Site Suitability Review of the Missouri River 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. 9

SITE SUITABILITY REVIEW
OF THE
MISSOURI RIVER SANITATION LANDFILL

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INTRODUCTION

Purpose

The North Dakota State Engineer and the North Dakota State Geologist were instructed by the 52^{nd} 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 Missouri River Sanitation solid waste landfill is one of the landfills being evaluated.

Location of the Missouri River Sanitation Landfill

The Missouri River Sanitation solid waste landfill is located two miles east and one-mile south of the City of Underwood in Township 146 North, Range 82 West, SE 1/4 of Section 23 and NE 1/4 of Section 26 (Fig. 1). The landfill site encompasses approximately 80 acres of which about 20 acres has been used.

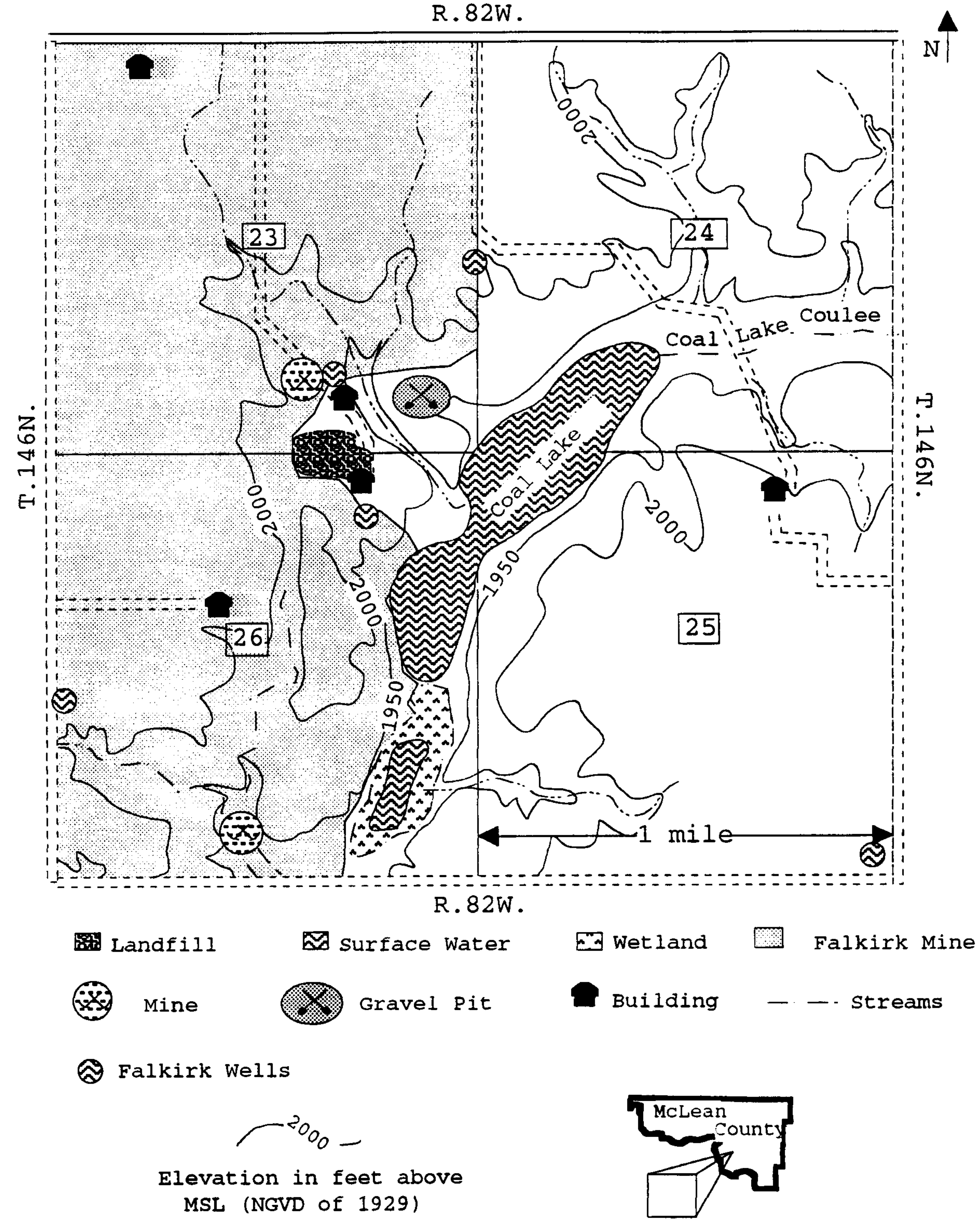

Figure 1. Location of the Missouri River Sanitation landfill in the SE 1/4 of section 23 and NE 1/4 of Section 26, T146N, R82W.

Previous Site Investigations

The area surrounding the landfill location has been studied extensively by the Falkirk Mining Company for the purpose of lignite mining. The Falkirk Mine Permit application NAFK-8405 (1990) described six hydrostratigraphic units in the area of the landfill. Monitoring wells were installed throughout the region for ground-water information in the Cole Harbor Formation, Underwood sand, Hagel A and B coal beds, and Hensler coal bed. The report provided a detailed analysis of the local and regional hydrogeology and hydrochemistry.

Methods of Investigation

The Missouri River Sanitation study was accomplished by means of: 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 Missouri River Sanitation landfill was based on the site's geology and depth to ground water, as determined by the preliminary evaluation. A solid-stem auger was used at the Missouri River Sanitation landfill because the sediments were poorly consolidated and because the depth to the water table was expected to be less than 70 feet. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Three monitoring wells installed at the Missouri River Sanitation landfill were based on the geologic and topographic characteristics of the site. Three additional wells that were already in place were also used in this study. 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 near the active area of the landfill.

Monitoring 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

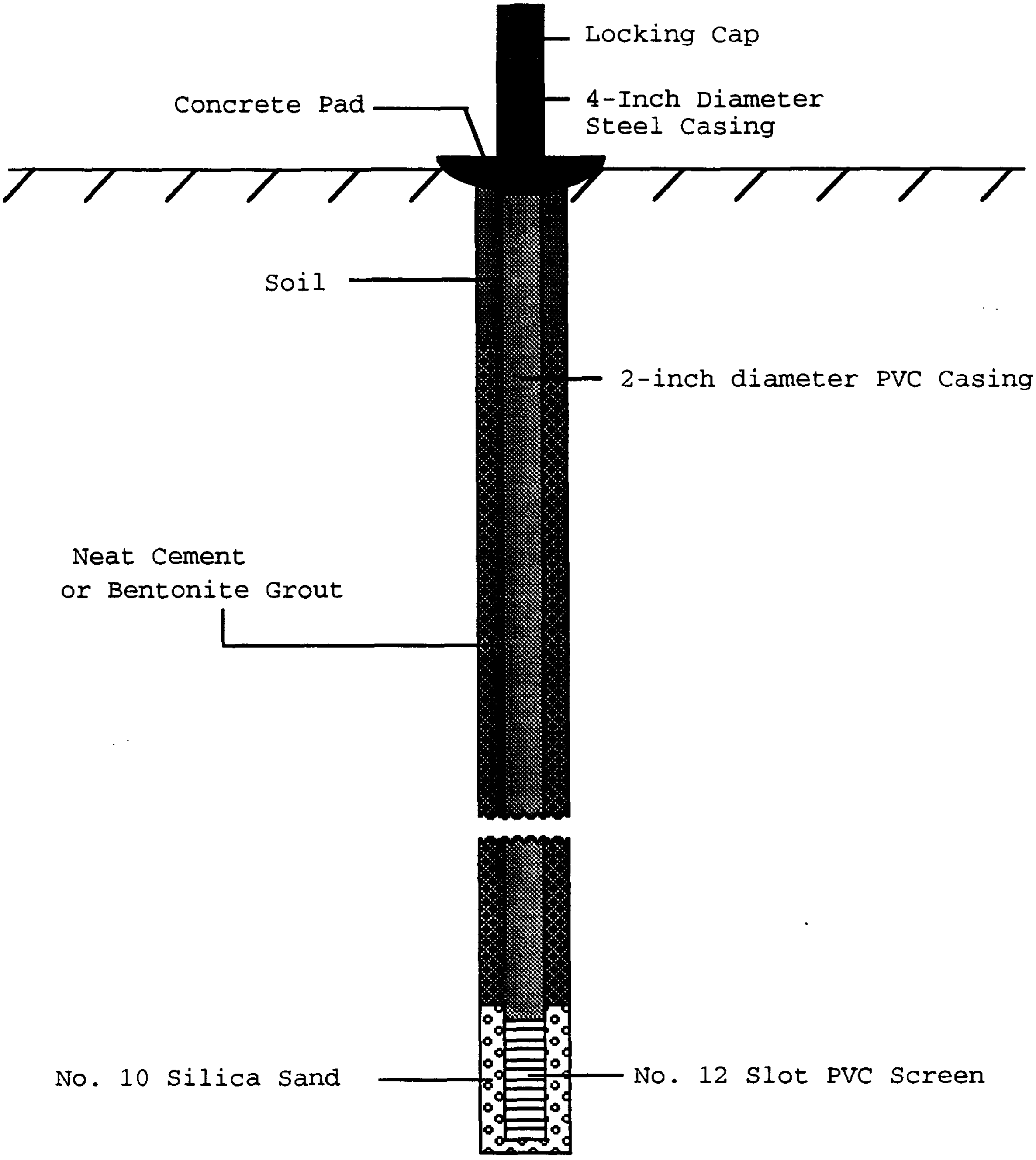

Figure 2. Construction design used for monitoring wells installed at the Missouri River Sanitation landfill.

(grain-size diameter) silica sand to a height of two feet above the top of the screen. High-solids bentonite grout and/or neat cement was placed above the silica sand to seal the annulus to approximately five feet below land surface. The remaining annulus was filled with drill cuttings. The permanent wells were secured with a protective steel casing and a locking cover protected by a two-foot-square concrete pad.

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

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

Collecting and Analyzing Water Samples

Water-quality analyses were used to determine if leachate is migrating from the landfill into the underlying ground-water system. Selected field parameters, major ions, and trace elements were measured for each water sample. These field parameters and analytes are listed in Appendix A with their Maximum Contaminant Levels (MCL). MCLs are 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 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 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

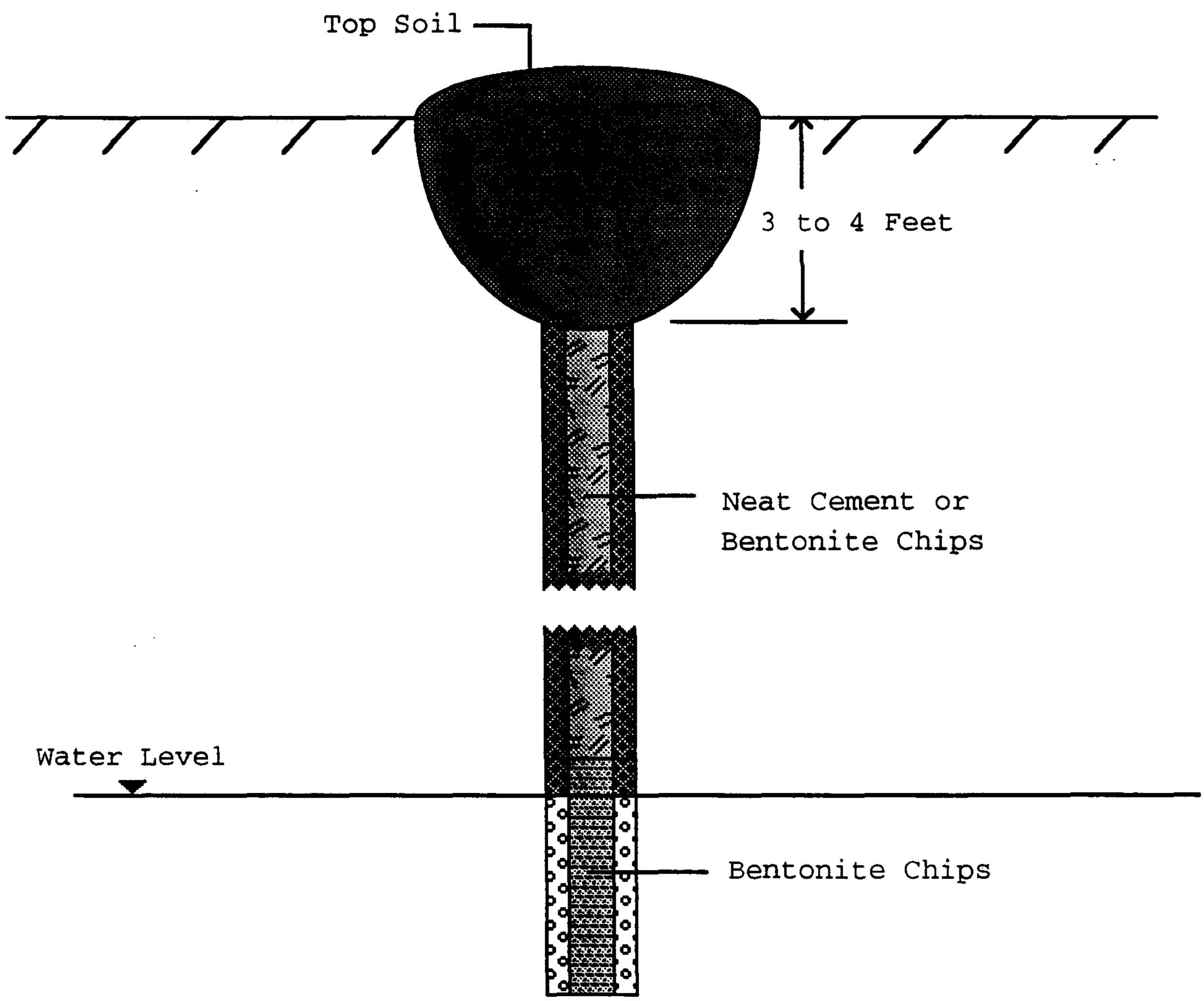

Figure 3. Monitoring well abandonment procedure.

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 146-082-23DCA would be located in the NE1/4, SW1/4, SE1/4 Section 23, Township 146 North, Range 82 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 146-082-23DCA1 and 146-082-23DCA2.

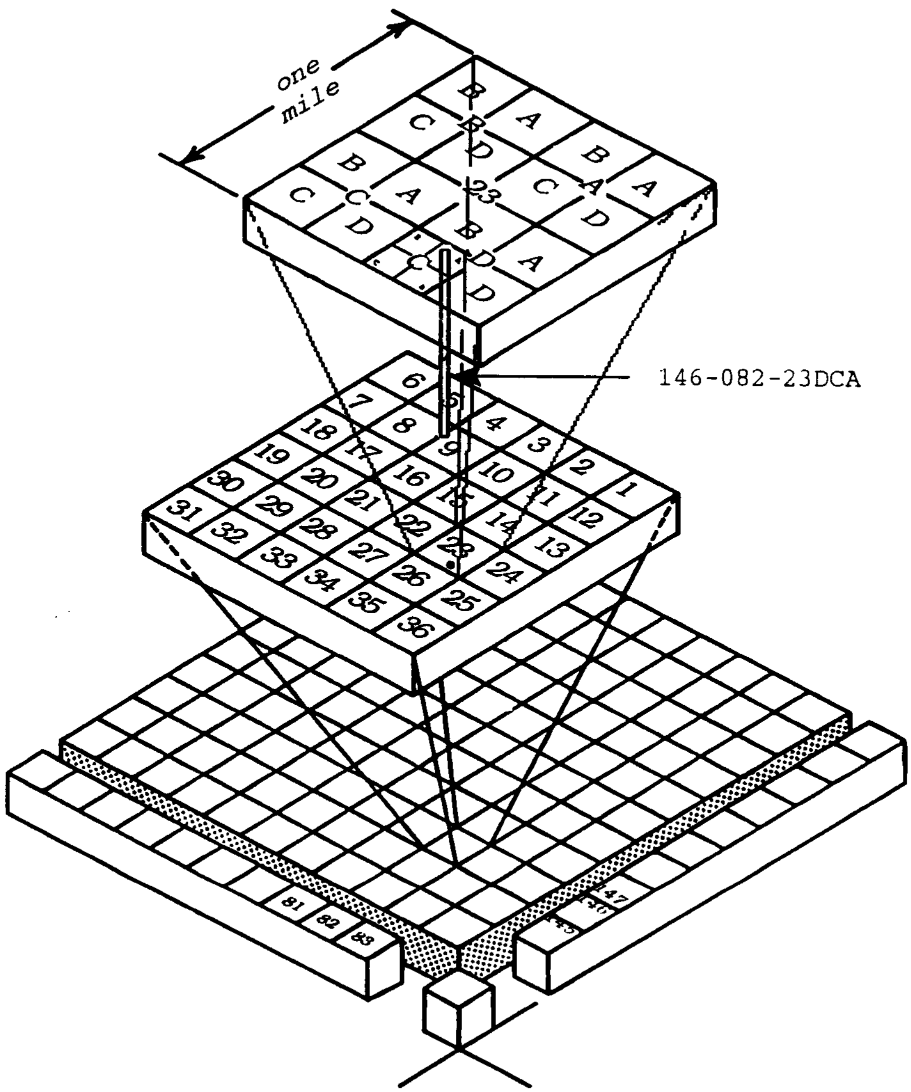

Figure 4. Location-numbering system for the Missouri River Sanitation landfill.

GEOLOGY

Regional Geology

The area surrounding the Missouri River Sanitation landfill is covered by a thin layer of glacial sediments draped over the pre-existing bedrock topography. The glacial sediments are mainly till comprised of an unsorted mixture of clay, silt, and sand along with small percentages of pebbles, cobbles, and boulders (Bluemle, 1971). Bedrock is exposed at the surface in a few areas, primarily along the sides of Coal Lake Coulee and its tributary drainages.

Coal Lake Coulee, to the east of the landfill, is a glacial meltwater channel apparently connected the ancestral Knife River with the interglacial Missouri River Channel (Falkirk, 1990). Two test holes were drilled in Coal Lake Coulee by the North Dakota State Water Commission. One test hole encountered 24 feet of alluvium and slough deposits (mainly clay and silt) underlain by 84 feet of outwash deposits (mainly sand and gravel). The other test hole encountered 63 feet of alluvium and slough deposits and 127 feet of outwash (Klausing, 1971).

The Sentinel Butte and Bullion Creek Formations underlie the glacial sediments. These formations were deposited during the Paleocene Epoch in a deltaic environment (Jacob, 1976). They are composed of sand, sandstone, silt, clay, lignite, and limestone.

Local Geology

The Missouri River Sanitation landfill is located in the abandoned Underwood Coal Company strip mine (Fig. 5). A ravine on the east side of the landfill drains into Coal Lake. This lake occupies a depression in Coal Lake Coulee and is approximately 1/4 mile from the landfill.

Test hole 146-082-26ABB, located southwest of the landfill, drilled through 17 feet of glacial drift (Fig. 6, lithologic logs in Appendix C). The glacial drift is of varuable thickness around the site and is generally absent east of the landfill along Coal Lake Coulee. A layer of bedrock sand underlies the glacial drift. Test holes drilled by Falkirk Mining Company near the site also encountered the sand, which ranges from 10 to 30 feet thick. The sand was not reported in wells 146-082-26AAB and 146-082-26ABA, which were drilled by Broneskew Drilling Company.

Two lignite beds, the Hagel A and B beds of the Sentinel Butte Formation, were mined at the site. The Hagel A bed has an average thickness of 9 feet. A layer of clay, 5 to 20 feet thick, overlies the Hagel A bed and underlies the bedrock sand. The Hagel A bed outcrops along the flanks of Coal Lake Coulee at elevations of about 1950 to 1960 feet.

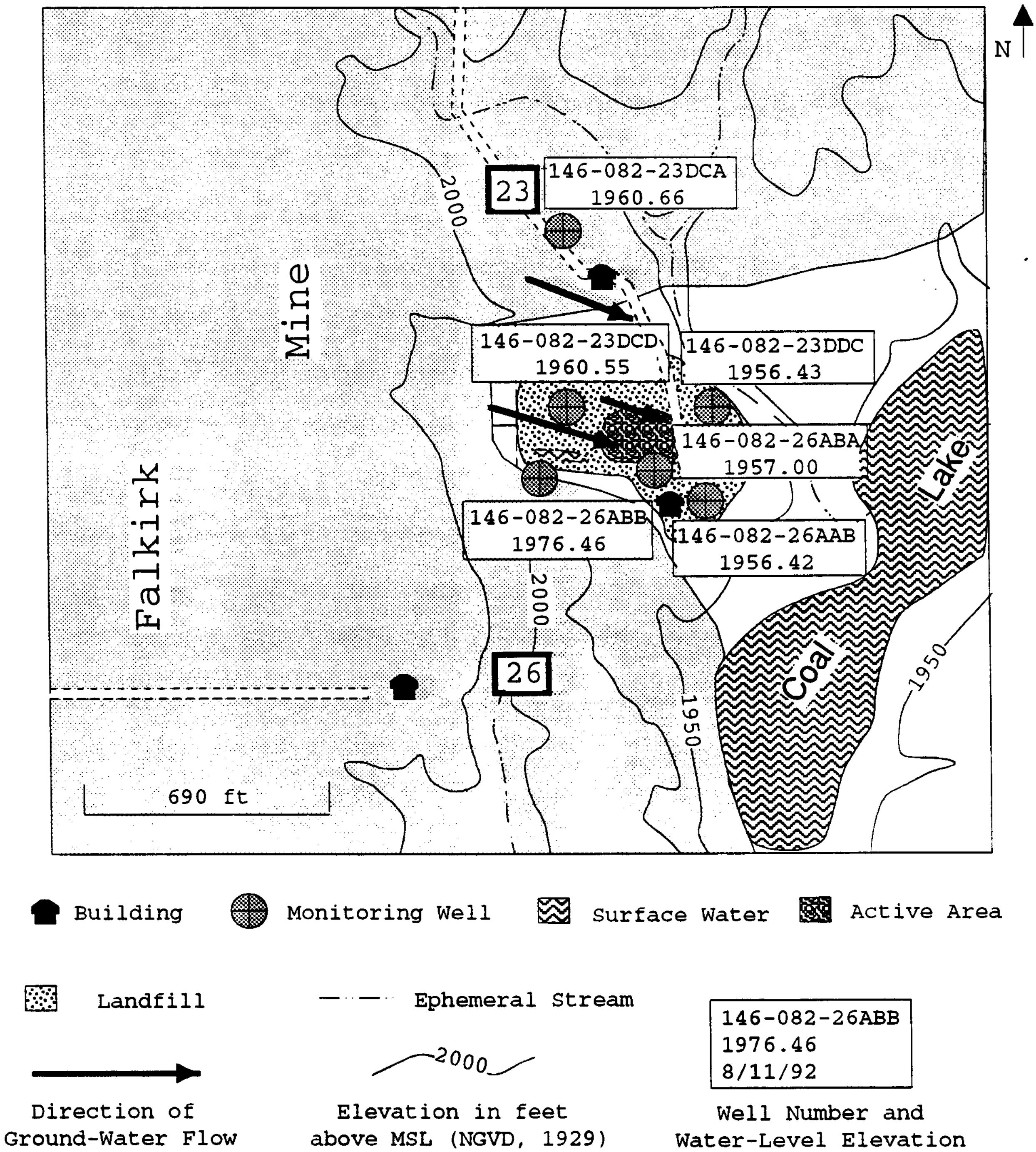

Figure 5. Location of monitoring wells and the direction of ground-water flow at the Missouri River Sanitation landfill.

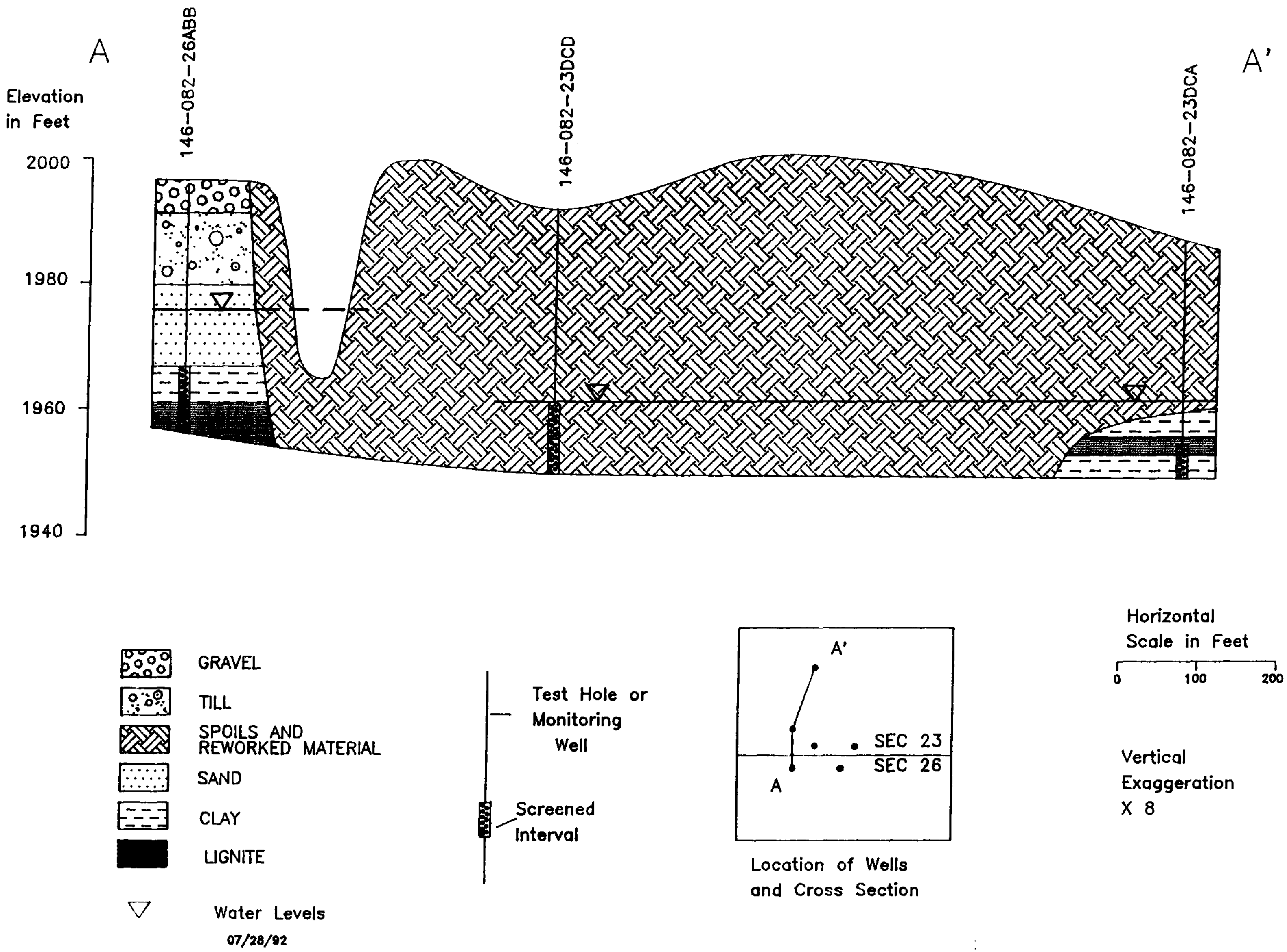

Figure 6. Geohydrologic section A-A' in the Missouri River Sanitation landfill

Test holes in this study did not reach the Hagel B bed. Test holes drilled by Falkirk indicate that it has an average thickness of approximately 2 1/2 feet. The two lignite beds are separated by 6 to 12 feet of clay. A layer of clay and silt underlies the Hagel B bed.

Test holes 146-082-23DCD and 146-082-23DCA were drilled within the mined area. The spoil material within the mine site contains varied proportions of clay, sand, and silt, with a trace of gravel.

HYDROLOGY

Surface-Water Hydrology

Coal Lake is located about 1/4 mile east of the landfill at an elevation of about 1915 feet MSL (Falkirk Mining Report, 1990). Coal Lake appears to drain north through Coal Lake Coulee toward Turtle Lake during periods of high water table. Coal Lake is recharged by numerous ephemeral streams along the length of Coal Lake Coulee. Ground-water discharge provides another source of recharge to Coal Lake.

Wetlands exist along Coal Lake Coulee and in the mine tailings. A small semi-permanent wetland is located on the west side of the landfill in the mine tailings that appears to be at the same elevation as the ground-water. This wetland may represent a "window" in the water table associated with the upper sand aquifer. The use of the surface water in the area is generally wildlife habitat (Falkirk Mining Report, 1990).

Regional Ground-Water Hydrology

Both bedrock and glacial aquifers comprise the regional ground-water flow system. Bedrock aquifers are located within the Sentinel Butte and Bullion Creek Formations. The Underwood sand sequence, within the Sentinel Butte Formation, consists of sand deposits and is mostly saturated (Falkirk Report,1990). The Underwood sand is extensive and overlies the Hagel lignite beds. The aquifer is characterized by a calcium-magnesium-bicarbonate type water with varying amounts of sodium. This aquifer discharges into the Coal Lake Coulee.

The Hagel A and B lignite beds, located in the Sentinel Butte Formation, appear to be saturated. Discharge from the Hagel A and B lignite beds occurs along Coal Lake Coulee, which is hydraulically connected to the Coal Lake Coulee aquifer. A spring was located northeast of the landfill in a southeast-trending ravine along the outcrop of the Hagel A lignite bed (Falkirk Mine Report, 1990). The two Hagel lignite beds are characterized by calcium-magnesium-bicarbonate type waters.

The Sheet sand sequence underlies the Hagel beds and is characterized by a calcium-magnesium-bicarbonate type water with increased sodium and sulfate concentrations. This sequence discharges into the Coal Lake aquifer.

The Hensler sand sequence is located in the Bullion Creek Formation and is characterized by a sodium-bicarbonate type water. The Hensler sand underlies the Sheet sand and discharges into the Coal Lake aquifer.

The Coal Lake Coulee aquifer is located in Coal Lake Coulee about 1/4 mile east of the landfill and is a part of the Turtle Lake aquifer. This aquifer consists of glacial meltwater deposits with an average thickness of 30 to 40 feet. Ground-water flow in this aquifer is to the north through the coulee into the Turtle Lake-Lake Nettie aquifer systems (Falkirk Mine Report, 1990). This aquifer is a discharge area for the surrounding bedrock aquifers. The Coal Lake Coulee aquifer is characterized by a calcium-magnesium-bicarbonate type water.

Local Ground-water Hydrology

Three test holes were drilled at the Missouri River Sanitation landfill with monitoring wells installed in all three. In addition, three monitoring wells (one from Falkirk Mine Corp., and two from Missouri River Sanitation) were used in evaluating this site. The screens were placed in mine spoils and in the Hagel lignite layer. Four water-level measurements were taken over a seven-week period.

The uppermost aquifer, throughout most of the landfill site, is in the mine tailings or Hagel A lignite layer (Fig. 6). Water-level measurements indicate that the direction of ground-water flow in this aquifer is east-southeast toward Coal Lake, which may function as a local discharge area (Fig. 5).

Water Quality

Chemical analyses of water samples are shown in Appendix E. Well 146-082-23DCD was used as an up-gradient well for the aquifer in the mine tailings. Water in this well is characterized by high concentrations of manganese, calcium, sulfate, and total dissolved solids. These concentrations appear to be caused by natural weathering of the mine tailings. Well 146-082-23DCA, also located in the mine tailings, indicated high concentrations of these major ions plus high concentrations of magnesium, sodium, and chloride. This well is located north of the landfill and should not be affected by the landfill. Monitoring wells located down-gradient indicated lower concentrations of all major ions as compared to those associated with the up-gradient wells.

The trace element analyses indicated high concentrations of strontium in all wells. Strontium concentrations ranged from 360μg/L to 12,000 μg/L. The highest concentration was detected in well 146-082-23DCA. Skoustad and Horr (1963, in Hem, 1989) found median concentrations of strontium for large

U.S. public water supplies to be 110 µg/L. Increased strontium can result from incineration ash, municipal waste ash, or burning pile ash. Increased concentrations of strontium can also be a result of the weathering of mine tailings.

The VOC analyses, from wells 146-082-23DCA and 146-082-26ABA, are shown in Appendix F and G, respectively. These analyses indicated concentrations of tetrahydrofuran (736 µg/L and 356 µg/L, respectively). This compound is man-made and is not found in natural ground waters. Tetrahydrofuran is used in glues and liquid cements for fabricating packages and polyvinyl-chloride materials. These detections were from wells already in place and their construction methods are not known. These wells may have been constructed using a PVC cement compound containing tetrahydrofuran. Well 146-082-23DCA is located outside the area of influence of the landfill and should not be affected by leachate migration from the landfill.

CONCLUSIONS

The Missouri River Sanitation landfill is located on the south side of the abandoned Underwood Coal Company strip mine. The area surrounding the landfill is covered by a thin layer of glacial sediments over the pre-existing bedrock topography. The thickness of the glacial drift is variable across the site and is generally absent east of the landfill along Coal Lake Coulee. The upper bedrock consists of the Sentinel Butte and the Bullion Creek Formations. Coal Lake Coulee is a glacial meltwater channel which apparently connected the ancestral Knife River with the interglacial Missouri River Channel.

Coal Lake is located within Coal Lake Coulee and is the local discharge area for the surrounding bedrock aquifers of the Sentinel Butte and Bullion Creek Formations. The Coal Lake Coulee aquifer is a glacial meltwater channel that underlies Coal Lake Coulee. This aquifer also is a local discharge area for surrounding bedrock aquifers. The water quality of the Coal Lake Coulee aquifer in the study area, ranges from a calcium-magnesium-bicarbonate to a sodium-bicarbonate type.

The mine tailings are partially saturated at well 146-082-23DCD. The direction of ground-water flow in the mine tailings is southeast toward Coal Lake Coulee.

Water quality analyses from the monitoring wells completed in mine tailings indicated high concentrations of sulfate, calcium, manganese, and total dissolved solids. These concentrations appear to be caused by the weathering of the mine tailings. Strontium was detected in high concentrations in all the wells. These concentrations also appear to be the result of weathering of the mine tailings. Mobilization of major ions and trace elements from the mine tailings may effectively mask input of major ions and trace elements from the landfill.

The VOC analyses indicated tetrahydrofuran in wells 146-082-23DCA and 146-082-26ABA. The well completion reports for these two wells are not known. The wells may have been constructed using a PVC cement compound containing tetrahydrofuran. The VOC detections, in this case, may not suggest leachate migration from the landfill into the underlying aquifer. Additional study may be needed to determine the source of the tetrahydrofuran.

Coal Lake Coulee and Coal Lake Coulee aquifer may be susceptible to leachate migration from the landfill because they are discharge areas for the surrounding surface and ground-water systems. The bedrock aquifers do not appear to be susceptible to leachate migration because of the thick layer of clay seperating the refuse from the aquifer. Based on water quality analyses from wells down-gradient, there does not appear to be any leachate migration from the landfill.

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APPENDIX A

WATER QUALITY STANDARDS
AND
MAXIMUM CONTAMINANT LEVELS

Water Quality Standards and Maximum Contaminant Levels

Parameter	MCL (mg/L)
Field Parameters	
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

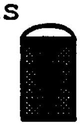
1. Three samples must be collected in the 40ml bottles that are provided by the lab. One is the sample and the others are duplicates.

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

146-082-23DCA
NDSWC

Date Completed:	8/14/89	Well Type:	P2
Depth Drilled (ft):	42	Source of Data:	Falkirk Mining
Screened Interval (ft):	37-42	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1991.34

Owner: Falkirk Mining Co.

Lithologic Log

Unit	Description	Depth (ft)
CLAY	Silty with pebbles, spoils, brown.	0-32
CLAY	Brown.	32-36
LIGNITE	With clay, black.	36-39
CLAY	Silty with sand, gray, bedrock.	39-42

146-082-23DCD

NDSWC

Date Completed:	6/26/92	Well Type:	P2
Depth Drilled (ft):	43	Source of Data:	
Screened Interval (ft):	33-43	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1991.52
Owner: Underwood			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SANDY, TRACE GRAVEL, DARK YELLOWISH-BROWN (10YR 4/2), (MINE SPOILS)	1-12
CLAY	TRACE SAND AND GRAVEL, OLIVE GRAY (5Y 4/1)	12-26
SAND	CLAYEY, OLIVE GRAY (5Y 4/1)	26-43

146-082-23DDC

NDSWC

Date Completed:	6/26/92	Well Type:	P2
Depth Drilled (ft):	38	Source of Data:	
Screened Interval (ft):	28-38	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1979.75
Owner: Underwood			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	FINE-GRAINED, SILTY, MODERATE YELLOWISH-BROWN (10YR 5/4), (SENTINEL BUTTE FORMATION)	1-8
CLAY	SILTY, TRACE SAND, MODERATE YELLOWISH-BROWN (10YR 5/4)	8-13
CLAY	MODERATE YELLOWISH-BROWN (10YR 5/4)	13-20
LIGNITE		20-22
CLAY	PALE BROWN (5YR 5/2)	22-23
LIGNITE		23-27
CLAY	WITH INTERBEDDED LIGNITE, PALE BLUE-GREEN (5BG 7/2)	27-38

146-082-26AAB

NDSWC

Date Completed:	87	Well Type:	P2,BRONESKEW DRILL
Depth Drilled (ft):	54	Source of Data:	
Screened Interval (ft):	49-54	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1983.99

Owner: Underwood

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY		2-21
ROCK		21-23
CLAY		23-31
LIGNITE		31-41
CLAY		41-54

146-082-26ABA

NDSWC

Date Completed:	87__	Well Type:	P2,BRONESKEW DRILL
Depth Drilled (ft):	54	Source of Data:	
Screened Interval (ft):	49-54	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1996.57
Owner: Underwood			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY		2-40
LIGNITE		40-51
CLAY		51-54

146-082-26ABB
NDSWC

Date Completed:	6/26/92	Well Type:	P2
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	30-40	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1996.79
Owner: Underwood			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
GRAVEL	SANDY, MODERATE YELLOWISH-BROWN (GLACIAL DRIFT)	1-6
CLAY	SILTY, TRACE GRAVEL, DARK YELLOWISH-BROWN	6-17
SAND	MEDIUM-GRAINED, MODERATE YELLOWISH-BROWN (10YR 4/4), (SENTINEL BUTTE FORMATION)	17-22
SAND	MEDIUM-GRAINED, CLAYEY, MODERATE YELLOWISH-BROWN (10YR 5/4).	22-30
CLAY	SANDY, OLIVE GRAY (5Y 4/1), DAMP	30-36
LIGNITE		36-40

APPENDIX D

WATER-LEVEL TABLES

Missouri River Sanitation Water Levels
7/8/92 to 8/24/92

146-082-23DCA LS Elev (msl,ft)=1991.34
Undefined Aquifer SI (ft.)=37-42

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/10/92	30.41	1960.93	08/11/92	30.68	1960.66
07/28/92	30.42	1960.92	08/24/92	30.53	1960.81

146-082-23DCD LS Elev (msl,ft)=1991.52
Undefined Aquifer SI (ft.)=33-43

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/08/92	30.44	1961.08	08/11/92	30.97	1960.55
07/28/92	30.66	1960.86	08/24/92	31.06	1960.46

146-082-23DDC LS Elev (msl,ft)=1979.75
Undefined Aquifer SI (ft.)=28-38

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/09/92	24.33	1955.42	08/11/92	23.32	1956.43
07/10/92	23.23	1956.52	08/24/92	23.36	1956.39
07/28/92	23.28	1956.47			

146-082-26AAB LS Elev (msl,ft)=1983.99
Undefined Aquifer SI (ft.)=49-54

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/09/92	27.38	1956.61	08/11/92	27.57	1956.42
07/28/92	27.50	1956.49	08/24/92	27.47	1956.52

146-082-26ABA LS Elev (msl,ft)=1996.57
Undefined Aquifer SI (ft.)=49-54

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/10/92	39.52	1957.05	08/11/92	39.57	1957.00
07/28/92	39.56	1957.01	08/24/92	39.59	1956.98

146-082-26ABB LS Elev (msl,ft)=1996.79
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/08/92	21.53	1975.26	08/11/92	20.33	1976.46
07/28/92	20.78	1976.01	08/24/92	19.92	1976.87

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Missouri River Sanitation Water Quality

Major Ions 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)																					
146-082-23DCA	37-42	07/10/92	17	0.07	1.5	560	330	230	20	634	0	2500	230	0.1	0	0.44	4200	2800	2200	15	1.9	4590	20	7.76
146-082-23DCD	33-43	07/08/92	21	0.2	1.1	290	140	24	23	764	0	730	3.1	0.1	1.7	0.21	1610	1300	670	4	0.3	2100	17	7.67
146-082-23DDC	28-38	07/09/92	17	0.08	0.56	160	76	44	9.4	607	0	300	81	0.1	3.4	0.25	991	710	210	12	0.7	1521	14	6.52
146-082-26AAB	49-54	07/09/92	15	0.03	0.28	100	46	18	6	430	0	170	14	0.1	1.3	0.18	583	440	86	8	0.4	924	16	7.52
146-082-26ABA	49-54	07/10/92	16	0.07	0.31	140	58	27	8.5	562	0	210	39	0.1	1.5	0.28	778	590	130	9	0.5	1202	12	6.91
146-082-26ABB	30-40	07/08/92	17	0.02	0.14	67	24	4	7	341	0	11	2	0.2	0.1	0.05	301	270	0	3	0.1	499	14	7.88

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
145-082-23DCA	7/10/92	2	0	0	0	8	11	12000
146-082-23DCD	7/8/92	1	0	0	0	6	0	2600
146-082-23DDC	7/9/92	0	0	0	0	6	1	3500
145-082-26AAB	7/9/92	1	0	0	0	3	0	2000
145-082-26ABA	7/10/92	0	0	0	0	5	0	2700
145-082-26ABB	7/8/92	0	0	0	0	2	3	360

APPENDIX F

VOLATILE ORGANIC COMPOUNDS
FOR WELL 146-082-23DCA

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	736*
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection

APPENDIX G

VOLATILE ORGANIC COMPOUNDS FOR WELL 146-082-26ABA

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	356*
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection