# Site Suitability Review of the Halliday Municipal Landfill

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Prepared by the
North Dakota Geological Survey
and the
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**ND Landfill Site Investigation No. 31**

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Bismarck, North Dakota
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# INTRODUCTION

## Purpose

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

## Location of the Halliday Municipal Landfill

The Halliday solid waste landfill is located about one-quarter mile south of the City of Halliday in Township 145 North, Range 92 West, S 1/2 Section 25 (Fig. 1). The active area of the landfill encompasses approximately 10 acres.

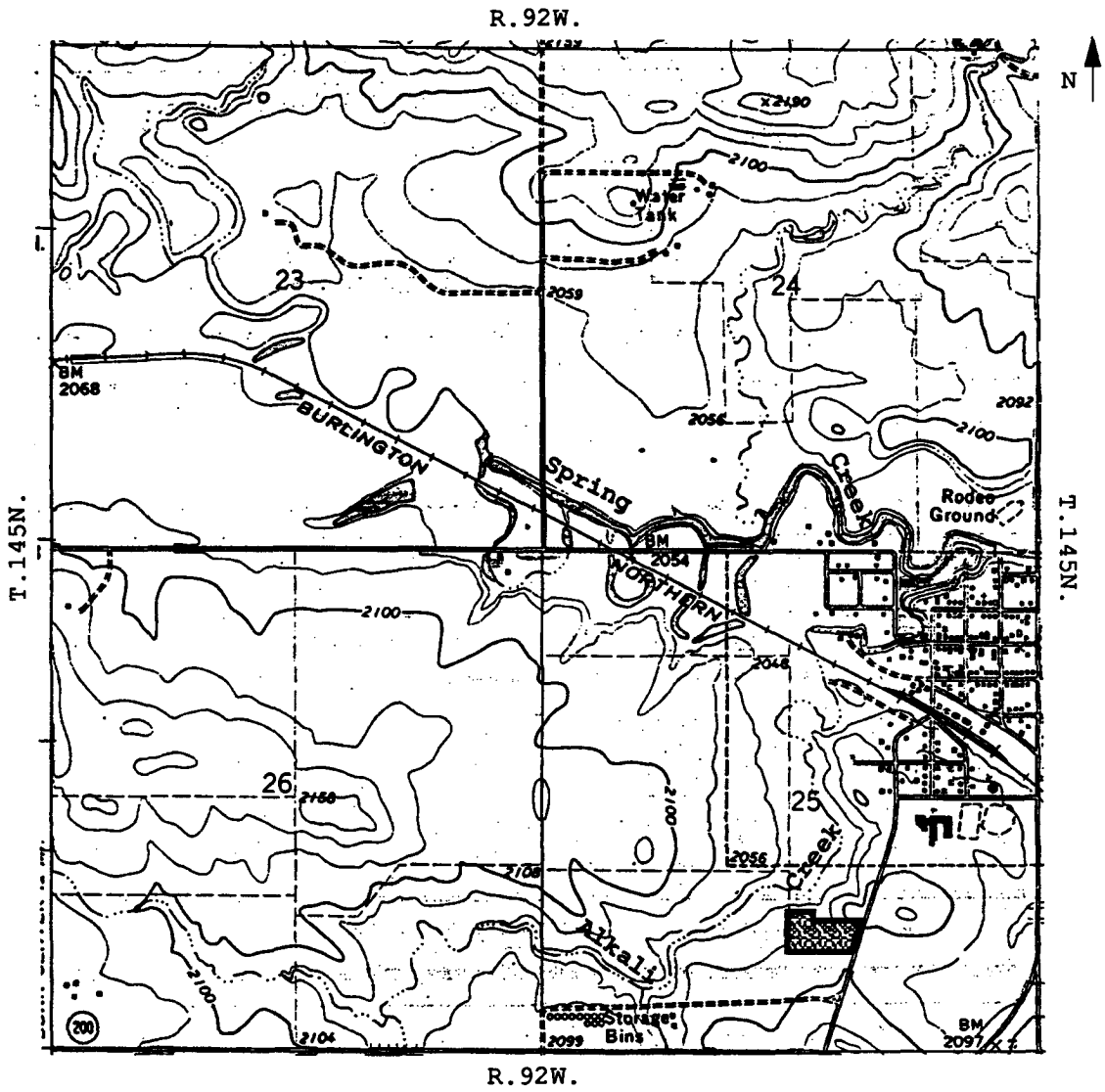


Figure 1. Location of the Halliday municipal landfill in the SE 1/4,section 25, T.145N., R.92W.

## Previous Site Investigations

Midwest Testing, Inc. drilled a 50-foot soil boring at the landfill in 1984. The boring log shows a layer of sand at the surface underlain by clay and lignite.

## Methods of Investigation

The Halliday municipal landfill study was accomplished by means of: 1) drilling test holes; 2) constructing and developing 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 was based on the site's geology and depth to ground water, as determined by the preliminary site evaluation. A forward rotary rig was used at the Halliday landfill because the depth to the water table was expected to be more than 70 feet. The lithologic descriptions were determined from the drill cuttings. The water used with the rig was obtained from municipal water supplies.

## Monitoring Well Construction and Development

Four test holes were drilled at the Halliday landfill, and monitoring wells were installed in each test hole. The number of wells installed at the landfill was based on the geologic and topographic characteristics of the site. The wells were screened to monitor the top of the uppermost aquifer. The test holes were located around the perimeter 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

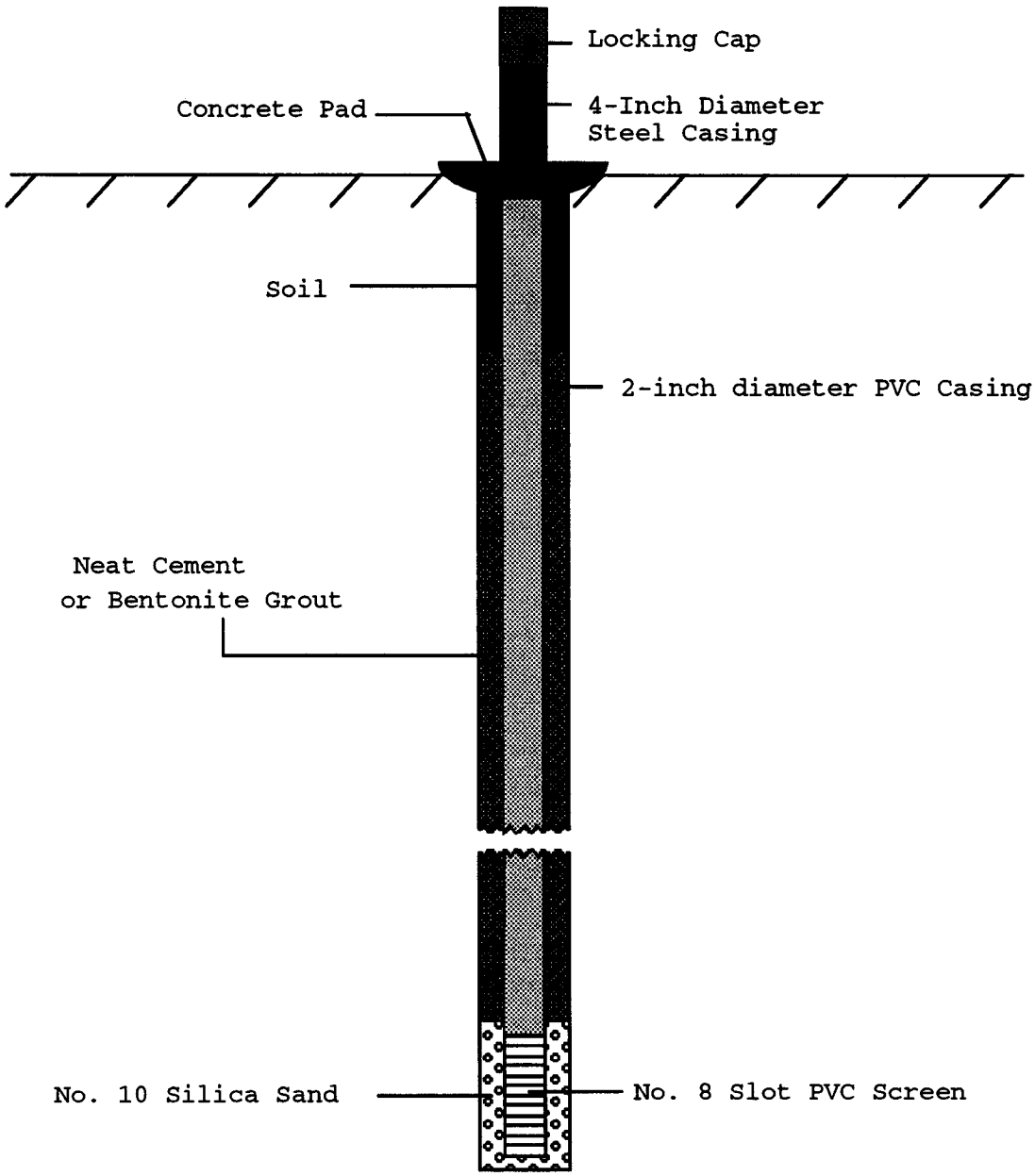


Figure 2. Construction design used for monitoring wells installed at the Halliday landfill.

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 enforcable drinking water standards that represent the maximum permissible level of a contaminant as stipulated by the U.S. Environmental Protection Agency (EPA).

Water samples were collected using a bladder pump constructed of stainless steel with a teflon bladder. A teflon bailer was used in monitoring wells with limited transmitting capacity. Before sample collection, three to

four well volumes were extracted to insure that unadulterated formation water was sampled. Four samples from each well were collected in high density polyethylene plastic bottles as follows:

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

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

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

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

## Water-Level Measurements

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

## Well-Abandonment Procedure

The test holes and monitoring wells that were not permanent were abandoned according to NDSDHCL and Board of Water Well Contractors regulations (North Dakota Department of Health, 1986). The soil around the well was dug to a depth of approximately three to four feet below land surface (Fig. 3) to prevent disturbance of the sealed wells. The screened interval of the well was plugged with bentonite chips to a height of approximately one foot above the top of the screen and the remaining well casing was filled with neat cement. The upper three to four feet was then filled with cuttings and the disturbed area was blended into the surrounding land surface. Test holes were plugged with high-solids bentonite grout and/or neat cement to a depth approximately five feet below land surface. The upper five feet of the test hole was filled with soil cuttings.

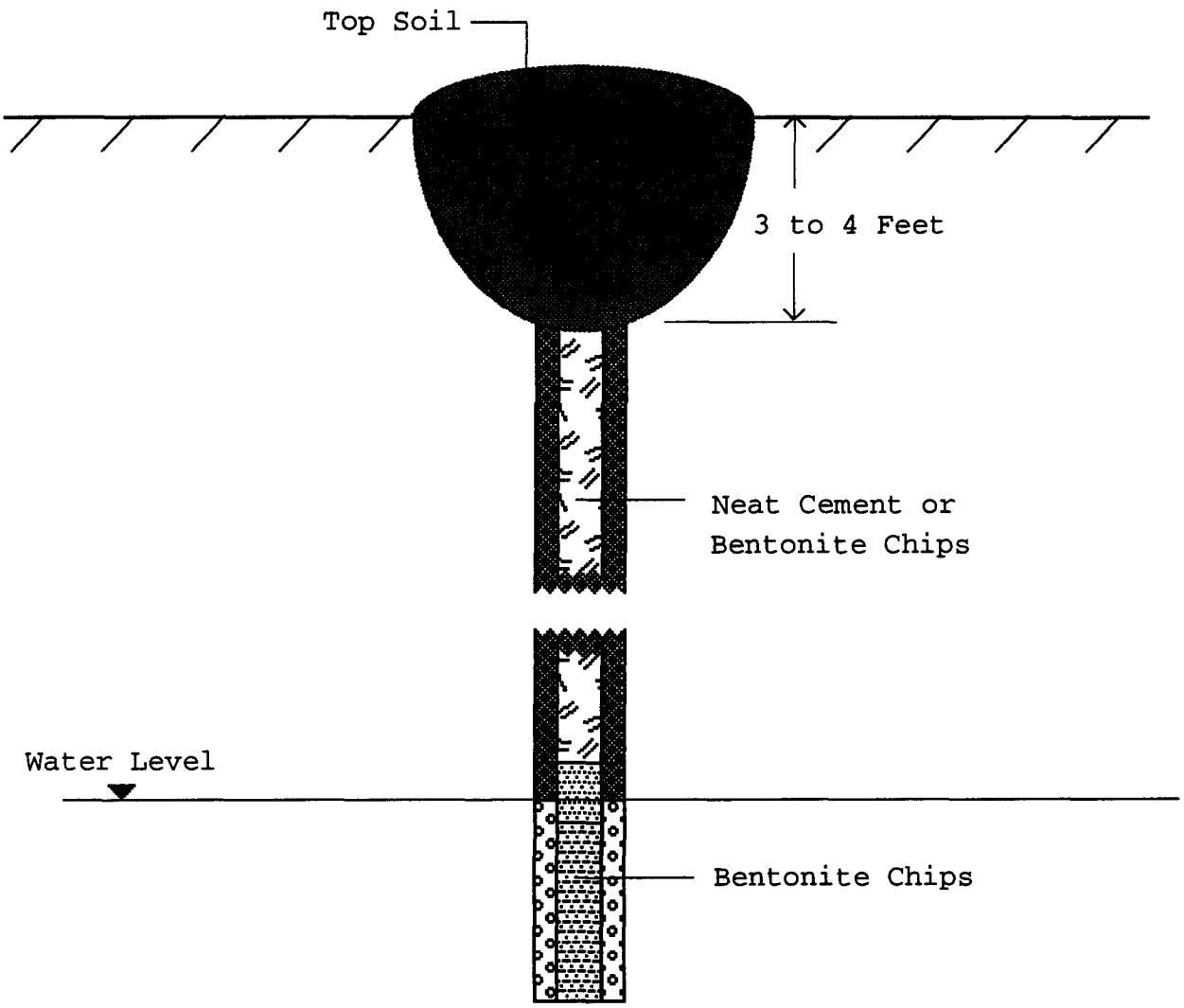


Figure 3. Monitoring well abandonment procedures.

## 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 145-092-25DBC would be located in the SW1/4, NW1/4, SE1/4, Section 25, Township 145 North, Range 92 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 145-092-25DBC1 and 145-092-25DBC2.

# GEOLOGY

The Halliday landfill is situated in an area of eroded bedrock of the Sentinel Butte Formation (Paleocene). This formation was deposited in a deltaic environment and is composed of interbedded clay, shale, sand, sandstone, and lignite. Scattered deposits of till are present at higher elevations; the nearest of these is about one-half mile south

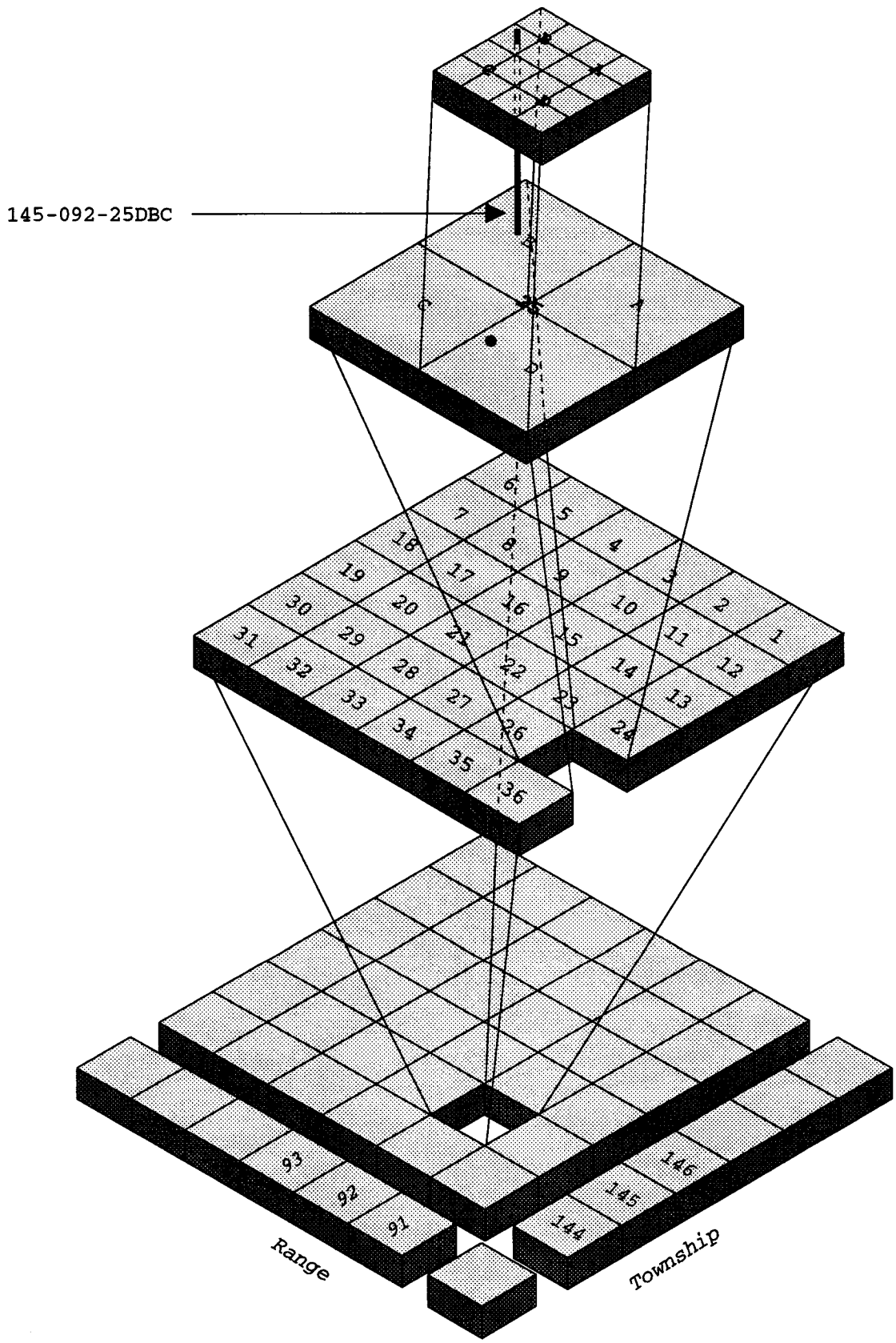


Figure 4. Location-numbering system for the Halliday landfill.

of the landfill (Murphy, 1994). Alluvium occurs in the valley of Spring Creek about three-fourths mile northeast of the landfill.

The landfill is located on the west slope of a hill (Fig. 5). Test holes drilled around the perimeter of the landfill for this study encountered clay, sand, and lignite (lithologic logs are shown in Appendix C). Clay and silty clay make up well over half of the samples retrieved during drilling. A ten-foot-thick lignite bed occurs at depths ranging from about 30 to 50 feet (Fig. 6).

Two sand units were observed at the landfill. A relatively thin sand occurs at the surface on the west end of the site (test hole 145-092-25CAD). This sand was encountered at depths of 12 to 16 feet in test holes 145-092-25DBC and DCB. The sand was absent in the fourth test hole. A second sand occurs at depths ranging from 40 to 60 feet. All four test holes bottomed in the lower sand.

Drilling logs from domestic water wells in and near the City of Halliday indicate that the Sentinel Butte Formation in that area is composed of hard shale, clay, sand, and lignite (Klausing, 1976). These wells are screened in fractured lignite or sand at depths of 40 to 100 feet (corresponding to elevations of approximately 1,940 to 2,000 feet).

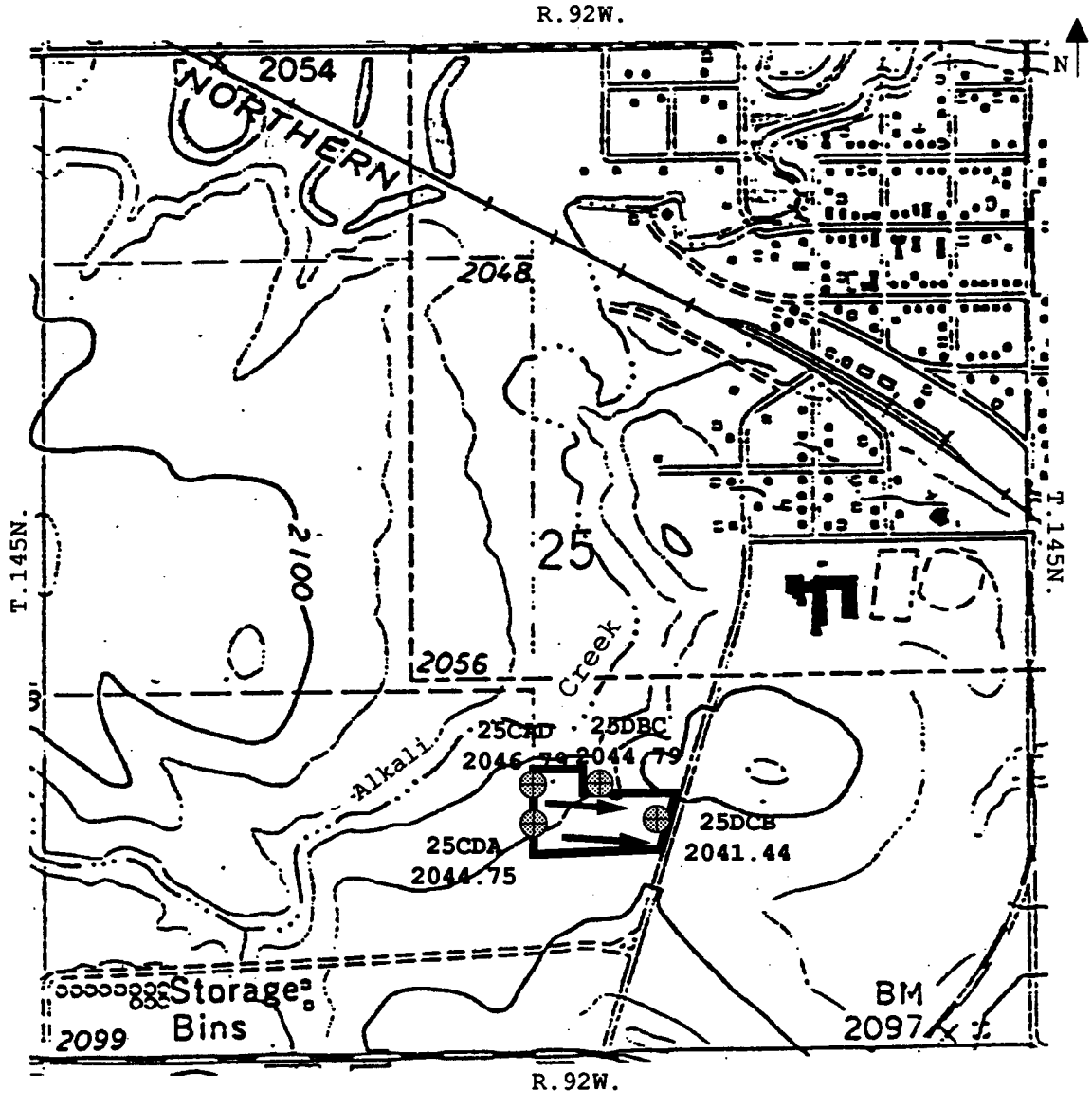


Figure 5. Location of monitoring wells at the Halliday municipal landfill.

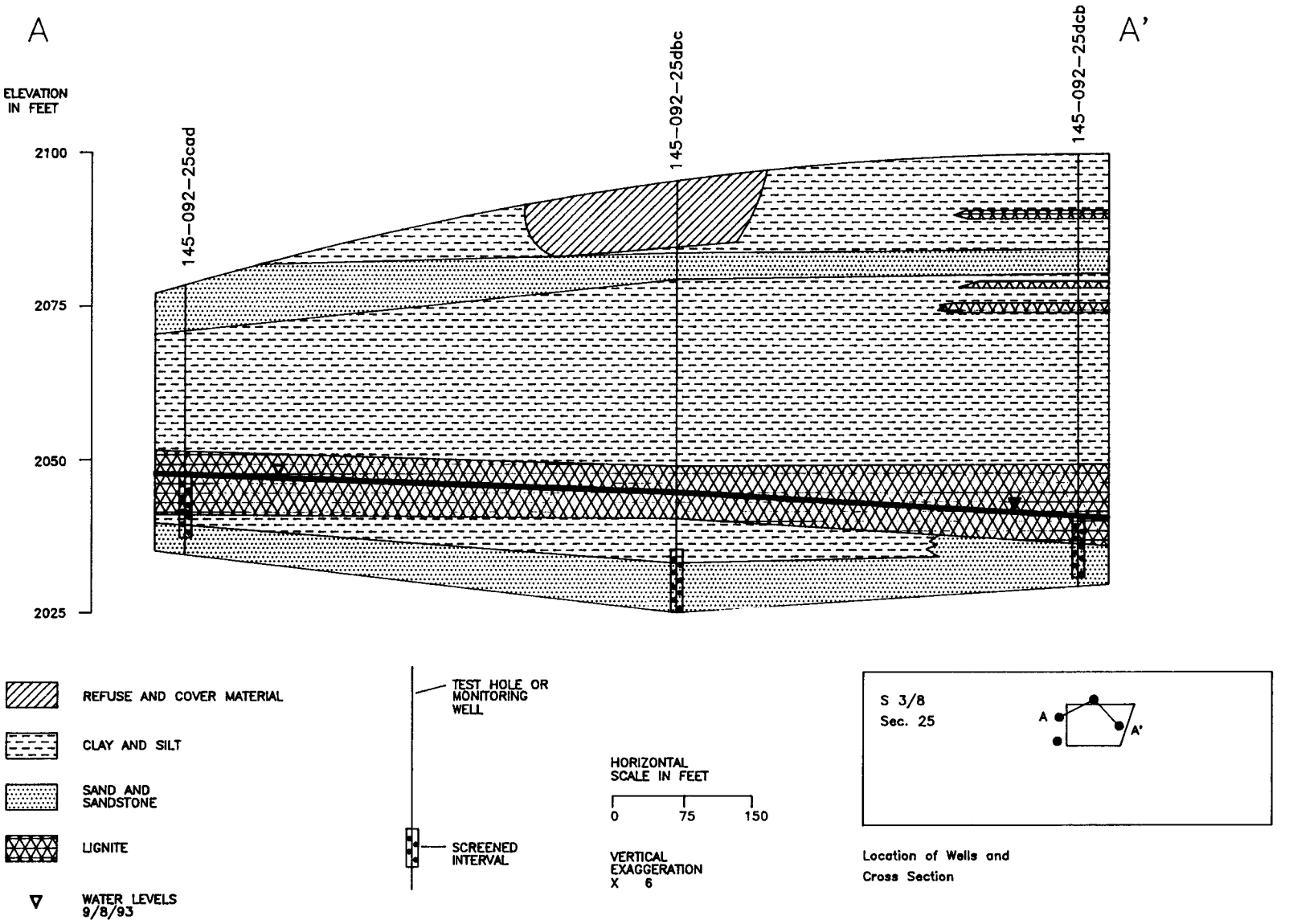


Figure 6. Geohydrologic section A–A' in the Halliday landfill.

# HYDROLOGY

## Surface-Water Hydrology

Two creeks are located within a one-mile radius of the Halliday landfill. Spring Creek is located about three-quarters of a mile north and east of the site (Fig. 1). This creek flows through the City of Halliday to the east-southeast. Spring Creek is a regional discharge zone for the local surface and ground-water systems. Spring Creek should not be affected by contaminant migration from the landfill due to its distance from the landfill.

Alkali Creek is located about 1000 feet west of the landfill site. This is an intermittent stream that flows only during spring snow melt periods or during periods of heavy precipitation. Alkali Creek flows to the north and discharges into Spring Creek at the north end of the City of Halliday. Local surface runoff from the landfill flows towards Alkali Creek  Alkali Creek may be receive contaminants from surface-water runoff at the landfill.

## Regional Ground-Water Hydrology

Regional aquifers near the Halliday landfill occur within the Fox Hills, Hell Creek, Bullion Creek, Cannonball-Ludlow, and Sentinel Butte Formations. The Fox Hills aquifer occurs at a depth of about 1,500 feet and is comprised of fine-grained sandstone. Recharge is by infiltration into

outcrop areas and lateral flow from adjacent aquifers (Klausing, 1979). The Fox Hills aquifer is characterized by a sodium-bicarbonate type water (Klausing, 1979). The City of Halliday obtains its water supply from this aquifer.

The Hell Creek Formation overlies the Fox Hills aquifer and is comprised of fine-grained sandstone beds at a depth of about 1,200 feet (Klausing, 1979). Recharge is by infiltration into outcrop areas. The Hell Creek aquifer is characterized by a sodium-bicarbonate type water.

Undifferentiated aquifers occur in the Cannonball-Ludlow Formations and overlie the Hell Creek aquifer (Klausing, 1979). The undifferentiated Cannonball-Ludlow aquifers are comprised of sandstone and lignite beds at depths ranging from 570 to 1,130 feet. Recharge to the upper portion of the formation is by leakage from the overlying Bullion Creek aquifer and recharge to the lower portion of the aquifer is by infiltration into outcrop areas. The Cannonball-Ludlow aquifer is characterized by a sodium-bicarbonate type water (Klausing, 1979).

The Bullion Creek Formation overlies the Cannonball-Ludlow aquifer and is comprised of very fine to fine-grained sandstone and lignite beds at a depth of about 500 feet (Klausing, 1979). Recharge is by leakage from the overlying Sentinel Butte Formation (Klausing, 1979). The Bullion Creek aquifer is characterized by a sodium-bicarbonate type water.

The Sentinel Butte aquifer is comprised of unconsolidated sandstone and fractured lignite and is the

uppermost aquifer in the vicinity of the landfill (Klausing, 1979). This aquifer is the main source of domestic water supply for the region around the landfill. Recharge is by infiltration of precipitation (Klausing, 1979). The Sentinel Butte aquifer is characterized by a sodium-bicarbonate type water.

The regional aquifers, except the Sentinel Butte aquifer, should not be affected by contaminant migration from the landfill because of large depths and intervening low hydraulic conductivity clay layers.

There are no major glacial aquifers within a three-mile radius of the landfill. It is not known if any undifferentiated glacial aquifers exist within a three-mile radius.

## Local Ground-Water Hydrology

Four monitoring wells were installed at the Halliday landfill. Five water-level measurements were taken over about an eight-week period (Appendix D). All four well screens intersected a lignite bed in the Sentinel Butte aquifer within the landfill boundaries (Fig. 5). The uppermost ground water beneath the landfill occurs at depths of about 30 feet in a lignite bed and underlying sand layer. A layer of buried refuse was penetrated during the drilling process at well 25DBC (Fig. 6). The water-level measurements

indicate the direction of the local ground-water flow is to the east towards Spring Creek (Fig. 6).

## Water Quality

Chemical analyses of water samples are shown in Appendix E. Locally, the Sentinel Butte aquifer is characterized by a sodium-sulfate type water. The major ion and trace element analyses are typical of the Sentinel Butte aquifer in the study area.

The results of the VOC analysis, from well 145-092-25CAD, are shown in Appendix F. The analysis did not detect any VOC compounds.

# CONCLUSIONS

The Halliday landfill is located on the west slope of a hill about one-quarter mile south of the City of Halliday. The site is directly underlain by the Sentinel Butte Formation, consisting of clay with interbedded sand and lignite. The uppermost ground water beneath the landfill occurs at a depth of about 30 feet in a lignite bed and underlying sand layer. A layer of clay, about 20 feet thick, occurs between the buried refuse and the uppermost lignite/sand aquifer. The local ground-water flow direction in the uppermost Sentinel Butte aquifer is eastward.

A number of domestic wells in and near Halliday obtain water from aquifers in the Sentinel Butte Formation. These wells are completed in fractured lignite or sand beds. The wells are unlikely to be affected by the landfill because of the intervening layers of clay which have a low hydraulic conductivity.

The City of Halliday obtains its water from the Fox Hills Formation at a depth of about 1,500 feet. This well should not be affected by contaminant migration from the landfill.

Chemical analyses of water samples from the landfill study area indicates that the uppermost Sentinel Butte aquifer is characterized by a sodium-sulfate type water. Major ion and trace element concentrations are within the expected range for ground water in the Sentinel Butte Formation. No volatile organic compounds were detected in the VOC analysis from well 145-092-25CAD.

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Klausing, R.L., 1976, Ground-water basic data for Dunn County, North Dakota: North Dakota Geological Survey, Bulletin 68, North Dakota State Water Commission, County Ground-Water Studies 25, Part II, 501 p.

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# APPENDIX A

## WATER QUALITY STANDARDS
## AND
## CONTAMINANT LEVELS

## Water Quality Standards and Contaminant Levels

**Field Parameters**

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

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

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

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

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

# APPENDIX B

## SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

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

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

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

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

convex meniscus

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

6. Screw 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

**145-092-25CAD**
NDSWC

| | | | |
|---|---|---|---|
| Date Completed: | 8/9/93 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2078.17 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 48 | Aquifer: | UND |
| Screened Interval (ft): | 35-45 | Source: | |
| | | Owner: | HALLIDAY LANDFILL |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| SAND | YELLOWISH-BROWN, FINE TO MEDIUM GRAIN, BEDROCK | 1-7 |
| CLAY | YELLOWISH-BROWN | 7-15 |
| CLAY | SILTY, MEDIUM GRAY WITH YELLOWISH-ORANGE MOTTLES | 15-20 |
| CLAY | SILTY, MEDIUM GRAY WITH YELLOWISH-ORANGE MOTTLES | 20.5-25 |
| CLAY | BROWNISH | 25-26 |
| LIGNITE | | 26-31 |
| CLAY | MEDIUM GRAY | 31-32 |
| LIGNITE | | 32-37 |
| CLAY | MEDIUM GRAY | 37-39 |
| SAND | FINE GRAIN, BLUEISH-GRAY, SILTY | 39-53 |
| SANDSTONE | FINE GRAIN, (6 INCHES THICK) | 20-20.5 |

**145-092-25CDA**
NDSWC

| | | | |
|---|---|---|---|
| Date Completed: | 8/9/93 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2086.01 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 58 | Aquifer: | UND |
| Screened Interval (ft): | 40-50 | Source: | |
| | | Owner: | HALLIDAY LANDFILL |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | YELOWISH-BROWN, SILTY, BEDROCK | 1-23 |
| CLAY | YELLOWISH-GRAY, STIFF | 23-33 |
| CLAY | BROWNISH | 33-34 |
| LIGNITE | | 34-39 |
| CLAY | BROWNISH-GRAY | 39-40 |
| LIGNITE | | 40-45 |
| CLAY | GRAYISH-GREEN | 45-48 |
| SAND | CLAYEY, SILTY, BLUEISH-GRAY | 48-49 |
| CLAY | MEDIUM GRAY | 49-51 |
| SAND | SILTY, CLAYEY, BLUEISH-GRAY | 51-58 |

**145-092-25DBC**
NDSWC

| | | | |
|---|---|---|---|
| Date Completed: | 8/9/93 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2094.97 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 68 | Aquifer: | UND |
| Screened Interval (ft): | 57-67 | Source: | |
| | | Owner: | HALLIDAY LANDFILL |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | YELLOWISH-BROWN, TILL | 1-7 |
| CLAY | BLACK, REFUSE | 7-12 |
| SAND | SILTY, VERY FINE GRAIN, YELLOWISH-BROWN | 12-16 |
| CLAY | SANDY, SILTY, BLACKISH | 16-18 |
| CLAY | SILTY, YELLOWISH-ORANGE | 18-24 |
| CLAY | VERY FINE SAND, SILTY, YELLOWISH-ORANGE | 24-40 |
| CLAY | MEDIUM GRAY, BEDROCK | 40-46 |
| CLAY | BROWNISH | 46-47 |
| LIGNITE | | 47-50 |
| CLAY | BROWNISH | 50-51 |
| LIGNITE | | 51-56 |
| CLAY | MEDIUM-GRAY | 56-62 |

| | | |
|---|---|---|
| SAND | SILTY, BLUEISH-GRAY | 62-67 |
| CLAY | MEDIUM GRAY | 67-68 |
| SANDSTONE | FINE GRAIN, INDURATED, TD | 68-68 |

**145-092-25DCB**
NDSWC

| | | | |
|---|---|---|---|
| Date Completed: | 8/9/93 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2099.16 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 70 | Aquifer: | UND |
| Screened Interval (ft): | 58-68 | Source: | |
| | | Owner: | HALLIDAY LANDFILL |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | SILTY, YELLOWISH-GREEN, BEDROCK | 1-10 |
| LIGNITE | SOFT | 10-11 |
| CLAY | SILTY, YELLOWISH-GREEN, BEDROCK | 11-12 |
| CLAY | SILTY, MEDIUM GRAY | 12-16 |
| SAND | FINE GRAIN, YELLOWISH-ORANGE MOTTLES, OLIVE-GREEN | 16-18 |
| CLAY | OLIVE GREEN | 18-21 |
| LIGNITE | | 21-22 |
| CLAY | OLIVE GREEN | 22-26 |
| SANDSTONE | INDURATED, FINE GRAIN, LIGHT GRAY | 26-27 |
| CLAY | MEDIUM GRAY | 27-30 |
| CLAY | VERY FINE SAND, SILT, YELLOWISH-GRAY | 30-44 |
| CLAY | MEDIUM GRAY, STIFF | 44-49 |

| | | |
|---|---|---|
| CLAY | LIGHT GRAY, STIFF | 49-51 |
| LIGNITE | | 51-55 |
| CLAY | MEDIUM GRAY | 55-56 |
| LIGNITE | | 56-62 |
| SAND | SILTY, BLUEISH, FINE GRAIN | 62-70 |

# APPENDIX D

# WATER-LEVEL TABLES

# Halliday Landfill Water Levels
# 8/11/93 to 9/21/93

**145-092-25DCB** LS Elev (msl,ft)=2099.16
UND Aquifer SI (ft.)=58-68

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 08/11/93 | 50.77 | 2048.39 | 08/28/93 | 57.72 | 2041.44 |
| 08/12/93 | 58.08 | 2041.08 | 09/08/93 | 57.62 | 2041.54 |
| 08/19/93 | 57.79 | 2041.37 | | | |

**145-092-25DBC** LS Elev (msl,ft)=2094.97
UND Aquifer SI (ft.)=57-67

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 08/12/93 | 48.16 | 2046.81 | 09/08/93 | 50.18 | 2044.79 |
| 08/19/93 | 50.32 | 2044.65 | 09/21/93 | 50.08 | 2044.89 |
| 08/28/93 | 50.23 | 2044.74 | | | |

**145-092-25CDA** LS Elev (msl,ft)=2086.01
UND Aquifer SI (ft.)=40-50

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 08/12/93 | 40.70 | 2045.31 | 09/08/93 | 41.26 | 2044.75 |
| 08/19/93 | 41.29 | 2044.72 | 09/21/93 | 41.21 | 2044.80 |
| 08/28/93 | 41.28 | 2044.73 | | | |

**145-092-25CAD** LS Elev (msl,ft)=2078.17
UND Aquifer SI (ft.)=35-45

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 08/12/93 | 30.84 | 2047.33 | 09/08/93 | 31.38 | 2046.79 |
| 08/19/93 | 31.40 | 2046.77 | 09/21/93 | 31.38 | 2046.79 |
| 08/28/93 | 31.40 | 2046.77 | | | |

# APPENDIX E

## MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

# Halliday Municipal Landfill Water Quality
## Major Ions

| Location | Screened Interval (ft) | Date Sampled | $SiO_2$ | Fe | Mn | Ca | Mg | Na | K | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | $NO_3$ | B | TDS | Hardness $CaCO_3$ | as NCH | % Na | SAR | Spec Cond (µmho) | Temp (∞C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ←(milligrams per liter)→ | | | | | | | | | | | | | | | | | | | | | |
| 145-092-25CAD | 35-45 | 08/28/93 | 28 | 3.5 | 1.2 | 170 | 90 | 630 | 13 | 462 | 0 | 1800 | 13 | 0.2 | 11 | 0.76 | 2990 | 790 | 420 | 63 | 9.8 | 3670 | 9 | 6.17 |
| 145-092-25CDA | 40-50 | 08/28/93 | 16 | 1.7 | 0.92 | 400 | 350 | 620 | 24 | 634 | 0 | 3300 | 18 | 0.2 | 22 | 0.59 | 5070 | 2400 | 1900 | 35 | 5.5 | 5130 | 9 | 6.23 |
| 145-092-25DBC | 57-67 | 08/28/93 | 13 | 0.14 | 1.3 | 260 | 160 | 710 | 24 | 621 | 0 | 2200 | 20 | 0.3 | 0.4 | 0.51 | 3700 | 1300 | 800 | 54 | 8.6 | 4280 | 9 | 6.53 |
| 145-092-25DCB | 58-68 | 08/28/93 | 9.7 | 0.14 | 1.1 | 110 | 83 | 870 | 22 | 1150 | 0 | 1700 | 11 | 0.4 | 0.1 | 0.37 | 3370 | 620 | 0 | 75 | 15 | 4220 | 9 | 6.92 |

## Trace Element Analyses

| Location | Date Sampled | Selenium | Lead | Cadmium | Mercury | Arsenic | Molybdenum | Strontium |
|---|---|---|---|---|---|---|---|---|
| | | (micrograms per liter) | | | | | | |
| 145-092-25CAD | 8/28/93 | 0 | 0 | 0 | 0 | 9 | 0 | 3400 |
| 145-092-25CDA | 8/28/93 | 2 | 0 | 0 | 0 | 0 | 0 | 8100 |
| 145-092-25DBC | 8/28/93 | 0 | 0 | 0 | 0 | 2 | 1 | 5500 |
| 145-092-25DCB | 8/28/93 | 0 | 0 | 1 | 0 | 0 | 8 | 3900 |

# APPENDIX F

## VOLATILE ORGANIC COMPOUNDS FOR WELL 145-092-25CAD

Volatile Organic Compounds
and
Minimum Concentrations

Concentrations are based only on detection limits. Anything over the detection limit indicates possible contamination.

| Constituent | Chemical Analysis µg/L |
|---|---|
| Benzene | <2 |
| Vinyl Chloride | <1 |
| Carbon Tetrachloride | <2 |
| 1,2-Dichlorethane | <2 |
| Trichloroethylene | <2 |
| 1,1-Dichloroethylene | <2 |
| 1,1,1-Trichloroethane | <2 |
| para-Dichlorobenzene | <2 |
| Acetone | <50 |
| 2-Butanone (MEK) | <50 |
| 2-Hexanone | <50 |
| 4-Methyl-2-pentanone | <50 |
| Chloroform | <5 |
| Bromodichloromethane | <5 |
| Chlorodibromomethane | <5 |
| Bromoform | <5 |
| trans1,2-Dichloroethylene | <2 |
| Chlorobenzene | <2 |
| m-Dichlorobenzene | <5 |
| Dichloromethane | <5 |
| cis-1,2-Dichloroethylene | <2 |
| o-Dichlorobenzene | <2 |
| Dibromomethane | <5 |
| 1,1-Dichloropropene | <5 |
| Tetrachlorethylene | <2 |
| Toluene | <2 |
| Xylene(s) | <2 |
| 1,1-Dichloroethane | <5 |
| 1,2-Dichloropropane | <2 |
| 1,1,2,2-Tetrachloroethane | <5 |
| Ethyl Benzene | <2 |
| 1,3-Dichloropropane | <5 |
| Styrene | <2 |
| Chloromethane | <5 |
| Bromomethane | <5 |
| 1,2,3-Trichloropropane | <5 |
| 1,1,1,2-Tetrachloroethane | <5 |
| Chloroethane | <5 |
| 1,1,2-Trichloroethane | <5 |

* Constituent Detection

VOC Constituents cont.

| | |
|---|---|
| 2,2-Dichloropropane | <5 |
| o-Chloroluene | <5 |
| p-Chlorotoluene | <5 |
| Bromobenzene | <5 |
| 1,3-Dichloropropene | <5 |
| 1,2,4-Trimethylbenzene | <5 |
| 1,2,4-Trichlorobenzene | <5 |
| 1,2,3-Trichlorobenzene | <5 |
| n-Propylbenzene | <5 |
| n-Butylbenzene | <5 |
| Naphthalene | <5 |
| Hexachlorobutadiene | <5 |
| 1,3,5-Trimethylbenzene | <5 |
| p-Isopropyltoluene | <5 |
| Isopropylbenzene | <5 |
| Tert-butylbenzene | <5 |
| Sec-butylbenzene | <5 |
| Fluorotrichloromethane | <5 |
| Dichlorodifluoromethane | <5 |
| Bromochloromethane | <5 |
| Allylchloride | <5 |
| 2,3-Dichloro-1-propane | <5 |
| Tetrahydrofuran | <50 |
| Pentachloroethane | <5 |
| Trichlorotrofluoroethane | <5 |
| Carbondisufide | <5 |
| Ether | <5 |

* Constituent Detection