Site Suitability Review of the Valley City Landfill

by
Jeffrey Olson
North Dakota State Water Commission
and
Phillip L. Greer
North Dakota Geological Survey

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

ND Landfill Site Investigation No. 11

SITE SUITABILITY REVIEW
OF THE
VALLEY CITY MUNICIPAL LANDFILL

By Jeffrey M. Olson, North Dakota State Water Commission,

and Phillip L. Greer, North Dakota Geological Survey

North Dakota Landfill Site Investigation 11

Prepared by the NORTH DAKOTA STATE WATER COMMISSION
and the NORTH DAKOTA GEOLOGICAL SURVEY

Bismarck, North Dakota
1993

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

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 Valley City municipal solid waste landfill is one of the landfills being evaluated.

Location of the Valley City Landfill

The Valley City municipal solid waste landfill is located one mile south of the City of Valley City in Township 140 North, Range 58 West, NE 1/4 Section 31 (Fig. 1). The landfill site encompasses approximately 25 acres, all of which has been used.

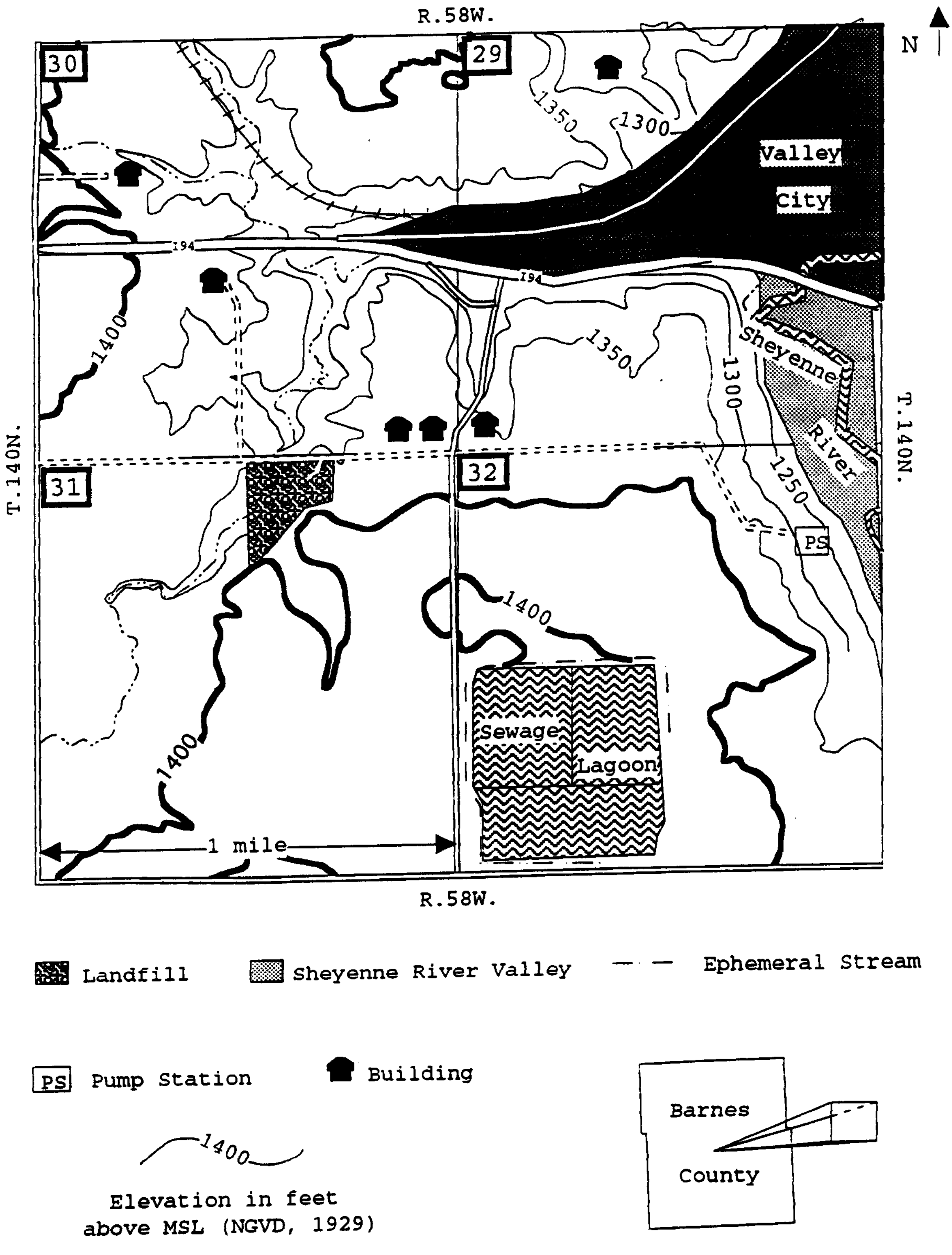

Figure 1. Location of the Valley City landfill in the NE 1/4 of section 31.

Previous Site Investigations

A soil investigation report by Midwest Testing was completed in June 1983. Two soil borings were drilled, one to a depth of 11.5 feet and the other to a depth of 39.5 feet. These borings were drilled on the west side of the south-north trending ravine about .5 mile west of the landfill site. The first boring was halted at 11.5 feet because of a boulder. The soil consisted of silty clay with laminations of silt and fine sand to a depth of ten feet. Fine silty sand was encountered below the clay. The second boring consisted of stiff glacial material through its 39.5-foot depth. No ground water was encountered in either of the soil borings.

Methods of Investigation

The Valley City landfill 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 Valley City 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 Valley City landfill because cobbles and boulders were anticipated in the till and because the depth to the water table was expected to be greater than 70 feet. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Seven test holes were drilled at the Valley City landfill, and monitoring wells were installed in five of the test holes. The number of wells installed at the Valley City 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

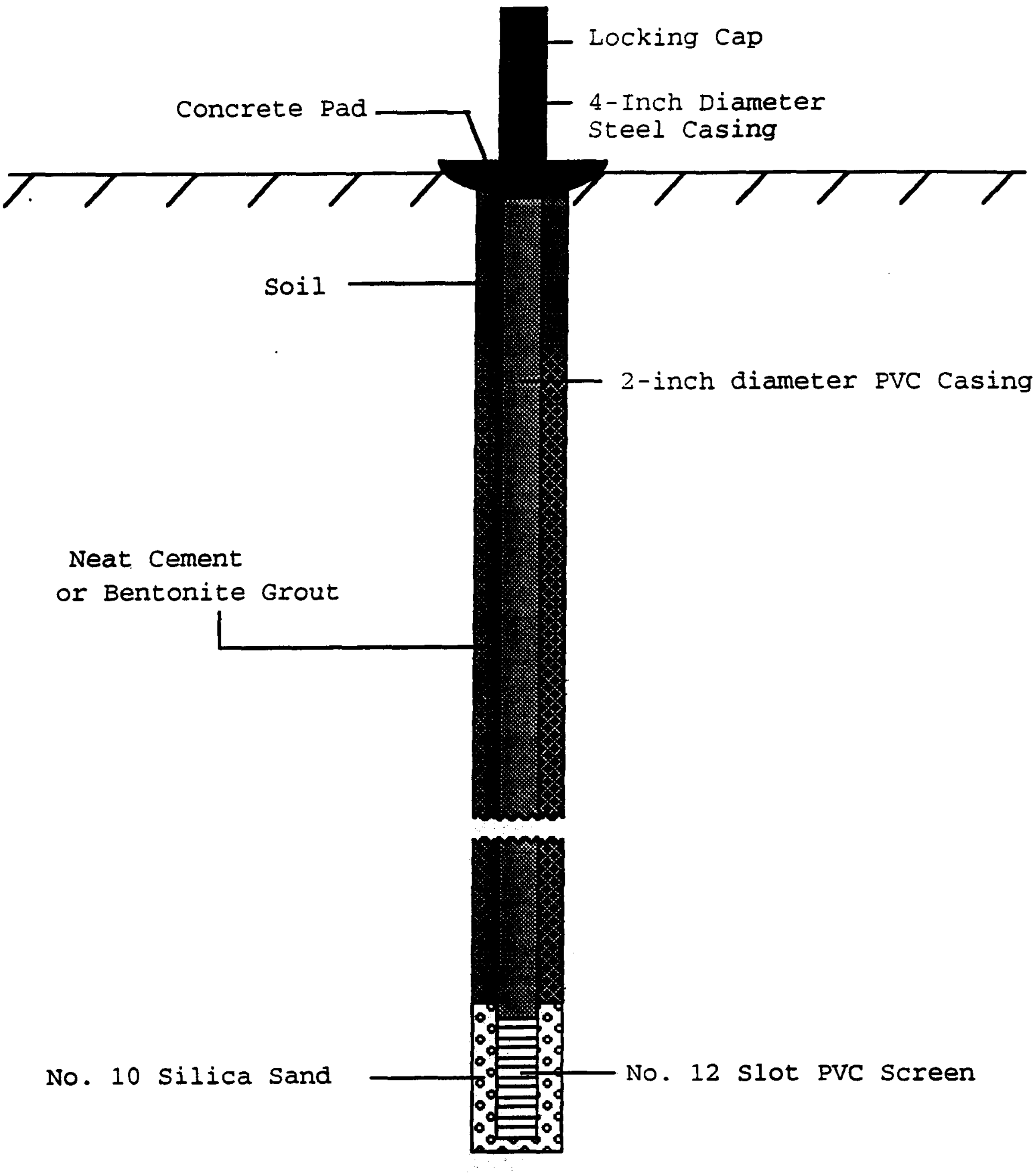

Figure 2. Construction design used for monitoring wells installed at the Valley City landfill.

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 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.

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.

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

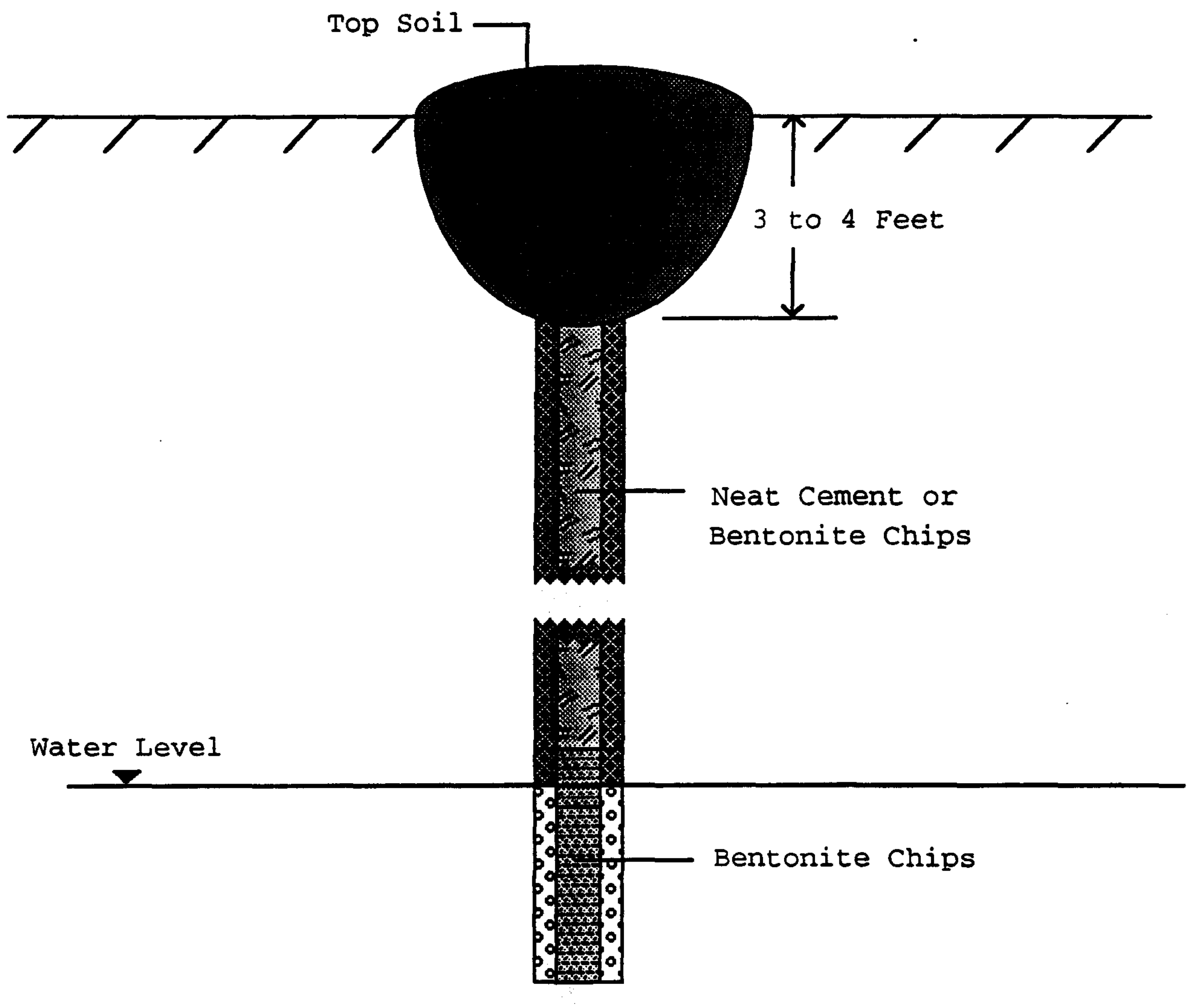

Figure 3. Monitoring well abandonment procedure.

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 140-058-31ABA would be located in the NE 1/4, NW 1/4, NE 1/4, Section 31, Township 140 North, Range 58 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 140-058-31ABA1 and 140-058-31ABA2.

GEOLOGY

Regional Geology

The geologic materials in the vicinity of the Valley City landfill include glacial drift and bedrock. The drift in the region consists of till with interbedded sand and gravel deposits (Kelly and Block, 1967). Ice-contact features, such as kames and eskers, are common on the drift sheet.

The Cretaceous Pierre Formation underlies the glacial drift and is exposed at the surface along the Sheyenne River Valley and its tributary drainages. The Pierre Formation

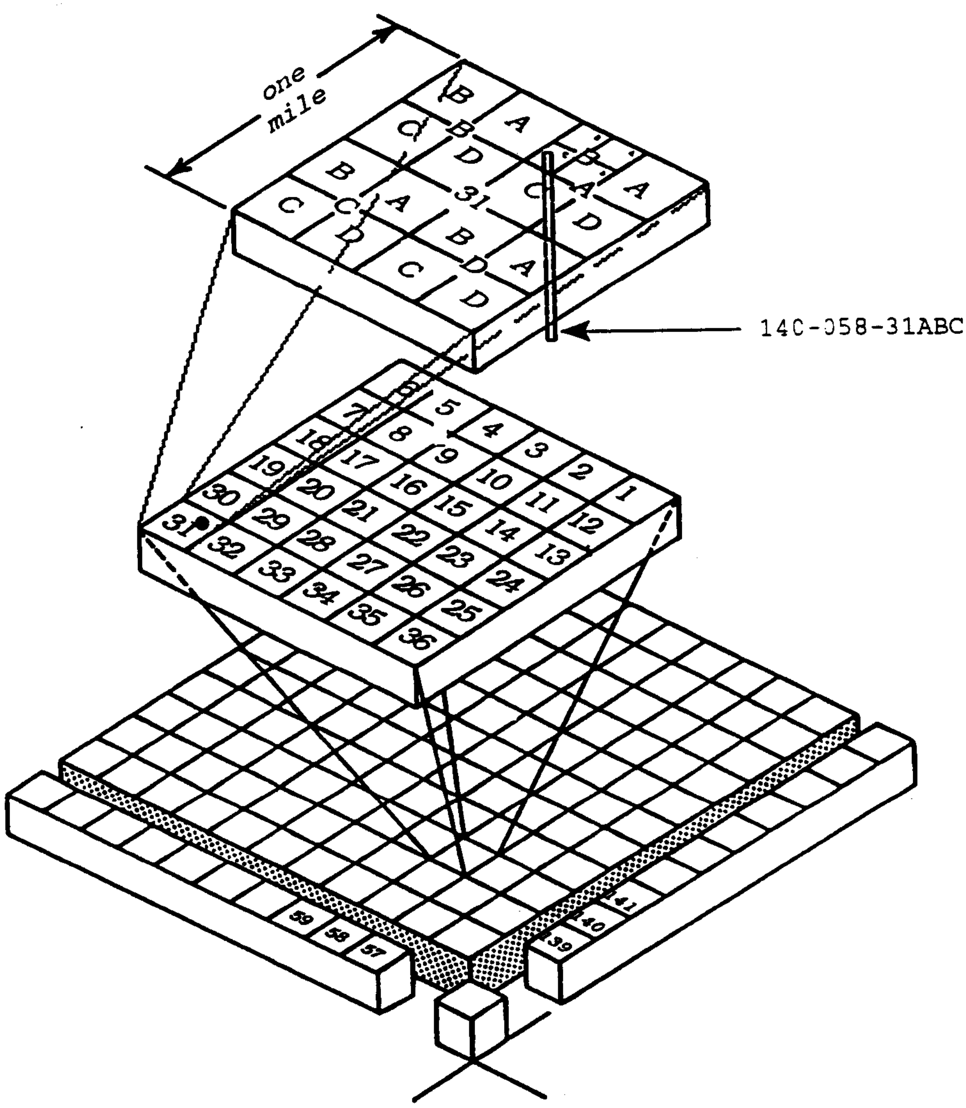

Figure 4. Location-numbering system for the Valley City landfill.

consists of shale and clay with the clay being commonly bentonite. Both hard, blocky, siliceous shales and soft, fissile shales occur within the formation.

Local Geology

The Valley City landfill is located on the southeast slope of a ravine (Fig. 5). Elevations range from about 1300 feet in the bottom of the ravine to 1400 feet on the east side of the site. An ephemeral stream in the ravine flows north and discharges into the Sheyenne River about a mile east of the landfill. The site may be susceptible to water erosion because of the proximity of the ephemeral stream and the steepness of the slopes.

The higher areas on the east side of the site are covered with glacial drift to a depth of 25 to 35 feet (Fig. 6). The till at the site is composed of clay, sandy clay, and sandy, pebbly clay. Thin layers of gravel are interbedded with the till in test holes 140-058-31ABA2 and 140-058-31ABC1 (lithologic logs in Appendix B).

The Pierre Formation underlying the glacial sediments is composed of clay and shale in colors ranging from light gray to dark gray, bluish gray, and greenish gray. The Pierre Formation outcrops on the slopes of the ravine. Landslides and slumps are common features of the Pierre Formation in areas with steep slopes (Kelly and Block, 1967).

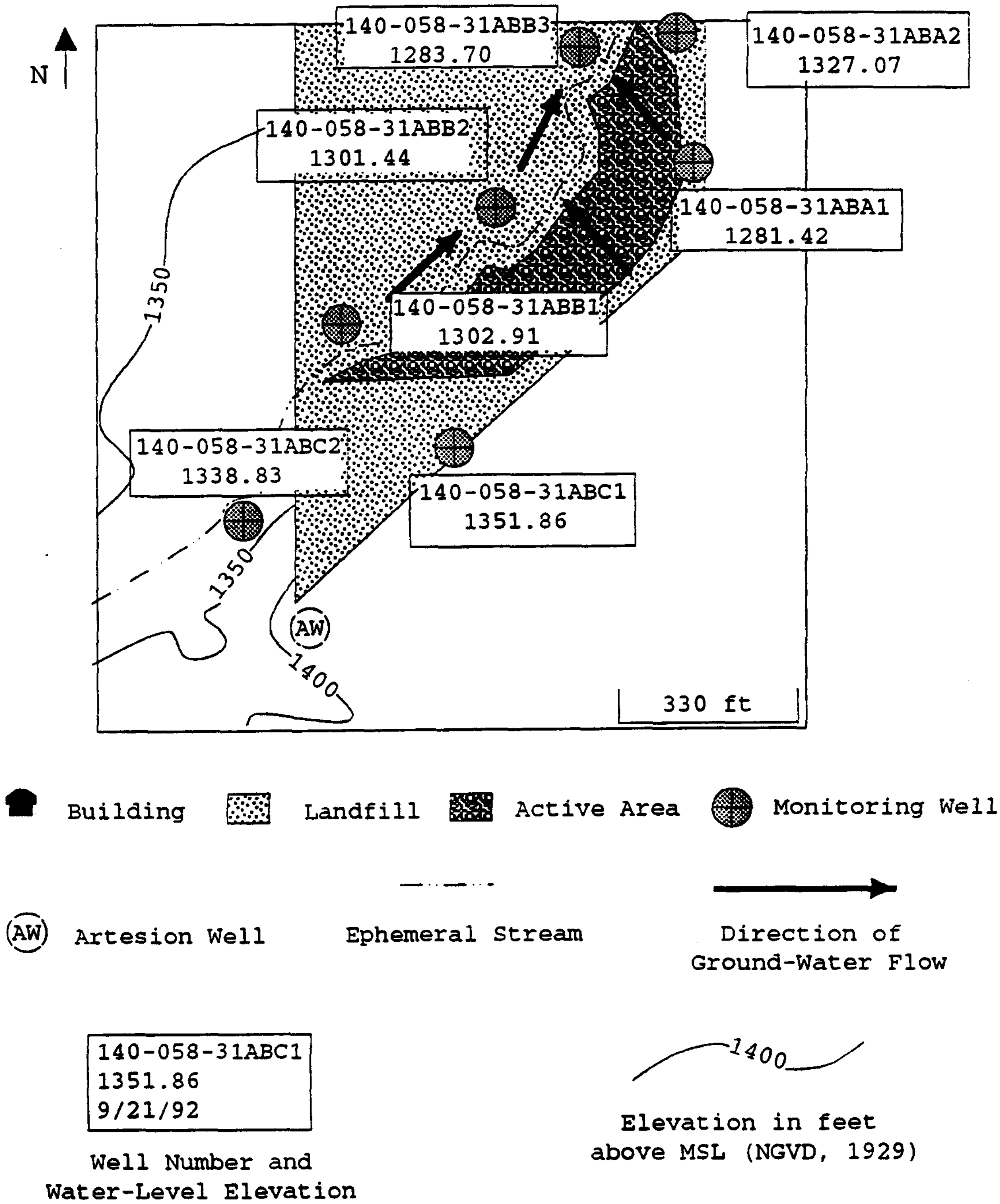

Figure 5. Location of monitoring wells and ground-water flow at the Valley City landfill.

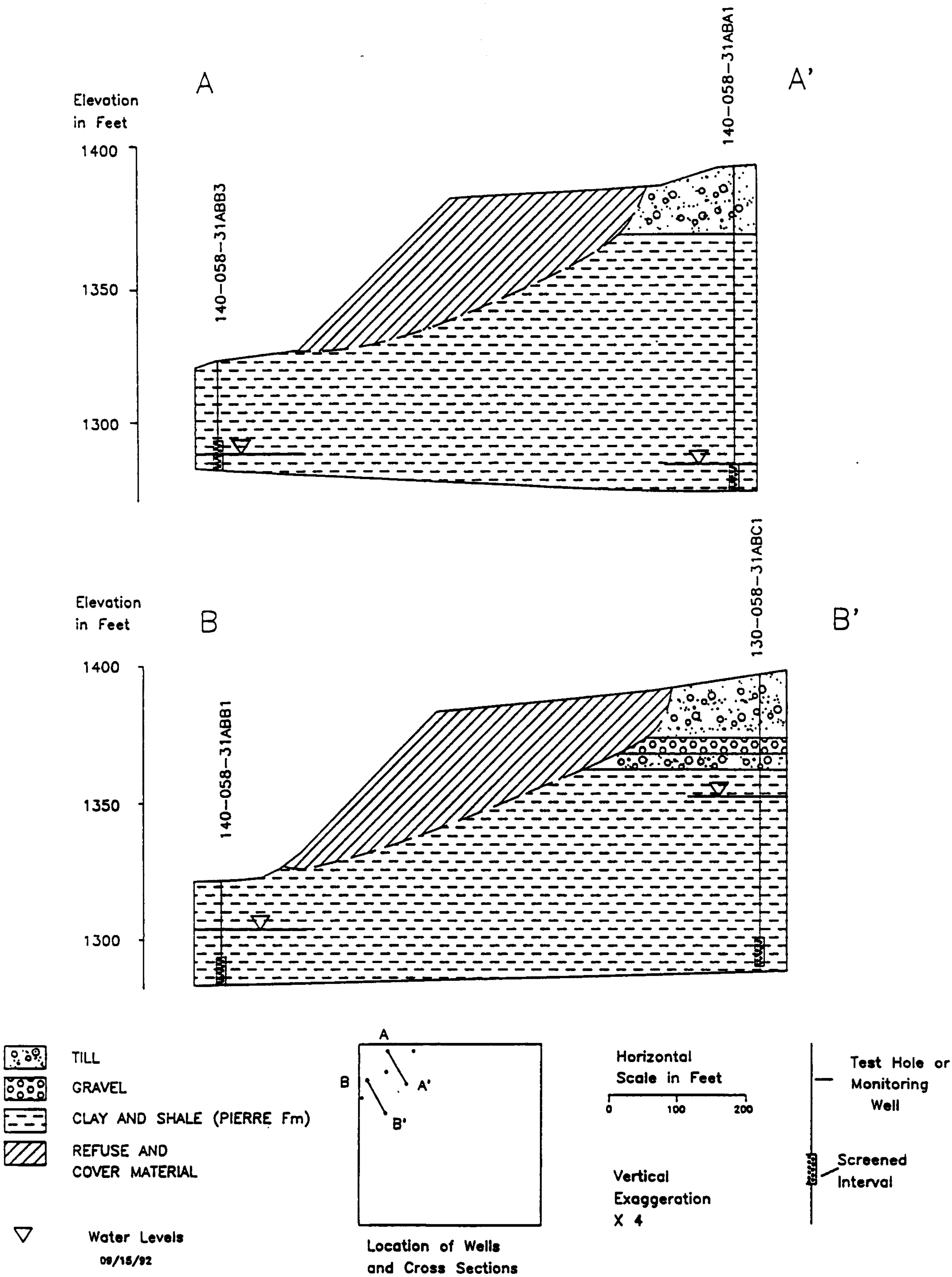

Figure 6. Geohydrologic sections A–A' and B–B' in the Valley City Landfill

The refuse was placed on the slope near the base of the ravine. The original slope was increased, thus creating a higher potential for erosion and slumping.

HYDROLOGY

Surface-Water Hydrology

An ephemeral stream is located along the western boundary of the active area of the landfill (Fig. 5). This stream appears to flow to the north and eventually discharges into the Sheyenne River.

The Sheyenne River is located about one-mile east of the landfill (Fig. 1). The Sheyenne River should not be affected by leachate migration from the landfill.

The Valley City sewage pond is located about 3/4 mile southeast of the landfill. The water from the sewage pond is used for irrigation on agricultural land surrounding the landfill.

There are no surface water diversions or impoundments at the landfill. Surface water runoff from the landfill is toward the ephemeral stream.

Regional Ground-Water Hydrology

Regional aquifers near the Valley City landfill consist of bedrock and glacial aquifers. Numerous wells are screened in the Pierre Formation throughout Barnes County. Water in the Pierre Formation moves primarily through fractures. Kelly (1966) determined that recharge to the Pierre aquifer is from the overlying glacial material. The Pierre Formation is characterized by a sodium-sulfate or sodium-chloride type water.

The Dakota Sandstone was penetrated by a few domestic wells around Valley City. A flowing well completed in the Dakota Sandstone is located at the southwest corner of the landfill property (Fig. 5). It was observed that the discharge from this well was toward the ephemeral stream along the western side of the active area. Water from the Dakota Sandstone aquifer is characterized as a sodium-sulfate type water (Kelly, 1966). Water from both the Pierre and Dakota Sandstone Formations generally contain concentrations of chloride, fluoride, iron, sulfate, and zinc above their MCL's.

The glacial aquifers consist of the Valley City aquifer and isolated layers of sand within the till. The Valley City aquifer is located about two miles northeast of the landfill and occupies a terraced outwash deposit in the Sheyenne River Valley (Kelly, 1966). Because of its location, the aquifer does not appear to be susceptible to leachate migration from the landfill. Valley City obtains its municipal water supply from this aquifer. Recharge to the Valley City aquifer is artificially obtained by piping water from the Sheyenne River to an abandoned gravel pit. The Valley City aquifer is characterized by a sodium-bicarbonate type water.

Small, isolated sand aquifers within the till are present in many locations (Kelly, 1966). These aquifers generally produce small quantities of water for domestic use and are characterized by calcium-sulfate and sodium-sulfate type waters.

Local Ground-Water Hydrology

Seven monitoring wells were installed within the landfill boundaries (Fig. 5). The well screens were placed in the Pierre Formation. Well 140-058-31ABC1 indicates a water-level elevation about 70 feet higher than the other wells (Fig. 6). The water level in this well may be influenced by a leaking well annulus. The information from this well will not be used in evaluating this site.

The direction of ground-water flow in the Pierre Formation beneath the landfill is to the west toward the ephemeral stream. At the stream, the direction of ground-water flow is to the north along a south-north trending ravine (Fig.5). The main source of domestic water near the landfill is by rural-water system.

Water Quality

Chemical analyses of water samples are shown in Appendix D. Well 140-058-31ABA1, located at the east boundary of the landfill, was used as an up-gradient well.

The Pierre aquifer is characterized by a sodium-chloride type water. The water quality analyses indicated high concentrations of sodium, chloride, sulfate, nitrate, and total dissolved solids at all well locations. These high concentrations (except for nitrates) are typical for wells screened within the Pierre Formation. Elevated nitrate concentrations (17 mg/L to 34 mg/L, as NO_3) were detected in five of the seven wells (Fig. 7). The location of the sewage irrigation system may be the cause of nitrates. Sewage water is usually high in nitrates and steady application of this water may accumulate in the soil and percolate through the soil profile to the underlying aquifer. Elevated pH's were detected in four of the seven wells (Fig. 8). Due to lack of background pH data in the Pierre aquifer, it is inconclusive as to whether the high pH's are anthropogenic in origin.

Trace element analyses indicated high concentrations of strontium (950 µg/L to 1900 µg/L). Skougstad and Horr (1963, in Hem, 1989) found the median concentration of strontium for large U.S. water supplies to be 110 µg/L. Increased strontium can result from leaching of incineration ash and municipal waste ash. These ashes are usually found in municipal landfills. The increase may also be due to the

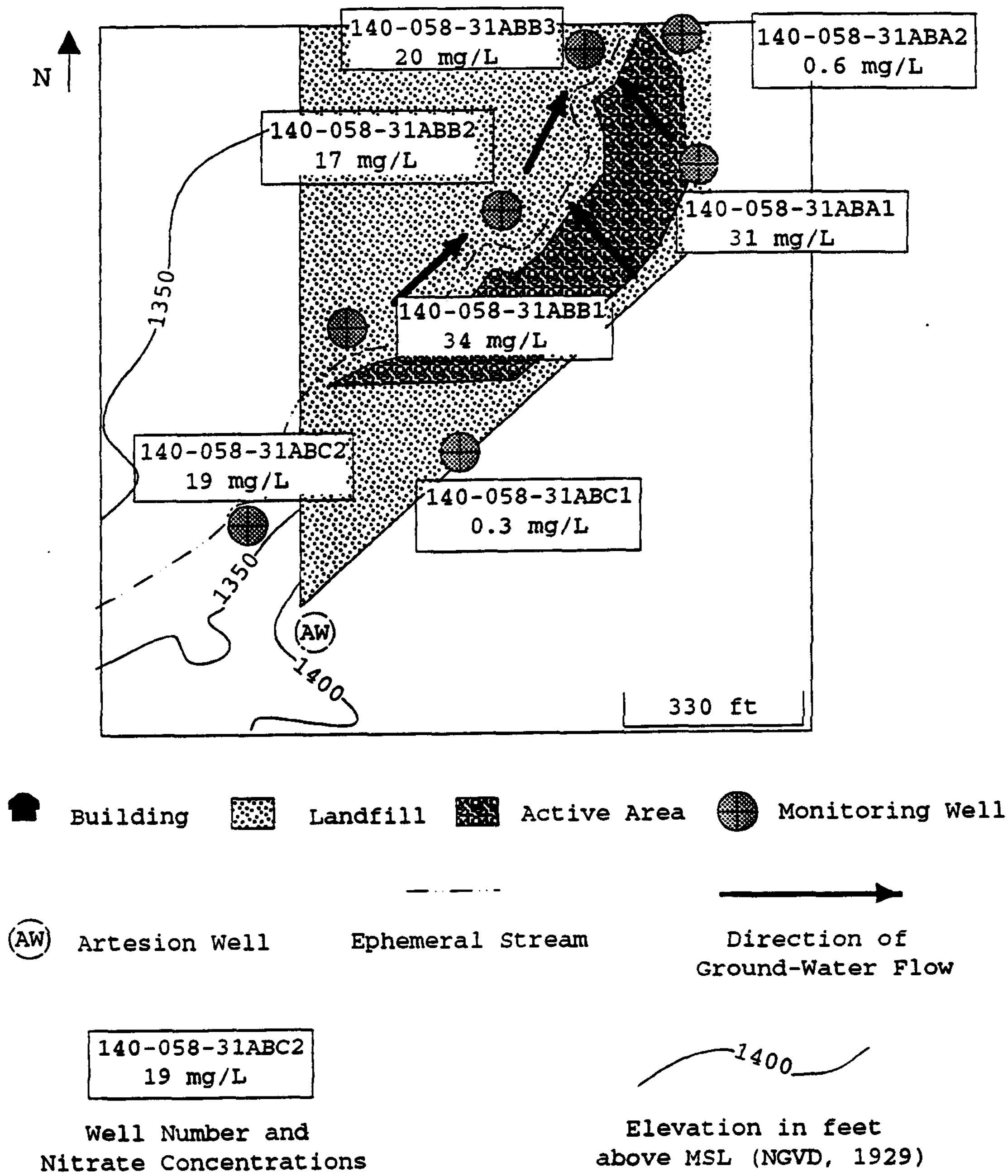

Figure 7. Nitrate concentrations at the Valley City landfill.

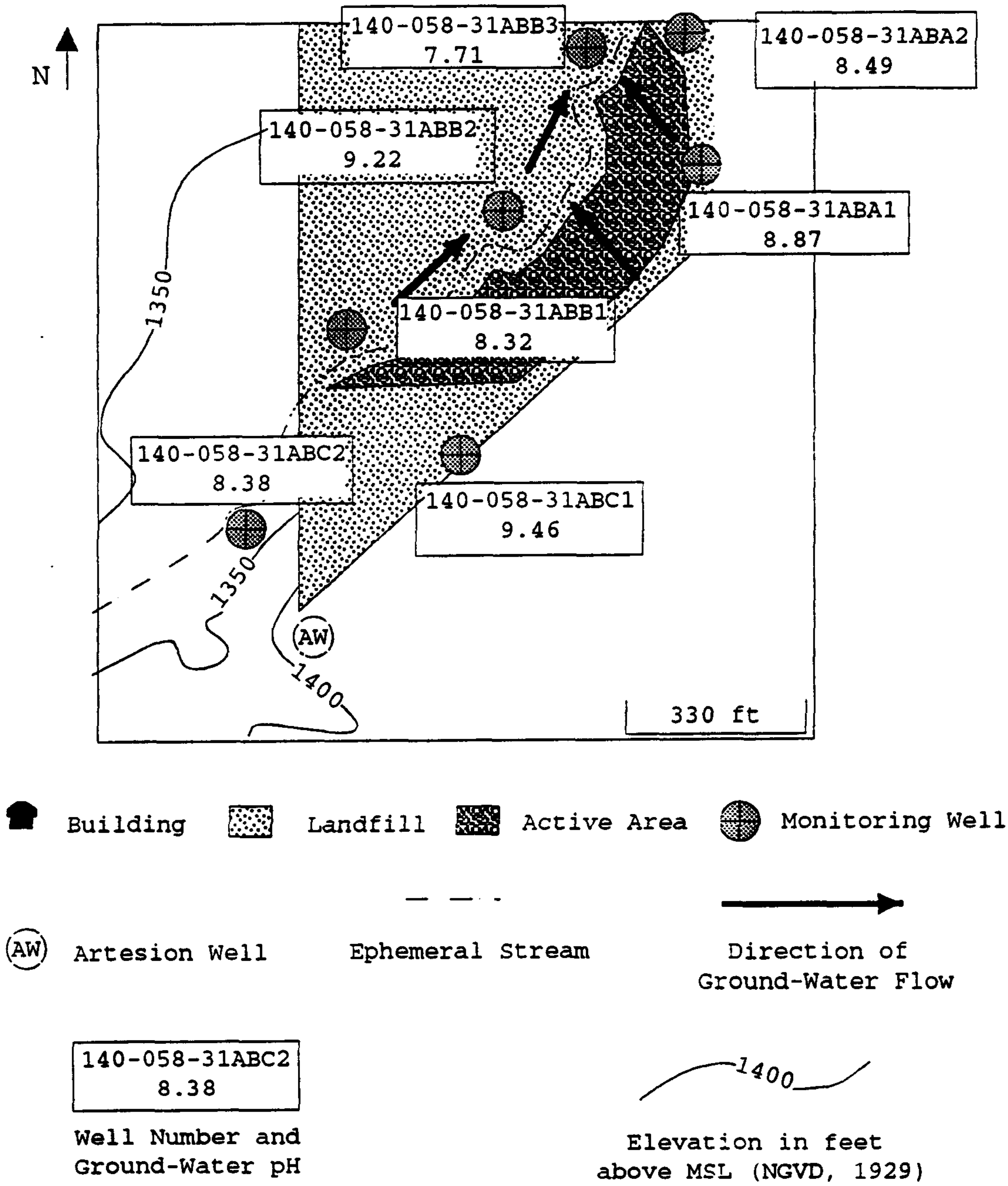

Figure 8. Ground-water pH at the Valley City landfill..

oxidation of overburden associated with the excavation process of the landfill operation. Well 140-058-31ABA1 indicated increased concentrations of arsenic (16 µg/L) and molybdenum (240 µg/L). This well is located up-gradient of the landfill and does not appear to be affected by leachate migration from the landfill. There were no VOC samples taken because the down-gradient wells were destroyed due to the landfill closure excavation.

CONCLUSIONS

The Valley City municipal landfill is located on the southeast slope of a ravine occupied by an ephemeral stream. The geology of the area consists of a 25 to 35-foot layer of glacial till overlying the Pierre Formation along the eastern boundary. The thickness of the till decreases toward the ravine due to erosion.

Surface water in the vicinity of the landfill consists of an ephemeral stream that discharges into the Sheyenne River about one-mile to the east. The Sheyenne River does not appear to be affected by leachate migration from the landfill. The Valley City sewage pond is located about 3/4 mile southeast of the landfill and is used as irrigation water for surrounding agricultural land.

Glacial aquifers within a two-mile radius of the landfill are the Valley City aquifer and isolated sand layers in the till. The Valley City aquifer is located two-miles northeast of the landfill and does not appear to be affected by the leachate migration from the landfill. There were no isolated sand aquifers encountered at the landfill.

The principal aquifer in the landfill study area is the Pierre Formation. The aquifer material was described as a green-gray to a blue-green clay. This aquifer is located about 110 feet below land surface at the eastern boundary of the landfill and 20 to 30 feet below land surface within the ravine. Ground-water flow in this aquifer is to the west until it reaches the ravine where it flows to the north.

The Pierre Formation in the landfill study area is characterized by a sodium-chloride type water. Water quality analyses indicated high concentrations of sodium, chloride, sulfate, and total dissolved solids in all wells. These concentrations are not unusual for water within the Pierre Formation. The elevated nitrate concentrations may be from the application of sewage water on irrigated agricultural land. The cause of the increased pH at four wells was not determined from this study. Trace element analyses indicated high concentrations of strontium in all wells. This concentration does not appear to be due to leachate migration from the landfill. There was no VOC sample collected for this site. The water quality analysis did not detect any leachate migration based on the major ion and trace element analyses.

The main disadvantage of the Valley City landfill site is its location on the slope of the ravine. Steep slopes in the Pierre Formation tend to be unstable, and the construction of the landfill cells have increased the degree of slope toward the stream. This could increase the potential for slumping and erosion at the site.

In the fall of 1992 the city of Valley City excavated a closure cover on the landfill. The ephemeral stream was also relocated about 500 to 1000 feet to the west of the original stream bed. The sides of the stream bed were terraced to reduce the effects of erosion and slumping.

REFERENCES

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

Kelly, T.E., 1966, Geology and ground water resources, Barnes County, North Dakota, part III, ground water resources: North Dakota Geological Survey, Bulletin 43, North Dakota State Water Commission, County Ground Water Studies 4, 67 p.

Kelly, T.E., and Block, D.A., 1967, Geology and Ground Water Resources, Barnes County, North Dakota, Part I, Geology: North Dakota Geological Survey, Bulletin 43, North Dakota State Water Commission, County Ground Water Studies 4, 51 p.

Midwest Testing, 1983, Report of soil investigation, proposed land disposal site Valley City, North Dakota, Project No. J457, 12 p.

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

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

LITHOLOGIC LOGS
OF WELLS AND TEST HOLES

140-058-31ABA1

NDSWC

Date Completed:	8/6/92	Well Type:	P2
Depth Drilled (ft):	120	Source of Data:	
Screened Interval (ft):	110-120	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1392.83
Owner: Valley City			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
TILL	CLAY, DUSKY YELLOW, OXIDIZED	1-2
TILL	GRAVELLEY CLAY, OLIVE, OXIDIZED	2-12
TILL	CLAY, DARK OLIVE GRAY, OXIDIZED	12-28
SHALE	MEDIUM GRAY, BEDROCK, (PIERRE FM.)	28-45
CLAY	BENTONITIC, WHITE	45-46
CLAY	MEDIUM GRAY	46-74
CLAY	LIGHT GREEN-GRAY, STIFF	74-81
CLAY	MEDIUM GREEN-GRAY, SOFT	81-120

140-058-31ABA2

NDSWC

Date Completed:	8/6/92	Well Type:	P2
Depth Drilled (ft):	70	Source of Data:	
Screened Interval (ft):	58-68	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1362.86
Owner: Valley City			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	WITH GRAVEL	0-7
TILL	CLAY WITH GRAVEL, OXIDIZED, YELLOW-BROWN	7-10
ROCKS		10-13
TILL	CLAY WITH GRAVEL, OXIDIZED, YELLOW-BROWN	13-17
CLAY	BROWN-RED, OXIDIZED	17-21
SHALE	MEDIUM GRAY, BEDROCK, (PIERRE FM.)	21-41
CLAY	BENTONITIC	41-43
CLAY	MEDIUM GREEN-GRAY, STIFF	43-52
CLAY	LIGHT GREEN-GRAY, SOFT	52-70

140-058-31ABB1

NDSWC

Date Completed:	8/5/92	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)	1319.45
Owner: Valley City			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-4
CLAY	OLIVE BROWN, STIFF	4-10
CLAY	BLUE-GRAY, STIFF	10-11
CLAY	LIGHT BLUE-GRAY, BEDROCK, (PIERRE FM.)	11-40

140-058-31ABB2
NDSWC

Date Completed:	8/6/92	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)	1322.65

Owner: Valley City

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	OXIDIZED, CLAY, YELLOW-BROWN	2-5
CLAY	OXIDIZED, YELLOW-BROWN, STIFF, BEDROCK, (PIERRE FM.)	5-8
CLAY	UNOXIDIZED, DARK GRAY, STIFF	8-15
CLAY	LIGHT BLUE-GRAY, STIFF	15-19
CLAY	LIGHT BLUE-GRAY, SOFT	19-40

140-058-31ABB3

NDSWC

Date Completed:	8/6/92	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)	1321.27
Owner: Valley City			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-3
CLAY	OXIDIZED, DUSKY BROWN, BEDROCK, (PIERRE FM.)	3-6
CLAY	LIGHT GRAY	6-11
CLAY	MEDIUM BLUE-GRAY, UNOXIDIZED, STIFF	11-13
CLAY	LIGHT BLUE-GRAY, STIFF	13-33
CLAY	LIGHT BLUE-GREEN, SOFT	33-40

140-058-31ABC1
NDSWC

Date Completed:	8/6/92	Well Type:	P2
Depth Drilled (ft):	110	Source of Data:	
Screened Interval (ft):	98-108	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1396.16
Owner: Valley City			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	OXIDIZED, YELLOW-BROWN	1-4
CLAY	SANDY, OXIDIZED, YELLOW-RED, TILL	4-22
CLAY	SANDY, UNOXIDIZED, LIGHT GRAY	22-26
GRAVEL	MEDIUM	26-29
TILL	CLAY, LIGHT GRAY	29-35
SHALE	MEDIUM GRAY, HARD, (PIERRE FM.)	35-48
CLAY	BENTONITIC	48-49
SHALE	MEDIUM GRAY, BEDROCK STIFF	49-82
CLAY	MEDIUM GREEN-GRAY	82-88
CLAY	LIGHT GREEN-GRAY	88-110

140-058-31ABC2

NDSWC

Date Completed:	8/6/92	Well Type:	P2
Depth Drilled (ft):	50	Source of Data:	
Screened Interval (ft):	38-48	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1347.56
Owner: Valley City			

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-4
TILL	CLAY, OXIDIZED, DUSTY BROWN, MIXED SAND	4-29
SHALE	DARK GRAY, BEDROCK, (PIERRE FM.)	29-33
CLAY	MEDIUM GREEN-GRAY, HARD	33-35
CLAY	LIGHT GREEN-GRAY, SOFT, WEATHERED SHALE	35-50

APPENDIX C

WATER-LEVEL TABLES

Valley City Water Levels
8/14/92 to 9/21/92

140-058-31ABA1 LS Elev (msl,ft)=1392.83
Undefined Aquifer SI (ft.)=110-120

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/18/92	114.18	1278.65	09/15/92	109.48	1283.35
08/19/92	116.94	1275.89	09/21/92	111.41	1281.42

140-058-31ABA2 LS Elev (msl,ft)=1362.86
Undefined Aquifer SI (ft.)=58-68

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/14/92	38.08	1324.78	09/21/92	35.79	1327.07
09/15/92	35.30	1327.56			

140-058-31ABB1 LS Elev (msl,ft)=1319.45
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/17/92	25.99	1293.46	09/15/92	18.54	1300.91
08/19/92	34.36	1285.09	09/21/92	16.54	1302.91

140-058-31ABB2 LS Elev (msl,ft)=1322.65
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/17/92	26.75	1295.90	09/15/92	12.45	1310.20
08/19/92	33.62	1289.03	09/21/92	21.21	1301.44

140-058-31ABB3 LS Elev (msl,ft)=1321.27
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/17/92	34.77	1286.50	09/15/92	35.44	1285.83
08/19/92	38.22	1283.05	09/21/92	37.57	1283.70

140-058-31ABC1 LS Elev (msl,ft)=1396.16
Undefined Aquifer SI (ft.)=98-108

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/18/92	64.73	1331.43	09/21/92	44.30	1351.86
09/15/92	46.18	1349.98			

140-058-31ABC2 LS Elev (msl,ft)=1347.56

Undefined Aquifer SI (ft.)=38-48

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/17/92	11.84	1335.72	09/16/92	9.25	1338.31
08/19/92	19.35	1328.21	09/21/92	8.73	1338.83

APPENDIX D

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Valley City Municipal Landfill

Major Ions

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
			(milligrams per liter)																					
140-058-31ABA1	110-120	09/15/92	12	0.04	0.55	85	30	2100	45	268	0	410	3200	0.6	31	2.1	6050	340	120	92	50	10100	12	8.87
140-058-31ABA2	58-68	08/19/92	14	0.04	0.22	70	30	2300	32	369	0	49	3600	0.4	0.6	3.2	6280	300	0	94	58	10720	10	8.49
140-058-31ABB1	30-40	08/19/92	7.3	0.17	0.17	75	35	2500	34	485	0	140	3900	0.7	34	3.7	6970	330	0	94	60	11550	19	8.32
140-058-31ABB2	30-40	09/15/92	5.6	0.03	0.02	30	10	1300	38	295	54	82	1900	0.6	17	2.6	3580	120	0	95	52	6360	14	9.22
140-058-31ABB3	30-40	09/15/92	7.2	0.18	0.95	70	20	1700	23	393	0	370	2200	0.8	20	2.2	4610	260	0	93	46	7570	12	7.71
140-058-31ABC1	98-108	08/18/92	32	0.05	0.02	65	20	2200	57	164	0	230	3200	0.5	0.3	2.4	5890	240	110	94	62	9750	14	9.46
140-058-31ABC2	38-48	08/19/92	10	1.1	0.44	50	15	1600	19	643	0	120	2200	0.5	19	3.6	4360	190	-0	94	50	7350	15	8.38

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
140-058-31ABA1	9/15/92	5	1	0	0.1	16	240	1900
140-058-31ABA2	8/19/92	0	1	0	0.1	4	1	1700
140-058-31ABB1	8/19/92	0	2	0	0.1	1	14	1900
140-058-31ABB2	9/15/92	5	0	0	0.1	8	60	700
140-058-31ABB3	9/15/92	5	0	0	0.1	7	30	1100
140-058-31ABC1	8/18/92	9	1	0	0	9	401	1400
140-058-31ABC2	8/19/92	0	1	0	0	3	9	950