Site Suitability Review of the Beach Municipal Landfill

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

ND Landfill Site Investigation No. 19

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OF THE
BEACH MUNICIPAL LANDFILL

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INTRODUCTION

Purpose

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

Location of the Beach Landfill

The Beach municipal solid waste landfill is located one mile east of the City of Beach in Township 140 North, Range 105 West, NW 1/4 Section 30 (Fig. 1). The landfill site encompasses approximately 40 acres.

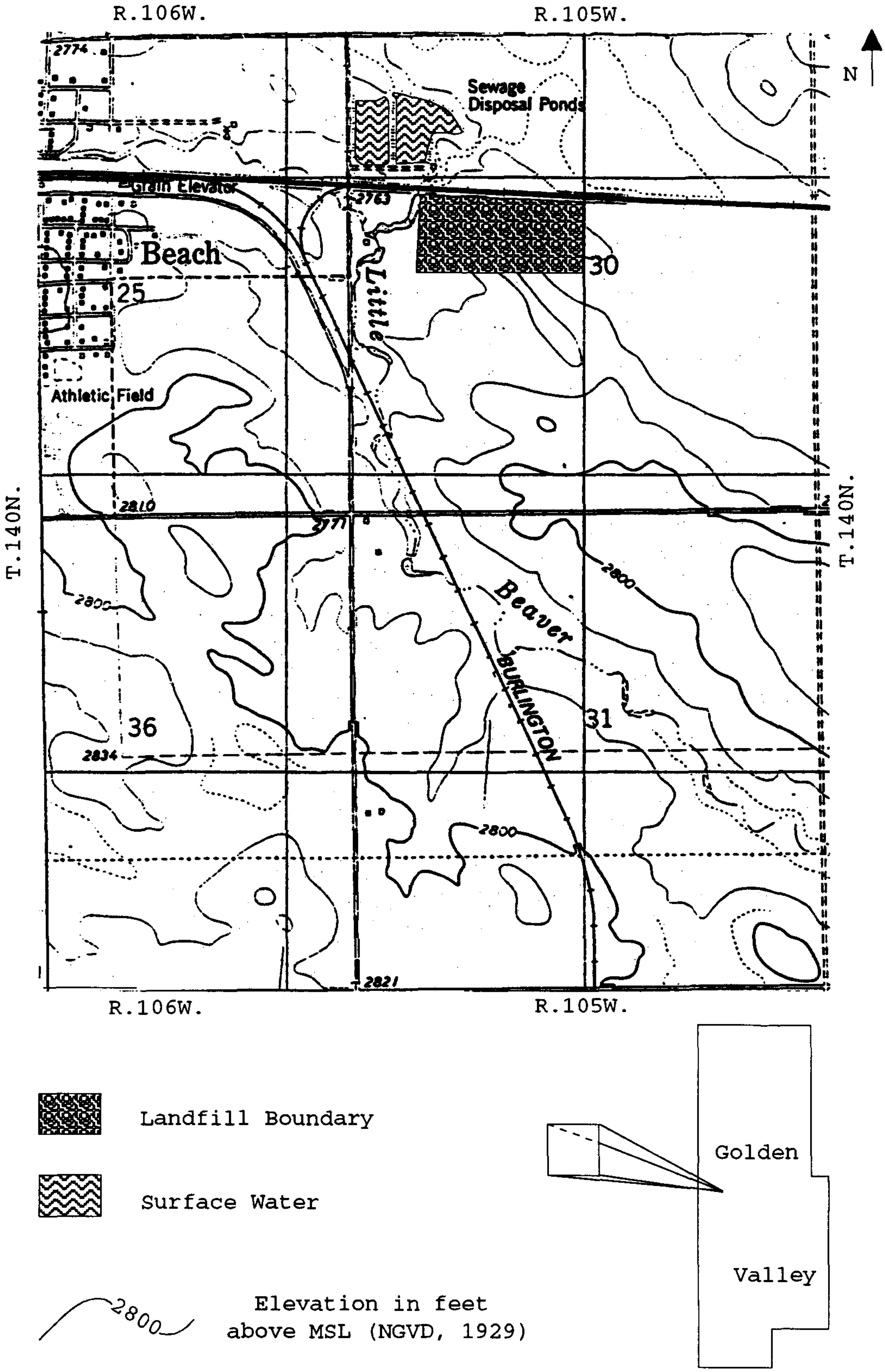


Figure 1. Location of the Beach Municipal landfill in the S 1/2 of the NW 1/4 of section 30, T.140N., R.105W.

Previous Site Investigations

Two soil borings were completed to a depth of 22 and 11 feet. It is not known who drilled the borings. The descriptions from the borings consisted of interbedded layers of unconsolidated sandstone, clay, and lignite. No other information is available.

Methods of Investigation

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

Test Drilling Procedure

The drilling method at the Beach landfill was based on the site's geology as determined by the preliminary evaluation. A forward rotary drill rig was used at the Beach landfill because the sediments appeared to be consolidated. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Six test holes were drilled at the Beach landfill, and monitoring wells were installed in five of the test holes. The number of wells installed at the Beach landfill was based on the geologic and topographic characteristics of the site. The depth and intake interval of each well was selected to monitor the water level at the top of the uppermost aquifer. The wells were located within a one-half mile radius of the active area of the landfill.

Wells were constructed following a standard design (Fig. 2) intended to comply with the construction regulations of the NDSDHCL and the North Dakota Board of Water Well Contractors (North Dakota Department of Health, 1986). The wells were constructed using a 2-inch diameter, SDR21, polyvinyl chloride (PVC) well casing and a PVC screen, either 5 or 10 feet long, with a slot-opening size of 0.012 or 0.013 inches. The screen was fastened to the casing with stainless steel screws (no solvent weld cement was used). After the casing and screen were installed into the drill hole, the annulus around the screen was filled with No. 10 (grain-size diameter) silica sand to a height of two feet above the top of the screen. High-solids bentonite grout and/or neat cement was placed above the silica sand to seal the annulus to approximately five feet

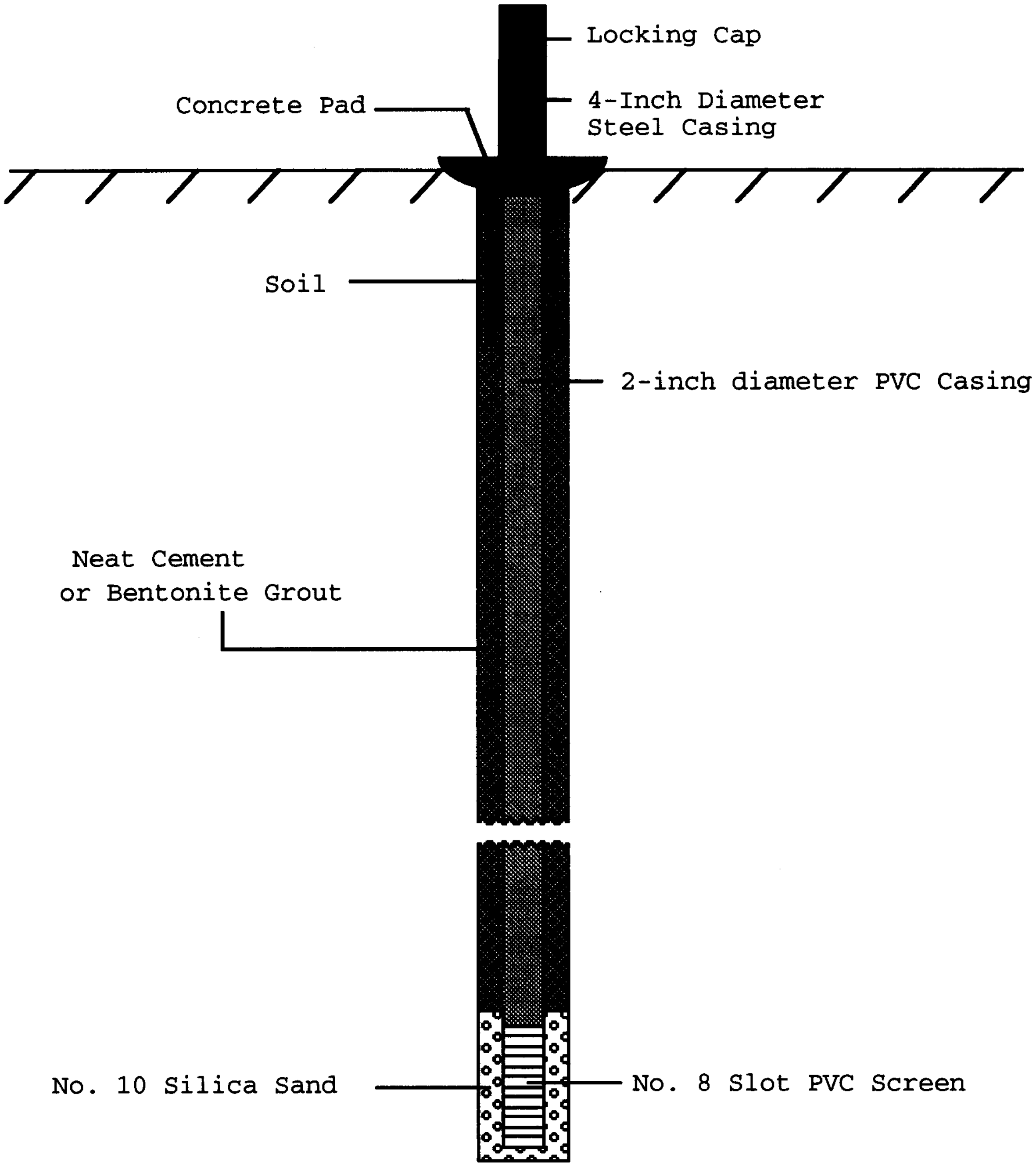


Figure 2. Construction design used for monitoring wells installed at the Beach landfill.

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 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 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

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

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,

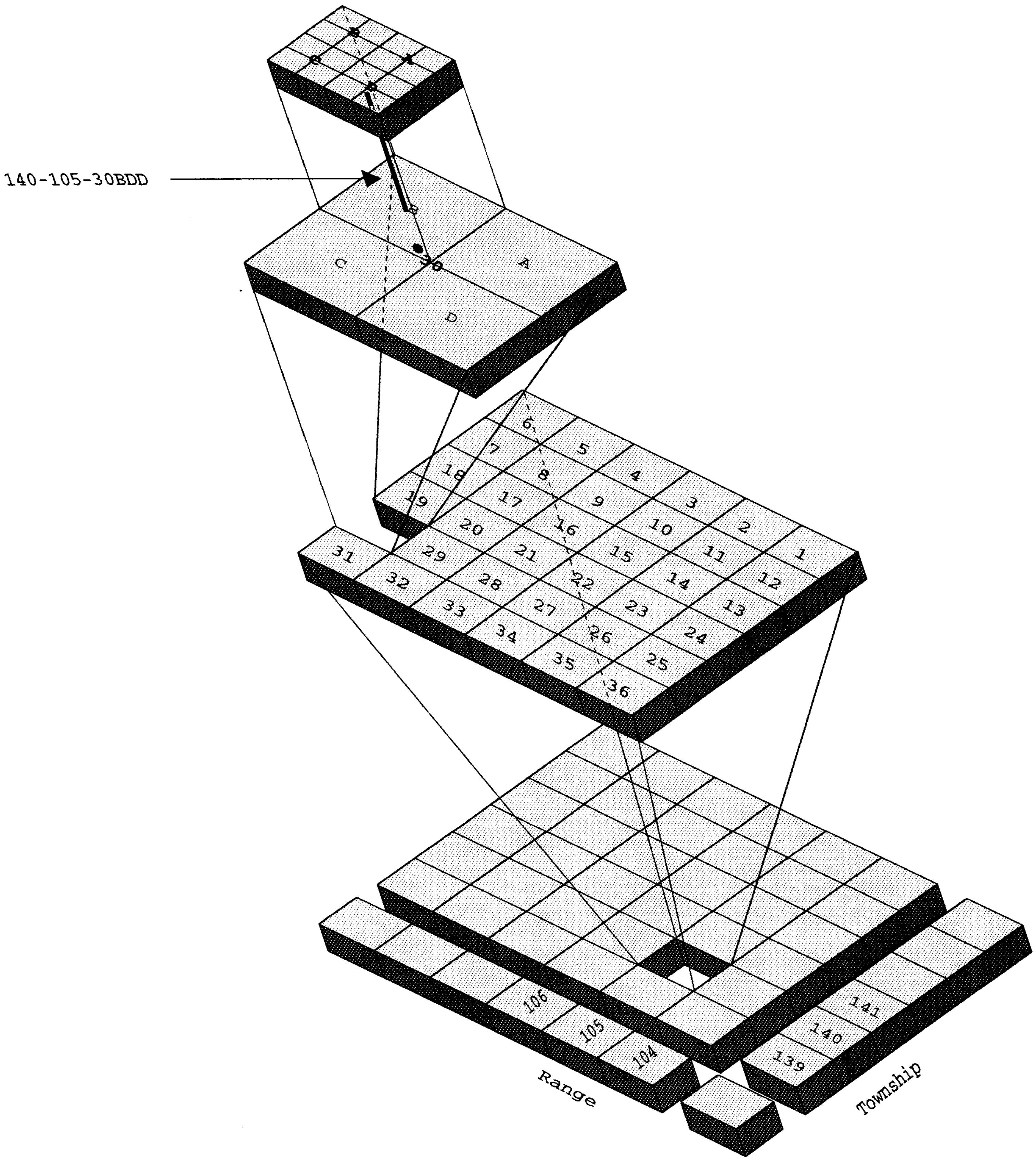


Figure 3. Location-numbering system for the Beach landfill.

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 140-105-30BDD would be located in the SE1/4, SE1/4, NW1/4, Section 30, Township 140 North, Range 105 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 140-105-30BDD1 and 140-105-30BDD2.

GEOLOGY

The Beach landfill is located in an area of gentle relief on the east side of an intermittent stream, Little Beaver Creek (Fig. 4). The geologic materials at the site consist of clay, silt, sand, and lignite of the Bullion Creek Formation (Paleocene). The surficial layer of sediment is composed of silt, fine-grained, silty sand, and silty clay loam. (Fig. 5). This layer ranges in thickness from a few feet on the west end of the landfill to about 20 feet on the east end of the landfill.

This poorly sorted interval of silt, clay, and sand is underlain by clay and silty clay interbedded with thin layers of lignite. The shallowest lignite beds occur at depths of between 10 and 15 feet on the west end of the landfill. These two lignite beds are less than two feet thick. Several

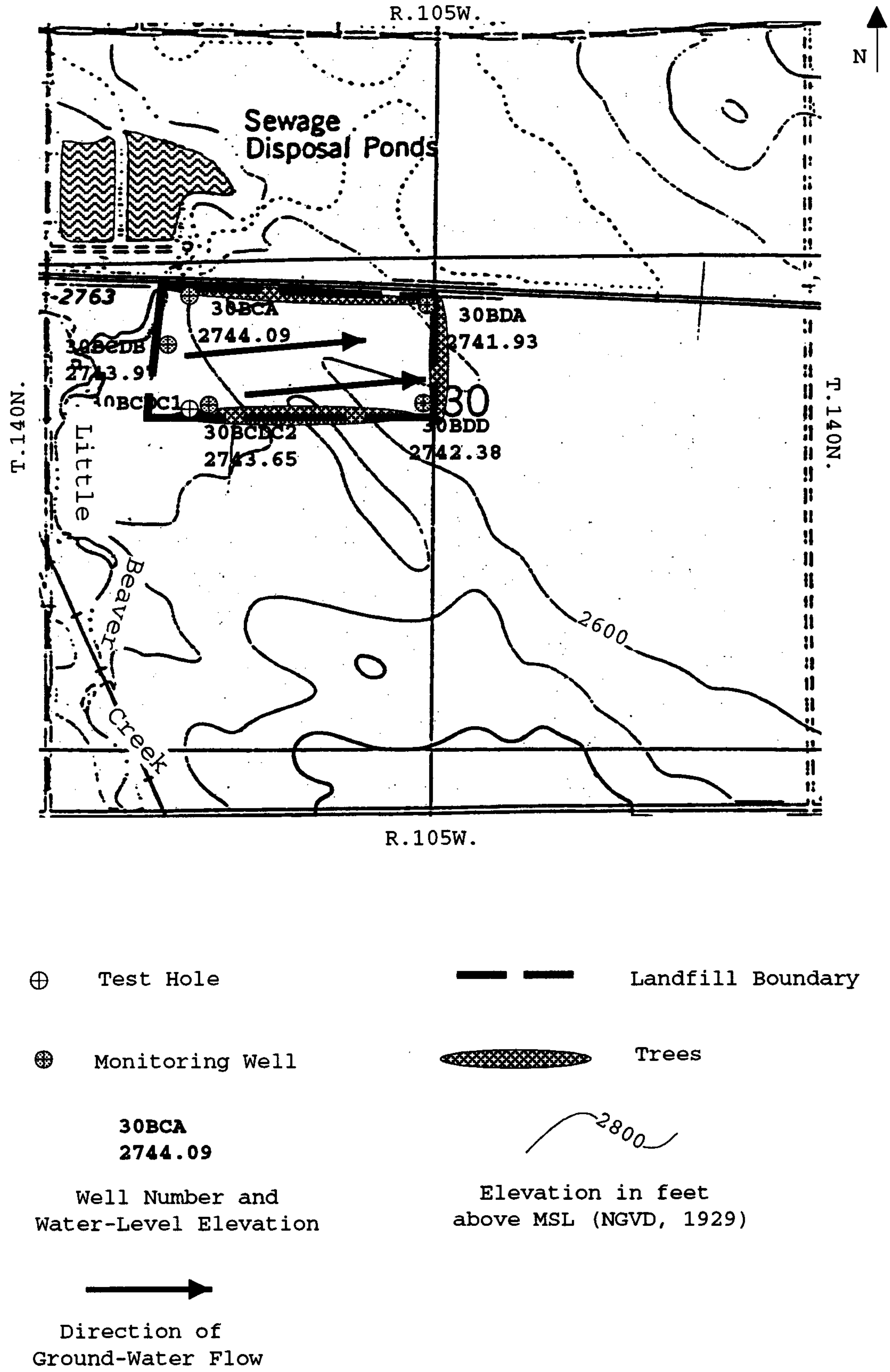


Figure 4. Location of monitoring wells and ground-water flow at the Beach landfill.

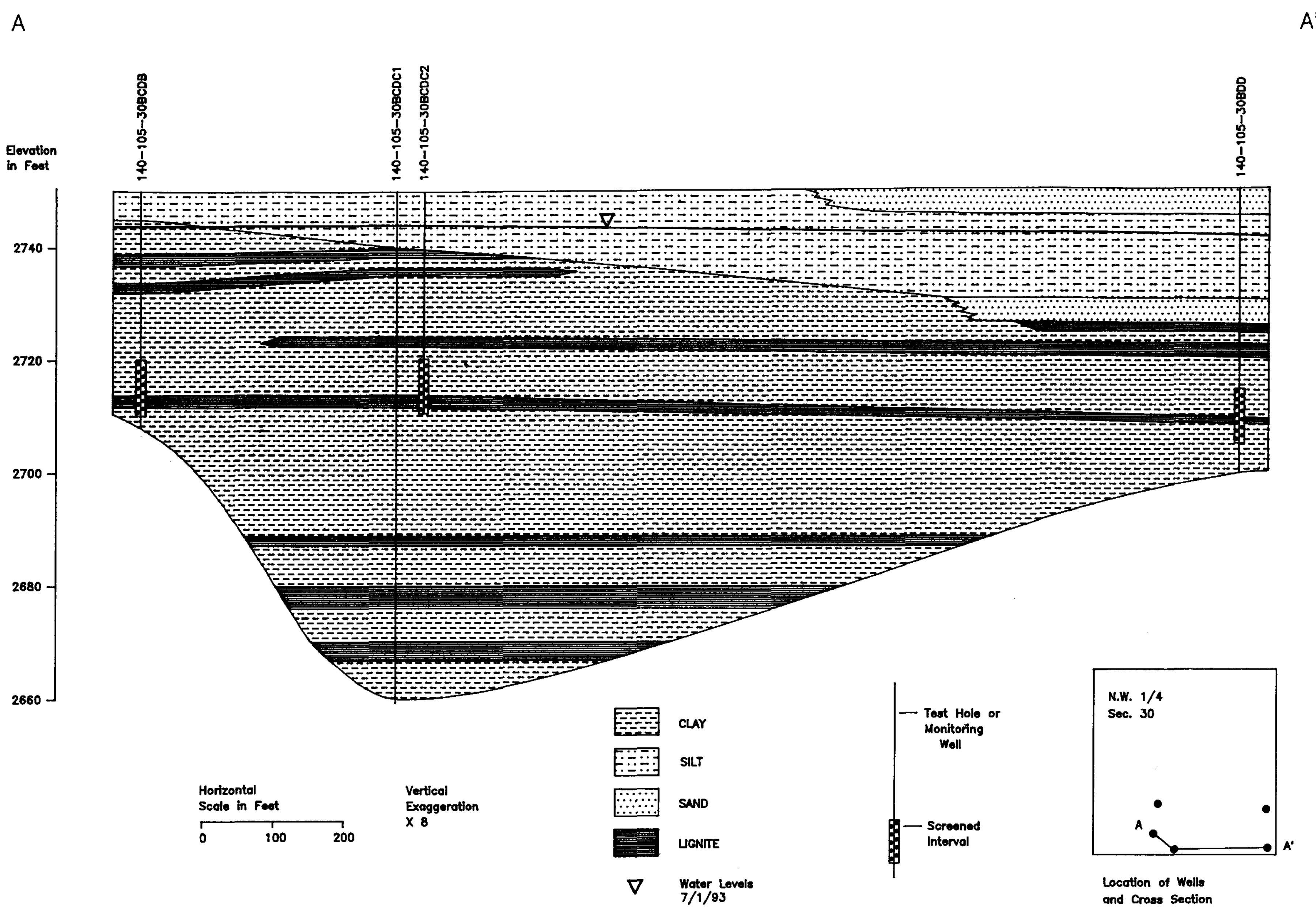


Figure 5. Geohydrologic section A–A' in the Beach landfill.

other lignite beds occur at depths greater than 25 feet (Fig. 5).

HYDROLOGY

Surface-Water Hydrology

Little Beaver Creek flows north along the western edge of the landfill property and is the surface-water basin for the landfill (Fig. 1). The creek may be susceptible to contaminated surface runoff from the landfill due to the absence of surface-water impoundments. Little Beaver Creek flows through the area of the sewage holding ponds, which are located about a quarter mile north of the landfill. The creek may be susceptible to contamination from the overflow of the sewage lagoons.

Regional Ground-Water Hydrology

Bedrock aquifers are the source of ground water in the study area. These aquifers occur in the Bullion Creek, Fox Hills, and Pierre Formations. Ground water from the Pierre Formation is extracted only from fractured zones.

The Fox Hills Formation overlies the Pierre Formation and consists mainly of fine to medium grained sandstone (Anna, 1981). The Fox Hills and the Lower

Hell Creek Formations comprise an extensive aquifer (Anna, 1981). This aquifer follows the dip of the formations to the northeast beneath the landfill. The depth to the aquifer is about 1,400 feet near Beach. The Fox Hills-Lower Hell Creek aquifer is characterized by a sodium-bicarbonate type water (Anna, 1981). This aquifer should not be affected by the landfill due to its depth and low hydraulic conductivity of intervening clays and silty clays (aquitards).

The Lower Ludlow and Upper Hell Creek Formations comprise an aquifer that overlies the Fox Hills-Lower Hell Creek aquifer. The aquifer consists of lignite and sandstone, and occurs at depths of about 1300 feet near the landfill. The Lower Ludlow-Upper Hell Creek aquifer is characterized by a sodium-bicarbonate type water (Anna, 1981). This aquifer should not be affected by the landfill due to its depth and the low hydraulic conductivity of intervening aquitards.

The Bullion Creek-Sentinel Butte Formations overly the Lower Ludlow-Upper Hell Creek aquifer. In the area of the landfill, the Bullion Creek Formation is at the surface. The Bullion Creek aquifer consists of sandstone and lignite. Ground-water chemistry in the Bullion Creek aquifer is variable depending on depth and proximity to lignite beds (Anna, 1981). The major cation is sodium which increases in concentration with depth. The major anions are bicarbonate and sulfate with sulfate increasing slightly with depth (Anna, 1981). The upper part of the Bullion Creek aquifer may be susceptible to contamination from the landfill because of its shallow depth and lack of intervening low hydraulic conductivity lithologies.

Local Ground-Water Hydrology

Six test holes were drilled at the Beach landfill and monitoring wells were installed in five of them (Fig. 4). The well screens were placed near the top of the Bullion Creek aquifer beneath the landfill. The sand aquifer beneath the landfill is unconfined and has very little overlying clay material. Four water levels were taken over a six-week period (Appendix D). The monitoring wells along the western side of the landfill (140-105-30BCA, 30BCDB, and 30BCDC2) are screened through a 1- to 2-foot thick lignite bed and clay interbedded with sandstone. Wells 140-105-30BDA and 30BDD are screened in silty clay. The lignite was absent at the eastern end of the landfill. The direction of ground-water flow in the shallow Bullion Creek aquifer is to the east (Fig. 4), parallel to the regional ground-water flow direction.

Water Quality

Chemical analyses of water samples are shown in Appendix E. The total dissolved solids concentrations (>2,000 mg/L) are high, but are typical of lignite aquifers in the western part of North Dakota. Ground water in the 5 monitoring wells is characterized by a mixed calcium-sodium-sulfate type (Fig. 6). Well 140-105-30BDD appears to show a slight increase in the percentage of sodium. This increase in sodium appears to originate from the Bullion Creek Formation. The geochemistry of lignite is complex and may be a significant source of ions (both major and trace) used to evaluate the affects of the landfill. As a result, analysis of the distribution of major ions and trace elements was not considered an effective method to assess contaminate migration from the landfill.

The trace element analyses did not indicate any influence by the landfill. The high strontium concentrations appear to be typical in bedrock material in western North Dakota.

Results of VOC analyses from wells 140-105-30BCA and 30BDD are shown in Appendix F. These analyses detected the compound tetrahydrofuran (224 µg/L and 243 µg/L respectively). Tetrahydrofuran is a man-made compound used in glues and liquid cement for fabricating packages and polyvinyl-chloride materials. No glue was

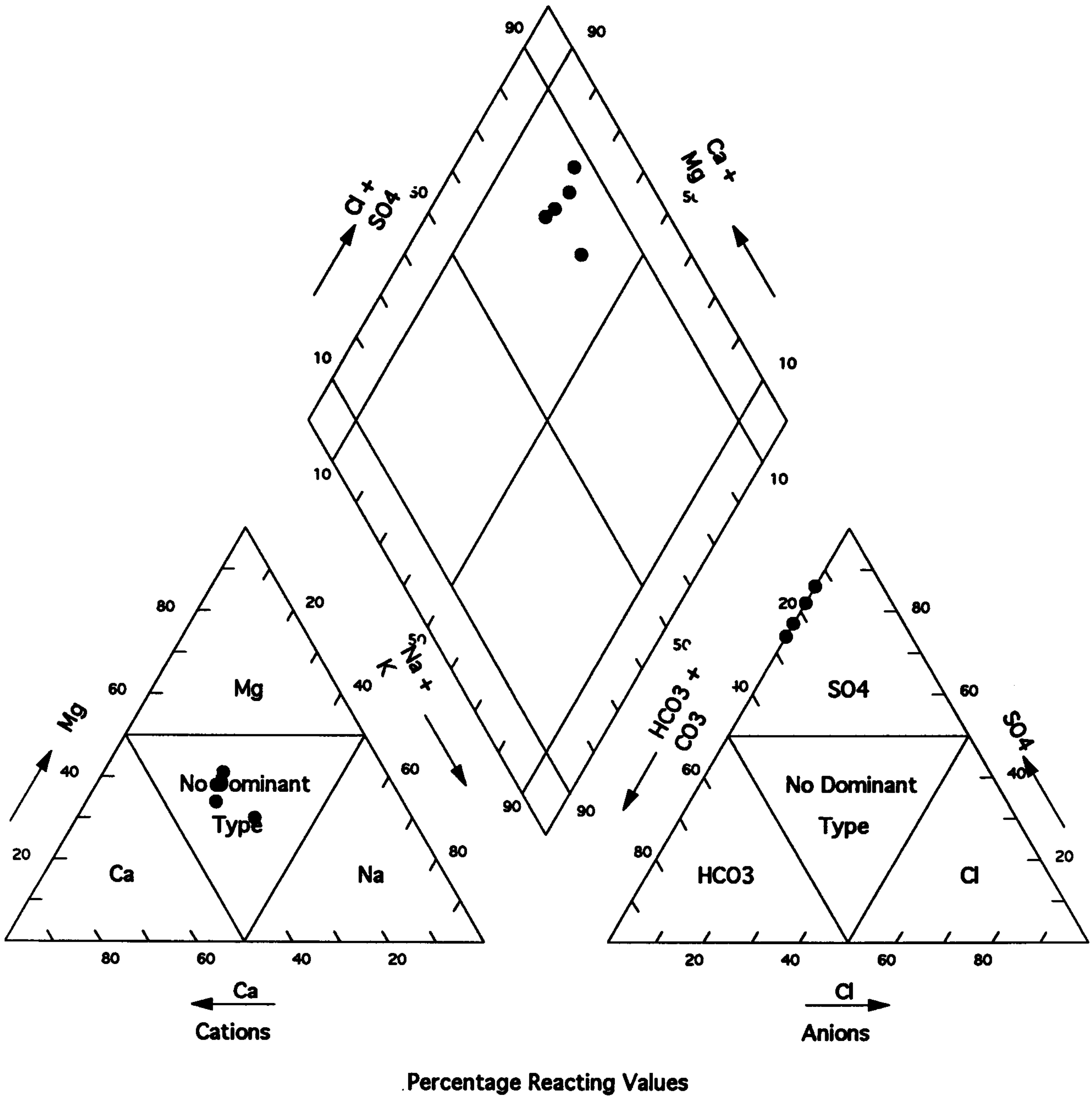


Figure 6. Piper diagram showing the general ground-water chemistry for the Bullion Creek aquifer underlying the Beach landfill.

used in the construction of the monitoring wells but, manufactured check valves do contain a small amount of glue in their construction. The source of the tetrahydrofuran may originate from these check valves or from leachate migration from the landfill.

CONCLUSIONS

The Beach landfill is located in an area of gentle relief of the Bullion Creek Formation. This formation consists of clay, sand, silt, and lignite. Shallow lignite layers (1 to 2 feet thick) are present about 10 to 15 feet below land surface with additional lignite layers below 25 feet.

The uppermost water table beneath the landfill is located in the lignite layers of the Bullion Creek aquifer. The Bullion Creek aquifer is unconfined with a very thin overlying layer of clay. This aquifer may be susceptible to contamination from the landfill due to its shallow depth and the lack of intervening aquitards. Water-level measurements in the shallow aquifer indicates ground-water flow to the east which parallels the regional direction of ground-water flow.

Regional water supplies are derived from the Fort Union Group, Fox Hills, Hell Creek, and Pierre Formations. The Fort Union Group consists of the

Bullion Creek, Sentinel Butte, and Ludlow Formations. Due to their depths, and the occurrence of intervening aquitards, the regional aquifers (excluding the Bullion Creek aquifer) should not be affected by contamination from the landfill.

In this study, the Bullion Creek aquifer is characterized by a mixed calcium-sodium-sulfate type water, and is typical for water in the Bullion Creek Formation. Due to the large background concentrations of major ions in the Bullion Creek aquifer study area, standard water chemistry analyses did not provide conclusive evidence for landfill contamination.

Results of the VOC analyses detected the compound tetrahydrofuran. This compound may have originated from the landfill or from check valves that are used in well construction.

REFERENCES

Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: United States Geological Survey Water-Supply Paper 2254, 263 p.

Anna, L.O., 1981, Ground-water resources of Billings, Golden Valley, and Slope Counties, North Dakota: North Dakota Geological Survey, Bulletin 76, North Dakota State Water Commission, County Ground-Water Studies 29, Part III, 56 p.

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

APPENDIX A

WATER QUALITY STANDARDS AND CONTAMINANT LEVELS

Water Quality Standards and Contaminant Levels

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

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

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

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

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

APPENDIX B

SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

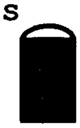
1. Three samples must be collected in the 40ml bottles that are provided by the lab. One is the sample and the others are duplicates.

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

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

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

convex meniscus



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

6. 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

140-105-30BCA
NDSWC

Date Completed:	5/4/93	Well Type:	PVC
Depth Drilled (ft):	45	Source of Data:	
Screened Interval (ft):	32-42	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2752.91

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	SILTY, TRACE SAND, LIGHT OLIVE GRAY, 5Y6/1.	2-6
CLAY	DARK YELLOWISH-ORANGE, 10YR6/6, (BULLION CREEK FORMATION).	6-9
CLAY	STIFF, LIGHT OLIVE GRAY, 5Y6/1.	9-12
CLAY	STIFF, BROWNISH-GRAY, 5YR3/2.	12-13
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y6/1.	13-15
LIGNITE		15-16
CLAY	SILTY, GREENISH-GRAY, 5GY6/1.	16-18
LIGNITE		18-19
CLAY	GREENISH-GRAY, 5GY6/1.	19-20
LIGNITE		20-21
CLAY AND SILT	GREENISH-GRAY, 5GY6/1.	21-26
SANDSTONE	FINE GRAINED, GREENISH GRAY, 5GY6/1.	26-27
SILT AND CLAY	TRACE FINE SAND, GREENISH-GRAY, 5GY6/1.	27-33
CLAY	INTERBEDDED WITH FINE GRAINED SANDSTONE, GREENISH-GRAY, 5GY6/1.	33-40
LIGNITE		40-41
CLAY	STIFF, GREENISH-GRAY, 5GY6/1.	41-45

140-105-30BCDB

NDSWC

Date Completed:	5/3/93	Well Type:	PVC
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	30-40	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2748.8

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	SANDY, MODERATE YELLOWISH-BROWN, 10YR5/4.	2-4
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y6/1, (BULLION CREEK FORMATION).	4-11
LIGNITE		11-13
CLAY	STIFF, GREENISH-GRAY, 5GY6/1.	13-16
LIGNITE		16-17
CLAY	SILTY, GREENISH-GRAY, 5GY6/1.	17-22
CLAY	STIFF AND SILTY, GREENISH-GRAY, 5GY6/1.	22-29
CLAY	SILTY, TRACE SAND, MEDIUM GRAY, N5.	29-36
LIGNITE		36-38
CLAY	SANDY, GREENISH-GRAY, 5GY6/1.	38-40

140-105-30BCDC1
NDSWC

Date Completed:	5/3/93	Well Type:	PVC
Depth Drilled (ft):	100	Source of Data:	
Screened Interval (ft):	0-0	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2750

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	SANDY, PALE YELLOWISH-BROWN, 10YR6/2, (BULLION CREEK FORMATION).	2-10
LIGNITE		10-11
CLAY	STIFF, LIGHT GREENISH-GRAY, 5GY8/1.	11-13
LIGNITE		13-14
CLAY	STIFF, BROWNISH-GRAY, 5YR4/1.	14-21
CLAY	STIFF, LIGHT MEDIUM GRAY, N6.	21-26
LIGNITE		26-27
CLAY	STIFF CLAY INTERBEDDED WITH SILTY CLAY, MEDIUM LIGHT GRAY, N6.	27-36
LIGNITE		36-38
CLAY	STIFF, BROWNISH-GRAY, 5YR4/1.	38-41
CLAY	STIFF, GREENISH-GRAY, 5G6/1.	41-45
CLAY	STIFF CLAY INTERBEDDED WITH SILTY CLAY, GREENISH-GRAY, 5G6/1.	45-62
LIGNITE		62-63
CLAY	SILTY, BROWNISH-GRAY, 5YR4/1.	63-66
CLAY	INTERBEDDED STIFF AND SILTY CLAY, LIGHT OLIVE GRAY, 5Y6/1.	66-70
LIGNITE		70-74

CLAY	STIFF TO SILTY, GREENISH-GRAY, 5GY6/1.	74-80
LIGNITE		80-83
CLAY	SILTY, GREENISH-GRAY, 5G,6/1.	83-92
LIGNITE		92-93
CLAY	SILTY, GREENISH-GRAY, 5G6/1.	93-100

140-105-30BCDC2

NDSWC

Date Completed:	5/3/93	Well Type:	PVC
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	30-40	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2750.23

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	SANDY, MODERATE YELLOWISH-BROWN, 10YR5/4, (BULLION CREEK FORMATION).	2-10
LIGNITE		10-11
CLAY	STIFF, GREENISH-GRAY, 5GY6/1.	11-14
LIGNITE		14-16
CLAY	STIFF, BROWNISH-GRAY, 5YR4/1.	16-17
SILT	TRACE SAND, MODERATE YELLOWISH-BROWN, 10YR5/4.	17-18
CLAY	STIFF, GREENISH-GRAY, 5GY6/1.	18-22
CLAY	STIFF TO SILTY, MEDIUM GRAY, N5.	22-27
LIGNITE		27-28
CLAY	STIFF TO SILTY, GREENISH-GRAY, 5GY6/1.	28-37
LIGNITE		37-39
CLAY	SILTY, GREENISH-GRAY, 5GY6/1.	39-40

140-105-30BDA
NDSWC

Date Completed:	5/4/93	Well Type:	PVC
Depth Drilled (ft):	66	Source of Data:	
Screened Interval (ft):	53-63	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2766.85

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	CLAYEY, DARK YELLOWISH-ORANGE, 10YR6/6.	1-4
CLAY	LIGHT OLIVE GRAY, 5Y6/1, (BULLION CREEK FORMATION).	4-5
LIGNITE		5-6
CLAY	MEDIUM GRAY, N5.	6-10
CLAY	CLAY, DARK YELLOWISH-BROWN, 10YR4/2.	10-11
CLAY	SILTY, MEDIUM GRAY, N5	11-15
CLAY	SILTY, TRACE FINE SAND, PALE YELLOWISH-BROWN, 10YR6/2.	15-19
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y6/1	19-23
LIGNITE		23-24
CLAY	STIFF, PALE GREEN, 10G6/2.	24-35
CLAY	SILTY, BROWNISH-GRAY, 5YR3/2.	35-38
CLAY	SILTY, GREENISH-GRAY, 5GY6/1.	38-40
LIGNITE		40-44
CLAY	SILTY, GREENISH-GRAY, 5GY6/1.	44-45
LIGNITE		45-47
CLAY	SILTY, GREENISH-GRAY, 5GY6/1, 3 INCH LIGNITE AT 62'.	47-66

140-105-30BDD
NDSWC

Date Completed:	**5/4/93**	**Well Type:**	**PVC**
Depth Drilled (ft):	**50**	**Source of Data:**	
Screened Interval (ft):	**35-45**	**Principal Aquifer :**	**Undefined**
Casing size (in) & Type:		**L.S. Elevation (ft)**	**2751.18**

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND	SILTY, FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4, (BULLION CREEK FORMATION).	2-5
SILT	CLAYEY, SANDY, LIGHT OLIVE GRAY, 5Y6/1.	5-9
SILT	CLAYEY, DARK YELLOWISH-ORANGE, 10YR6/6.	9-11
SILT	CLAYEY, SANDY, PALE BROWN, 5YR5/2.	11-15
SILT	CLAYEY, SANDY, LIGHT OLIVE GRAY, 5Y6/1.	15-20
SAND	FINE GRAINED, LIGHT OLIVE GRAY, 5Y6/1.	20-24
LIGNITE		24-25
CLAY	STIFF, GREENISH-GRAY, 5GY6/1.	25-27
LIGNITE	WITH INTERBEDDED CLAY.	27-30
CLAY	SILTY, GREENISH-GRAY, 5GY6/1, 4 INCH OF LIGNITE AT 43'.	30-45
CLAY	WITH INTERBEDDED SILT, GREENISH-GRAY, 5GY6/1.	45-50

APPENDIX D

WATER-LEVEL TABLES

Beach Water Levels
5/18/93 to 7/1/93

140-105-30BCA LS Elev (msl,ft)=2752.91
Undefined Aquifer SI (ft.)=32-42

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/18/93	9.41	2743.50	06/15/93	8.82	2744.09
05/27/93	9.57	2743.34	07/01/93	9.05	2743.86

140-105-30BCDB LS Elev (msl,ft)=2748.8
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/18/93	5.62	2743.18	06/15/93	4.83	2743.97
05/27/93	5.46	2743.34	07/01/93	4.92	2743.88

140-105-30BCDC2 LS Elev (msl,ft)=2750.23
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/18/93	6.79	2743.44	06/15/93	6.58	2743.65
05/27/93	7.16	2743.07	07/01/93	6.62	2743.61

140-105-30BDA LS Elev (msl,ft)=2766.85
Undefined Aquifer SI (ft.)=53-63

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/18/93	25.04	2741.81	06/15/93	24.92	2741.93
05/27/93	25.66	2741.19	07/01/93	24.91	2741.94

140-105-30BDD LS Elev (msl,ft)=2751.18
Undefined Aquifer SI (ft.)=35-45

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/18/93	8.63	2742.55	06/15/93	8.80	2742.38
05/27/93	8.99	2742.19	07/01/93	8.53	2742.65

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Beach Water Quality
Major Ions

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	Hardness as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
			(milligrams per liter)																					
140-105-30BCA	32-42	05/27/93	9.9	1.2	0.16	260	170	210	14	542	0	1300	6	0.1	0.2	0.85	2240	1300	900	25	2.5	2690	10	7.72
140-105-30BCDB	30-40	05/27/93	15	0.05	0.7	310	210	280	17	616	0	1700	3.6	0.1	6.9	1	2850	1600	1100	27	3.1	3260	11	7.7
140-105-30BCDC2	30-40	05/27/93	9.2	1.8	0.25	430	330	390	17	571	0	2900	5.2	0.1	0.2	1	4370	2400	2000	26	3.5	4580	9	7.75
140-105-30BDA	53-63	05/27/93	11	8	1.3	440	250	370	18	602	0	2300	14	0.2	0.2	1.8	3710	2100	1600	27	3.5	4030	9	6.73
140-105-30BDD	35-45	05/27/93	9.4	1.1	0.27	280	170	390	15	610	0	1700	4.9	0.1	0.1	1.2	2870	1400	900	37	4.5	3430	8	7.6

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
140-105-30BCA	5/27/93	0	0	0	0	0	0	5100
140-105-30BCDB	5/27/93	0	0	0	0	0	1	5000
140-105-30BCDC2	5/27/93	0	0	0	0	0	0	6900
140-105-30BDA	5/27/93	0	0	0	0	0	0	5500
140-105-30BDD	5/27/93	0	0	0	0	0	0	5700

APPENDIX F

VOLATILE ORGANIC COMPOUNDS
FOR WELL 140-105-30BDD

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	243*
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection

APPENDIX G

VOLATILE ORGANIC COMPOUNDS
FOR WELL 140-105-30BCA

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	224*
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection