Site Suitability Review of the Dakota Sanitation Landfill

by
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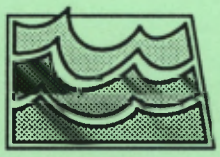

Prepared by the
North Dakota State Water Commission
and the
North Dakota Geological Survey

ND Landfill Site Investigation No. 22

SITE SUITABILITY REVIEW OF THE DAKOTA SANITATION LANDFILL

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Bismarck, North Dakota
1994

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INTRODUCTION

Purpose

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

Location of the Dakota Sanitation Landfill

The Dakota Sanitation solid waste landfill is located nine miles north of the City of Bismarck in Township 140 North, Range 81 West, E1/2, NW1/4, SW1/4 and NE1/4, SW1/4, Section 12 (Fig. 1). The landfill site encompasses approximately 60 acres.

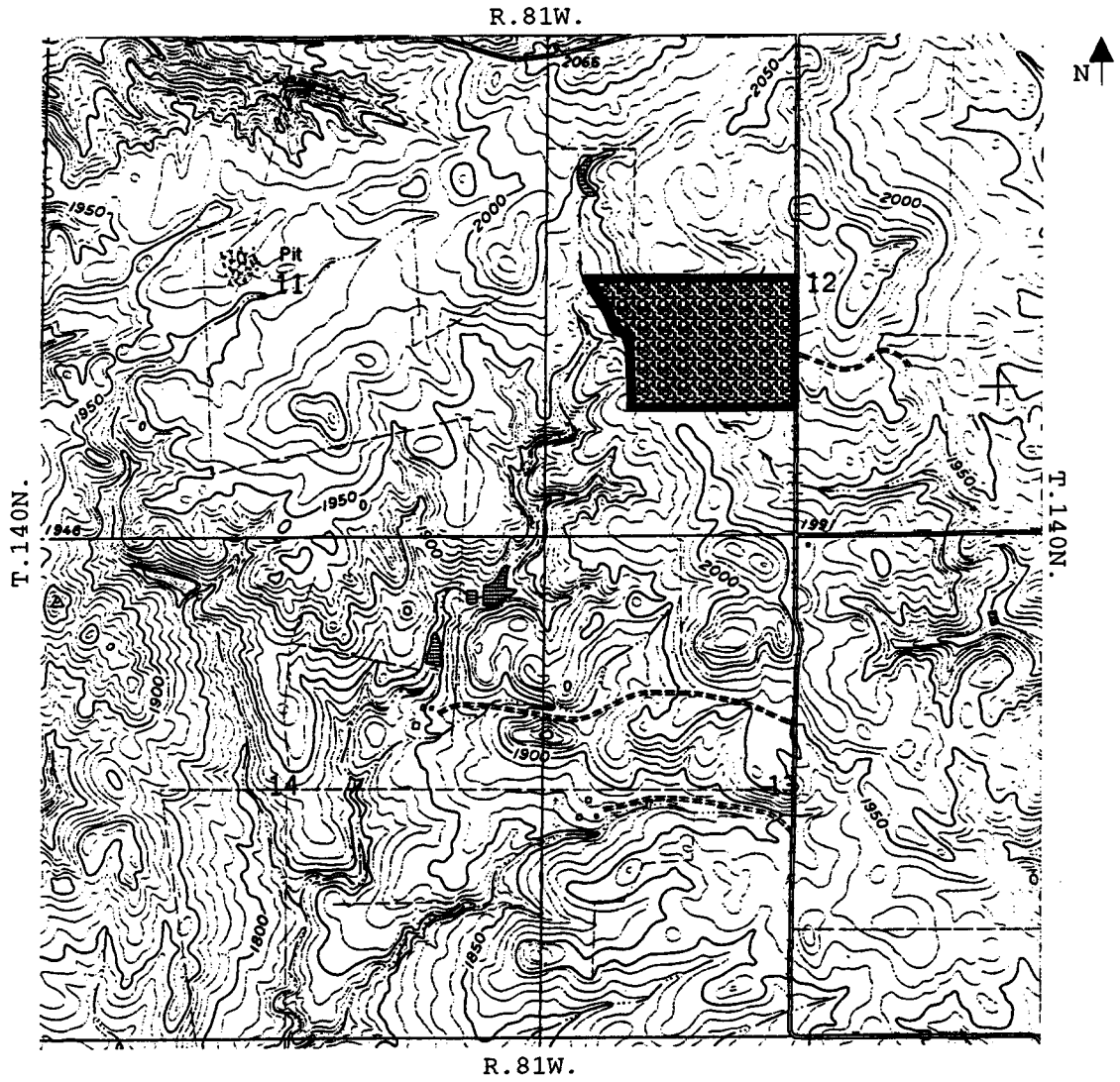

Figure 1. Location of the Dakota Sanitation landfill in the E1/2, NW1/4,SW1/4 and NE1/4, SW1/4, of section 12, T.140N., R.81W.

Previous Site Investigations

There were no previous hydrologic or geologic investigations completed at Dakota Sanitation site.

Methods of Investigation

The Dakota Sanitation study was accomplished by means of: 1) drilling test holes; 2) constructing and developing of monitoring wells; 3) collecting and analyzing water samples; and 4) measuring water levels. Well abandonment procedures were followed for non-permanent monitoring wells.

Test-Drilling Procedure

The drilling method at the Dakota Sanitation landfill was based on the site's geology and depth to ground water, as determined by the preliminary evaluation. A forward-rotary drill rig was used at the Dakota Sanitation landfill because the sediments were consolidated and because the depth to the water table was expected to exceed 70 feet. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Eight test holes were drilled at the Dakota Sanitation landfill, and monitoring wells were installed in five of the

test holes. Two of the monitoring wells were dry and eventually abandoned according to EPA and NDSDHCL regulations. The number of wells installed at the Dakota Sanitation 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 along the boundaries of the landfill property.

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.

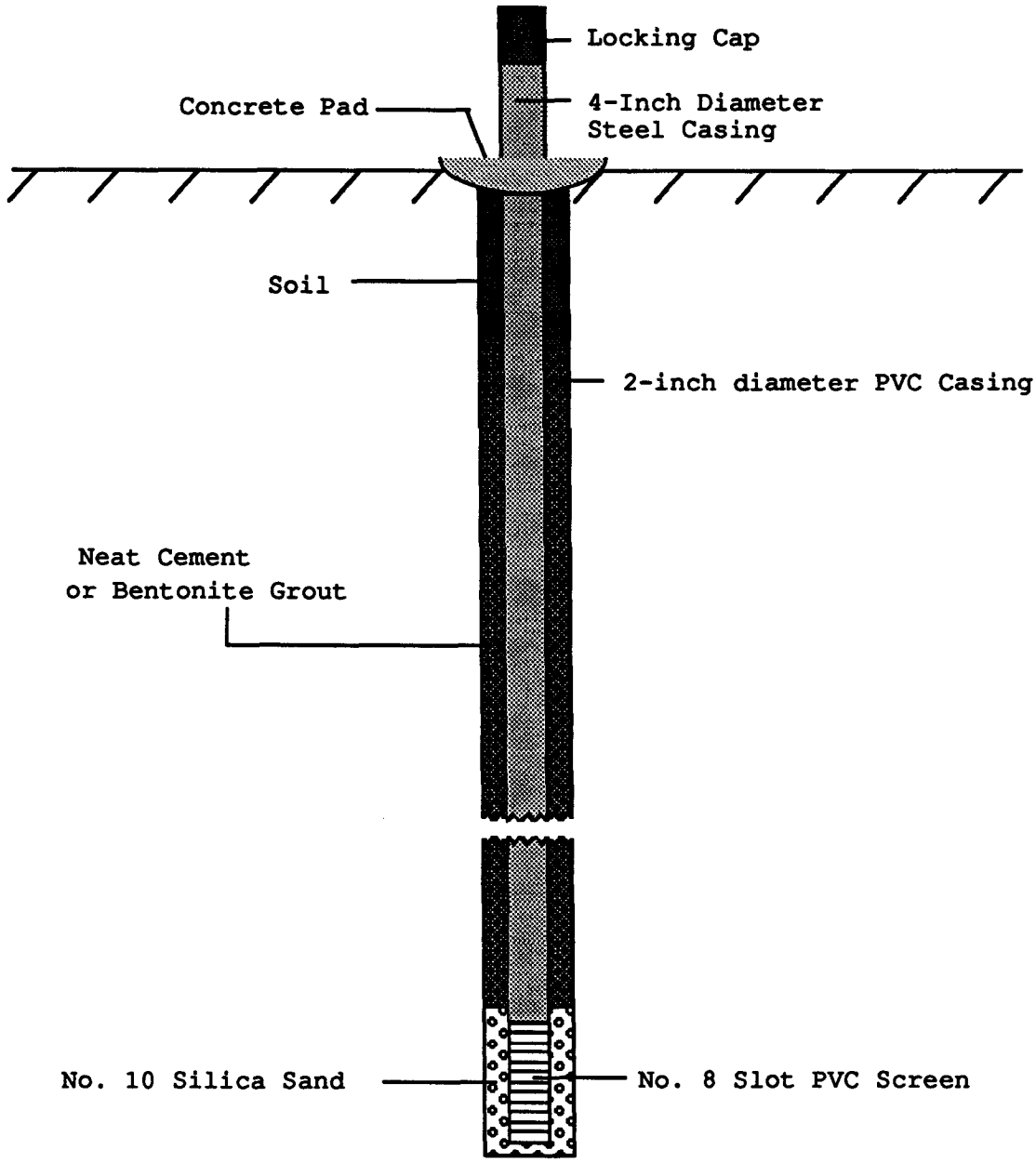

Figure 2. Construction design used for monitoring wells installed at the Dakota Sanitation landfill.

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

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

Collecting and Analyzing Water Samples

Water-quality analyses were used to determine if leachate is migrating from the landfill into the underlying ground-water system. Selected field parameters, major ions, and trace elements were measured for each water sample. These field parameters and analytes are listed in Appendix A with their Maximum Contaminant Levels (MCL). MCLs are enforcable drinking water standards that represent the maximum permissible level of a contaminant as stipulated by the U.S. Environmental Protection Agency (EPA).

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

were collected in high density polyethylene plastic bottles as follows:

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

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

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

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

Water-Level Measurements

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

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 of 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. 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.

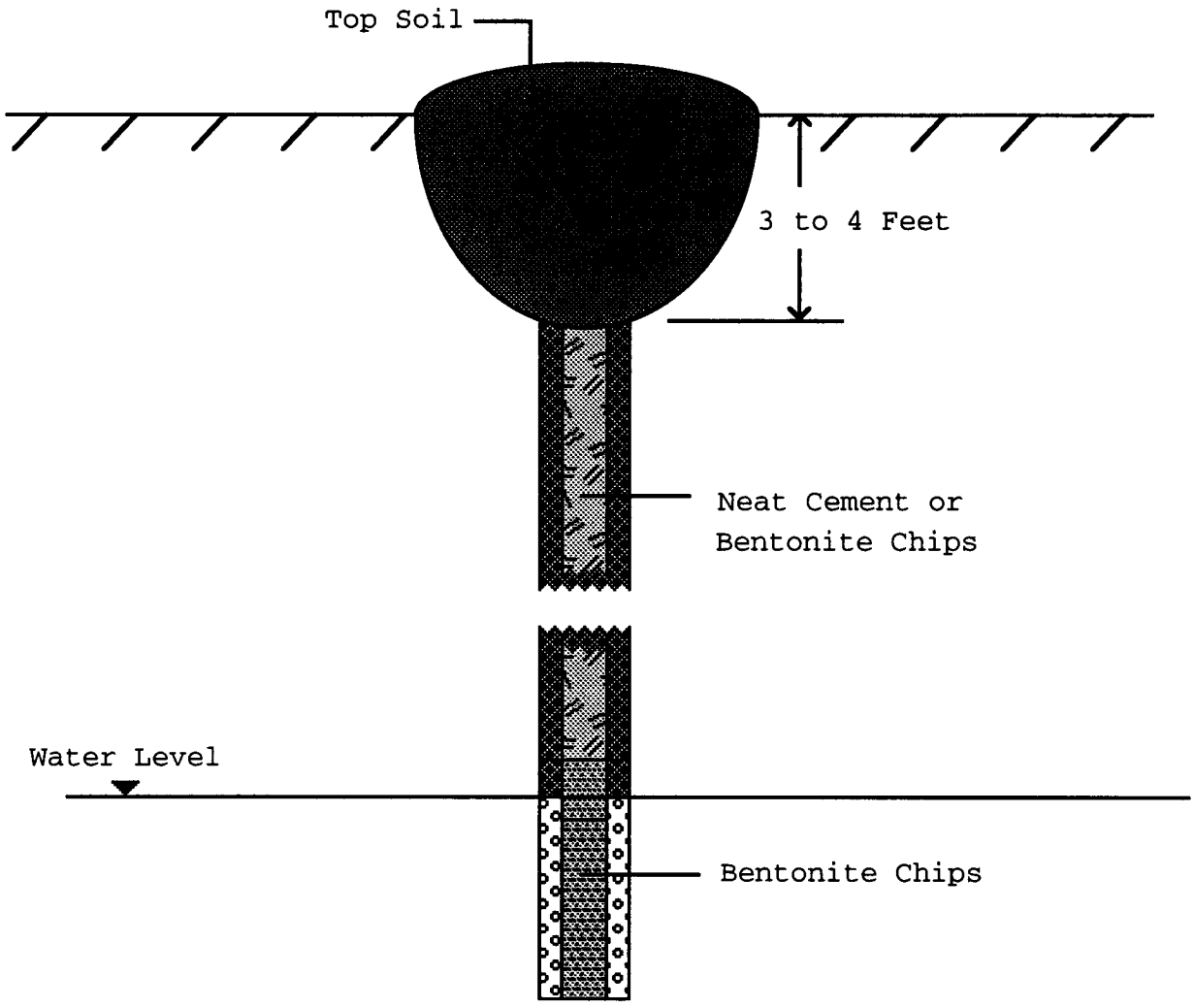

Figure 3. Monitoring well abandonment procedure.

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 140-081-12CBB would be located in the NE1/4, NE1/4, SW1/4, Section 12, Township 140 North, Range 81 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 140-081-12CBB1 and 140-081-12CBB2.

GEOLOGY

The Dakota Sanitation landfill is situated in an area of dissected upland on the crest and slopes of a ridge. This north-south trending ridge forms a drainage divide between the Missouri River and Burnt Creek. A ravine on the west side of the landfill drains southward toward the Missouri

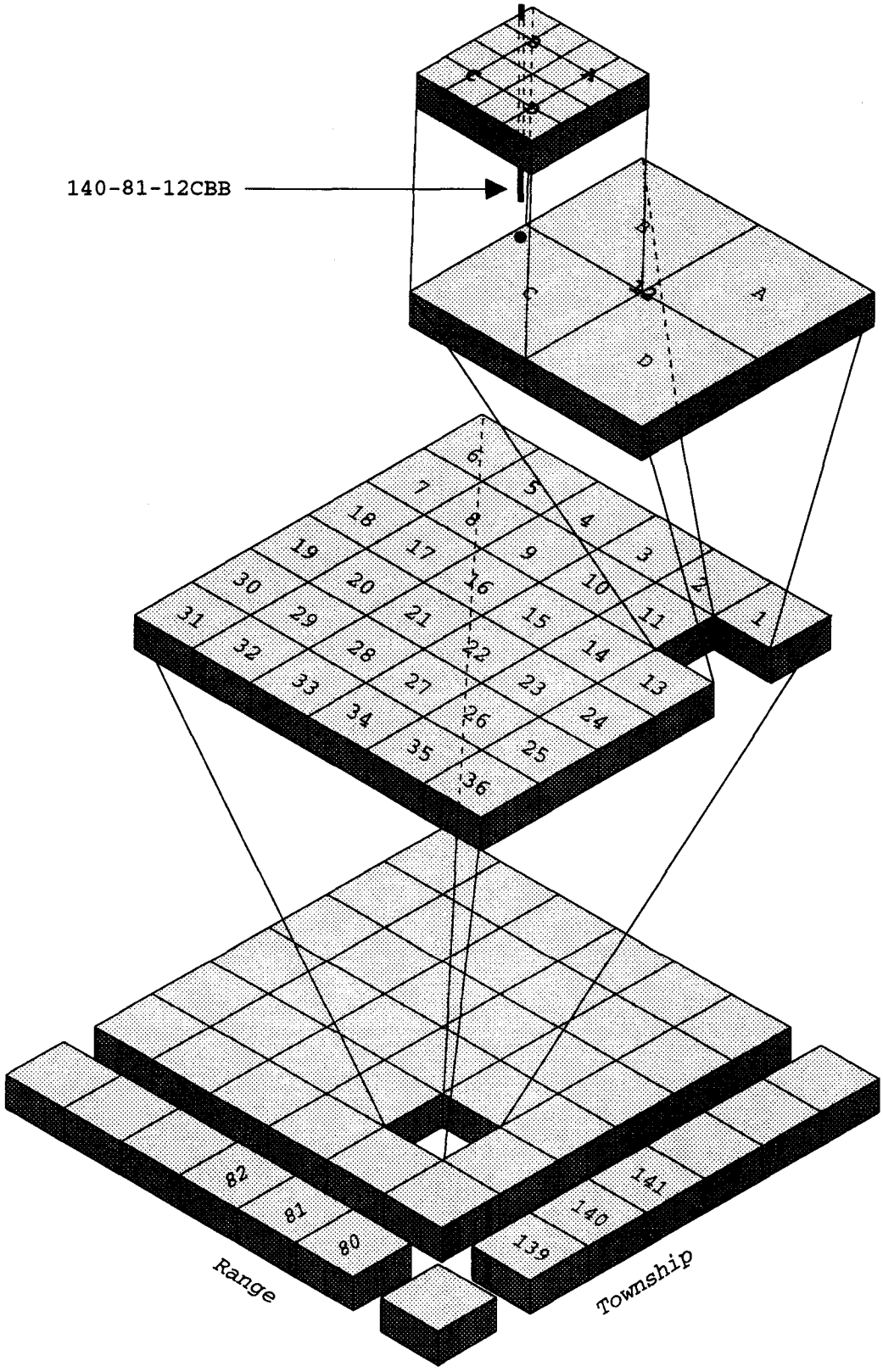

Figure 4. Location-numbering system for the Dakota Sanitation landfill.

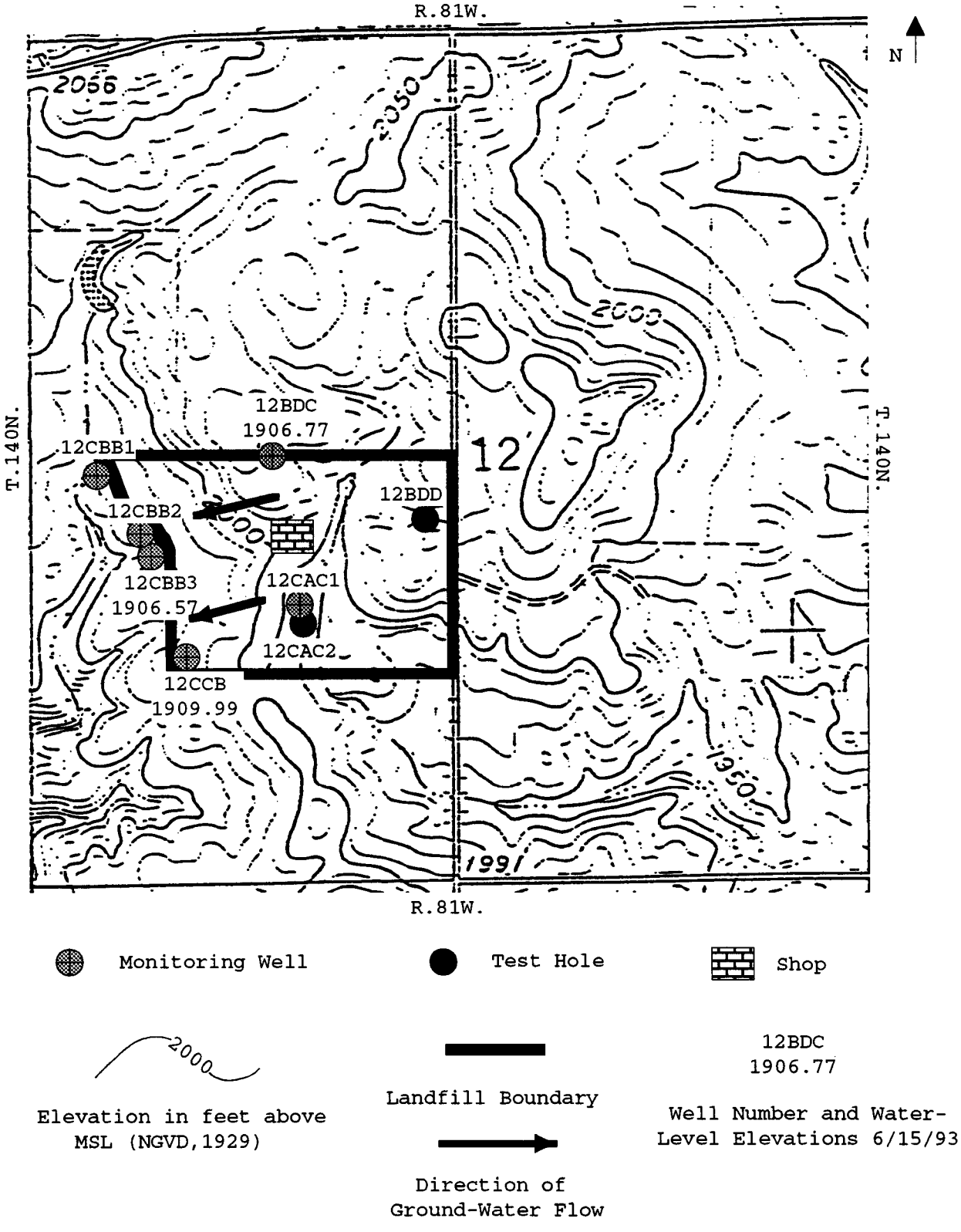

Figure 5. Location of monitoring wells and test holes at the Dakota Sanitation landfill.

River (Fig. 5). Another intermittent stream on the east side of the landfill drains southeast toward Burnt Creek. Elevations on the landfill property range from about 1,880 feet to 2,040 feet.

Except for a thin layer of glacial till and gravel on the crest of the ridge, the sediments at the landfill are part of the Bullion Creek Formation. The Bullion Creek Formation was deposited during the Paleocene Epoch in a deltaic environment (Jacob, 1976). It is underlain by the Cannonball, Hell Creek, and Fox Hills Formations.

Within the landfill the Bullion Creek Formation consists of interbedded sand, silt, and clay (Fig. 6). Test holes drilled in the lower elevations along the slopes of the ridge encountered a thick interval of sand at or near the surface (140-081-12CAC2, 12CBB1, 12CBB2, and 12CCB, lithologic logs in Appendix C). Two test holes drilled near the top of the ridge encountered glacial sediments underlain by clay and sand (140-081-12BDC and 12BDD).

HYDROLOGY

Surface-Water Hydrology

Surface waters near the landfill consist of intermittent streams that appear to flow away from the landfill to the south. One intermittent stream is located west and down-gradient of the landfill and may be susceptible

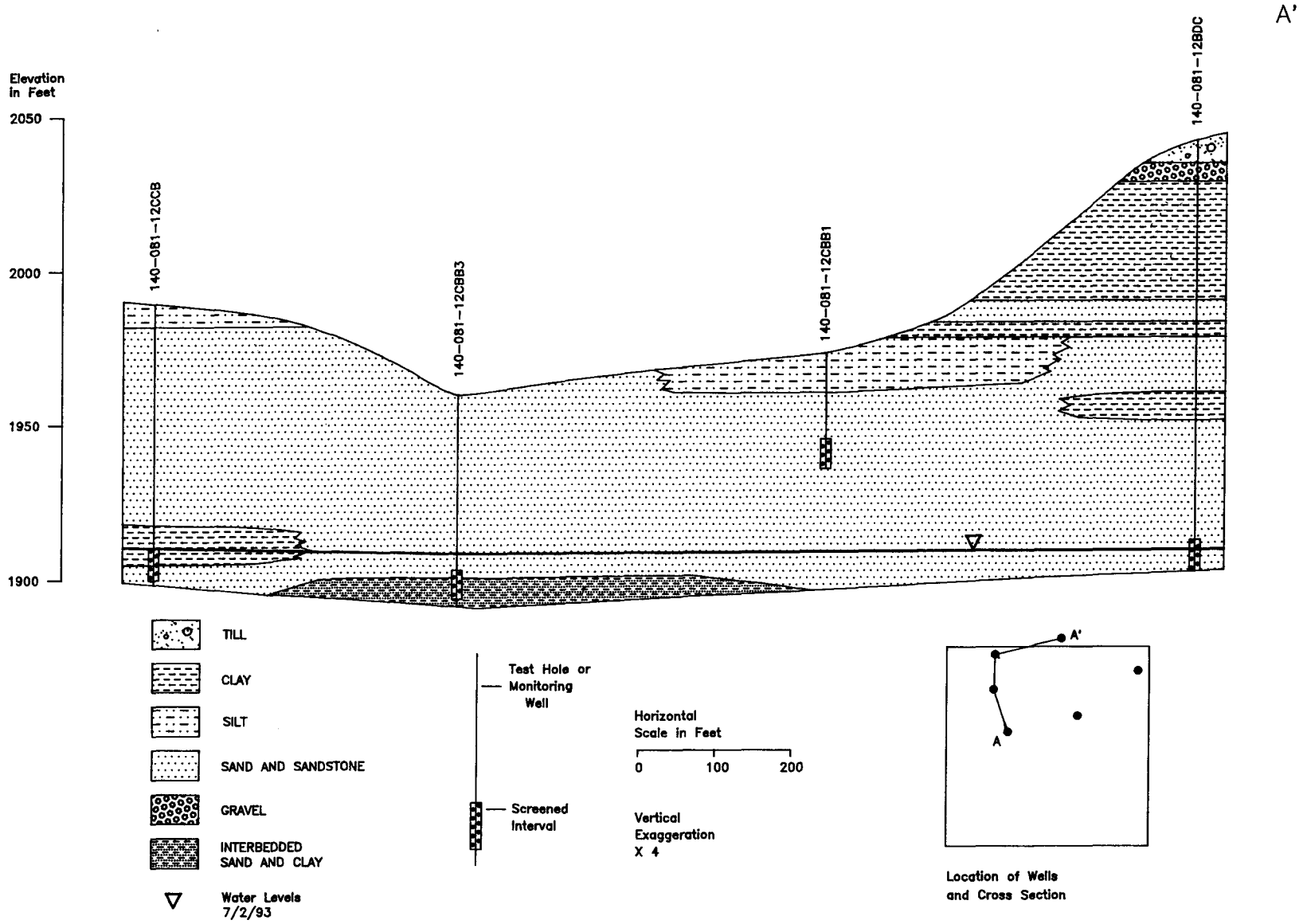

Figure 6. Geohydrologic section A–A' in the Dakota Sanitation landfill.

to contamination from the landfill during periods of high precipitation and snowmelt (Fig. 5). A stock dam located up-gradient in the streambed may reduce the amount of flow down the stream (Fig. 5). Other stock ponds are located about one-half mile southwest of the landfill and may recieve contaminated surface runoff from the landfill. This stream may also act as a local ground-water discharge area from beneath the landfill. Another intermittent stream is located east of the active area. This intermittent stream may also receive contaminated surface runoff from the landfill.

The Missouri River basin is located about 2 1/2 miles southwest of the landfill. The Missouri River should not be influenced by runoff from the landfill. No other surface waters are located within a three-mile radius of the landfill.

Regional Ground-Water Hydrology

The regional aquifers within a three-mile radius of the landfill consist of glacial and bedrock materials. The glacial aquifers include the Wagonsport aquifer and the Burnt Creek aquifer. The Wagonsport aquifer is located about 2 1/2 miles west of the landfill, adjacent to the Missouri River. It ranges from 20 to 50 feet thick (Randich, 1966). This aquifer is characterized by a sodium bicarbonate type water. The Wagonsport aquifer is recharged by precipitation, and

lateral flow from adjacent bedrock aquifers and the Missouri River (Randich, 1966). This aquifer is located up-gradient from the landfill and should not be affected by the landfill operation.

The Burnt Creek aquifer, located about 2 1/2 miles southwest of the landfill adjacent to the Missouri River, ranges from 20 to about 80 feet thick. This aquifer is characterized by a sodium-calcium-bicarbonate type water (Randich, 1966). The Burnt Creek aquifer is recharged by precipitation, seepage from Burnt Creek and the Missouri River, and lateral flow from adjacent bedrock aquifers. This aquifer may be affected by the landfill if a hydraulic connection exists with the Bullion Creek aquifer.

The bedrock aquifers are located in the Fox Hills, Cannonball, and Bullion Creek Formations. Near the landfill the Fox Hills aquifer is located at a depth greater than 300 feet. This aquifer is characterized by a sodium-chloride-bicarbonate type water. This aquifer should not be influenced by the landfill due to its depth and the intervening aquitards.

The Cannonball aquifer underlies the Bullion Creek aquifer in the area of the landfill. This aquifer is characterized by a sodium-bicarbonate-sulfate type water. This aquifer may be influenced by the landfill in outcrops that occur along the ravines in the study area.

The Bullion Creek aquifer is the uppermost aquifer in the area of the landfill. This aquifer is overlain by 50 to

100 feet of unconsolidated-fine grained sand with interbedded clay and silt. This aquifer is characterized by a sodium-calcium-bicarbonate type water.

Local Ground-Water Hydrology

Eight test holes were drilled at the Dakota Sanitation landfill with monitoring wells installed in six of them (Fig. 4). Wells 140-081-12CAC2, 12CBB1, and 12CBB2 were dry and abandoned at the beginning of this study. The well screens were placed in the lower Bullion Creek aquifer beneath the landfill. Six water-level measurements were taken over a nine-week period (Appendix D). The direction of ground-water flow appears to be west towards the ravine along the western boundary of the landfill and then to the south-southwest (Fig.4).

The overlying unconsolidated sand allows precipitation to infiltrate through the refuse and into the Bullion Creek aquifer. Because of the high infiltration through the overlying material, the Bullion Creek aquifer may be susceptible to contamination from the landfill. The interbedded clay and silt layers may act as aquitards during periods of high infiltration and could create temporary perched water tables beneath the landfill.

Water Quality

Chemical analyses of water samples are shown in Appendix E. The chemical analyses did not detect any influence from the landfill. The major ion constituents are typical of ground water in the Bullion Creek aquifer. The water is a calcium-sodium-bicarbonate type. The trace element analysis from well 12BDC detected a selenium concentration of 8 µg/L, which is near the MCL of 10 µg/L. This concentration appears to be natural as this well is located up-gradient of the landfill. This well also detected an increase of arsenic that is higher than the surrounding wells but within the typical concentrations found in the Bullion Creek aquifer.

Results of a VOC analysis from well 12CBB3 is shown in Appendix F. There were no VOC compounds detected from this analysis.

CONCLUSIONS

The Dakota Sanitation landfill is located on the crest of a north-south ridge that forms a drainage divide between the Missouri River and Burnt Creek. The surface elevation at the landfill ranges from 1,880 to 2,040 feet MSL.

A thin layer of till overlies the Bullion Creek Formation. This formation consists of interbedded sand, silt, and clay. Test holes at the landfill encountered a thick interval of sand at or near the surface.

Surface drainage from the landfill is toward the Missouri River on the west side of the landfill and toward Burnt Creek on the east side of the landfill. Stock dams are located within the ravine along the western boundary of the landfill. This intermittent stream may be susceptible to contamination by surface runoff from the landfill and also by ground water that may discharge into the ravine.

The intermittent stream along the eastern boundary may also be susceptible to contamination from the landfill by surface runoff. This intermittent stream does not appear to be deep enough to act as a ground-water discharge area.

The Wagonsport and Burnt Creek aquifers are two glacial aquifers that occur within 2 1/2 miles of the landfill. The Wagonsport aquifer should not be affected by contaminant migration from the landfill because it is located up-gradient from the landfill. The Burnt Creek aquifer is down-gradient of the landfill and may be susceptible to contaminant migration from the landfill if a hydraulic connection exists between the Bullion Creek and Burnt Creek aquifers.

The Bullion Creek aquifer is the uppermost aquifer beneath the landfill. It is overlain by 50 to 100 feet of unconsolidated, fine grained sand with interbedded silt and clay. The direction of ground-water flow in the Bullion Creek aquifer is west toward the ravine along the western boundary of the landfill and then to the south-southwest following the base of the ravine. The overlying unconsolidated sand allows precipitation to infiltrate

through the refuse and into the Bullion Creek aquifer. Because of the high infiltration through the overlying material, the Bullion Creek aquifer may be susceptible to contamination from the landfill. The interbedded silt and clay layers may act as aquitards during periods of high infiltration and create temporary perched water levels.

The chemical analyses did not detect anomalous concentrations of major ions in the Bullion Creek aquifer. The trace element analyses detected a selenium concentration in well 12BDC that was near the MCL. This concentration appears to be typical for this aquifer because this well is located up-gradient of the landfill. An elevated arsenic concentration was also detected in this well. A VOC analysis did not detect any VOC compounds.

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APPENDIX A

WATER QUALITY STANDARDS
AND
CONTAMINANT LEVELS

Water Quality Standards and Contaminant Levels

Field Parameters

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

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

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

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

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

APPENDIX B

SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

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

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

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

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

convex meniscus

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

6. 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

140-081-12BDC
NDSWC

Date Completed:	4/30/30	Purpose:	Observation Well
L.S. Elevation (ft):	2041.11	Well Type:	2" PVC
Depth Drilled (ft):	140	Aquifer:	Undefined
Screened Interval (ft):	130-140	Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	SILTY, PEBBLES, DARK YELLOWISH BROWN, 10YR4/2, TILL.	2-8
GRAVEL		8-12
SILT	SANDY, MODERATE YELLOWISH-BROWN, (BEDROCK).	12-14
CLAY	STIFF, PALE YELLOWISH-BROWN, 10YR6/2.	14-17
CLAY	SILTY, PALE YELLOWISH-BROWN, 10YR6/2.	17-24
CLAY	STIFF, DARK YELLOWISH-ORANGE, 10YR6/6.	24-28
CLAY	STIFF, GRAYISH-BROWN, 5YR3/2.	28-34
CLAY	STIFF, MEDIUM GRAY, N5.	34-36
CLAY	STIFF, GRAYISH-BROWN, 5YR3/2.	36-38
CLAY	STIFF, LIGHT OLIVE GRAY, 5Y6/1.	38-45
CLAY	TRACE FINE SAND, DARK YELLOWISH-ORANGE TO MEDIUM GRAY.	45-51

SAND	CLAYEY, FINE GRAINED, LIGHT OLIVE GRAY, 5Y6/1.	51-58
CLAY	STIFF, MEDIUM GRAY, N5.	58-62
SAND	CLAYEY, FINE GRAINED, LIGHT OLIVE GRAY, 5Y6/1.	62-71
SAND	SILTY, FINE GRAINED, LIGHT OLIVE GRAY, 5Y6/1.	71-82
CLAY	SILTY, MEDIUM LIGHT GRAY, N6.	82-84
CLAY	SANDY, MEDIUM LIGHT GRAY, N6.	84-91
SAND	SILTY,WITH INTERBEDDED CLAY, MODERATE YELLOWISH-BROWN, THIN LIGNITE BED AT 96'.	91-100
SAND	SILTY, FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	100-110
SAND	SILTY, FINE GRAINED, DUSKY YELLOW, 5Y6/4.	110-130
SAND	FINE GRAINED, DARK GRAY, N3.	130-140

140-081-12BDD
NDSWC

Date Completed:	4/28/93	Purpose:	Test Hole
L.S. Elevation (ft):	2037.65	Well Type:	
Depth Drilled (ft):	160		
		Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SANDY, YELLOWISH-BROWN 10YR5/4, TILL.	1-21
GRAVEL	MEDIUM TO COARSE GRAINED, YELLOWISH-BROWN, 10YR5/4.	21-24
CLAY	BEDROCK, OXIDIZED.	24-34
SAND	FINE GRAINED, YELLOWISH-BROWN, 10YR5/4.	34-46
CLAY	TRACE OF SAND.	46-48
CLAY	SILTY, MODERATELY YELLOWISH-BROWN, 10YR5/4.	48-58
SILT	WITH CLAY AND VERY FINE GRAINED SAND, PALE BROWN, 5YR5/2.	58-67
CLAY	SILTY, MEDIUM LIGHT GRAY, N6.	67-70
SANDSTONE	FINE TO MEDIUM GRAINED, WELL CEMENTED, MEDIUM LIGHT GRAY, N6.	70-71
SAND	FINE GRAINED, YELLOWISH-BROWN.	71-80
SANDSTONE		80-81

SAND	FINE GRAINED, BROWNISH-ORANGE.	81-89
SAND	FINE GRAINED, GREENISH-YELLOW.	89-98
SILT	TRACE OF CLAY AND SAND, REDDISH-BROWN.	98-100
SAND	WITH SILT, FINE GRAINED, GREENISH-YELLOW.	100-122
SAND	FINE GRAINED, OLIVE.	122-128
CLAY	MEDIUM GRAY.	128-131
CLAY	DARK GRAY.	131-137
SILT	WITH VERY FINE SAND, MEDIUM GRAY.	137-140
CLAY	DARK GRAY.	140-147
SAND	SILTY, FINE GRAINED, DARK GRAY.	147-160

140-081-12CAC1
NDSWC

Date Completed:	4/29/93	Purpose:	Observation Well
L.S. Elevation (ft):	1995.5	Well Type:	2" PVC
Depth Drilled (ft):	68	Aquifer:	Undefined
Screened Interval (ft):	55-60	Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	SANDY, MODERATE YELLOWISH-BROWN, 10YR5/4.	2-5
SAND	SILTY, FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	5-9
SANDSTONE	FINE TO MEDIUM GRAINED, WELL CEMENTED, MEDIUM LIGHT GRAY, N6.	9-10
SAND	FINE TO MEDIUM GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	10-22
CLAY	YELLOWISH GRAY, 5Y 8/1.	22-26
CLAY	SILTY, MODERATE YELLOWISH-BROWN, 10YR5/4.	26-37
SAND	SILTY, FINE GRAINED, OLIVE GRAY, 5Y4/1.	37-46
SAND	FINE GRAINED, OLIVE GRAY, 5Y4/1.	46-60
SHALE	MODERATE YELLOWISH-BROWN, 10YR5/4.	60-62
SANDSTONE	FINE GRAINED, WELL CEMENTED, MEDIUM DARK GRAY, N4.	62-64
SILT	WITH SAND AND CLAY, MEDIUM DARK GRAY, N4.	64-68

140-081-12CAC2
NDSWC

Date Completed:	5/11/93	Purpose:	Test Hole
L.S. Elevation (ft):	1995.58	Well Type:	
Depth Drilled (ft):	152		
		Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	2-9
SANDSTONE	FINE GRAINED, GRAYISH-ORANGE, 10YR7/4.	9-10
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN WITH MANY BLACK GRAINS, 10YR7/4.	10-22
CLAY	STIFF, MEDIUM GRAY, N5.	22-28
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	28-41
SAND	FINE GRAINED, LIGHT OLIVE GRAY, 5Y5/2.	41-61
CLAY	SILTY, MODERATE YELLOWISH-BROWN TO DARK YELLOWISH-ORANGE.	61-62
SAND	FINE GRAINED, LIGHT GRAY, 5Y5/2.	62-85
SAND	FINE GRAINED, OLIVE GRAY WITH MANY BLACK (LIGNITE) GRAINS, 5Y4/1.	85-91
CLAY	STIFF, MEDIUM DARK GRAY, N4.	91-96
CLAY	SILTY, SANDY, MEDIUM GRAY, N5.	96-98

SANDSTONE		98-99
CLAY	STIFF TO SILTY, MEDIUM GRAY, N5.	99-135
CLAY	SANDY, MEDIUM DARK GRAY, N4.	135-138
CLAY	STIFF TO SILTY, MEDIUM DARK GRAY, N4.	138-142
CLAY	STIFF, MEDIUM DARK GRAY, N4.	142-152

140-081-12CBB1
NDSWC

Date Completed:	4/29/93	Purpose:	Observation Well
L.S. Elevation (ft):	1972.71	Well Type:	2" PVC
Depth Drilled (ft):	50	Aquifer:	Undefined
Screened Interval (ft):	45-50	Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	SANDY, MODERATE YELLOWISH BROWN, 10YR5/4.	2-10
SANDSTONE	FINE GRAINED, LIGHT GRAY, N7.	10-11
CLAY	SANDY, MODERATE YELLOWISH-BROWN, 10YR5/4.	11-13
SAND	FINE GRAINED, YELLOWISH GRAY, 5Y7/2.	13-24
SAND	MODERATE REDDISH-ORANGE, 10YR6/6.	24-26
SAND	FINE GRAINED, OLIVE GRAY, 5Y4/1.	26-37
SAND	FINE TO MEDIUM GRAINED, OLIVE GRAY, 5Y4/1.	37-50

140-081-12CBB2
NDSWC

Date Completed:	4/29/93	Purpose:	Observation Well
L.S. Elevation (ft):	1958.8	Well Type:	2" PVC
Depth Drilled (ft):	40	Aquifer:	Undefined
Screened Interval (ft):	28-33	Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-5
SAND	VERY FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	5-13
SANDSTONE	FINE GRAINED, WELL CEMENTED, MODERATE YELLOWISH-BROWN, 10YR5/4.	13-20
SAND	FINE GRAINED, OLIVE GRAY, 5Y4/1.	20-33
SHALE	MODERATE REDDISH-ORANGE, 10YR6/6.	33-35
CLAY	MODERATE YELLOWISH-BROWN, 10YR5/4.	35-40

140-081-12CBB3
NDSWC

Date Completed:	5/11/93	Purpose:	Observation Well
L.S. Elevation (ft):	1958.85	Well Type:	2" PVC
Depth Drilled (ft):	70	Aquifer:	Undefined
Screened Interval (ft):	58-68	Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	2-33
SANDSTONE	FINE GRAINED, PALE YELLOWIH-BROWN, 10YR6/2.	33-35
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	35-46
SAND	FINE GRAINED, MODERATE BROWN, 5YR4/4.	46-60
CLAY	MEDIUM GRAY, N5.	60-61
SANDSTONE	INTERBEDDED LIGNITE	61-62
CLAY	SILTY, MEDIUM GRAY, N5.	62-64
SAND	FINE GRAINED, MEDIUM GRAY, N5.	64-67
CLAY	GRAYISH-BROWN, 5YR3/2.	67-70

140-081-12CCB

NDSWC

Date Completed:	4/29/30	Purpose:	Observation Well
L.S. Elevation (ft):	1989.01	Well Type:	2" PVC
Depth Drilled (ft):	91	Aquifer:	Undefined
Screened Interval (ft):	78-88	Source:	
		Owner:	DAKOTA SANITATION

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SILT	SANDY, LIGHT GREENISH-GRAY, 5GY8/1.	2-6
SANDSTONE	FINE GRAINED, WELL CEMENTED, MODERATE REDDISH-ORANGE, 10YR6/6.	6-7
SANDSTONE	FINE GRAINED, MODERATELY CEMENTED, MODERATE YELLOWISH-BROWN, 10YR5/4.	7-13
SAND	FINE GRAINED, LIGHT OLIVE GRAY, 5Y6/1.	13-21
SAND	FINE GRAINED, OLIVE GRAY 5Y, 4/1.	21-44
SAND	SILTY, FINE GRAINED, OLIVE GRAY, 5Y4/1.	44-53
SANDSTONE	FINE GRAINED, WELL CEMENTED, MEDIUM DARK GRAY, N4.	53-57
SAND	SILTY, FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4.	57-69
SAND	FINE GRAINED, LIGHT OLIVE GRAY, 5Y6/1.	69-71
CLAY	SILTY, MODERATE YELLOWISH-BROWN, 10YR5/4.	71-73
CLAY	SILTY, GREENISH-GRAY, 5G6/1.	73-78

CLAY	SANDY, MEDIUM DARK GRAY, N4.	78-81
CLAY	MEDIUM DARK GRAY, N4.	81-84
SAND	VERY FINE GRAINED, MEDIUM DARK GRAY, N4.	84-89
CLAY	MEDIUM DARK GRAY, N4.	89-91

APPENDIX D

WATER-LEVEL TABLES

Dakota Sanitation Water Levels

140-081-12BDC LS Elev (msl,ft)=2041.11
Undefined Aquifer SI (ft.)=130-140

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/03/93	134.15	1906.96	06/04/93	134.21	1906.90
05/13/93	134.24	1906.87	06/15/93	134.34	1906.77
05/14/93	134.21	1906.90	07/02/93	134.33	1906.78
05/24/93	133.71	1907.40			

140-081-12CCB LS Elev (msl,ft)=1989.01
Undefined Aquifer SI (ft.)=78-88

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/03/93	79.05	1909.96	06/04/93	79.07	1909.94
05/13/93	79.00	1910.01	06/15/93	79.02	1909.99
05/14/93	79.07	1909.94	07/02/93	79.07	1909.94
05/24/93	80.09	1908.92			

140-081-12CBB3 LS Elev (msl,ft)=1958.85
Undefined Aquifer SI (ft.)=58-68

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/13/93	52.25	1906.60	06/04/93	52.30	1906.55
05/14/93	52.31	1906.54	06/15/93	52.28	1906.57
05/24/93	52.32	1906.53	07/02/93	52.31	1906.54

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Dakota Sanitation 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)																					
140-081-12BDC	130-140	06/04/93	13	0.02	0.22	91	56	65	8	513	0	140	48	0.7	0.5	0.26	647	460	0	23	1.1	970	12	7.77
140-081-12CBB3	58-68	06/04/93	13	0.11	0.46	130	71	88	5.5	791	0	200	4.6	0.1	0.1	0.13	903	620	0	23	1.5	1346	12	7.48
140-081-12CCB	78-88	06/04/93	13	0.01	0.27	58	35	120	5.3	446	0	200	7.9	0.3	0.4	0.18	660	290	0	47	3.1			

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
140-081-12BDC	6/04/93	8	0	0	0	9	4	700
140-081-12BDC	6/04/93	0	0	0	0	0	0	940
140-081-12BDC	6/04/93	0	0	0	0	0	2	840

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 140-081-12CBB3

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