE YELLOWISH-BROWN (10YR5/4) WITH MOTTLE STREAKS OF DARK YELLOWISH-ORANGE (10YR6/6), TILL.	6-12
CLAY	TRACE OF SAND AND GRAVEL, MODERATE YELLOWISH-BROWN, 10YR5/4, TILL.	12-21
CLAY	TRACE OF SAND AND GRAVEL, OLIVE GRAY, 5Y4/1.	21-29
CLAY	SANDY, TRACE OF GRAVEL, OLIVE GRAY, 5Y4/1.	29-55

APPENDIX D

LITHOLOGIC LOGS OF PREVIOUS WELLS AND TEST HOLES

LOG OF TEST BORING

JOB NO. 5200-87-0047 VERTICAL SCALE 1" = 4' BORING NO 1

PROJECT SOLID WASTE DISPOSAL SITE - NEAR BELCOURT, NORTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL — SURFACE ELEVATION 85.2'	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	LL/PL	Qu
	FAT CLAY, brownish gray, frozen (CH)	LACUSTRINE			1	FA				
3					2	FA				
	SANDY MEDIUM FAT CLAY WITH A LITTLE GRAVEL, brownish gray mottled, medium to rather stiff, boulder at 3' (CL-CH)	GLACIAL TILL	6		3	SB				
					4	3T				
					5	B				
			12		6	SB				
			12		7	SB				
11½	SANDY LEAN CLAY WITH A LITTLE GRAVEL, gray, rather stiff (CL)		13		8	SB				
				▼						
			9		9	SB				
16	END OF BORING									

Note: Collective bag sample from 4'-10'

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
1-27	3:15	16'	None	14'	to	None
1-27	4:47	16'	None	14'	to	None
1-27	8:13	16'	None	14'	to	14'
					to	

START 1-27-87 COMPLETE 1-27-87

METHOD 6"FA 0-14½' @ 3:10

CREW CHIEF Jacobson

LOG OF TEST BORING

JOB NO 5200-87-0047 VERTICAL SCALE 1" = 4' BORING NO 2

PROJECT SOLID WASTE DISPOSAL SITE - NEAR BELCOURT, NORTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL — SURFACE ELEVATION 88.8'	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	L.L. / P.L.	Qu
	FAT CLAY, brownish gray mottled, medium to rather stiff, a few lime deposits (CH)	LACUSTRINE DEPOSIT	5		1	SB				
			9	▼	2	SB	34	86		
4	SANDY FAT CLAY WITH A LITTLE GRAVEL, brownish gray mottled, medium (CH)	GLACIAL TILL	7		3	SB				
6½	FAT CLAY, brownish gray mottled, rather stiff (CH)	LACUSTRINE DEPOSIT			4	B				
			9		5	SB				
10	SANDY MEDIUM FAT CLAY WITH A LITTLE GRAVEL, brownish gray mottled, medium to rather stiff (CL-CH)	GLACIAL TILL	8		6	SB				
			10		7	SB				
					8	B				
			9		9	SB				
16	END OF BORING									

Note: Bag samples from 4'-10' and 10'-16'

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
1-27	4:20	16'	None	15'	to	11'
1-28	8:18	16'	None	12½'	to	3½'
					to	
					to	

START 1-27-87 COMPLETE 1-27-87

METHOD 6"FA 0-14½' @ 4:15

CREW CHIEF Jacobson

LOG OF TEST BORING

JOB NO 5200-87-0047 VERTICAL SCALE 1" = 4' BORING NO 3

PROJECT SOLID WASTE DISPOSAL SITE - NEAR BELCOURT, NORTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 104.8')	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	L.L./P.L.	Qu
	FILL, mostly SANDY LEAN CLAY, grayish brown, frozen	FILL			1	FA				
3	FILL, ORGANIC SANDY LEAN CLAY WITH A LITTLE GRAVEL, black		28		2	SB				
4	FILL, mostly SANDY MEDIUM FAT CLAY WITH A LITTLE GRAVEL, grayish brown, layers of organic lean clay		14		3	SB				
					4	3T	18	103	50/23	
			20		5	SB				
					6	B				
9	FILL, mostly FAT CLAY, grayish brown, pockets of organic lean clay		16		7	SB				
					8	3T	37	81	63/26	
12	TOPSOIL, ORGANIC LEAN CLAY, black, rather stiff (OL)	TOPSOIL	15		9	SB				
					10	B				
			11		11	SB				
16	FAT CLAY, grayish brown, rather stiff (CH)	LACUSTRINE DEPOSIT								
			9		12	SB				
				▼						
25	FAT CLAY, gray, stiff (CH)		17		13	SB				
	Note: Collective bag samples taken from 4'-12' and 12'-16'		16		14	SB				
31	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
1-28	9:55	31'	None	29'	to	None
1-28	11:25	31'	None	29'	to	28.5'
1-28	3:35	31'	None	29'	to	23.5'

START 1-28-87 COMPLETE 1-27-87

METHOD 6"FA 0-29½' @ 9:50

LOG OF TEST BORING

JOB NO 5200-87-0047 VERTICAL SCALE 1" = 4' BORING NO 4

PROJECT SOLID WASTE DISPOSAL SITE - NEAR BELCOURT, NORTH DAKOTA

SURFACE ELEVATION 105.1'

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	L.L./P.L.	Qu
	FILL, mostly SANDY FAT CLAY, grayish brown, frozen to 3', a few pockets of organic lean clay	FILL			1	FA				
			9		2	SB	34	83		
			11		3	SB				
					4	3T				
7½	FILL, ORGANIC LEAN CLAY, black		6		5	SB				
					6	SB				
10½	FILL, mostly FAT CLAY, grayish brown and black		19		7	SB				
11½	FAT CLAY, grayish brown mottled, stiff (CH)	LACUSTRINE DEPOSIT	21		8	SB				
					9	B				
					10	3T				
			20		11	SB				
			18		12	SB				
21	SANDY LEAN CLAY WITH A LITTLE GRAVEL, grayish brown, stiff (CL)	GLACIAL TILL	26		13	SB				
26	END OF BORING Note: Collective bag samples from 6½'-10½' and 10½'-19'									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
1-28	1:25	26'	None	24'	to	None
1-29	8:55	26'	None	24'	to	None
1-30	8:43	26'	None	20'	to	None
					to	

START 1-28-87 COMPLETE 1-28-87

METHOD 6"FA 0-24½' @ 1:20

CREW CHIEF Jacobson

LOG OF TEST BORING

JOB NO 5200-87-0047 VERTICAL SCALE 1" = 4' BORING NO 5

PROJECT SOLID WASTE DISPOSAL SITE - NEAR BELCOURT, NORTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 109.1')	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	L.L./P.L.	Qu
	FILL, mostly LEAN CLAY, brown and black mixed, frozen	FILL			1	FA				
2	FILL, organic LEAN CLAY, black, frozen to 2½'		14		2	SB	*			
					3	3T	76	56		
4	FILL, ORGANIC FAT CLAY, black and brown		9		4	B				
					5	SB				
					6	3T	35	83	66/32	
			15		7	SB				
9	SANDY LEAN CLAY WITH A LITTLE GRAVEL, brown, rather stiff (CL)	GLACIAL TILL	13		8	SB				
					9	B				
11½	FAT CLAY, brown mottled, rather stiff to stiff (CH)	LACUSTRINE DEPOSIT	14		10	SB				
			19		11	SB				
16	END OF BORING									

Note: Collective bag samples from 2'-8' and 8'-14'

*High moisture content may have been influenced by presence of organic material.

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
28	2:49	16'	None	14'	to	None
					to	
					to	
					to	

START 1-28-87 COMPLETE 1-28-87

METHOD 6"FA 0-14½' @ 2:45

CREW CHIEF Jacobson

APPENDIX E

WATER-LEVEL TABLES

Turtle Mountain Landfill Water Levels
6/9/93 to 9/15/93

163-071-36DDBA LS Elev (msl,ft)=2038.5
UND Aquifer SI (ft.)=0-0

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/09/93	9.85	2028.65	08/19/93	39.38	1999.12
06/29/93	40.75	1997.75	08/31/93	35.35	2003.15
07/30/93	40.39	1998.11	09/15/93	30.43	2008.07

163-071-36DDC LS Elev (msl,ft)=2036.49
Undefined Aquifer SI (ft.)=45-55

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/09/93	50.32	1986.17	08/19/93	49.70	1986.79
06/29/93	50.57	1985.92	08/31/93	48.89	1987.60
07/30/93	49.09	1987.40	09/15/93	47.92	1988.57

APPENDIX F

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Turtle Mountain Landfill Water Quality

Major Ions

Location	Screened Interval (ft)	Date Sampled	SiO_2 (milligrams per liter)	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
163-071-36DDBA	0-0	07/30/93	15	0.03	1.4	430	130	110	16	468	0	1500	16	0.1	19	0.52	2470	1600	1200	13	1.2	2800	11	6.94
163-071-36DDC	45-55	07/30/93	26	0.01	0.14	270	33	140	26	83	0	1100	21	0.2	0.1	0.23	1660	810	740	27	2.1	1890	11	8.47

Trace Element Analyses

Location	Date Sampled	Selenium (micrograms per liter)	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
163-071-36DDC	7/30/93	3	0	0	0	4	99	1400
163-071-36DDBA	7/30/93	3	0	0	0.1	1	8	2500

APPENDIX G

VOLATILE ORGANIC COMPOUNDS
FOR WELL 163-071-36DDBA

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