Site Suitability Review of the New Salem Landfill

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

ND Landfill Site Investigation No. 2

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OF THE
NEW SALEM LANDFILL

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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 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 New Salem municipal solid waste landfill is one of the landfills being evaluated.

Location of the New Salem Landfill

The New Salem municipal solid waste landfill is located 1/2 mile east of the City of New Salem in Township 139 North, Range 85 West, E1/2, NW1/4 Section 22 (Fig. 1). The landfill site encompasses approximately 10 acres, of which all the area has been used.

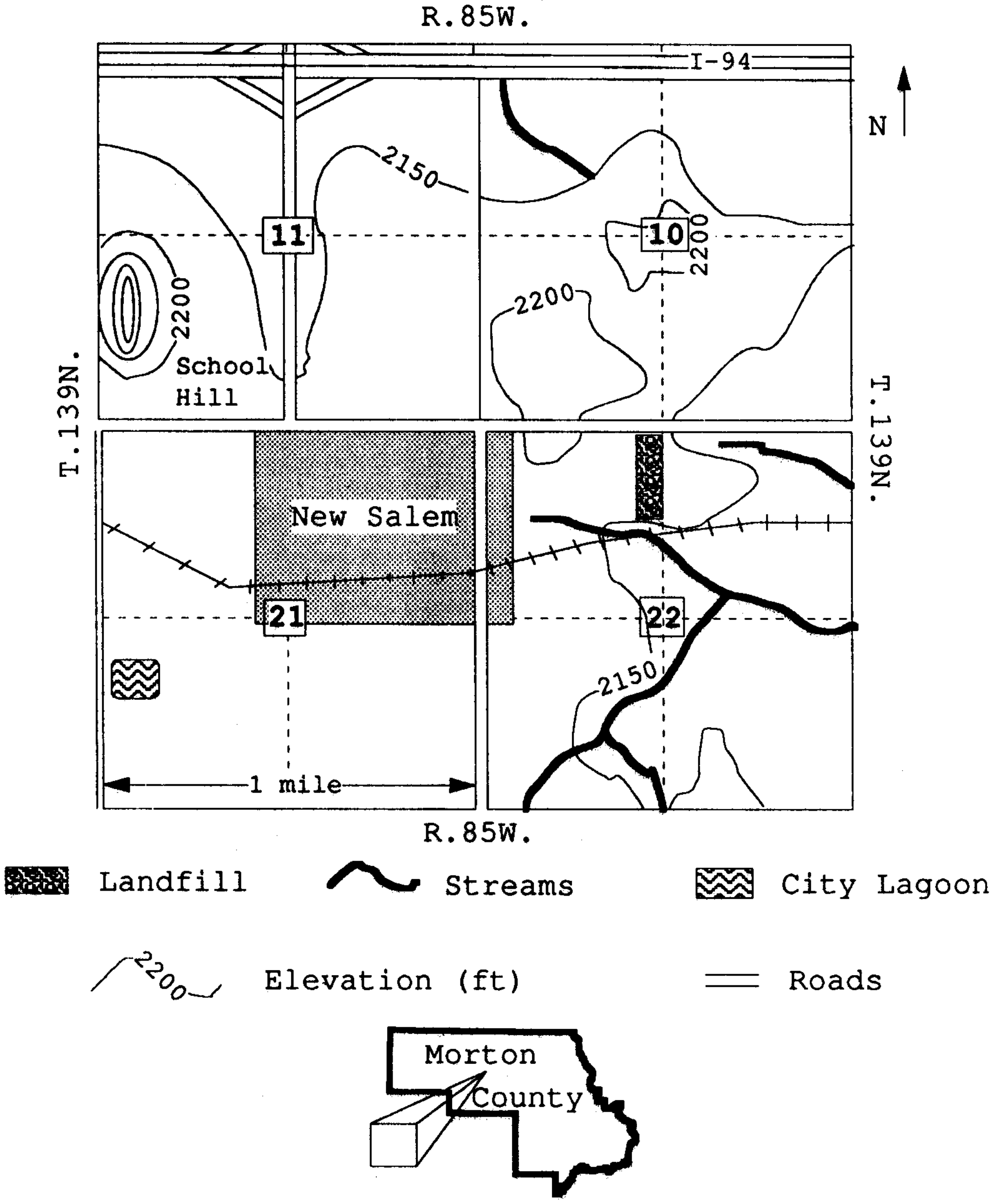

Figure 1. Location of the New Salem landfill in the NW 1/4 of section 22 T139 N. R85 W.

Previous Site Investigations

No previous geological or hydrological investigations have been completed at the New Salem landfill. A test hole, drilled by Opp Well Drilling in 1982, was completed to determine the site geology. The test hole was drilled to a depth of 50 feet and did not detect any ground water. The exact location of the test hole is not known. The log for the test hole is included in Appendix C.

Methods of Investigation

The current New Salem landfill 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. Well abandonment procedures were followed for non-permanent monitoring wells.

Test Drilling Procedure

The drilling method at the New Salem landfill was based on the site's geology and depth to ground water, as determined by the preliminary site evaluation. A forward rotary drilling rig was used at the New Salem landfill for the initial drilling. This method was selected by the depth to ground water and the presence of layers of lignite. The lithologic descriptions were determined from the drill cuttings. The water used with the forward rotary rig was obtained from the New Salem municipal water system.

An eight-inch hollow-stem auger was used to drill well 139-085-22BAD3. When using the hollow-stem auger, the well casing is installed through the center of the auger and placed at the desired depth. No additional water was used in this method of drilling.

Monitoring Well Construction and Development

The number of wells installed at the New Salem landfill was based on the geologic and topographic characteristics of the site. Seven test holes were drilled at the New Salem landfill, and monitoring wells were installed in six of the seven locations. Well 139-085-22BAD1 was abandoned and replaced with well 139-085-22BAD3 because of the lack of water in the well. The depth and intake interval of each well was selected to monitor the water level at the top of the uppermost aquifer.

Wells were constructed following a standard design (Fig. 2) and 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

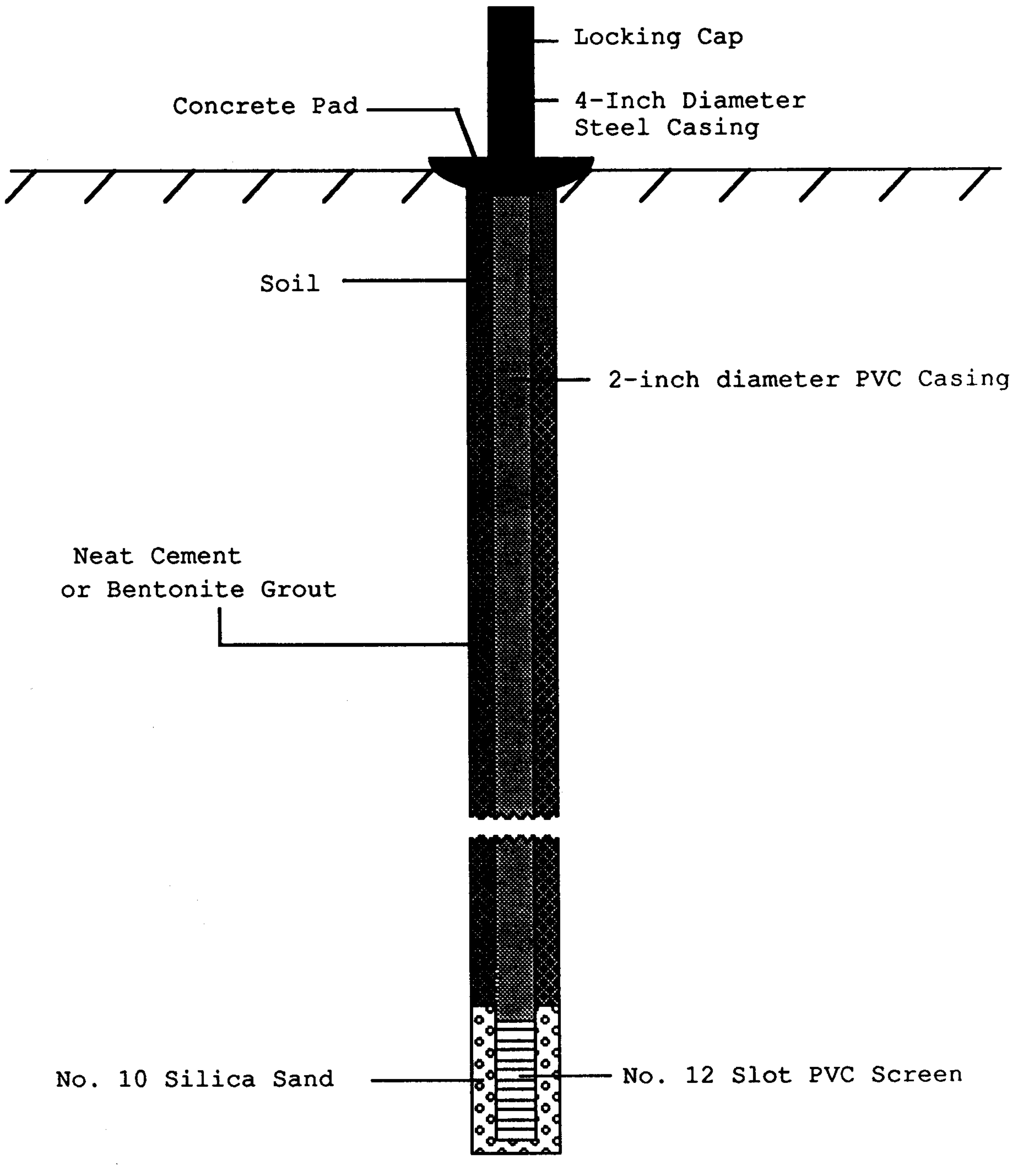

Figure 2. Construction design used for monitoring wells installed at the New Salem landfill.

screws (no solvent weld cement was used). After the casing and screen were inserted 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. 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 enforceable 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 from the filtered-acidified sample. Cadmium, lead, arsenic, and mercury were analyzed using the filtered-double acidified sample.

One well was later sampled for Volatile Organic Compounds (VOC) analysis. 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.

Well-Abandonment Procedure

The test holes and monitoring wells that were not permanent were abandoned according to NDSDHCL and Board of Water Well Contractors regulations (North Dakota Department Health, 1986). The soil around the well was dug to a depth of approximately three to four feet below land surface (Fig. 3) to prevent disturbance of the sealed wells. The screened interval of the well was plugged with bentonite chips to a height of approximately one foot above the top of the screen and the remaining well casing was filled with neat cement.

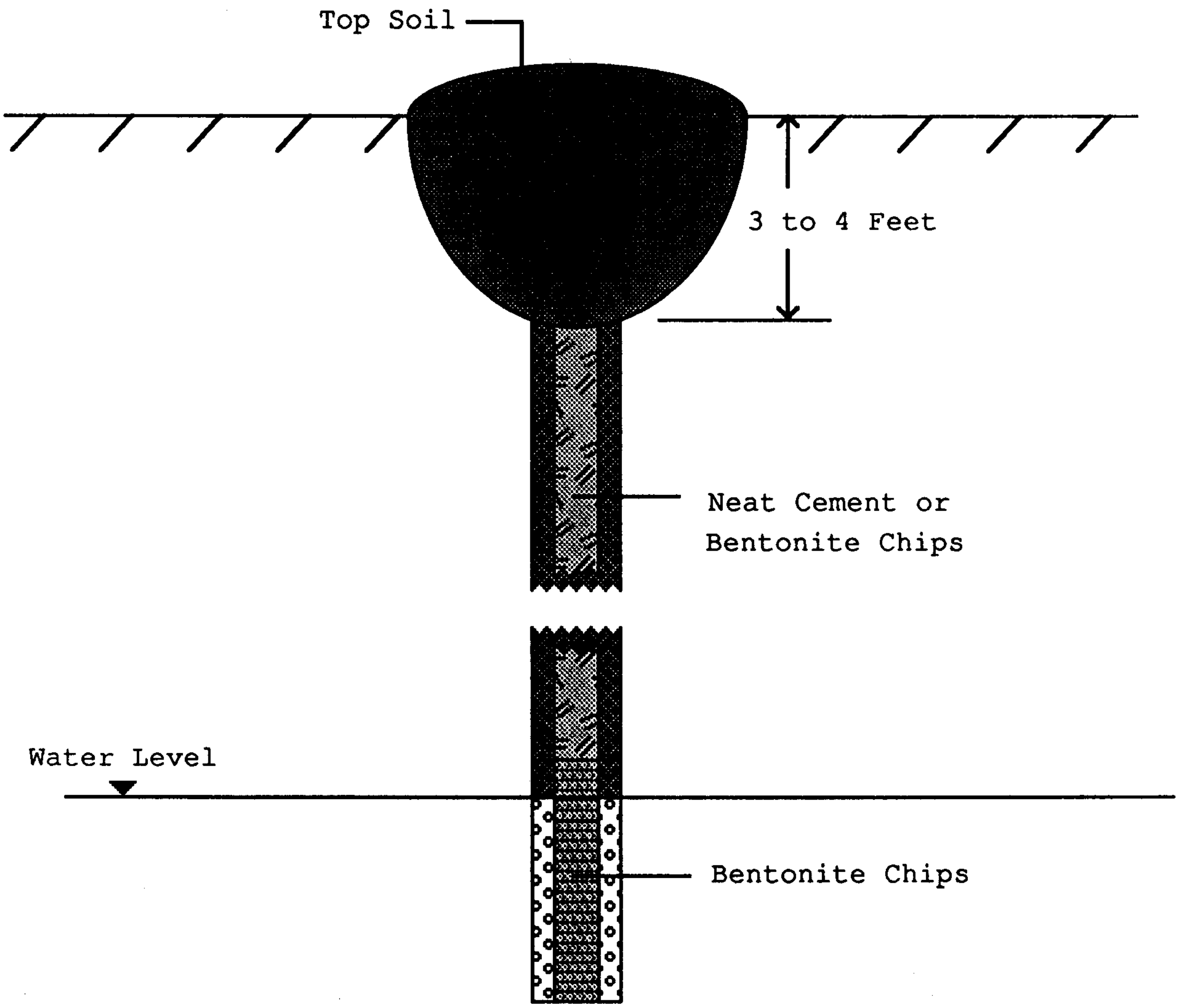

Figure 3. Monitoring well abandonment procedure.

The upper three to four feet was then filled with cuttings and the disturbed area was blended into the surrounding land surface. Test holes were plugged with high-solids bentonite grout and/or neat cement to a depth approximately five feet below land surface. The upper five feet of the test hole was filled with soil cuttings.

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. 4). 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 139-85-22BAD would be located in the SE1/4, NE1/4, NW1/4 Section 22, Township 139 North, Range 85 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 139-85-22BAD1 and 139-85-22BAD2.

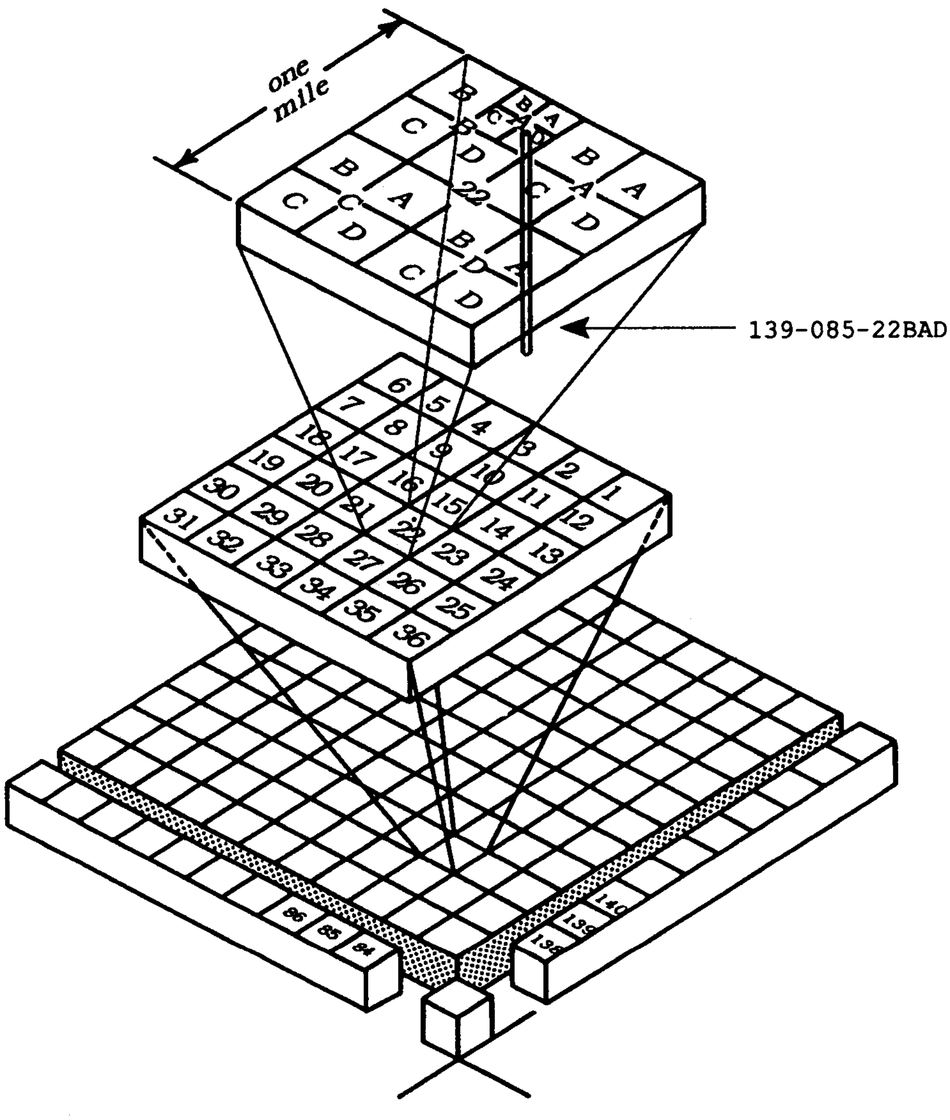

Figure 4. Location-numbering system.

GEOLOGY

Regional Geology

The lithologies in the New Salem area consist of eroded bedrock sediments and discontinuous bodies of glacial sediment. Bedrock in the New Salem area is assigned to the Sentinel Butte Formation and the Bullion Creek Formation (formerly called Tongue River Formation). These formations are Paleocene in age and were deposited in deltaic environments (Jacob, 1976). They are composed of sand, sandstone, silt, clay, lignite, and limestone. The formations are similar in appearance. The main distinguishing characteristic is a difference in color in weathered exposures: the Sentinel Butte Formation is dark gray or brown; the Bullion Creek Formation is light gray or buff.

The contact between the two formations is difficult to recognize. However, information from test holes (Ackerman, 1977) and from the Morton County Geologic Map (Carlson, 1983) indicates that the contact occurs at or near the base of a local lignite bed.

Local Geology

The New Salem landfill is in an area of moderate relief. An intermittent stream at the southwest corner of the landfill drains eastward (Fig. 5).

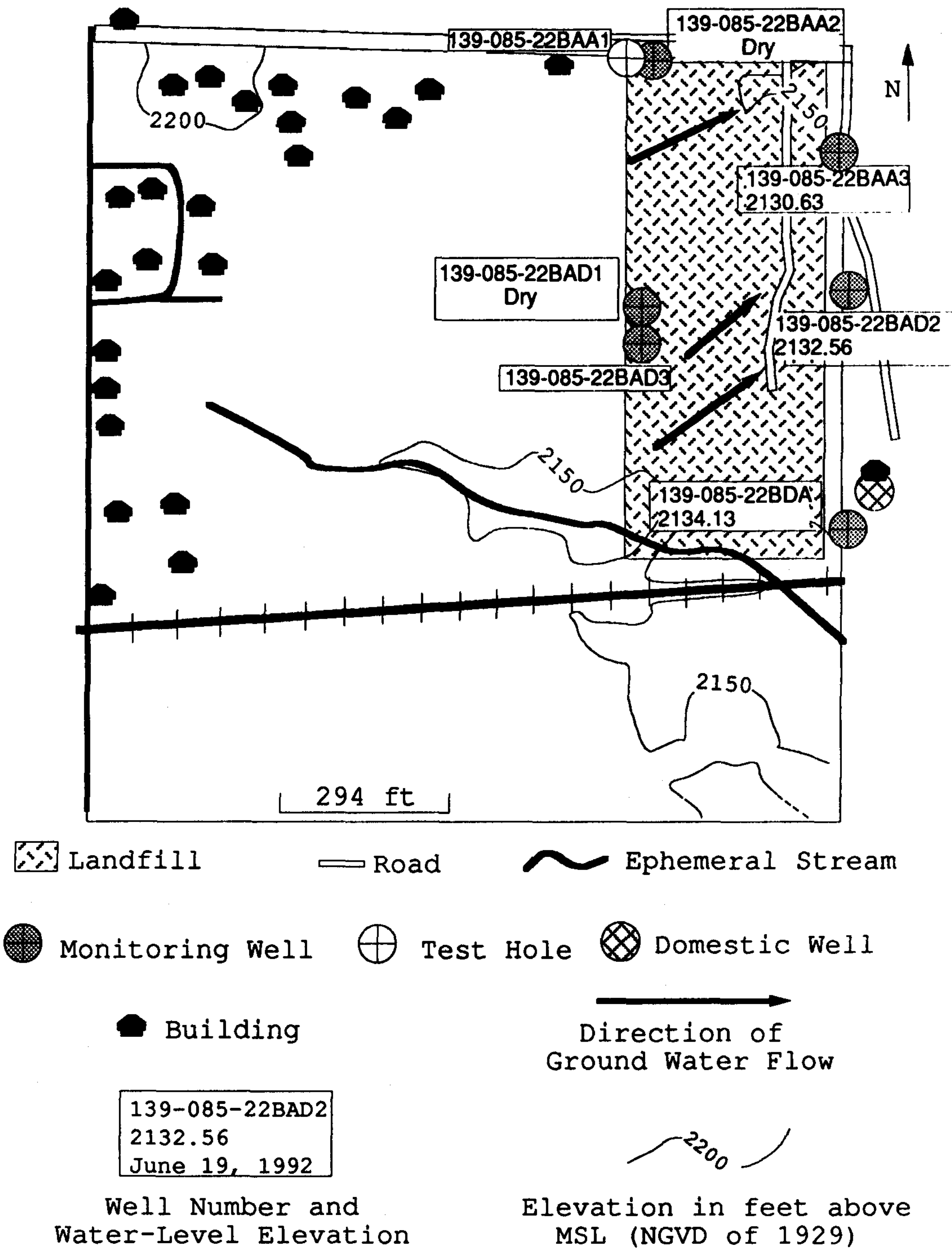

Figure 5. Location of monitoring wells and test holes at the New Salem landfill and direction of ground-water flow in the uppermost aquifer beneath the landfill.

A small amount of glacial drift occurs in the landfill area. Several erratic boulders were observed on the property. A refuse cell near the southwest corner of the landfill exposed a layer of sandy clay till, approximately 6 feet thick, overlying bedrock. Wells 139-085-22BAD1 and 139-085-22BAD3, which are located on the western side of the landfill, also encountered a thin layer of till (Appendix C). No till was observed on the east or north sides of the landfill.

Where till is absent, the lower part of the Sentinel Butte Formation is present at land surface. The upper part of the Sentinel Butte Formation has been removed by erosion and the remaining 30 to 35 feet is composed primarily of fine to medium grained sand (Fig. 6). It is poorly consolidated except for thin zones of indurated sandstone which were encountered in two of the wells. In the northwest corner of the landfill clay is interbedded with the sand (wells 139-085-22BAA1 and 139-085-22BAA2).

The refuse cells on the east side of the landfill were placed within the bedrock sand. The cells in the southwest corner were placed partly in sand and partly in till. Those in the northwest corner were placed partly in sand and partly in clay.

Below the sand there is a lignite bed which ranges from 2 feet to 6 feet thick. This bed is the lowest unit of the Sentinel Butte Formation.

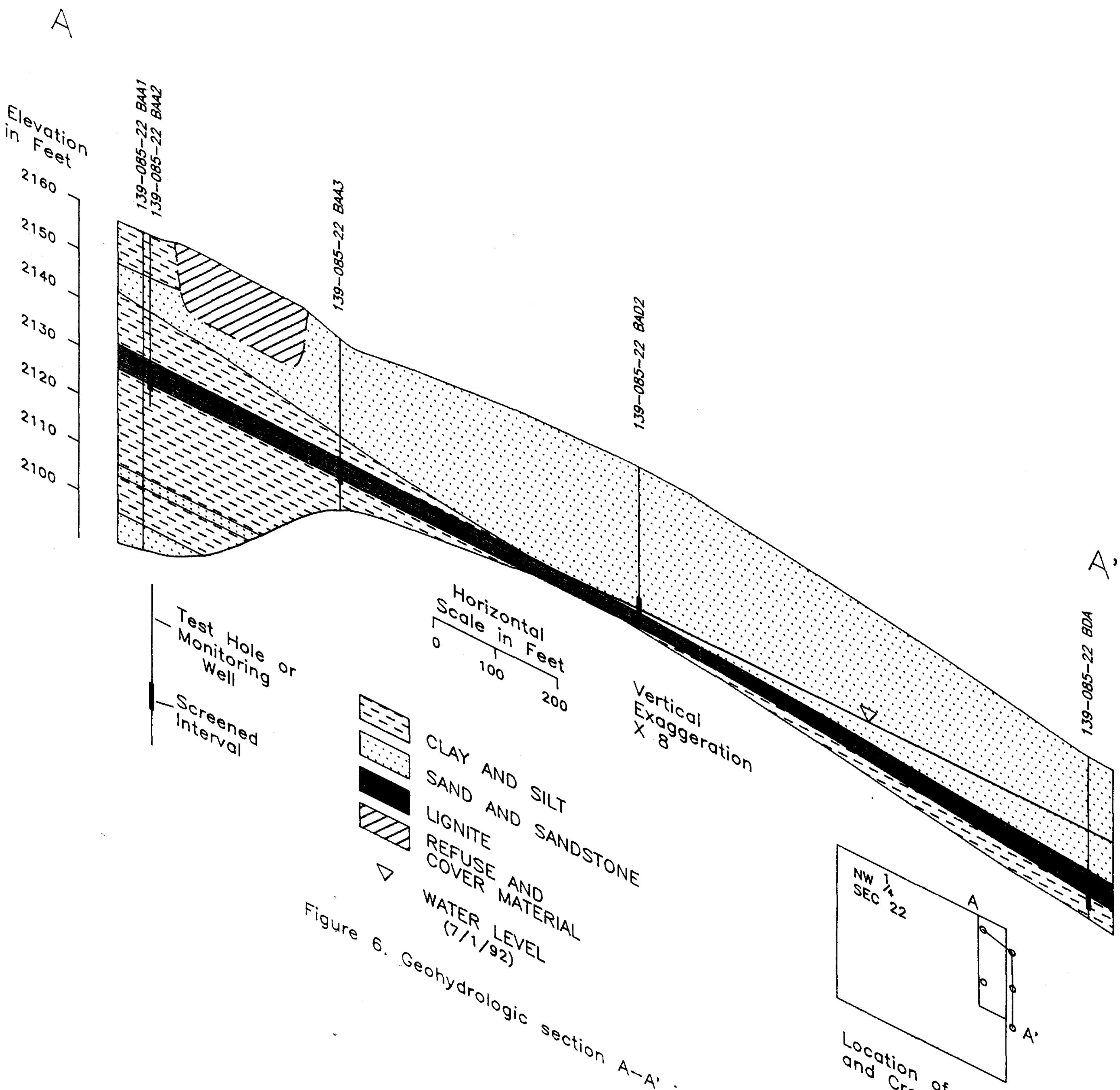

Figure 6. Geohydrologic section A-A' in the New Salem landfill

The areal extent of the sand and lignite units beyond the landfill is not precisely known. A review of local wells and test holes revealed that both units are present at least one-half mile to the west and south of the landfill. To the north, in Sections 15 and 16, T. 139 N., R. 85 W., the lignite bed is present but the sand has been largely replaced by clay. In some areas to the east of the landfill the sand and lignite have been removed by erosion.

The material below the lignite bed is part of the Bullion Creek Formation. A 20-foot-thick layer of clay occurs immediately below the lignite. The remainder of the Bullion Creek Formation is composed of clay, sand, sandstone, and lignite.

HYDROLOGY

Surface-Water Hydrology

No surface-water impoundments are located within a one-mile radius of the landfill. An ephemeral stream that intersects the landfill at the southwest corner of the property appears to flow only during large precipitation and/or snow melt events. Surface ponding is likely at the south end of the landfill boundary during large precipitation events. There is no diversion or interception of the runoff at the landfill. Surface ponding on the landfill site may increase infiltration through the sandy cover material thereby increasing leachate production.

Regional Ground-Water Hydrology

The regional aquifers around the New Salem landfill consist of bedrock. Most of the domestic wells are screened in the Bullion Creek Formation, although a few are screened in the Sentinel Butte Formation or the Cannonball Formation. The average depth of the wells in the Bullion Creek Formation is approximately 250 feet below ground surface. The flow direction in these aquifers is south-southeast from the landfill (Ackerman, 1980). These aquifers tend to be characterized by a sodium-bicarbonate type water.

Local Ground-Water Hydrology

Six monitoring wells were installed in and around the landfill boundaries (Fig. 5). The landfill boundaries intersect a lignite layer and the bedrock sand at a shallow depth. The well screens were placed near the top of the uppermost aquifer. The uppermost aquifer beneath the landfill is perched within the lignite layer and bedrock sand. The lignite layer was present at all the well locations and was used as the target horizon for placing the screens of the monitoring wells.

Up-gradient of the landfill the lignite layer was unsaturated, while the down-gradient wells screened in the same lignite layer supplied sufficient water for sampling. Wells 139-085-22BAA2 and 139-085-22BAD1 were screened up-gradient of the landfill within the bedrock sand and lignite layer and were dry throughout the study period. Well 139-085-22BAD3 was screened at a lower depth than 139-085-22BAA1 and 139-085-22BAD1 and the down-gradient wells. A hydraulic head difference of almost 30 feet between this well and other down-gradient wells suggest that this well is in a different aquifer.

There are three domestic wells screened within the same lignite layer within one mile of the landfill to the west and south. These wells are used for drinking water. These wells are up-gradient of the landfill and should not be affected by leachate migration.

Three to four water-level measurements were taken over a six-week period (Appendix D). The water levels indicate a northerly flow within the upper bedrock sands and lignite aquifer beneath the landfill.

It is highly possible that stored water in the refuse will contribute downward to the water table. The fine sandy soil in which the refuse is buried provides an easy medium for water and leachate to move through the landfill and into the ground-water system.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Wells 139-085-22BAA2 and 139-085-22BAD1 were dry. Due to the lack of an up-gradient well, water quality analyses from the Morton County Ground-Water Study (Ackerman, 1977) were used to determine the formation ground-water quality within the surrounding township. Most of the ground water in the study area is a sodium-bicarbonate type (Fig. 7).

Water quality analyses indicate increased concentration of five major ions in well 139-085-22BAD2 (Appendix E). Concentrations consist of 460 mg/L of calcium (Fig. 8), 200 mg/L of magnesium (Fig. 9), 5 mg/L of manganese (Fig. 10) and 1900 mg/L of sulfate (Fig. 11). These concentrations are above the maximum contaminant levels (MCL). Figure 12 shows a chloride concentration of 180 mg/L which is below the MCL. Chloride, a conservative ion, may be a primary indicator for leachate migration. This well is characterized by a calcium-sulfate type water (Fig. 7). The increased concentration of five constituents at well 139-085-22BAD2 suggests downward movement of leachate into the underlying sand/lignite aquifer.

The trace-element analysis indicates a higher concentration of strontium (2400 µg/L) in well 139-085-22BAD2. Strontium occurs in low concentrations in natural ground-water systems (110 µg/L) (Hem, 1989). Increased strontium can result from leaching of incineration ash, municipal waste incineration, and burning piles. These ashes are usually found in municipal waste landfills. The increase may also be caused from the oxidation of overburden associated with the excavation process at the landfill.

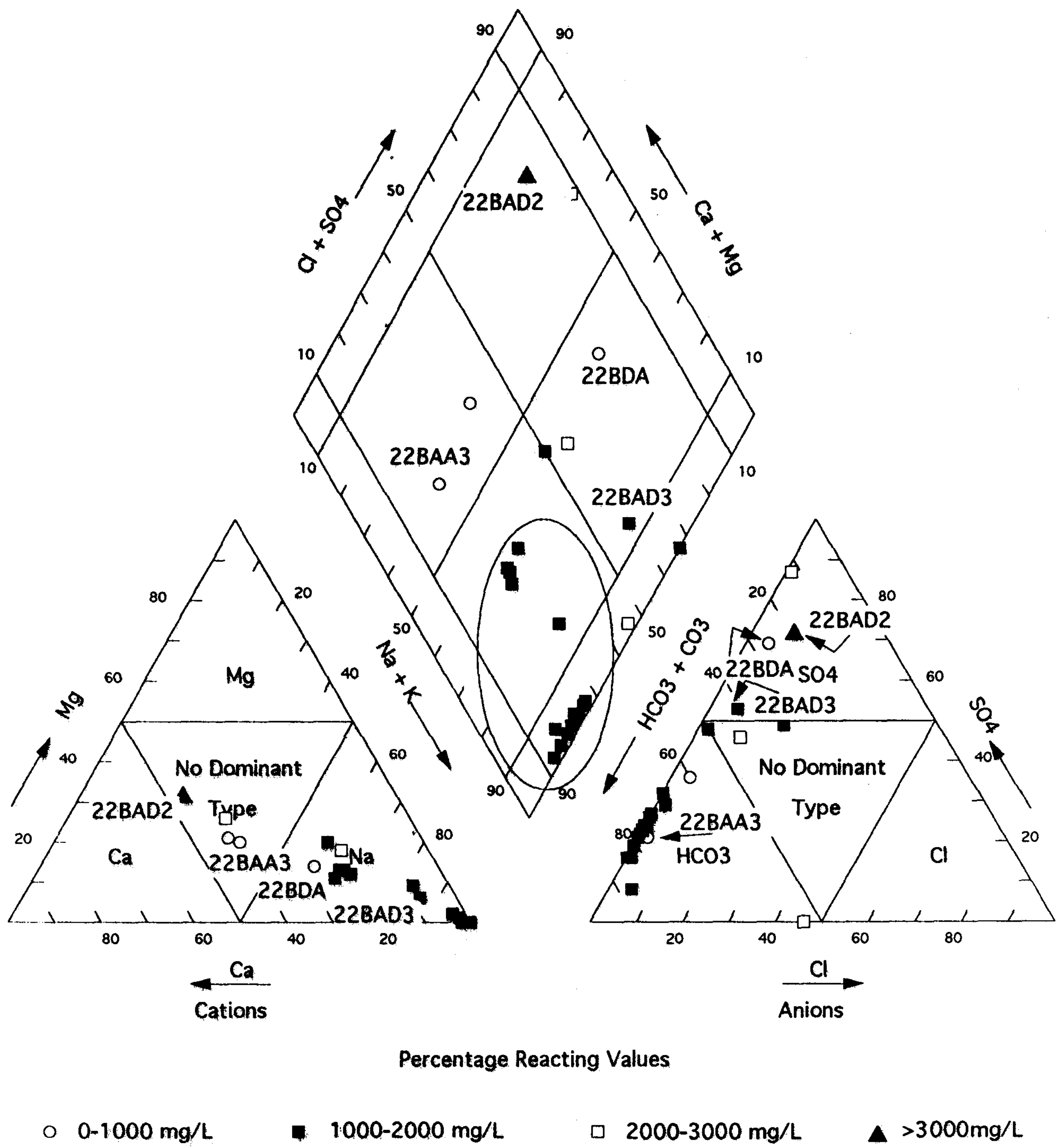

Figure 7. Piper trilinear diagram showing range in water quality in the New Salem landfill study area.

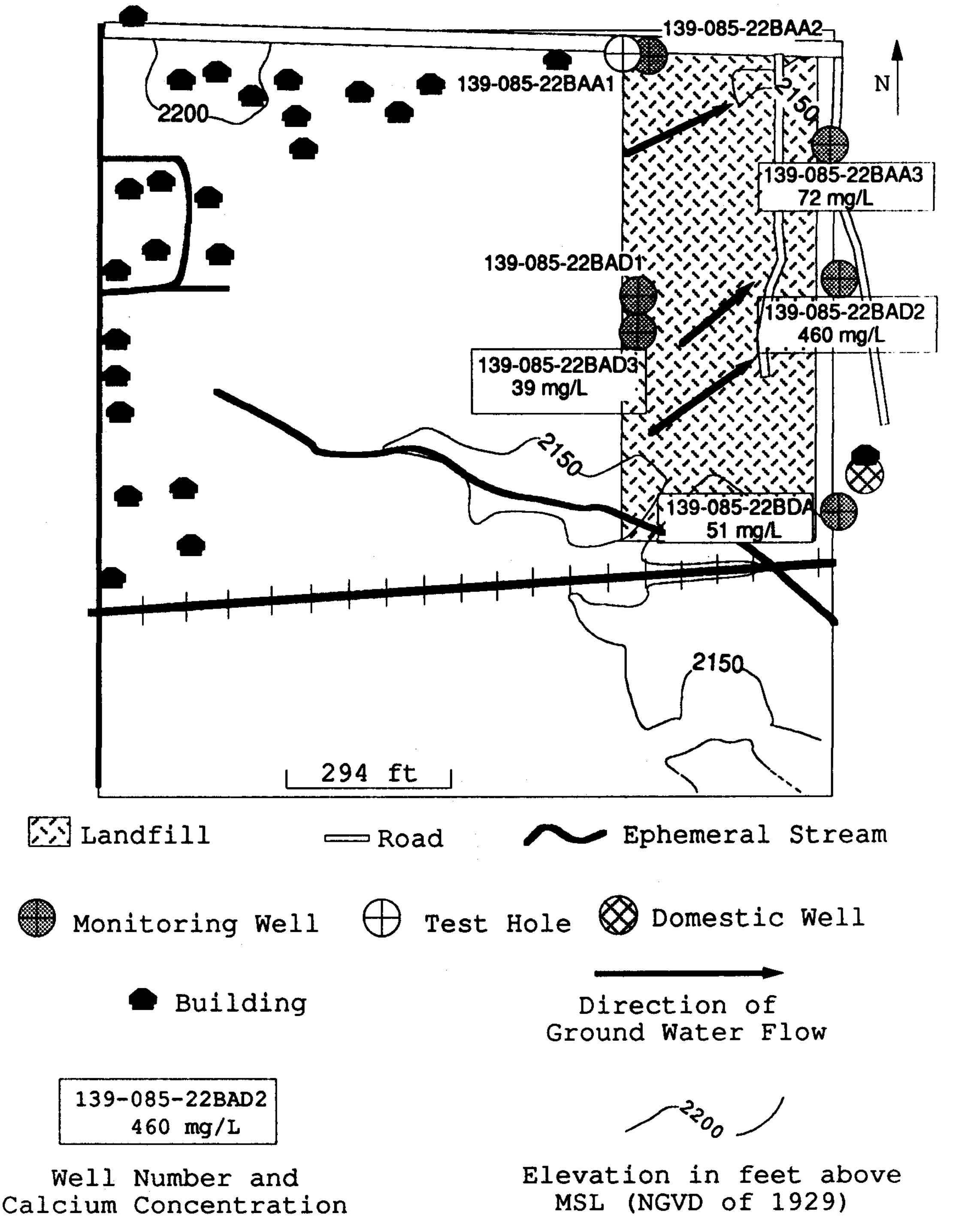

Figure 8. Calcium concentration at the New Salem landfill.

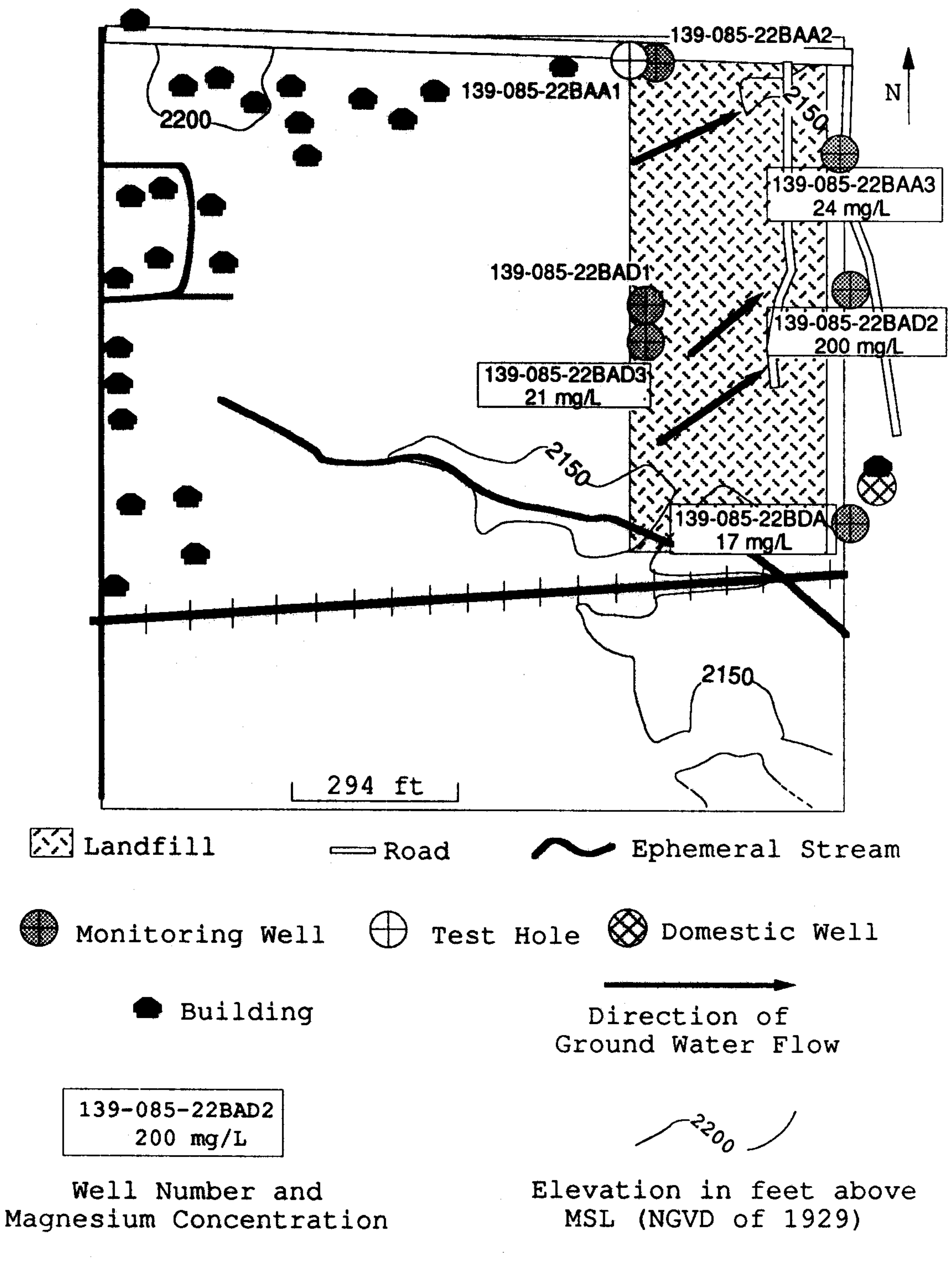

Figure 9. Magnesium concentration at the New Salem landfill.

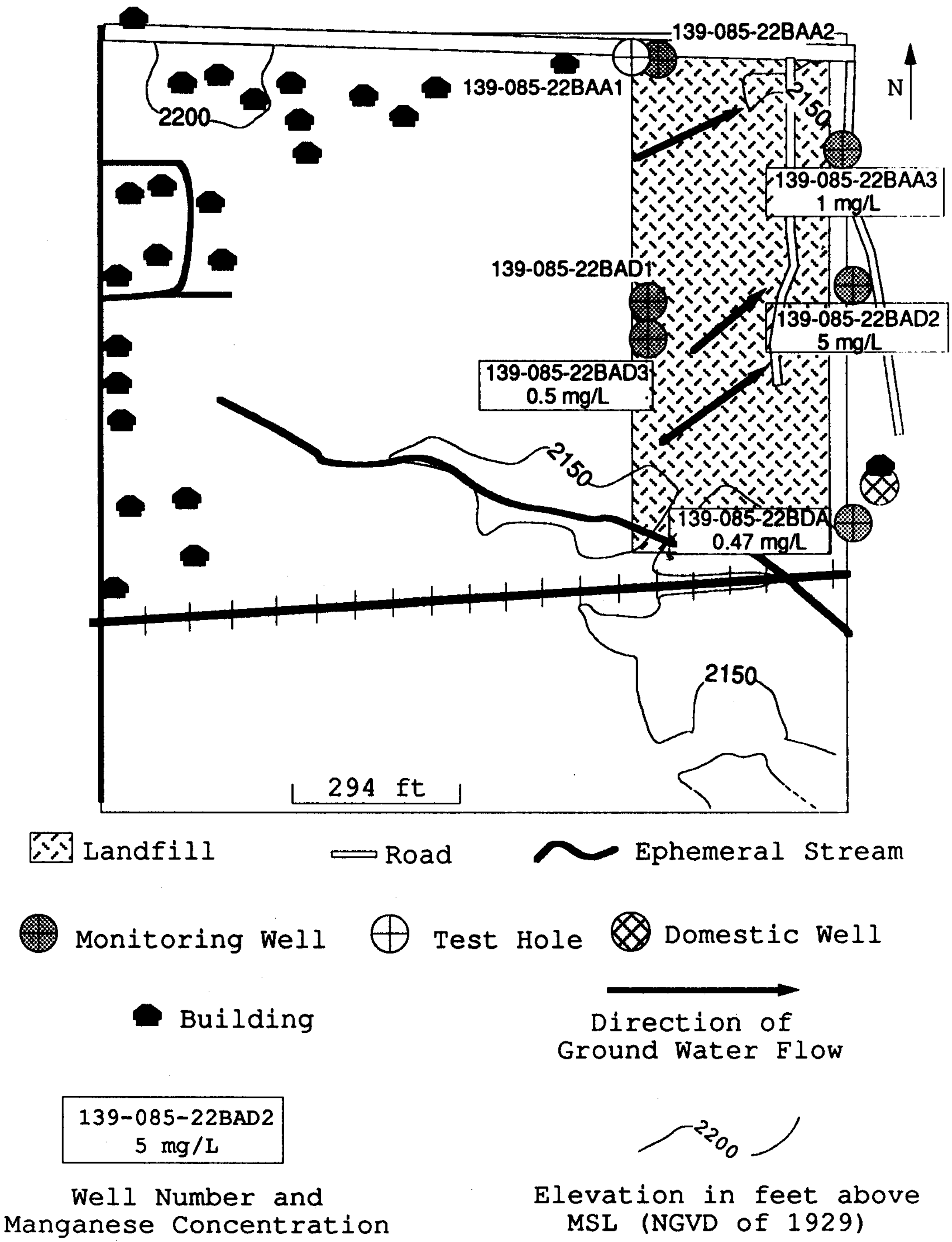

Figure 10. Manganese concentration at the New Salem landfill.

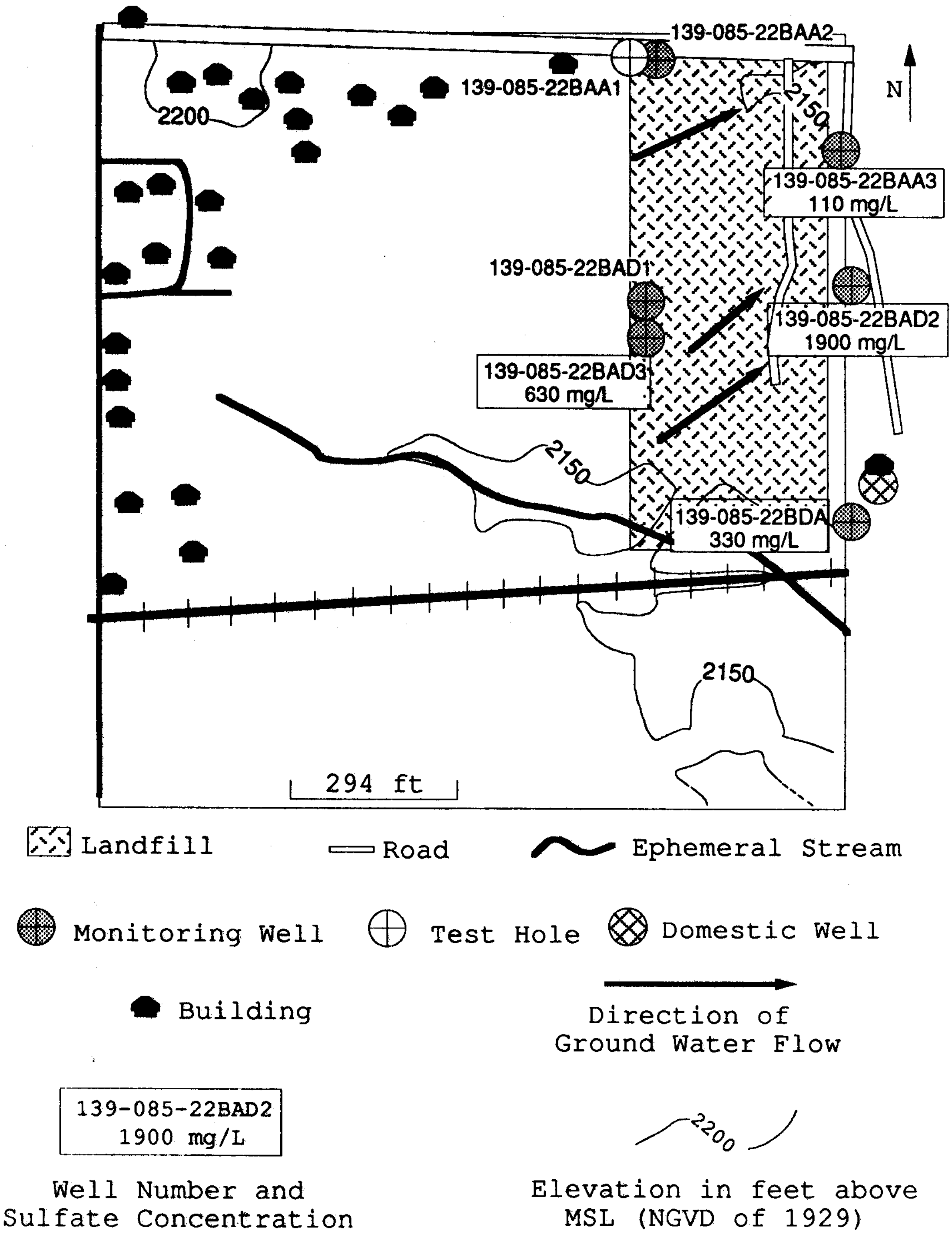

Figure 11. Sulfate concentration at the New Salem landfill.

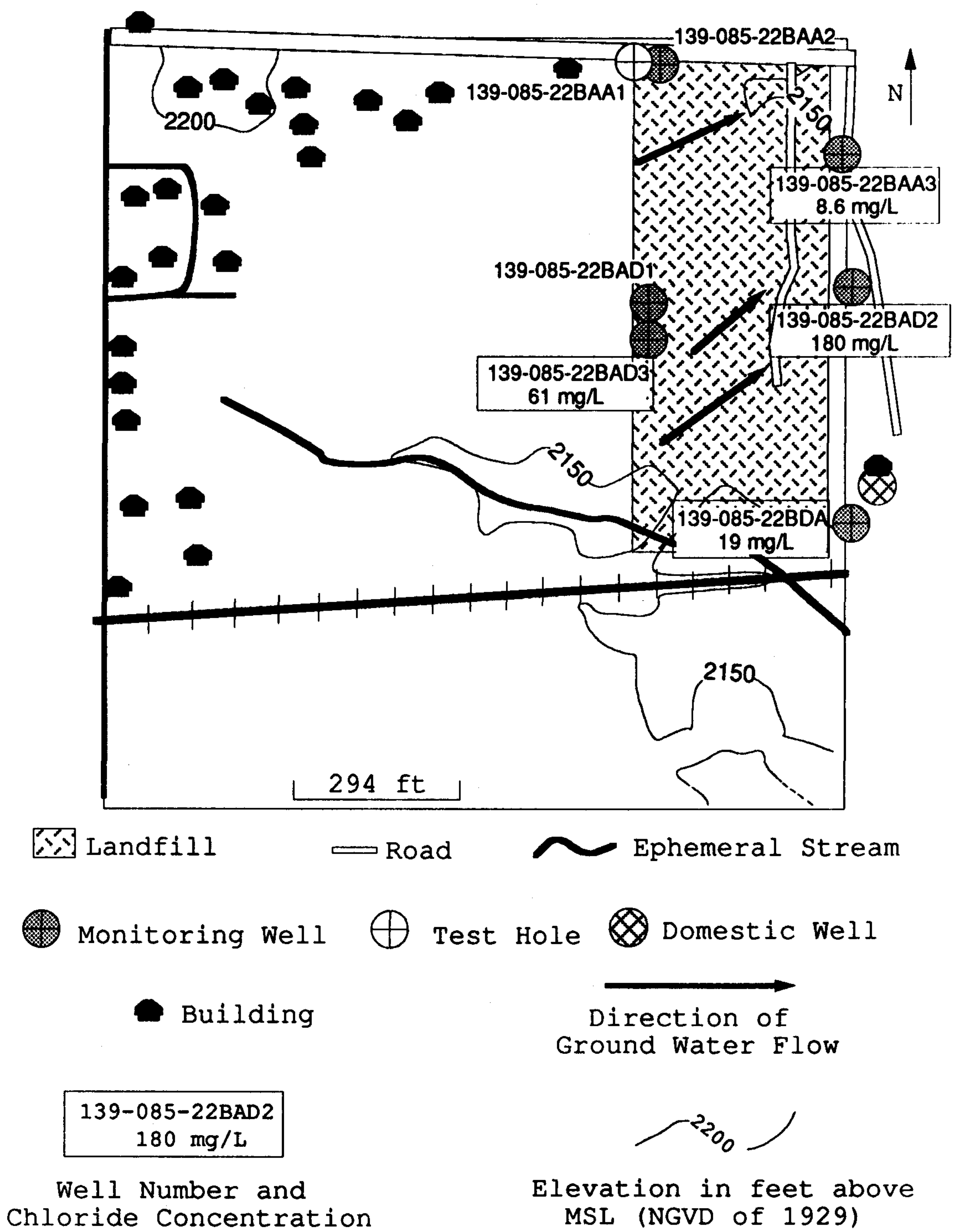

Figure 12. Chloride concentration at the New Salem landfill.

A VOC sample was collected from well 139-085-22BDA. This well was not directly down-gradient from the landfill and therefore may not be a valid sampling point to detect leachate migration from the landfill. The results of the VOC analysis are shown in Appendix F. The analysis did not detect any VOC migration.

CONCLUSIONS

The New Salem landfill is located within the Sentinel Butte Formation and the Bullion Creek Formation. These formations consist of sand, sandstone, silt, clay, limestone, and lignite. Glacial till exists at the surface along the western boundary of the landfill. Where till has been eroded, the Sentinel Butte Formation is exposed at the surface. The interval of the Sentinel Butte Formation exposed consists of fine to medium grained sand underlain by a layer of lignite. The landfill operation has deposited refuse within the fine to medium-grained bedrock sand which provides an excellent medium for leachate migration.

There is no surface-water diversion or control at the landfill site. This could lead to an increased leachate production.

The direction of ground-water flow in the Bullion Creek aquifer is south-southeast. The landfill operation does not appear to affect the deeper bedrock aquifers. The uppermost sand/lignite aquifer appears to flow in a north-northeast direction.

The water quality analyses indicate increased concentrations of five major ions in the down-gradient well 139-085-22BAD2. One of these constituents is chloride, a conservative ion, which is commonly an indicator of leachate migration.

Ground-water degradation from organic materials was not detected from the VOC analysis. The VOC sample was collected from a well that was not directly down-gradient from the landfill and therefore may not be a valid sampling point to detect leachate migration from the landfill. The hydrogeologic setting of the study area is conducive to downward leachate migration from the landfill into the uppermost sand/lignite aquifer.

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APPENDIX A

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

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. 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 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

139-085-22BAA1

NDSWC

Date Completed:	5/11/92	Purpose:	Test Hole
Depth Drilled (ft):	160	Source of Data:	
L.S. Elevation (ft)	2160.41	Owner: New Salem	

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	FINE GRAINED, SILTY, LIGHT OLIVE-GRAY 5Y6/1, (SENTINEL BUTTE FORMATION)	1-3
SAND	FINE GRAINED, SILTY, CLAYEY, DARK YELLOWISH-ORANGE 10YR6/6	3-9
SAND	FINE GRAIN, SILTY, LIGHT OLIVE-GRAY, 5Y6/1	9-11
CLAY	LIGHT OLIVE-GRAY, 5Y6/1	11-16
CLAY	MODERATE YELLOWISH-BROWN, 10YR5/4	16-24
CLAY	DARK BROWN 5YR2/2	24-25
LIGNITE		25-30
CLAY	GRAYISH-GREEN, 5G5/2, (BULLION CREEK FORMATION)	30-42
CLAY	PALE BROWN, 5YR5/2	42-45
CLAY	GRAYISH-GREEN, 5G5/2	45-50
SANDSTONE	FINE GRAIN, MEDIUM GRAY, N5, WELL CEMENTED	50-52
CLAY	LIGHT OLIVE-GRAY, 5Y6/1	52-54
CLAY	GRAYISH-GREEN, 5G5/2	54-57
CLAY	SANDY, GRAYISH-GREEN 5G5/2	57-60
SAND	FINE GRAIN, SILTY, GRAYISH-GREEN, 5G5/2	60-67
CLAY	SILTY AND SANDY, GRAYISH-GREEN, 5G5/2	67-72
LIGNITE		72-73
CLAY	GRAYISH-GREEN, 5G5/2, TO PALE GREEN, 10G6/2	73-82
CLAY	SANDY, LIGHT OLIVE-GRAY 5Y6/1	82-84
SAND	FINE GRAIN, SILTY, LIGHT OLIVE-GRAY, 5Y6/1	84-86
CLAY	MEDIUM GRAY, N5	86-96
CLAY	SANDY, MEDIUM GRAY, N5	96-102
LIGNITE		102-103
CLAY	SILTY, MEDIUM GRAY, N5	103-115
CLAY	MEDIUM GRAY, N5	115-121

LIGNITE		121-127
CLAY	OLIVE-GRAY, 5Y4/1	127-141
CLAY	SILTY, OLIVE-GRAY, 5Y4/1	141-160

139-085-22BAA2

NDSWC

Date Completed:	5/11/92	Well Type:	P2
Depth Drilled (ft):	35	Source of Data:	
Screened Interval (ft):	26-31	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2160.41
Owner: New Salem			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	SANDY, MODERATE YELLOWISH-BROWN, 5Y4/1, (SENTINEL BUTTLE FORMATION)	2-8
SAND	FINE GRAIN, SILTY, OLIVE-GRAY, 5Y4/1	8-13
SAND	FINE GRAIN, SILTY, DARK YELLOWISH-BROWN, 10YR6/6	13-15
CLAY	OLIVE-GRAY, 5Y4/1	15-17
CLAY	DARK YELLOWISH-ORANGE, 10YR 6/6	17-25
LIGNITE		25-30
CLAY	GREENISH-GRAY, 5G6/1, (BULLION CREEK FORMATION)	30-35

139-085-22BAA3

NDSWC

Date Completed:	5/12/92	Well Type:	P2
Depth Drilled (ft):	34	Source of Data:	
Screened Interval (ft):	24-29	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2157.98

Owner: New Salem

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	MEDIUM TO FINE GRAIN, TRACE OF GRAVEL, PALE BROWN, 5YR5/2	1-5
SAND	FINE GRAIN, BEDROCK, OLIVE-GRAY, 5Y4/1, (SENTINEL BUTTE FORMATION)	5-8
SILT	CLAYEY AND SANDY, DARK REDDISH-BROWN, 10R3/4	8-10
SAND	MEDIUM TO FINE GRAIN, LIGHT OLIVE-GRAY, 5Y6/1	10-20
CLAY	SILTY, GRAYISH-ORANGE, 10YR7/4	20-22
CLAY	MEDIUM GRAY, N5	22-24
LIGNITE		24-29
CLAY	GRAYISH-GREEN, 5G/2, (BULLION CREEK FORMATION)	29-34

139-085-22BAD1

NDSWC

Date Completed:	5/11/92	Well Type:	P2 (PLUGGED)
Depth Drilled (ft):	36	Source of Data:	
Screened Interval (ft):	29-34	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2170.51
Owner: New Salem			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	SILTY, SANDY, AND GRAVELLY, GRAYISH-ORANGE, 10YR7/4, (GLACIAL DRIFT)	0-9
SAND	FINE GRAIN, MODERATE YELLOWISH-BROWN, 10YR5/4, (SENTINEL BUTTE FORMATION)	9-16
SANDSTONE	MEDIUM GRAIN, WELL CEMENTED, MODERATE REDDISH-BROWN, 10R4/6	16-19
SAND	MEDIUM TO FINE GRAIN, OLIVE-GRAY, 5Y4/1	19-34
CLAY	MEDIUM GRAY, N5	34-35
SANDSTONE	FINE GRAIN, WELL CEMENTED, MEDIUM GRAY, N5	35-36

139-085-22BAD2
NDSWC

Date Completed:	5/12/92	Well Type:	P2
Depth Drilled (ft):	33	Source of Data:	
Screened Interval (ft):	27-32	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2162.86

Owner: New Salem

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	FINE GRAIN, DARK YELLOWISH-BROWN, 10YR4/2	1-4
SAND	WITH SANDSTONE FRAGMENTS, (SENTINEL BUTTE FORMATION)	4-14
SAND	FINE GRAIN, OLIVE-GRAY, 5Y4/1	14-30
LIGNITE		30-32
SANDSTONE	FINE GRAIN, HARD, MEDIUM GRAY, N5, (BULLION CREEK FORMATION)	32-33

139-085-22BAD3
NDSWC

Date Completed:	6/1/92	Well Type:	P2
Depth Drilled (ft):	90	Source of Data:	
Screened Interval (ft):	80-90	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2170.51
Owner: New Salem			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SILTY, TRACE GRAVEL, GRAYISH-BROWN, 5YR 3/2, (GLACIAL DRIFT)	1-7
GRAVEL	MEDIUM GRAIN	7-10
SAND	FINE-GRAINED, TRACE OF GRAVEL, MODERATE YELLOWISH-BROWN, 10YR 5/4, (SENTINEL BUTTE FORMATION)	10-12
SAND	FINE-GRAINED, TRACE SMALL PEBBLES, MODERATE YELLOWISH-BROWN, 10YR5/4, WITH MOTTLES OF MODERATE REDDISH ORANGE, 10R 6/6	12-21
SAND	FINE-GRAINED, TRACE GRAVELS AND SMALL PEBBLES, DARK YELLOWISH-BROWN, 10YR 4/2	21-33
CLAY	LIGHT MEDIUM GRAY, N6	33-36
SANDSTONE	WELL CEMENTED,FINE-GRAINED, PALE YELLOWISH-ORANGE 10YR 8/6	36-37
CLAY	SANDY, DARK YELLOWISH-BROWN, 10YR 4/2	37-40
LIGNITE		40-44
CLAY	SILTY, GREENISH-GRAY, 5GY 6/1, (BULLION CREEK FORMATION)	44-47
CLAY	GREENISH-GRAY, 5GY 6/1	47-59
CLAY	SILTY, GREENISH-GRAY, 5GY 6/1, MOIST	59-66
CLAY	GRAYISH-GREEN, 10G 4/2	66-78
CLAY	SILTY, GRAYISH-GREEN, 10G 4/2	78-85
CLAY	SILTY, GRAYISH-GREEN, 10G 4/2, MOIST	85-90

139-085-22BDA

NDSWC

Date Completed:	5/11/92	Well Type:	P2
Depth Drilled (ft):	33	Source of Data:	
Screened Interval (ft):	25-30	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2149.71
Owner: New Salem			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND	FINE GRAIN, CLAYEY, MODERATE YELLOWISH-BROWN, 10YR5/4, (SENTINEL BUTTE FORMATION)	2-8
SAND	MEDIUM TO FINE GRAIN, OLIVE-GRAY, 5Y4/1	8-10
SAND	FINE GRAIN, OLIVE-GRAY, 5Y4/1	10-23
LIGNITE		23-29
CLAY	MEDIUM GRAY, N5, (BULLION CREEK FORMATION)	29-33

BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58505

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

WELL OWNER

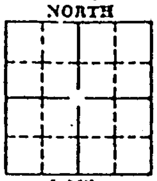
Name: City of New Salem Sanitary Landfill

Address: New Salem, N.D.

WELL LOCATION

Sketch map location must agree with written location.

NORTH



1 Mile

County: Morton

__¼ __¼ __¼ Sec. __ Twp. __ N. Rg. __ W.

PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Industrial
☐ Stock ☐ Municipal ☑ Test Hole

METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☑ Forward Rotary ☐ Jetted ☐ Other
If other, specify ____

WATER QUALITY

Was a water sample collected for chemical analysis?
☐ Yes ☐ No
If so, to what laboratory was it sent ____

WELL CONSTRUCTION

Diameter of hole 4 3/4 inches. Depth 50 feet.

Casing: ☐ Steel ☐ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☐ Other
If other, specify ____

Pipe Weight:	Diameter:	From:	To:
__ lb/ft.	__ inches	__ feet	__ feet
__ lb/ft.	__ inches	__ feet	__ feet
__ lb/ft.	__ inches	__ feet	__ feet
__ lb/ft.	__ inches	__ feet	__ feet

Was perforated pipe used? ☐ Yes ☐ No
Length of pipe perforated ____ feet
Was casing left open end? ☐ Yes ☐ No
Was a well screened installed? ☐ Yes ☐ No
Material ____ Diameter ____ inches
(stainless steel, bronze, etc.)
Slot size ____ set from ____ feet to ____ feet
Slot size ____ set from ____ feet to ____ feet
Slot size ____ set from ____ feet to ____ feet
Slot size ____ set from ____ feet to ____ feet
Was a packer or seal used? ☐ Yes ☐ No
If so, what material ____
Type of well: Straight screen ☐ Gravel packed ☐
Was the well grouted? Yes ☐ No ☐
To what depth? ____ feet
Material used in grouting ____
Well head completion: Pitless adapter ____
12" above grade ____ Other ____
If other, specify ____
Was well disinfected upon completion? ☐ Yes ☐ No

7. WATER LEVEL

Static water level ____ feet below land surface
If flowing: closed-in pressure ____ psi
GPM flow ____ through ____ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify ____

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other
Pumping level below land surface:
__ ft. after __ hrs. pumping __ gpm
__ ft. after __ hrs. pumping __ gpm
__ ft. after __ hrs. pumping __ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
top soil	0	1/2
brown sand	1/2	20
orange sand	20	25
brown sand	25	35
Brown clay	35	38
coal (dry)	38	43
blue clay	43	50

(Use separate sheet if necessary.)

10. DATE COMPLETED 10-14-82

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☐ No
If so, how ____

12. REMARKS: No seepage
No water
Coal are extremely hard & dry

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report true to the best of my knowledge.

C&C Well Drilling — 19
Driller's or Firm's Name — Certificate No.

Glen Ullin, N.D.
Address

Allen R. Bitter
Signed by — Date

APPENDIX D

WATER-LEVEL TABLES

New Salem Landfill Water-Level Data
6/5/92 to 7/27/92

139-085-22BAA2 LS Elev (msl,ft)=2160.41

Undefined Aquifer SI (ft.)=26-31

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/05/92	30.55	2129.86			

139-085-22BAA3 LS Elev (msl,ft)=2157.98

Undefined Aquifer SI (ft.)=24-29

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/05/92	27.29	2130.69	07/01/92	27.35	2130.63
06/19/92	27.35	2130.63			

139-085-22BAD2 LS Elev (msl,ft)=2162.86

Undefined Aquifer SI (ft.)=27-32

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/05/92	29.64	2133.22	07/01/92	30.24	2132.62
06/19/92	30.30	2132.56	07/27/92	30.22	2132.64

139-085-22BAD3 LS Elev (msl,ft)=2170.51

Undefined Aquifer SI (ft.)=80-90

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/05/92	69.35	2101.16	07/01/92	69.51	2101.00
06/19/92	69.32	2101.19			

139-085-22BDA LS Elev (msl,ft)=2149.71

Undefined Aquifer SI (ft.)=25-30

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/26/92	15.58	2134.13	06/19/92	15.58	2134.13
06/05/92	15.67	2134.04	07/01/92	15.47	2134.24

APPENDIX E

MAJOR IONS AND TRACE-ELEMENT CONCENTRATIONS

New Salem 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 as $CaCO_3$	NCH	% Na	SAR	Spec Cond (μmho)	Temp (°C)	pH
			(milligrams per liter)																					
139-085-22BAA3	24-29	06/23/92	18	0.09	1	72	24	86	4.4	486	0	110	8.6	0.3	1.9	0.27	566	280	0	40	2.2	667	13	7.03
139-085-22BAD2	27-32	07/27/91	27	2.2	5	460	200	260	9.6	615	0	1900	180	0.2	3.1	2.6	3350	2000	1500	22	2.5	3810	14	6.17
139-085-22BAD3	80-90	06/23/92	9.6	0.12	0.5	39	21	550	21	585	6	630	61	0.8	3.7	0.43	1630	180	0	85	18	2030	14	8.64
139-085-22BDA	25-30	05/26/92	22	9.7	0.47	51	17	130	5	153	0	330	19	0.1	0	0.26	660	200	72	58	4	933	12	6.09

Heavy Metal Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium	TDS (mg/L)
		(micrograms per liter)							
139-085-22BAA3	6/23/92	0	0	0	0	1	0	940	544
139-085-22BAD2	6/27/92	1	0	0	0	3	9	2400	3590
139-085-22BAD3	6/23/92	0	7	0	0.4	10	28	950	1720
139-085-22BDA	5/26/92	0	0	0	0	5	4	410	714

APPENDIX F

VOLATILE ORGANIC COMPOUNDS
FOR WELL 139-085-22BDA

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