SECTION 2.2

HYDROGEOLOGIC INVESTIGATION

2.2 HYDROGEOLOGIC INVESTIGATION

Shaw Environmental, Inc. (Shaw) performed a hydrogeologic investigation for the proposed Veolia E. S. Zion Landfill Site 2 East Expansion (Site 2 East Expansion) in order to supplement information previously collected for characterization and permitting of the existing facility. Ultimately, the collected information was evaluated to determine the suitability of the site for development of a landfill expansion.

The design of the Site 2 East Expansion is supplemented by existing geologic features to provide a high level of environmental safety. The naturally present clay beneath the site will work in conjunction with the engineered features of the expansion to protect groundwater resources in the vicinity of the site. This investigation, along with previous investigation activities, demonstrates that the proposed Facility is located and designed so as to protect the public health, safety, and welfare. Key findings include the following:

- ❑ A significant amount of hydrogeolgic investigation activities have been conducted at the site prior to the most recent investigation. Data collected during the previous hydrogeologic investigation activities was obtained through the advancement of over 250 borings (over 100 of which were continuously sampled) and the installation of over 200 monitoring wells.

- ❑ The most recent site investigation included a review of previous site investigations and the advancement of an additional ten borings, five of which were advanced at previous boring locations to supplement existing site information and five of which were advanced in new locations. The geology beneath the horizontal portion of the Site 2 East Expansion, as characterized by the ten borings, is consistent with the geology encountered beneath the existing Facility and the geologic setting which is described in regional publications[1], providing additional support to the findings of this investigation. The continuity observed from boring to boring demonstrates that the investigation activities were adequate in extent to verify the geologic and hydrogeolgic features beneath the site. Six of the ten borings were converted to piezometers or monitoring wells to supplement the hydrogeologic information for the site.

- ❑ A low-permeability cohesive soil (Wadsworth Formation) is present across the proposed site which will separate the footprint of the proposed Site 2 East Expansion from the uppermost aquifer. This low permeability cohesive soil (clayey till) has an average thickness of approximately 87.3 feet in the expansion area with maximum and minimum thicknesses of 101.7 feet and 75.0 feet, respectively. Field and laboratory test results and field observations indicated that this soil will effectively restrict vertical and horizontal movement of groundwater and will serve as an additional environmental safeguard at the proposed expansion. The average thickness of the Wadsworth Formation includes discontinuous lenses of silt, sand, and gravel (Intra-Till Sediments) which are contained within the till.

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1 Csallany and Walton (1963), Frye and Willman (1975), Hansel and Johnson (1996), Horberg (1950), Johnson, et al. (1985), Kammerer, et al. (1998), Larsen (1973), Leetaru et al. (2003), Piskin, et al. (1975), Thwaites (1927), Visocky, et al. (1985), Willman, et al. (1975), and Willman (1971).

- The clay will act as a permanent barrier and supplemental protective feature of the Site 2 East Expansion by restricting contaminant movement from the expansion in both vertical and horizontal directions.

- As discussed in the design report, the engineered liner system beneath the expansion area will include 5 feet of recompacted clay and a high density polyethylene (HDPE) liner. Such a liner exceeds the requirements of the U.S. EPA and has been accepted by the Illinois Environmental Protection Agency (IEPA) and other experts in the landfill field as providing a high level of environmental safety. The natural clay that is present on the site below the liner system will act as a second, natural liner system for the landfill expansion.

- In addition to following the requirements of the City of Zion Pollution Control Facility Siting Ordinance, the investigation was performed in general accordance with the requirements contained in 35 Ill. Admin. Code, Section 811.315, 812.314, and 812.315. These regulations specify the necessary content of hydrogeologic investigations submitted to the IEPA as part of an application for a landfill expansion permit.

- The proposed Site 2 East Expansion is located in an area that is classified by Berg and Kempton (1984) as Map Unit E (low aquifer sensitivity with respect to land burial of municipal solid waste) with uniform, relatively impermeable silty or clayey till at least 50 feet thick. The site is also located in an area that has been classified by Larson (1973) as being geologically optimal for the development of a landfill within Lake County.

- Based on discussions with the site operator, the geologic interpretations that have been established within this report are consistent with the conditions observed during the development of large-scale excavations at the existing facility. The site-specific observations verify the thickness of the clayey till and discontinuous nature of the intra-till sediments as described within this analysis. IEPA review and approval of construction documentation reports supports this as well.

- The hydrogeologic conditions at the site will allow a comprehensive groundwater monitoring system to be implemented which will be able to adequately verify if groundwater resources are being impacted by the landfill.

Objectives of the Investigation

The most recent hydrogeologic investigation was conducted from March 2007 through June 2007. The objectives of the hydrogeologic investigation were: 1) to meet the general requirements set forth in criterion ii from Sec. 39.2(a)(2) of the Illinois Environmental Protection Act, which requires that the facility be designed, located, and operated so that the public health, safety and welfare will be protected; 2) to meet the applicable requirements set forth in the City of Zion Pollution Control Facility Siting Ordinance, 3) to provide the geotechnical and hydrogeologic information necessary for facility design, and 4) to meet the requirements of 35 Ill. Admin. Code, Sections 811.315, 812.314, and 812.315.

Prior to mobilization to the site, a detailed literature survey of the available regional hydrogeologic information was performed in accordance with 35 Ill. Admin. Code Section 811.315(c) requirements. In addition to the regional hydrogeologic information, information collected at the site during previous hydrogeologic investigations was reviewed. The regional information and previous hydrogeologic investigations assisted in devising a field investigation plan and understanding site geology. This plan enabled an accurate determination of the stratigraphic, physical, and hydrogeologic properties of the geologic materials beneath the proposed site.

Once the available regional and site hydrogeological information was studied and a field investigation plan was established, the field investigation was initiated. The field investigation included the advancement of five new borings, the collection of additional data at five previously advanced boring locations through supplemental drilling, and the installation of six new piezometers/monitoring wells within and near the proposed horizontal waste expansion boundary. One of the supplemental borings, B-6-06, was advanced through the Wadsworth Formation, Intra-Till Sediments (within the Wadsworth Formation), Shallow Drift (Uppermost Aquifer), Lower Till, Intra-Till Sediments (within the Lower Till), lacustrine deposits, Basal Drift, and 4.8 feet into bedrock. The depth to the top of bedrock was approximately 215.2 feet below ground surface. Additionally, an existing boring, (TB-1), which was supplemented with additional information collected within B-4-07, was originally advanced through these materials to a depth of approximately 213.1 feet below ground surface to the top of bedrock, and then 10.9 feet into bedrock.

A detailed description and discussion of the most recent investigation is presented in the following sections along with the supporting data and information from previous investigations. Conclusions derived in this report revealed that the geologic and hydrogeologic conditions at the proposed site are suitable and favorable for development of the Site 2 East Expansion that will protect the public health, safety, and welfare.

Project Background

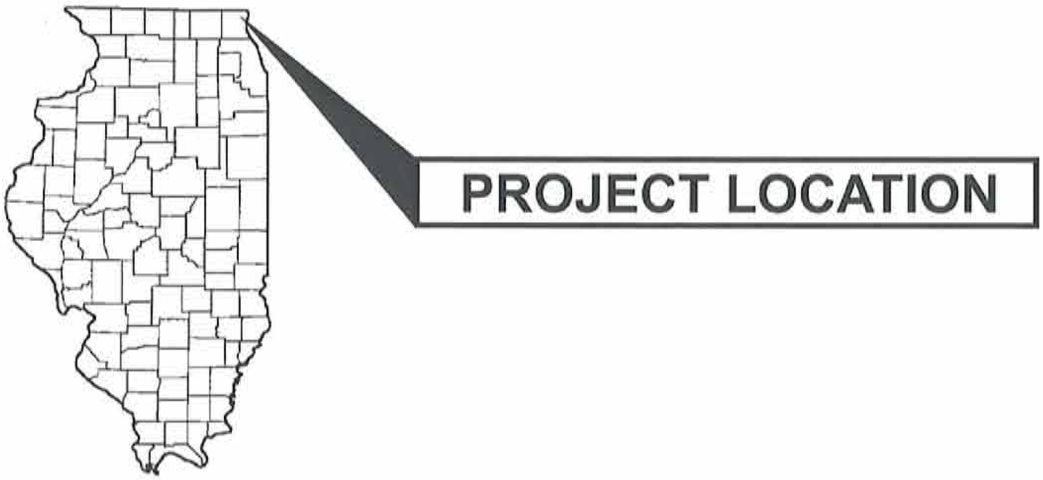
This section describes information related to the location and the physical setting of the proposed site and surrounding area.

Proposed Location

The proposed Site 2 East Expansion is located within the City of Zion, Illinois in the northeast quarter of Section 7 of Township 46 North, Range 12 East of the 3rd Principal Meridian (Refer to Figure 2.2-1). Figure 2.2-2 includes an aerial photo illustrating the location of the proposed waste expansion area in relation to the surrounding area. The proposed waste expansion area includes a component to the east of the existing and permitted Site 2. The proposed waste expansion area also includes a component which will expand vertically onto Site 2.

Site History

The Zion Landfill was initially permitted in 1976 and owned by BFI Waste Systems of North America, Inc (BFI). BFI operated the site until July 30, 1999 when Allied Waste Industries, Inc. (Allied) acquired Browning-Ferris Industries, Inc, which was the parent company of BFI Waste Systems of North America, Inc. On March 31, 2000, Allied sold the site to Superior Zion Landfill, Inc. On the same day, Superior Zion Landfill, Inc. changed its name to Onyx Zion Landfill, Inc. On July 1, 2006, Onyx Zion Landfill, Inc. changed its name to Veolia E.S. Zion Landfill, Inc. The Veolia E.S. Zion Landfill Inc. Facility consists of a number of older units that have ceased acceptance of waste and are closed, as well as the currently active unit.



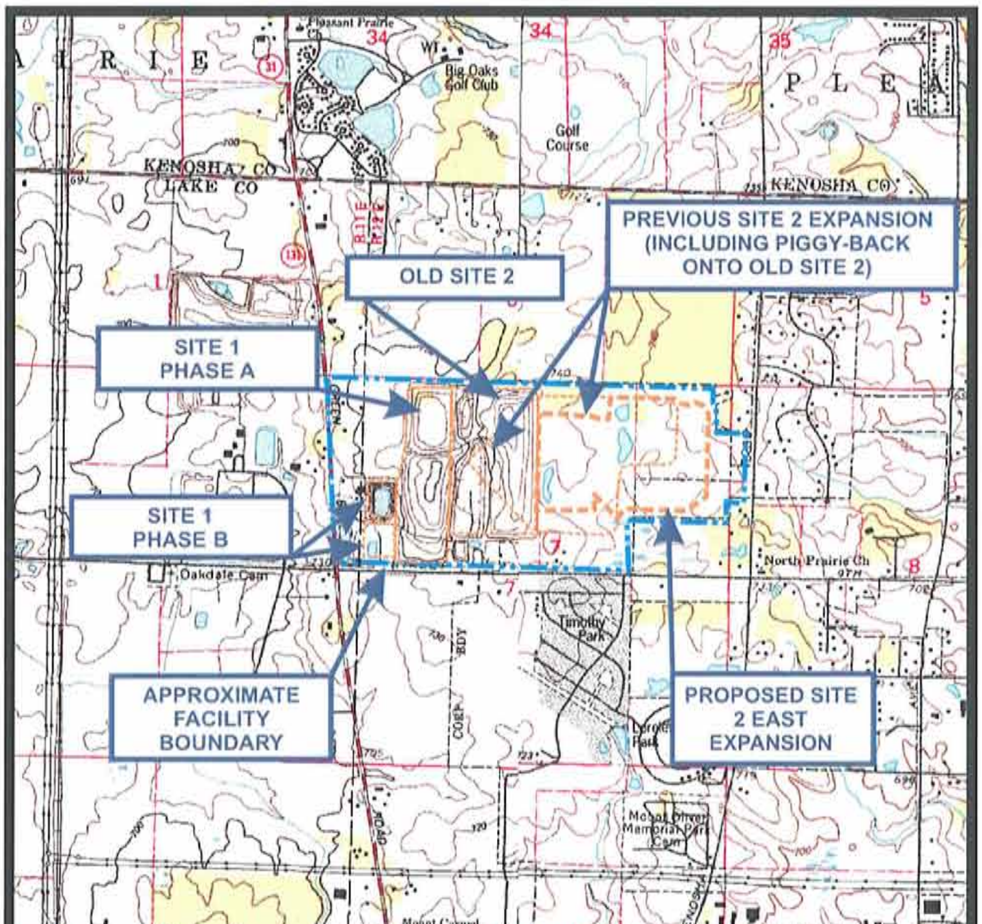


Figure adapted from USGS topographic quadrangles for Zion (1993) and Wadsworth (1993)

0 ft 2,700 ft

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-1
REGIONAL SITE LOCATION MAP

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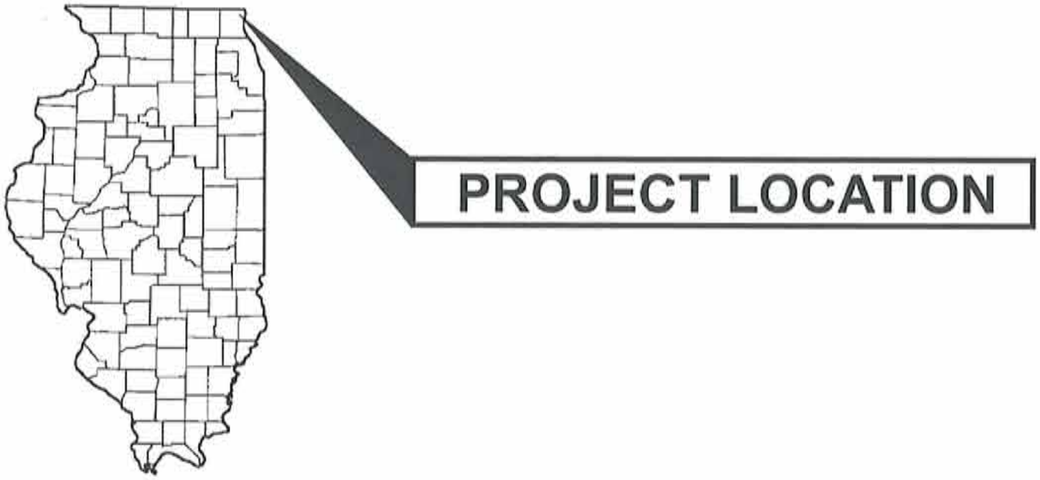

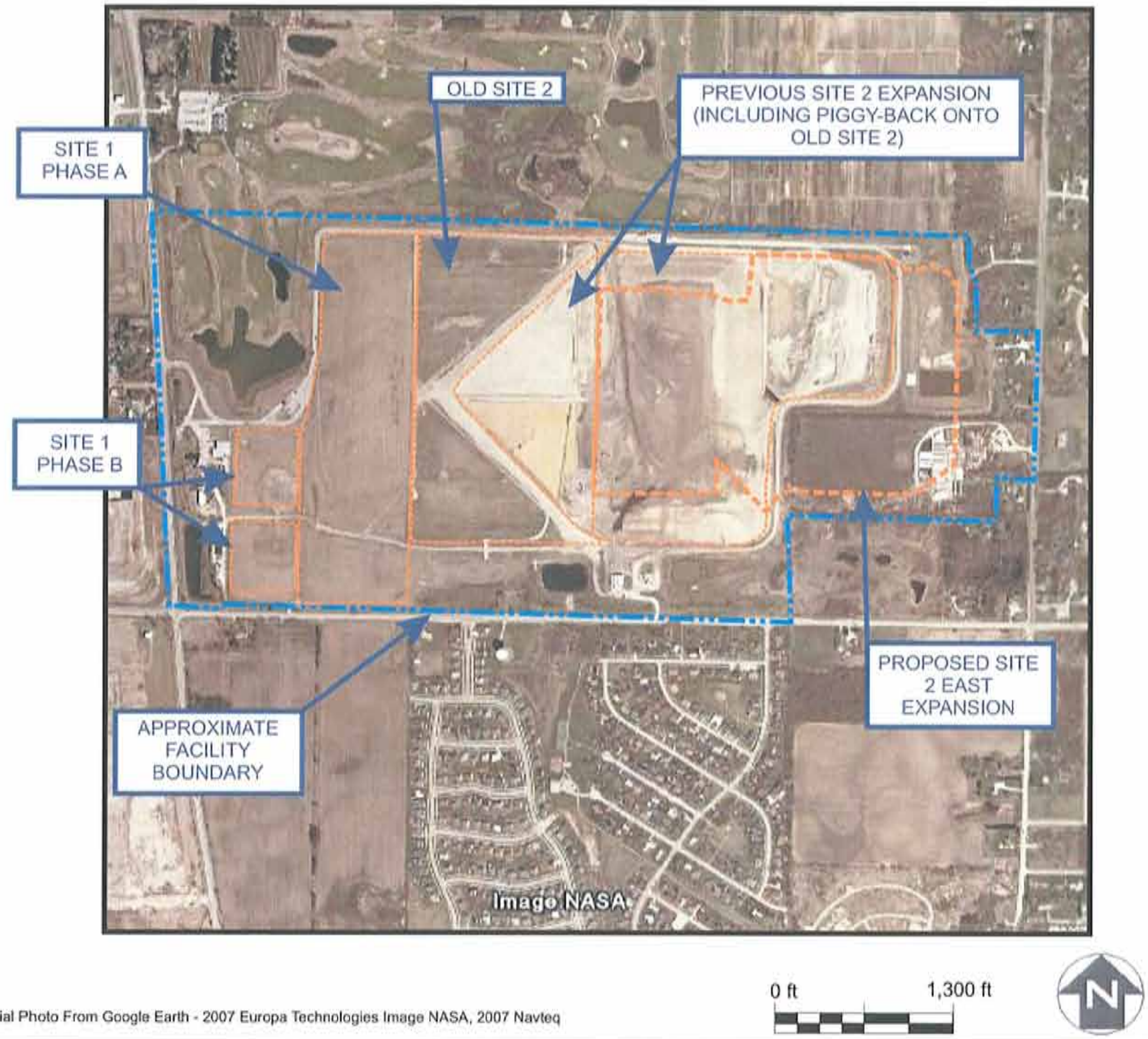

Aerial Photo From Google Earth - 2007 Europa Technologies Image NASA, 2007 Navteq

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-2
SITE LOCATION MAP

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The portion of the facility referred to herein as the Veolia E.S. Zion Landfill consists of two areas individually referred to as Old Site 2 and the Site 2 Expansion. Old Site 2 is a non-hazardous solid waste unit that was regulated under 35 IAC, Part 807. Old Site 2 commenced landfilling operations on December 23, 1981, pursuant to IEPA permit No. 1980-24-DE. In 1993, a final cover system was constructed over the site. Siting approval for the Site 2 Expansion (initially identified as Site 3 at that time) was granted by the Zion City Council on April 17, 1995 which approved a new landfill unit east of Old Site 2 including a "piggyback" onto the eastern portion of Old Site 2. The Site 2 Expansion was originally permitted under 35 IAC, Part 812, Subparts A and C, and is now regulated under Subtitle D landfill regulations[2]. Collectively, Old Site 2 and the Site 2 Expansion are referred to as the Veolia E.S. Zion Landfill. This application proposes to expand horizontally to the east of the currently permitted landfill and vertically onto the previously permitted Site 2 Expansion. Figures 2.2-1 and 2.2-2 illustrate the location of the various landfill units.

Climate Data

Lake County has a continental climate typical of northeastern Illinois. Annual normal precipitation averages 34.7 inches, more than half of which normally falls during the growing season from May through September. The average yearly temperature is 47.2 degrees Fahrenheit with average normal minimum and maximum temperatures of 39.9 and 54.5 degrees Fahrenheit, respectively. Average climatic data was obtained from the National Climatic Data Center (NCDC) in Asheville North Carolina which was recorded between 1971 and 2000 in Kenosha, WI, located approximately 4 miles north of the proposed expansion. This data has been summarized in Table 2.2-1. Appendix G contains the data obtained from the NCDC.

TABLE 2.2-1
AVERAGE MONTHLY TEMPERATURE EXTREMES AND PRECIPITATION FOR KENOSHA, WI (1971-2000)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Ann
Normal Max Temp (°F)	28.4	32.3	41.5	50.9	62.1	72.7	78.7	77.7	70.5	59.3	46.0	33.8	54.5
Normal Min Temp (°F)	13.2	17.8	27.2	37.3	47.7	57.2	63.9	63.9	55.2	44.0	31.5	20.0	39.9
Average Temp (°F)	21.4	24.2	34.6	44.1	54.4	65.3	70.4	70.3	62.8	52.0	39.1	27.8	47.2
Maximum Precip. (in)	5.1	3.7	5.5	7.7	8.4	9.1	8.6	12.7	11.7	7.0	6.6	5.2	47.0
Minimum Precip. (in)	0.1	0.00	0.3	0.7	0.2	0.8	0.7	0.3	0.04	0.08	0.2	0.2	18.7
Normal Precip. (in)	1.67	1.29	2.34	3.85	3.38	3.59	3.68	4.19	3.49	2.49	2.68	2.09	34.7

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2 The commonly referred to Subtitle D regulations were created by the USEPA in 1991 to revise the previously existing RCRA regulations. The Subtitle D regulations became effective in 1993 and continue to provide stringent landfill design, construction, operation, monitoring, closure, and post-closure care procedures. Under Subtitle D, the state and local governments are the primary planning, permitting, regulating, implementing, and enforcement agencies for management and disposal of solid wastes but must adopt, at a minimum, the technical design and operating criteria which was developed by the USEPA under Subtitle D. All new landfills and landfill expansions must comply with Subtitle D.

Regional Geology and Hydrogeology

The regional geology and hydrogeology were interpreted prior to performing any additional site specific investigation. The regional hydrogeologic investigation provided a better understanding of the geologic conditions, including the unconsolidated deposits, bedrock, and groundwater characteristics. These sections describe the methods used to review the available regional geologic and hydrogeologic information and provide a detailed description of the results of the review.

Methodology

Existing published information on the area was obtained from several general sources. The first source was the available water well logs obtained from the Illinois State Geological Survey (ISGS) and Illinois State Water Survey (ISWS) in Champaign, Illinois, and the Wisconsin Geological and Natural History Survey (WGNHS) in Madison, Wisconsin. Additionally, the Lake County Health Department (LCHD) was contacted. The second source consisted of statewide and regional reports and maps available from the United States Geological Survey (USGS), ISGS, ISWS, and Federal Emergency Management Agency (FEMA). These publications were utilized in the development of the regional hydrogeologic investigation and creation of this report. The publications used to prepare this section are provided in the Hydrogeologic References at the end of this report.

Water Wells

The water well logs on file with the ISGS, ISWS, WGNHS, and LCHD were requested for all wells located within approximately one mile of the proposed Facility boundary. The LCHD indicated that all records that they receive are forwarded to the ISWS and, therefore, did not provide logs.

A total of 281 well logs were obtained from the state agencies. The locations of these wells were plotted on USGS 7.5 minute quadrangle maps based primarily on the location information provided on the Well Construction Report (County, Section, Township, Range, Quarter, and Quarter of the previous Quarter). In addition to the 281 well logs which were obtained from the state agencies, 174 probable well locations for which no log was available were identified in the field within one mile of the facility. Identification of one of these wells was done by assuming that every resident location not served by a public water supply has a private well for supplying drinking water.

Although they can sometimes provide useful information, it should be noted that historical well records are known to include old data, lack detail, or in some cases include inaccurate information. Due to this lack of precision, it is not always possible to accurately determine the exact location of wells or the formations in which all of the wells are screened. The water well data was obtained to assist with the understanding of regional geology and hydrogeology, and is not meant to supersede the extensive geological and hydrogeological data collected on the site of the proposed Site 2 East Expansion.

A street-level field reconnaissance was performed to verify the approximate location of wells identified from well logs, and to determine whether there are additional wells for which well logs do not exist. Using the USGS 7.5 minute quadrangle maps discussed above, all roads that are easily accessible were driven to field verify the location of the plotted wells. Verifying the location meant driving by the property and seeing a house, a grove of trees where a house may have stood, a barn, a concrete pad, a distant irrigation well, or other signs that indicate that a well currently exists or may have once been located at each respective location. Because the intended purpose of the well log data was to assist with characterization of regional geology and hydrogeology, it was not judged necessary to gain access to each property and visually observe a well. The information contained on these logs is consistent with the geology and hydrogeology described in regional publications.

No water wells were found to exist within the proposed expansion waste boundary, however, if a well is found to exist within the waste boundary during construction of the proposed expansion, it will be properly abandoned in accordance with all applicable IEPA and Illinois Department of Public Health (IDPH) regulations prior to the start of operations in those areas.

The locations of the water wells are illustrated in Drawing No. G2. Copies of the well logs and a summary table are provided in Appendix G.

Topography and Relief

The proposed Site 2 East Expansion is located within the physiographic division known as the Wheaton Morainal Country of the Great Lakes Section of the Central Lowland Province as seen in Figure 2.2-3. The Wheaton Morainal Country is characterized by glacial morainic topography which includes a series of broad parallel morainic ridges which encircle Lake Michigan. Due to the morainic topography, relief in the vicinity of the site is highly variable. The total relief in Lake County is approximately 377 feet, with the high elevation being approximately 957 feet above MSL in the northwest corner of the County on Gander Mountain, and the low elevation being less than 580 feet above MSL on the Lake Michigan shore near Waukegan.

Surficial Soils

Figures 2.2-4 illustrates the locations of various soil associations in the vicinity of the proposed expansion. As illustrated in Figure 2.2-4, the major soil type at the site is the Wauconda Silt Loam which consists of loess or other silty material and the underlying outwash and is somewhat poorly drained (Calsyn, 2003).

Regional Bedrock Stratigraphy

The regional bedrock consists of a succession of sedimentary rocks over two thousand feet thick overlying Pre-Cambrian basement rock. A generalization of the stratigraphic column for the northeastern Lake County region is provided in Figure 2.2-5. The limited samples of crystalline basement rock in Illinois consist predominantly of granite with a few other granitic type rocks. The Mt. Simon Formation is a Cambrian age sandstone which unconformably overlies the crystalline bedrock surface. The unconformity that separates the crystalline basement rock from sedimentary rock represents more than 500 million years. The Mt. Simon Formation is generally described as consisting of fine to predominantly coarse grained, more angular, predominantly white, friable sandstone which also may be reddish, yellowish, or light greenish gray (Willman et al., 1975). Regional publications report that in Lake County, the unit ranges in thickness from approximately 1,000 to 1,500 feet, with a surface elevation of approximately 975 feet below mean sea level. Figure 2.2-6 illustrates the top elevation of the Mt. Simon Formation in Lake County.

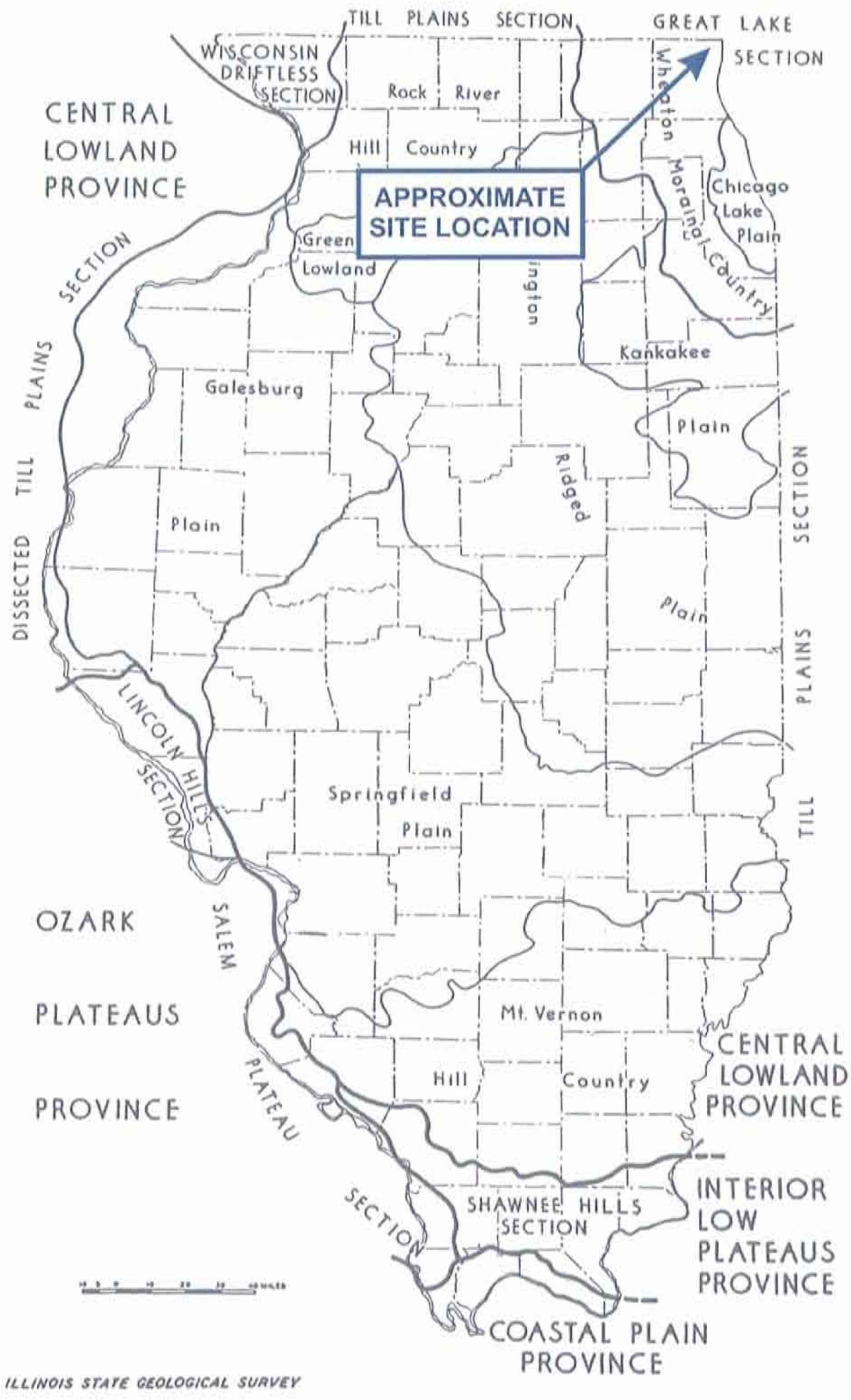

Figure taken from Leighton et al., 1948.

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-3
PHYSIOGRAPHIC DIVISIONS OF ILLINOIS

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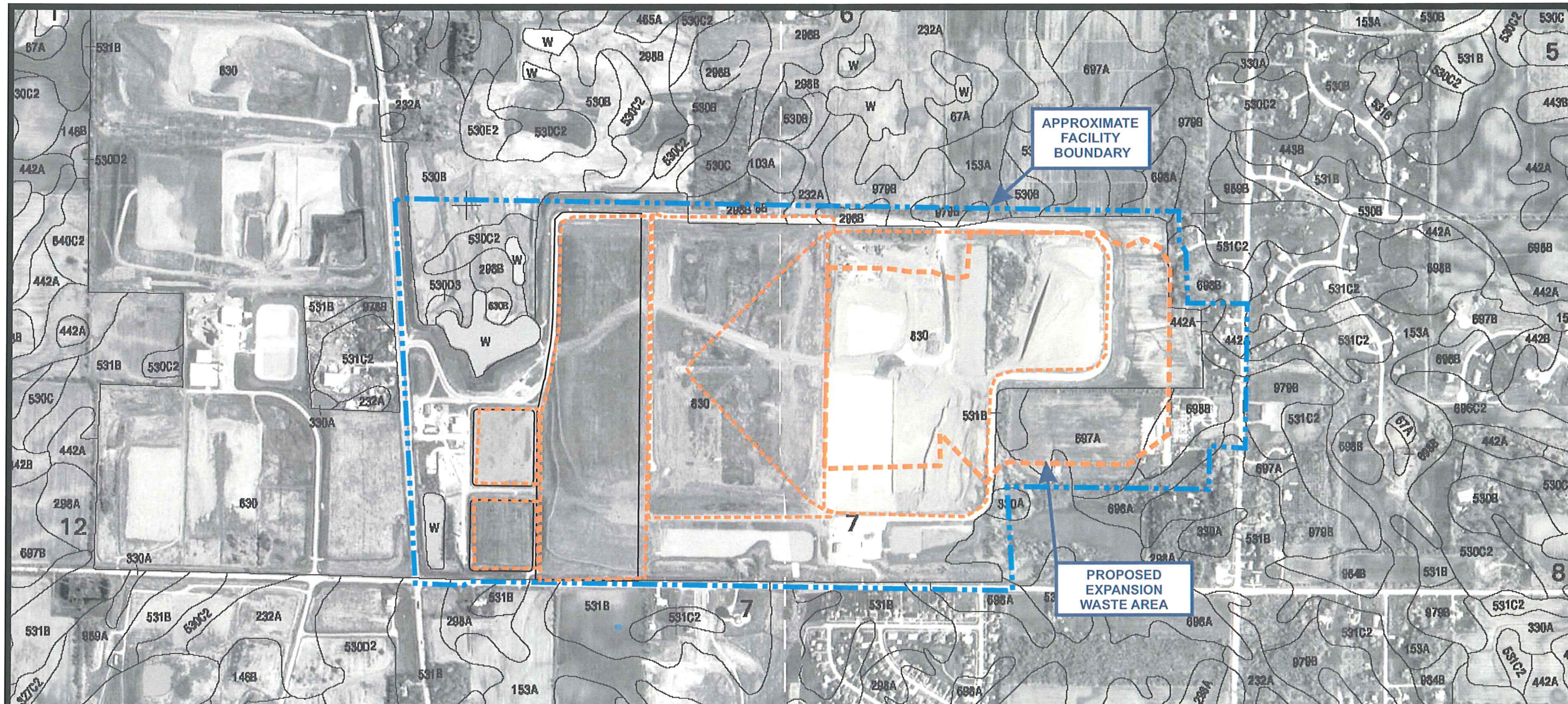

298A	Beecher silt loam, 0 to 2 percent slopes
330A	Peotone silty clay loam, 0 to 2 percent slopes
442A	Mundelein silt loam, 0 to 2 percent slopes
531B	Markham silt loam, 2 to 4 percent slopes
531C2	Markham silt loam, 4 to 6 percent slopes
696A	Zurich silt loam, 0 to 2 percent slopes
697A	Wauconda silt loam, 0 to 2 percent slopes
698B	Grays silt loam, 0 to 2 percent slopes
830	Landfills

Notes:

1. Figure adapted from "Soil Survey of Lake County, Illinois," 2002.

2. Soils depicted on this drawing have formed within the upper portion of the Peoria Silt where it is present. The Peoria Silt is a relatively thin layer of sandy or clayey silt (and small amounts of eolian sand) that was predominantly derived from glacial meltwater and has since been modified by erosional and soil formation processes.

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NOT TO SCALE

ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-4
GENERAL SOIL MAP FOR THE VICINITY OF THE PROPOSED EXPANSION

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SYSTEM	SERIES AND MEGAGROUP	GROUP AND FORMATION	HYDROSTRATIGRAPHIC UNITS Aquigroup	HYDROSTRATIGRAPHIC UNITS Aquifer/aquitard	LOG	APPROX. THICKNESS (ft)	DESCRIPTION
Quaternary	Pleistocene	Undifferentiated	Prairie	Pleistocene		200+	Unconsolidated glacial deposits - pebbly clay (till) silt, and gravel. Loess (windblown silt), and alluvial silts, sands and gravels.
Silurian	Niagaran	Port Byron Fm Racine Fm Waukesha Ls Joliet Ls	Upper Bedrock	Silurian dolomite aquifer		200	Dolomite, silty at base, locally cherty.
	Alexandrian	Kankakee Ls Edgewood Ls					
Ordivician	Cincinnatian	Maquoketa Shale Group		Maquoketa confining unit		225	Shale, gray or brown; locally dolomite and/or limestone, argillaceous.
	Mohawkian (Ottawa Ls Megagroup)	Galena Group Decorah Subgroup Platteville Group		Galena-Platteville unit		300	Dolomite and/or limestone, cherty. Dolomite, shale partings, speckled. Dolomite and/or limestone, cherty, sandy at base.
	Chazyan	Ancell Gr: Glenwood Fm St. Peter Ss		Ancell aquifer		200–275	Sandstone, fine- and coarse-grained; little dolomite; shale at top. Sandstone, fine- to medium-grained; locally cherty red shale at base.
Cambrian	St. Croixian (Knox Megagroup)	Eminence Fm - Potosi Dolomite	Midwest Bedrock	Middle confining unit: Eminence-Potosi		70–95	Dolomite, white, fine-grained, geodic quartz, sandy at base.
		Franconia Fm		Middle confining unit: Franconia			Dolomite, sandstone, and shale, glauconitic, green to red, micaceous.
		Ironton Ss		Ironton-Galesville aquifer		110	Sandstone, fine- to medium-grained, well sorted, upper part dolomitic.
		Galesville Ss					
		Eau Claire Fm	Basal Bedrock	Eau Claire		410	Shale and siltstone; dolomite, glauconitic; sandstone, dolomitic, glauconitic.
		Mt. Simon Fm		Elmhurst-Mt.Simon aquifer		1,000–1,500	Sandstone, coarse grained, white, red in lower half; lenses of shale and siltstone, red micaceous
Pre-Cambrian			Crystalline				No aquifers in Illinois

This column has been modified from Visocky et al., 1985. Approximate thicknesses are estimated as described in the text.

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-5
GENERALIZED STRATIGRAPHIC COLUMN IN THE VICINITY OF THE PROPOSED EXPANSION

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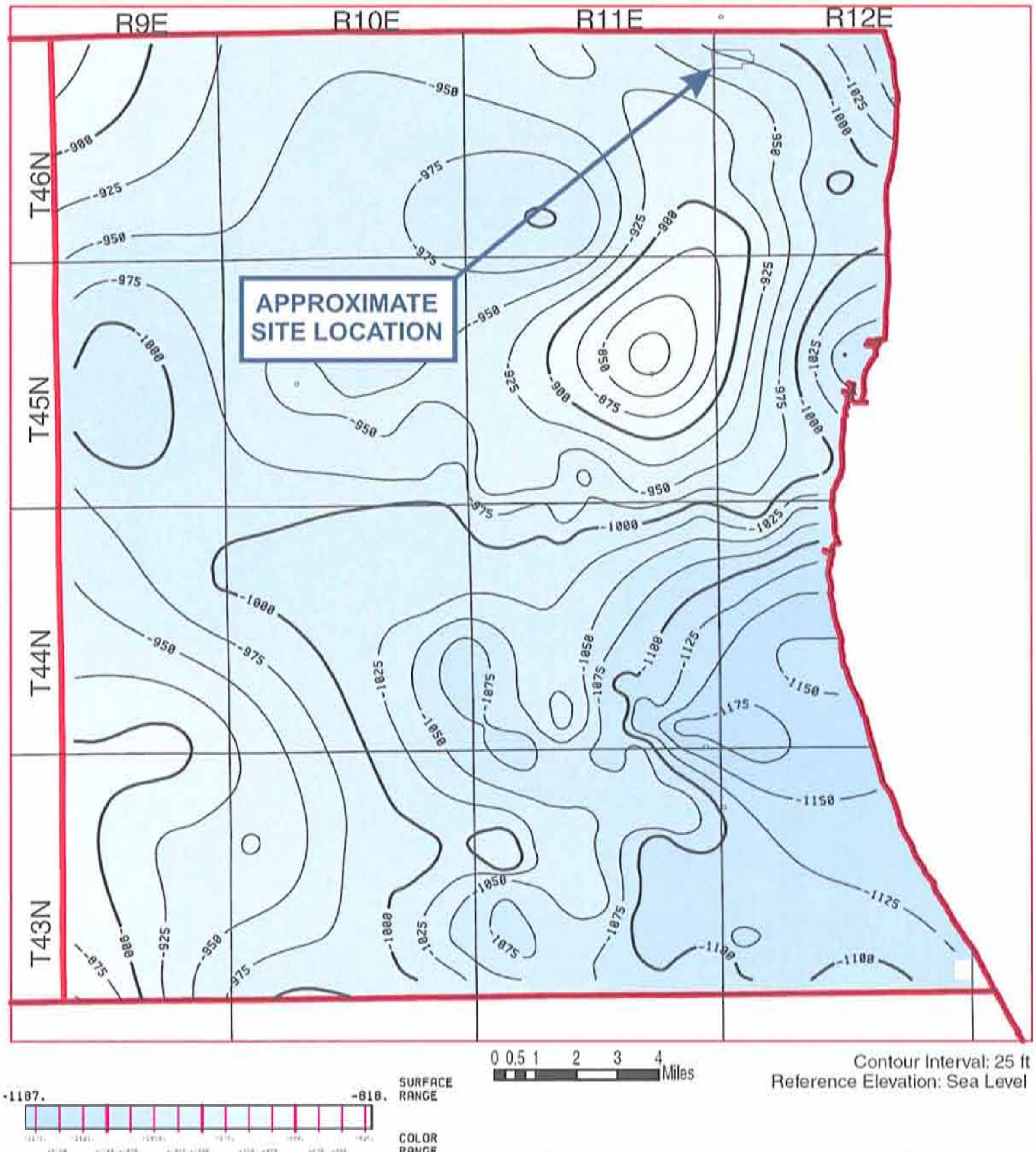

Top of the Mt. Simon Sandstone

Figure adapted from ISGS Open File Series 2003-12

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-6
TOP ELEVATION OF THE MT. SIMON SANDSTONE

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The Cambrian and Ordovician age Knox Dolomite Megagroup unconformably overlies the Mt. Simon Formation. The Knox Dolomite Megagroup consists of the Cambrian Age Eau Claire Formation, Galesville Sandstone, Ironton Sandstone, Fraconia Formation, Potosi Dolomite, and the Eminence Formation, conformably. It should be noted that the Eau Claire Formation and Ironton-Galesville Sandstone have been attributed to the Knox Megagroup within this report based upon information obtained from Willman et al. (1975). The report published by Visocky, et al., (1985) does not include these units within the Knox Megagroup as shown on Figure 2.2-5.

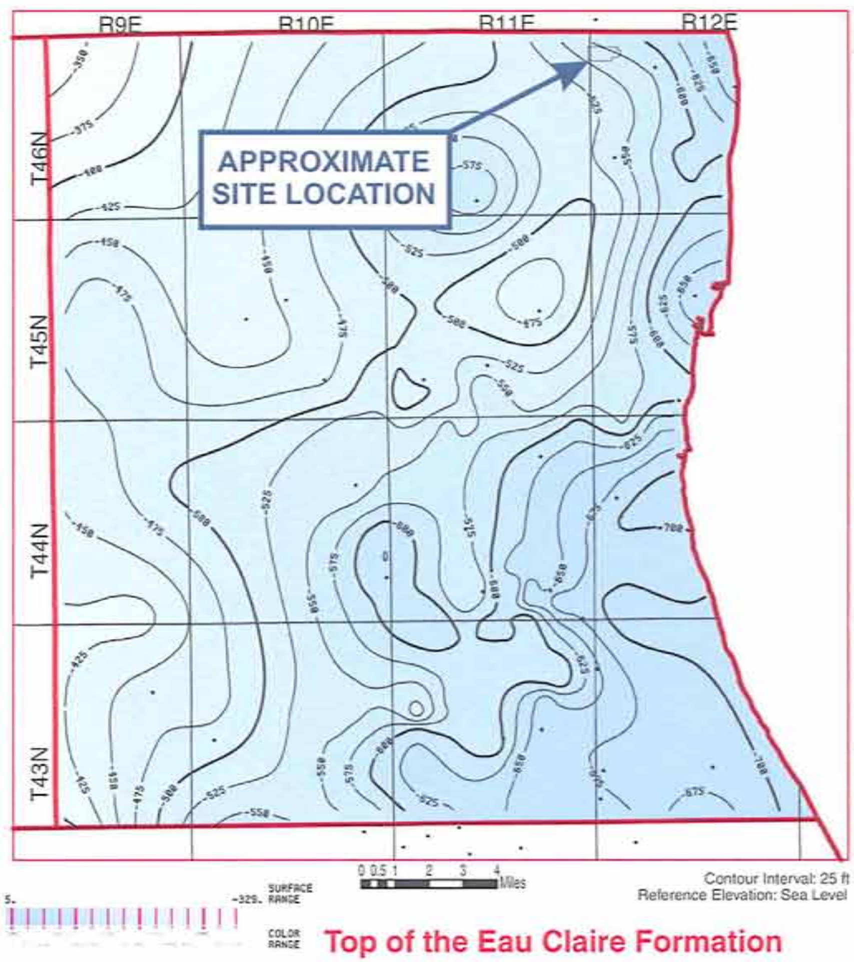
The Eau Claire Formation consists predominantly of gray dolomitic sandstone, which may include shaley siltstone and silty, sandy, glauconitic, brownish gray dolomite (Willman et al., 1975). Regional publications indicate that the Eau Claire Formation has an approximate thickness of 410 feet in the vicinity of the site and can be found at an approximate elevation of 575 feet below mean sea level (Willman et al., 1975 and Leetaru et al., 2003). The Eau Claire Formation is an aquitard, which acts as a confining unit to the underlying Mt. Simon Formation (Visocky, et al., 1985). Figure 2.2-7 illustrates the top elevation and thickness of the Eau Claire Formation in Lake County.

The Ironton-Galesville Sandstone conformably overlies the Eau Claire Formation. The Galesville Sandstone is described as white to light buff, fine grained, moderately well-sorted sandstone. The Ironton Sandstone is described as a light pinkish-buff, medium grained, poorly sorted, dolomitic sandstone. Regional publications report the Ironton-Galesville Sandstone near the proposed site is approximately 110 feet thick and can be found at an approximate elevation of 475 feet below mean sea level (Leetaru et al., 2003). This sandstone is the most productive unit of the Midwest Bedrock Aquigroup with yields over 500 gallons per minute in northern Illinois (Visocky, et al., 1985). Figure 2.2-8 illustrates the top elevation and thickness of the Ironton-Galesville Formation in Lake County.

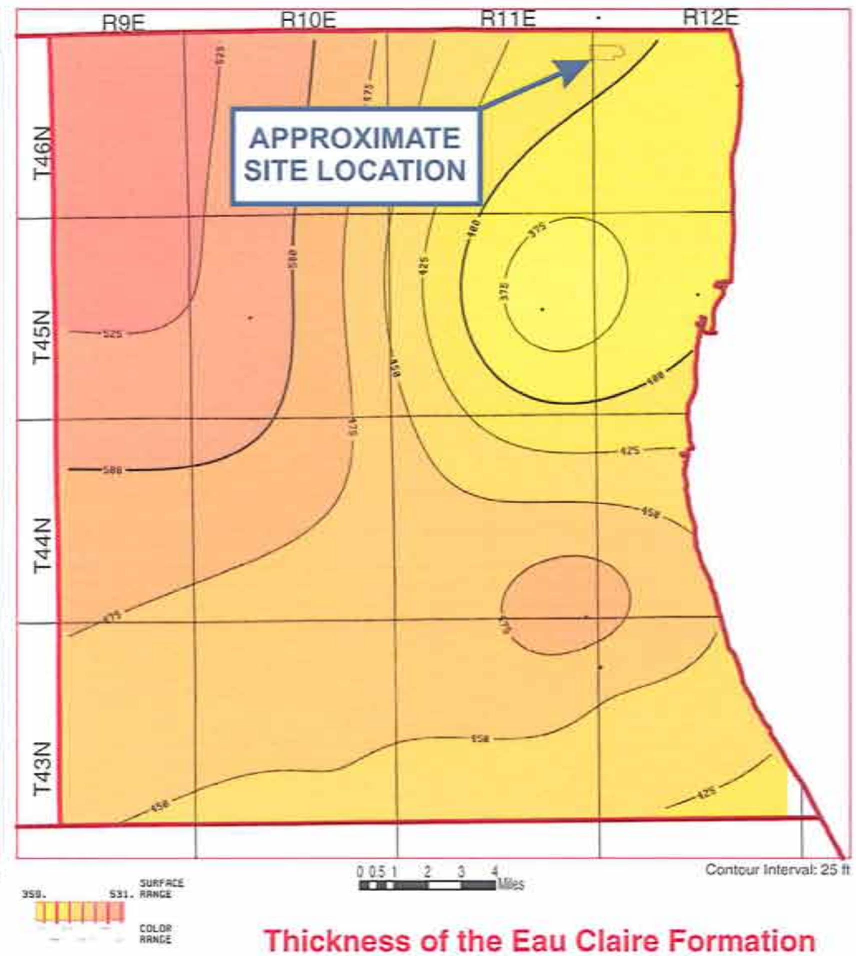
The Franconia Formation in northern Illinois is described as gray fine-grained dolomitic sandstone. The lowermost part of the Franconia Formation (Davis Member) becomes increasingly shaley and the uppermost part grades to silty and sandy dolomite (Derby-Doerun Member). In the vicinity of the proposed expansion, the Franconia Formation has an approximate range in thickness of 50 to 75 feet (Willman, et al., 1975 and Anderson, 1919).

The Potosi Dolomite is brown to pinkish gray, fine crystalline dolomite that may be argillaceous and glauconitic. The Eminence Formation consists of light gray to brown or pink, sandy, fine to medium grained dolomite that contains oolitic chert and thin sandstone strata. In the vicinity of the proposed expansion, the combined thickness of the Eminence and Potosi Formations is approximately 20 feet (Willman et al., 1975).

The Ordovician age Ancell Group is separated from the underlying Knox Megagroup by a distinctive unconformity. The unconformity is classified as major, resulting in an irregular erosional surface and rubble zone at the base of the Ancell Group. Erosion which took place prior to deposition of the Ancell Group removed the entire Ordovician Prairie du Chien Group and Cambrian Jordan Sandstone and truncated the Potosi and Eminence Formations in the vicinity of the proposed expansion. The Ancell Group includes the St. Peter Sandstone and Glenwood Formation. In the vicinity of the proposed expansion, the St. Peter Sandstone is composed entirely of the Tonti Sandstone Member. The Tonti Sandstone Member is white, fine-grained, well sorted, friable, highly porous sandstone. Available literature indicates that the St. Peter Sandstone is friable and crumbles easily (Willman et al., 1975). As the sandstone is generally poorly cemented, lithification of the sandstone is primarily the result of compaction by the weight of the overlying strata. The overlying Glenwood Formation is described as a highly varied unit of poorly sorted sandstone, impure dolomite, green shale, and dolomitic, fine to medium grained sandstone.



Top of the Eau Claire Formation



Thickness of the Eau Claire Formation

Figure adapted from ISGS Open File Series 2003-12

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-7
ELEVATION AND THICKNESS OF THE EAU CLAIRE FORMATION IN LAKE COUNTY

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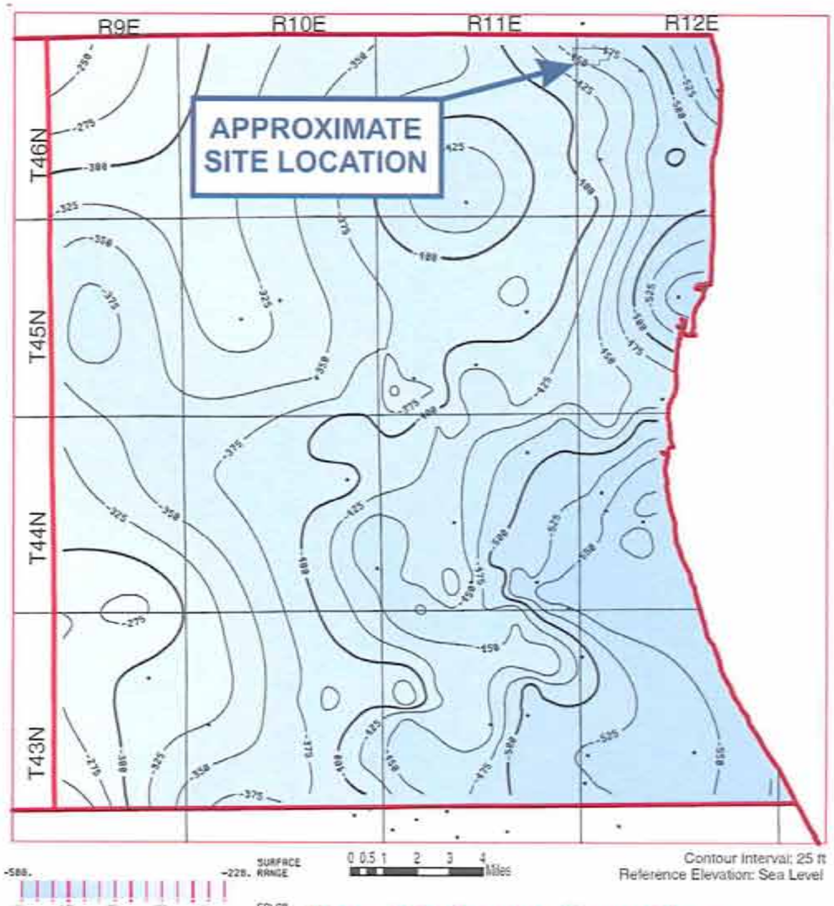
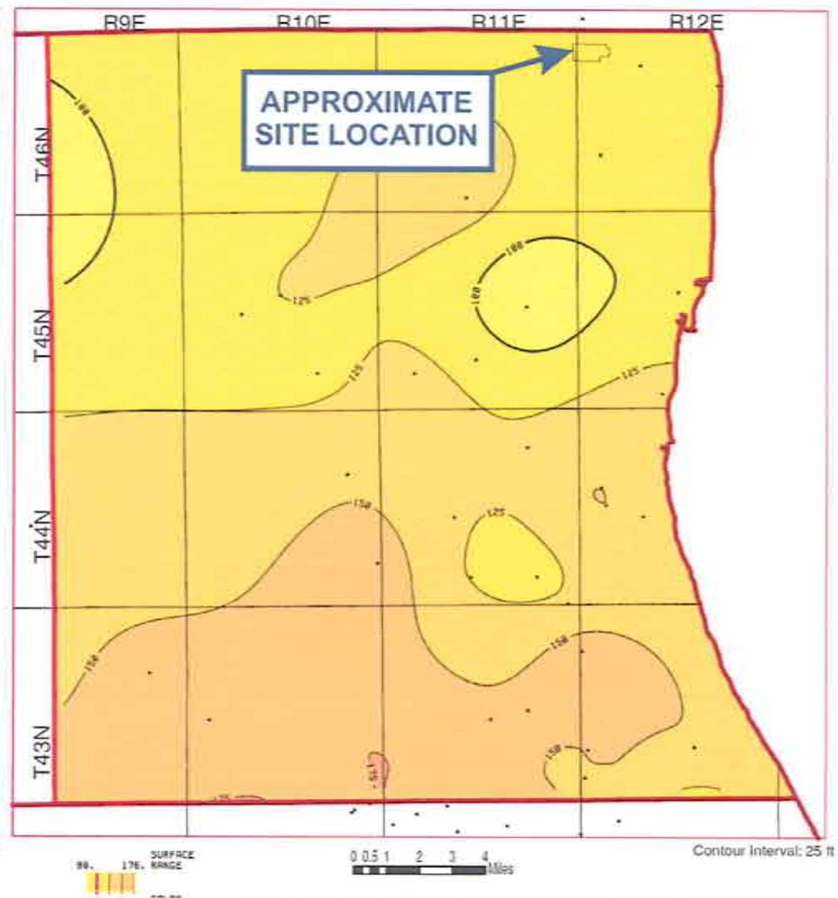


Top of the Ironton Formation



Thickness of the Ironton-Galesville Interval

Figure adapted from ISGS Open File Series 2003-12

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-8
ELEVATION AND THICKNESS OF THE IRONTON-GALESVILLE FORMATION IN LAKE COUNTY

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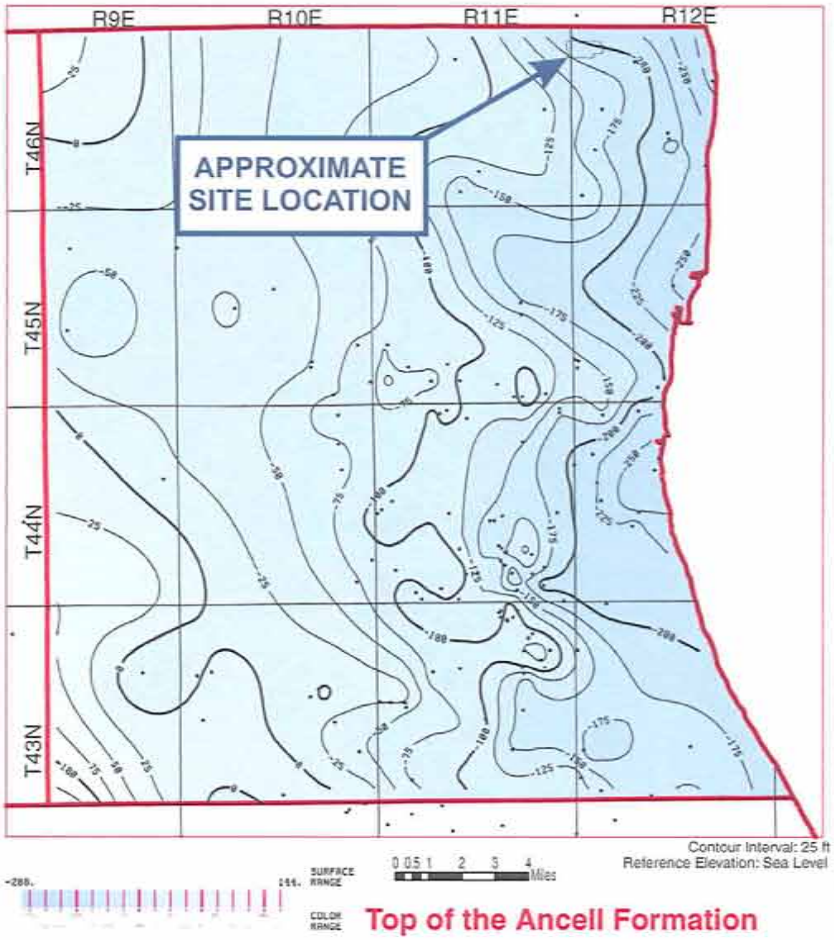
The thickness of the Ancell group, varies greatly, as the St. Peter Sandstone was deposited on an irregular erosional surface. Regional publications indicate that the thickness of the Ancell Group near the proposed site is approximately 200 to 275 feet (Willman et al., 1975, Anderson, 1919, and Leetaru et al., 2003). The top of the Ancell Group can be found approximately 200 feet below mean sea level in the vicinity of the proposed expansion (Leetaru et al., 2003). Where tapped to provide water supplies, the Ancell Group typically provides small to moderate quantities of potable water (Visocky, et al., 1985). Figure 2.2-9 illustrates the top elevation and combined thickness of the Ancell, Franconia, Eminence and Potosi units in Lake County.

The Ordovician age deposits of the Galena and Platteville groups overlie the Ancell Group in the vicinity of the proposed expansion (Figure 2.2-5). The Galena and Platteville Groups, which are comprised of numerous dolomite and limestone formations of varying composition, are referred to as simply the Galena-Platteville Group or Galena-Platteville Dolomite within this report. In the vicinity of the proposed site, several formations of the Galena-Platteville Group are present. These include the Pecatonica, Mifflin, Grand Detour, Nachusa, Quimbys Mill, Spechts Ferry, Guttenberg, Dunleith, Wise Lake, and Dubuque Formations.

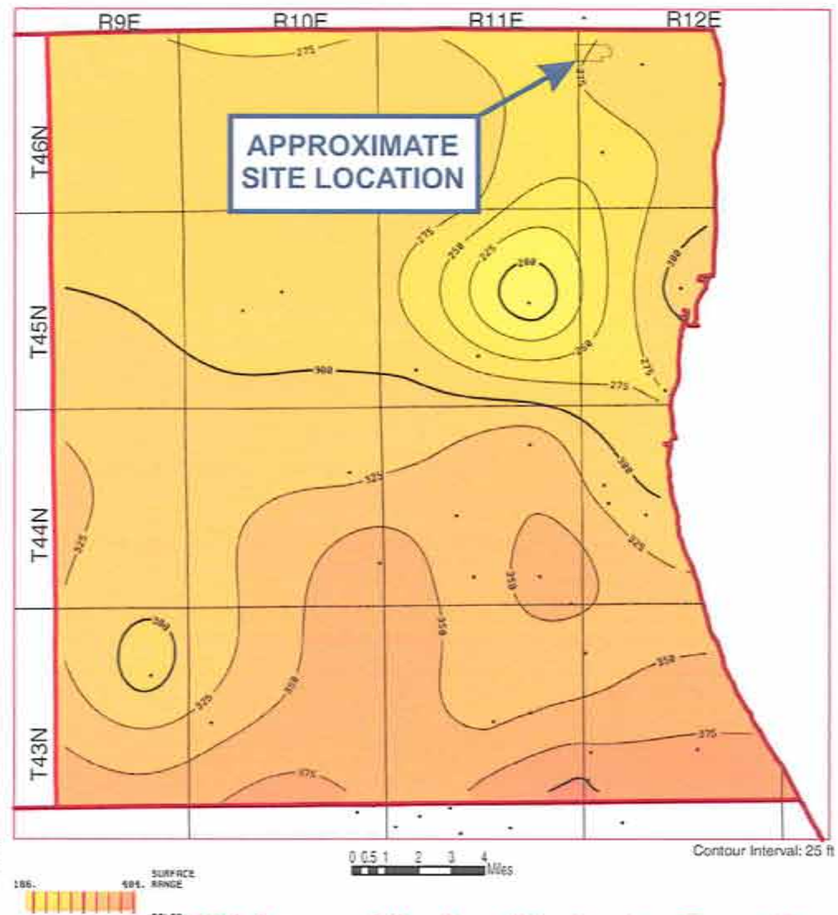
The Pecatonica Formation is the basal unit in the Galena-Platteville Group and is characterized by brown, relatively pure, cherty dolomite. The Mifflin Formation consists of gray very fine grained to lithographic limestone or fine grained dolomite in thin wavy beds separated by beds of shale. The Grand Detour Formation varies laterally from medium grained dolomite to lithographic limestone and vertically from pure to argillaceous and shaley. The Nachusa Formation is a light gray, medium-grained, vuggy dolomite or lithographic limestone. The Quimbys Mill Formation consists of medium to thin-bedded argillaceous to shaley limestone or dolomite. The Spechts Ferry Formation is dominantly shale, containing thin beds of limestone and bentonite. The Guttenberg Formation consists of thin-bedded fine grained limestone interbedded with brown-red shale. The Dunleith Formation is slightly argillaceous, thin to medium bedded mostly cherty dolomite with a gray to light brown appearance. The Wise Lake Formation is pure light brown vesicular to vuggy dolomite. The Dubuque Formation is a light brownish gray to buff, fine grained dolomite that is strongly argillaceous and is characterized by well defined, flat bedding (Willman, 1978). The Galena-Platteville Dolomite has been found to be greater than 300 feet thick in the vicinity of the proposed expansion with a surface elevation of approximately 100 feet above mean sea level (Leetaru et al., 2003). Figure 2.2-10 illustrates the top elevation of the Galena Group and the thickness of the combined interval of the Galena and Platteville Groups in Lake County.

The Galena-Platteville Dolomite is unconformably overlain by the Maquoketa Shale Group (Maquoketa Group). The Maquoketa Group consists of a lower unit comprised of predominantly shale (Scales Shale), overlain by a middle limestone (Fort Atkinson Limestone), and two upper shales (Brainard Shale and Neda Formation). The Maquoketa Group is approximately 225 feet thick in the vicinity of the proposed expansion and has a surface elevation of approximately 325 feet above mean sea level (Leetaru et al., 2003). Figure 2.2-11 illustrates the top elevation and thickness of the Maquoketa Group in Lake County.

In Lake County, the Silurian dolomite lies unconformably above the Maquoketa Group and directly beneath the glacial drift. It has been subdivided into the Niagaran Series and the underlying Alexandrian Series. In the area of the site, the Silurian dolomite is approximately 200 feet thick with an approximate elevation of 525 feet above mean sea level (Leetaru et al., 2003). It is extremely argillaceous, silty, and cherty to exceptionally pure dolomite. The upper portion of the dolomite has numerous fractures, crevices, and solution cavities. Figure 2.2-12 illustrates the top elevation and thickness of the Silurian dolomite in Lake County.



Top of the Ancell Formation



Thickness of the Ancell to Ironton Formations

Figure adapted from ISGS Open File Series 2003-12

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HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-9
ELEVATION OF ANCELL FORMATION AND THICKNESS OF THE ANCELL, FRANCONIA, POTOSI, AND EMINENCE UNITS IN LAKE COUNTY

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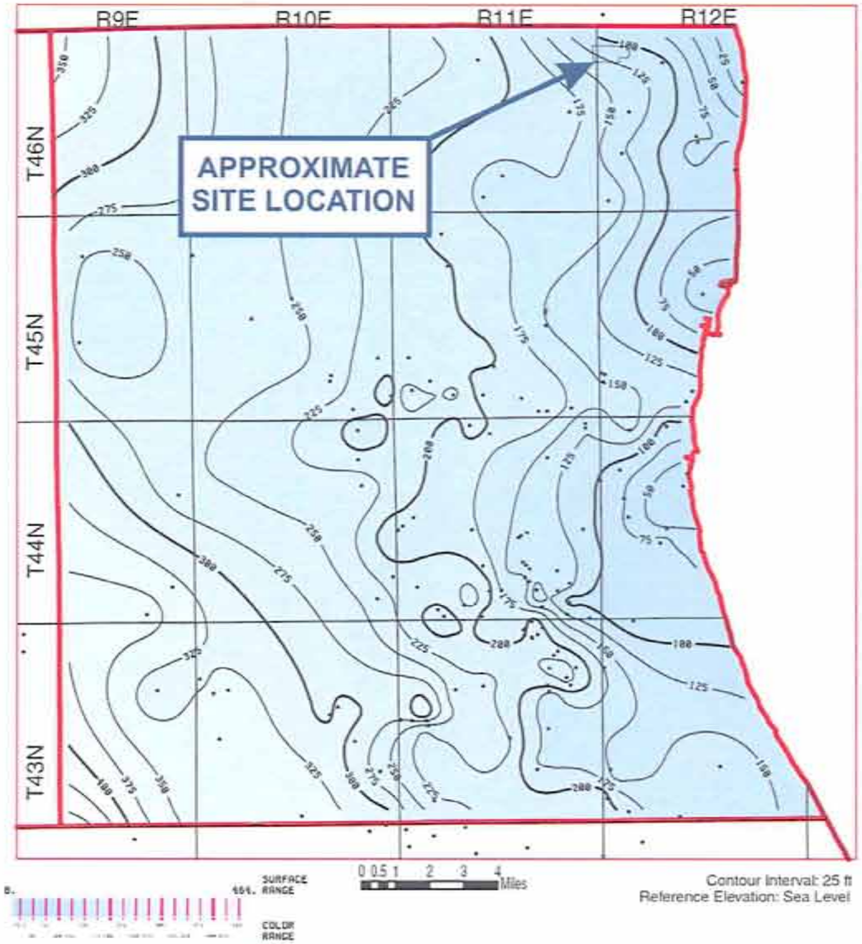
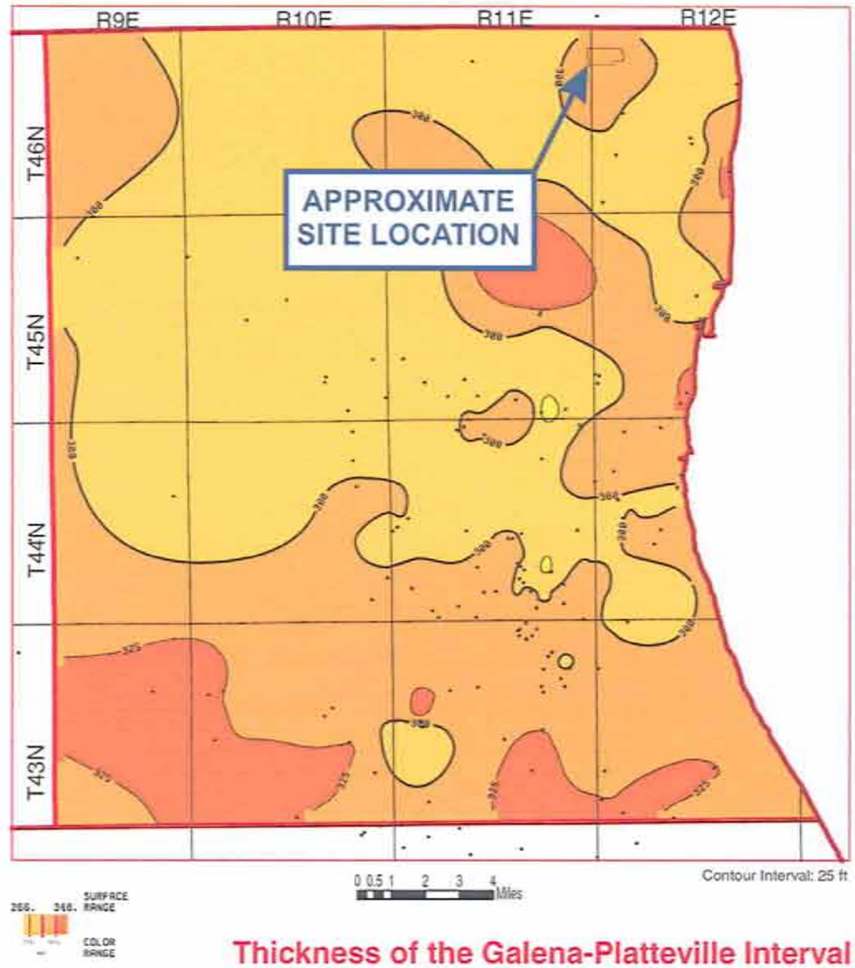


Top of the Galena Limestone



Thickness of the Galena-Platteville Interval

Figure adapted from ISGS Open File Series 2003-12

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-10
ELEVATION AND THICKNESS OF THE GALENA-PLATTEVILLE DOLOMITE IN LAKE COUNTY

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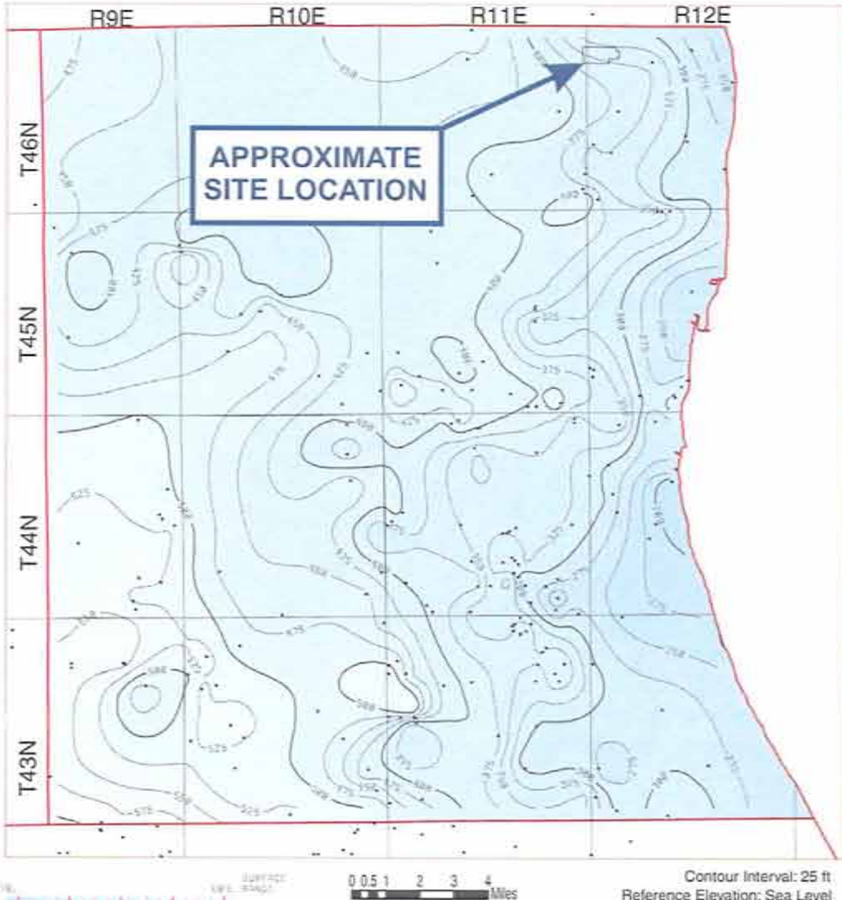
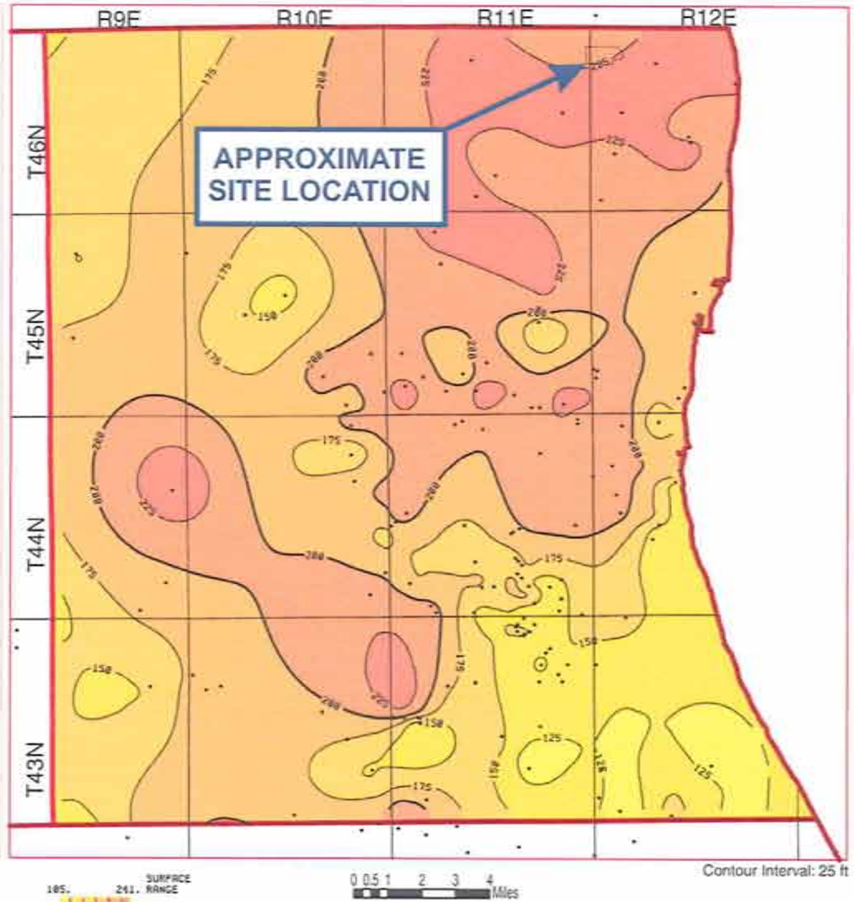


Top of the Maquoketa Formation



Thickness of the Maquoketa Formation

Figure adapted from ISGS Open File Series 2003-12

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-11
ELEVATION AND THICKNESS OF THE MAQUOKETA FORMATION IN LAKE COUNTY

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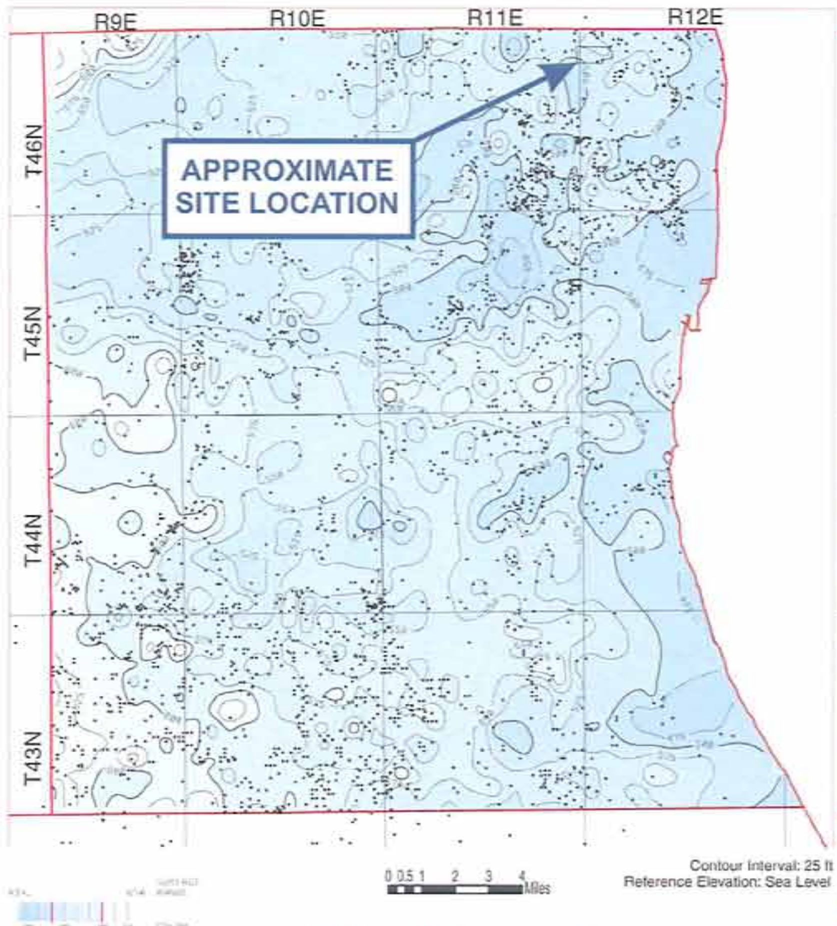
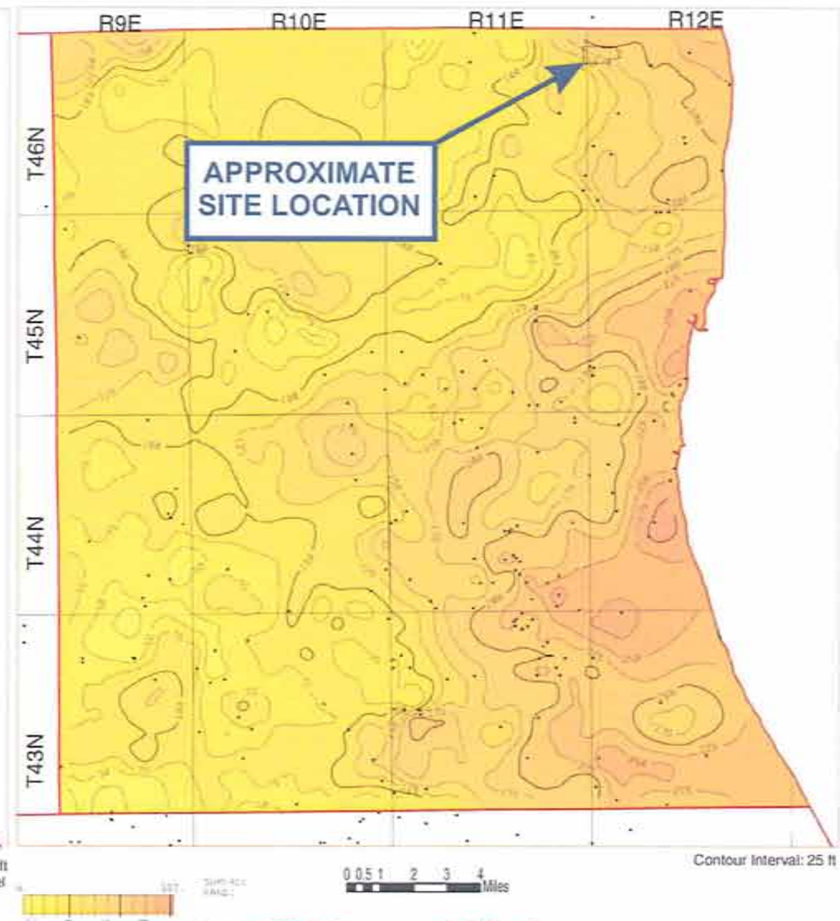


Bedrock Topography



Thickness of Silurian

Figure adapted from ISGS Open File Series 2003-12

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-12
BEDROCK TOPOGRAPHY AND THICKNESS OF THE SILURIAN DOLOMITE IN LAKE COUNTY

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Regional Bedrock Topography

As is illustrated in Figure 2.2-13, the bedrock surface in northern Illinois is an undulating plane on which valleys have been incised by glacial and pre-glacial erosion. Figure 2.2-13 reveals a system of valleys which have been carved deep into the bedrock surface. These bedrock valleys were carved by the fluvial processes of the ancient Rock, Sugar, Pecatonica, and Troy Rivers. Figure 2.2-12 illustrates the bedrock surface in Lake County, Illinois. In the vicinity of the site, the bedrock surface is greater than 200 feet below ground surface at an approximate elevation of 530 feet above mean sea level.

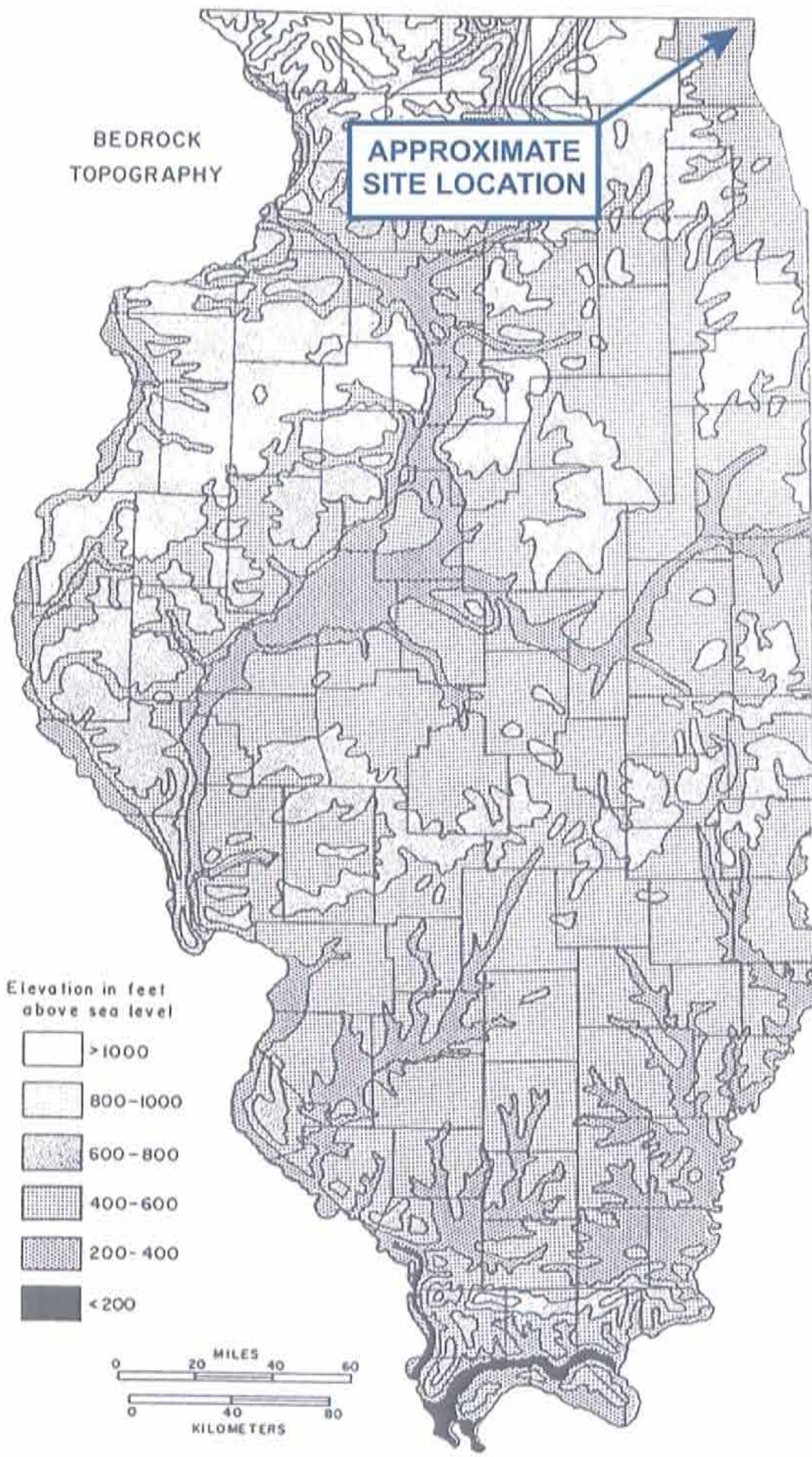
Regional Bedrock Structural Features

The predominant structural feature which has influenced the regional bedrock in the northeastern Illinois region, in addition to glacial action and fluvial processes, is the Wisconsin Arch. This feature is a broad positive area which separates the Michigan Basin on the east from the Forest City Basin on the West. To the southeast, this arch connects with the Kankakee Arch which runs between the Michigan and Illinois Basins (Figure 2.2-14).

Seismic Risk

Earthquakes are formed when the stresses within the bedrock reach a point at which rupture or breakage of bedrock occurs. This breakage releases a significant amount of energy that is known as an earthquake. The proposed site is located in a low seismic impact zone. Over the last 200 years, the nearest area of major seismic activity is the New Madrid Seismic Zone along the Mississippi River Valley in southeastern Missouri and western Tennessee. In 1811 and 1812, earthquakes with magnitudes of VIII or greater on the Mercalli scale shook the Mississippi Valley. The zone is continuously active with hundreds of tremors recorded each year, however, most are too small to be felt. Away from the zone, epicenters are randomly scattered in a large area. The southern one third of Illinois falls in this area.

The Wabash Valley Fault Zone near southwestern Indiana has experienced structural movement during the post-late Pennsylvanian to pre-Pleistocene time (between 1.6 and 300 million years ago) and the Sandwich Fault zone in northern Illinois has demonstrated significant movement in upper Silurian aged rocks (Nelson, 1995). The youngest rock demonstrably displaced by the Sandwich Fault Zone are of Pennsylvanian age, which ended 286 million years ago. As recently as 1999, a small earthquake was registered in Lee County near Amboy. However, this earthquake and others since Silurian time are not strong enough to displace the glacial sediments. The location of the Wabash Valley and Sandwich fault zones are shown on Figure 2.2-14.



Topography of the bedrock surface of Illinois (after Horberg, 1950a, and Willman and Frye, 1970).

Figure adapted from Willman, 1975.

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HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-13
BEDROCK TOPOGRAPHY OF ILLINOIS

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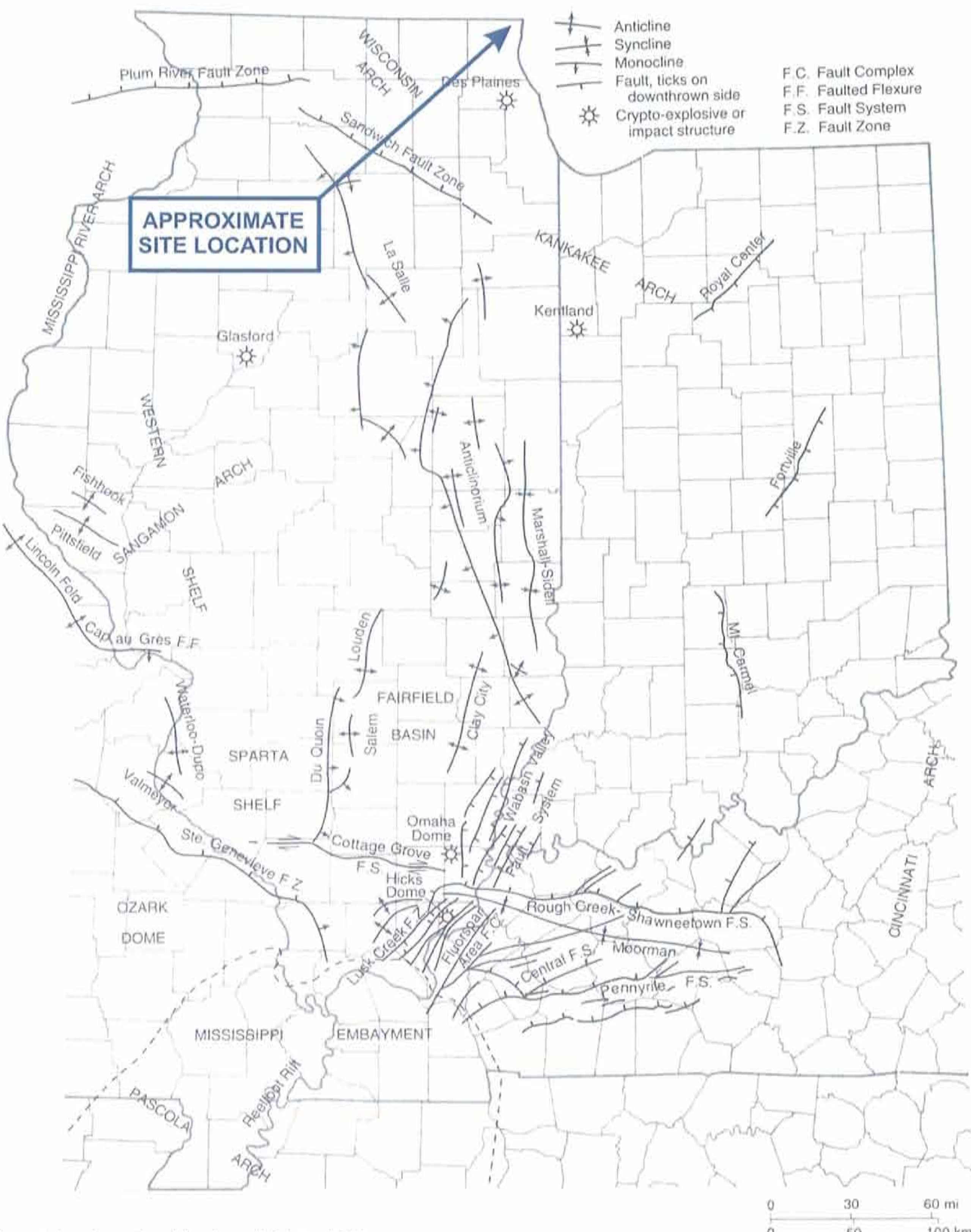

Figure taken from Buschbach and Kolata, 1991.

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FIGURE 2.2-14
STRUCTURAL FEATURES IN ILLINOIS

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Southeastern Wisconsin also has some documented faults. As summarized by Kammerer, et al. (1998), faults extend from Wiota (Lafayette County) to Milton (Rock County) and from east of Dodgeville (Iowa County) to Waukesha (Waukesha County). Per an article obtained through the Wisconsin Groundwater Association (Trotta, 2007), the Wiota to Milton Fault has little offset in Lafayette and Green County but about 80 feet of offset near Milton. Kammerer, et al. indicate that the eastern end of the long east-west fault from east of Dodgeville to Waukesha intersects an additional fault which extends to the northwest and one which crosses from the southwest to the northeast. Trotta (2007) further documents those faults and a series of faults associated with the fault running from east of Dodgeville to Waukesha in the area of the Yahara Hills Golf Course which is approximately halfway across the east-west trending fault. The main fault in the Yahara Hills area has about 80 feet of offset but has up to 200 feet of offset south of Fitchburg. Associated faults in the Yahara Hills Area are documented to have up to 400 feet of offset. The Waukesha Fault documented by Kammerer, et al. and Trotta has been more recently studied (Sverdrup, et al., 1997) through the use of gravity data. The results of the gravity survey indicate that the Waukesha fault actually extends from approximately 2 miles south of Eagle northwest at least to Port Washington. Of these Wisconsin faults, the Waukesha Fault is the closest to the proposed expansion site at approximately 40 miles away.

The proposed Site 2 East Expansion is located in an area that has a 90% probability of not exceeding a horizontal acceleration of 0.0629 g in 250 years (Refer to Figure 2.2-15). USEPA landfill locational criteria with respect to seismic sensitivity indicates that landfills are not to be located in seismically active zones characterized by an area with a 90% probability of exceeding 0.1 g in 250 years unless all containment structures are designed to withstand the maximum horizontal acceleration for the site. Figure 2.2-15 indicates that the Facility is not within a defined seismic impact zone. However, a seismic analysis of the Site 2 East Expansion has been conducted, which is discussed in further detail within the Design Report (Section 2.3).

Unconsolidated Deposits

The Pleistocene Epoch marked the advance and retreat of four major recognized glaciations in Illinois. These glaciations, from oldest to youngest, are known as the Nebraskan, Kansan, Illinoisan, and Wisconsinan. All four of the glacial periods have greatly modified the landscape they covered.

Unconsolidated materials and several feet of bedrock were eroded, transported, and redeposited near the ice margins. The Pleistocene deposits in Illinois display a wide range of lithologies, varying from bouldery glacial tills, well sorted silts, and fine grained lacustrine clays. Figure 2.2-16 shows the distribution of Quaternary deposits in Illinois. Figure 2.2-17 illustrates the distribution of Quaternary deposits within the vicinity of the site and Figure 2.2-18 shows a regional cross section depicting the relationships between quaternary deposits and bedrock in the region.

Glacial deposits strongly reflect their mode of origin and source area. Glacial regimen changes based on temperature and thickness of the ice, the rate of ice flow, and the manner in which the ice disappeared (Willman et al., 1975). Figure 2.2-17 illustrates the location of various glacial units that have been deposited in the vicinity of the site. As illustrated in Figure 2.2-18, glacial deposits in the vicinity of the site are generally more than 200 feet thick.

USGS

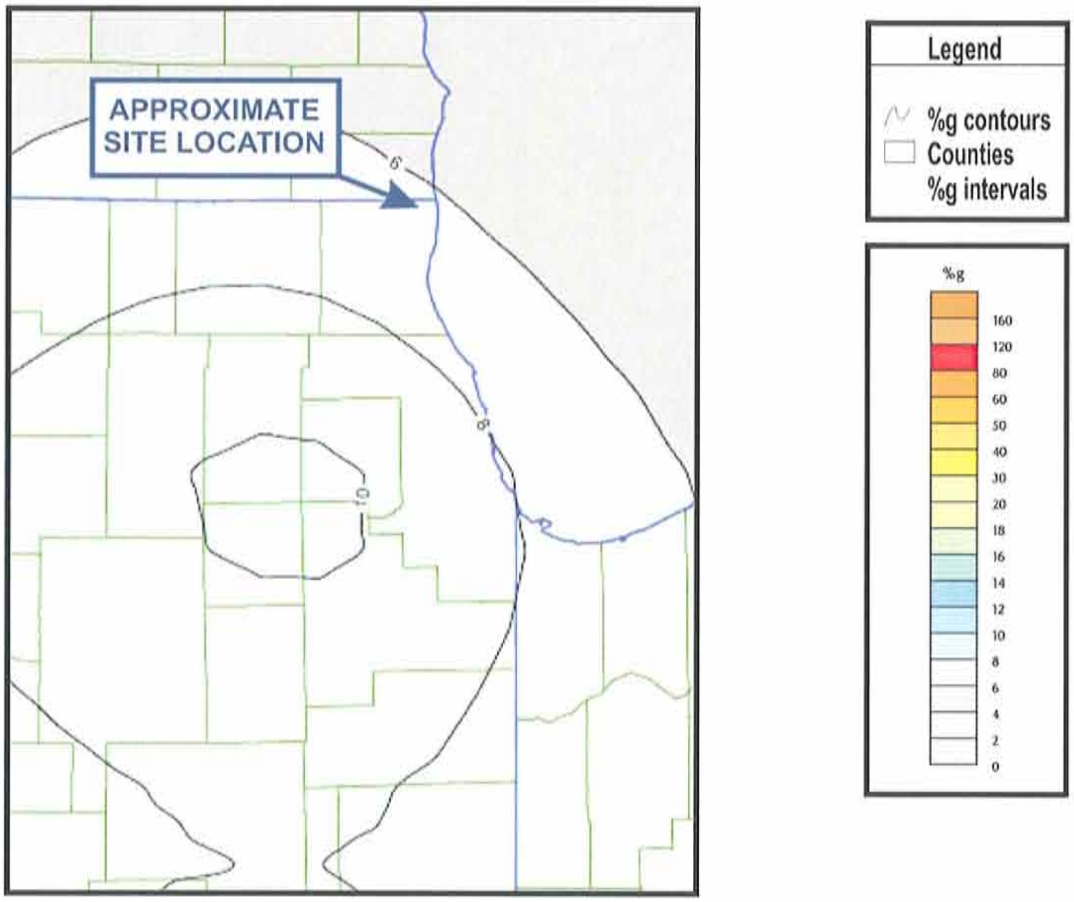
Earthquake Hazards Program

LOCATION	**42.48 Lat.**	**-87.87 Long.**

The interpolated Probabilistic ground motion values, in %g, at the requested point are:

	10%PE in 50 yr	**2%PE in 50 yr (equivalent to 10% in 250 years)**
PGA	**2.04**	**6.29 (equivalent to 0.0629g)**
0.2 sec SA	**4.55**	**13.10**
1.0 sec SA	**1.94**	**5.09**

\- -



Peak Horizontal Acceleration (%g) with 2% Probability of Exceedance in 50 Years. Information taken from the United States Geological Survey website.

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	FIGURE 2.2-15 MAP OF HORIZONTAL ACCELERATION	
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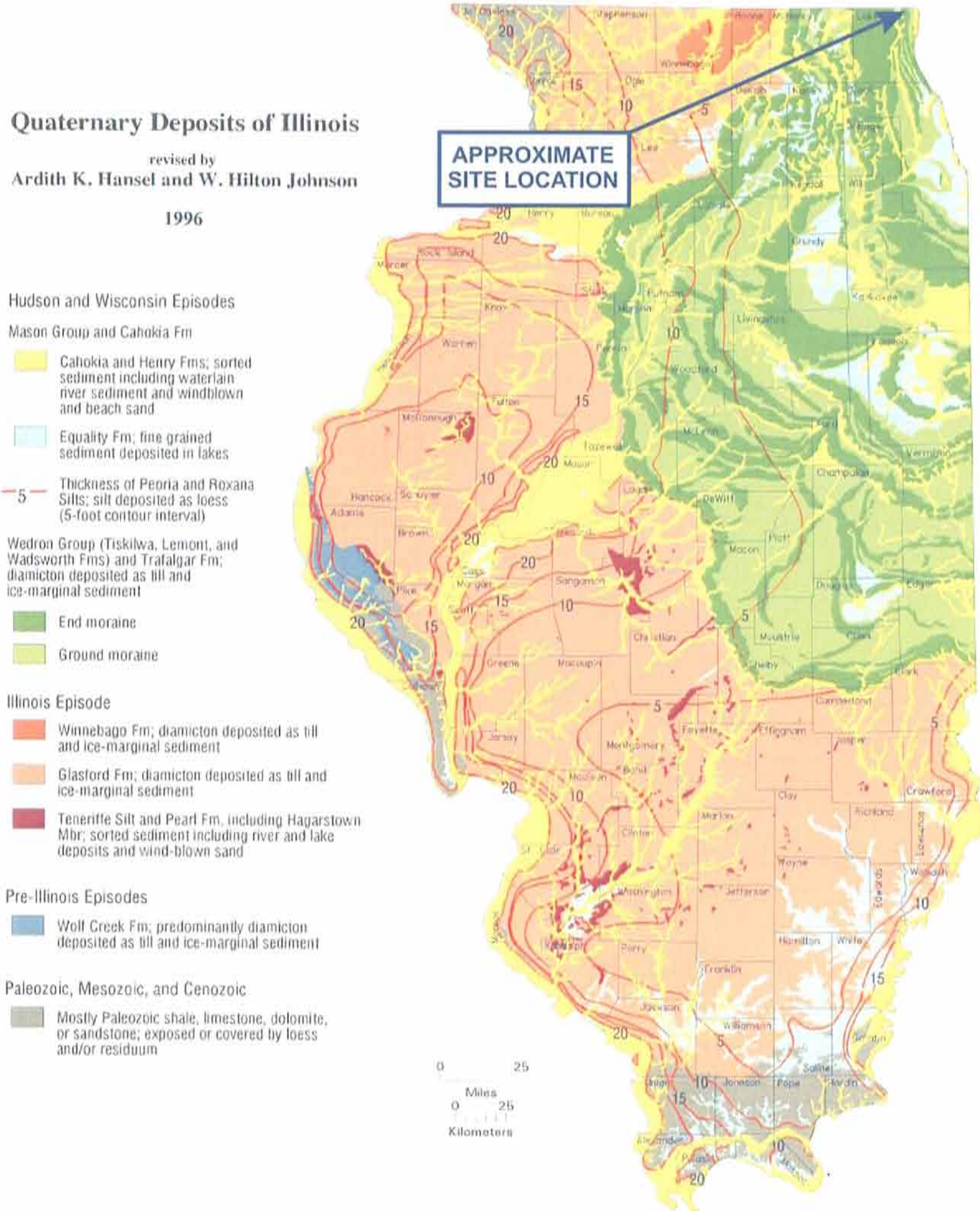

Figure adapted from Hansel and Johnson, 1996.

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-16
QUATERNARY DEPOSITS OF ILLINOIS

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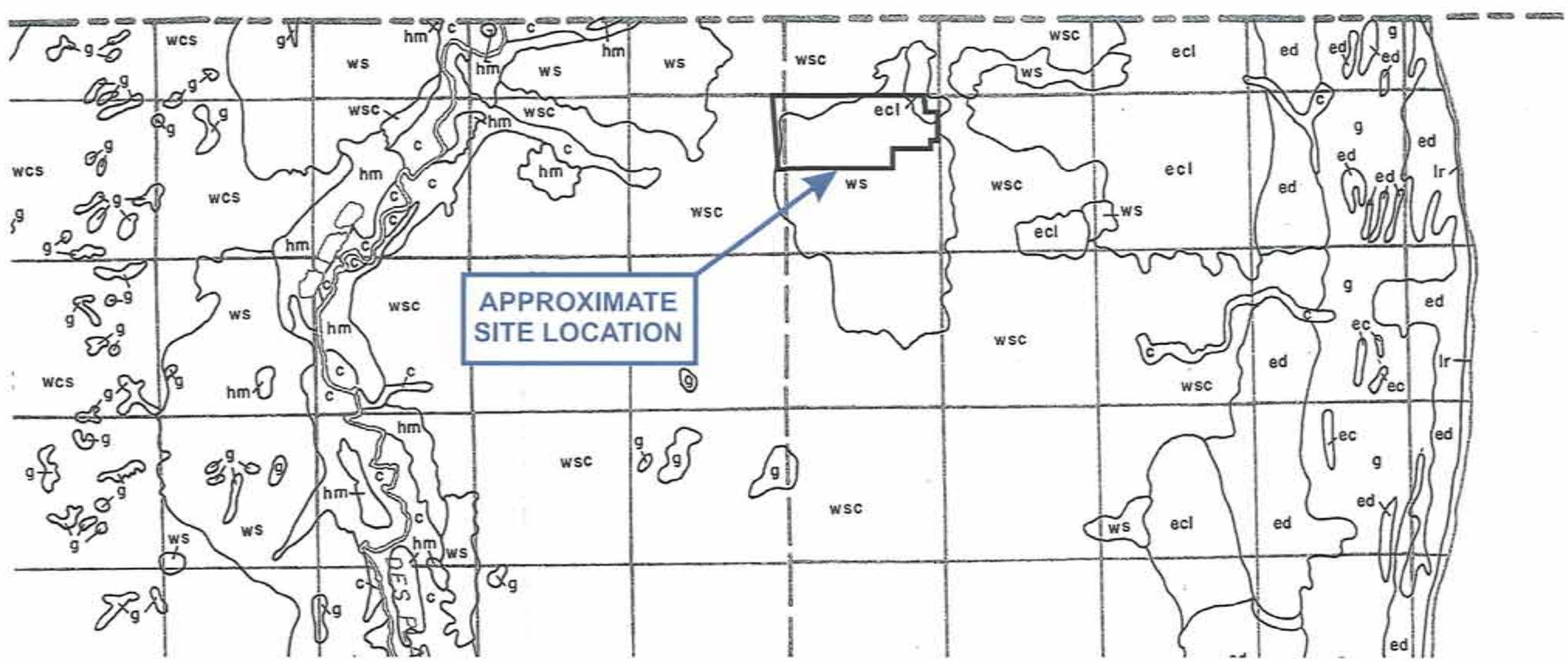

KEY TO MATERIALS

Peat and muck
g = peat and muck

Clay and silt
ec = lacustrine silt and clay
ecl = silt, fine sand, and clay; less than 10 feet thick; over scoured till

Clay, silty, pebbly—glacial till
wc = clay, pebbly (till), with associated lacustrine deposits; olive brown to gray
wsc = clay, silty, pebbly (till); olive yellow to olive brown to gray
wcs = silt, pebbly, locally clayey (till); yellow brown to gray brown
ws = silt, clayey, pebbly, locally sandy (till); brownish yellow

Silt and sand, poorly sorted
c = alluvium

Sand, locally containing some clay, silt, and rubbish
m = made land

Sand, medium-grained, and sandy gravel
ed = beach and shore deposits
lr = beach deposits immediately along present Lake Michigan shore

Sand, gravel, and silt
hw = sand, silt, and some gravel
hb = gravel, fine-grained; sand; and silt
hm = sand and gravel in valleys
hww = sand and gravel in hills

Figure adapted from ISGS Circular 481 - Plate 1 (Larsen, 1973)

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-17
SURFICIAL DEPOSITS IN THE VICINITY OF THE SITE

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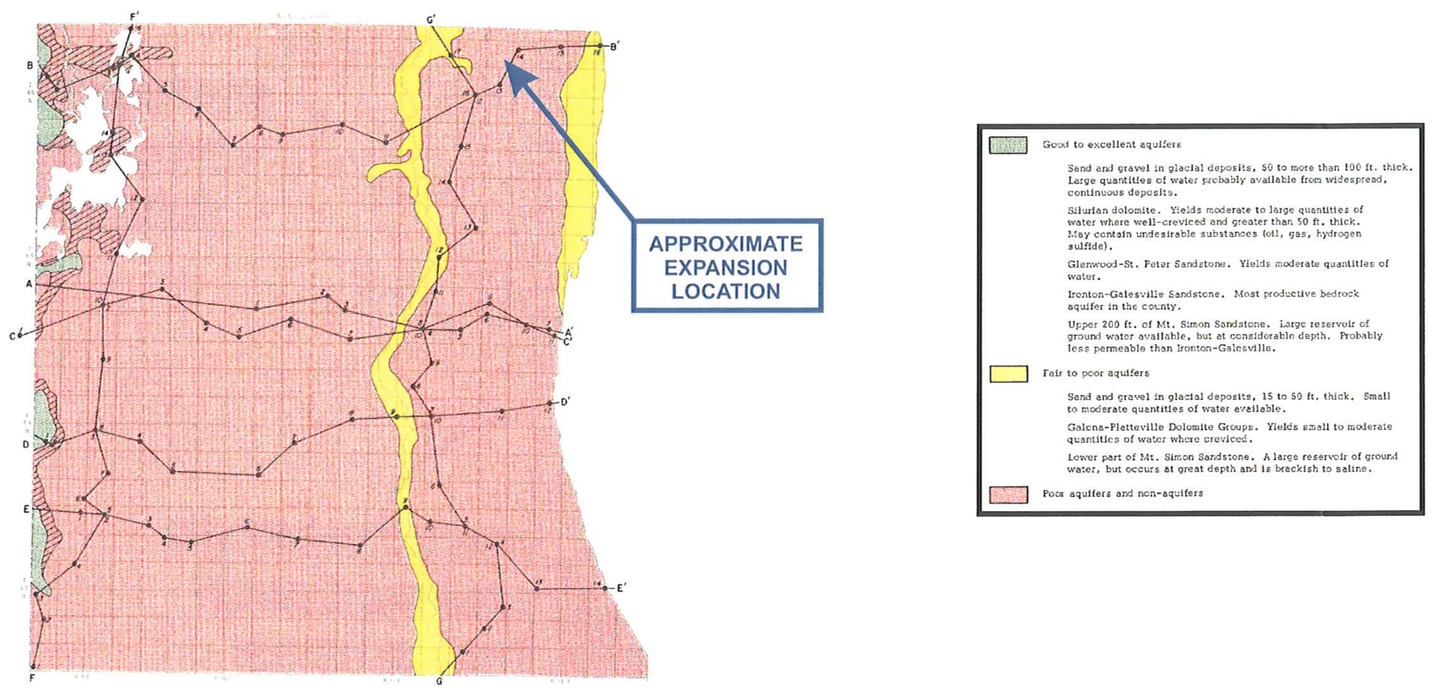

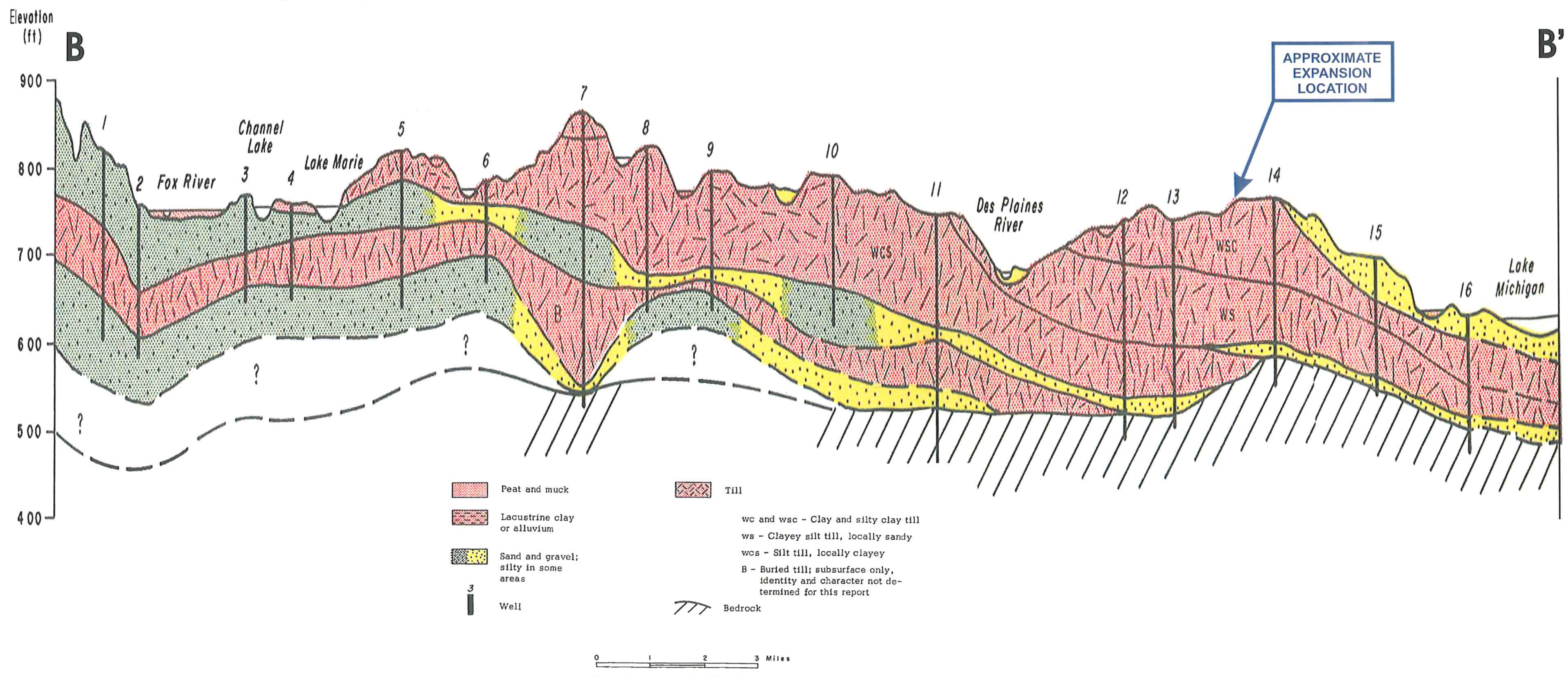

Figure adapted from Larsen (1973)

ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-18
REGIONAL CROSS SECTION

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APPROVED BY: MNF

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The proposed Site 2 East Expansion is located in an area where several Wisconsin aged moraines merged or overlapped. Although it is likely that many advances and retreats of glacial ice occurred in the vicinity of the site, only evidence of the most recent glacial advances remains. Figure 2.2-19 illustrates the location of moraines in Lake County.

Multiple minor advances and retreats have been theorized to explain the remaining unconsolidated deposits in the vicinity of the proposed expansion. The silt, sand, and gravel zone which lies directly above the bedrock (Basal Drift) was deposited by the advance and retreat of a glacier which had moved into the area across the bedrock surface. As the glacier retreated, outwash from the melting glacier formed the Basal Drift deposit. After the deposition of the Basal Drift, multiple cycles of glacial ice advance, retreat, and re-advance, resulted in the deposition of the Lower Till above the Basal Drift. Due to the homogeneity of the Lower Till, it is likely that cycling of the same glacier caused deposition of these materials.

The presence of lacustrine deposits beneath and within the Lower Till is an indicator that during the periods of glacial retreat, lakes formed between the retreating ice to the east and older moraines to the west. During the last retreat of the glacier which deposited the Lower Till, outwash from the retreating glacier deposited the silt, sand, and gravel deposits above the Lower Till. These deposits are referred to as the Shallow Drift throughout this report.

Advancement of another glacier ultimately deposited the succession of clayey glacial till of the Wadsworth Formation (Wedron Group) above the Shallow Drift. It is likely that some erosion of the Shallow Drift took place during the advancement of this glacial event.

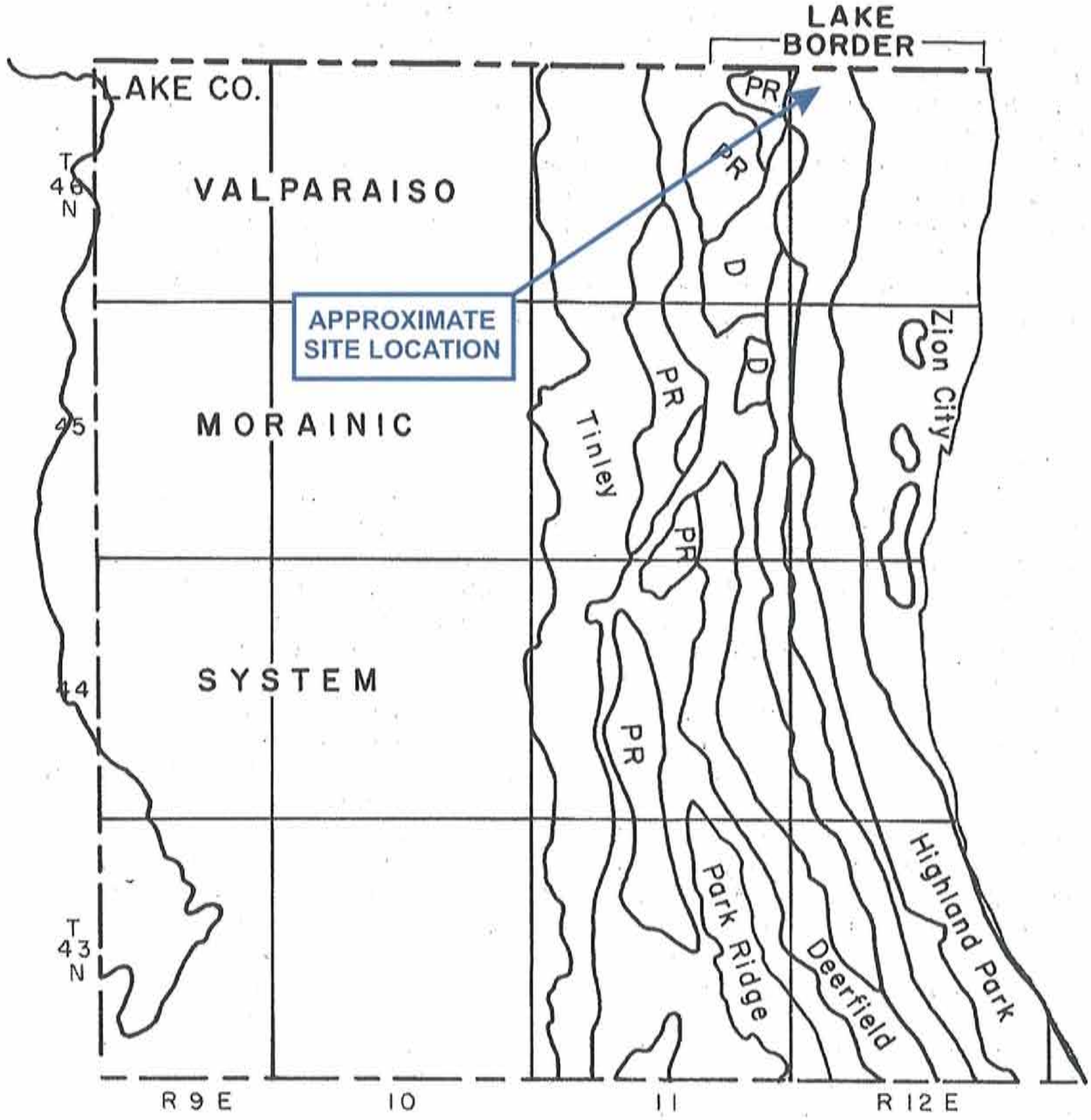
The Wisconsin Age Wadsworth Formation is a distinct gray clay-rich lithostratigraphic unit that consists of calcareous, gray, fine textured diamicton that contains lenses of sorted and stratified sediment (Hansel and Johnson, 1996).

Holocene, or recent deposits overlie all of the above mentioned deposits in the vicinity of the site. The Holocene deposits which are mainly referred to as the Peoria Silt consist of a light yellow tan to gray silt that grades from sandy silt to clayey silt. In some areas it may contain beds of well-sorted (eolian) sand, fossil and snail shells, organic debris, wood, and rarely clay layers (Hansel and Johnson, 1996). Other Holocene deposits, including beach and shore deposits of the Lake Michigan Member (Ravinia Formation) along Lake Michigan and areas of peat and muck of the Grayslake Peat Formation can be found throughout the region (Figure 2.2-17).

Other Wisconsin age glacial units are present in Lake County including the Haeger Member of the Lemont Formation on the far western edge of the County and the glacial outwash deposits of the Henry Formation which are found at the ground surface in the northeastern portion of the County and inter-tongued with the Wisconsin age glacial tills.

Regional Groundwater Resources

There are four aquigroups identfied in the vicinity of the site. They are the Basal Bedrock, Midwest Bedrock, Upper Bedrock, and Prairie Aquigroups, as illustrated in Figure 2.2-5. The Basal Bedrock Aquigroup is composed of the Elmhurst-Mt. Simon Aquifer. The Midwest Bedrock Aquigroup contains the Ironton-Galesville, Ancell, and Galena-Platteville dolomite aquifers. The Upper Bedrock Aquigroup is composed of the Silurian Dolomite, and the Prairie Aquigroup contains aquifers composed of glacial outwash silt, sand, and gravel deposits (Visocky, 1985).



MORAINES DISPLAYED ON MAP

TINLEY
PARK RIDGE (PR)
DEERFIELD (D)
HIGHLAND PARK
ZION CITY

Adapted from Larsen 1973.

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ZION LANDFILL SITE 2 EAST EXPANSION
HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-19
MORAINES IN LAKE COUNTY

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Bedrock Groundwater Resources

The Elmhurst - Mt. Simon Aquifer includes productive sandstone aquifers below thick, regionally extensive shale of the Eau Claire Formation. The sandstone of the Elmhurst - Mt. Simon Aquifer lies unconformably above Cambrian granite and can be greater than 1,500 feet thick in Lake County (Visocky, 1985).

The Ironton-Galesville Aquifer system is comprised of the Galesville and Ironton Sandstones. The Galesville Sandstone is fine-grained, well-sorted sandstone, essentially free from shale and glauconite, whereas the Ironton is medium-grained, generally poorly-sorted, dolomitic sandstone. Both sandstones occur throughout the northern half of Illinois and lie above the shale deposits of the Eau Claire Formation and beneath the glauconitic, argillaceous sandstone of the Fraconia Formation. The aquifer system is approximately 150 ft. thick in the vicinity of the proposed expansion (Visocky, 1985).

The St. Peter Sandstone of the Ancell Aquifer is a relatively pure and very fine to coarse grained sandstone present across most of Illinois. The St. Peter Sandstone is situated directly beneath the Platteville Group carbonates and unconformably overlying uneroded carbonates of the Knox Megagroup. Where tapped to provide water supplies, the Ancell Group typically provides small to moderate quantities of potable water (Visocky, et al., 1985).

Groundwater obtained from the Galena-Platteville dolomite is less highly mineralized than in deeper bedrock formations. However, the transmissivity of this formation is dependent upon the degree of interconnectedness of fractures through which groundwater migrates. As the nature of the fractures is highly variable from one location to another, the quantity of water obtainable from this formation is variable.

The Silurian Dolomite is commonly tapped for domestic water wells in the vicinity of the proposed expansion. It is separated from the underlying Galena-Platteville dolomite by the Maquoketa Shale. The upper third of the Silurian Dolomite is the most productive part because numerous fractures, crevices, and solution cavities occur there. The greater the number of such openings intersected in the well bore, the higher the well yield. However, it should be noted that in many areas, the water quality of the Silurian dolomite is adversely affected by the presence of naturally occurring gas, oil, and hydrogen sulfide.

The Elmhurst-Mt. Simon Sandstone, the Ironton-Galesville Sandstone, and the St. Peter Sandstone (Ancell Group) are found throughout northeastern Illinois and furnish large quantities of water to the cities, villages, and industries of this region. In Lake County, domestic water wells which tap bedrock are primarily screened within the St. Peter Sandstone, Galena-Platteville Dolomite, or Silurian age dolomites. In the vicinity of the site, most wells which utilize the bedrock for a drinking water source are screened within the Silurian dolomite. This is primarily due to its relatively shallow depth and lower well installation and maintenance costs. The deeper aquifers are used only for larger municipal and industrial water supplies because construction and maintenance costs are high (Berg, et al., 1984).

Surficial and Glacial Deposit Groundwater Resources

The other major sources of water supply in the vicinity of the site are surface water bodies (Lake Michigan), aquifers located within the glacial drift (Shallow Drift Aquifer), and aquifers located below the glacial drift connected with the bedrock surface (Basal Drift Aquifer).

Lake Michigan serves as the primary surficial source of community water supply within the site region. The City of Zion, began purchasing water from the Zion-Benton Treatment Plant (Lake County Public Water District) in 1957.

The silt, sand, and gravel deposits of the Shallow Drift and Basal Drift Aquifers (Prairie Aquigroup) are utilized by many of those nearby residents which do not have access to water from the Lake County Public Water District (Lake Michigan). Generally these shallow deposits are preferable over deeper bedrock formations in the area due to the lower cost of construction and lower mineralization than the deeper aquifers. Although, it should be noted that in some cases, those wells which pull water from the Basal Drift Aquifer also utilize the upper portion of the Silurian Dolomite.

Discontinuous silt, sand, and gravel deposits which are contained within the Wadsworth Formation and Lower Till (Intra-Till Sediments) do not generally exhibit sufficient yield to serve as a water source. This is clearly illustrated through site-specific data that has been collected and through analysis of regional water well logs. Only 5 of the 281 well logs that were obtained from within 1 mile of the proposed expansion appear to indicate that the well is screened within a zone above the Shallow Drift Aquifer.

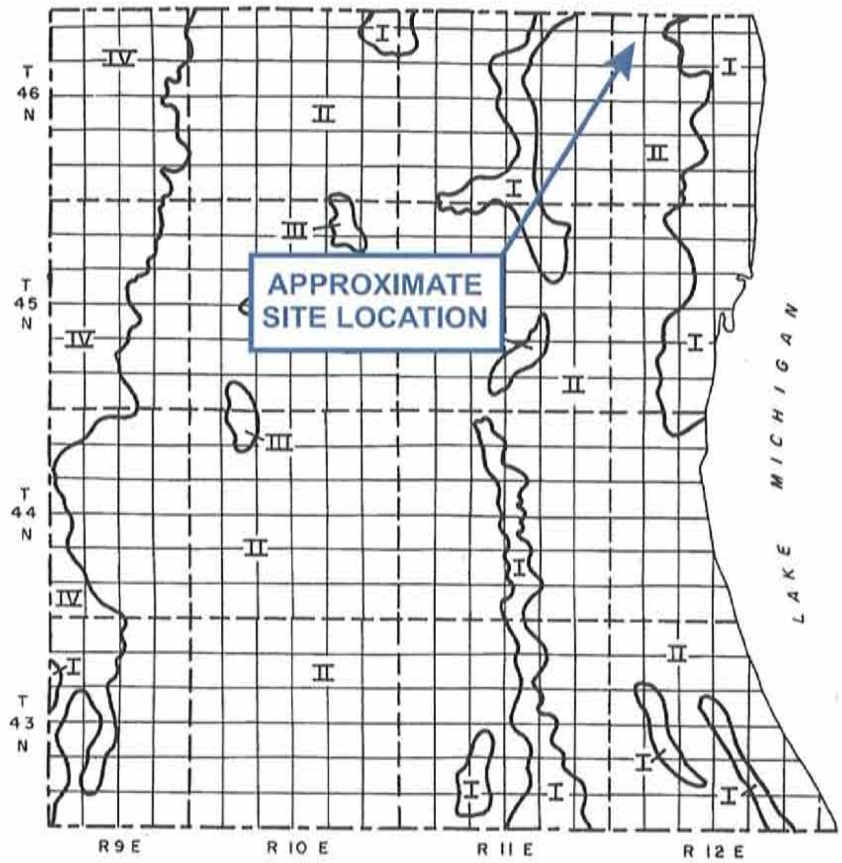
Aquifer Sensitivity

The publication "Geology for Planning in Lake County, Illinois," (Larsen, 1973) states that, "Suitable sites for solid-waste disposal may be found in the widespread morainic uplands of the county, where the relatively fine-grained surficial materials naturally re-strict the movement of pollutants." Figure 2.2-20 illustrates the surficial materials of Lake County which have been differentiated by Larsen on the basis of their properties related to waste disposal. As can be seen in Figure 2.2-20, the proposed expansion site is located in an area which has been identified as being geologically optimal for the development of a landfill within Lake County.

In 1984, Berg et. al. created another map which classified the area on a basis of potential for contamination of shallow aquifers from land burial of municipal wastes. The map created by Berg et al., (Refer to Figure 2.2-21) indicates that the site is in an area designated as category "E", exhibiting the lowest potential for aquifer contamination within Lake County. It should also be noted that Category "E" indicates that the area is one of the best locations in the State of Illinois for land burial of municipal waste.

Site Specific Hydrogeologic Investigation

Throughout the history of the Veolia E.S. Zion Landfill, numerous subsurface investigations have been performed within,and surrounding the various landfill units. With the exception of site-wide potentiometric maps and some previously created cross-sections (adapted from a 1995 hydrogeologic investigation report for the site) that have been provided to supplement this report, all site-specific geological conditions discussed herein were derived from the evaluation of continuously sampled borings located within or near the vertical and horizontal expansion area. Table 2.2-2 lists those continuously sampled borings which were used for construction of new geologic cross-sections through the horizontal expansion area, an isopach map of the Wadsworth Formation, a surface contour map of the Shallow Drift, and/or to obtain other information presented within this discussion of site-specific geology. The location of these borings are illustrated on Drawing No. G3.



I Surficial sand, gravel, or silt, 5–40 ft. thick, overlying till
II Silty clay till, silt till, or clay till, 40–80 ft. thick
III Fine sand, silt, or gravel, 10–20 ft. thick, overlying till
IV Coarse sand and gravel, some silt, up to 100 ft. thick

Area I "Dissolved substances migrating from landfills tend to move laterally with the ground water through the relatively permeable surficial deposits and downward into the underlying till."

Area II "In most of Area II, there is not much danger of polluting groundwater resources by the disposal of solid wastes although pollution of surface water is possible. Most of the dissolved substances migrating into the subsurface would move downward through the till and be attenuated to low levels within short distances."

Area III "Dissolved substances migrating from waste disposal activities could move with the ground water through the relatively permeable surficial materials into lakes or swamps. Hydrogeologic conditions are such that caution is necessary in planning waste-disposal activities."

Area IV "The potential to pollute groundwater through waste-disposal activities is greater in Area IV than in any other in Lake County. Waste disposal activities in Area IV should therefore be planned with care."

Figure adapted from Larsen 1973.

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-20
SURFICIAL MATERIALS OF LAKE COUNTY DIFFERENTIATED ON BASIS OF PROPERTIES RELATED TO WASTE DISPOSAL

APPROVED BY: MNF	PROJ. NO.: 122150	DATE: JULY 2009

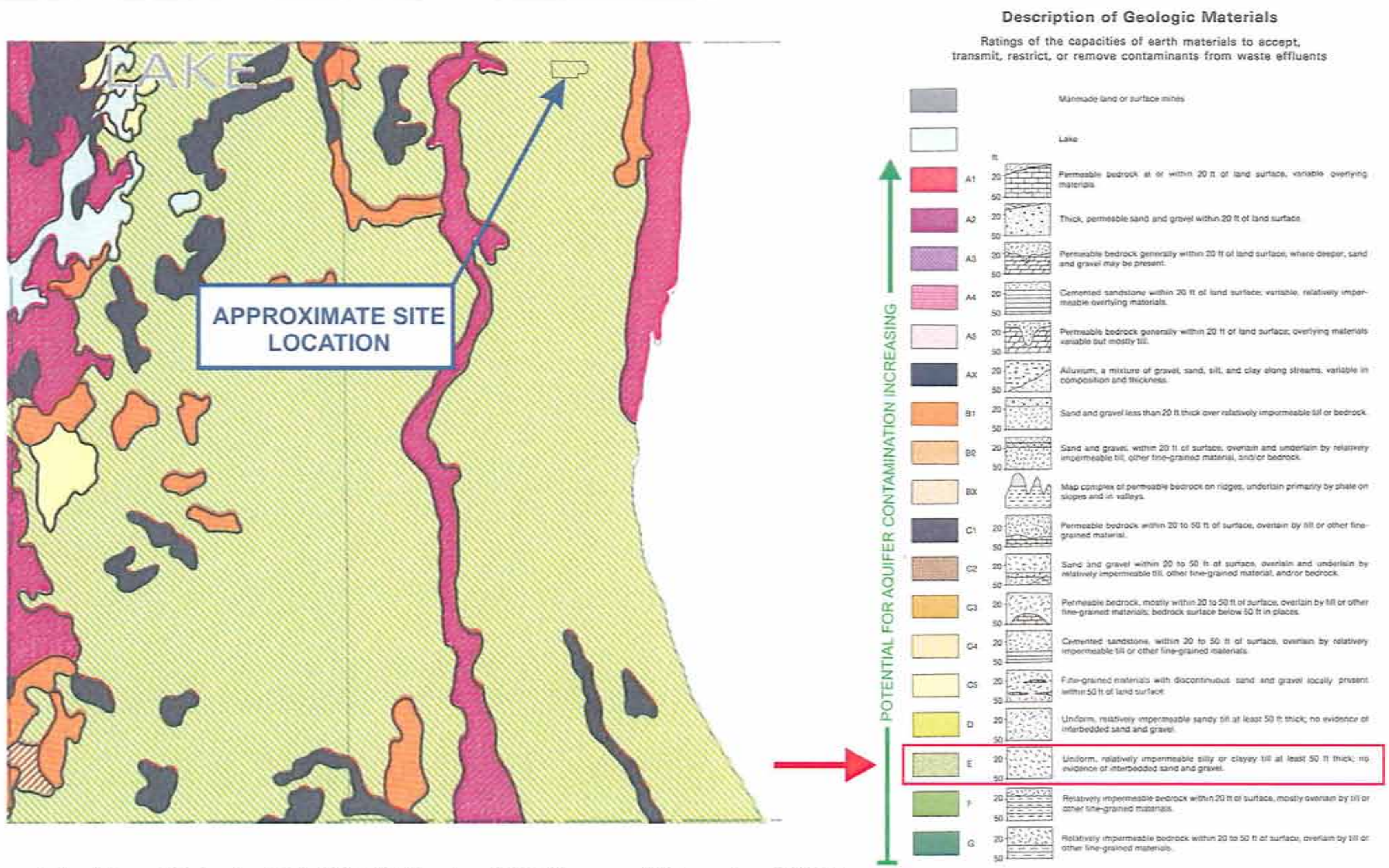

Figure modified from Plate 1 within ISGS Circular 532 (Berg and Kempton, 1984)

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ZION LANDFILL SITE 2 EAST EXPANSION HYDROGEOLOGIC INVESTIGATION

FIGURE 2.2-21
POTENTIAL FOR CONTAMINATION OF SHALLOW AQUIFERS FROM LAND BURIAL OF MUNICIPAL WASTES

APPROVED BY: MNF	PROJ. NO.: 122150	DATE: JULY 2009

TABLE 2.2-2 SUMMARY OF BORING AND MONITORING WELL/PIEZOMETER INFORMATION WITHIN OR NEAR THE PROPOSED VERTICAL AND HORIZONTAL EXPANSION AREA			
Previously Advanced Boring	**Existing Monitoring Well(s) / Piezometer(s) at Location Prior to the Most Recent Investigation**	**New Boring Advanced**	**New Monitoring Well / Piezometer Installed**
-	-	B-1-07	G170
EB-8	P-8	B-2-07	-
-	-	B-3-07	MW-3-07
TB-1	-	B-4-07	-
EB-11	-	B-5-07	-
EB-10	EP-10SR, EP-10D, and EP-10I	B-6-07	MW-6-07-D
G178	G178	B-7-07	-
-	-	B-8-07	MW-8-07
-	-	B-9-07	MW-9-07
-	-	B-10-07	G175
GK3D	-	-	-
GK4D	-	-	-
GK5D	-	-	-
GK6D	G183 (GK6D(R))	-	-
GK9D	G172 (GK9D) and GF2S (GK9S(R))	-	-
GK11D	R193	-	-
EB-2	EP-2D, EP-2I, and EP-2S(R)	-	-
EB-6/GK8D	EP-6D (GK8D), EP-6I, EP-6S, and EP-6SS	-	-
EB-7	-	-	-
EB-12	-	-	-
EB-13	-	-	-
EB-14	-	-	-
EB-15	-	-	-
EB-16	-	-	-

As shown in Table 2.2-2, ten of the continuously sampled borings (B-1-07 through B-10-07) were advanced during the most recent hydrogeological investigation. This investigation was performed in order to supplement previously collected information and to characterize the geologic and hydrogeologic characteristics beneath the proposed horizontal expansion area. During the most recent investigation five borings were advanced within 10 feet of the locations of previously advanced borings. In addition, five new borings were advanced across the horizontal expansion site. The additional sampling which was conducted at the five previously advanced boring locations was done in order to verify the geology in cases where portions of the original boring were not continuously sampled or to allow for the continuous collection of soil samples from areas below the terminus of the previously advanced boring. In addition to boring advancement, six new piezometers/monitoring wells (G170, MW-3-07, MW-6-07-D, MW-8-07, MW-9-07, and G175), were installed as summarized in Table 2.2-2. Table 2.2-2 also summarizes additional piezometers or monitoring wells which currently exist at the continuously sampled boring locations within, or near, the expansion site. The locations of all monitoring wells, piezometers, and gas probes which currently exist at the site are illustrated on Drawing No. G4. Drawing No. G5 illustrates only those existing monitoring well and landfill gas probe locations which are part of the permitted monitoring network.

All new borings have a -07 designation. The other borings from previous investigations which were used in the characterization of geology beneath the horizontal and vertical expansion areas have either an EB- or GK prefix.

The EB- borings (EB-1 through EB-16) were advanced by Testing Service Corporation in March of 1986. Initially, ten piezometers were installed at these boring locations, including: EP-2S, -2I, and -2D; EP-6SS, -6S, -6I, and -6D; and EP-10S, -10I, and -10D. The S piezometers screen glacial till, I-piezometers screen intra-till sediments, and D-piezometers screen the Shallow Drift Aquifer. Two of these shallow piezometers, EP-2S and EP-10S, were ultimately replaced with EP-2S(R) and EP-10S(R) due to ineffective seals. Only EB-1, EB-6, EB-7, EB-8, and EB-10 through EB-16 are located within or near the proposed expansion area.

The GK borings were advanced during September and October of 1989 for the purpose of installing monitoring wells for a United States Environmental Protection Agency RCRA investigation of Site 1. These wells were labeled with either an S or D suffix, where an S suffix indicates wells screened in the intra-till sediments and a D suffix indicates wells are screened in the Shallow Drift Aquifer. EP-6D, P-7 (not continuously sampled), and P-9 (not continuously sampled) installed during previous explorations were re-designated as GK8D, GK2D, and GK10D, respectively. GK1D (not located within or near the proposed horizontal expansion area) and GK6D were ultimately replaced with RGK-1(D) and GK6DR.

In April of 1990, five additional wells were installed at the request of the IEPA. These wells were GK3S, GK3D, GK4D, GK5S, and GK5D. These five wells have since been abandoned as a result of the landfill filling progression. However, information from these boring locations has been used to evaluate the site-specific geology within this report.

TB-1, which is a partially continuously sampled boring (approximately 80 feet below ground surface to bedrock), was advanced during the winter of 1992. To collect continuous samples from ground surface to 80 feet below ground surface this boring was supplemented during the most recent investigation with B-4-07 which was advanced within 10 feet of TB-1.

Boring logs and as-built diagrams from previously advanced borings and installed piezometers and monitoring wells are located in Appendix G, along with boring logs and piezometer/monitoring well as-built diagrams from the most recent investigation. The procedures used to conduct the most recent investigation activities are discussed in detail within the following sections.

Recent Hydrogeologic Investigation Methodology

Drilling and Field Procedures

All field exploration was performed by a team of experienced geologists and engineers under the direction of a Registered Professional Engineer and Licensed Professional Geologist. The borings were drilled by an experienced drilling crew using rotary drill rigs mounted on a truck or an all-terrain vehicle (ATV). The field geologists and engineers maintained daily drilling records, logged the soil samples and rock cores, selected representative samples for laboratory testing, performed field hydraulic conductivity testing, and supervised the installation of the piezometers and monitoring wells. The boring logs, as-built diagrams, IDPH well construction reports, and required borehole sealing forms are provided in Appendix G. Borings or portions of borings logged during this most recent investigation were logged according to the Unified Soil Classification System (ASTM D 2487) along with locally adapted soil description terminology, both of which are presented with the boring logs in Appendix G. It should be noted that in those cases where a supplemental boring was advanced within 10 feet of the location of a previously advanced boring, the boring log for the new boring location was created to include the logged information from the continuously sampled portions of the previously advanced boring. All original boring logs are also included in Appendix G. The results of the hydraulic conductivity testing and laboratory testing are located in Appendices H and I, respectively.

Soil Sampling

Boreholes were advanced through unconsolidated deposits using either a set of 8 inch O.D. by 4 1/4 inch I.D. hollow stem augers, a set of 8 inch O.D. by 6 1/4 inch I.D. hollow stem augers (0 to 20 feet), a 3 7/8 inch tri-cone roller bit, or a 5 7/8 inch tri-cone roller bit. Continuous sampling was conducted at each of the 10 boring locations advanced during the most recent investigation. In those borings which were drilled to collect supplemental information at locations where borings were previously advanced, continuous sampling was only conducted in those areas not previously continuously sampled. At 6 of the 10 locations, a new piezometer or monitoring well was installed within the completed continuously sampled boring. The locations of the recently advanced and previously advanced boring locations are illustrated on Drawing No. G3.

Soil samples were obtained using one of the following methods: 1) using a 5-foot split spoon driven by a CME Continuous Sample Split Spoon System, 2) driving a 2-inch O.D. standard penetration test split spoon sampler in accordance with ASTM D1586, or 3) pushing a thin-walled 3-inch diameter Shelby tube in accordance with ASTM D1587. The sample method, soil type, location, and recovery for each sample interval are shown on the boring logs located in Appendix G.

Soil samples were logged in accordance with the Unified Soil Classification System (USCS). Representative soil samples obtained using the CME Continuous Sample Split Spoon System or by the standard penetration method were placed into 8-ounce clear glass jars sealed with air-tight screw top lids. When a break in the soil stratigraphy was logged within a split spoon sample interval, the sample was split and samples above and below the break were collected. After sealing the jars, individual samples were labeled, boxed and transported for possible testing to the STS Consultants, Ltd. (STS) laboratory in Vernon Hills, Illinois.

In addition, representative samples obtained using Shelby tubes were sealed with paraffin wax, and then capped at the ends. All thin-walled Shelby tube samples were carefully transported in a vertical position to the STS laboratory for extrusion, logging, and testing. Several samples were also sent to Dirt-N-Turf in Hinckley, Illinois and Brookside Laboratories, Inc. in New Knoxville, Ohio for total cation exchange capacity testing.

Hand-held, calibrated penetrometer tests were performed in the field on cohesive samples. The test results serve as a general measure of consistency and to estimate unconfined compressive strengths.

Piezometer and Monitoring Well Installation

A total of 6 new open standpipe piezometers / monitoring wells were installed at 6 of the 10 boring locations advanced during the most recent hydrogeologic investigation. The locations of the recently installed piezometers or monitoring wells are illustrated on Drawing Nos. G3 and G4. The piezometers and monitoring wells were installed to provide long term water levels and measurement of aquifer characteristics.

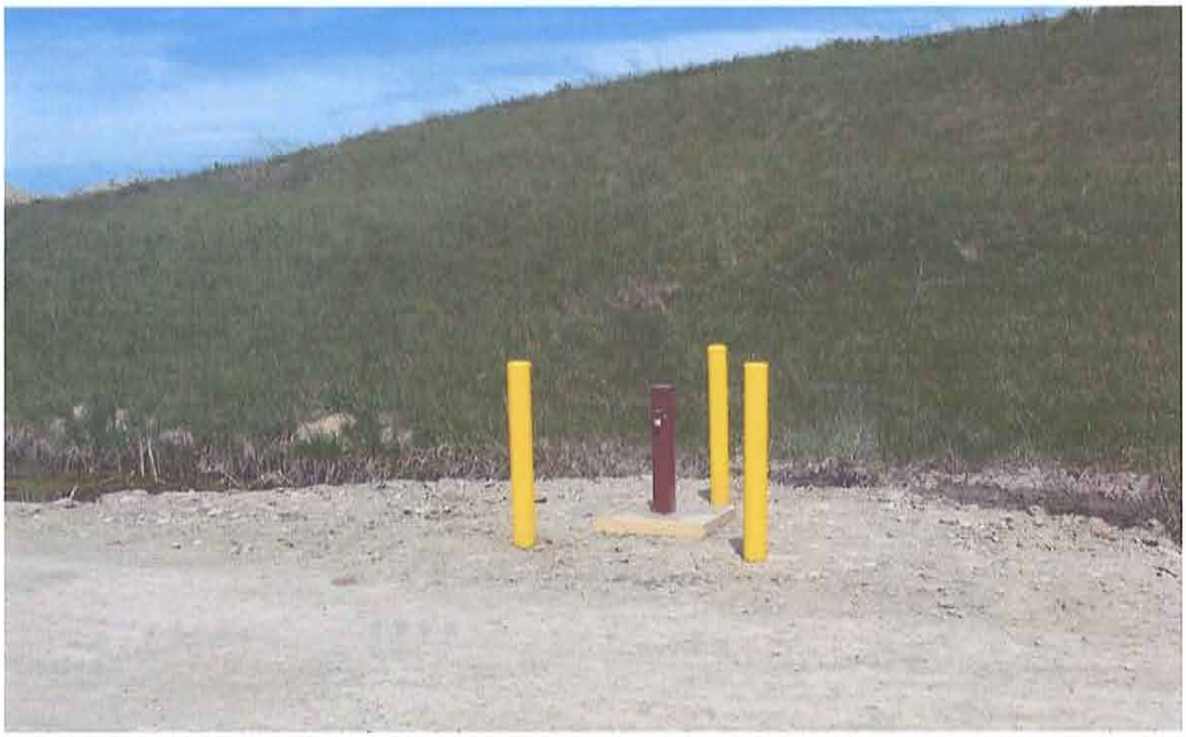
All piezometer or monitoring well boreholes were thoroughly flushed with fresh potable water prior to construction of the well. The boreholes were flushed until the return water was clear of suspended fines.

The piezometers and monitoring wells consisted of a 2-inch diameter type Schedule 40 PVC pipe with a 5 or 10 foot long, 0.010-inch slotted type Schedule 40 PVC well screen. A sand filter pack was installed from the bottom of the boring to at least two feet above the top of the slotted well screen. The depth of the screen elevation and the top of the sand pack was measured and recorded in the field by the project engineer/geologist. A bentonite chip seal was installed at the top of the sandpack and the annular space above the seal was tremie grouted to approximately two feet below the ground surface using bentonite grout. All piezometers and monitoring wells were installed in accordance with 35 Ill. Admin. Code, Sections 811.318 and the USEPA Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Table 2.2-3 summarizes the location and depths of the newly installed piezometers and monitoring wells. Appendix G includes copies of all boring logs and piezometers / monitoring well as-built diagrams.

TABLE 2.2-3
SUMMARY OF NEW PIEZOMETER AND MONITORING WELL INFORMATION

Piezometer/ Monitoring Well	Northing	Easting	Unit	Top of Screen Elevation (FT-MSL)	Bottom of Screen Elevation (FT-MSL	Top of Sandpack Elevation (FT-MSL)	Bottom of Sandpack Elevation (FT-MSL)
G170	12,494.15	12,422.13	Shallow Drift	651.13	641.13	653.9	640.9
MW-3-07	12,039.70	13,077.93	Shallow Drift	652.90	642.90	658.6	642.6
MW-6-07-D	11,400.75	13,283.41	Basal Drift	529.52	524.51	534.1	524.1
MW-8-07	10,868.75	12,490.36	Shallow Drift	655.50	645.50	659.2	645.2
MW-9-07	10,924.54	12,901.47	Shallow Drift	649.73	639.73	652.5	639.5
G175	11,485.09	12,154.43	Shallow Drift	648.20	638.20	650.4	637.4

A 4-inch circular locking steel protective outer casing was installed around each new piezometer or monitoring well. A bentonite chip seal was installed at the top of the bentonite grout. Concrete was placed above the grout/chip seal between the protective cover and borehole. Padlocks were placed on the outer casings. Protective bumper posts were placed around all piezometers and monitoring wells (Photograph 2.2-1). After installation, the locations and elevations of the PVC piezometers and monitoring wells were surveyed into the site control system. After completion, well construction reports were sent to the LCHD on IDPH well construction report forms. As-built diagrams and IDPH well construction reports are provided in Appendix G.



Photograph 2.2-1
Finished Piezometer / Monitoring Well Location

Piezometer and Monitoring Well Development

Development of the piezometers and monitoring wells was accomplished by pumping the wells dry or until a minimum of 5 well volumes were removed and the water was clear of suspended fines. All piezometers and monitoring wells were developed in accordance with the USEPA Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Refer to Appendix G for development forms.

Surveying

The locations and elevations of all the borings, piezometers, and monitoring wells installed during this investigation were determined by conventional surveying procedures. All surveying work was performed under the direction of a Registered Land Surveyor. The locations are shown on Drawing No. G3. All surveying was conducted in accordance with national map accuracy standards. Horizontal locations are accurate to ±0.5 feet. Ground surface elevations are accurate to ±0.1 feet. Well casing elevations are accurate to ±0.01 feet.

Borehole Abandonment Procedures

Boreholes which were not converted into piezometers or monitoring wells were abandoned and sealed in accordance with the applicable IDPH regulations and 35 Ill. Admin. Code, Section 811.316. The boreholes were tremie grouted from the bottom of the borehole to the ground surface with bentonite grout. The geologist or engineer documented the abandonment and sealing and prepared the required IDPH well abandonment forms. The forms were submitted to the LCHD. Copies of the forms are enclosed in Appendix G.

Water Level Measurements

Water level measurements were obtained from on-site piezometers and monitoring wells on July 17, 2007, October 8, 2007, January 23, 2008, and April 16, 2008. The depth to water from the top of the riser was measured using an electronic water level indicator. The water levels were converted to MSL elevations using the surveyed top of PVC riser elevations for each piezometer or monitoring well. The water level elevations are summarized in Appendix G.

In-Situ Hydraulic Conductivity Testing

Slug tests were performed in all 6 new piezometers or monitoring wells using falling and/or rising head tests in order to determine the in-situ hydraulic conductivities of the geologic units at the site. Each test measures the hydraulic conductivity of the zones into which the screens and the sand packs were installed. The testing procedures and test results are summarized in the following sections.

Falling and/or rising head tests were performed by lowering or retrieving a solid PVC slug of known volume into or from the static water column or by removing a volume of water with a disposable bailer (See Diagram 2.2-1). An In-Situ Level Troll 700 data logger/pressure transducer was used to record the water level versus time following the removal/insertion of the slug or water.

The potentiometric data for various geologic formations encountered at the subject site indicate that the Shallow Drift Aquifer and the Basal Drift Aquifer are under confined conditions. Therefore, a confined aquifer solution proposed by Bouwer-Rice was selected for analyzing the slug test data from these wells. This method, as described by Freeze and Cherry (1979), is appropriate for analyzing slug test data under confined conditions. This method assumes that the aquifer is homogeneous and isotropic $(k_h/k_v)=1$, of uniform thickness, and flow to the well is horizontal. The analyses were performed using the AQTESOLV™ for Windows™ program. The results of the analysis, including the data plots and a summary table, are provided in Appendix H. Also included in Appendix H is a summary table of slug test results for previously installed piezometers and monitoring wells at the existing landfill and expansion property.

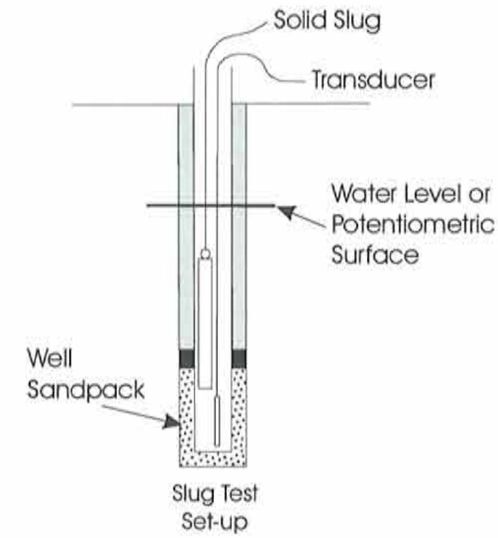


Diagram 2.2-1
Simplified Diagram of Slug Test Assembly

Laboratory Soil Testing

Upon completion of the site specific hydrogeologic investigation, ten Shelby tubes were submitted to STS in Vernon Hills, Illinois for laboratory testing of the clayey till deposit (Wadsworth Formation) that will envelop the proposed expansion. The results of these tests were used in conjunction with a wealth of previously collected geotechnical data collected from the existing facility, in order to develop an understanding of the material properties of the unconsolidated deposits in the proposed waste expansion area.

Testing completed during this investigation was performed in general accordance with the American Society of Testing Materials (ASTM) standard procedures, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846 (3rd Edition), and Methods of Soil Analysis (MSA). The results of all laboratory tests performed during the investigation, including a summary table of test results from the existing Veolia E.S. Zion Landfill are presented in Appendix I. A brief description of the tests and their purpose are provided below:

- Moisture Content Tests (ASTM D2216) - Moisture Content tests were performed on selected cohesive soil samples. Moisture contents indicate the state of the soils relative to the soil plasticity and density, i.e., whether the soils are generally dry, moist, wet, or saturated. Further, if the soils are saturated, the moisture content is indicative of the soil's total porosity.

- Atterberg Limit Tests (ASTM D 4318) - Atterberg limit tests were performed on samples to evaluate plasticity characteristics. Soil plasticity values near the moisture content suggest that the soils should be relatively easy to compact. Liquid limit values near the soil moisture content suggest that the soils will need to be worked/dried prior to compaction.

- Grain Size Analyses (ASTM D 422) - Combined hydrometer grain size analyses were performed to evaluate grain size distribution (percentages of gravel, sand, silt, and clay). This test provides a basis for classifying the soil profile constituents.

- Specific Gravity (ASTM D 854) - Specific gravity analyses were performed in order to calculate the relative volume of solids to water and air in a given volume of soil.

- Hydraulic Conductivity Tests (ASTM D 5084) - Hydraulic conductivity tests were performed on undisturbed soil samples to evaluate the coefficient of hydraulic conductivity in the vertical direction.

  Soil samples were placed in the triaxial cell and were backpressure saturated under confining stress. After saturation was verified, the specimen was subjected to an effective confining stress approximately equal to the anticipated field conditions and thus reducing the possibility of excessive confining pressure.

  Pore water was then forced through the specimen from the bottom to the top. Flow quantity was monitored using a calibrated manometer system. The test continued until steady state conditions were reached. Due to the orientation of the specimens during the tests, the values obtained reflect the soil matrix permeability in the vertical direction.

- Consolidated Undrained Triaxial Compression Tests (ASTM D4767) - Triaxial Compression Tests were performed on undisturbed cohesive soil samples in order to determine their strength and stress-strain relationships. These tests also measured axial load, axial deformation, and pore-water pressure so that total and effective stresses and axial compression could be calculated. The data obtained through these tests is extremely important in developing the landfill design.

- Cation Exchange Capacity (CEC) Tests (Carter, 1993) - Cohesive soil samples were collected and tested for cation exchange capacity (CEC). CEC provides information on the ability of a material to absorb and attenuate constituents in the groundwater through the presence of readily exchangeable cations. The total number of cations a soil can hold, or its total negative charge, is the soil's cation exchange capacity. A high TEC is desirable since the higher the TEC, the higher the negative charge and the more cations that can be held.

- Total Organic Content (TOC) Tests (ASTM D2974) -Cohesive soil samples were collected and tested for organic content. The organic content of the soil material is used to estimate the ability of the material to retard the migration of specific organic compounds. The more organic material that is present in a material generally correlates with its ability to attenuate certain organic compounds, therefore, a high TOC content is desirable.

Site Geology

Review of the results of the recent hydrogeologic investigation for the proposed horizontal expansion site and of information collected during previous investigations conducted within the expansion area indicate that the uppermost geology consists of glacial till and other unconsolidated deposits overlying dolomite bedrock. Each geologic unit is discussed in detail in the following sections.

Bedrock

Across the expansion site, there are two borings which have been advanced into the top of the bedrock surface. One boring, TB-1 was advanced approximately 10.9 feet into the bedrock surface during a previous hydrogeologic investigation and was supplemented during this investigation with the advancement of B-4-07. B-4-07 was advanced to collect continuous sampling data from the portion of TB-1 which was not continuously sampled from approximately 0 to 80 feet below ground surface during the previous investigation.

Additionally, during the most recent field investigation, a second boring, B-6-07, was advanced approximately 4.8 feet into the bedrock surface at the location of previously advanced boring EB-10. B-6-07 was advanced to collect continuous sampling data from below the terminus of the previously advanced EB-10 (approximately 110 feet below ground surface) and to install a deep well within the Basal Drift Aquifer.

Although no core samples of the bedrock were collected during the advancement of either of these borings, observation of drill cuttings and rock collected in split spoon samplers identified the rock as the Silurian dolomite. This is consistent with regional publications which indicate that the Silurian dolomite underlies the unconsolidated deposits across Lake County[3]. The bedrock and its relationship to the overlying glacial till, outwash deposits, and other unconsolidated deposits (referred to collectively as overburden) beneath the horizontal expansion area is illustrated in the geologic cross sections (Drawing Nos. G6 through G12). Select cross sections from the 1995 expansion application have also been included within the drawing set as Drawing Nos. G13 through G19 to illustrate the geologic relationships beneath the vertical expansion area. These cross sections have been modified to include the approximate location of the proposed mass excavation grades where applicable.

Unconsolidated Deposits

Unconsolidated deposits overlie the bedrock and extend upward to the ground surface. From the surface downward, the deposits are the Peoria Silt, Wadsworth Formation, Intra-Till Sediments (within the Wadsworth Formation), Shallow Drift, Lower Till, lacustrine deposits inter-tongued with the Lower Till, and Basal Drift. The thickness of these unconsolidated deposits ranges from approximately 215.3 feet (B-6-07 / EB-10) to 213.2 feet (B-4-07 / TB-1). The individual geologic units which comprise the unconsolidated deposits are discussed below.

<u>Peoria Silt</u>. The Wisconsinan Age Peoria Silt was identified at the surface across the proposed horizontal expansion as a rich, modern topsoil. Across the proposed expansion site, the Peoria Silt ranges from approximately 0.0 to 4.6 feet thick with an average thickness of

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3 Csallany and Walton (1963), Horberg (1950), Larsen (1973), Leetaru et al. (2003), Thwaites (1927), Visocky, et al. (1985), Willman, et al. (1975), and Willman (1971).

1.2 feet, where present. In some locations, the Peoria Silt had been removed and was replaced with roadbed fill material.

Wadsworth Formation. The Wisconsinan Age Wadsworth Formation is a succession of fine grained, gray diamicton units located immediately beneath the Peoria Silt at the site and was encountered in all 25 of the continuously sampled borings which have been advanced within and near the expansion site. The top of the Wadsworth Formation was encountered at depths ranging from the ground surface (B-6-07 / EB-10 and B-7-07 / G178) to 10.2 feet bgs (GK4D where fill was encountered at the surface), with the top present at an average depth of 2.7 feet bgs. The top of the Wadsworth Formation was found at elevations ranging from 751.8 feet above MSL (GK6D) to 724.8 feet above MSL (B-7-07 / G178) with an average surface elevation of 738.4 feet above MSL. Drawing No. G20 illustrates the top elevation of the Wadsworth Formation beneath the expansion area. Photograph 2.2-2 illustrates a typical sample of the Wadsworth Formation.

Photograph 2.2-2
Typical Wadsworth Formation Sample Obtained with Split-Spoon Sampler

The Wadsworth Formation was found to exhibit maximum and minimum thicknesses of 101.7 feet and 75.0 feet, respectively across the expansion site. The average thickness of this unit was calculated to be approximately 87.3 feet, which includes a weathered zone with brown to grayish brown or olive brown coloring that ranges in thickness from approximately 0.0 feet to 13.5 feet with an average thickness of approximately 7.5 feet. Drawing No. G21 illustrates an isopach of the Wadsworth Formation in the expansion area assuming pre-landfill conditions.

Within the Wadsworth Formation, and consistent with regional publications[4], discontinuous lenses of silt, sand, and gravel were also identified. These discontinuous lenses of sediment (Intra-till Sediments) are not sufficiently saturated to serve as a water source. This is clearly illustrated through site-specific data (refer to geologic cross sections on Drawing Nos. G6 through G12) and observation during construction of the existing landfill units.

The laboratory test results from the proposed expansion area are provided in Appendix I. Also included in Appendix I is a summary table of geotechnical testing at the existing Zion Landfill. Soil testing results for the Wadsworth Formation indicates that it is generally classified by USCS standards as a silty clay (CL or CL-ML) based on grain size. The grain size analysis from the most recent investigation yielded an average of 4.4 percent gravel, 12.3 percent sand, 40.9 percent silt, and 42.4 percent clay. Based on 22 samples, the average liquid limit and plastic limit are 28.8 and 15.8, respectively. The soil exhibits an average plasticity index of 12.9. The average specific gravity of the Wadsworth Formation was found to be 2.72. The average dry density and porosity of the Wadsworth Formation were found to be 126.9 pounds per cubic foot and 0.25, respectively.

Total cation exchange capacity (TEC) and total organic content (TOC) have also been measured for the Wadsworth Formation through laboratory testing of 8 samples. The Wadsworth Formation exhibits a TEC with a range of 5.0 meq/100g to 12.5 meq/100g with an average exchange capacity of 8.8 meq/100g.

Total organic content (TOC) analysis was performed in order to measure the percentage of organic material present in the Wadsworth Formation. The Wadsworth Formation exhibits a TOC range of 0.24 percent to 0.96 percent with an average of 0.67 percent.

The laboratory measured vertical hydraulic conductivity of the Wadsworth Formation in the proposed expansion area from 9 samples collected during the most recent investigation ranges from 4.10×10^{-7} cm/sec to 3.63×10^{-8} cm/sec, with a geometric mean value of 1.04×10^{-7} cm/sec. The laboratory measured vertical hydraulic conductivity of the Wadsworth Formation at the existing Zion Landfill from samples collected during previous investigations was reported to range from 3.70×10^{-7} cm/sec to 6.00×10^{-9} cm/sec, with a geometric mean value of 2.08×10^{-8} cm/sec.

Horizontal hydraulic conductivity determined from previous slug testing of wells within the Wadsworth Formation at the existing Zion Landfill during previous investigations ranges from 9.53×10^{-8} cm/sec to 6.07×10^{-9} cm/sec with a geometric mean hydraulic conductivity of 1.85×10^{-8} cm/sec. A summary table of the slug testing performed at the existing Zion Landfill is provided in Appendix H.

As previously discussed, a weathered zone with an average thickness of 7.5 feet was identified within the Wadsworth Formation directly below the Peoria Silt, or at ground surface where the Peoria Silt is absent. Research which has been conducted on clay-rich glacial deposits within the region has indicated that these deposits have the potential to exhibit fractures within the upper 20 feet (weathered zone) (McKay, et al., 1993 and Abichou, et al., 2002). Fracturing in the weathered zone was not identified at the site during the most recent hydrogeologic investigation. Additionally, the proposed excavation for the expansion (approximately 60 feet) will remove this weathered zone.

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4 Frye and Willman (1975), Hansel and Johnson (1996), Johnson, et al. (1985), and Larsen (1973).

Discontinuous lenses of silt, sand, and gravel were also identified throughout the Wadsworth Formation beneath the site (Intra-Till Sediments). In most cases, these deposits exhibit a very similar color to the Wadsworth formation, but have also been identified in varying shades of brown. The thickness of these lenses at the site range from a fraction of a foot to as much as 8.0 feet.

Soil testing results for the Intra-Till Sediments during the most recent investigation indicate that it is generally classified by USCS standards as a silty sand (SM). The grain size analysis yielded an average of 24.3 percent gravel, 52.0 percent sand, 16.9 percent silt, and 6.9 percent clay for the discontinuous deposits. The results of these tests are provided in Appendix I.

Horizontal hydraulic conductivity determined from slug testing of wells within the Intra-till Sediments at the existing Zion Landfill Site 2 ranges from 3.39×10^{-3} cm/sec to 2.74×10^{-7} cm/sec with a geometric mean hydraulic conductivity of 2.85×10^{-5} cm/sec. A summary table of the slug testing performed at the existing Zion Landfill is provided in Appendix H.

Shallow Drift The Shallow Drift underlies the Wadsworth Formation and is recognized as a zone of inter-tongued gray to dark gray silt, sand, and gravel deposits. The top of the Shallow Drift was encountered at depths ranging from 80.8 feet bgs (GK11D) to 101.7 feet bgs (GK6D) with an average depth of 90.2 feet bgs and at elevations ranging from 656.2 feet above MSL (GK5D) to 644.2 feet above MSL (EB-2) with an average surface elevation of 651.1 feet above MSL. Drawing No. G22 illustrates the top elevation of the Shallow Drift beneath the expansion area.

Soil testing results for the Shallow Drift from 8 samples submitted during the most recent investigation indicate that it is generally classified by USCS standards as a silty sand (SM) or a silt (ML). The grain size analysis yielded an average of 4.9 percent gravel, 53.0 percent sand, 34.9 percent silt, and 8.2 percent clay. The results of these tests are provided in Appendix I. Also included in Appendix I is a summary table of geotechnical testing for the existing Zion Landfill.

Lower Till Beneath the Shallow Drift is another till unit which has been identified within this report as the Lower Till. The Lower Till is identified at the site as being similar to the Wadsworth Formation in that it is a succession of fine grained, gray diamicton units (refer to Photograph 2.2-3). The Lower Till ranges in thickness from 103.0 feet to 106.3 feet with an average thickness of approximately 104.6 feet across the site. It should be noted that the thickness of the Lower Till includes inter-tonguing silty clay lacustrine deposits. These lake deposits are identified at the site as gray silty clay deposits that are predominantly fine grained and are distinguishable from the more massive till units by distinct bedding structures. The top of the Lower Till was encountered at depths ranging from 89.7 feet bgs (B-8-07) to 111.0 feet bgs (GK6D) with an average depth of 99.6 feet bgs and at elevations ranging from 649.6 feet above MSL (B-2-07 / EB-8) to 633.4 feet above MSL (B-6-07 / EB-10) with an average surface elevation of 641.7 feet above MSL.

Soil testing results from 5 samples of the Lower Till deposits tested during the most recent investigation indicate that they are generally classified by USCS standards as a silty clay (CL or CL-ML). The grain size analysis yielded an average of 4.6 percent gravel, 28.3 percent sand, 42.5 percent silt, and 24.6 percent clay based on geotechnical testing of 4 samples. The average liquid limit and plastic limit are 21.0 and 13.3, respectively. The soil exhibits an average plasticity index of 7.7. The dry density and porosity of the Lower Till were measured to be 126.7 and 0.26, respectively. The results of the laboratory testing are provided in Appendix I.

Photograph 2.2-3
Typical Lower Till Sample Obtained with Split-Spoon Sampler

Basal Drift The Basal Drift underlies the Lower Till and lacustrine deposits, and overlies bedrock. It is recognized as a zone of inter-tongued gray to dark gray silt, sand, and gravel deposits. The top of the Basal Drift was encountered at depths ranging from 202.0 feet bgs (B-4-07 / TB-1) to 213.7 feet bgs (B-6-07 / EB-10) with an average depth of 207.8 feet bgs and at elevations ranging from 536.2 feet above MSL (B-4-07 / TB-1) to 530.4 feet above MSL (B-6-07 / EB-10) with an average surface elevation of 533.3 feet above MSL.

Rising and falling head slug tests performed on one well installed within the Basal Drift during the most recent investigation indicated a hydraulic conductivity of 3.42×10^{-4} cm/sec. Slug testing and data printouts from the recent tests are provided in Appendix H.

Site Hydrogeology

This section presents a discussion of the hydrogeology associated with the Shallow Drift Aquifer, which is the predominant water bearing geologic unit below the proposed expansion area. Potentiometric maps were created for the Shallow Drift Aquifer (Uppermost Aquifer) utilizing groundwater data collected July 17, 2007, October 8, 2007, January 23, 2008, and April 16, 2008. Drawing Nos. G25 through G28 depict the potentiometric surface of the Shallow Drift Aquifer across the facility, including the expansion area. Drawing Nos. G6 through G12 show geological cross sectional relationships across the horizontal expansion site. Drawing Nos. G13 through G19 are select cross sections from the 1995 expansion application which run through or near the vertical expansion area. Boring logs and well construction diagrams are contained in Appendix G.

Analysis of the potentiometric maps developed for the Shallow Drift Aquifer across the site indicates that groundwater flow within this unit is to the east with an average horizontal gradient of approximately 0.00037 measured across the central portion of the horizontal expansion site (refer to Appendix G). The maximum and minimum horizontal gradients were measured to be 0.00018 and 0.00054, respectively.

Slug tests were performed in wells screened within the Shallow Drift Aquifer in the subsurface below the horizontal expansion site during the most recent investigation. The horizontal hydraulic conductivities of the deposits obtained from slug testing range from 7.37×10^{-4} cm/sec to 2.04×10^{-5} cm/sec with a geometric mean of 1.77×10^{-4} cm/sec.

By multiplying the average horizontal gradient (0.00037) by the geometric mean hydraulic conductivity (1.77×10^{-4} cm/sec), a Darcy Velocity of 0.02 m/yr (0.07 ft/yr) was calculated. The porosity of the Shallow Drift Aquifer was estimated to be 0.28 which is the average of the porosity range for a sand and gravel deposit provided by Walton, 1991. Using this porosity, the seepage velocity in the Shallow Drift Aquifer is approximately 0.07 m/yr (0.23 ft/yr).

At several locations, it was possible to calculate a vertical groundwater flow gradient through the Wadsworth Till (refer to Appendix G for a summary of vertical gradient calculations). The average calculated vertical gradient through the Wadsworth Till is 1.01 with minimum and maximum calculated gradients of 0.86 and 1.25, respectively. At each of these locations, the gradient was in the downward direction. A vertical gradient was also calculated through the Lower Till using piezometers MW-06-07-D and EP-10D. The calculated vertical gradient through the Lower Till at this location is 0.13 in the downward direction (refer to Appendix G).

Uppermost Aquifer

The uppermost aquifer at the site was identified per IEPA definitions. 35 Ill. Admin. Code, Section 810.103 defines an aquifer as:

> *"Aquifer" means saturated (with groundwater) soils and geologic materials which are sufficiently permeable to yield economically useful quantities of water to wells, springs, or streams under ordinary hydraulic gradients and whose boundaries can be identified and mapped from hydrogeologic data.*

The same regulation defines the uppermost aquifer as the following:

> *"Uppermost aquifer" means the first geologic formation above or below the bottom elevation of a constructed liner or wastes, where no liner is present, which is an aquifer, and includes any lower aquifer that is hydraulically connected with this aquifer within the facility's permit area.*

Due to its hydrogeologic properties, fairly continuous nature, location below the base of the proposed liner, and use as a potable water source in the vicinity of the site, the uppermost aquifer below the proposed expansion has been determined to be the Shallow Drift Aquifer.

Geologic and Hydrogeologic Conclusions

Based on the findings of this investigation, the geologic and hydrogeologic site conditions present at the proposed site are suitable for the development of a landfill and will serve to protect the public health, safety, and welfare. The following conclusions can be made concerning the geologic and hydrogeologic conditions at the site.

- ❑ A significant amount of hydrogeolgic investigation activities have been conducted at the site prior to the most recent investigation. Data collected during the previous hydrogeologic investigation activities was obtained through the advancement of over 250 borings (over 100 of which were continuously sampled) and the installation of over 200 monitoring wells.

- ❑ The most recent site investigation included a review of previous site investigations and the advancement of an additional ten borings, five of which were advanced at previous boring locations to supplement existing site information and five of which were advanced in new locations. The geology beneath the horizontal portion of the Site 2 East Expansion, as characterized by the ten borings, is consistent with the geology encountered beneath the existing Facility and the geologic setting which is described in regional publications[5], providing additional support to the findings of this investigation. The continuity observed from boring to boring demonstrates that the investigation activities were adequate in extent to verify the geologic and hydrogeolgic features beneath the site. Six of the ten borings were converted to piezometers or monitoring wells to supplement the hydrogeologic information for the site.

- ❑ A low-permeability cohesive soil (Wadsworth Formation) is present across the proposed site which will separate the footprint of the proposed Site 2 East Expansion from the uppermost aquifer. This low permeability cohesive soil (clayey till) has an average thickness of approximately 87.3 feet in the expansion area with maximum and minimum thicknesses of 101.7 feet and 75.0 feet, respectively. Field and laboratory test results and field observations indicated that this soil will effectively restrict vertical and horizontal movement of groundwater and will serve as an additional environmental safeguard at the proposed expansion. The average thickness of the Wadsworth Formation includes discontinuous lenses of silt, sand, and gravel (Intra-Till Sediments) which are contained within the till.

- ❑ The clay will act as a permanent barrier and supplemental protective feature of the Site 2 East Expansion by restricting contaminant movement from the expansion in both vertical and horizontal directions.

- ❑ As discussed in the design report, the engineered liner system beneath the expansion area will include 5 feet of recompacted clay and a high density polyethylene (HDPE) liner. Such a liner exceeds the requirements of the U.S. EPA and has been accepted by the Illinois Environmental Protection Agency

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5 Csallany and Walton (1963), Frye and Willman (1975), Hansel and Johnson (1996), Horberg (1950), Johnson, et al. (1985), Kammerer, et al. (1998), Larsen (1973), Leetaru et al. (2003), Piskin, et al. (1975), Thwaites (1927), Visocky, et al. (1985), Willman, et al. (1975), and Willman (1971).

(IEPA) and other experts in the landfill field as providing a high level of environmental safety. The natural clay that is present on the site below the liner system will act as a second, natural liner system for the landfill expansion.

- In addition to following the requirements of the City of Zion Pollution Control Facility Siting Ordinance, the investigation was performed in general accordance with the requirements contained in 35 Ill. Admin. Code, Section 811.315, 812.314, and 812.315. These regulations specify the necessary content of hydrogeologic investigations submitted to the IEPA as part of an application for a landfill expansion permit.

- The proposed Site 2 East Expansion is located in an area that is classified by Berg and Kempton (1984) as Map Unit E (low aquifer sensitivity with respect to land burial of municipal solid waste) with uniform, relatively impermeable silty or clayey till at least 50 feet thick. The site is also located in an area that has been classified by Larson (1973) as being geologically optimal for the development of a landfill within Lake County.

- Based on discussions with the site operator, the geologic interpretations that have been established within this report are consistent with the conditions observed during the development of large-scale excavations at the existing facility. The site-specific observations verify the thickness of the clayey till and discontinuous nature of the intra-till sediments as described within this analysis. IEPA review and approval of construction documentation reports supports this as well.

- The hydrogeologic conditions at the site will allow a comprehensive groundwater monitoring system to be implemented which will be able to adequately verify if groundwater resources are being impacted by the landfill.

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