Site Suitability Review of the Devils Lake Landfill

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

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

ND Landfill Site Investigation No. 7

SITE SUITABILITY REVIEW OF THE DEVILS LAKE LANDFILL

By Jeffrey M. Olson, North Dakota State Water Commission,

and Phillip L. Greer, North Dakota Geological Survey

North Dakota Landfill Site Investigation 7

Prepared by the NORTH DAKOTA STATE WATER COMMISSION
and the NORTH DAKOTA GEOLOGICAL SURVEY

Bismarck, North Dakota
1993

TABLE OF CONTENTS

TABLE OF CONTENTS cont.

LIST OF FIGURES

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 municipal 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. Additional studies may be necessary to meet the requirements of the NDSDHCL for continued operation of municipal solid waste landfills. The Devils Lake municipal solid waste landfill is one of the landfills being evaluated.

Location

The Devils Lake municipal solid waste landfill is located six miles north of the city of Devils Lake in Township 154 North, Range 64 West, NE 1/4 Section 5 (Fig. 1). The landfill encompasses 80 acres of which about 40 acres are actively being used for refuse disposal.

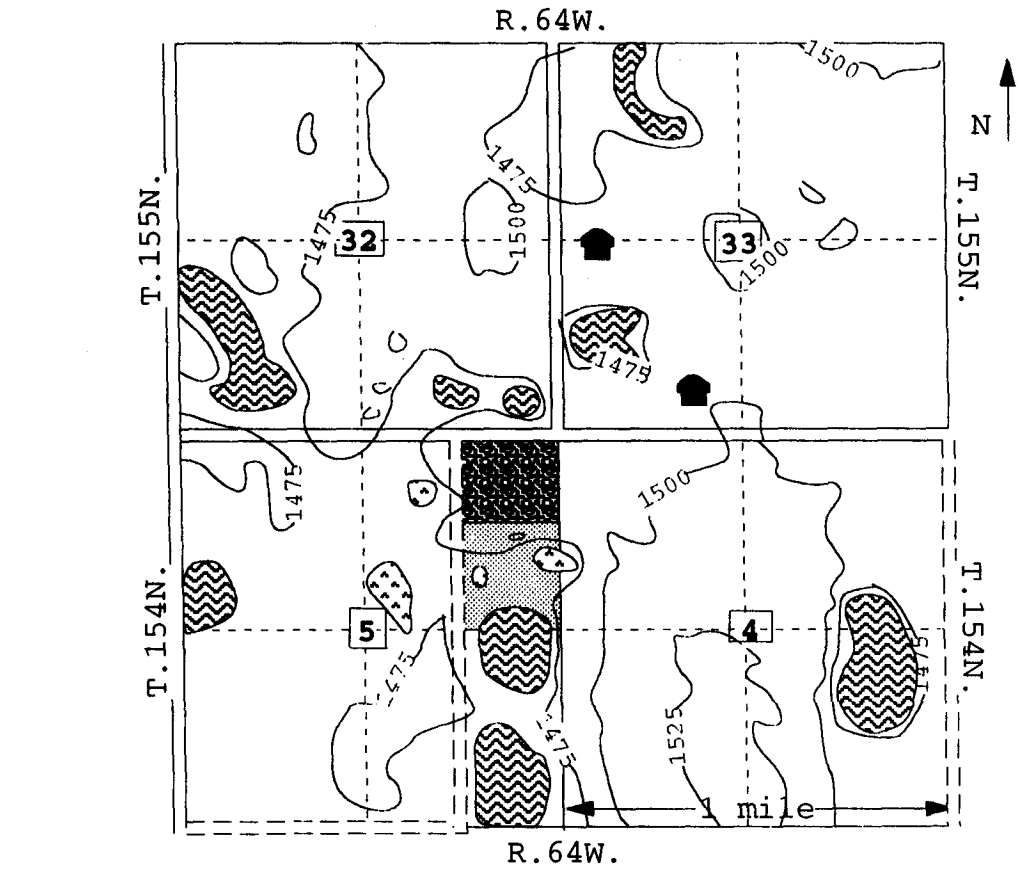

Figure 1. Location of the Devils Lake landfill in the NE 1/4 of section 5.

Previous Site Investigations

A study of six landfills in North Dakota that included the Devils Lake landfill was completed in 1992 by the NDGS (Murphy, 1992). This study was based on data collected from 13 monitoring wells at the landfill. The wells were generally nested in pairs to monitor the top of the uppermost aquifer and 10 to 20 feet below the top of the uppermost aquifer. Till occured at land surface to depths of 50 to 100 feet. A 3 to 15-foot-thick sand layer within the till was continuous across the landfill at depths of about 15 to 20 feet from the surface. Dark gray shale (Pierre Formation) occured below the sand at a couple of well locations and was considered to be an isolated block within the till.

The water table in the till occurred at depths of 12 to 18 feet below the land surface. It was also determined that the refuse was buried within 5 feet of the water table. The NDGS study indicated a water table mound under the landfill with ground-water flowing to the west, southwest, and northwest. Water-quality analyses showed leachate migration from the refuse into the underlying aquifer. VOC compounds were detected in four of the thirteen wells. The results did not indicate leachate migration past the landfill boundaries.

Methods of Investigation

The Devils Lake study was accomplished by: 1) test drilling; 2) construction and development of monitoring wells; 3) collecting and analyzing water samples; and 4) measuring water levels.

Test Drilling Procedure

The drilling method at the Devils Lake landfill was based on the site's geology and depth to ground water, as determined by the preliminary site evaluation. An eight-inch hollow-stem auger drill rig was used at the Devils Lake landfill. The lithologic descriptions were determined from drill cuttings. Water used with the drill rig was obtained from the Devils Lake landfill well.

Monitoring Well Construction and Development

The number of wells installed at the Devils Lake landfill was based on the geologic and topographic characteristics of the site. Eight test holes were drilled at the Devils Lake landfill, and monitoring wells were installed in five of the test holes. The wells were screened to monitor the top of the uppermost aquifer. Thirteen North Dakota Geological Survey (NDGS) monitoring wells were also used in this investigation (Murphy, 1992).

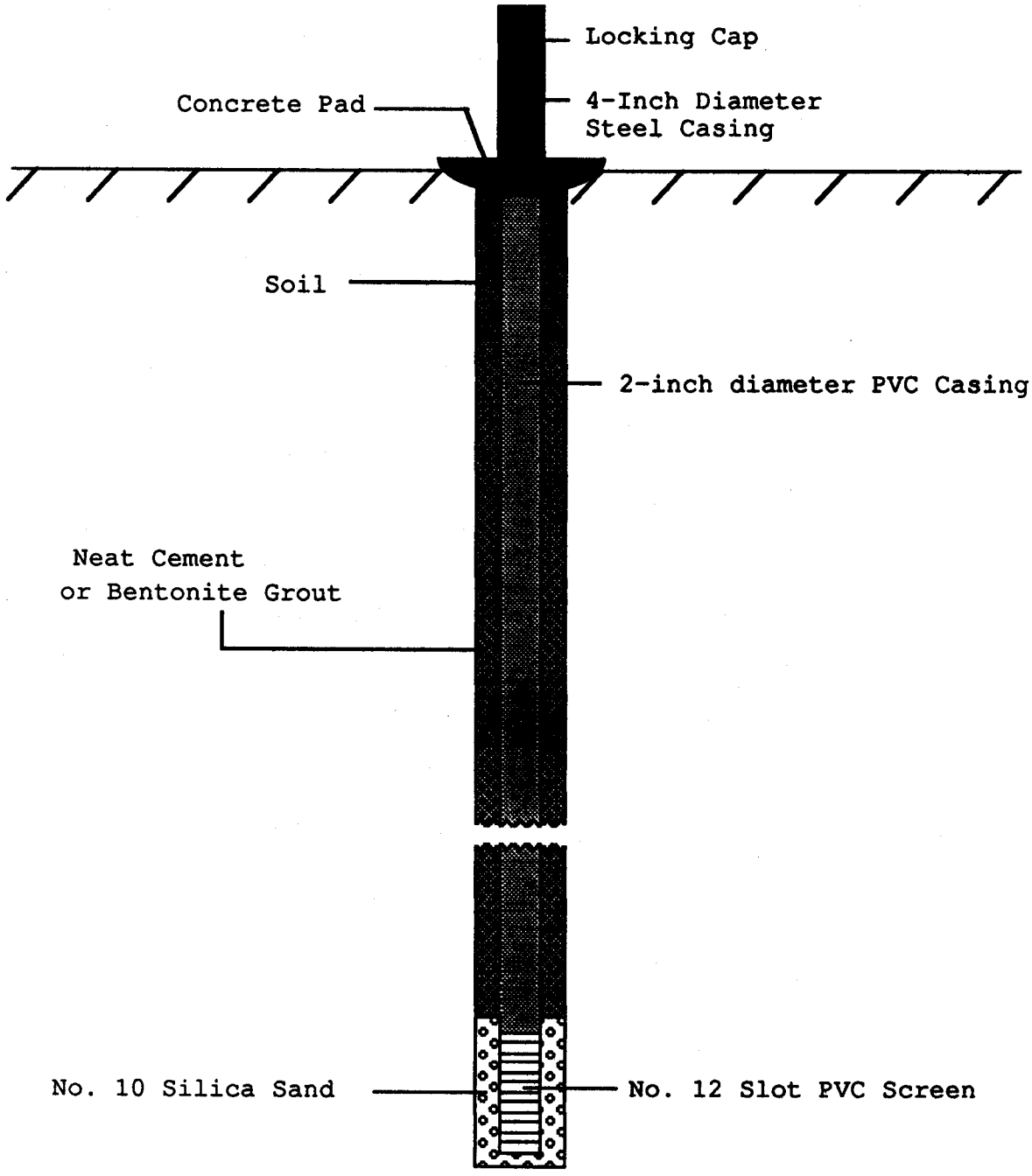

Figure 2. Construction design used for monitoring wells installed at the Devils Lake landfill.

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 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 and 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 using 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.

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 154-064-05AAD would be located in the SE1/4, NE1/4, NE1/4 Section 5, Township 154 North, Range 64 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 154-064-05AAD1 and 154-064-05AAD2.

GEOLOGY

Regional Geology

The surface and near-surface materials in the region around the Devils Lake landfill include a variety of Pleistocene glacial sediments and minor Holocene sediments (Hobbs and Bluemle, 1987). The glacial sediments, consisting of till, outwash, and lake sediments, were deposited at this site during at least two and up to five glacial advances. Holocene sediments consist primarily of stream, pond, and slough deposits.

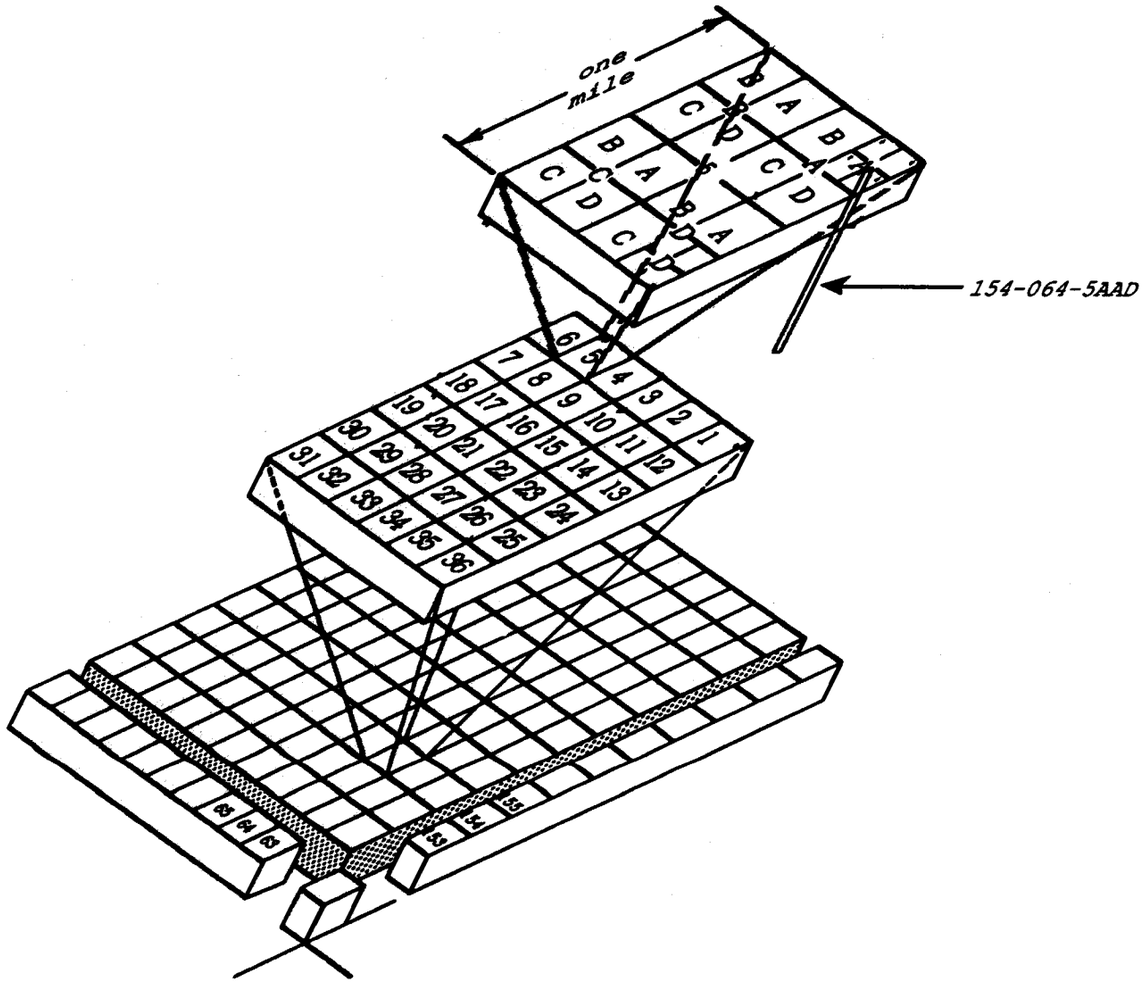

Figure 3. Location-numbering system for the Devils Lake landfill.

Bedrock occurs only in the subsurface. The uppermost bedrock unit, the Pierre Formation, consists of light gray to dark gray shale, clay, and bentonite. The depth to bedrock in sections surrounding the landfill ranges from 60 to 140 feet (Hutchinson, 1977).

Much of the sedimentation and topography of the region resulted from the last (Late Wisconsinan) glacial advance. Collapsed sediment from the Late Wisconsinan glacier covers the area surrounding the landfill and obscures the pre-existing topography. Large-scale ice thrusting that occurred during the Late Wisconsinan glaciation was an important factor in determining the configuration of the land surface in the region.

As the Late Wisconsinan glacier receded, proglacial lakes developed, first south and then north, of the landfill area. To the south, glacial Lake Minnewauken occupied roughly the same area as present-day Devils Lake. Glacial Lake Cando formed later in northwestern Ramsey County. Dry Lake (two miles northwest of the landfill) and Sweetwater Lake (two miles northeast of the landfill) are modern remnants of glacial Lake Cando.

Local Geology

The Devils Lake landfill is located in an area of collapsed glacial sediments with a hummocky topography. A large hill east of the landfill in section 4 rises 60 feet

higher than the landfill. Several smaller hills are present south of the landfill. Numerous wetlands surround the landfill, and several small depressions occur within the 40-acre site.

The sediments at the landfill site consist mainly of till and outwash. Till is present at the surface over the active area of the landfill. The surficial layer of till ranges from 16 to 25 feet thick. The till in this area is an unsorted mixture of clay, silt, sand, and gravel, with clay being the dominant particle size.

A layer of outwash, consisting of very-fine-grained to very-coarse-grained sand, underlies the till throughout the site. This sand ranges from 3 to 15 feet thick within the landfill boundaries (Murphy, 1992). North of the landfill, at 155-064-32DDA1, the sand is at least 22 feet thick (Figs. 4 and 5; lithologic logs in Appendix C). South of the landfill, at 154-064-05ADD1, it is at least 26 feet thick.

Although the origin of the sand layer is uncertain, available data suggests that it may be part of a buried meltwater channel. The topography that existed before the last ice advance has been largely covered, and the only clue to the pre-existing topography is the occurrence of several chains of wetlands. Many of the wetlands are found in the area between the landfill and Dry Lake. The wetlands, as well as Dry Lake, may mark the route of a buried valley that existed before the Late Wisconsinan glacial advance.

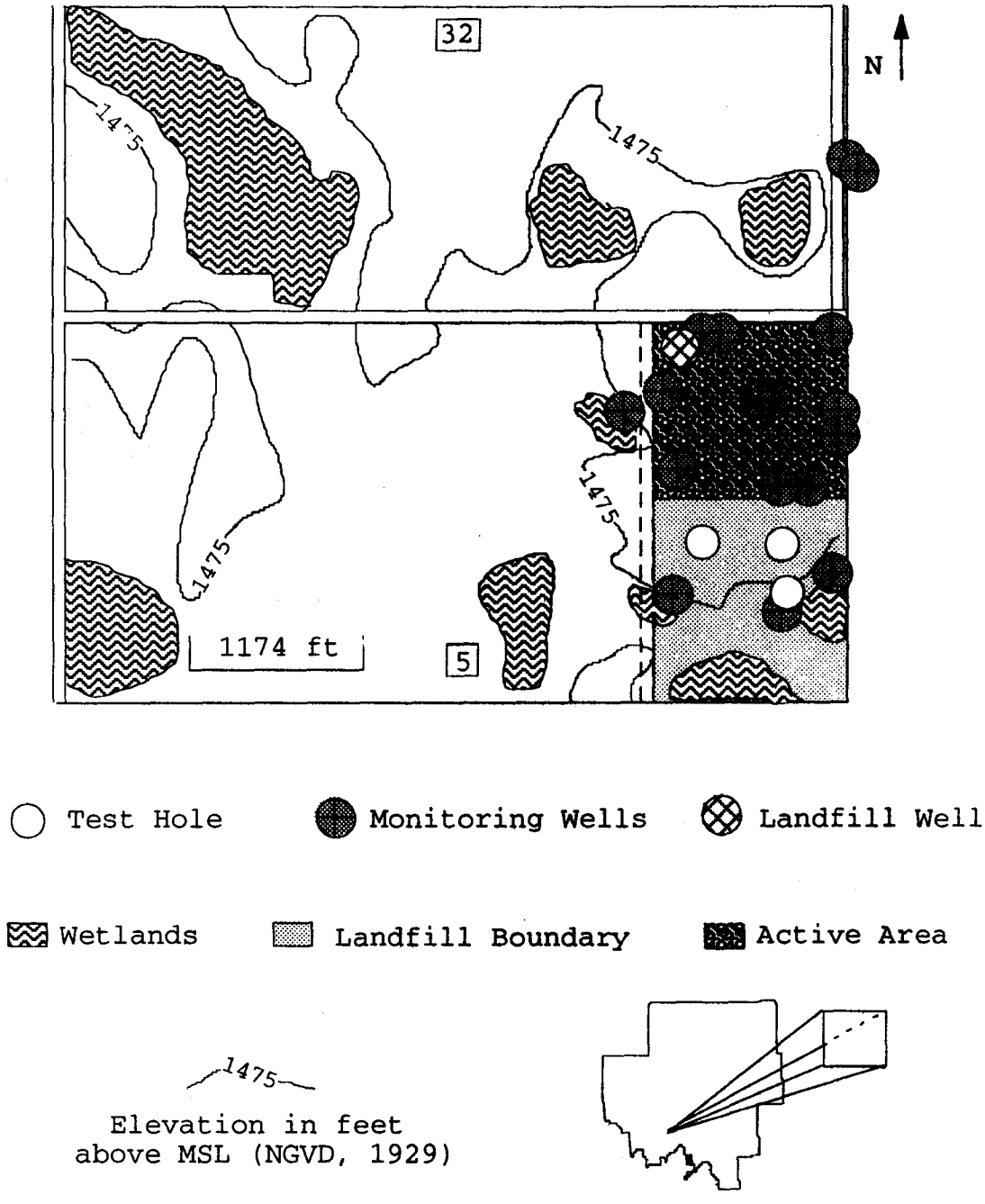

Figure 4. Location of monitoring wells and the direction of ground-water flow at the Devils Lake landfill.

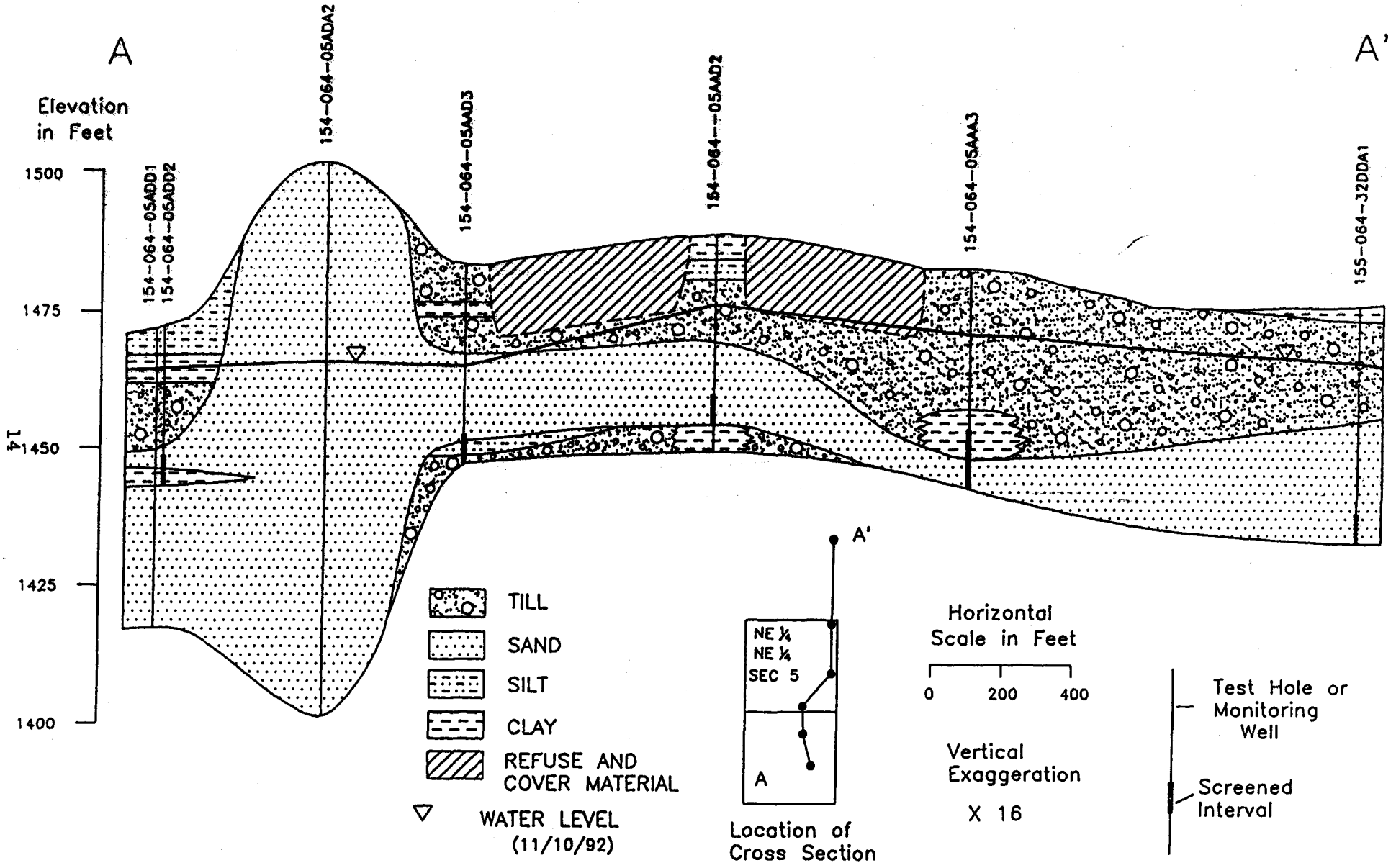

Figure 5. Geohydrologic section A–A' in the Devils Lake landfill

A test hole (154-064-05ADA2) on the highest hill south of the landfill encountered sand from the surface downward to a depth of 100 feet. This hill is probably some kind of an ice-contact deposit, possibly part of an esker. The sand in the hill merges with the layer of sand underlying the landfill (Fig. 5).

In addition to till and outwash, thin intervals of clay were encountered in several drill holes. Some of the clay was derived from the Pierre Formation, and some originated as pond and slough deposits. Intervals of clay definitely identified as Pierre Formation were encountered in two wells (154-064-05AAA3 and 155-064-05AAD2). These occurrences are believed to be isolated blocks contained within the till. None of the wells or test holes at the site reached in-place bedrock.

HYDROLOGY

Surface-Water Hydrology

The Devils Lake landfill is located in an area characterized by hummocky topography. Several wetlands and depressions are situated within a two-mile radius of the landfill. Water samples were not collected from any surface waters. Shallow depressions are located within the active

area of the landfill. These depressions may hold water during times of high precipitation.

Wetlands near the Devils Lake 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 recharge areas for the ground water during periods of high precipitation or runoff. Water that is not lost to evapotranspiration infiltrates into the till and may move downward into the underlying sand aquifer. During periods of low precipitation these wetlands may become local discharge areas for the ground-water flow system. As a result, contaminants may be introduced into these wetlands from lateral flow in the till and upward flow from the underlying sand aquifer.

Regional Ground-Water Hydrology

There are no major glacial aquifers within a two-mile radius of the Devils Lake landfill. The Spiritwood aquifer (a major glacial aquifer) is located about five miles west of the landfill. The Starkweather aquifer is located about nine miles east of the landfill. These aquifers should not be contaminated by leachate from the landfill.

A bedrock aquifer (Pierre Formation) is located about 600 feet below land surface at the landfill site (Hutchinson, 1980). This aquifer should not be contaminated by leachate because of its depth.

Local Ground-Water Hydrology

Eight test holes were drilled at the Devils Lake landfill with monitoring wells installed in five of the eight (Fig. 6). In addition, twelve monitoring wells from the NDGS study (Murphy, 1992) were used in evaluating this site. The well screens were placed near the top of the till and the top of the sand layer beneath the landfill. Four water-level measurements were taken over a seven-week period (Appendix D).

The till has a lower hydraulic conductivity than the underlying sand and functions as an aquitard with water in the sand aquifer occurring under confined conditions. Water levels in the till are above those in the underlying sand indicating downward flow through the till into the underlying sand aquifer (Fig. 7, A-A'). The water table in the till intersects the refuse cell at well 154-064-05AAA2 (Fig. 7, A-A'). Because the till is relatively thin and movement of ground water is downward through the till into the underlying sand, the potential exists for the sand aquifer to be contaminated by leachate from the landfill.

The thickness of the sand layer underlying the till (Fig. 7) ranges from two to greater than forty feet. The direction of ground-water flow in this aquifer is south-southwest and may, to some extent, discharge upward into the semi-permanent wetlands south of the landfill.

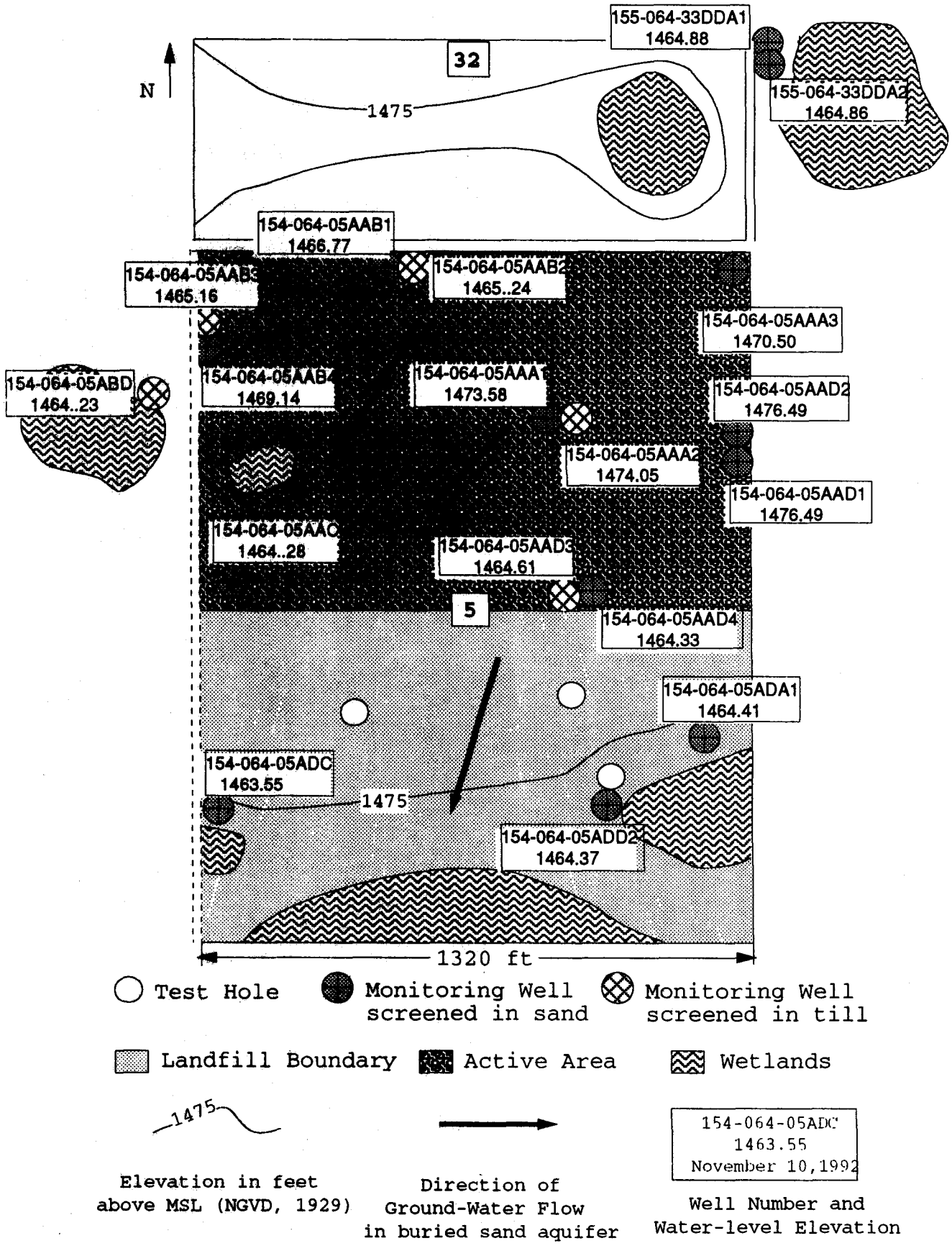

Figure 6. Water levels at the Devils Lake landfill and direction of ground-water flow in the buried sand aquifer.

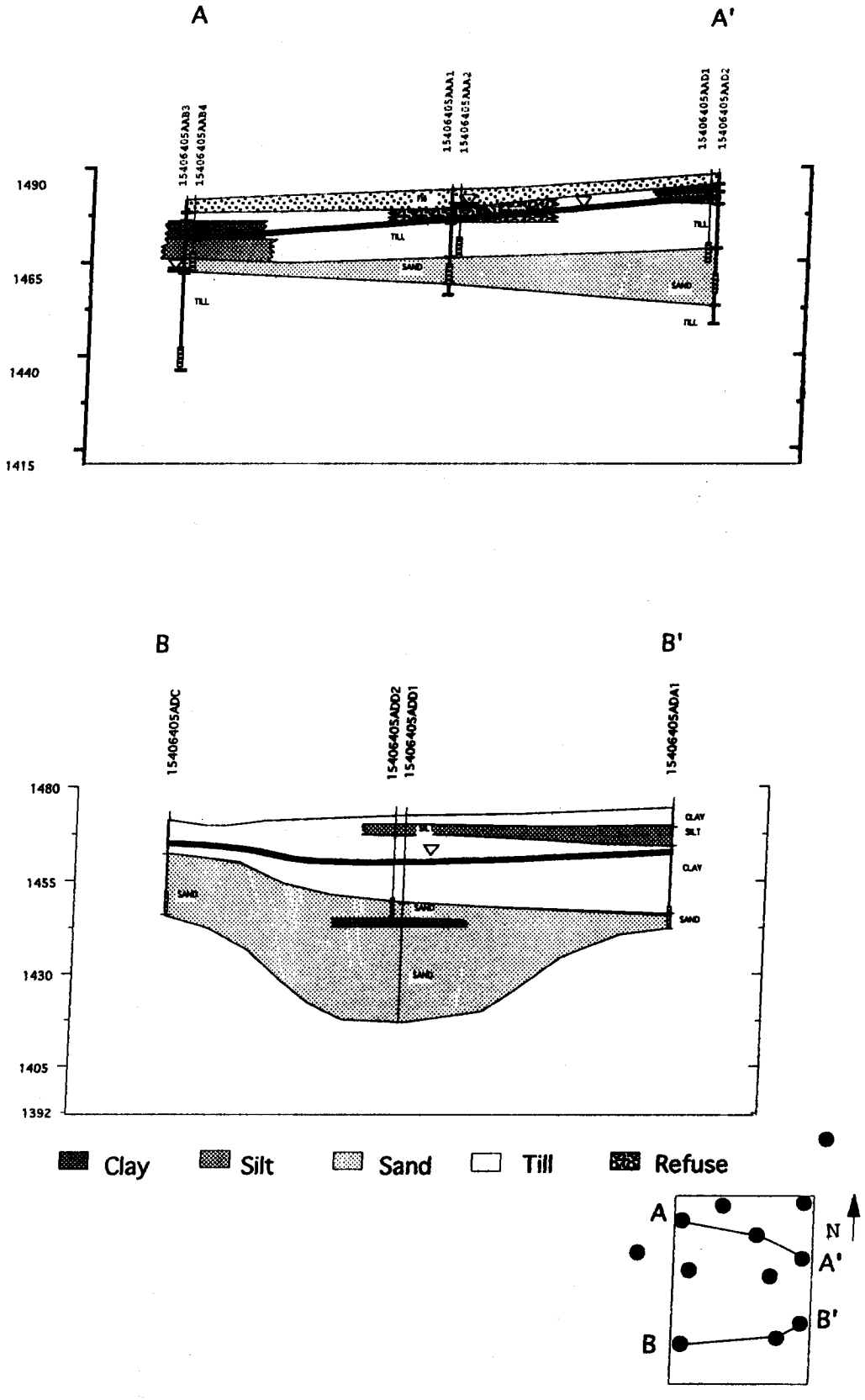

Figure 7. West to east transect cross-sections across the Devils Lake landfill.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Wells 155-064-33DDA1 (sand aquifer) and 155-064-33DDA2 (top of the sand aquifer) were used as up-gradient wells for this study. Based on the chemical concentrations at these wells leachate contamination was indicated in eight monitoring wells inside and one monitoring well outside the landfill boundaries. Five of the nine wells indicating contamination are screened in the sand aquifer and four wells are screened in the till above the sand.

Increased chloride concentrations were found in eight of the nine wells (Fig. 8). Chloride, a conservative ion, may be used as a primary indicator of leachate migration. Four of the eight wells with increased chloride concentrations are below the MCL (250 mg/L), but are considerably higher than the up-gradient concentrations (88 mg/L). Well 154-064-05AAA2 (screened in the till) shows a chloride concentration of 1100 mg/L, which is four and a half times higher than the MCL. This suggests leachate migration from the refuse downward through the till into the sand aquifer.

Well 154-064-05ABD, located west of and outside the landfill boundary, had a chloride concentration of 150 mg/L. This concentration indicate leachate movement to the south-southwest and beyond the landfill boundaries (Murphy, 1992). This chloride concentration increase may also be due to

accumulation by evapotranspiration caused by a possible discharge characteristic of the seasonal wetland.

Well 154-064-05AAC also detected nitrate concentrations of 34 mg/L (MCL=10 mg/L). This concentration is ten times higher than the up-gradient well. This well is located at the southwest corner of the active area.

The trace-element analyses indicate four wells with elevated arsenic concentrations (Fig. 9). Two of the wells are screened in the sand aquifer and the other two are screened in the till. The arsenic concentrations at these wells are 5 to 8 times higher than concentrations in the up-gradient wells (5 µg/L) suggesting leachate migration into the sand aquifer. Wells 154-064-05AAD1 and 154-064-05AAD2 (screened in the sand aquifer) detected the highest concentrations, 44 and 48 µg/L respectively.

Two wells detected concentrations of selenium (Fig. 10) greater than the MCL (10 µg/L). These two wells are screened in the sand aquifer. Well 154-064-05AAC, located on the west side of the landfill, indicated a selenium concentration (550 µg/L) fifty-five times higher than the MCL suggesting leachate migration into the underlying sand aquifer.

Two wells south of the active area were selected for a VOC analysis. The results from well 154-064-05ADC are shown in Appendix F and well 154-064-05AAD4 are shown in Appendix G. No VOC compounds were detected at these two locations.

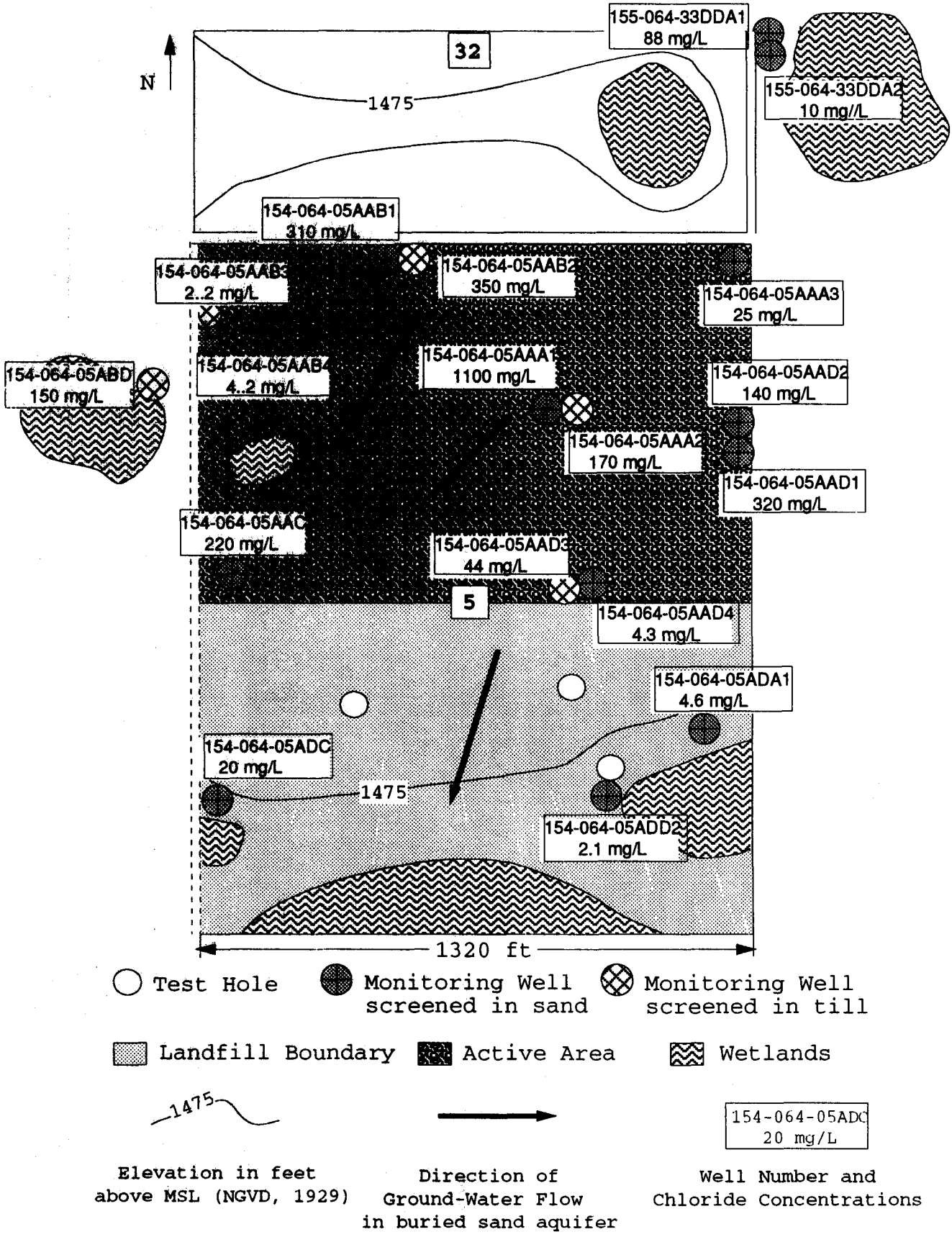

Figure 8. Chloride concentrations (mg/L) at the Devils Lake landfill.

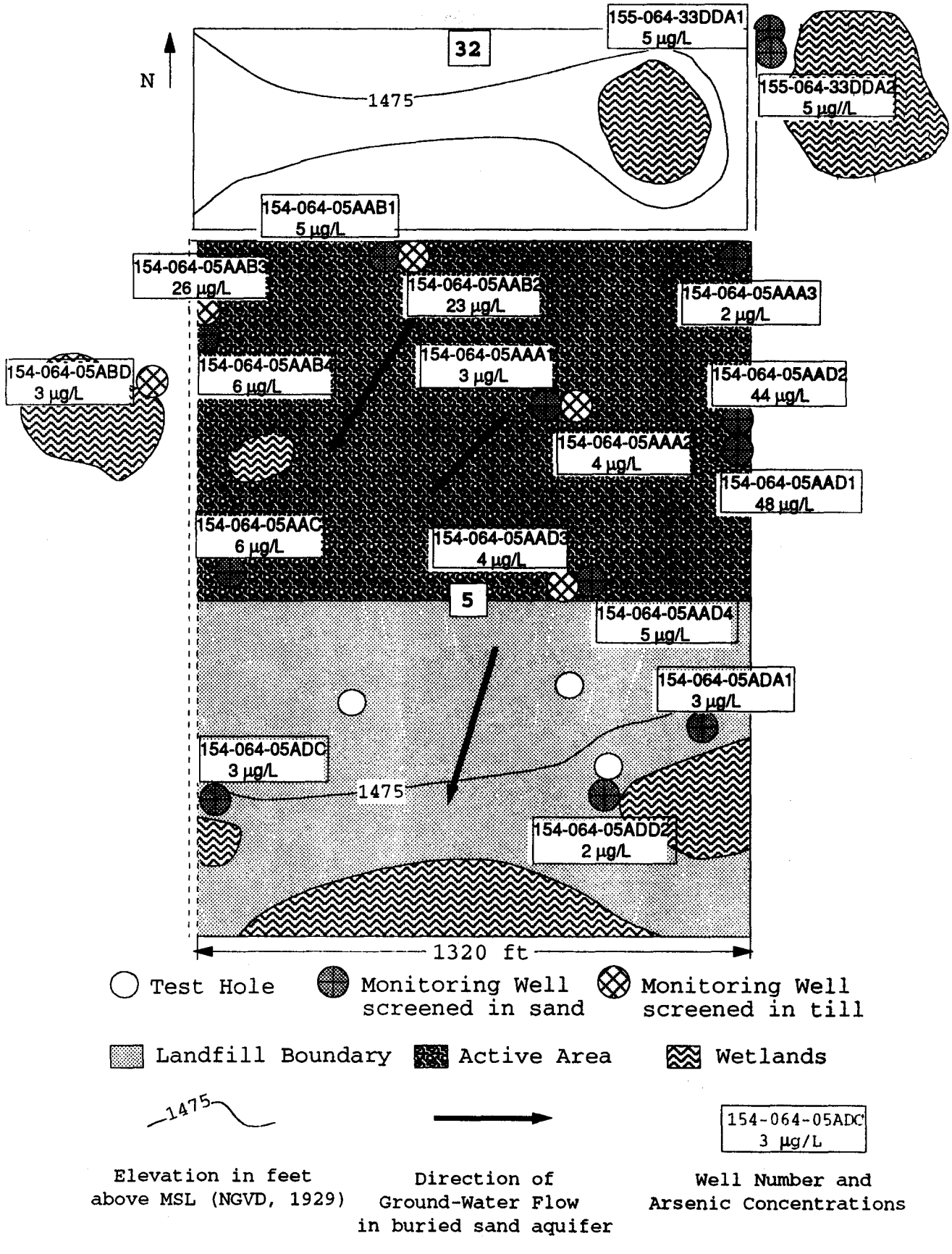

Figure 9. Arsenic concentrations (µg/L) at the Devils Lake landfill.

CONCLUSIONS

The Devils Lake landfill is located in an area of collapsed glacial sediments with a hummocky topography. The main lithologies at the landfill consist of till and outwash. Till is present at land surface and ranges in thickness from 16 to 25 feet. The till consists of a mixture of clay, silt, sand, and gravel, with clay being the dominant particle size. A layer of well-sorted sand ranging in thickness from 3 to greater than 40 feet, underlies the till throughout the site.

Several wetlands are present around the Devils Lake landfill. The semi-permanent wetlands, south of the landfill, appear to be discharge areas for the local ground-water flow system. Seasonal wetlands show flow-through characteristics based on visual observations of topographic location, and vegetation. These wetlands appear to discharge into the semi-permanent wetlands.

Within the landfill site, water occurs under confining conditions in the buried sand aquifer. The confining layer consists of till. Water levels in the till are above those in the underlying sand indicating downward flow through the till into the underlying sand aquifer. The water table in the till intersects the refuse cell. Because the till is relatively thin and movement of ground water is downward through the till into the underlying sand, the potential exists for the sand aquifer to be contaminated by leachate from the landfill.

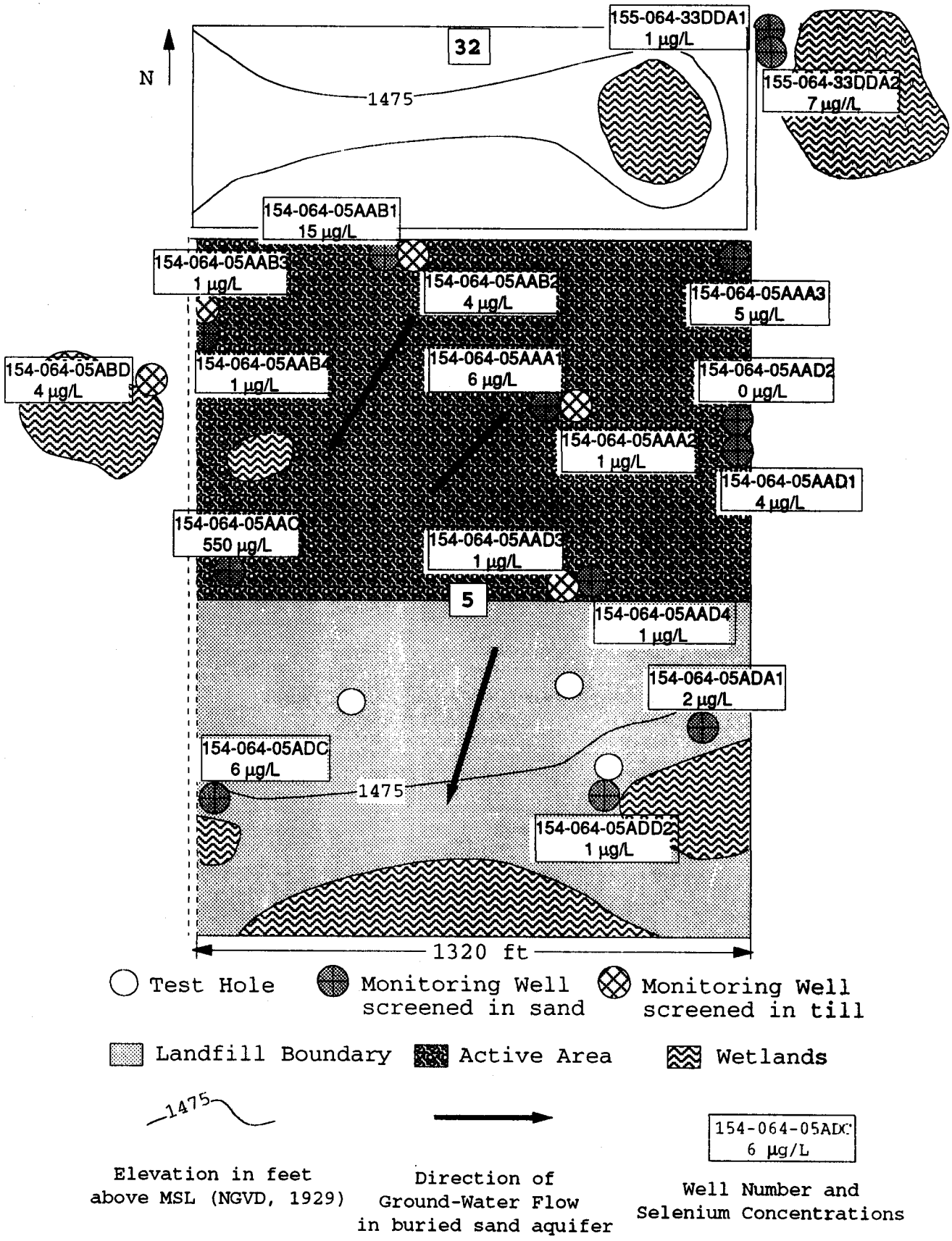

Figure 10. Selenium concentrations (µg/L) at the Devils Lake landfill.

The underlying sand aquifer appears to extend beyond the landfill boundaries. The direction of ground-water flow in the sand aquifer appears to be to the south-southwest and may, to some extent, discharge upward into the semi-permanent wetlands south of the landfill.

Chemical analyses of water samples indicate leachate migration into the till aquitard and underlying sand aquifer. Elevated chloride concentrations were detected in eight monitoring wells. Five of the eight wells are screened in the sand aquifer. Chloride detection in well 154-064-05ABD indicates leachate migration beyond the landfill boundaries. Well 154-064-05AAC (screened in the sand aquifer) also detected a nitrate concentration of 34 mg/L exceeding the MCL of 10 mg/L.

Trace-element analyses also detected elevated arsenic concentrations (23 to 48 µg/L) in four wells nearing the MCL (50 µg/L). Two of the wells are screened in the sand aquifer. Two other wells, screened in the sand aquifer, detected selenium concentrations of 15 and 550 µg/L exceeding the MCL of 10 µg/L. Well 154-064-05AAC indicated a selenium concentration (550 µg/L) 55 times higher than the MCL. An increase of this magnitude suggests leachate migration out of the landfill.

Water samples for VOC analyses were taken from two wells south of the active area. No VOC compounds were detected at these wells.

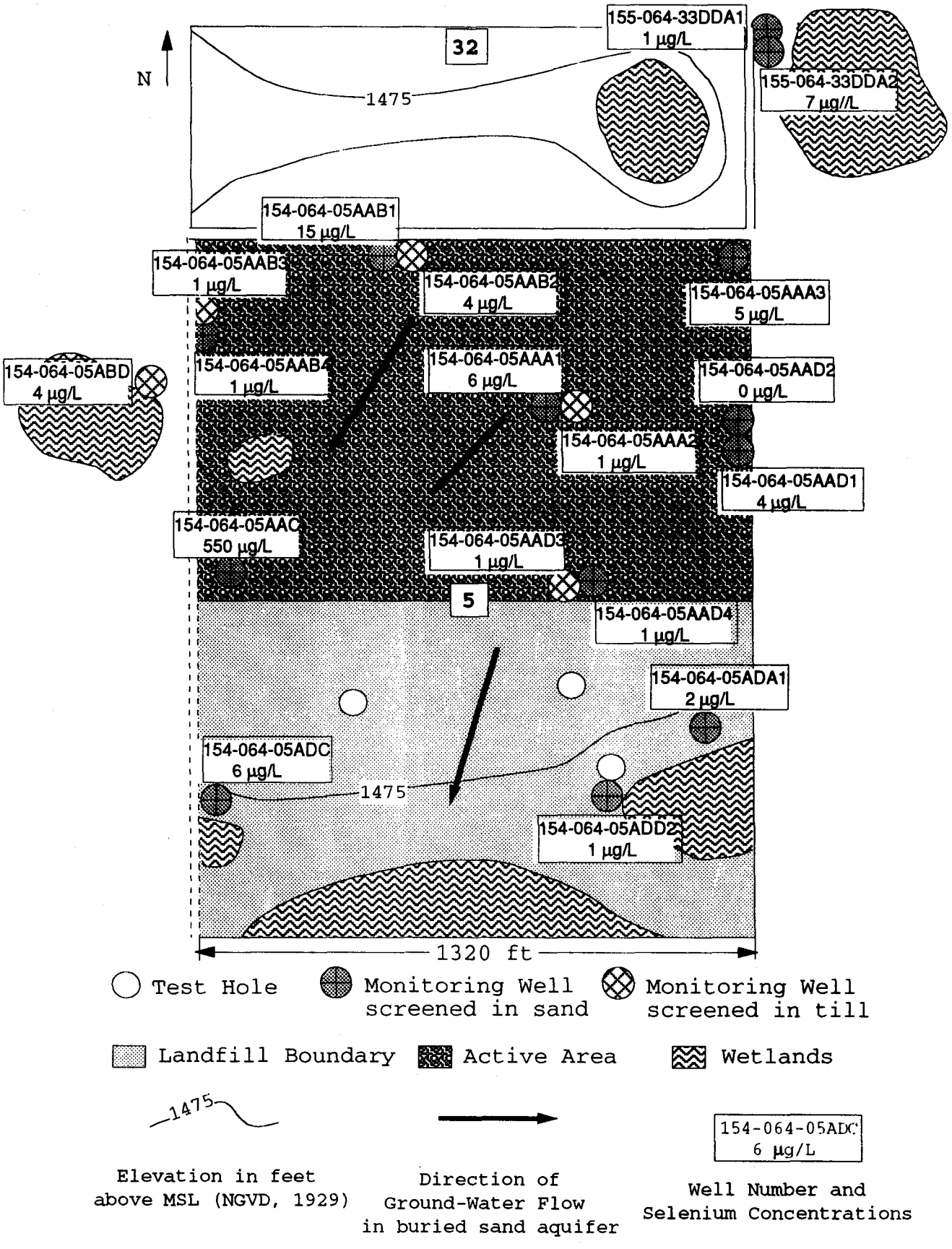

Figure 10. Selenium concentrations (µg/L) at the Devils Lake landfill.

The underlying sand aquifer appears to extend beyond the landfill boundaries. The direction of ground-water flow in the sand aquifer appears to be to the south-southwest and may, to some extent, discharge upward into the semi-permanent wetlands south of the landfill.

Chemical analyses of water samples indicate leachate migration into the till aquitard and underlying sand aquifer. Elevated chloride concentrations were detected in eight monitoring wells. Five of the eight wells are screened in the sand aquifer. Chloride detection in well 154-064-05ABD indicates leachate migration beyond the landfill boundaries. Well 154-064-05AAC (screened in the sand aquifer) also detected a nitrate concentration of 34 mg/L exceeding the MCL of 10 mg/L.

Trace-element analyses also detected elevated arsenic concentrations (23 to 48 µg/L) in four wells nearing the MCL (50 µg/L). Two of the wells are screened in the sand aquifer. Two other wells, screened in the sand aquifer, detected selenium concentrations of 15 and 550 µg/L exceeding the MCL of 10 µg/L. Well 154-064-05AAC indicated a selenium concentration (550 µg/L) 55 times higher than the MCL. An increase of this magnitude suggests leachate migration out of the landfill.

Water samples for VOC analyses were taken from two wells south of the active area. No VOC compounds were detected at these wells.

In summary, site conditions at the Devils Lake landfill are conducive to leachate migration downward into the buried sand aquifer. These conditions are: 1) relatively thin till aquitard (16 to 25 feet thick); 2) the water table in the till intersects the refuse cells; and 3) hydraulic gradient indicates downward flow through the till into the sand aquifer. Contamination from the landfill has been detected in the sand aquifer beyond the landfill boundaries.

REFERENCES

Hobbs, H.C., and Bluemle, J.P., 1987, Geology of Ramsey County, North Dakota: North Dakota Geological Survey, Bulletin 71, North Dakota State Water Commission, County Ground-water Studies 26, Part I, 69 p.

Hutchinson, R.D., 1977, Ground-water basic data for Ramsey County, North Dakota: North Dakota Geological Survey, Bulletin 71, North Dakota State Water Commission, County Ground-Water Studies 26, Part II, 344 p.

Hutchinson, R.D., and Klausing, R.L., 1980, Ground water resources of Ramsey County, North Dakota: North Dakota Geological Survey, Bulletin 71, North Dakota State Water Commission, County Ground-Water Studies 26, Part III, 36 p.

Murphy, E.C., 1992, Organic and inorganic contaminants in shallow groundwater at six minicipal landfills in North Dakota: North Dakota Geological Survey, Report of Investigation No. 94, 136 p.

North Dakota Department of Health, 1986, Water well construction and water well pump installation: Article 33-18 of the North Dakota Administrative Code.

APPENDIX A

STANDARD WATER QUALITY STANDARDS AND MAXIMUM CONTAMINANT LEVELS

Water Quality Standards and Maximum Contaminant Levels

Field Parameters	MCL (mg/L)
appearance	color/odor
pH	6-8 (optimum)
specific conductance	-----
temperature	-----
water level	-----
Geochemical Parameters	
iron	>0.3
calcium	25-50
magnesium	25-50
manganese	>0.05
potassium	------
total alkalinity	------
bicarbonate	150-200
carbonate	150-200
chloride	250
fluoride	0.7-1.2
nitrate+nitrite (N)	10
sulfate	300-1000
sodium	20-170
total dissolved solids (TDS)	>1000
cation/anion balance	------
hardness	>121 (hard to very hard)
Heavy Metals (µg/L)	
arsenic	50
cadmium	10
lead	50
molybdenum	100
mercury	2
selenium	10
strontium	*

* EPA has not set a MCL for strontium. The median concentration for most U.S. water supplies is 110 µg/L (Hem, 1989).

APPENDIX B

VOLATILE ORGANIC COMPOUND

SAMPLING PROCEDURE

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 lad. 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. Scew 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 colledtion 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

LITHOLOGY TABLES

154-064-05AAA1

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	28	Source of Data:	NDGS
Screened Interval (ft):	21-26	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1484.22
Owner: Devils Lake			

Lithologic Log

Unit	Description	Depth (ft)
Fill	Reworked material	0-5
Refuse		5-9
TILL	Gray-green, large shale pebbles, strong odor	9-13
TILL	Brown to gray, pebbles	13-18
SAND	Very coarse to very fine grain, silty, well sorted, gray-brown	18-25
TILL	Shaley, hematite staining along possible fractures, dark blue	25-28

154-064-05AAA2

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	18	Source of Data:	NDGS
Screened Interval (ft):	13-18	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1484.25

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
Fill	Reworked material	0-5
Refuse		5-9
TILL	Large shale pebbles, gray-green, strong odor	9-13
TILL	Brown to gray, pebbles	13-18

154-064-05AAA3

NDSWC

Date Completed:	9/3/92	Well Type:	P2
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	30-40	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1482.53
Owner: Devils Lake			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Silty, trace of pebbles, brownish gray 5YR 4/1 (till)	2-5
CLAY	Trace of sand and pebbles, brownish gray with moderate reddish brown mottles (till)	5-9
CLAY	Trace of sand and pebbles, dark yellowish brown 10YR 4/2 (till)	9-17
CLAY	Trace of sand and pebbles, fragments of dark gray shale (till)	17-26
SHALE	Dark gray N3 (block of Pierre shale)	26-31
CLAY	soft, dark gray N3 (Pierre Shale)	31-35
SAND	Fine to medium grain, very pale orange 10YR 8/2 (drift)	35-40

154-064-05AAB1

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	28	Source of Data:	NDGS
Screened Interval (ft):	22-28	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1481.61

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, brown-black	0-1
TILL	Gray-brown, cobbles	1-3
TILL	Brown, iron stained, cobbles	3-8
TILL	Light brown, pebbles	8-13
TILL	Light brown, pebbles, gypsum crystals and iron staining concentrated along fracture in core	13-23
TILL	Dark gray, cobbles and pebbles	23-25
SAND	Medium to very coarse grain, poorly sorted, gray-black	25-27
TILL	Dark gray, pebbles to small cobbles	27-28

154-064-05AAB2

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	46	Source of Data:	NDGS
Screened Interval (ft):	40-45	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1481.74

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, brown-black	0-1
TILL	Gray-brown, cobbles	1-3
TILL	Brown, iron stained, cobbles	3-8
TILL	Light brown, pebbles	8-13
TILL	Light brown, gypsum crystals and iron staining along fracture in core, pebbles	13-23
TILL	dark gray, pebbles and cobbles	23-25
SAND	medium to very coarse grain, cross bedded, poorly sorted,gray-black	25-27
TILL	Dark gray, pebbles to small cobbles	27-30
SILT	Very fine sands, well sorted, gray	30-33
TILL	Dark gray, small cobbles	33-40
TILL	Silty, dark gray, pebbles	40-43
TILL	Shaley, dark gray, pebbles	43-46

154-064-05AAB3

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	45	Source of Data:	NDGS
Screened Interval (ft):	38-43	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1481.12

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
Fill	Reworked material	0-3
TILL	Gray-brown to medium brown, pebbles	3-5
CLAY	Gray to black, organic rich, laminated, tree bark and common roots	5-8
CLAY	Gray, no longer organic	8-10
SILT	Well sorted, light brown-gray	10-13
SILT	Clayey, light brown to gray	13-15
SAND	Fine grain, well sorted, light brown	15-19
TILL	Green-gray, pebbly to cobbly	19-28
TILL	Shaley, dark gray, cobbly	28-45

154-064-05AAB4

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	18	Source of Data:	NDGS
Screened Interval (ft):	13-18	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1480.96

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
Fill	Reworked material	0-3
TILL	Gray-brown to brown, pebbles	3-5
CLAY	Gray to black, organic rich, laminated, tree bark and common roots	5-8
CLAY	Gray,no longer organic	8-10
SILT	Light brown-gray, well sorted	10-13
SILT	Clayey, light brown-gray	13-15
SAND	Fine grain, well sorted, light brown	15-18

154-064-05AAC

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	28	Source of Data:	NDGS
Screened Interval (ft):	23-28	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1484.38

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, reworked	0-1
TILL	Brown, pebbles	1-20
TILL	Silty, brown, pebbles	20-23
SAND	Very fine to medium grain, silty, well sorted, brown	23-25
SAND	Very fine to fine grain, well sorted, brown	25-28

154-064-05AAD1

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	23	Source of Data:	NDGS
Screened Interval (ft):	18-23	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1488.56

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
Fill	Reworked material	0-3
CLAY	Black, organic rich	3-5
SILT	Clayey, interbedded, yellow-brown	5-8
TILL	Gray-brown, hematite staining common, pebbles	8-11
TILL	Brown, hematite staining common, pebbles	11-20
SAND	medium to fine grain, interbedded silts, gray-blue to gray	20-23

154-064-05AAD2

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	40	Source of Data:	NDGS
Screened Interval (ft):	29-34	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1488.63

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
Fill	Reworked material	0-3
CLAY	Black, organic rich	3-5
SILT	Clayey, interbedded, gray-yellow-brown	5-8
TILL	Gray-brown, hematite staining common, pebbles	8-11
TILL	Brown hematite staining, pebbles	11-20
SAND	Medium grain, interbedded silt, well sorted, gray-blue to gray	20-33
SAND	Medium grain, well sorted, dark gray	33-35
CLAY	Shaley, dark gray	35-40

154-064-05AAD2
NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	36	Source of Data:	NDGS
Screened Interval (ft):	31-36	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1482.72
Owner: Devils Lake			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, reworked	0-1
TILL	Brown-gray, hematite stained, pebbles	1-7.5
CLAY	Very hard and compact, fissile, hematite staining, brown-gray	7.5-9
TILL	Hard and compact, shaley, blue-gray, pebbles	9-16
SAND	Fine to very fine grain, well sorted, brown-gray	16-22
SAND	Fine to very fine, well sorted, gray	22-32
SILT	Well sorted, gray	32-34
TILL	Brown-gray, pebbles	34-36

154-064-05AAD4

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	22	Source of Data:	NDGS
Screened Interval (ft):	17-22	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1482.52

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, reworked	0-1
TILL	Coarse sands, brown-gray, hematite staining,	1-7.5
CLAY	Very hard and compact, hematite staining, fissile, brown-gray	7.5-9
TILL	Hard and compact, shaley, pebbly, blue-gray	9-16
SAND	Very fine to fine grain, well sorted, brown-gray	16-22

154-064-05ABD

NDSWC

Date Completed:	9/3/92	Well Type:	P2
Depth Drilled (ft):	25	Source of Data:	
Screened Interval (ft):	18-23	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1471.27
Owner: Devils Lake			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	Clayey, grayish brown 5YR 3/2	2-6
CLAY	Trace of gravel, dark yellowish orange 10YR6/6, mottles(till)	6-12
CLAY	Trace of gravel, medium dark gray, wet (till)	12-21
CLAY	Sandy, dark greenish gray 5GY 4/1	21-25

154-064-05ADA1

NDSWC

Date Completed:	9/2/92	Well Type:	P2
Depth Drilled (ft):	30	Source of Data:	
Screened Interval (ft):	24-29	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1474.24

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Silty, dark yellowish brown 10YR 4/2	1-5
SILT	Sandy, trace clay, moderate yellowish brown 10YR 5/4	5-10
CLAY	Trace sand and pebbles, moderate yellowish brown 10YR 5/4 (till)	10-13
CLAY	Sandy with pebbles, moderate yellowish brown 10YR 5/4 (till)	13-17
CLAY	Sandy with pebbles, olive gray 5Y 3/2 (till)	17-25
SAND	Fine grain, silty, olive gray 5Y3/2	25-28
SAND	Fine to medium grain, olive gray 5Y3/2	28-30

154-064-05ADA2
NDSWC

Date Completed:	9/2/92	Purpose:	Test Hole
Depth Drilled (ft):	100	Source of Data:	
L.S. Elevation (ft)	1502.25	Owner: Devils Lake	

Lithologic Log

Unit	Description	Depth (ft)
SAND	Fine to medium grain, trace of pebbles, moderate yellowish brown 10YR 5/4 (glacial drift)	0-5
SAND	Fine to medium grain, moderate yellowish brown 10YR 5/4	5-9
SAND	Fine grain, moderate yellowish brown 10YR 5/4	9-17
SAND	Fine to coarse grain with small pebbles, moderate yellowish brown 10YR 5/4	17-32
SAND	Fine to coarse grain with pebbles, olive gray 5Y 3/2	32-75
SAND	Coarse grain with pebbles	75-100

154-064-05ADB

NDSWC

Date Completed:	9/2/92	Purpose:	Test Hole
Depth Drilled (ft):	50	Source of Data:	
L.S. Elevation (ft)	1486.73	Owner: Devils Lake	

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Trace of sand and pebbles, dark yellowish brown 10YR 4/2 (till)	2-4
CLAY	Silty, trace of sand, moderate yellowish brown 10YR 5/4, (till)	4-11
SILT	Clayey, moderate yellowish brown 10YR 5/4	11-16
CLAY	Silty, trace of pebbles, moderate yellowish brown 10YR 5/4, (till)	16-22
CLAY	Trace of sand and pebbles, moderate yellowish brown 10YR 5/4 (till)	22-24
CLAY	Trace of sand and pebbles, olive gray 5Y 4/1 (till)	24-38
SAND	Fine grain, silty, olive gray 5Y 4/1, wet	38-50

154-066-05ADC
NDSWC

Date Completed:	9/2/92	Well Type:	P2
Depth Drilled (ft):	25	Source of Data:	
Screened Interval (ft):	17-22	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1471.03
Owner: Devils Lake			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Trace of sand, brownish black 5YR 2/1	2-5
CLAY	Silty, light brownish gray 5YR 6/1	5-9
SAND	Very fine grain, silty, moderate yellowish brown 10YR 5/4, moist (glacial drift)	9-18
SAND	Fine to medium grain, moderate yellowish brown 10YR 5/4, wet	18-25

154-064-05ADD1

NDSWC

Date Completed:	9/2/92	Purpose:	Test Hole
Depth Drilled (ft):	55	Source of Data:	
L.S. Elevation (ft)	1471.88	Owner: Devils Lake	

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	Trace of sand, moderate yellowish brown 10YR 5/4	2-5
CLAY	Bright olive-gray 5Y 5/2	5-10
CLAY	Trace of sand and pebbles, moderate yellowish brown 10YR 5/4 (till)	10-23
SAND	Fine grain, silty, trace of clay, moderate yellowish brown 10YR 5/4, wet	23-27
CLAY	Medium dark gray N4	27-29
SAND	Fine grain, silty, dark yellowish brown 10YR 4/2	29-34
SAND	Fine grain, silty, olive gray 5Y 3/2	34-41
SAND	Fine to medium grain, olive gray 5Y 3/2	41-49
SAND	medium to coarse grain, olive gray 5Y 3/2	49-55

154-064-05ADD2
NDSWC

Date Completed:	9/2/92	Well Type:	P2
Depth Drilled (ft):	30	Source of Data:	
Screened Interval (ft):	24-29	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1471.88

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	Trace of sand, moderate yellowish brown 10YR 5/4	2-5
CLAY	Light olive gray 5Y 5/2	5-10
CLAY	Trace of sand and pebbles, moderate yellowish brown 10YR 5/4 (till)	10-23
SAND	Fine grain, silty, trace of clay, moderate yellowish brown 10YR 5/4	23-27
CLAY	Medium dark gray N4	27-30

155-064-33DDA1

NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	43	Source of Data:	NDGS
Screened Interval (ft):	38-43	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1476.21

Owner: Devils Lake

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, reworked	0-1
CLAY	Light brown-gray	1-3
TILL	Light brown, pebbles	3-5
TILL	Dark brown, pebbles	5-16
TILL	Dark gray, pebbles	16-18
TILL	Black-gray, pebbles	18-19
TILL	Blue-black, pebbles	19-21
SAND	Very fine grain, well sorted, blue-gray	21-28
SAND	Very fine to medium grain, well sorted, blue-gray	28-43

155-064-33DDA2
NDSWC

Date Completed:	8/1/88	Well Type:	P2
Depth Drilled (ft):	25	Source of Data:	NDGS
Screened Interval (ft):	20-25	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1476.36
Owner: Devils Lake			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Loess, reworked	0-1
CLAY	Light brown-gray	1-3
TILL	Light brown, pebbles	3-5
TILL	Dark brown, pebbles	5-16
TILL	Dark gray, pebbles	16-18
TILL	Black-gray, pebbles	18-19
SAND	Very fine grain, well sorted, blue-gray	19-25

APPENDIX D

WATER LEVEL TABLES

Devils Lake Water-Level Elevations
9/30/92 to 11/19/92

154-064-05AAA1
Undefined Aquifer

LS Elev (msl,ft)=1484.22
SI (ft.)=21-26

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	10.20	1474.02	11/10/92	10.64	1473.58
10/19/92	10.10	1474.12	11/19/92	10.82	1473.40

154-064-05AAA2
Undefined Aquifer

LS Elev (msl,ft)=1484.25
SI (ft.)=13-18

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	9.85	1474.40	11/10/92	10.20	1474.05
10/19/92	9.71	1474.54	11/19/92	10.43	1473.82

154-064-05AAA3
Undefined Aquifer

LS Elev (msl,ft)=1482.53
SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	11.32	1471.21	11/10/92	12.03	1470.50
10/19/92	11.85	1470.68	11/19/92	12.10	1470.43

154-064-05AAB1
Undefined Aquifer

LS Elev (msl,ft)=1481.61
SI (ft.)=22-28

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/29/92	14.46	1467.15	11/10/92	14.84	1466.77
10/19/92	14.34	1467.27	11/19/92	14.72	1466.89

154-064-05AAB2
Undefined Aquifer

LS Elev (msl,ft)=1481.74
SI (ft.)=40-45

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/29/92	16.37	1465.37	11/10/92	16.50	1465.24
10/19/92	16.34	1465.40	11/19/92	18.06	1463.68

154-064-05AAB3 LS Elev (msl,ft)=1481.12
Undefined Aquifer SI (ft.)=38-43

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	15.84	1465.28	11/10/92	15.96	1465.16
10/19/92	15.70	1465.42	11/19/92	16.18	1464.94

154-064-05AAB4 LS Elev (msl,ft)=1480.96
Undefined Aquifer SI (ft.)=13-18

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	11.52	1469.44	11/10/92	11.82	1469.14
10/19/92	11.61	1469.35	11/19/92	11.89	1469.07

154-064-05AAC LS Elev (msl,ft)=1484.38
Undefined Aquifer SI (ft.)=23-28

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/01/92	19.82	1464.56	11/10/92	20.10	1464.28
10/19/92	19.77	1464.61	11/19/92	20.09	1464.29

154-064-05AAD1 LS Elev (msl,ft)=1488.56
Undefined Aquifer SI (ft.)=18-23

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	11.89	1476.67	11/10/92	12.07	1476.49
10/19/92	11.50	1477.06	11/19/92	12.06	1476.50

154-064-05AAD2 LS Elev (msl,ft)=1488.63
Undefined Aquifer SI (ft.)=29-34

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/30/92	12.24	1476.39	11/10/92	12.43	1476.20
10/19/92	11.88	1476.75	11/19/92	12.40	1476.23

154-064-05AAD3 LS Elev (msl,ft)=1482.72
Undefined Aquifer SI (ft.)=31-36

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/01/92	17.89	1464.83	11/10/92	18.11	1464.61
10/19/92	17.85	1464.87	11/19/92	20.87	1461.85

154-064-05AAD4 LS Elev (msl,ft)=1482.52
Undefined Aquifer SI (ft.)=17-22

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/01/92	17.89	1464.63	11/10/92	18.19	1464.33
10/19/92	18.24	1464.28	11/19/92	16.48	1466.04

154-064-05ABD LS Elev (msl,ft)=1471.27
Undefined Aquifer SI (ft.)=18-23

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/02/92	7.24	1464.03	11/10/92	7.04	1464.23
10/19/92	6.82	1464.45	11/19/92	6.77	1464.50

154-064-05ADA1 LS Elev (msl,ft)=1474.24
Undefined Aquifer SI (ft.)=14-19

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/01/92	9.70	1464.54	11/10/92	9.83	1464.41
10/19/92	9.67	1464.57	11/19/92	9.91	1464.33

154-064-05ADC LS Elev (msl,ft)=1471.03
Undefined Aquifer SI (ft.)=17-22

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/02/92	7.74	1463.29	11/10/92	7.48	1463.55
10/19/92	8.04	1462.99	11/19/92	7.46	1463.57

154-064-05ADD2 LS Elev (msl,ft)=1471.88
Undefined Aquifer SI (ft.)=14-19

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
10/01/92	7.28	1464.60	11/10/92	7.51	1464.37
10/19/92	7.40	1464.48	11/19/92	7.54	1464.34

155-064-33DDA1 LS Elev (msl,ft)=1476.21

Unnamed Aquifer SI (ft.)=38-43

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/29/92	11.20	1465.01	11/10/92	11.33	1464.88
10/19/92	10.99	1465.22	11/19/92	11.52	1464.69

155-064-33DDA2 LS Elev (msl,ft)=1476.36

Unnamed Aquifer SI (ft.)=20-25

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/29/92	11.16	1465.20	11/10/92	11.50	1464.86
10/19/92	11.16	1465.20	11/19/92	11.68	1464.68

APPENDIX E

WATER QUALITY ANALYSES
FOR
MAJOR IONS AND TRACE ELEMENTS

Devils Lake Water Quality

Major Ion Analyses

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)→																					
154-064-05AAA1	21-26	09/30/92	29	0.1	1.6	490	290	24	8.7	1080	0	49	1100	0.1	0.3	0.28	2530	2400	1500	2	0.2	4020	14	7
154-064-05AAA2	13-18	09/30/92	26	0.03	2.3	260	99	51	9.8	771	0	180	170	0.1	0.6	0.27	1180	1100	420	9	0.7	2030	18	7.19
154-064-05AAA3	30-40	09/30/92	24	0.13	5.6	170	60	1300	22	528	0	3100	25	0.1	16	2.2	4990	670	240	80	22	5910	10	6.99
154-064-05AAB1	22-28	09/30/92	21	0.08	1.1	570	480	720	27	691	0	3900	310	0.1	1.1	0.36	6370	3400	2800	31	5.4	6610	8	7.66
154-064-05AAB2	40-45	09/29/92	22	1.2	2.7	640	200	300	19	545	0	2100	350	0.1	0.5	0.51	3900	2400	2000	21	2.7	4570	11	7.4
154-064-05AAB3	38-43	09/30/92	25	0.03	0.51	100	30	43	6.7	503	0	86	2.2	0.2	2.7	0.23	545	370	0	20	1	824	10	7.11
154-064-05AAB4	13-18	09/30/92	25	0.03	0.08	270	96	14	2	557	0	550	4.2	0.1	3.3	0.04	1240	1100	610	3	0.2	1690	16	7.01
154-064-05AAC	23-28	10/01/92	23	0.05	0.01	550	120	40	10	343	0	1300	220	0.2	34	0.04	2470	1900	1600	4	0.4	3060	17	7.78
154-064-05AAD1	18-23	10/01/92	25	0.12	0.64	82	84	270	8.5	629	0	210	320	0.2	0	0.12	1310	550	35	51	5	2230	12	7.39
154-064-05AAD2	29-34	09/30/92	20	0.03	0.29	99	50	160	7.3	752	0	13	140	0.2	0	0.07	860	450	0	43	3.3	1490	13	7.06
154-064-05AAD3	31-36	10/01/92	24	0.02	1.8	130	45	3.5	2.1	372	0	160	44	0.1	0	0.01	594	510	200	1	0.1	905	15	7.75
154-064-05AAD4	17-22	10/01/92	24	0.02	0.02	98	53	8	2	469	0	100	4.3	0.1	6.9	0.01	527	460	78	4	0.2	906	24	7.61
154-064-05ABD	18-23	10/02/92	27	0.06	1.9	250	140	350	16	455	0	1400	150	0.7	3.2	0.88	2560	1200	830	38	4.4	3230	12	7.81
154-064-05ADA1	14-19	10/01/92	26	0.03	1.2	140	43	11	7.5	454	0	170	4.6	0.2	0.2	0.04	628	530	150	4	0.2	929	17	7.61
154-064-05ADC	17-22	10/02/92	20	0.04	0.79	360	140	83	9.8	379	0	1300	20	0.3	3.4	0.1	2120	1500	1200	11	0.9	2480	8	7.75
154-064-05ADD2	14-19	10/01/92	26	0.02	0.62	110	28	8	2	431	0	27	2.1	0.3	0.08	0.07	417	390	37	4	0.2	679	16	7.78
155-064-32DDA1	38-43	09/29/92	22	0.08	1	390	190	2300	35	786	0	6000	88	0.1	1.5	2.1	9420	1800	1100	74	23	9940	16	7.92
155-064-32DDA2	20-25	09/29/92	21	0.06	0.99	400	420	660	18	521	0	3700	10	0.3	3.7	0.49	5490	2700	2300	34	5.5	5640	15	8.03

Devils Lake Water Quality
Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
154-064-05AAA1	9/30/92	6	0	0	0	3	40	3100
154-064-05AAA2	9/30/92	1	0	0	0	4	10	840
154-064-05AAA3	9/30/92	5	0	0	0	2	1	1700
154-064-05AAB1	9/30/92	15	0	0	0	5	35	4900
154-064-05AAB2	9/30/92	4	3	0	0	23	53	4600
154-064-05AAB3	9/30/92	1	0	0	0	26	59	810
154-064-05AAB4	9/30/92	1	0	0	0	6	0	450
154-064-05AAC	10/01/92	550	0	0	0	6	5	1600
154-064-05AAD1	10/01/92	4	0	0	0	48	81	750
154-064-05AAD2	9/30/92	0	0	0	0	44	16	890
154-064-05AAD3	9/30/92	1	0	0	0	4	160	270
154-064-05AAD4	10/01/92	1	0	0	0	5	0	250
154-064-05ABD	10/01/92	4	0	0	0	3	4	1600
154-064-05ADA1	10/01/92	2	0	0	0	3	4	420
154-064-05ADC	10/01/92	6	0	0	0	3	6	1300
154-064-05ADD2	10/01/92	1	0	0	0	2	3	250
155-064-33DDA1	9/30/92	1	1	0	0	5	140	5300
155-064-33DDA2	9/30/92	7	0	0	0	5	53	2000

APPENDIX F

WATER QUALITY RESULTS FOR VOLATILE ORGANIC COMPOUNDS
FOR WELL 154-064-05ADC

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

APPENDIX G

WATER QUALITY RESULTS FOR VOLATILE ORGANIC COMPOUNDS FOR WELL 154-064-05AAD4

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