Site Suitability Review of the Glen Ullin Landfill

by
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Prepared by the
North Dakota Geological Survey
and the
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ND Landfill Site Investigation No. 8

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INTRODUCTION

Purpose

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

Location of the Glen Ullin Landfill

The Glen Ullin municipal solid waste landfill is located one-half mile south of the City of Glen Ullin in Township 139 North, Range 88 West, SW 1/4 Section 31 (Fig. 1). The landfill site encompasses approximately 30 acres.

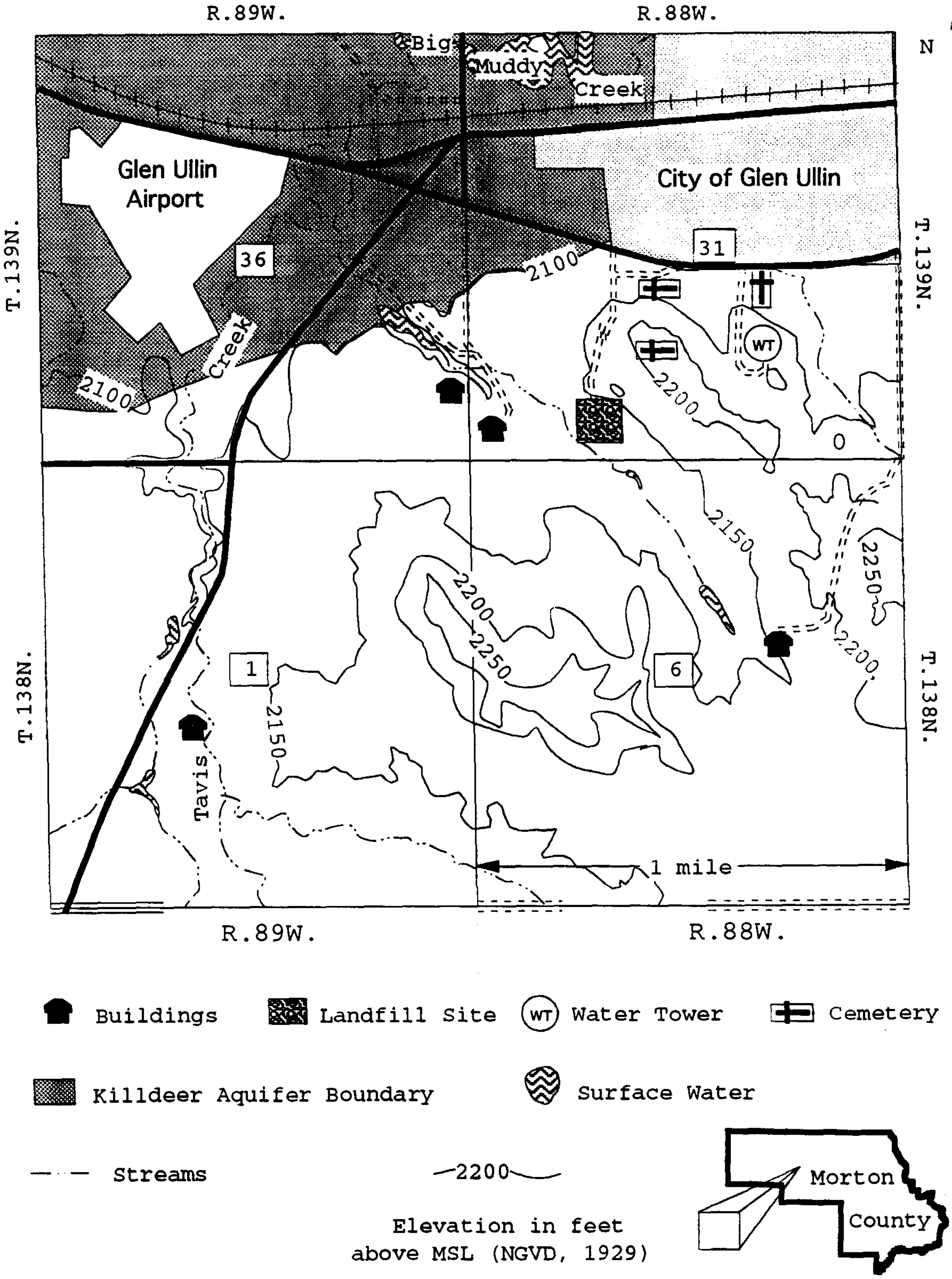

Figure 1. Location of the Glen Ullin landfill in the SW 1/4 of section 31, T139N, R88W.

Previous Site Investigations

No previous geologic or hydrologic investigations have been performed at the Glen Ullin landfill.

Methods of Investigation

The Glen Ullin 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.

Test Drilling Procedure

The drilling method at the Glen Ullin landfill was based on the site's geology and depth to ground water, as determined by the preliminary evaluation. A forward rotary rig was used at the Glen Ullin landfill because of the presence of lignite and clinker at the site. The lithologic descriptions were determined from the drill cuttings. The water used with the forward rotary drill rig was obtained from the Glen Ullin municipal water system.

Monitoring Well Construction and Development

Seven test holes were drilled at the Glen Ullin landfill, and monitoring wells were installed in six of the test holes. The number of wells installed at the 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 near 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 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

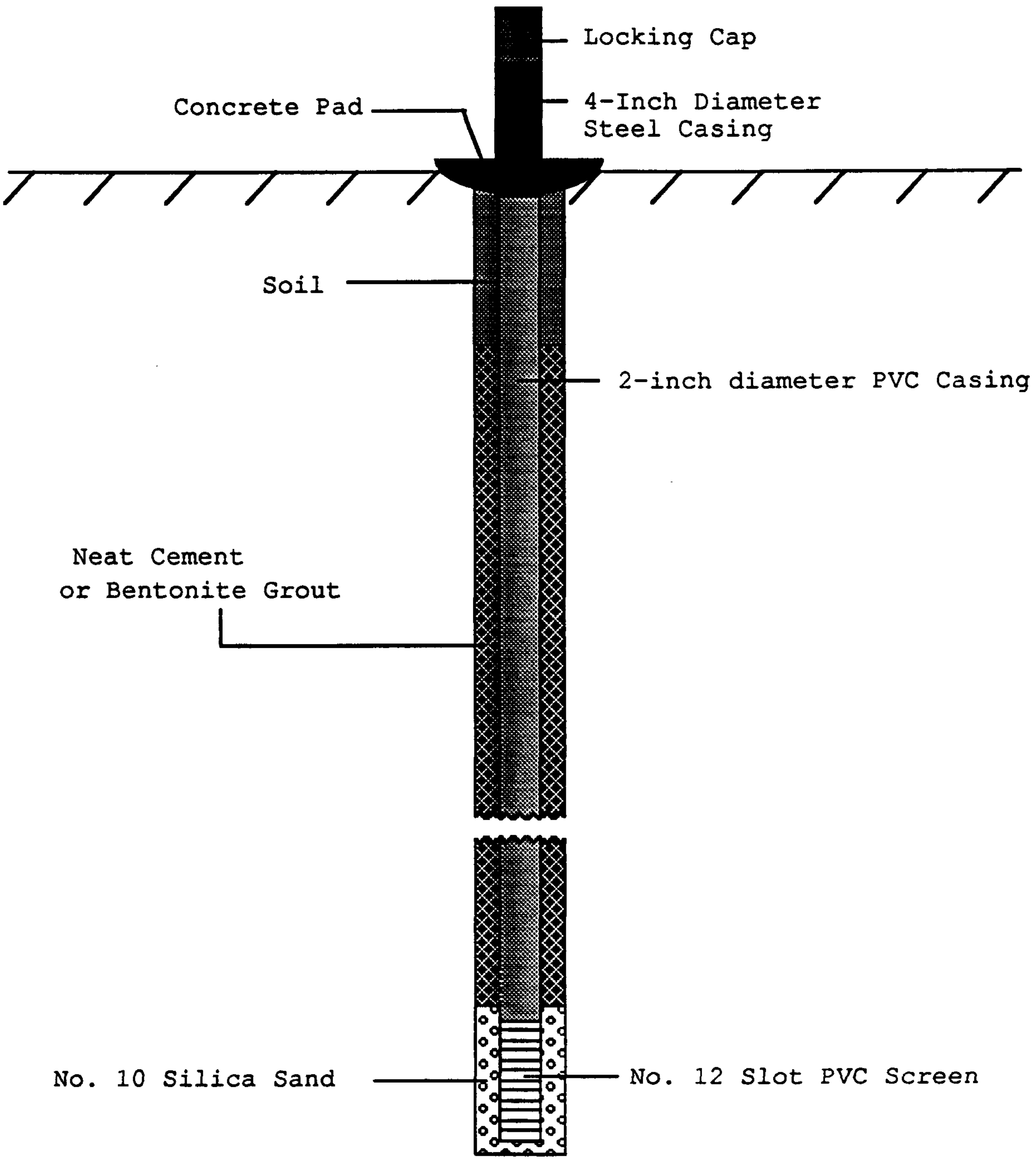

Figure 2. Construction design used for monitoring wells installed at the Glen Ullin landfill.

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.

Location-Numbering System

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township north and Range west of the 5th Principle Meridian and baseline (Fig. 3). The third number indicates the section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section (160-acre tract), quarter-quarter section (40-acre tract), and quarter-quarter-quarter section (10-acre tract). Therefore, a well denoted by 139-088-31CDC would be located in the SW1/4, SE1/4, SW1/4 Section 31, Township 139 North, Range 88 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 139-088-31CDC1 and 139-088-31CDC2.

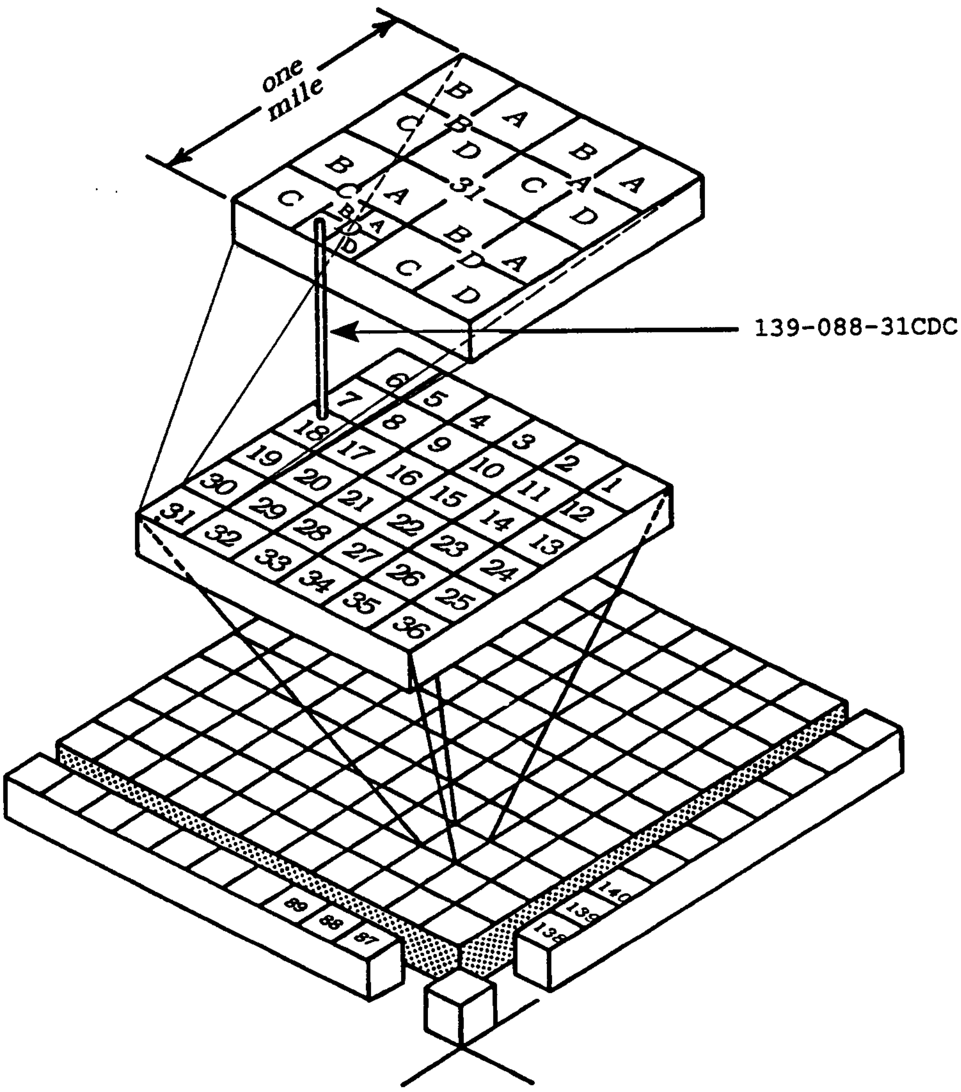

Figure 3. Location-numbering system for the Glen Ullin landfill.

GEOLOGY

Regional Geology

The Glen Ullin landfill is in an area of eroded bedrock assigned to the Sentinel Butte and Bullion Creek Formations. These formations are Paleocene in age and were deposited in deltaic environments (Jacob, 1976). They are composed of sand, sandstone, silt, clay, lignite, and limestone. The formations are similar in appearance, their main distinguishing characteristic being a difference in color in weathered exposures. The Sentinel Butte Formation is generally dark gray or brown; the Bullion Creek Formation is light gray or buff. The Bullion Creek Formation has generally brighter hues than does the Sentinel Butte Formation.

A broad valley located about 1/2 mile north of the landfill, and now occupied by Big Muddy Creek, marks the route of a glacial meltwater channel. During the Pleistocene Epoch the channel was the site of a large river which flowed along the margin of a glacier. Today the channel is largely filled with outwash deposits, including sand, gravel, silt, and clay. Lithologic logs from wells and test holes (Ackerman, 1977) indicate that the outwash is approximately 400 feet thick in the deepest parts of the channel. A thin layer of Holocene alluvium overlies the glacial deposits.

Local Geology

The Glen Ullin landfill is located on the south-facing slope of a hill (Fig. 4). The refuse has been placed on the sloping ground surface and covered with material excavated from the upper slopes of the hill. The sediments at the site include clay, sand, silt, lignite, and clinker of the Sentinel Butte and Bullion Creek Formations. The county geologic map (Carlson, 1983) places the contact between the two formations about midway down the hill.

On the north (uphill) side of the site the shallow sediments consist of clay with thin beds of sand, silt, and lignite (Fig. 5). A 6-foot-thick lignite bed (upper lignite) occurs 67 feet below the surface (well 139-088-31CDA2, lithologic logs in Appendix C). A 2-foot-thick lignite bed occurs 20 feet below the upper lignite bed. On the south (downhill) side of the site the upper lignite is 5 to 10 feet below the ground surface and is overlain by silt and clay. The lignite has been replaced by clinker at two locations (139-088-31CDC1 and 139-088-31CDC2).

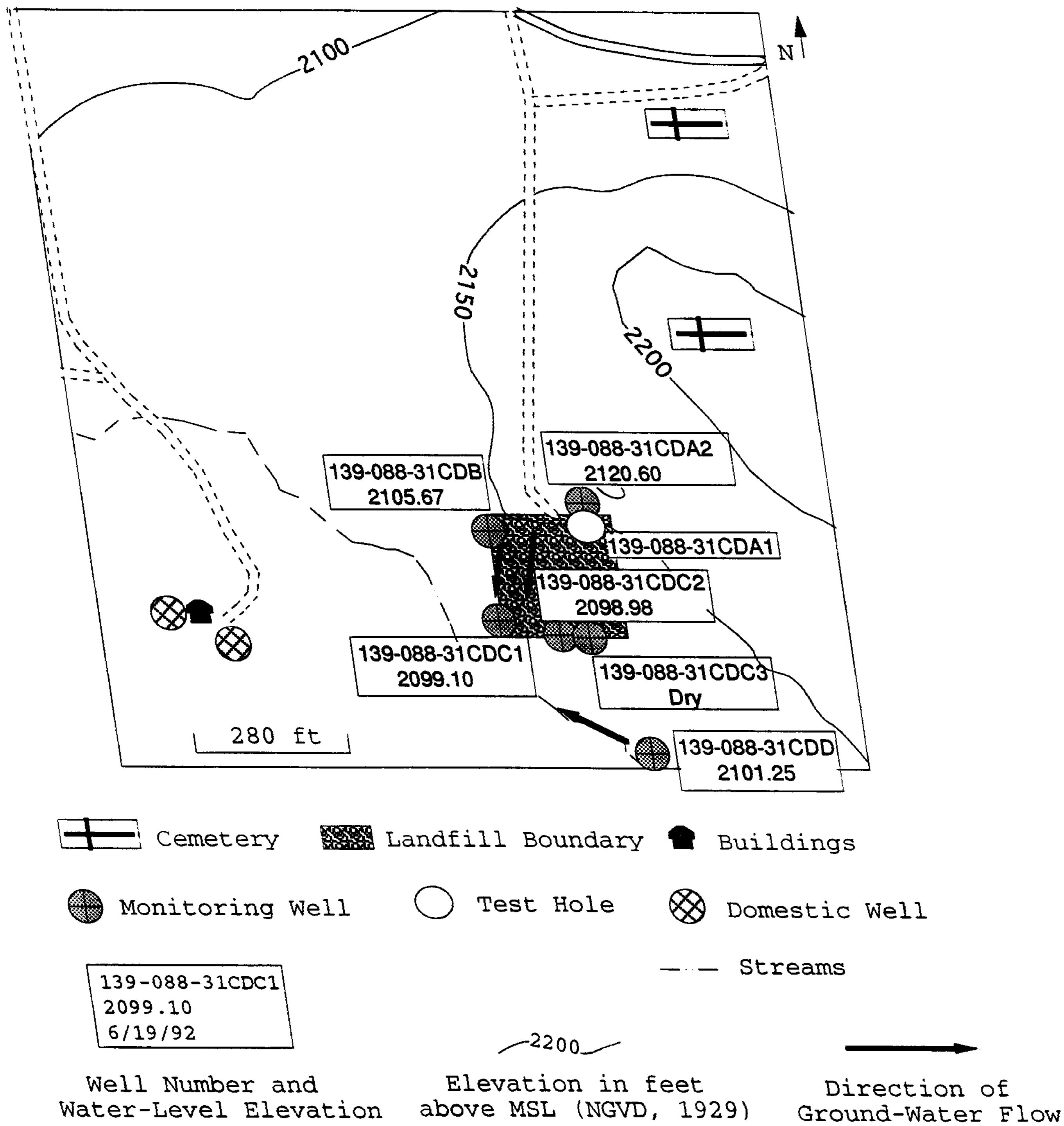

Figure 4. Location of monitoring wells and the direction of ground-water flow.

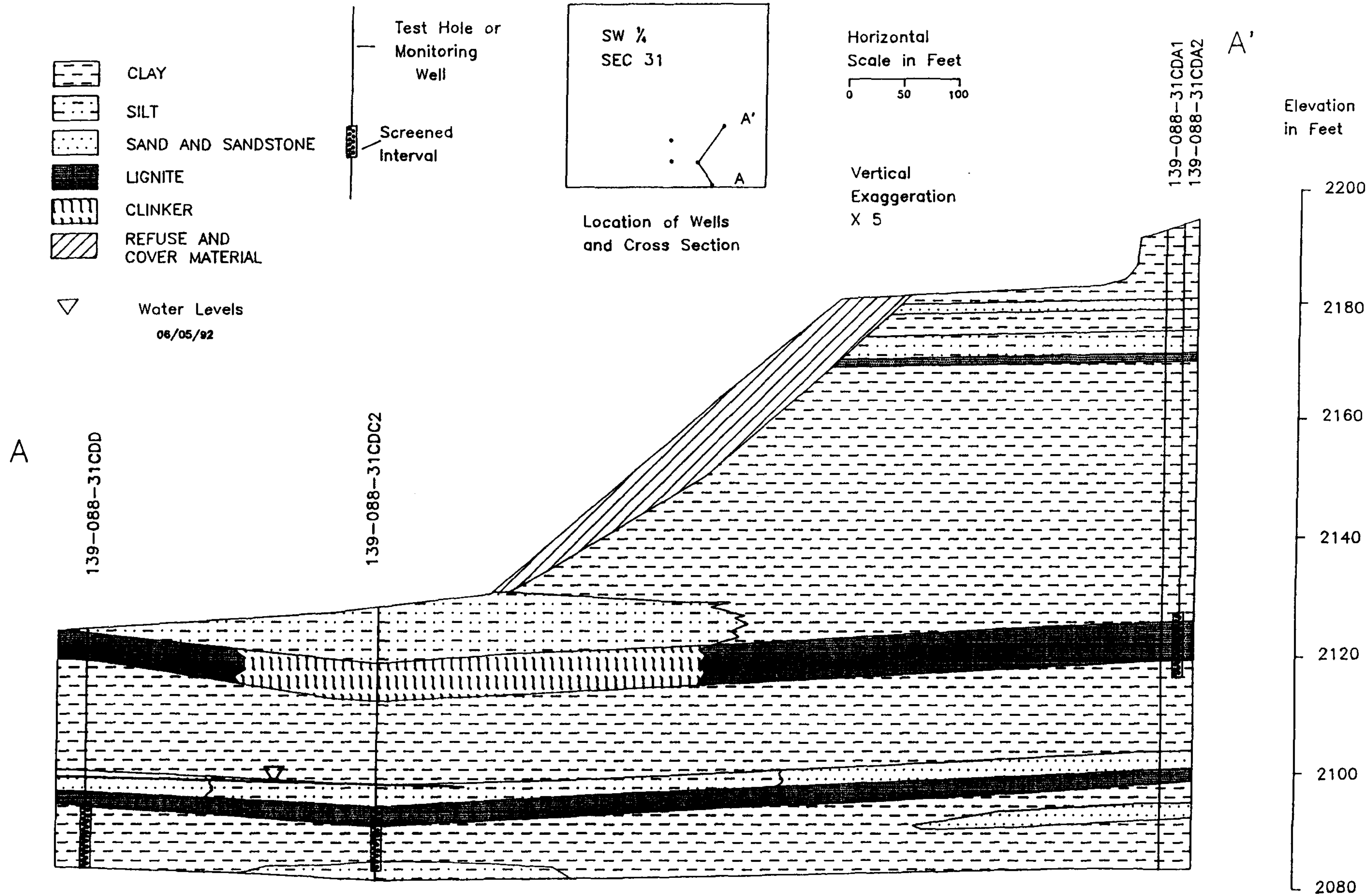

Figure 5. Geohydrologic section A–A' in the Glen Ullin landfill

HYDROLOGY

Surface-Water Hydrology

The Big Muddy Creek is located about one-mile north of the landfill (Fig. 1). The Big Muddy Creek recharges the underlying Killdeer aquifer during periods of high flow (Ackerman, 1980). This river may not be directly affected by the landfill.

Numerous ephemeral streams are located within a two-mile radius of the landfill. One stream is located along the southern boundary of the landfill. This stream may flow during periods of high runoff or precipitation into Tavis Creek, which flows north into the Big Muddy Creek.

Three stock ponds are located along the ephemeral stream. Two of the three ponds are located southeast of the landfill and should not be affected by the landfill. A monitoring well (139-088-31CDD) was installed adjacent to the northernmost pond south of the landfill (Fig. 4).

There are no diversions of surface water or collection ponds at the landfill site. Runoff from the landfill site flows into the ephemeral stream south of the landfill.

Regional Ground-Water Hydrology

The Killdeer aquifer (glaciofluvial aquifer) occupies a buried valley north-northwest of the landfill and underlies the Big Muddy Creek (Fig. 1; Ackerman, 1980). Recharge to the Killdeer aquifer is from precipitation, rivers and streams. The Killdeer aquifer flows eastward and discharges into the Elm Creek aquifer. Bedrock aquifers are in hydraulic connection with the Killdeer aquifer (Ackerman, 1980). The hydraulic gradient indicates water movement from the bedrock aquifers into the Killdeer aquifer.

Bedrock aquifers are also located beneath the Glen Ullin landfill. The city of Glen Ullin obtains its domestic water from the Bullion Creek Formation (Ackerman, 1980). This aquifer is about 330 feet below land surface. Aquifers are also located within the Fox Hills and Hell Creek Formations that underlie the Bullion Creek Formation. Bedrock aquifers should not be affected by the landfill because of their depths and the fact that ground-water movement is upward from the bedrock aquifer into the Killdeer aquifer.

Local Ground-Water Hydrology

Six monitoring wells were installed around the landfill boundaries (Fig. 4). Two separate lignite aquifers were encountered in this study. Wells 139-088-31CDA2 and 139-088-31CDB were screened in the uppermost lignite aquifer. Well 139-088-31CDC3 was screened in a layer of clinker at the same elevation as the lignite aquifer and was dry throughout the duration of the study.

Wells 139-088-31CDC1, 139-088-31CDC2, and 139-088-31CDD were screened within the lower lignite aquifer. Based on limited water-level measurements, the direction of ground-water flow in the lower lignite aquifer is southwest under the landfill and west along the axis of the ephemeral stream bed (Fig. 4).

Water Quality

Chemical analyses of water samples are shown in Appendix E. The upper lignite aquifer was unable to supply enough water at wells 139-088-31CDA2 and 139-088-31CDB for a complete water-quality analysis. Water quality analysis of the major ions in well 139-088-31CDA2 indicate a sodium-bicarbonate type water. Well 139-088-31CDD was used for water quality comparison of the ambient water in the lower lignite aquifer. This well is located southeast of the landfill within the stream bed. Wells 139-088-31CDC1 and 139-088-31CDD2 were screened in the same lower lignite aquifer and are located south of the landfill. The water quality results indicated high concentrations of sodium, sulfate, and total dissolved solids (Appendix E). These concentrations are not unusual for water in lignite beds and are found in high concentrations within the Sentinel Butte and Bullion Creek Formations. The water quality in this aquifer is a sodium-sulfate type water.

Two domestic wells southwest of the landfill were also sampled for water-quality analysis. These wells are screened at a deeper bedrock aquifer and do not appear to be affected by the landfill. High concentrations of sulfate, sodium, and total dissolved solids were detected. These concentrations are expected in bedrock aquifers in this area.

The results of the VOC analysis, from well 139-088-31CDC2, are shown in Appendix F. The analysis detected two VOC compounds, 2-Butanone and tetrahydrofuran. Both of these compounds are man-made and are not found in natural ground waters. 2-Butanone is a general organic compound used in many solvents and cleaners. Tetrahydrofuran is a compound used in glues and liquid cements for fabricating packages and polyvinyl-chloride materials. The detection of these compounds may indicate leachate migration from the landfill.

CONCLUSIONS

The Glen Ullin landfill is located on the south-facing slope of a hill. The refuse has been placed on the ground surface and covered with material excavated from the upper slopes of the hill. An intermittent stream south of the landfill drains northwest toward Tavis Creek and Big Muddy Creek.

The regional geology is characterized by eroded bedrock, except in the vicinity of Big Muddy Creek, where glaciofluvial sediments reveal the presence of a Pleistocene meltwater channel. The main regional aquifers are the Killdeer aquifer and bedrock aquifers. The Killdeer aquifer occupies the meltwater channel and is north-northwest of the landfill. Most of the wells near the landfill are screened in deep (more than one hundred feet) bedrock aquifers. A few wells produce from depths of less than 100 feet, but none of them are down-gradient from the landfill.

The sediments at the landfill belong to the Sentinel Butte and Bullion Creek Formations and consist of clay with interbedded sand, silt, lignite, and clinker. Two lignite beds occur beneath the site. The upper, 6-foot-thick lignite is 67 feet below the surface on the north side of the site and 5 to 10 feet below the surface on the south side of the site. Clinker has replaced the upper lignite at two locations. A 2 to 3-foot-thick lignite bed occurs 20 feet below the upper lignite.

The upper lignite aquifer was only partially saturated and yields small quantities of water. Water-level measurements of the lower lignite aquifer suggests a southwest flow beneath the landfill. A westward flow of the ground water beneath the intermittent stream was determined based on topographic location and slope of the stream bed.

Incomplete water quality results are available from the upper lignite aquifer because it supplied insufficient quantities of water for sampling. Water quality results on the lower aquifer are mixed. The major ion and trace element concentrations in the down-gradient wells do not suggest contamination due to leachate migration from the landfill. However, two volatile organic compounds, 2-Butanone and tetrahydrofuran, were detected in well 139-088-31CDC2. This well is on the south side of the landfill and near the buried refuse. VOC detections suggest leachate migration from the landfill into the shallow lignite aquifer.

The operating method used at the landfill, with refuse placed on the ground surface instead of in trenches, may allow some infiltration and circulation of water within the refuse. The buried refuse is more permeable than the underlying clay on the hillside. This could allow leachate to migrate downslope toward the lignite beds, which are close to the surface on the south side of the landfill. The deeper bedrock aquifers should not be affected by leachate migration from the landfill.

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

Jacob, A.F., 1976, Geology of the upper part of the Fort Union Group (Paleocene), Williston Basin, with reference to uranium: North Dakota Geological Survey, Report of Investigation No. 58.

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APPENDIX A

WATER QUALITY STANDARDS
AND
MAXIMUM CONTAMINANT LEVELS

Water Quality Standards
and
Maximum Contaminant Levels

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

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

APPENDIX B

SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

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

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

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

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

convex meniscus

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

6. Scew the cover on with the white Teflon side down. Shake vigorously, turn the bottle upside down, and tap gently to check if air bubbles are in the sample.

7. If air bubbles are present, take the cover off the bottle and add more water. Continue this process until there are no air bubbles in the sample.

8. The sample must be iced after collection and delivered to the laboratory as soon as possible.

9. The 40 ml bottles contain ascorbic acid as a preservative and care must be taken not to wash it out of the bottles. The concentrated acid must be added after collection as an additional preservative.

APPENDIX C

LITHOLOGIC LOGS
OF WELLS AND TEST HOLES

139-088-31CDA1

NDSWC

Date Completed:	5/4/92	Purpose:	Test Hole
Depth Drilled (ft):	200	Source of Data:	
L.S. Elevation (ft)	2180.13	Owner: Glen Ullin	

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SILTY, PALE, YELLOW-BROWN, 10YR6/2, SENTINEL BUTTE AND BULLION CREEK FORMATIONS	1-7
SILT	SANDY, PALE YELLOW-BROWN, 10YR6/2	7-11
LIGNITE		11-11.5
CLAY	LIGHT OLIVE-GRAY, 5Y6/1	11.5-17
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	17-25
CLAY	SILTY, MODERATE YELLOW-BROWN, 10YR5/4	25-28
SANDSTONE	FINE GRAIN,MEDIUM GRAY, N5, WELL CEMENTED	28-29
CLAY	MODERATE YELLOW-BROWN, INTERBEDDED WITH DARK YELLOW-ORANGE, 10YR5/4	29-39
CLAY	MEDIUM LIGHT GRAY, N6	39-42
SAND	FINE GRAIN, SILTY, MEDIUM GRAY, N5	42-44
CLAY	SANDY, MEDIUM LIGHT GRAY, N6	44-46
SANDSTONE	FINE GRAINED, SILTY, MEDIUM GRAY, N6, WELL CEMENTED	46-47
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	47-49
SAND	FINE GRAIN, MEDIUM LIGHT GRAY, N6	49-51
CLAY	PALE BROWN, 5YR5/2	51-55
LIGNITE		55-63
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	63-81
SAND	FINE GRAIN, CLAYEY, MEDIUM LIGHT GRAY, N6	81-82
LIGNITE		82-84
CLAY	PALE BROWN, 5YR5/2	84-87
SAND	FINE GRAIN, CLAYEY, MEDIUM LIGHT GRAY, N6	87-89
CLAY	GREEN-GRAY, 5G6/1	89-96
CLAY	MEDIUM LIGHT GRAY, N6	96-100
CLAY	YELLOW-GRAY, 5Y8/1	100-103
CLAY	GREEN-GRAY, 5G6/1	103-114

CLAY	DARK YELLOW-BROWN, 10YR4/2	114-116
CLAY	MEDIUM GRAY, N5	116-119
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	119-121
SAND	FINE GRAIN, SILTY, MEDIUM GRAY, N5	121-124
LIGNITE		124-125
CLAY	LIGHT OLIVE-GRAY,5Y6/1	125-127
CLAY	GREEN-GRAY, 5G6/1	127-135
LIGNITE		135-135.5
CLAY	GREEN-GRAY, 5G6/1	135.5-142
CLAY	MEDIUM LIGHT GRAY	142-149
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	149-161
SAND	FINE GRAIN, SILTY, MEDIUM GRAY	161-176
SAND	FINE GRAIN, SILTY, MEDIUM BLUE-GRAY, 5B5/1	176-184
CLAY	SANDY, LIGHT MEDIUM GRAY	184-185
CLAY	LIGHT GRAY	185-187
SAND	FINE GRAIN, SILTY, MEDIUM BLUE-GRAY, 5B5/1	187-196
LIGNITE		196-200

139-088-31CDA2
NDSWC

Date Completed:	5/4/92	Well Type:	2" PVC
Depth Drilled (ft):	77	Source of Data:	
Screened Interval (ft):	66-76	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2193.13
Owner: Glen Ullin			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SILTY, PALE BROWN 5YR 5/2, SENTINEL BUTTE AND BULLION CREEK FORMATIONS	1-4
CLAY	LIGHT OLIVE GRAY 5Y 6/1	4-7
SAND	FINE-GRAINED, CLAYEY, LIGHT OLIVE GRAY, 5Y 6/1	7-9
CLAY	SILTY, PALE YELLOW BROWN, 10YR 6/2	9-12
SAND	FINE-GRAINED, CLAYEY, PALE YELLOW BROWN, 10YR 6/2	12-15
CLAY	DARK YELLOWISH ORANGE, 10YR 6/6	15-16
SAND	FINE-GRAINED, MODERATE YELLOW BROWN, 10YR 5/4	16-18
SILT	CLAYEY, LIGHT OLIVE GRAY, 5Y 6/1, INTERBEDDED COAL	18-23
CLAY	MODERATE YELLOW BROWN, 10YR 5/4	23-25
CLAY	MEDIUM LIGHT GRAY, N6	25-36
CLAY	MODERATE YELLOW BROWN, 10YR 5/4	36-43
CLAY	SILTY, MODERATE YELLOW BROWN, 10YR 5/4	43-45
CLAY	MEDIUM LIGHT GRAY, N6	45-47
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	47-51
CLAY	MEDIUM LIGHT GRAY, N6	51-62
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	62-65
CLAY	GRAYISH BROWN, 5YR 3/2	65-67
LIGNITE		67-73
CLAY	MEDIUM LIGHT GRAY, N6	73-77

139-088-31CDB

NDSWC

Date Completed:	5/5/92	Well Type:	2" PVC
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	25-35	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2140.67
Owner: Glen Ullin			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	GRAYISH ORANGE, 10YR 7/4, SENTINEL BUTTE AND BULLION CREEK FORMATIONS	2-11
CLAY	DARK YELLOW ORANGE 10 YR 6/6	11-12
CLAY	PALE YELLOWISH BROWN, 10YR 6/2	12-18
CLAY	SILTY, PALE YELLOWISH BROWN, 10YR 6/2	18-20
CLAY	MEDIUM LIGHT GRAY, N6	20-21
CLAY	GRAYISH BROWN, 5YR 3/2	21-23
LIGNITE		23-29
CLAY	MEDIUM LIGHT GRAY	29-34
CLAY	GREENISH GRAY, 5G 6/1	34-37
CLAY	SILTY, GREENISH GRAY, 5G 6/1	37-40

139-088-31CDC1

NDSWC

Date Completed:		Well Type:	2" PVC
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	29-39	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2125.59
Owner: Glen Ullin			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	CLAYEY, PALE YELLOW BROWN 10YR 6/2, SENTINEL BUTTE AND BULLION CREEK FORMATIONS	1-7
CLINKER	MODERATE REDDISH ORANGE, 10R 6/6	7-15
CLAY	LIGHT MEDIUM GRAY, N6	15-26
SILT	SANDY, MODERATE YELLOW BROWN, 10YR 5/4	26-31
LIGNITE		31-34
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y 6/1	34-38
CLAY	GRAYISH GREEN, 10G 5/2	38-40

139-088-31CDC2
NDSWC

Date Completed:	5/5/92	Well Type:	2" PVC
Depth Drilled (ft):	47	Source of Data:	
Screened Interval (ft):	34-44	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2129.67

Owner: Glen Ullin

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	SILTY, LENSES OF CLINKER, PALE YELLOW BROWN, 10YR 6/2, SENTINEL BUTTE AND BULLION CREEK FORMATIONS	2-11
CLINKER	MODERATE REDDISH ORANGE, 10R 6/6	11-16
CLAY	LIGHT MEDIUM GRAY, N5	16-21
CLAY	PALE YELLOW BROWN, 10YR 6/2	21-26
CLAY	SILTY, PALE YELLOW BROWN, 10YR 6/2	26-31
CLAY	SILTY AND SANDY, MODERATE YELLOWISH BROWN, 10YR 5/4	31-34
LIGNITE		34-37
CLAY	DUSKY BROWN, 5YR 2/2	37-38
CLAY	PALE GREEN, 5G 7/2	38-43
SILT	CLAYEY, GRAYISH GREEN 5G 5/2	43-47

139-088-31CDC3
NDSWC

Date Completed:	5/5/92	Well Type:	2" PVC
Depth Drilled (ft):	20	Source of Data:	
Screened Interval (ft):	11-16	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2130.17

Owner: Glen Ullin

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SILTY, LENSES OF CLINKER, PALE YELLOW BROWN, 10YR 6/2	1-11
CLINKER	MODERATELY REDDISH ORANGE 10YR 6/6	11-16
CLAY	MEDIUM LIGHT GRAY, N5	16-20

139-088-31CDD

NDSWC

Date Completed:	5/5/92	Well Type:	2" PVC
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	29-39	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2127.31
Owner: Glen Ullin			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
LIGNITE	SENTINEL BUTTE AND BULLION CREEK FORMATION	1-5
CLAY	GRAYISH ORANGE, 10YR 7/4	5-8
CLAY	LIGHT OLIVE GRAY, 5Y 6/1	8-17
CLAY	MEDIUM GRAY, N5	17-19
CLAY	PALE YELLOWISH BROWN, 10YR 6/2 TO DARK YELLOWISH ORANGE, 10YR 6/6	19-22
CLAY	MEDIUM LIGHT GRAY, N6	22-24
CLAY	SILTY, MODERATE YELLOWISH BROWN, 10YR 5/4	24-25
SANDSTONE	WELL CEMENTED, FINE-GRAINED, LIGHT GRAY, N6	25-27
CLAY	SANDY, MODERATE YELLOWISH BROWN, 10YR 5/4	27-29
LIGNITE		29-30
CLAY	PALE GREEN, 5G 7/2	30-35
CLAY	SANDY, OLIVE GRAY, 5Y 4/1	35-40

APPENDIX D

WATER-LEVEL TABLES

Glen Ullin Water Levels
5/29/92 to 11/2/92

139-088-31CDA2 LS Elev (msl,ft)=2193.13

Undefined Aquifer SI (ft.)=66-76

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	63.15	2129.98	07/01/92	75.68	2117.45
06/05/92	72.83	2120.30	11/02/92	72.78	2120.35
06/19/92	72.53	2120.60	11/12/92	74.11	2119.02

139-088-31CDB LS Elev (msl,ft)=2140.67

Undefined Aquifer SI (ft.)=25-35

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	30.16	2110.51	06/19/92	34.79	2105.88
06/05/92	30.75	2109.92	07/01/92	0.00	2140.67

139-088-31CDC1 LS Elev (msl,ft)=2125.59

Undefined Aquifer SI (ft.)=29-39

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/13/92	26.54	2099.05	07/01/92	26.40	2099.19
06/05/92	26.38	2099.21	11/02/92	26.26	2099.33
06/19/92	26.49	2099.10			

139-088-31CDC2 LS Elev (msl,ft)=2129.67

Undefined Aquifer SI (ft.)=34-44

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/12/92	30.74	2098.93	07/01/92	30.55	2099.12
06/05/92	30.53	2099.14	11/02/92	30.47	2099.20
06/19/92	30.69	2098.98			

139-088-31CDD LS Elev (msl,ft)=2127.31

Undefined Aquifer SI (ft.)=29-39

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	24.93	2102.38	07/01/92	26.11	2101.20
06/05/92	25.89	2101.42	11/02/92	26.27	2101.04
06/19/92	26.06	2101.25			

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Glen Ullin Water Quality

Major Ion Analyses

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (µmho)	Temp (∞C)	pH
			(milligrams per liter)																					
139-088-31CDA2	66-76	06/24/92	12	1.9	0.29	6.2	7.5	1100	7.3	2520	0	300	140	1.3	15	1.3	2830	47	0	98	70	2910	12	7.43
139-088-31CDC1	29-39	05/13/92	15	0.83	0.93	190	160	3400	21	1760	0	7000	15	0.4	4.5	2.2	11700	1100	0	86	45	12570	12	7.13
139-088-31CDC2	34-44	05/12/92	19	0.24	0.58	85	70	1900	14	1430	0	3200	76	0.5	2.5	1.3	6070	500	0	89	37	7320	10	7.24
139-088-31CDD	29-39	05/29/92	10	0.08	0.46	100	58	2200	15	2130	0	3600	31	0.6	0	1.6	7070	490	0	90	43	8720	15	8.11

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
139-088-31CDA2	6/24/92	*	*	*	*	*	*	*
139-088-31CDC1	5/13/92	0	2	0	0	5	6	6400
139-088-31CDC2	5/12/92	0	2	0	0	2	14	1600
139-088-31CDD	5/29/92	0	0	0	0	1	5	1500

* Trace Element sample was not collected

APPENDIX F

VOLATILE ORGANIC COMPOUNDS
FOR WELL 139-088-31CDC2

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)	<892*
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	<408*
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection