# Geologic, Geophysical, and Hydrologic Investigations for a Supplemental Municipal Groundwater Supply, Danville, Illinois

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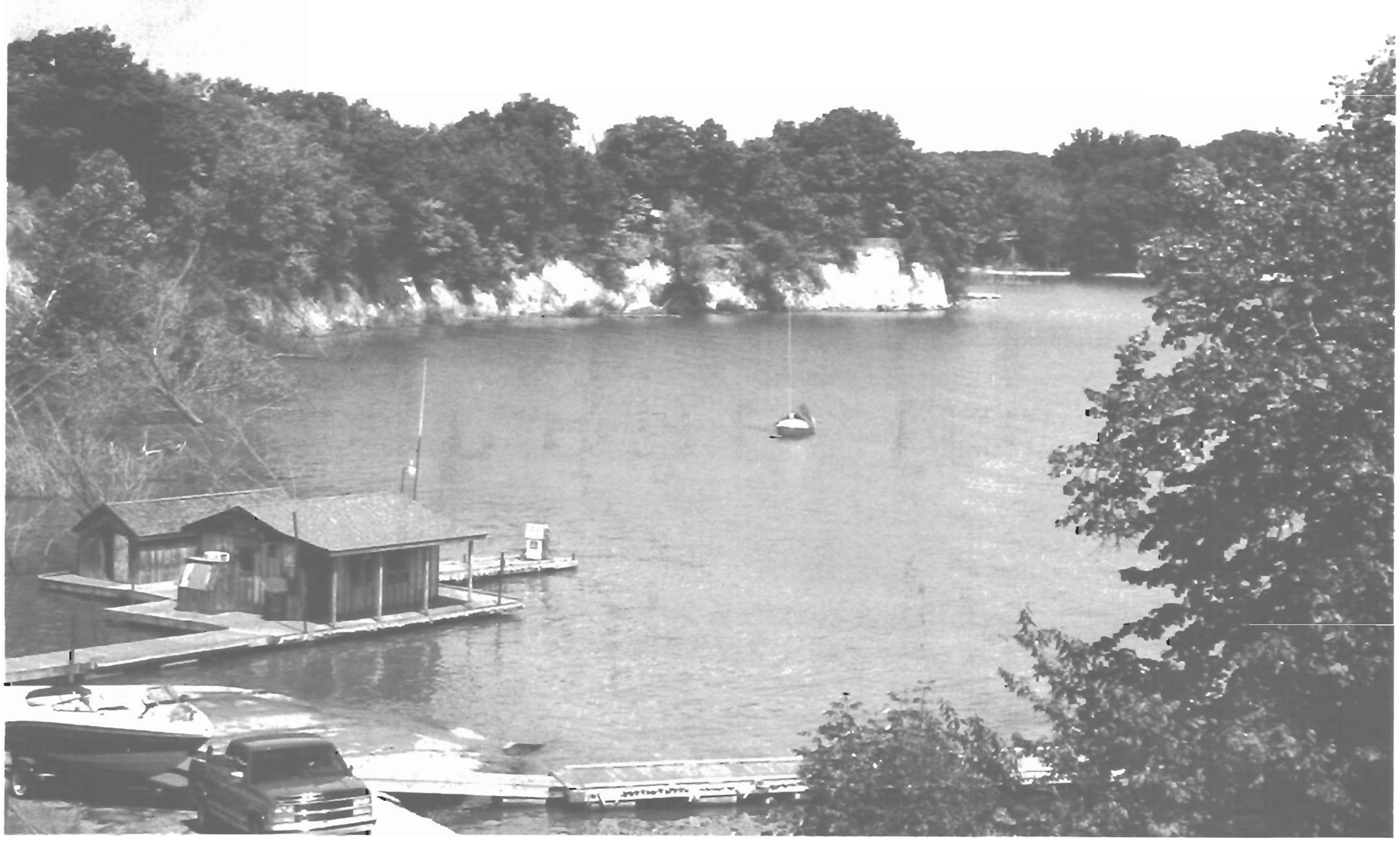

1997
Cooperative Groundwater Report 18
DEPARTMENT OF NATURAL RESOURCES

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Larson, David R.
GEOLOGIC, GEOPHYSICAL,
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# Geologic, Geophysical, and Hydrologic Investigations for a Supplemental Municipal Groundwater Supply, Danville, Illinois

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1997
Cooperative Groundwater Report 18

**Cover photo** Lake Vermilion, Danville, Illinois.

ILLINOIS
DEPARTMENT OF
NATURAL
RESOURCES

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## ABSTRACT

Danville obtains its water from Lake Vermilion, a reservoir located on the North Fork Vermilion River. There have been problems with both water quantity and quality. Runoff in the North Fork watershed decreases during times of low precipitation, resulting in lower water levels at Lake Vermilion and possible water shortages for Danville. Nitrate concentrations (as nitrogen) in the lake water occasionally exceed the maximum contaminant level (MCL) of 10 mg/L for drinking water.

The Danville-Lake Vermilion area is located over the Danville Bedrock Valley. Within this bedrock valley are sand and gravel outwash deposits that are sources of groundwater for wells in the area. An investigation of the potential for using groundwater from these deposits to supplement Danville's water supply indicated that

- the availability of groundwater is limited because the sand and gravel aquifers in the Danville Bedrock Valley are not extensive,
- groundwater pumpage from any additional high capacity wells will most likely cause a decline in the water levels of existing wells,
- the quantity of groundwater needed for a supplemental supply may exceed the rate of groundwater recharge,
- induced infiltration of water from Lake Vermilion may not significantly increase the availability of groundwater,
- the concentration of nitrate in the groundwater may increase significantly as a result of any induced infiltration from Lake Vermilion.

Available data indicate a high potential for the occurrence of thick, extensive deposits of sand and gravel within the confluence area of the Danville and Mahomet Bedrock Valleys in northern Vermilion County. An exploration program in the area from Lake Vermilion northward would better characterize the hydrogeology of these aquifers and define groundwater availability for all current and potential users. Test holes drilled into bedrock would ensure the evaluation of the entire sequence of the glacial deposits, particularly the thickness of sand and gravel aquifers.

## ACKNOWLEDGMENTS

The authors thank the staff of Inter-State Water Company for their cooperation in allowing access to company property and records while conducting this study. They also thank Layne-Western for providing the information from the test drilling and their cooperation in collecting the split spoon (core) samples and sample cuttings.

This report is the culmination of the compilation and analysis of data conducted by a number of individuals with the Illinois State Geological Survey (ISGS) and Illinois State Water Survey (ISWS). Special thanks are given to the following ISGS staff: Phil Reed performed the downhole geophysical logging of the test holes drilled for the study as well as conducted the EER surveys and interpreted the results; Paul Heigold conducted the seismic surveys and interpreted the results; Ross Brower ran the sieve analysis on the sediments from test hole #1-91; Mike Miller was responsible for the other sieve analyses run at the ISGS; Sam Panno gave advice on the subsurface geochemistry of nitrates; and H D. Glass (ISGS) performed the clay mineral and grain size analyses. Special thanks go to the following ISWS staff members: Ken Hlinka, Paul Jahn, and Jeffrey Stollhans conducted the Winter Avenue and Lake Vermilion aquifer tests; John Nealon and Adrian Visocky made the initial analysis of all of the aquifer test data; and Adrian Visocky offered valuable suggestions on data interpretation.

The authors thank Ross Brower (ISGS) and Adrian Visocky (ISWS) for their reviews of this report.

# INTRODUCTION

## Background

This report presents the results of an investigation on the hydrogeology of the glacial deposits in part of the Danville Bedrock Valley. It was previously thought that thick and extensive sand and gravel aquifers could possibly be found within this buried bedrock valley (Kempton et al. 1981). This study shows, however, that these aquifers are restricted in thickness and areal extent and the availability of groundwater is limited. The information provided in this report should be of assistance in future efforts to locate groundwater supplies in the study area, evaluate their suitability for long-term use, and manage the groundwater resource.

Lake Vermilion, the water supply reservoir for the City of Danville, is located on the North Fork Vermilion River. Problems with both water quantity and quality have been experienced with this source of supply. Decreased runoff in the North Fork watershed during periods of low precipitation lowers the water level of Lake Vermilion and presents Danville with potential water shortages. Nitrate concentrations (as nitrogen) in the reservoir periodically exceed the maximum contaminant level (MCL) of 10 mg/L for drinking water (Illinois Department of Public Health 1990).

Singh (1978) identified the sand and gravel aquifers within the Danville Bedrock Valley as a potential source of groundwater for a supplemental water supply for Danville. As part of assessing the feasibility of using groundwater from these aquifers to alleviate the water supply problems, Inter-State Water Company sought the advice and assistance of both the Illinois State Geological Survey (ISGS) and the Illinois State Water Survey (ISWS) to further investigate the distribution and hydrogeologic characteristics of the sand and gravel aquifers in the Danville area. A previous ISGS report on the hydrogeology of the Danville area (Vaiden 1987) recommended that electrical resistivity and seismic refraction surveys be conducted from Lake Vermilion northward along the trend of the Danville Bedrock Valley to its confluence with the Mahomet Bedrock Valley. This report (Vaiden 1987) also recommended that test drilling be done where the presence of thick deposits of sand and gravel was indicated so that subsurface conditions and aquifer properties could be determined.

An investigation into the hydraulic properties, potential yield, thickness, and areal extent of the aquifers was undertaken at two sites in the Danville area underlain by the Danville Bedrock Valley to evaluate groundwater availability from the sand and gravel deposits. The ISGS and ISWS helped design, perform, and evaluate the aquifer tests at the Winter Avenue and Lake Vermilion sites (fig. 1). The tests at these two sites were completed early in 1988.

Danville faced an imminent water shortage in October 1991 when the level of Lake Vermilion was extremely low. Immediate action was required. A review of previous work on the availability of groundwater in the Danville area produced three recommendations from the ISGS and ISWS: (1) construct an emergency supply well close to the west side of Lake Vermilion (site LV-3, fig. 1) so that water could be pumped directly into the lake; (2) install a test well (site LV-1, fig. 1) about 2,000 feet north-northwest of the emergency supply well; and (3) drill a test hole south and north (sites 2-91 and 3-91, respectively, fig. 1) of the two test wells to help better define the extent and characteristics of the sand and gravel units. Although all three recommendations were implemented, precipitation during late fall of 1991 raised the level of Lake Vermilion, and the emergency supply well was not used to pump groundwater into Lake Vermilion. The availability of groundwater in the Danville area was summarized in a short report completed by the ISGS and ISWS (Larson and Meyer 1993). Complete results of this study and a thorough discussion of groundwater availability are included in this more comprehensive report.

## Purpose and Scope

The test hole and well data obtained in the fall of 1991 are reviewed in this report and compiled with the information from the 1987-1988 studies. The results of the previous studies are evaluated with respect to the 1991 data. In this report, the effects of additional high capacity wells in the study area are evaluated; a succinct appraisal of the hydrogeologic conditions of part of northern Vermilion County is given; and a basis from which recommendations can be made about further study of the groundwater resources of the Danville area is provided. The information in this report should greatly assist those

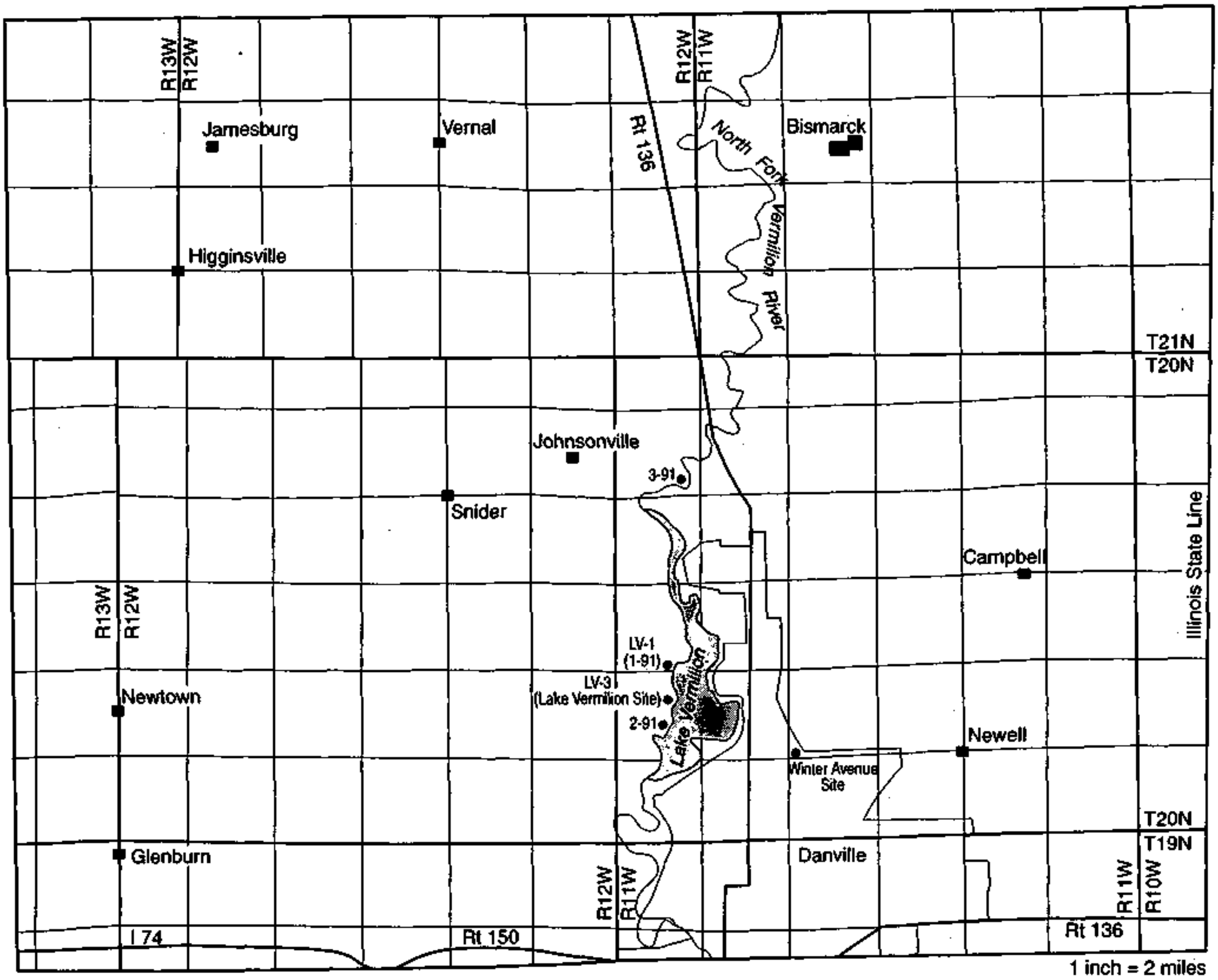


**Figure 1** Location of the two aquifer tests and recent test holes in the study area.

who are looking at groundwater for irrigation, municipal, or industrial uses. This report should also be useful for determining the potential impact of large groundwater withdrawals on nearby wells.

## Location and Geography

**Location and extent of study area** The study area covers about 152 square miles, extending from Danville northward to the Bismarck area and from the Illinois-Indiana state line westward to around Jamesburg (fig. 1). The Danville NE, NW, SE, and SW plus the Henning and Bismarck U.S. Geological Survey (USGS) 7.5-minute series quadrangles provide topographic map coverage at the 1:24,000 scale. The ISWS location scheme employed in this report uses the section-township-range system and is explained in appendix A.

**Physiography, drainage, and precipitation** The study area lies within the Bloomington Ridged Plain of the Till Plains Section, Central Lowland Province (fig. 2). The land surface of the study area is marked by the prominent ridges of the Illiana Moranic System (fig. 3), which were left by the last continental glacier that occupied the study area. These distinct features are part of a larger group of glacial end moraines that form broad, arcuate, partly discontinuous ridges across Vermilion County. Natural surface drainage within the study area is generally south and southeast by way of the Vermilion River and its tributaries.

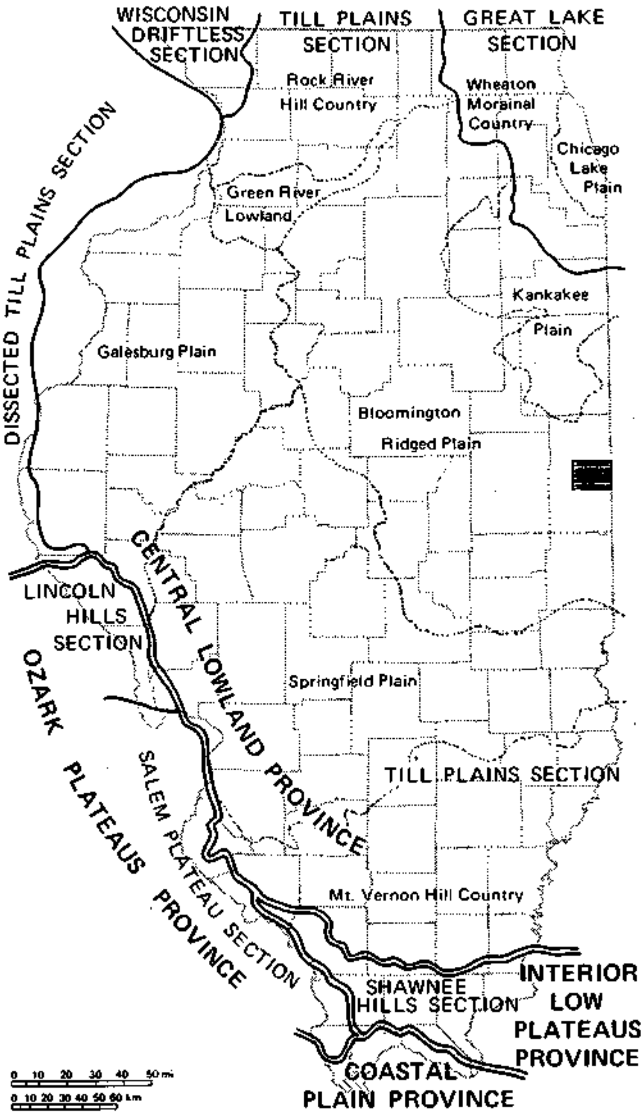


**Figure 2** Physiographic divisions of Illinois (from Leighton et al. 1948).

The highest land surface is at an elevation of nearly 730 feet above sea level and occurs in an area about 2 miles west of Lake Vermilion. The lowest elevation of about 520 feet is found near the confluence of North Fork and Middle Fork on the southwest side of Danville. This gives a maximum topographic relief of about 210 feet across the study area.

ISWS records show that the mean annual precipitation in the study area is nearly 37 inches and that monthly averages range from about 1.9 inches in February to about 4.4 inches in June. Jones (1966) included the Vermilion River basin of east-central Illinois in a statewide study on the variability of evapotranspiration. Using the 39 years of flow record available for the Vermilion River gaging station at Danville in 1960, he calculated the average annual evapotranspiration for the basin and the study area to be about 27 inches by subtracting the average annual runoff from the average annual precipitation. Jones assumed that there was no interbasin exchange of surface water and that the recharge and discharge of groundwater were essentially in equilibrium.

## Previous Studies

Basic geologic studies since the mid-1940s have established the geologic framework for Vermilion County. These include the work of Horberg (1945, 1950, 1953), Eveland (1952), Johnson (1971), Johnson et al. (1972a, 1972b), and Kempton et al. (1991).

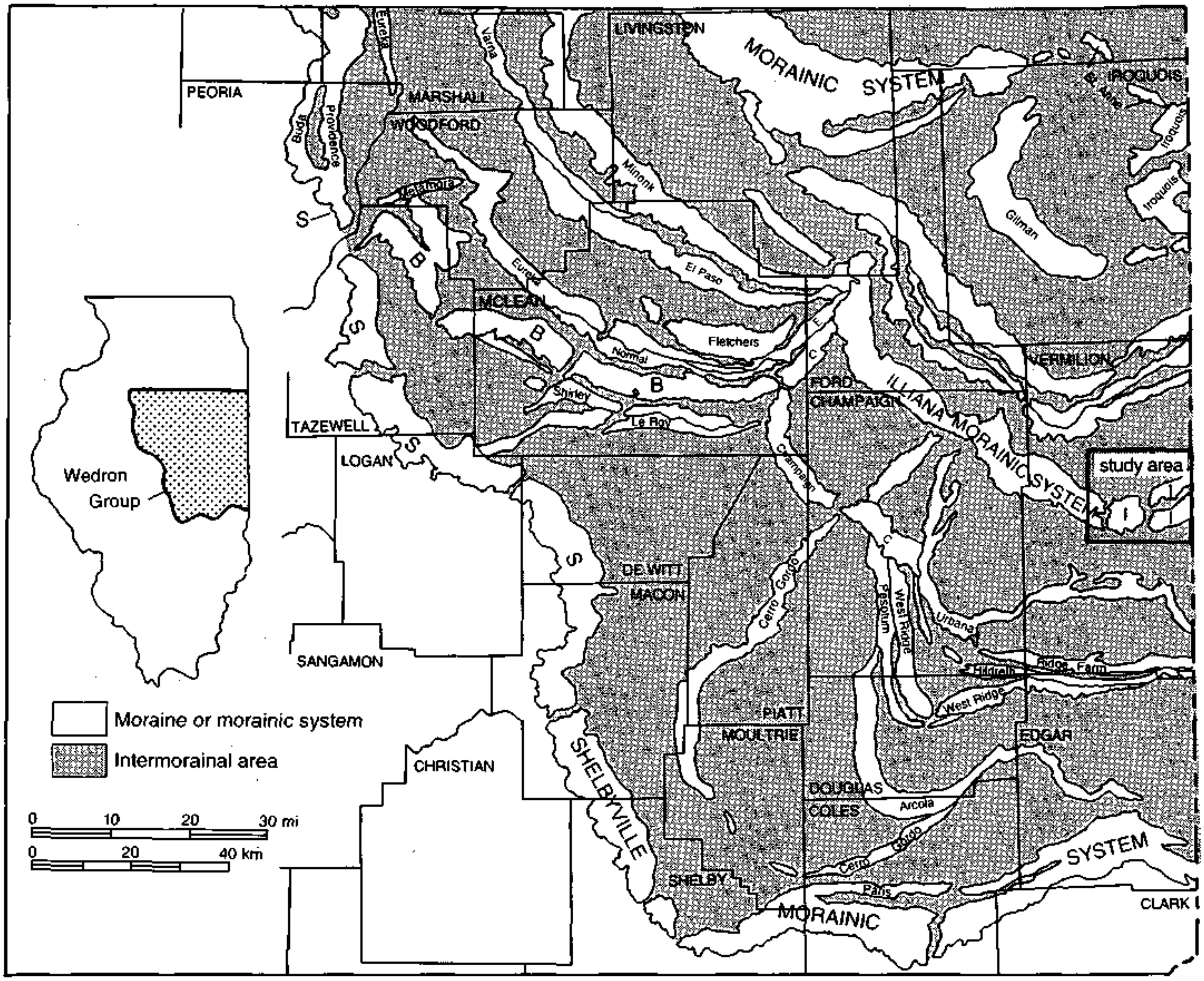


**Figure 3** Map of Wedron Group moraines (from Hansel and Johnson 1996).

Because the bedrock over much of east-central Illinois has a very limited potential for development of municipal groundwater supplies (Selkregg and Kempton 1958), geologic and hydrologic studies related to groundwater availability have focused on the glacial deposits (Foster 1953). Horberg's work (1945, 1950, 1953) and that of Piskin and Bergstrom (1975) provided some of the hydrogeologic background for later studies by establishing the regional character of bedrock topography plus the thickness and stratigraphic characteristics of the overlying glacial deposits. One of the most significant of Horberg's contributions was defining the thick, widely distributed Mahomet sand (then interpreted to be Kansan in age) and recognizing it as a major aquifer of east-central Illinois (including northern Vermilion County). Willman and Frye (1970) formally defined the Mahomet sand as the Mahomet Sand Member of the Banner Formation.

Several regional and local hydrogeologic studies have increased our knowledge of the hydrogeology of east-central Illinois. For example, Selkregg and Kempton (1958) summarized the groundwater geology of east-central Illinois, Stephenson (1967) focused on aquifers within the Mahomet Bedrock Valley in a broad area west of Vermilion County, and Gibb (1970) described the groundwater resources of Ford County. Kempton et al. (1981) investigated the thickness and distribution of glacial drift aquifers in northern Vermilion County. Vaiden (1987) provided a general summary of the groundwater conditions of the Danville area. Kempton et al. (1991) discussed the geologic aspects of the study area in their work on the Mahomet Bedrock Valley.

Hydrologic studies include evaluation of aquifers within the Mahomet Bedrock Valley by Visocky and Schicht (1969). Data on public groundwater supplies have been provided by Hanson (1950), Woller (1975), Poole and Heigold (1981), and Poole and Vaiden (1985). Detailed assessments of selected groundwater supplies were made by Visocky et al. (1978) and Wehrmann et al. (1980).

# AQUIFERS AND THE AVAILABILITY OF GROUNDWATER

## Aquifers

Although nearly all geologic materials transmit water, the rate of transmission depends on the permeability of the material. Groundwater moves relatively rapidly through highly permeable materials but slowly through those with low permeability. On this basis, geologic materials are classified as aquifers or aquitards (confining units), respectively. An aquifer is a body of saturated earth materials that yields useful quantities of groundwater to a well or spring. Examples of aquifers are saturated sand and gravel, fractured and jointed carbonate bedrock, or sandstone. Till (sandy, pebbly, silt and clay deposited directly from melting glaciers), lacustrine silt and clay (deposited in lakes), shale, and deposits of other fine grained sediments form aquitards, which restrict groundwater flow into or out of an adjacent aquifer.

**Aquifer types** Aquifers are identified as confined (artesian) or unconfined (water table). A confined aquifer has an aquitard above it and below it. The aquitards impede the vertical movement of groundwater and cause the water in the aquifer to be under greater than atmospheric pressure. The water level in a well completed in a confined aquifer will rise to a level above the top of the aquifer because of the pressure. A confined aquifer is described as semiconfined (or leaky artesian) if there is significant flow of groundwater across one or both of the aquitards. An unconfined aquifer has an aquitard only below it. Because the water table, or the top of the saturated zone, marks the top of an unconfined aquifer, the thickness of the aquifer varies as the water table fluctuates with time. The aquifer and water table can be in direct connection with rivers, lakes, streams, or other surface water bodies. The water level in a well completed in an unconfined aquifer closely approximates the water table adjacent to the well.

**Hydraulic properties of aquifers and aquitards** The ability of an aquifer to transmit and store groundwater is described by its hydraulic conductivity, transmissivity, and storage coefficient.

Hydraulic conductivity (K) is the capacity of an earth material to transmit groundwater. It is expressed as the volume of water that will move in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow (Heath 1989). Hydraulic conductivity depends on the permeability of the earth material as well as the viscosity and density of the water flowing through the material. Values of hydraulic conductivity for glacial till range from about $10^{-6}$ to 10 gallons per day per square foot (gpd/ft$^2$); values for sand and gravel range from about 10 to $10^5$ gpd/ft$^2$ (Heath 1989).

Transmissivity (T) is a measure of the capacity of the entire thickness of an aquifer to transmit groundwater. It is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient (Heath 1989). Transmissivity equals the hydraulic conductivity of the aquifer multiplied by its thickness.

Storage coefficient (S) is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Heath 1989). Storage coefficient describes the capacity of an aquifer to store groundwater. In a confined aquifer, this volume of water originates from the slight expansion of the water and the compression of the aquifer caused by the weight of the overlying materials. The storage coefficient for confined aquifers generally ranges between $10^{-5}$ and $10^{-3}$ (Heath 1989). In an unconfined aquifer, this volume of water stems mostly from the gravity drainage from or the refilling of the pore spaces of the aquifer through which the change in head occurs. A negligible amount of the water volume comes from the expansion of the water and the compression of the unconfined aquifer. The storage coefficient for an unconfined aquifer is essentially the same as the specific yield and typically ranges from 0.1 to 0.3 (Heath 1989).

The volume of groundwater leaking through an aquitard depends on its vertical hydraulic conductivity (K'), the most significant hydraulic property of an aquitard. Vertical hydraulic conductivity is the rate of flow of water vertically through a horizontal unit area under a unit vertical hydraulic gradient. Leakage is important in determining the influence of a confining bed on the availability of groundwater. The leakage coefficient, or leakance, is the ratio K'/m' where m' is the thickness of the confining bed (Hantush 1956). This ratio describes the quantity of flow of water that crosses a unit area of the interface between an aquifer and its confining bed under a unit difference in hydraulic head between the aquifer and the confining bed.

**Groundwater recharge and discharge** Groundwater recharge is the addition of water to the zone of saturation. Most of the added water is derived from the infiltration of precipitation; a lesser amount is contributed by infiltration from surface water bodies. Although most of the precipitation runs off directly to streams or evaporates into the atmosphere, some of it percolates downward through the soil and unsaturated zone. Some of this water is taken up by plants and returned to the atmosphere by transpiration. Water that passes through the unsaturated zone and reaches the water table becomes part of the groundwater flow system. If there is a downward hydraulic gradient within the groundwater flow system, the water moves downward and may recharge more deeply buried aquifers. Similarly, groundwater recharge because of infiltration from surface water bodies may occur if the hydraulic head decreases downward. This condition is typically produced by pumpage from an aquifer that underlies a lake or river. The pumping creates a downward vertical hydraulic gradient between the surface water body and the underlying aquifer, which causes the downward movement of surface water into the aquifer. This infiltration of surface water is referred to as induced infiltration. For induced infiltration to occur readily, the earth materials underlying the surface water body need to be permeable.

Groundwater recharge occurs mainly during the spring when rainfall is high, which helps maintain soil moisture at or above field capacity, and water losses due to evapotranspiration are low. Recharge decreases during the summer and early fall when evapotranspiration prevents most of the infiltrating water from reaching the water table. Recharge is usually negligible during the winter months because moisture in the soil profile is typically frozen. Recharge may occur at times during a mild winter if water in the soil profile does not freeze. Several factors control the rate of groundwater recharge. Among these are the hydraulic and geologic characteristics, thickness, and distribution of the subsurface materials both above and below the water table; topography; land use; vegetation; soil moisture content; depth to the water table; the intensity, duration, areal extent, and seasonal distribution of precipitation; the type of precipitation (e.g., rain or snow); and air temperature (Walton 1965).

Groundwater eventually discharges to surface water bodies such as springs, wetlands, streams, rivers, or lakes. Groundwater discharge provides water to surface water bodies when water loss resulting from evapotranspiration is high (late spring to early fall). Groundwater discharge maintains saturated conditions found in wetlands, sustains the flow from springs, and provides the baseflow of streams and rivers. An in-depth description of natural recharge in Illinois can be found in Hensel (1992).

**Water levels** The water level in a well indicates the elevation at which atmospheric pressure equals the hydrostatic pressure in the aquifer (Todd 1980). The water level fluctuates because of changes in the hydrostatic pressure. These changes can be caused by groundwater pumpage, natural and artificial groundwater recharge, atmospheric effects, evapotranspiration, aquifer loading, and earthquakes (Freeze and Cherry 1979). Measuring the fluctuation of water levels is a key element in any study of groundwater resources.

Water levels typically follow an annual cycle most noticeable in wells located away from high capacity wells. A decline in water levels begins in late spring and continues throughout the summer and into early fall. Groundwater discharge exceeds groundwater recharge during this time. Water levels begin to rise again late in the fall and peak during the spring. This is the time when groundwater recharge generally exceeds discharge (Visocky and Schicht 1969).

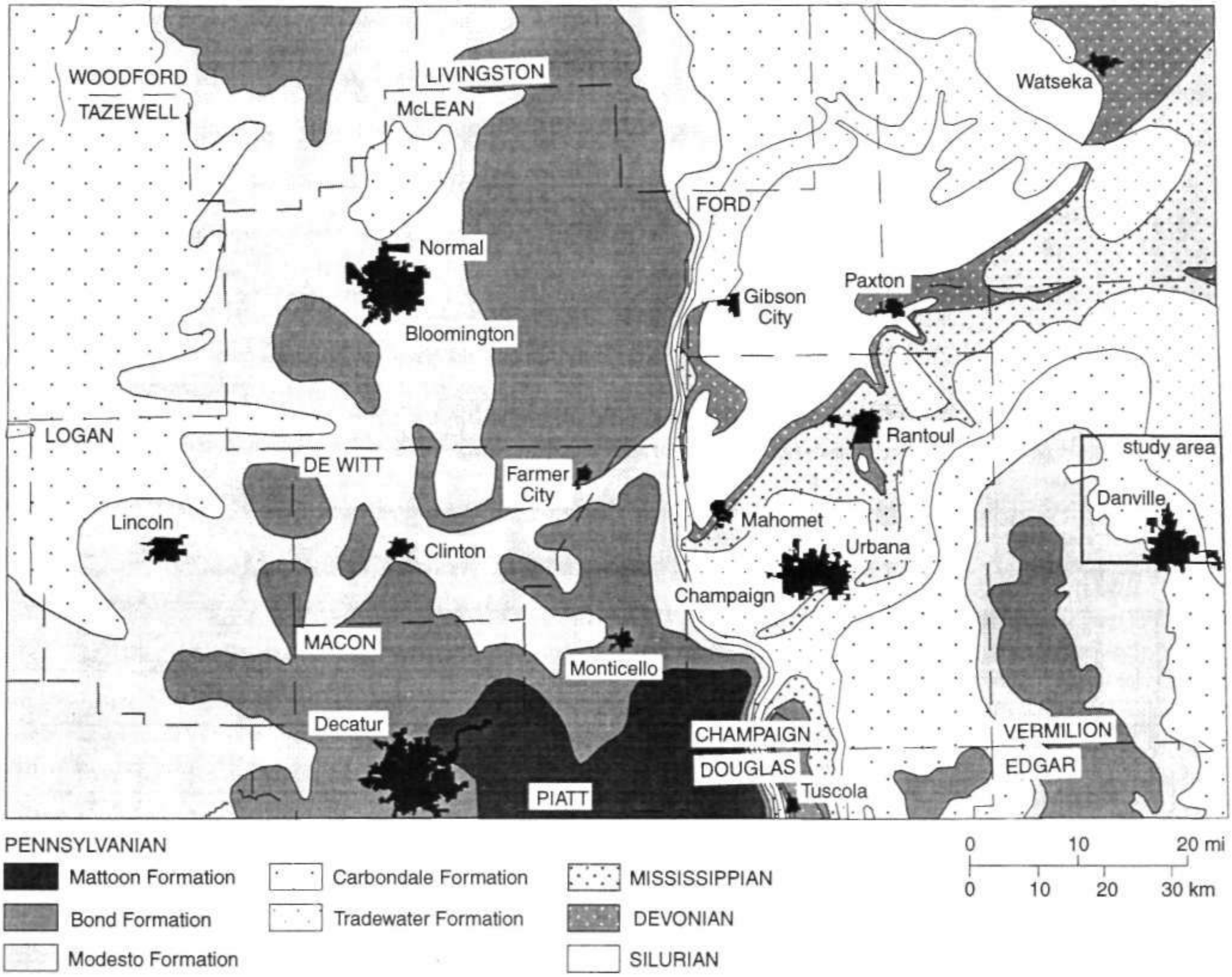


**Figure 4** Bedrock geology of east-central Illinois (from Kempton et al. 1991).

## Groundwater Availability

Two considerations are significant in determining the availability of groundwater: the amount of groundwater available for use from an aquifer and the distribution of aquifers and aquitards.

The amount of water available from an aquifer depends on a number of factors, including the hydraulic properties and dimensions of the aquifer as well as the type of aquifer (confined or unconfined). Because groundwater recharge varies with precipitation, recharge to and discharge from an aquifer can vary with climatic trends and affect the amount of groundwater available.

The distribution of aquifers and aquitards controls the availability of groundwater. Because the thickness, areal extent, hydraulic properties, and geologic characteristics of aquifers and aquitards can vary widely over relatively short distances, groundwater may be readily available in one area but not available in another nearby location. Consequently, gathering and interpreting information on the nature, distribution, and hydraulic characteristics of aquifers and any confining layers are essential in locating and properly developing a groundwater supply. Establishing the hydrogeologic framework of an area is a key first step in determining the availability of groundwater.

**Regional hydrogeologic framework—bedrock** The bedrock formations of east-central Illinois, including Vermilion County (fig. 4), consist of a succession of sedimentary rocks that is several thousand feet thick and includes sandstone, limestone, dolomite, shale, and coal. These rocks were

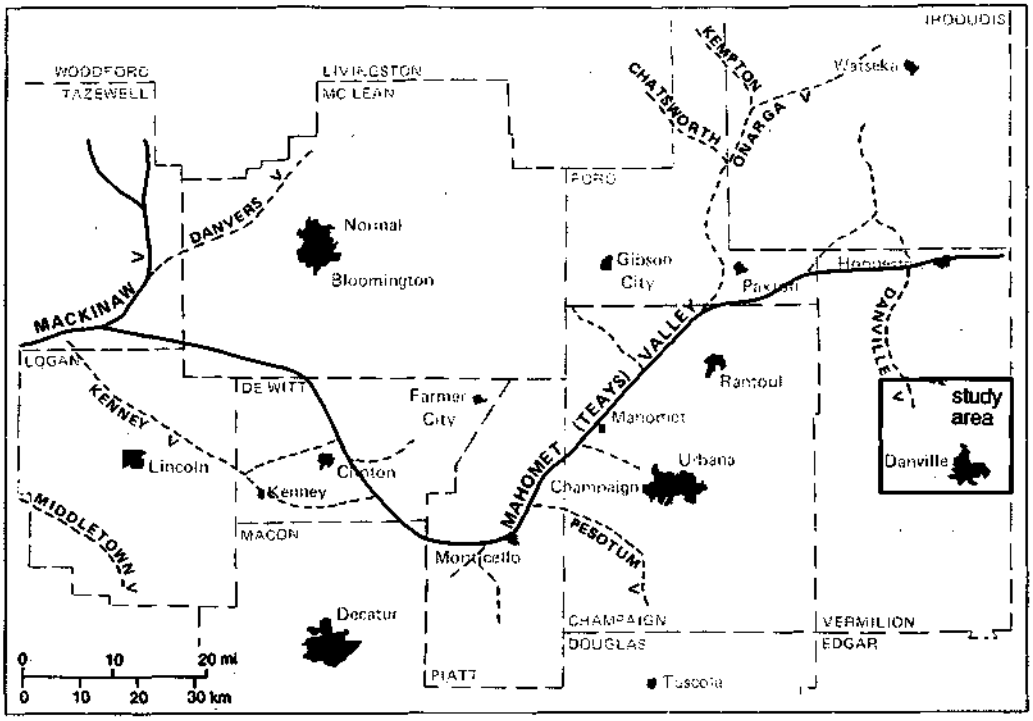


**Figure 5** Bedrock valleys of east-central Illinois (modified from Kempton et al. 1991).

warped and tilted over many millions of years to form the Illinois Basin, which is centered in southeastern Illinois. Older and generally deeper rocks of central Illinois are mainly carbonates (limestone and dolomite) or sandstone. These rocks are typically aquifers, yielding groundwater from fractures (carbonates) or permeable units (sandstone). Younger rocks found at or within a few hundred feet of land surface are predominantly shale with occasional, relatively thin layers of sandstone, limestone, and coal. These rocks may yield small quantities of groundwater from fractures in the shale, limestone, or coal and from the thin permeable sandstone beds. Below depths of 200 to 400 feet, water in the bedrock is highly mineralized and generally nonpotable.

After deposition and lithification of the sediments that form the bedrock of the region, erosional topography developed on the bedrock surface during a long period of uplift. This erosional surface developed mainly during preglacial time several million years ago. This ancient landscape included major river valleys and the numerous large and small tributary valleys associated with them. The major bedrock valleys in east-central Illinois are the ancient Mahomet and Danville Bedrock Valleys (fig. 5).The confluence of these two valleys lies in northern Vermilion County.

**Regional hydrogeologic framework—glacial deposits** The onset of continental glaciation some 2 million years ago profoundly changed the landscape of the bedrock surface of east-central Illinois by disrupting drainage patterns and by deepening and ultimately burying the preglacial bedrock valleys. Repeated pulses of debris-laden ice covered much of Illinois. The earlier ice advances of the pre-Illinois and Illinois Glacial Episodes covered larger areas of the state than the later advances of the Wisconsin Episode (fig. 6). Pre-Illinois ice sheets directly and indirectly caused significant modification of the preglacial bedrock surface by the deepening the existing bedrock valleys through erosion and subsequently by nearly filling them mostly with sand and gravel. These sediments blocked and diverted several major channels away from the glacial margins. As each glacier melted, it left a layer of debris commonly called glacial drift. These deposits can be classified and mapped from subsurface information, such as logs of boreholes or samples obtained from them, as well as from information obtained from exposures of these deposits at land surface. The complex series of events that ended about 14,000 years ago modified the landscape of the region to the extent that the bedrock is now covered with as much as 300 feet of glacial drift (fig. 7). Figure 8, which uses Hansel and Johnson's revisions (1996) of the nomenclature for the Quaternary deposits of Illinois, shows the

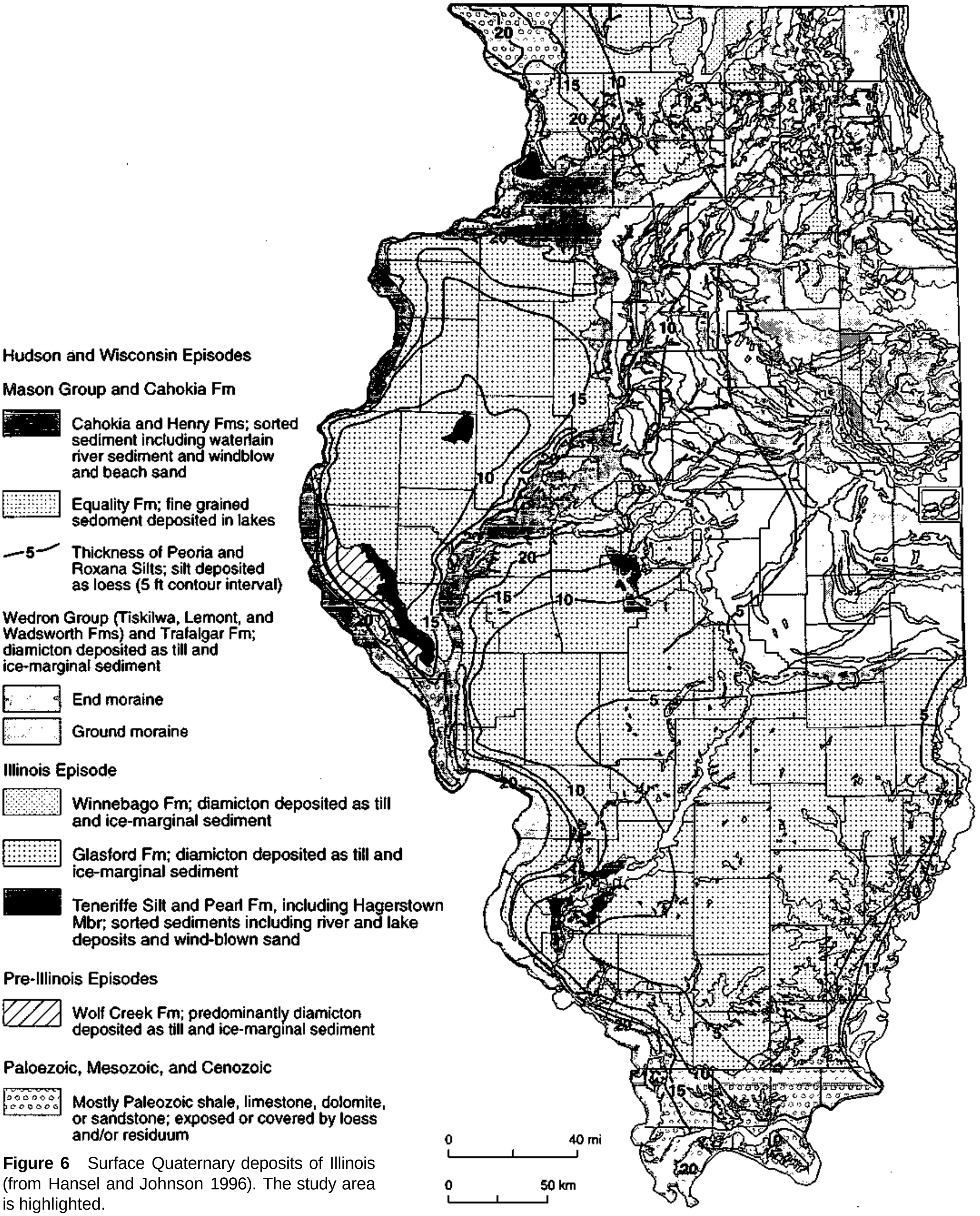


**Figure 6** Surface Quaternary deposits of Illinois (from Hansel and Johnson 1996). The study area is highlighted.

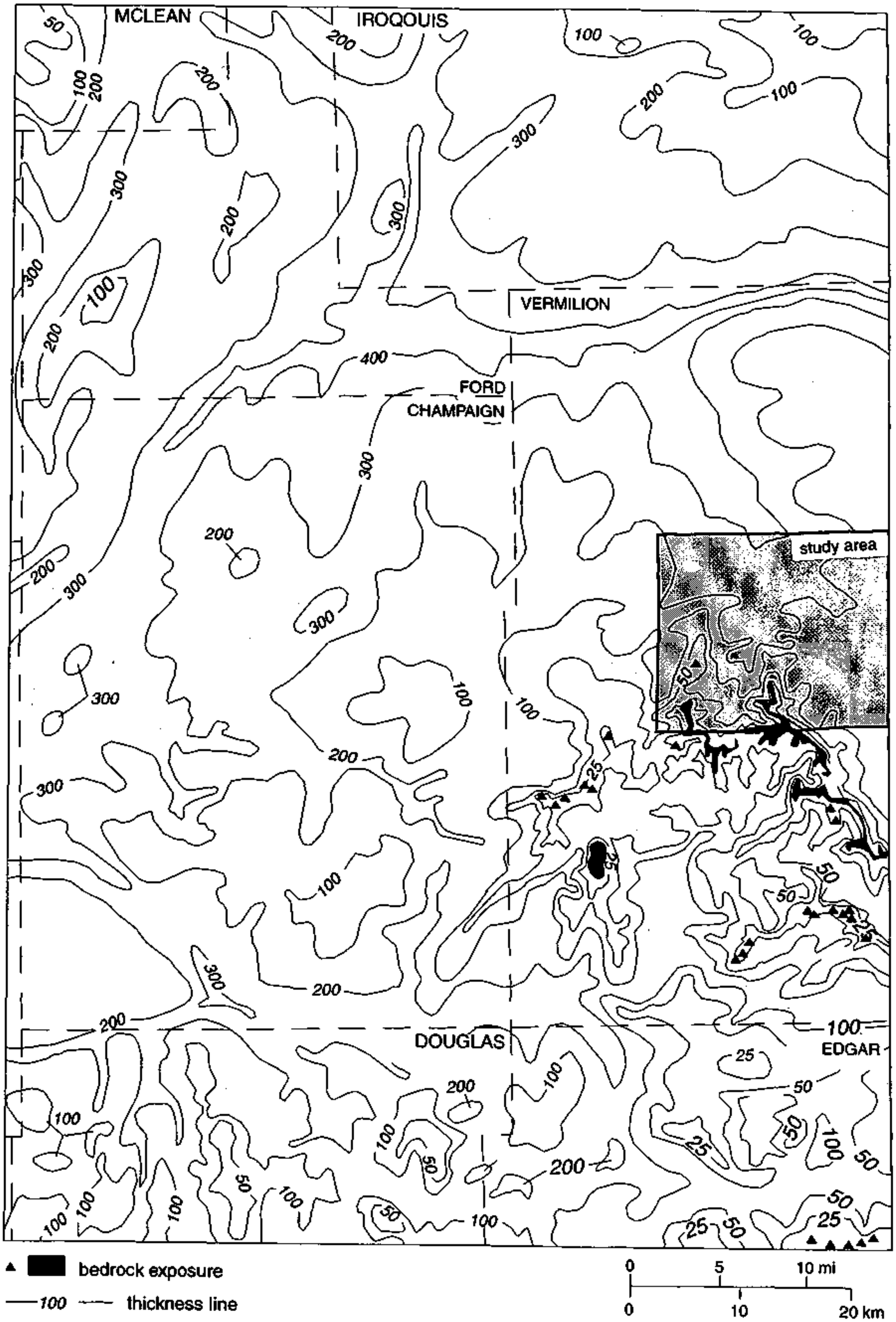


**Figure 7** Drift thickness of part of east-central Illinois including the study area (from Piskin and Bergstrom 1975).

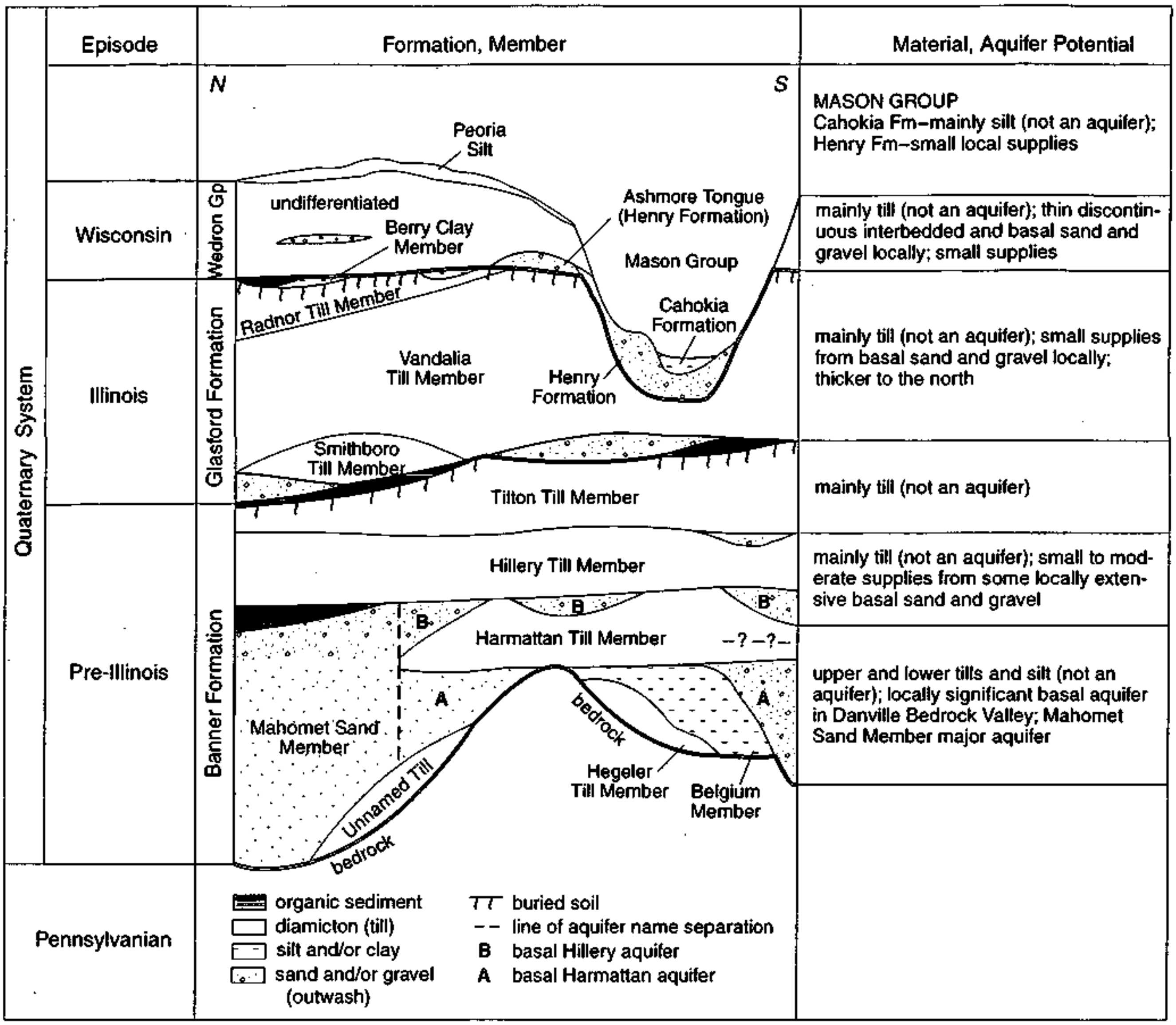


**Figure 8** Sequence of glacial deposits from the study area into northern Vermilion County and their potential as aquifers.

general sequence of deposits and the stratigraphic position of sand and gravel aquifers typically found within the study area and extending into northern Vermilion County.

## DATA SOURCES, STUDY METHODS, AMD PROCEDURES

### Data Availability, Sources, and Utilization

The primary sources of data used in studying subsurface materials are the descriptive logs of water wells or other test holes, samples collected during drilling, and the data obtained by both surface and downhole geophysical methods. Samples and/or downhole geophysical measurements taken from boreholes are the most direct and definitive sources of data on the depth, layering, and nature of subsurface materials. Hydrologic data are obtained from water well records, water level and stream gage measurements, and aquifer tests.

Most of the subsurface data used for this study were obtained from ISGS water well records completed by water well drilling contractors. A water well record typically contains the driller's description of the subsurface materials encountered while drilling the borehole for the well as well as information about well construction, static and pumping water levels, and well yield. The descriptive and geophysical logs of numerous test holes and wells drilled for the City of Danville prior to 1987 provided additional data. The depths of sand and gravel aquifers, as well as the depth to bedrock, were determined from the descriptive and downhole geophysical logs of oil, gas, and coal tests in the study area.

The quality of much of the data available for the study area is good to excellent, although the distribution of the data points within the area is not uniform. Verification of the accuracy of the location given in the record for each well was required. Many of the water wells were completed in the upper few feet of the first sand and gravel aquifer that gave an adequate yield for the intended use of the well. Such wells are not drilled to bedrock and do not penetrate the entire thickness of glacial deposits. No information is available from such wells about total aquifer thickness, the existence of deeper aquifers, or the depth to bedrock. Water wells are generally drilled into bedrock where sand and gravel aquifers are thin or entirely absent. The information from the water well logs is sufficient to outline the occurrence of the principal sand and gravel aquifers and suggest the location of some priority areas for further exploration. Additional information gathered from further test drilling is needed to establish the continuity of sand and gravel aquifers.

Water well records also provided basic hydrologic data mentioned above. These data were supplemented with the results of controlled aquifer and pumping tests that had been performed on a few wells in the study area. These tests often last many hours or days. The data obtained from these tests are available from the ISWS. Analysis of the data gave the extent and hydraulic characteristics of an aquifer and made it possible to assess the impacts of large groundwater withdrawals on nearby wells.

## Geologic Methods/Mapping Procedures

All drillers' logs, sample descriptions, and downhole geophysical logs available for the study area were evaluated. For wells in rural areas, the location given on the well record was verified where possible by matching the well owner's name shown on the well record with the location of property under the same name in the plat book of about the same year that the well was drilled.

Well locations and data were plotted on the six USGS 7.5-minute topographic quadrangle maps that provide topographic coverage for the study area. The depth and elevation of the bedrock surface, if it was encountered, were noted beside the plotted location. The depth and elevation of the top of the principal sand and gravel aquifer were also noted. Typically, the thickness of the aquifer could not be determined from the well log because the entire thickness of the aquifer was not penetrated. The elevations of marker horizons and other identifiable geologic units were recorded. Marker horizons, such as "peat" beds, provide stratigraphic data that help in correlating the various geologic units. If available, the depth of the static water level reported in the well record was also noted together with its corresponding elevation.

Numerous sample sets of earth materials collected from the drilling of water wells and other boreholes have been described by W.H. Johnson (Department of Geology, University of Illinois) and by J.P. Kempton for this study (appendix B). A sample set consists of a portion of the cuttings of the sediments encountered as the borehole is drilled. The sediments are normally collected in 5-foot intervals and put into a sample bag for that interval. In addition, split spoon samples taken at selected intervals during the 1991 and earlier test drilling (appendix C) were examined for moisture content, clay mineralogy, and particle size to aid in correlating the geologic units.

This study uses the stratigraphic sequence of glacial deposits developed by Johnson (1971) and Johnson et al. (1972a, 1972b) as revised by Hansel and Johnson (1996). Seismic and water well data were used to modify the preliminary map of the bedrock surface topography of Vermilion County prepared by W.H. Johnson (circa 1980) and the Vermilion County part of the statewide map of Herzog et al. (1994). The modified map guided the bedrock topography interpretation derived for this study.

A series of cross sections, which are discussed in more detail later in this report, was prepared to help correlate the sequence of deposits exposed in stream banks and strip mines described by Johnson et al. (1972b) with the drillers' logs and other logs prepared from the study of sample cuttings and cores of the materials encountered in the water wells and test holes. These cross sections helped establish the distribution of the various types of geologic materials within the glacial drift throughout the study area. The cross sections were drawn to take advantage of as many sample descriptions as possible as well as to depict the relationship of the various sand and gravel aquifers to each other, the bedrock surface, the fine grained sediments, and marker units. The cross sections reflect the greater continuity of the glacial tills as compared with that of the outwash sands and gravels. Because of depositional and erosional processes, not all deposits found within the study area are necessarily present at any specific site or even within part of the study area. Aquifer boundaries were established from water well data, stratigraphic position and elevation of the various units, and the cross sections. The topography of the bedrock surface was the limiting factor in establishing the distribution of the deeper sand and gravel aquifers.

## Geophysical Methods

Surficial and downhole geophysical techniques were used to obtain data that helped in the interpretation of the available test hole and water well data and the correlation of the various lithostratigraphic units within the study area. The surficial techniques included reversed seismic refraction profiling and electrical earth resistivity (EER) surveys.

**Reversed seismic refraction** A total of 46 reversed seismic refraction profiles were run northwest of Lake Vermilion to help refine the topographic map of the bedrock surface in this area. A 12-channel, EG&G Geometric Model ES-1225 seismograph system was used. Profile length was usually 1,200 feet with geophone spacings of 100 feet and a shot point located at both ends of each profile. The energy source was a 10-ounce charge of dynamite detonated in a 5-foot shot hole.

First arrival time-distance plots were interpreted using a procedure described by Heiland (1940) and assuming three seismic layers: a thin, top layer representing the surficial weathering layer; a middle layer representing the deposits of glacial drift usually comprised of till, sand, and gravel; and a lower layer representing solid or broken and weathered bedrock. It was not always possible to calculate the velocity, and therefore the thickness, of the upper layer using the data from the 1,200-foot seismic refraction profiles. Shorter seismic refraction profiles with close geophone spacings were periodically run to help define the velocity and thickness of this top layer.

The seismic refraction method yields the best results where velocities of the seismic layers increase downward from the land surface. The presence of a slow velocity layer beneath a high velocity layer creates a velocity inversion that causes difficulties in data interpretation. In a glaciated area, a slow velocity layer may consist of sand and gravel. If the slow velocity layer is of considerable thickness and occurs between a compact till and solid bedrock, both of which have higher velocities than the sand and gravel, the slow velocity layer will not be readily apparent on the first arrival, time-distance plots. Consequently, the plots are interpreted as if they were the result of till directly overlying bedrock. The resulting calculated depths to bedrock are greater than the actual depths to bedrock by an amount that is directly proportional to the thickness of the undetected, or hidden, slow velocity layer. In areas where the hidden layer is present, this difference between calculated and actual depth to bedrock can lead to misinterpretations of the configuration of the bedrock surface. This is the essence of the "hidden layer" problem.

Data from water well records show that a slow velocity layer is present in the part of the study area where seismic profiling was conducted. Because the presence of a slow velocity layer would adversely affect the interpretation of the seismic refraction data, a series of charges was detonated at various depths in a test hole where the sequence of till over sand and gravel indicated a velocity inversion was likely. The results of the seismic waves recorded at land surface verified that the sequence of till over sand and gravel caused a velocity inversion of the seismic waves. They also provided layering parameters (thickness and velocity) that were helpful in validating the interpretation of the entire seismic refraction survey.

**Electrical Earth Resistivity** A total of 73 EER profiles was obtained in a 35-square-mile part of the study area northwest of Lake Vermilion. These EER surveys, using the Wenner (1916) array, measured the electrical potential of earth materials from the land surface to some depth below it. The measurements were processed to determine the apparent electrical resistivity of the materials. Sand and gravel deposits have relatively higher resistivity values than do fine grained materials, such as the clay-rich tills or shale bedrock found in Vermilion County. The results of EER surveys can help distinguish aquifers from aquitards in the glacial drift, particularly at shallower depths. The EER profiles were evaluated in terms of the distribution of resistivity values at the 500-foot elevation. This elevation was chosen to represent the edge of the Danville Bedrock Valley.

The resistivity values were divided into three groups: greater than 50,40 to 50, and less than 40 ohm-meters. These groups correspond to three different sediment textural groups. Sand and gravel is assumed to be prevalent in the areas with resistivity values of greater than 50 ohm-meters. These deposits have the highest hydraulic conductivities. For resistivity values between 40 and 50 ohm-meters, the sediments are assumed to be somewhat finer in texture than the sand and gravel and have a correspondingly lower hydraulic conductivity. Resistivity values of less than 40 ohm-meters are assumed to indicate fine grained sediments (silt, clay, or glacial till), which have the lowest hydraulic conductivities. EER is an effective method for identifying continuous and relatively thick units to a depth of about 150 feet (Driscoll 1986).

**Downhole logging** Natural gamma logs were run on the test holes drilled in 1987,1988, and 1991. A natural gamma log can be used qualitatively for stratigraphic correlation (Driscoll 1986). Commercial downhole geophysical logs, mostly natural gamma logs, have been used in mapping the extent and thickness of the Mahomet Sand and shallower aquifers north of the study area (Kempton et al. 1981).

## Hydrologic Methods

The results of 11 controlled pumping tests in the study area and 13 in northern Vermilion County (on file at the ISWS) were analyzed to determine the hydraulic properties of the aquifers and aquitards discussed in this report (appendixes D and E). A controlled pumping test involves pumping water from a well for a specific period of time at a controlled, closely monitored rate. Controlled pumping tests include aquifer tests and single well pumping tests. Water levels are measured in the pumped well and simultaneously in other observation wells (in an aquifer test) while the well is pumped and for a period of time after pumping has stopped. The effect of the pumping on the aquifer is monitored by noting the changes in water levels in the wells.

**Aquifer tests** An aquifer test involves a test well with one or more observation wells screened in the source aquifer and, less commonly, in other hydrologic units. The observation wells are usually situated at a range of distances and, ideally, in various directions from the test well. The test well is pumped at a controlled and measured rate for a given period of time. If the purpose of the aquifer test is to determine the hydraulic properties of the aquifer, the pumping rate is held as constant as possible and closely monitored to detect variations that could influence the results of the test. If the purpose of the aquifer test is to provide information pertaining to the efficiency of the well and pump, the pumping rate is systematically increased in successive steps.

Water levels in the pumped well and observation wells are measured during pumping and for a period of time after pumping has stopped. Water levels usually decline while the well is being pumped (drawdown) and rise after pumping ceases (recovery). The measured water level and the time after the start (for drawdown) and end of pumping (for recovery) are noted for each water level measurement. The transmissivity, hydraulic conductivity, and storage coefficient of the tested aquifer are derived from the analysis of the water level data. The presence of hydraulic boundaries to the aquifer and the vertical hydraulic conductivity of aquitards can also be determined from analysis of the data. The influence of the pumping on other hydrologic units can be determined from the data if some of the observation wells are screened in these other hydrologic units.

**Single well pumping tests** A single well pumping test involves only a pumped well; no observation wells are used. The pumping rate is closely monitored and controlled. The water level in the pumped well is measured throughout the test. Values for hydraulic conductivity and aquifer transmissivity are derived by the analysis of the water level data from a single well pumping test. The storage coefficient cannot be quantified by such a test.

A single well pumping test performed to measure the productivity and efficiency of a well is called a specific capacity test. The specific capacity of a well is defined as the yield of the well per unit drawdown for a given pumping period and discharge rate. The information recorded from a specific capacity test often includes only the pumping rate, the nonpumping (static) water level, and the water level at the end of pumping. In general, the specific capacity of a well is directly proportional to the transmissivity of the aquifer. In the absence of aquifer test data, transmissivity can be estimated from specific capacity data. A high specific capacity typically indicates a highly transmissive aquifer whereas a low specific capacity typically indicates the opposite. Specific capacity is only a relative measure of transmissivity, however, because other factors not related to transmissivity typically affect the results of a specific capacity test. These include partial penetration of the aquifer by the well, well loss (drawdown due to well inefficiency), hydrogeologic boundaries to the aquifer, and gravity drainage in an unconfined aquifer.

**Data analysis** The data obtained from controlled pumping tests can be analyzed through the use of one or more similar graphical techniques. These techniques involve evaluating graphs on which are plotted drawdown or recovery data versus elapsed time since pumping started or ended, respectively, or synchronous drawdown or recovery data for the observation wells versus distance from the pumped well. The derived graphs are evaluated by comparing them to type curves developed from equations that characterize the relationship between the hydraulic properties of an ideal aquifer to the drawdown and recovery of water levels in the vicinity of the pumped well in the ideal aquifer over a range of hydrologic settings. The graphical techniques used in this study included the nonleaky artesian method (Theis 1935), the modified nonleaky artesian method (Cooper and Jacob 1946), the leaky artesian method (Walton 1960), and the inflection point leaky artesian method (Hantush 1956).

Aquifer transmissivity can be estimated from specific capacity data by using the theoretical relationship between specific capacity and transmissivity developed by Walton (1962) from the modified nonleaky artesian formula (Cooper and Jacob 1946). Only approximate values of transmissivity can be derived by this technique. As mentioned previously, the specific capacity of a well can be influenced by factors not directly related to the hydraulic properties of the aquifer. The specific capacity data may be adjusted to account for the influence of some of these factors before applying Walton's technique, but the information that allows for this is usually not available. This technique uses assumed values for the storage coefficient of the aquifer and the effective well radius, which adds to the uncertainty of the values for transmissivity derived from specific capacity data.

## RESULTS OF SURFACE GEOPHYSICAL SURVEYS

### Reversed Seismic Refraction

Interpretation of the first arrival, time-distance plots provided the following characteristic values for the velocity and thickness of each of the three seismic layers. The thin upper layer has a consistent velocity of approximately 1,250 ft/s. This value was assumed to be constant for the upper layer throughout the area surveyed. This assumption allowed the thickness of the surficial weathering layerto be calculated for each seismic refraction profile. The calculated thickness varied from 2 to 10 feet and averaged 7 feet. The velocity of the middle layer ranged from 5,743 to 6,947 ft/s and averaged 6,315 ft/s. Calculated thickness of this layer varied from 109 to 240 feet and averaged 182 feet. The velocity of the lower layer ranged from 8,244 to 11,833 ft/s; average velocity was 10,264 ft/s. The calculated depth to bedrock varied from 115 to 245 feet.

The bedrock elevations derived from the seismic survey (fig. 9) supplemented the bedrock elevations obtained from the water well records and helped to better define the shape of the Danville Bedrock Valley in an area west and north of Lake Vermilion. The extent to which velocity inversion layers may have biased the bedrock elevations calculated from the seismic survey should be evaluated through test drilling. The bedrock high at Snider, which was identified through the seismic survey, is a good example of where the seismic data should be verified with additional subsurface data. The results of the seismic survey indicate that the bedrock surface may be quite variable within a relatively small area.

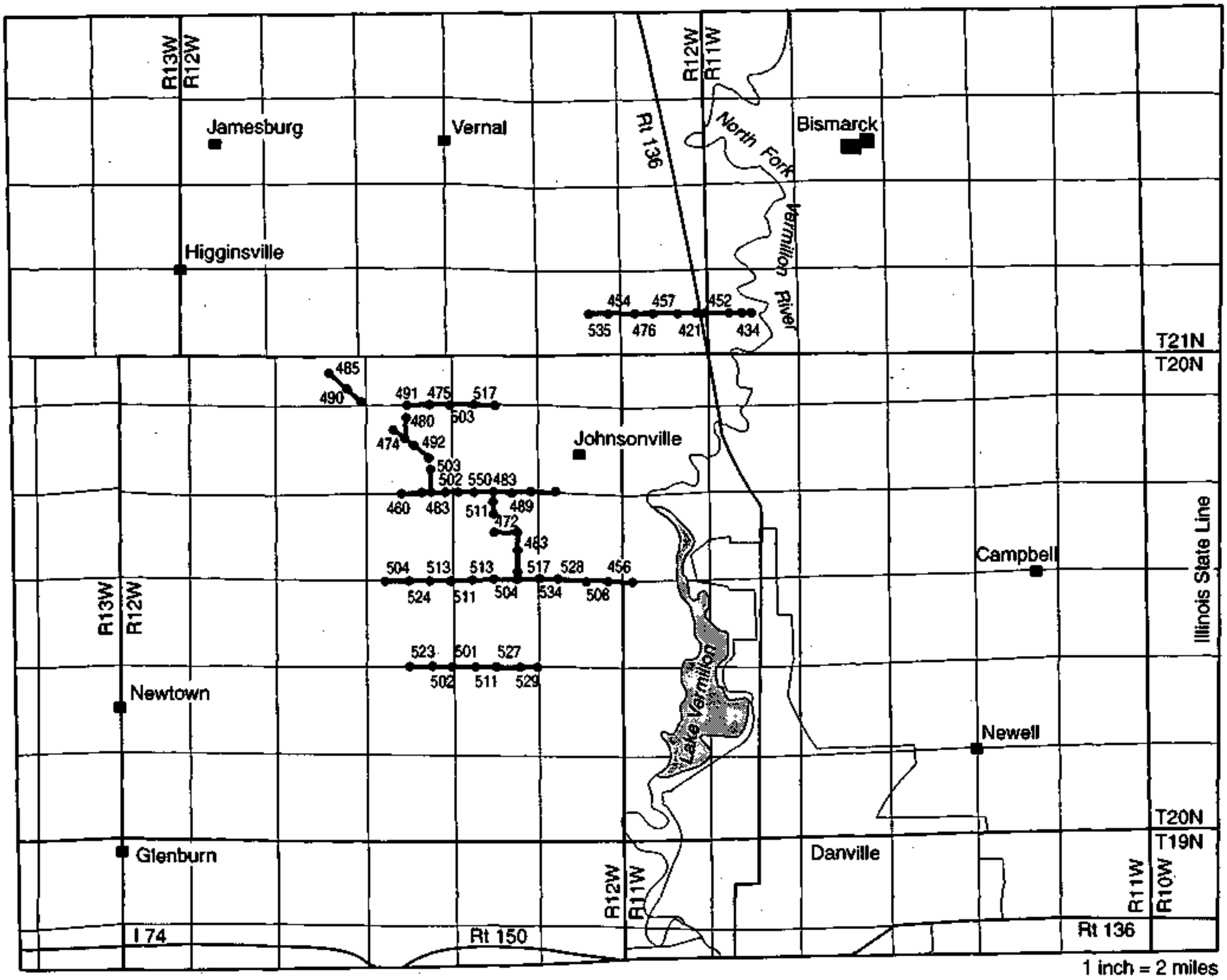


**Figure 9** Elevation (feet) of the bedrock surface in part of the study area northwest of Lake Vermilion interpreted from the reversed seismic refraction survey data.

●—● reversed seismic refraction line
517 elevation of bedrock surface in feet

## Electrical Earth Resistivity

The resistivity values at the 500-foot elevation in the area west and north of Lake Vermilion ranged from 28 to 84 ohm-meters (fig. 10). The distribution of resistivity values suggests that the sediments at the 500-foot elevation become finer grained from north to south across the 35-square-mile area. Sand and gravel deposits are most likely to be prevalent in the reaches of the Danville Bedrock Valley where the resistivity values are the highest; silts and clays are most likely to be prevalent where the values are the lowest.

The area of the highest resistivity values extends beyond the edge of the bedrock valley, as defined by the 500-foot elevation. These high resistivity values may indicate the presence of shallower sand and gravel deposits over some of the higher bedrock areas. These data suggest that sand and gravel deposits in the study area may not be restricted to the deeper parts of the bedrock valley.

# HYDROGEOLOGY OF THE DANVILLE STUDY AREA

## Basic Framework

This study generally confirmed the currently recognized basic stratigraphic sequence of glacial deposits (fig. 8). Because no significant aquifers with potable groundwater appear to be present in the bedrock, the hydrogeology of the bedrock is not discussed further. However, the topography of the

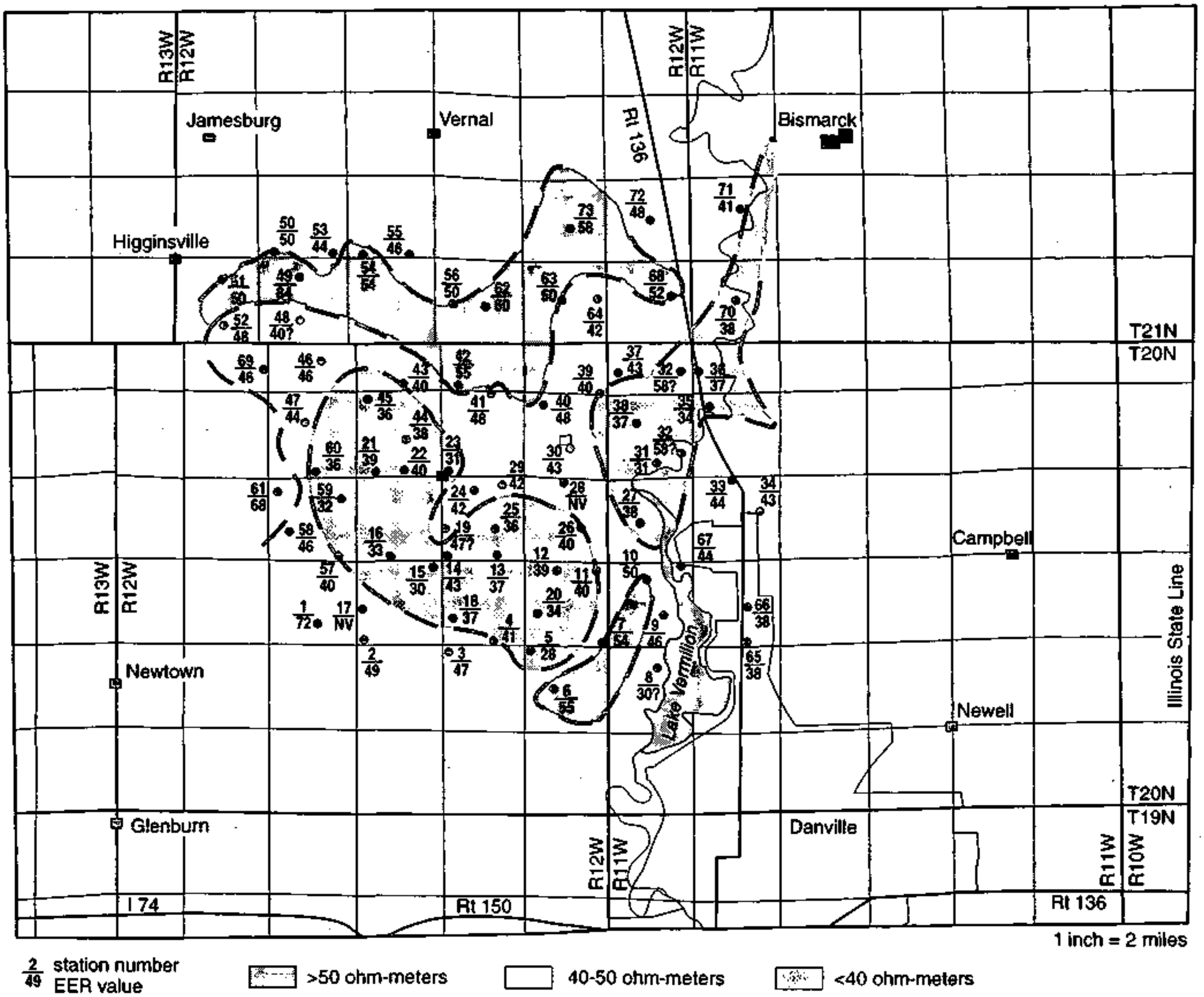


**Figure 10** Electrical resistivity values at the 500-foot elevation in part of the study area northwest of Lake Vermilion.

bedrock surface and the stratigraphy of the glacigenic and related deposits that cover the bedrock are significant in controlling the occurrence and distribution of sand and gravel deposits that comprise the aquifers.

## Bedrock Topography

Horberg (1945, 1950) and Eveland (1952) recognized the existence of the Danville Bedrock Valley, and Johnson's (circa 1990) preliminary map added further detail to our understanding of the valley and general features of the bedrock surface. Kempton et al. (1991) described the regional bedrock surface. The bedrock surface configuration for this study (fig. 11) used the buried bedrock surface map of Herzog et al. (1994) as a basis and was modified using the data from recent test drilling (fig. 1), surficial geophysical surveys (fig. 9), and the records of water wells located in the study area (fig. 11).

Bedrock uplands are distinguished from lowlands in the study area on the basis of the 500-foot bedrock elevation contour. The topography of the bedrock surface exhibits a rather narrow valley that is about 0.5 to 1 mile wide, trends southeast to northwest, and underlies parts of Danville (fig. 11). The highest known elevation in the study area is somewhat in excess of 550 feet on the bedrock uplands, whereas the lowest known elevation is somewhat less than 415 feet within the bedrock valley.

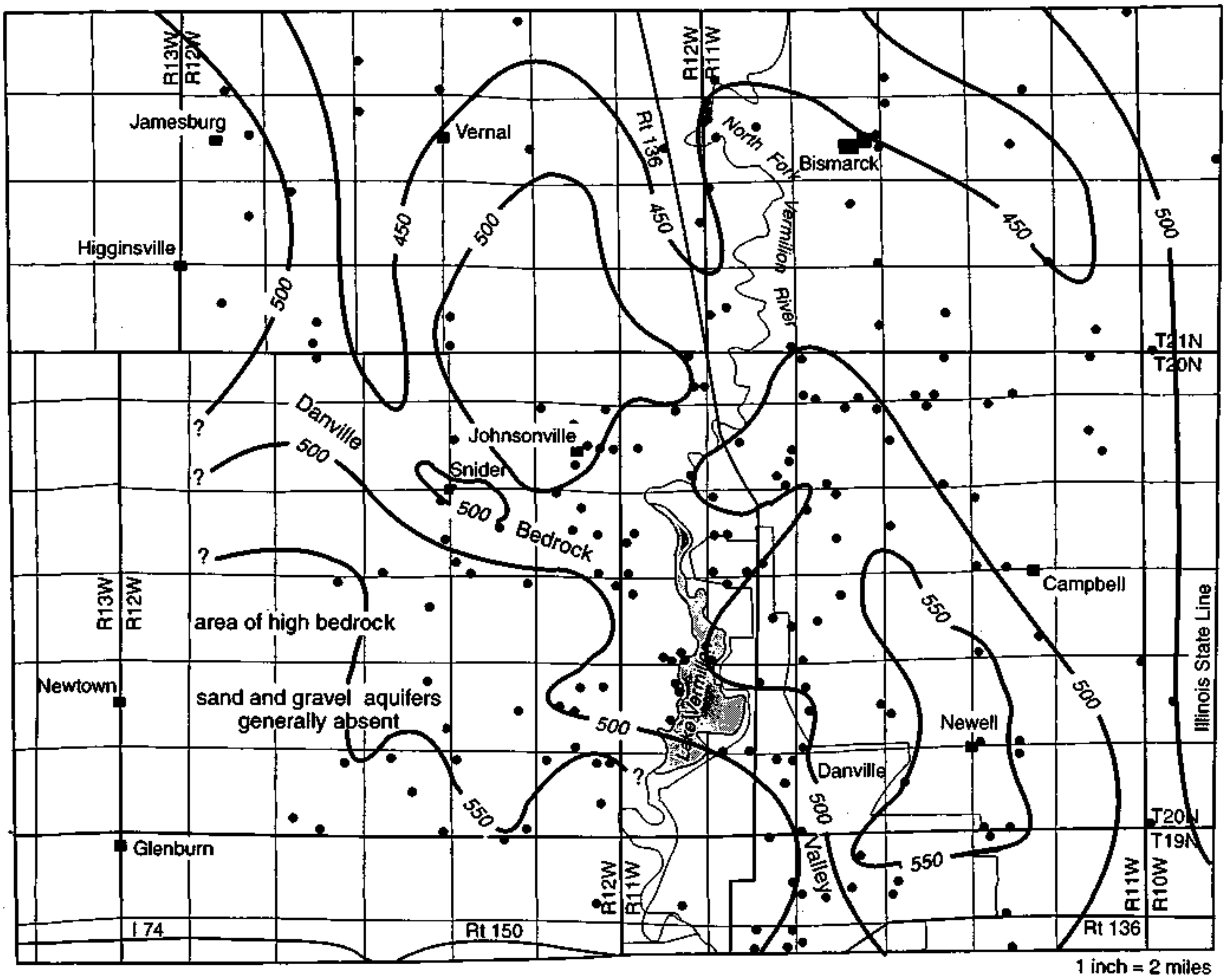


**Figure 11** Elevation (feet) of the bedrock surface within the study area (modified from Herzog et al. 1994).

The narrowest part of the valley is about 0.5 mile wide and underlies Danville. Between Lake Vermilion and Snider, the width of the valley increases to about 1.5 miles. The main channel continues northwestward past Snider (where the seismic refraction data indicate a bedrock high exists), makes a gradual bend to the north, and joins an east-west-trending channel just north of Vernal. This valley, which is generally referred to as the Danville Bedrock Valley, continues northward to its confluence with the Mahomet Bedrock Valley in northern Vermilion County (Kempton et al. 1991). A tributary bedrock valley extends westward from the Bismarck area to north of Vernal where it joins the Danville Bedrock Valley. A small valley branches to the south of the larger tributary extends for about 3 miles.

The bedrock valleys in the study area are part of a larger valley system within a broad bedrock lowland in north-central Vermilion County, where bedrock elevations are generally below 500 feet (Herzog et al. 1994). This larger valley system extends westward from the Indiana-Illinois border into north-central Vermilion County. It lies just south of and is tributary to the Mahomet Bedrock Valley.

The system of bedrock valleys has both broad and narrow reaches, indicating that the development of the bedrock surface topography has a rather complex history (fig. 11). The changes in width indicate several episodes of erosion and filling. During the numerous advances of the continental glaciers near or across the study area, filling took place while erosional development of the valley was interrupted.

The present bedrock surface reflects preglacial features, erosion during Pleistocene glaciation, and local postglacial erosion. The narrow bedrock "gorge" at Danville is an example of local postglacial erosion along the Vermilion River. Present drainage is only locally coincident with the bedrock valley from just south of Winter Avenue to south of Danville, where the bedrock valley underlies the Vermilion River.

## Glacial and Related Deposits

**Thickness** The total thickness of glacigenic and associated deposits can generally be determined for any given location by subtracting the bedrock surface elevation from land surface elevation. A somewhat generalized drift thickness map can be produced by plotting a series of points together with measurements made where bedrock crops out below the drift near land surface and drift thicknesses determined from wells drilled into bedrock. Although such a map was not prepared specifically for this study, the map shown in figure 7 gives a general overview of the drift thickness in the study area.

The configuration of the present land surface, the filling of the bedrock valleys, and the stacking of drift sheets above the bedrock uplands are reflected in the thickness of the glacial drift. Where the land surface is relatively flat, the drift thickness map shows thickening of the drift within bedrock valleys. Where the bedrock surface is relatively flat, the map reflects changes in drift thickness due to surficial features such as morainal ridges or modern stream valleys. Drift thickness may be quite variable and complex where topographic features of the land surface and bedrock surface are superimposed.

Bedrock lowlands generally contain the greatest thickness of older (pre-Illinois Episode) glacial deposits. These deposits are only thinly draped over or entirely absent on the bedrock highs. The deposits of intermediate age (Illinois Episode) are generally more uniform in thickness. Younger glacial units, particularly the tills of the Wedron Group, generally display a large variation in thickness related to land surface topography (i.e., thickness is generally the greatest where the end moraines are located).

**Stratigraphy (sequence of units)** The three main geologic units present in the study area are the Banner and Glasford Formations and the Wedron Group. The Banner Formation is the oldest of these three units, and the Wedron Group is the youngest (fig. 8). The Wedron Group contains several smaller units (formations). The Banner and Glasford Formations each include several locally extensive units (members). The general sequence and distribution of deposits across the study area along seven lines of cross section (fig. 12) are shown in figures 13 and 14. Figure 15 shows the sequence of glacial deposits exposed in the now abandoned Harmattan strip mine located about 3 miles west of Danville in Section 34, T20N, R12E.

This report uses the common genetic classification of drift deposits based on texture and composition. The most widespread of the deposits are glacial till and outwash. Till is predominantly fine textured, pebbly silt and clay deposited directly from melting glaciers. Outwash is mostly coarse textured sand and gravel carried from the glaciers by meltwaters. Till is the predominant earth material in the study area. Most till members have some distinguishing characteristics that make them identifiable in exposures or in borehole cuttings. Where relatively thick and extensive, the outwash deposits form the principal aquifers in the study area.

In addition to recognizable properties of the till, other features of the drift deposits are used to help distinguish individual members. These features include the presence of locally preserved buried soils and related deposits between the Banner and Glasford Formations as well as between the Glasford Formation and Wedron Group (fig. 8). These sediments represent warm periods between glacial episodes during which earlier deposits were weathered and eroded. Although not extensively preserved in the study area, these soils and deposits do occur and are helpful in tracing the associated stratigraphic units both above and below them.

As shown by the cross sections (figs. 13,14), a relatively predictable sequence of glacigenic deposits occurs throughout the study area. Tills and associated sand and gravel outwash of the Banner Formation (pre-Illinois Episode) lie directly on the bedrock surface. Thickness of this formation in the study area ranges from about 50 feet to more than 150 feet, with the greater thickness found in the Danville Bedrock Valley. The top of the Banner Formation is generally at an elevation of about 590 feet within the study area. Thickness of the Glasford Formation (Illinois Episode) averages about 30 feet, but this formation

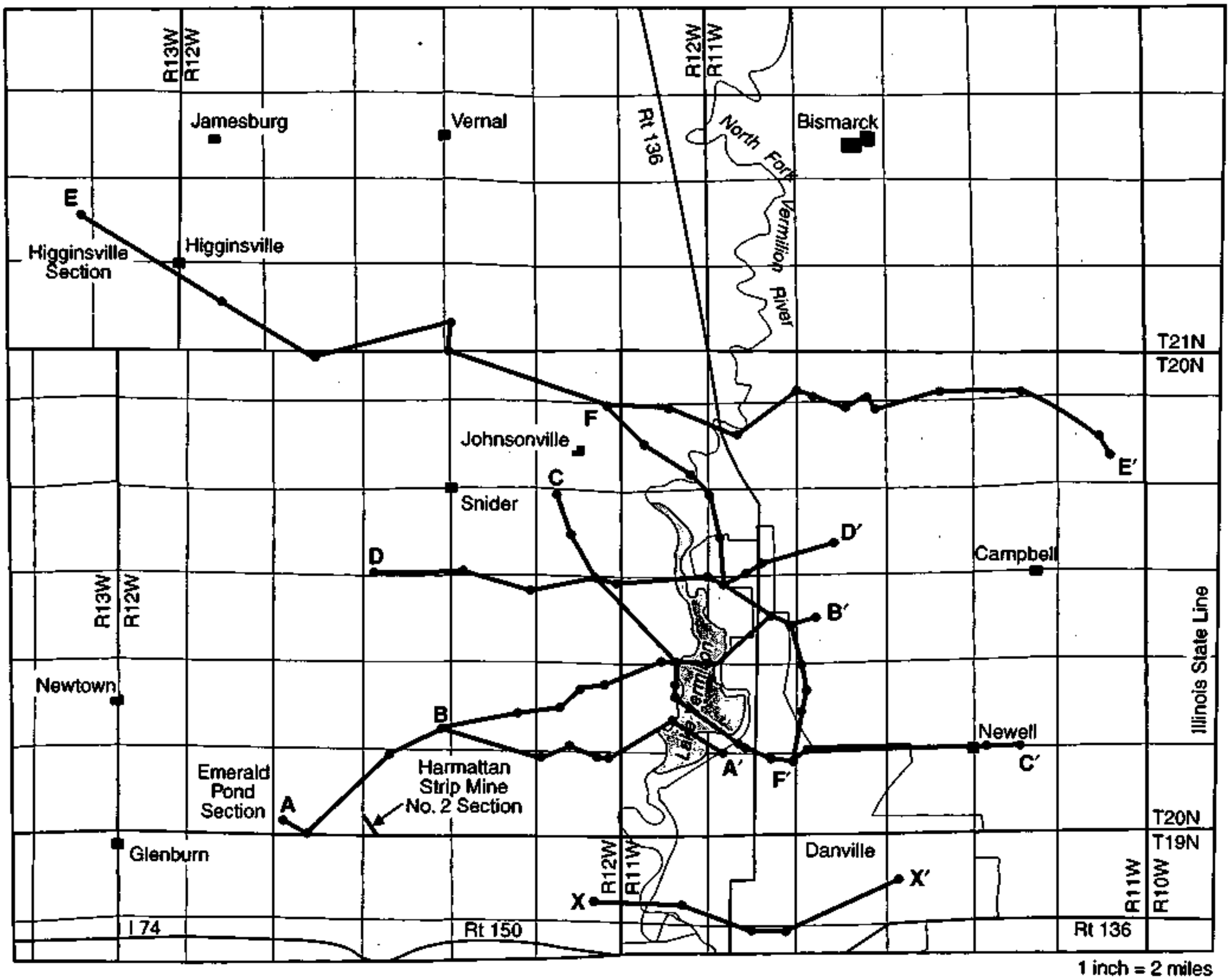


**Figure 12** Location of cross sections shown in figures 13, 14, and 15.

can be absent locally in the study area (e.g., see fig. 13a). The top of the Glasford is generally at an elevation of about 630 feet in the study area. The Wedron Group (Wisconsin Episode) ranges in thicknessfrom about 10 feet to more than 100 feet. It becomes considerably thinner south of the outer margin of the Newtown Moraine (fig. 3). The Wedron Group is absent where it has been eroded by the principal streams of the area (e.g., see fig. 13c). The Henry Formation is outwash sand and gravel deposited in the major valleys by meltwaters from the glaciers that deposited the tills of the Wedron Group. Thickness of the Henry may be 60 feet or more along parts of North Fork Vermilion River and Stony Creek (fig. 14).

Four principal till members within the Banner Formation have been recognized in the Danville area. From oldest to youngest, these are the Hegeler, Harmattan, Hillery, and Tilton Till Members (fig. 8). Another unnamed member is present in some very small areas. It may be related to either the Harmattan or Hegeler Till Members. Associated with the Hillery and Harmattan Members, which are generally found throughout the area, are underlying deposits of sand and gravel outwash that locally are rather thick and areally extensive. These outwash deposits are called the basal Hillery aquifer and basal Harmattan aquifer for this report (fig. 8). These sources of groundwater were found along Winter Avenue as well as on the west side of Lake Vermilion during the 1987, 1988, and 1991 test drilling (figs. 13, 16-18). Where the Harmattan member is absent to the north, the outwash deposits apparently coalesce with other outwash deposits and laterally grade into the Mahomet Sand in the Mahomet Bedrock Valley (figs. 8, 19). The silt facies of the Mahomet Sand (fig. 19) is relatively sparse in the study area.

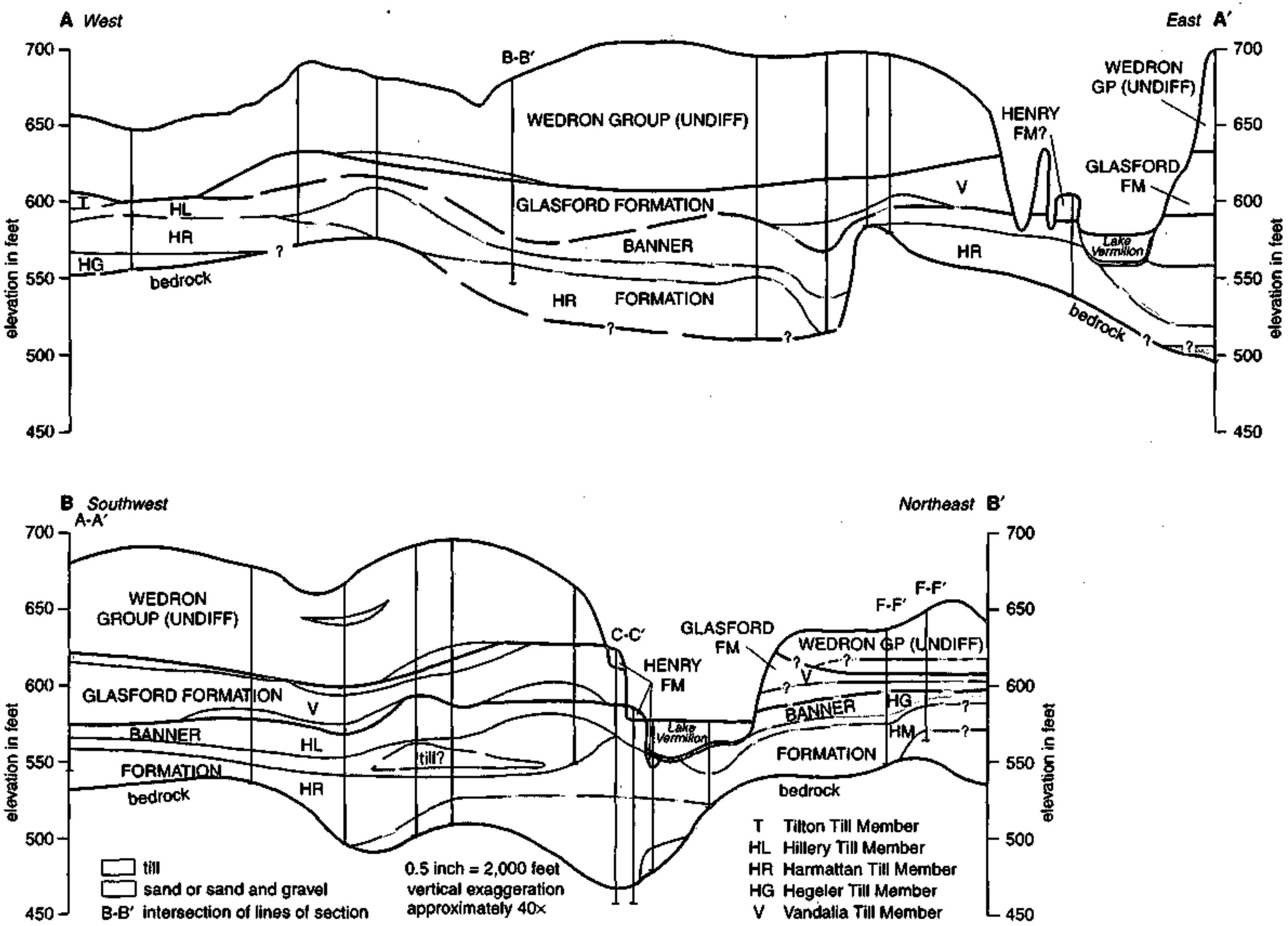


**Figure 13** **(a)** West-east cross section (A-A') from the Emerald Pond section to the top of the east bank of Lake Vermilion just north of Winter Avenue. **(b)** Southwest-northeast cross section (B-B') from the southwest part of the study area northeastward across the Lake Vermilion test site and Lake Vermilion to the uplands.

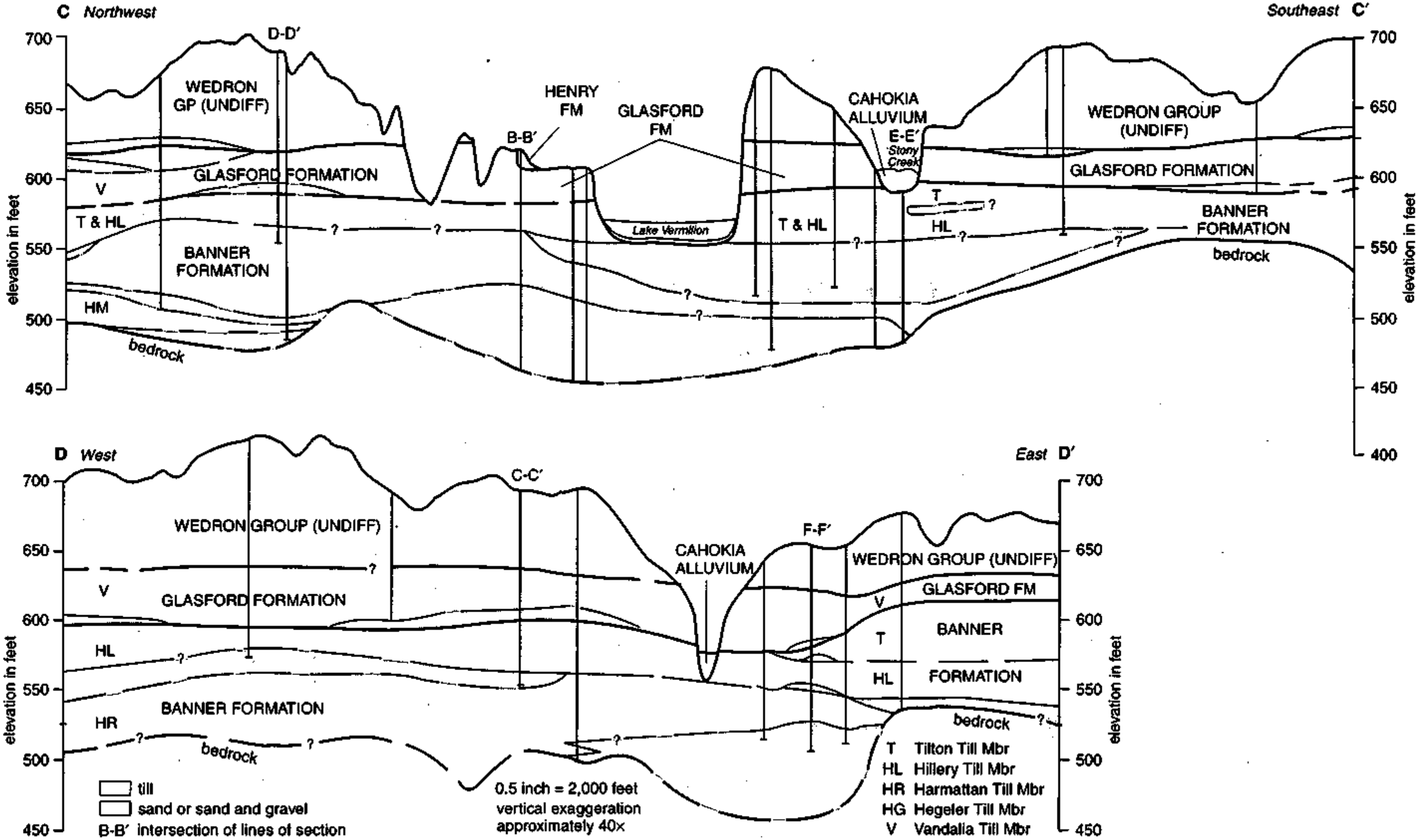


**Figure 13 (c)** Northwest-southeast cross section (C-C') from northwest of Lake Vermilion southeastward to the Lake Vermilion test site, southeastward to the Winter Avenue test site, then approximately 2 miles eastward along Winter Avenue. **(d)** West-east cross section (D-D') from northwest of Danville eastward across the northern part of Lake Vermilion to just west of the Vermilion County airport.

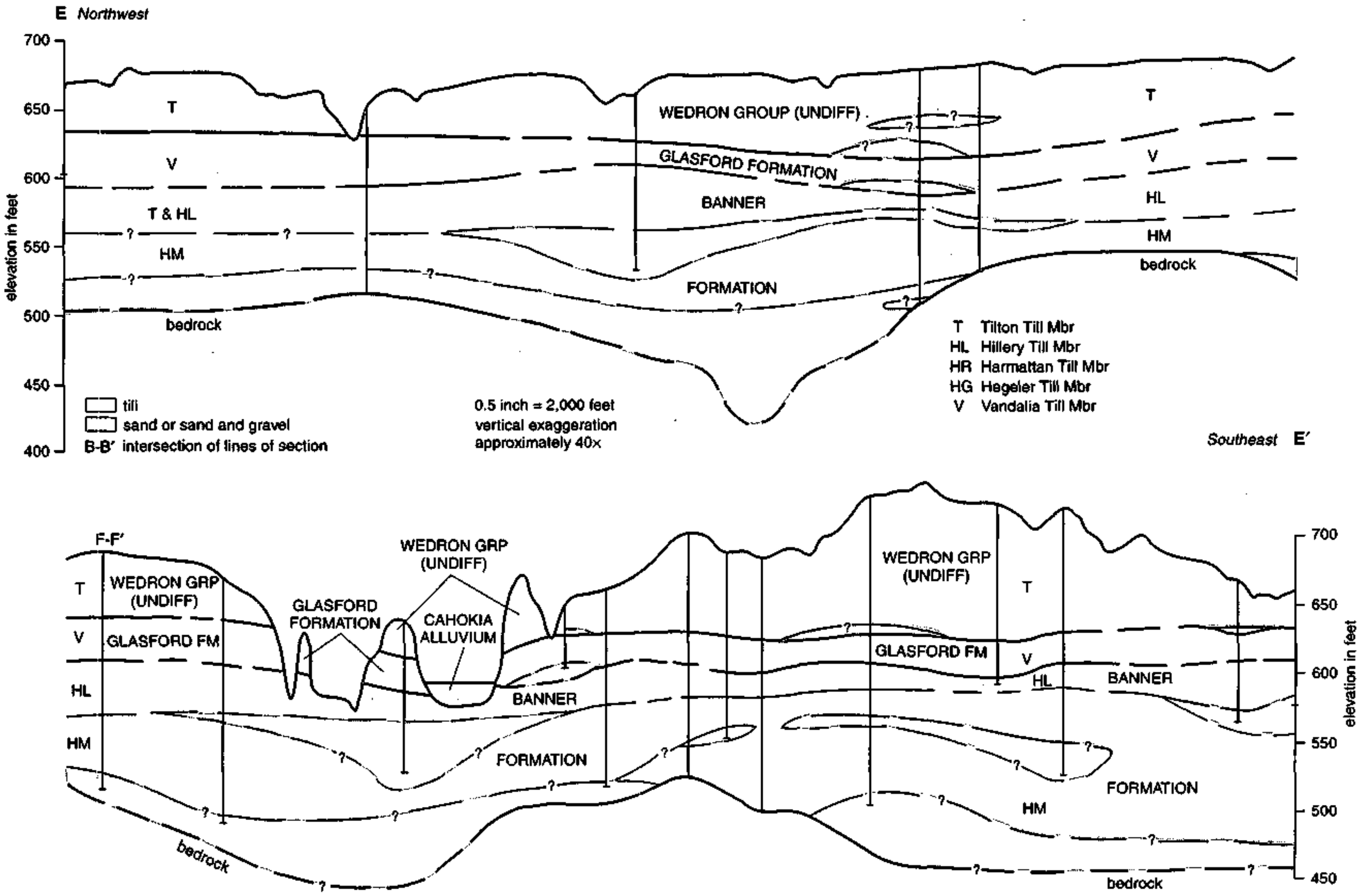


**Figure 13 (e)** Northwest-southeast cross section (E-E') from the Higginsville section (Johnson et al. 1972a, 1972b) southeastward to the North Fork Valley north of Lake Vermilion then generally eastward along the northern part of T20N, R11W.

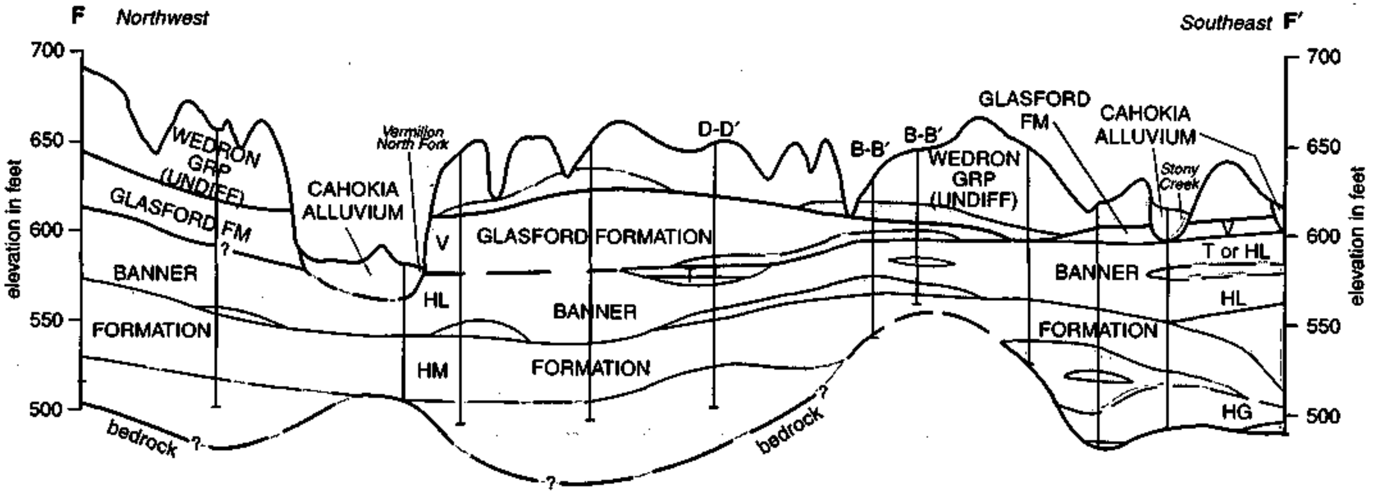
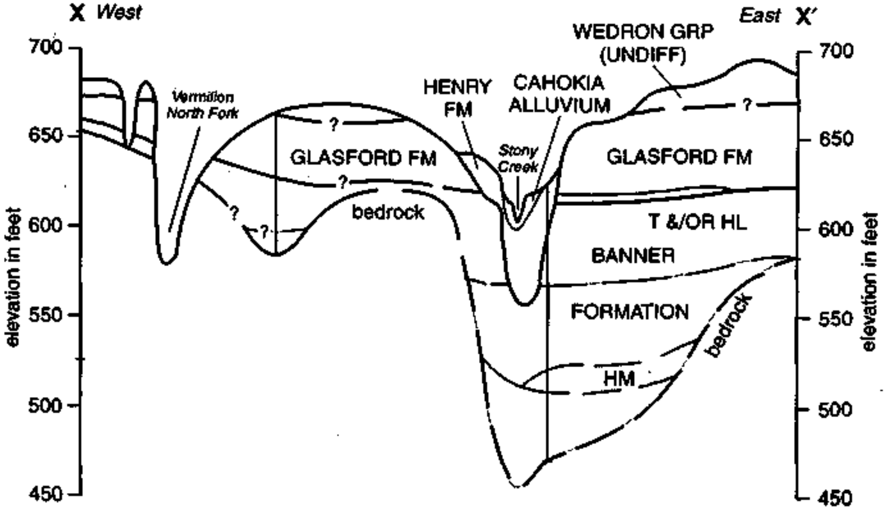


**Figure 13 (f)** Northwest-southeast cross section (F-F') from northwest of Lake Vermilion then generally eastward along the northern part of T20N, R11W.



▭ till
▭ sand or sand and gravel
B-B′ intersection of lines of section

| | |
|---|---|
| T | Tilton Till Mbr |
| HL | Hillery Till Mbr |
| HR | Harmattan Till Mbr |
| HG | Hegeler Till Mbr |
| V | Vandalia Till Mbr |

0.5 inch =2,000 feet
vertical exaggeration approximately 40×

**Figure 14** Generalized west-east cross section (X-X') of the deposits within the Danville Bedrock Valley across the central part of Danville.

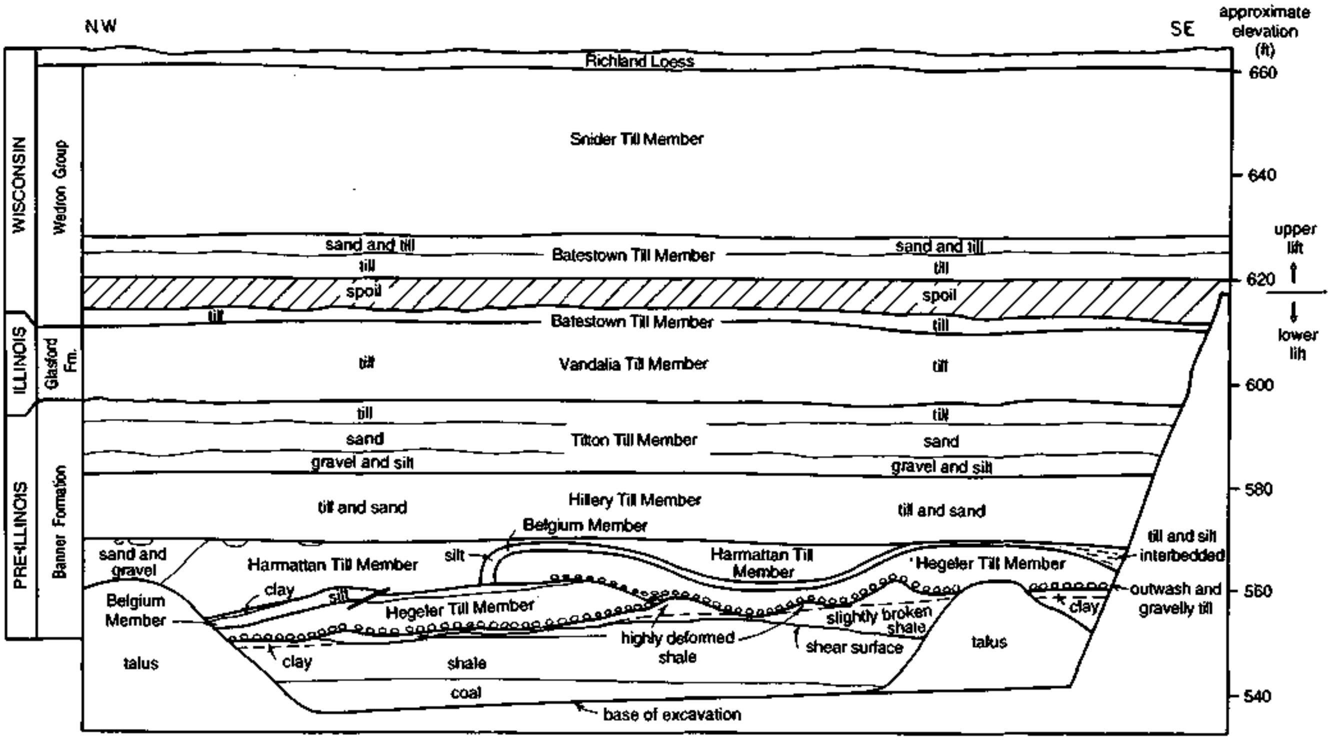


**Figure 15** Harmattan Strip Mine No. 2 Section (SW¼, Sec. 34, T20N, R12W; from Johnson 1971).

The Glasford Formation contains four members that have been recognized in the Danville area (fig. 8). From oldest to youngest, these are the Smithboro, Vandalia, and Radnor Till Members; the Glasford also includes the Berry Clay Member. The Vandalia is the most extensive of these members. In the immediate Danville area, it contains a generally thin and discontinuous basal sand and gravel that becomes thicker and more extensive to the north (fig. 20).

The Wedron Group includes five formations. These are, from oldest to youngest, the Oakland, Fairgrange (Tiskilwa elsewhere), Piatt, Batestown, and Snider Formations. Of these, the Fairgrange, Batestown, and Snider are the most extensive and persistent across the study area. The southern limit of the Snider is at the outer margin of the Illiana Moranic System (fig. 3). Thin, discontinuous deposits of sand and gravel can be found within the Wedron Group, but these are very limited in areal extent. A basal sand and gravel deposit, the Ashmore (fig. 8), occurs locally and is a local source of groundwater for domestic and farmstead supplies. For this report, the Wedron Group is considered as an undifferentiated unit because the sand and gravel deposits it contains are not significant aquifers.

The Henry Formation consists of outwash sand and gravel deposited along the edges of the melting Wisconsin Episode glacier and within the principal valleys. The Henry may overlie any of the till units or other outwash deposits (figs. 13, 14), particularly in the North Fork and Stony Creek valleys. This is hydraulically significant in that there may be locations in the study area where sand and gravel may be continuous from land surface to bedrock (fig. 14).

The Cahokia Alluvium consists of the alluvial sediments deposited along stream courses since the melting of the last glaciers that covered the study area. The Cahokia is composed mostly of silt, clay, and organic materials with some sand and gravel (fig. 8) deposited by normal fluvial processes in the drainage system. The Henry Formation may or may not underlie the Cahokia Alluvium.

## Aquifer Occurrence and Distribution

The stratigraphic relationships of the glacial deposits in the study area indicate that the major sand and gravel aquifers are outwash deposits associated with and at the base of the Hillery and the Harmattan Till Members of the pre-Illinois Banner Formation (fig. 8). Outwash deposits of both of these till members appear to be present in the middle of the Danville Bedrock Valley under the central

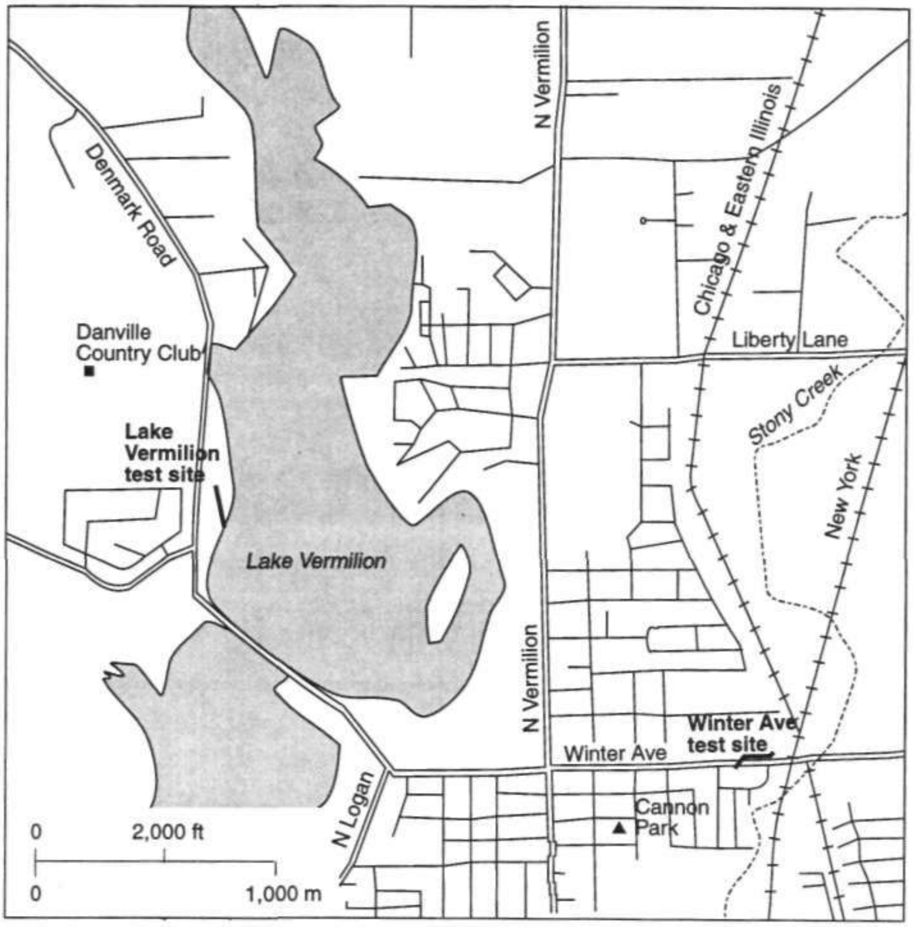


**Figure 16** Location of cross sections through the Winter Avenue and Lake Vermilion test sites.

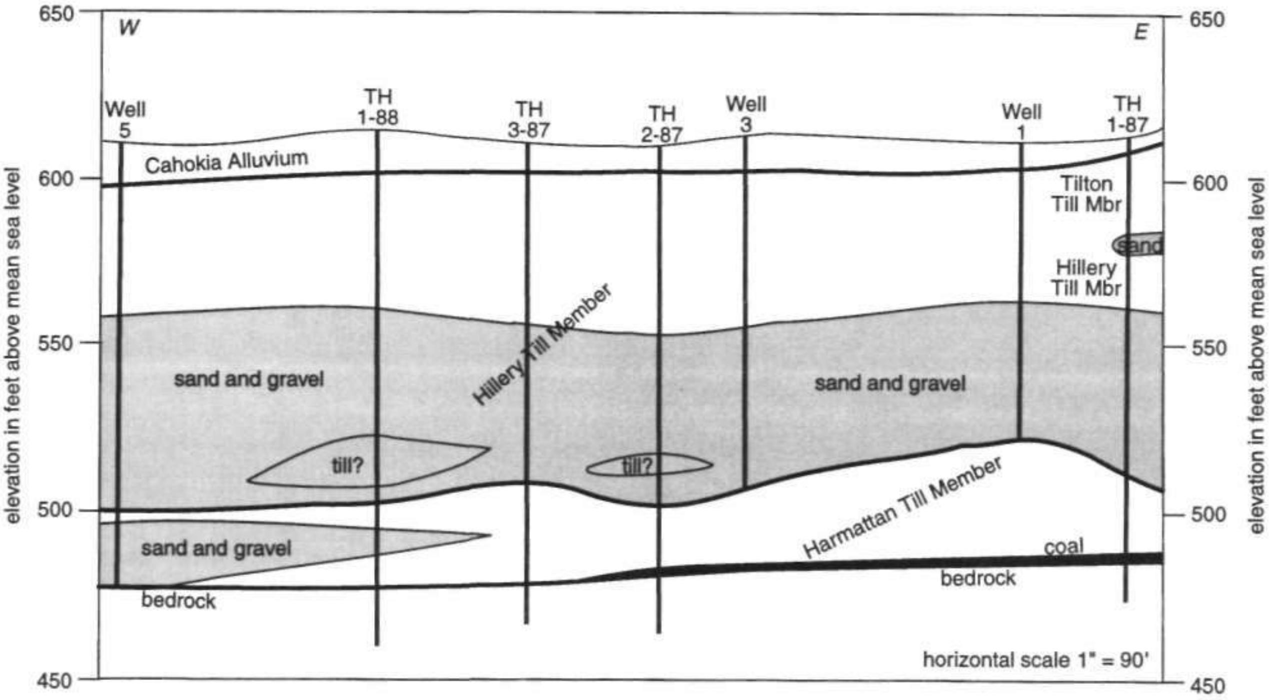


**Figure 17** West-east cross section of the Winter Avenue test site from well 5 to test hole 1 -87.

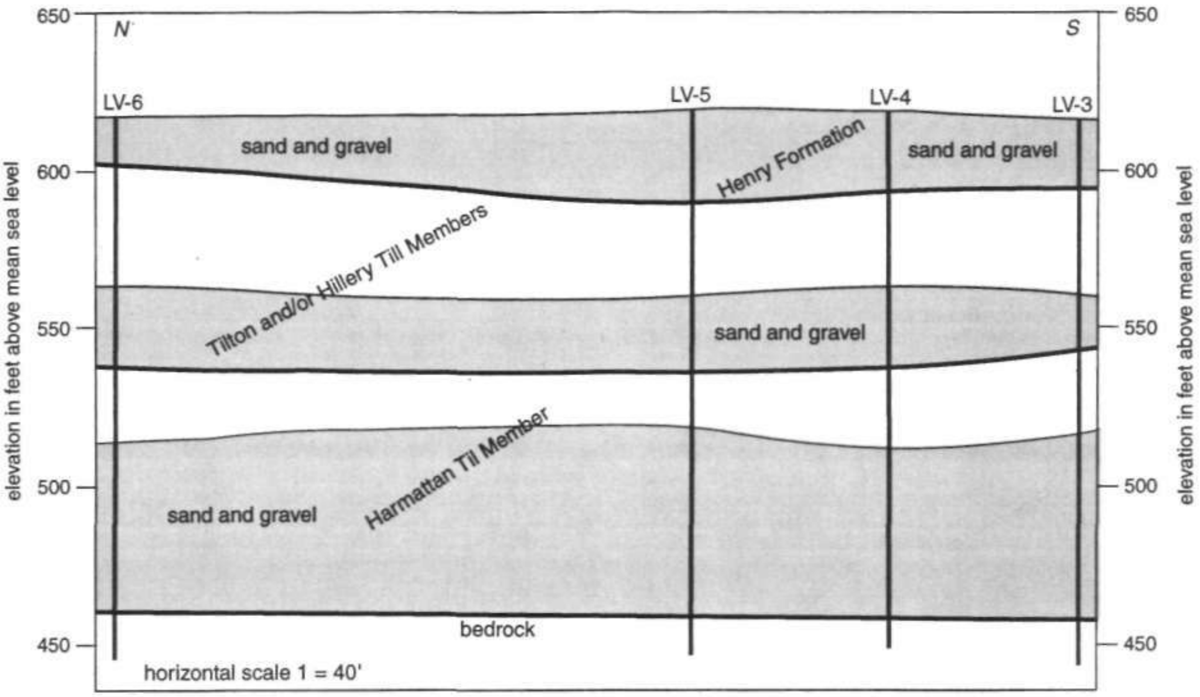


**Figure 18** North-south cross section across the Lake Vermilion test site from test hole LV-6 to LV-3.

and probably the northern portions of Lake Vermilion, and the Harmattan Till Member separates the two sand and gravel units. Subsurface data indicate that the principal aquifer at the Winter Avenue test site on the east side of the Danville Bedrock Valley (fig. 16) is outwash associated with the Hillery Till Member (figs. 13c, 17). The outwash deposits associated with the Harmattan Till Member apparently pinch out in this vicinity. The reverse situation is found across the bedrock valley just west of Lake Vermilion (fig. 16) where Harmattan outwash deposits form the principal aquifer (figs 13c, 18) and the Hillery outwash deposits apparently pinch out along the west side of the Danville Valley (fig. 13a). The occurrence and extent of the Hillery and Harmattan outwash deposits were somewhat refined by the information provided by test holes 2-91 and 3-91 (figs. 1, 13a, f).

Subsurface geologic data indicate that the Hillery and Harmattan outwash deposits extend discontinuously northwestward along the Danville Bedrock Valley to Snider, then northward beyond the study area. These data also suggest that the till of the Harmattan Till Member pinches out just north of the study area. The basal Harmattan outwash deposits appear to directly underlie the basal Hillery outwash deposits and form a single body of sand and gravel that grades laterally into the Mahomet Sand Member of the Banner Formation in north-central Vermilion County (figs. 8, 19).

Two other sand and gravel units form aquifers that yield sufficient water to supply domestic and farm wells in the study area (fig. 8). The first of these units is outwash associated with and at the base of the Vandalia Till Member, Glasford Formation (Illinoian). The second is outwash of the Ashmore sand, which is locally present at the base of the Wedron Formation. Thickness of the sand and gravel deposits within the Glasford Formation increases to about 50 feet north of the study area (fig. 20), particularly in the vicinity of Hoopeston where it is a significant aquifer above the Mahomet Sand.

The Henry Formation, which may be as much as 60 feet thick, is the surficial sand and gravel that occurs locally in the valleys of the North Fork and Middle Fork Vermilion River and the lower reaches of Stony Creek. Where Stony Creek overlies the Danville Bedrock Valley within Danville, several wells penetrate more than 150 feet of nearly continuous sand and gravel (fig. 14) with little or no clay noted in the well records. Yields of as much as 1,000 gallons per minute (gpm) are reported. The Henry Formation rests directly on the Hillery sand and gravel which, in turn, directly overlies the Harmattan sand and gravel. This sequence of sand and gravel, which appears to be hydrogeologically unique for the study area, is locally an important water supply source within Danville.

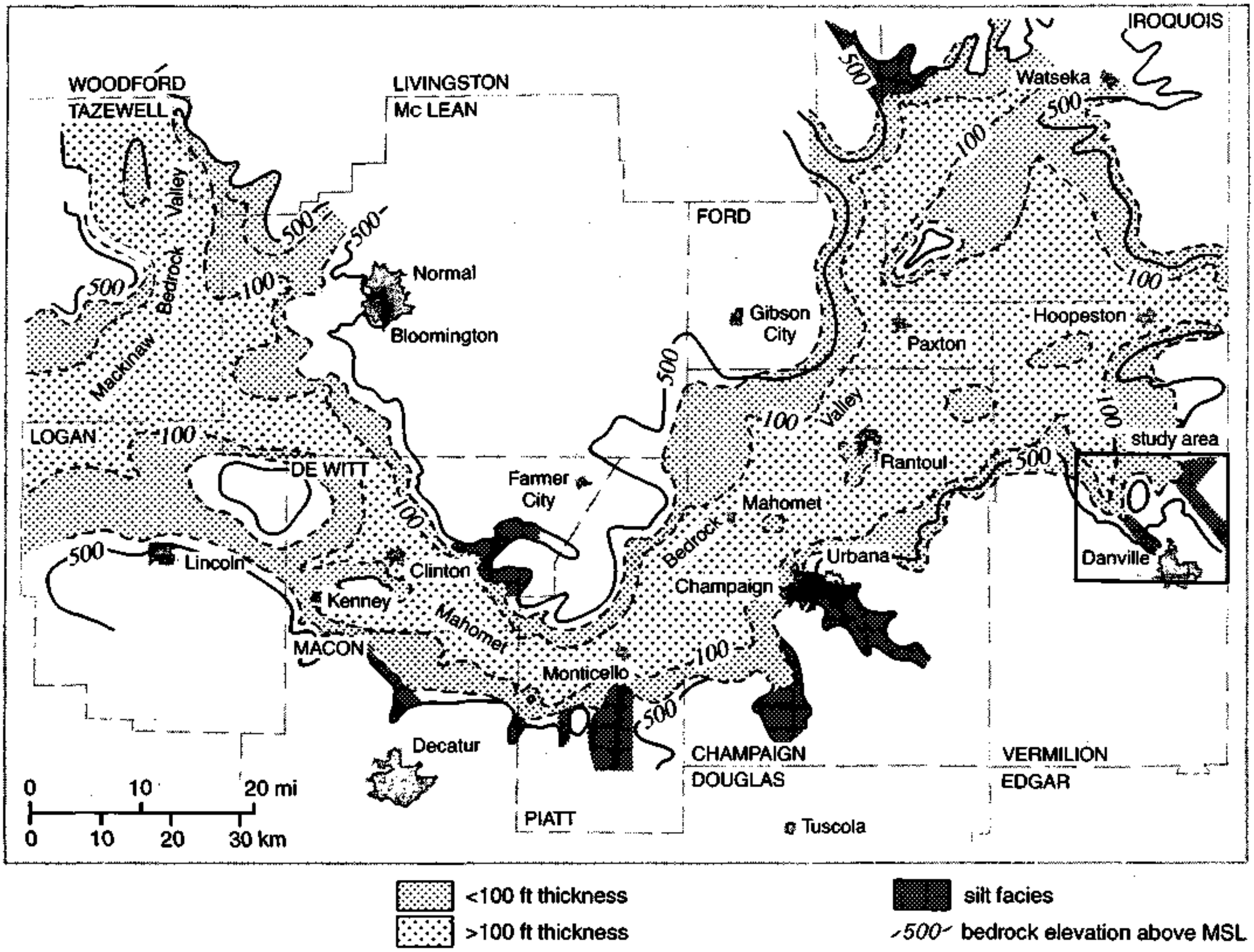


**Figure 19** Distribution and thickness of the Mahomet Sand in east-central Illinois (from Kempton et al. 1991).

## HYDROLOGIC APPRAISAL OF SAND AND GRAVEL AQUIFERS

### Aquifer Hydraulic Properties

Appendix D shows the results of controlled pumping tests of sand and gravel aquifers at 11 sites within the study area; appendix E shows those of tests at 13 sites within a larger area that extends to the northern and western borders of Vermilion County. These data are on file at the ISWS. The results of the tests within the study area helped in characterizing the hydraulic properties of the aquifers. The results of the other 13 tests gave a regional perspective to the hydraulic properties of the sand and gravel aquifers found across much of the northern half of Vermilion County.

Most of the entries in appendixes D and E show a range of values for transmissivity and hydraulic conductivity. A range of values for storage coefficient is given only for the entries derived by the graphical analysis of aquifer test data (appendixes D and E). The data collected from single well pumping tests are not adequate for determining values of storage coefficient.

The range of values for transmissivity, hydraulic conductivity, and storage coefficient derived from the graphical analysis of data collected during controlled pumping tests reflects not only the variability of aquifer thickness, grain size distribution, and other heterogeneities inherent in glacial deposits, but also the uncertainty and error inherent in an aquifer test. The uncertainty and error can arise from the difficulty in maintaining a constant pumping rate during the drawdown portion of the test, the effects

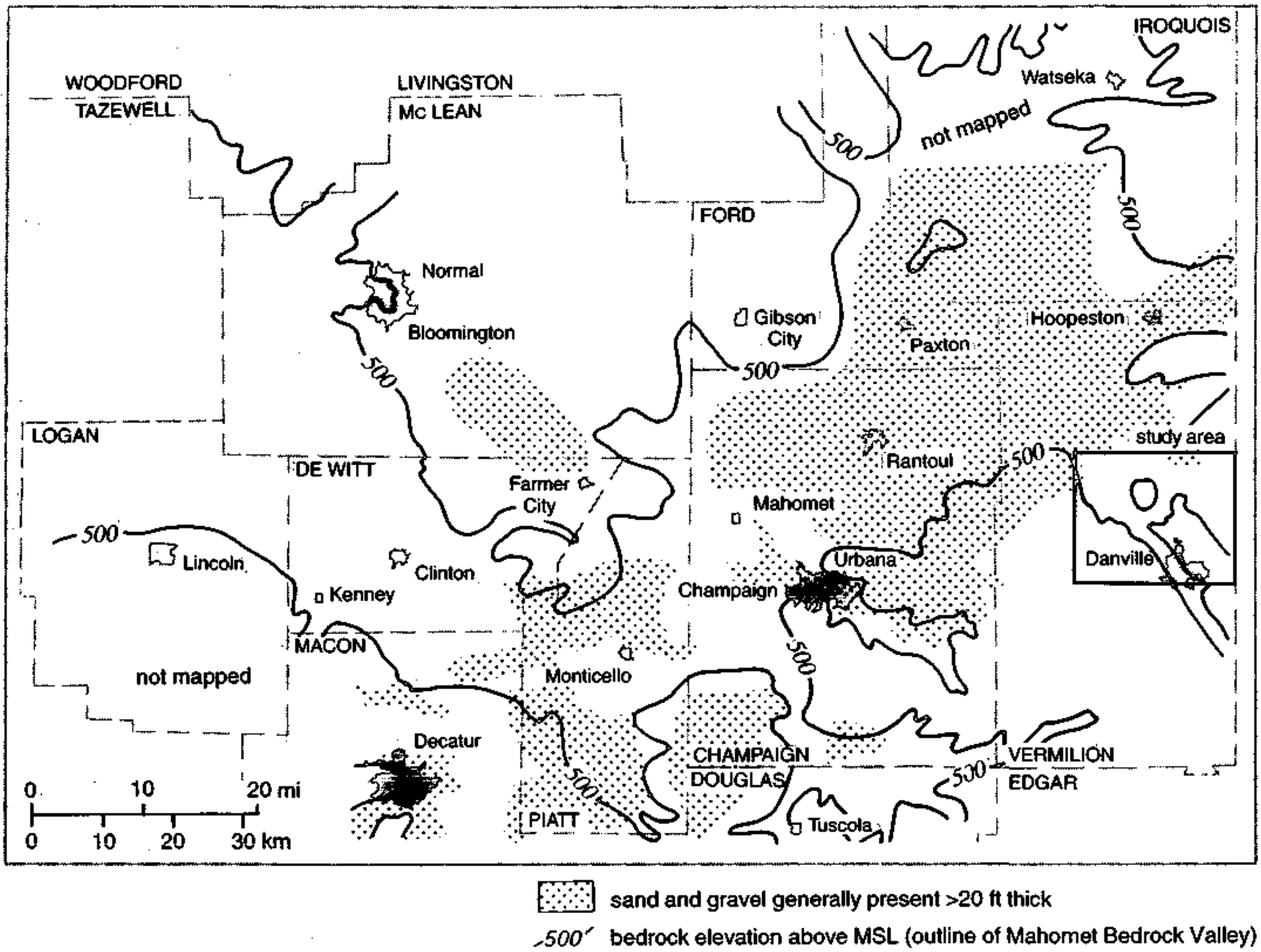


**Figure 20** Distribution of the basal Glasford Formation aquifer in east-central Illinois (from Kempton et al. 1991).

of partial aquifer penetration on water level fluctuations in the pumped well and observation wells if these wells are not screened across the entire thickness of the aquifer, the effects of well inefficiencies, equipment problems and failures, and so forth.

In the specific capacity analysis method, a range of values is assumed for storage coefficient. The range of values selected depends on whether the aquifer is confined or unconfined. Confined aquifers are distinguished from unconfined aquifers on the basis of the position of the water level in the well relative to the top of the aquifer at the end of the pumping period. The assumed range of values used was $10^{-5}$ to $10^{-3}$ for confined aquifers and 0.1 to 0.3 for unconfined aquifers, although only the terms "confined" and "unconfined" are used in appendixes D and E. The specific capacity analysis method also uses a range of assumed values for well radius. The low end of the range is the radius of the well screen; the high end is the radius of the borehole. The range of values for transmissivity and hydraulic conductivity listed for the seven pumping tests, designated with an S in appendixes D and E, comes from using the assumed values for storage coefficient and well radius. It also reflects the same sources of variability, uncertainty, and error mentioned above regarding the controlled pumping test.

Table 1 summarizes the values of transmissivity, hydraulic conductivity, and storage coefficient for aquifers in the Banner and Glasford Formations, and the Wedron Group. The specific capacities of wells completed in these aquifers are also presented. The Banner Formation aquifers found in the northern part of Vermilion County generally exhibit higher transmissivities than those situated in the rather narrow Danville Bedrock Valley in the study area (table 1, appendixes D and E). This finding is

**Table 1** Summary of results from controlled pumping tests, arranged by formation in which aquifer occurs.*

| | Transmissivity (gpd/ft) | | Hydraulic conductivity (gpd/ft$^2$) | | Storage coefficient | | Specific capacity (gpm/ft) | |
|---|---|---|---|---|---|---|---|---|
| Aquifer unit | Study area | Region | Study area | Region | Study area | Region | Study area | Region |
| Wedron | 400–1,300*a* | 400–1,300*a* | 40–130*a* | 40–130*a* | — | — | 1.1*a* | 1.1*a* |
| Glasford | — | 1,700–221,000*b* | — | 170–3,900*b* | — | $9.4\times10^{-5}$ – $2.5\times10^{-3}$*c* | — | 1.3–93.3*b* |
| Banner | 2,000–64,000*d* | 2,000–296,000*e* | 250–3,300*d* | 80–5,300*e* | $5.0\times10^{-4}$ – $8.9\times10^{-2}$*a* | $4.8\times10^{-4}$ – $1.8\times10^{-3}$*a* | 0.9–41.3*d* | 0.9–41.3*d* |

*a* = 1 test, *b* = 9 tests, *c* = 2 tests, *d* = 8 tests, *e* = 12 tests

* Results of controlled pumping tests in the study area are based on data available for locations solely within the study area (fig. 1 and appendix D). Results of regional pumping tests include the study area data and data available for a larger area, extending to the west and north borders of Vermilion County (appendix E). Not included are the Lauhoff Grain Company wells (appendix D), which appear to be completed in a thick but areally limited sand and gravel body related to localized superposition of sand and gravel units in the Henry and Banner Formations.

consistent with the geologic data that show a northward thickening and coalescing of sand and gravel deposits within the Banner Formation (fig. 19). The lack of information about the Glasford Formation aquifers in the study area similarly reflects the absence of thick Glasford sand and gravel units that would be useful for large municipal and industrial groundwater supplies in the Danville area. Several pumping tests of Glasford Formation aquifers in the northern part of Vermilion County (table 1, appendix E) corroborate the geological data that show a northward thickening of Glasford sand and gravel horizons (fig. 20). For example, data from pumping tests on municipal and industrial wells in Hoopeston indicate transmissivities of as much as 221,000 gallons per day/foot (gpd/ft) for Glasford aquifers. The limited thickness and areal extent of the Wedron sand and gravel units is demonstrated by the existence of only one recorded pumping test of an aquifer in the Wedron Group.

Analyses of pumping test data collected from the Lauhoff Grain Company wells located nearthe center of Danville gave transmissivities of 200,000 to 400,000 gpd/ft. These high values reflect localized superposition of Henry and Banner Formation sand and gravel horizons that combine to form a thick, highly productive aquifer.

**Winter Avenue aquifer test** The Winter Avenue aquifer test used a test well that was located at T20N-R11W-28.8a (TH1-88, fig. 17) and screened in the basal Hillery aquifer. The test lasted 2,794 minutes during which the pumping rate varied between 638 and 720 gpm. Water levels in the test well and four observation wells were measured with an air line, a relatively imprecise method for measuring water levels.

Analysis of water level data from the observation wells used in the test yielded values of 30,000 to 58,000 gpd/ft for transmissivity, 800 to 1,200 gpd/ft$^2$ for hydraulic conductivity, and $3.6 \times 10^{-4}$ to $1.5 \times 10^{-2}$ for storage coefficient (appendix D). The values for storage coefficient indicate confined to semiconfined conditions for the aquifer.

Analysis of the test data indicated the presence of multiple barrier boundaries relatively close to the pumped well. Geological data show that the thinning and pinching out of the basal Hillery aquifer south and east of the pumped well forms one of these barrier boundaries (figs. 13c, f) and that the bedrock upland east of the well forms another (fig. 13c). The low specific capacity of the test well (about 9.5 gpm/ft) reflects the proximity of the barrier boundaries. The long-term sustainable yield of a well at the Winter Avenue test site was estimated to be 200 to 250 gpm on a continuous pumping basis (ISWS 1988, unpublished correspondence with Inter-State Water Company, Danville, Illinois).

**Lake Vermilion aquifer test** The Lake Vermilion aquifer test used a test well located on the west side of Lake Vermilion at T20N-R11W-30.3f and screened in the basal Harmattan aquifer. The test lasted 2,795 minutes during which the pumping rate was held at 715 gpm. Water levels in the test well and five observation wells were monitored.

Although hydraulic property values were derived by analyzing the water level data from the pumped well and five observation wells, a thorough assessment of these results showed that the values obtained from the analysis of water level data from only two of the observation wells could be considered representative of the aquifer and confining bed. The pumped well was screened in only part of the aquifer. This partial penetration of the aquifer influenced the data obtained from the pumped well and the two nearest observation wells, located 12 and 58 feet from the pumped well, and values for hydraulic properties derived from the analysis of these data were not considered not to be representative of the aquifer and confining bed. Fluctuations in the pumping rate, the inefficiency of the pumped well, and the use of an air line for measuring water levels affected the quality of data obtained from the pumped well. The water level in the fifth observation well, the one most distant from the pumped well, was measured only four times during the test. These few data were analyzed only for comparison with the analytical results of the data from the two middle observation wells.

The Lake Vermilion test well was screened in the lower 35 feet of the basal Harmattan aquifer. This partial penetration of the aquifer caused distortion of the radial flow pattern of groundwater toward the pumped well and added to the drawdown in this well. The distance from the pumped well at which partial penetration effects become negligible is 1.5 (Hantush 1964) to 2 times (Butler 1957) the thickness of the aquifer. This distance corresponds to 88.5 to 118 feet from the Lake Vermilion test well. Measured drawdowns can be adjusted to compensate for partial penetration effects (Butler 1957) if the ratio of vertical to horizontal hydraulic conductivity for the aquifer is known. This information is not available for the basal Harmattan aquifer.

Analysis of the water level data from the two observation wells located 118 and 298 feet from the Lake Vermilion test well, using the type curve method of Walton (1960) and the semilogarithmic inflection point method of Hantush (1956), gave values of 41,000 to 45,000 gpd/ft for transmissivity, 800 $\mathrm{gpd/ft^2}$ for hydraulic conductivity, and $4.8 \times 10^{-4}$ to $1.8 \times 10^{-2}$ for storage coefficient (appendix D). The storage coefficient indicates confined to semiconfined conditions for the aquifer. Vertical leakage of groundwater into the aquifer from overlying sediments is clearly indicated. Analysis of the data from the two observation wells indicated that the vertical hydraulic conductivity is 0.1 to 0.3 $\mathrm{gpd/ft^2}$. The geological setting (figs. 13b, 13c) suggests that the source of the leakage most likely is the overlying basal Hillery aquifer.

Analysis of the data did not indicate the presence of barrier boundaries near the Lake Vermilion site. The long-term sustained yield of a well at this site was estimated to be 715 gpm (ISWS 1988, unpublished correspondence with Inter-State Water Company, Danville, Illinois). Interpretation of the 1991 test hole data regarding the thickness and areal extent of the basal Harmattan and Hillery aquifers suggests that recharge to these aquifers is limited and that the long-term sustained yield will most likely be less than 715 gpm.

## Groundwater Pumpage

Information furnished to the ISWS Illinois Water Inventory Program and to the Illinois Environmental Protection Agency (IEPA) indicates that groundwater pumped for public, industrial, and commercial uses in the study area averaged 2.3 million gallons per day (mgd) in 1993. Four public water supplies in the study area accounted for about 4% of this total: the Bismarck Community Water District, Danville Unit School District #118, Kickapoo State Park, and the Walnut Hill Well Association. The largest of these four, the Bismarck Community Water District, used about 0.06 mgd of groundwater from aquifers in the Banner Formation. The remaining 96% of the reported 1993 public, industrial, and commercial groundwater withdrawals was pumped by Lauhoff Grain Company, a large industrial user located near Stony Creek in the southern part of the study area. It obtains groundwater from the combined Henry and Banner Formations as shown in figure 14.

## Groundwater Quality

Table 2 shows the range and mean concentrations for selected water quality parameters for groundwater from aquifers in the Wedron Group and Glasford and Banner Formations. The concentrations were determined by the analysis of 36 samples of untreated groundwater from private and public water supply wells within the study area. The analyses were conducted by the ISWS and the IEPA.

Groundwater in all of these aquifers is hard to very hard (Gibb 1973) and contains relatively high concentrations of dissolved iron, two characteristics typical of groundwater from sand and gravel aquifers in Illinois. Hardness also appears to decrease with depth, but alkalinity and dissolved iron concentration increase with depth. The concentration of nitrate in the groundwater pumped at the Lake Vermilion test site is discussed in the water quality section of the Lake Vermilion aquifer test.

## Groundwater Recharge and Runoff

Estimates of groundwater recharge rates used for this study are based on Walton's (1965) research into groundwater recharge and runoff in Illinois. Under natural conditions, groundwater runoff (discharge) generally balances groundwater recharge overtime. Groundwater recharge in the part of the drainage basin upstream of a gaging station can be estimated by quantifying groundwater runoff using stream gage data. This technique underestimates actual groundwater recharge because it does not account for groundwater loss through evapotranspiration, a process that increases significantly during the growing season. Walton (1965) estimated groundwater runoff to be 0.3 to 0.4 cubic feet per second per square mile (cfs/mi$^{-2}$) in the western half of the study area (fig. 21), or 194,000 to 259,000 gallons per day per square mile (gpd/mi$^{-2}$). This estimate of groundwater runoff most likely remains reasonable because groundwater pumpage in this part of the study area appears not to have changed significantly since 1965. Walton (1965) did not estimate groundwater runoff for the eastern part of the study area. Because there appears to be little significant difference between the western and eastern parts of the study area, Walton's (1965) estimate of 0.3 to 0.4 cfs/mi$^{-2}$ for groundwater runoff seems to be a reasonable estimate for groundwater recharge for all of the study area, assuming a long-term equilibrium between groundwater runoff and groundwater recharge.

The groundwater recharge rate estimated on the basis of groundwater runoff applies only to saturated earth materials near land surface. Deeply buried, confined aquifers are recharged mostly by vertical leakage of groundwater through fine grained deposits, such as till or lacustrine sediments. Because these deposits have low hydraulic conductivities, recharge of deeply buried aquifers is typically slower than recharge of surficial, unconfined aquifers. Recharge to a deeply buried aquifer may be increased by withdrawing groundwater from the aquifer. Pumping water from a confined aquifer creates a cone of depression in the aquifer's potentiometric surface. This increases the vertical hydraulic gradient between the aquifer and the water table, diverting water into the deeper aquifer that would otherwise have become groundwater runoff. Because groundwater moves laterally as well as vertically, not all groundwater runoff can be diverted into cones of depression associated with pumping water from

Table 2 Summary of selected water quality parameters.

| | Total dissolved minerals (mg/L) | | Hardness as $CaCO_3$ (mg/L) | | Alkalinity as $CaCO_3$ (mg/L) | | Dissolved iron (mg/L) | |
|---|---|---|---|---|---|---|---|---|
| Aquifer | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| *a* Wedron Group | 434–1182 | 682 | 348–772 | 516 | 278–400 | 325 | BDL–1.5 | 0.5 |
| *b* Glasford Formation | 398–684 | 542 | 384–559 | 439 | 296–436 | 366 | 0.2–5.0 | 1.9 |
| *c* Banner Formation | 308–2936 | 639 | 110–752 | 338 | 252–552 | 430 | 0.4–17.5 | 4.4 |

BDL = below detection limit

*a* = 4 water samples, *b* = *8* water samples, c = 24 water samples

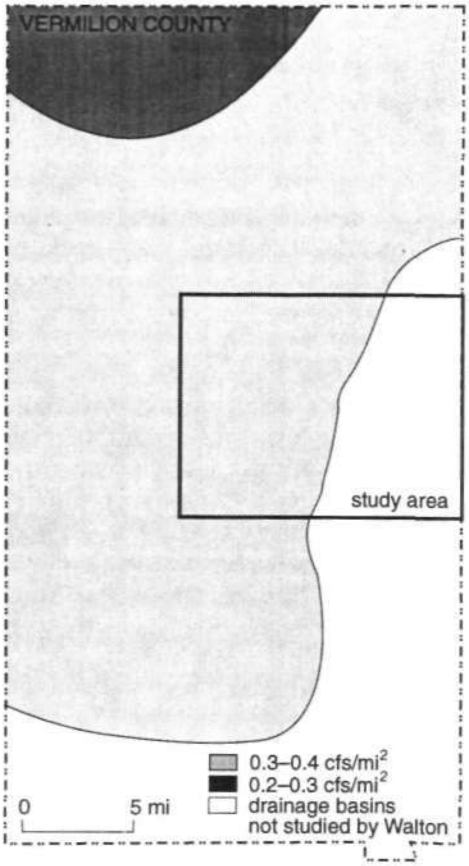


**Figure 21** Annual groundwater runoff in Vermilion County, Illinois, during year of normal precipitation (from Walton 1965).

deeply buried aquifers. Zeizel et al. (1962) suggested that up to 60% of groundwater runoff can be diverted into such cones of depression. Maximum recharge to the deeply buried sand and gravel aquifers in the study area was estimated to range from 116,000 to 155,000 gpd/mi$^{-2}$ if groundwater recharge is equivalent to 60% of groundwater runoff.

Recharge rates can also be estimated by using flow net analysis to delineate diversion areas on potentiometric surface maps. Using diversion area analysis, Walton (1965) estimated that the recharge rate to the heavily pumped, deeply buried sand and gravel aquifer supplying Champaign-Urbana was about 115,000 gpd/mi$^{-2}$ in 1947. This figure, 44% to 59% of the annual groundwater runoff in the Champaign-Urbana area (Walton 1965), is consistent with the 60% figure of Zeizel et al. (1962).

## DISCUSSION

Evaluating the potential for developing a supplemental municipal groundwater supply for Danville in the Danville-Lake Vermilion area involves addressing three main concerns: the availability of the groundwater resource, the feasibility for exploration and development of the resource, and the groundwater quality.

### Groundwater Availability

The results of this study show that the potential for the occurrence of sand and gravel aquifers (aquifer potential), and therefore the availability of groundwater, is limited in the study area (fig. 22). This area includes the reach of the Danville Bedrock Valley in and just north of Danville and the sites of the Winter Avenue and Lake Vermilion test wells as well as several high capacity wells near Vermilion Street and Bowman Avenue in the central part of Danville. Figure 22 summarizes the aquifer potential

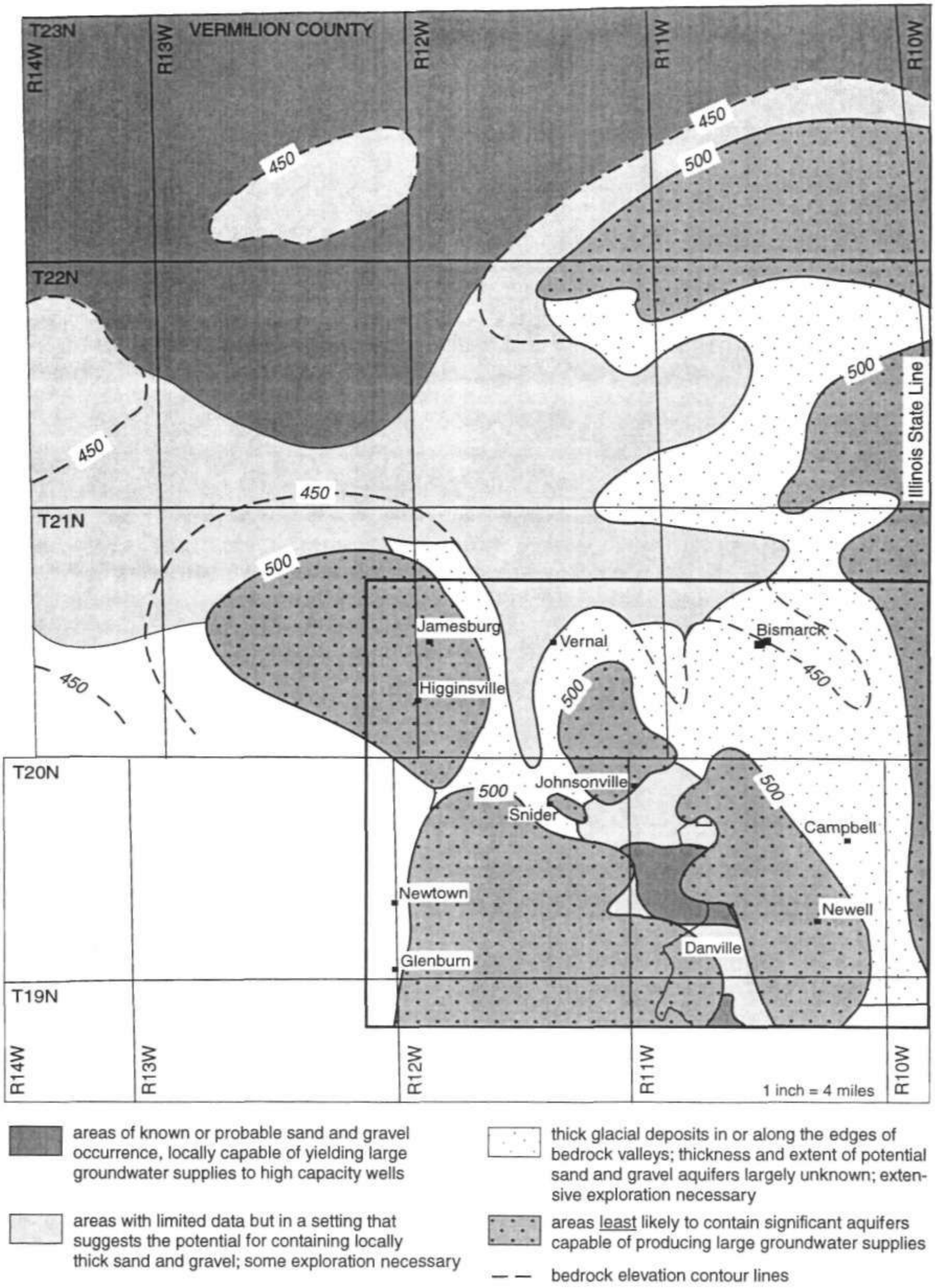


**Figure 22** Summary of the potential occurrence of sand and gravel aquifers in the study area and the Mahomet Bedrock Valley north of the study area.

of the study area as well as that across the north half of Vermilion County. The aquifer potential in the study area was developed from water well records, seismic and resistivity data, and other information gathered during this study. Kempton et al. (1981) was used as a basis for determining the aquifer potential for northern Vermilion County.

Subsurface data indicate that the basal Harmattan aquifer, the sand and gravel aquifer supplying the Lake Vermilion test well, is relatively thin and extends over an area of 9.7 mi$^2$. This restricted areal extent limits groundwater recharge to the aquifer and precludes any large-scale development of this groundwater resource. As noted previously, as much as 60% of groundwater runoff may be diverted into a cone of depression in the potentiometric surface of a deeply buried aquifer (such as the basal Harmattan aquifer) because of the increased vertical hydraulic gradients generated by large groundwater withdrawals (Zeizel et al. 1962). Recharge to the basal Harmattan aquifer is estimated to be 1.1 to 1.5 mgd based on a diversion rate of 60% and a groundwater runoff rate of 0.3 to 0.4 cfs/mi$^2$ (Walton 1965). This recharge rate is the equivalent of one well continuously pumping at a rate of 750 to 1,000 gpm. The more conservative diversion rate of 50% of the groundwater runoff gives an estimate of 0.9 to 1.3 mgd of recharge to the aquifer, which is the equivalent of one well continuously pumping 600 to 900 gpm. These estimates were made, however, on the basis of assumptions regarding the extent of the aquifer and variability of groundwater recharge, both of which need further study.

Aquifer test and geologic data indicate that recharge to the basal Harmattan aquifer during pumping could include leakage from the overlying basal Hillery aquifer and may also include induced infiltration from Lake Vermilion. Induced infiltration of lake water into the aquifers may somewhat reduce the total volume of water available in Lake Vermilion for water supply purposes. The infiltration may also carry nitrates present in the lake water into the groundwater flow system, which could possibly cause the concentration of nitrates in the basal Hillery and basal Harmattan aquifers to increase. Both of these factors should be considered in determining the suitability of using the Lake Vermilion site as a supplemental groundwater supply. Additional information is needed to quantify the induced recharge to the basal Harmattan aquifer from the lake and the overlying basal Hillery aquifer so that the potential nitrate concentration in the water pumped from the basal Harmattan aquifer can be determined.

Although high transmissivities are found in the central part of Danville (Lauhoff Grain Company wells, appendix D), subsurface geologic data indicate that the extent of the high transmissivities is very restricted (figs. 14,22) and precludes any further large-scale groundwater development. Groundwater withdrawals may be exceeding groundwater recharge in at least part of the study area, as suggested by the decline of the static water level in the two Danville High School wells completed in the Banner Formation aquifers. Between i 955 and 1981, the static water level in Danville High School Well 1 fell from 32 feet to 45 feet below land surface. The static water level in Danville High School Well 2 (appendix D), which replaced Well 1, was about 50 feet below land surface in 1989.

The availability of groundwater in the north half of Vermilion County is not as well known as that within the study area. Few of the water wells in northern Vermilion County penetrate the full thickness of the glacial drift because there is a relatively low demand for large groundwater supplies and water supply needs can be adequately met by groundwater from sand and gravel aquifers found at relatively shallow depths. The geologic and hydrologic data available for the north half of Vermilion County indicate a high potential for significant sand and gravel aquifers to be present in the Danville and Mahomet Bedrock Valleys (fig. 22). Within these bedrock valleys north of the study area, basal Glasford sands and gravels thicken and become more areally extensive. The sand and gravel units in the Banner Formation thicken, coalesce, and grade laterally into the Mahomet Sand Member (fig. 19).

Groundwater use by the two largest public water supply systems in northern Vermilion County, about 0.8 mgd for Hoopeston and 0.1 mgd for Rossville, is not indicative of the productive capacity of the sand and gravel aquifers in the area. Most of the high capacity wells are completed in Glasford Formation sands and gravels. The Mahomet Sand, a deeper and potentially more productive aquifer than the Glasford Formation aquifers, is untapped through much of northern Vermilion County. Only 4 of the 13 pumping tests conducted in this part of the county involved wells screened in the Banner Formation (appendix E), which contains the Mahomet Sand. Wells used in the other nine tests are screened in Glasford Formation aquifers (appendix E). Analyses of the pump test data from wells completed in the Banner Formation, except for Rankin Well 1, indicate transmissivity values ranging from 104,000 to 296,000 gpd/ft. For wells screened in the Glasford Formation aquifers, transmissivity values range from 1,700 to 221,000 gpd/ft.

Another source of groundwater that may have the potential yield to supplement Danville's water supply is the sand and gravel deposited within the Wabash River Valley in Indiana (Wayne et al. 1966). These deposits are located about 5 miles east of the Illinois state line. Watkins and Jordan (1965a, 1965b) suggested that relatively large yields may be possible from these deposits. Singh (1978) provided a detailed discussion of this possible source of groundwater. He concluded that pumping at least 10 mgd would be required to make this alternative economically feasible.

## Feasibility of Exploration and Development

Where the occurrence of extensive, highly productive aquifers is uncertain, such as in the Danville-Lake Vermilion area, exploration for and development of the groundwater resource can involve significant investigative efforts. The geological, geophysical, and hydrological data assembled for this study suggest that additional investigation should focus on the light gray area shown in T21N and T22N, R11W and R12W. The hydrogeologic setting of this area (fig. 22) has the greatest potential for the presence of locally thick sand and gravel deposits (fig. 22). This area should be given a high priority in any further groundwater resources assessment.

Well interference, the decline of water levels in wells near a high capacity well, is caused by the cone of depression surrounding the high capacity well. Well interference with nearby wells is of concern because it may result in increased pumping costs, decreased yields of the wells, or even possible failure of the wells to produce water. The size and shape of the cone of depression resulting from anticipated pumping schedules should be evaluated prior to installing a high capacity well in order to determine the effects of pumping on nearby existing wells. This evaluation also helps in determining a minimum spacing requirement for wells in a well field. The data required for such an evaluation can be acquired using aquifer tests with a test well and a suitable number of observation wells.

The available data are insufficient to evaluate in detail the possible well interference associated with a new high capacity well located in the recommended area of exploration. The interference at various distances caused by such a well can be estimated using the hydraulic properties of the basal Harmattan aquifer and its confining bed. These estimates were derived from the Lake Vermilion aquifer test and subsurface geologic data showing the thickness and distribution of the aquifer at this test site in an analysis that uses the theoretical type curve for a leaky artesian aquifer under steady state conditions (Walton 1960, Jacob 1946). For this analysis, the basal Harmattan aquifer was simulated by a rectangular block with an overlying leaky confining bed that was assumed to cover the entire aquifer. Table 3 gives the dimensions and the hydraulic properties of the simulated aquifer and confining bed as well as the basis for the values used for these characteristics. A simulated pumping well was placed at the center of the simulated aquifer because the geologic data suggest that the Lake Vermilion test well is reasonably close to the middle of the actual basal Harmattan aquifer. The edges of the simulated aquifer were treated as barrier boundaries (i.e., it was assumed that groundwater did not to flow across these boundaries). The effect of treating the edges of the simulated aquifer as barrier boundaries was determined by using image well theory (Ferris 1959), which uses discharge image wells to simulate barrier boundaries.

Long-term interference effects at selected distances ranging from 200 to 5,000 feet from a single high capacity well pumping at 500, 600, 700, 800, and 900 gpm were estimated (table 4). This range of pumping rates is that which the basal Harmattan aquifer most likely could sustain as determined from the estimate of aquifer recharge. Although the pumping rates of 800 and 900 gpm may exceed the estimated recharge rate, they are included in case the estimates of aquifer dimensions, recharge, and yield prove to be too conservative. Table 4 shows that the additional drawdown from one well pumping between 500 and 900 gpm is calculated to be 3 feet or less at a distance of 2,000 feet from the well. In the image well analysis, drawdown resulting from barrier boundaries was found to be negligible for all of the pumping rates considered.

**Table 3** Basis for the characteristics of the simulated basal Harmattan aquifer.

| Characteristic | Assumed value | Basis |
|---|---|---|
| Hydraulic conductivity | 773 gpd/ft$^2$ | The average of the analytical results of the data from two observation wells, Lake Vermilion aquifer test; March 1988. |
| Thickness | 34 ft | Average thickness of basal Harmattan aquifer from 58 data points spaced at 1,000-foot intervals along the cross sections shown in figure 13. |
| Area | 9.7 mi$^2$ | Cross sections (fig. 13). |
| Dimensions | length = 29,100 ft<br>width = 9,300 ft | Cross sections (fig. 13) show the basal Harmattan aquifer to be irregular in area but elongated along a northwest-southeast axis. The width of the simulated aquifer is the average width of the basal Harmattan aquifer along 29 profiles spaced at 1,000-foot intervals perpendicular to this axis. The volume of the basal Harmattan aquifer was calculated to be $9.2 \times 10^9$ ft$^3$. The length of the simulated aquifer was derived by dividing the volume of the basal Harmattan aquifer by its average width and thickness. |
| Location of well | Center of aquifer | The location of the Lake Vermilion test well is relatively near the center of the basal Harmattan aquifer as shown by the subsurface data (fig 13). |
| Vertical hydraulic conductivity of leaky confining bed | 0.2 gpd/ft$^2$ | The average of the analytical results of the data from two observation wells, Lake Vermilion aquifer test. |
| Thickness of leaky confining bed | 26 ft | Log of the Lake Vermilion test well. |
| Aquifer hydraulic conditions | Leaky artesian | Analytical results of the data from the Lake Vermilion aquifer test. |

Table 4 Estimated long-term interference drawdown at selected distances from a single well completed in the basal Harmattan aquifer.

| | Long-term interference drawdown (ft) | | | | |
|---|---|---|---|---|---|
| Distance from well (ft) | 500 gpm | 600 gpm | 700 gpm | 800 gpm | 900 gpm |
| 200 | 10 | 13 | 15 | 17 | 19 |
| 400 | 7 | 9 | 10 | 12 | 13 |
| 600 | 6 | 7 | 8 | 9 | 10 |
| 800 | 5 | 5 | 6 | 7 | 8 |
| 1,000 | 4 | 4 | 5 | 6 | 7 |
| 2,000 | 2 | 2 | 2 | 2 | 3 |
| 3,000 | 1 | 1 | 1 | 1 | 1 |
| 4,000 | <1 | <1 | 1 | 1 | 1 |
| 5,000 | <1 | <1 | <1 | <1 | <1 |

The effects of more than one additional pumping well on an existing well can be estimated by adding the drawdowns caused by each of the new wells. For example, suppose two additional wells are to be located 800 and 2,000 feet from an existing well and each new well is to pump 600 gpm. The total interference drawdown from both new wells at the existing well should be 6 feet, that is 5 feet of drawdown caused by the new well located 800 feet away plus 1 foot of drawdown produced by the new well located 2,000 feet from the existing well.

### Groundwater Quality

The fluctuating level of nitrate in Lake Vermilion is an ongoing concern about Danville's water supply. The concentration of nitrate (as nitrogen) periodically exceeds the drinking water standard of 10 mg/L (Illinois Department of Public Health 1990). One possible alternative for reducing the nitrate concentration in the treated water to acceptable levels is to blend groundwater with the lake water when the nitrate level in Lake Vermilion is high. Two groundwater samples collected during the Lake Vermilion aquifer test each had nitrate concentrations below the detection level of 0.1 mg/L, suggesting that groundwater from the basal Harmattan aquifer at the Lake Vermilion test site would be suitable for blending. The hydrogeological data suggest, however, that long-term pumping may induce leakage of lake water into the basal Hillery aquifer and subsequently into the basal Harmattan aquifer, thereby increasing the nitrate concentration in the groundwater. An increased level of nitrates in the groundwater would reduce the suitability of using groundwater for blending to reduce the nitrate concentration in Danville's water supply.

The effect of induced leakage of lake water on the nitrate concentration in the groundwater pumped from the basal Harmattan aquifer at the Lake Vermilion site cannot be quantified from the existing data. A well located at the Lake Vermilion test site and pumping about 700 gpm could induce groundwater flow from the basal Hillery aquifer and surface water flow from Lake Vermilion. The volume and rate of flow of water from these two sources into the basal Harmattan aquifer cannot be accurately determined from the available data. The volume and flow rate depend on a number of hydrogeologic considerations, including the distribution and thickness of the source aquifer (the basal Harmattan sand and gravel), intervening aquitard (the till facies of the Harmattan Member), and overlying aquifer (the basal Hillery sand and gravel); the area covered by Lake Vermilion and the elevation of its water surface; the hydraulic properties of the basal Harmattan and Hillery aquifers as well as that of the intervening aquitard; the hydraulic gradient between the basal Harmattan and Hillery aquifers and between the two aquifers and Lake Vermilion; and the type and thickness of lake bottom sediments and the effect of these sediments on the hydraulic connection between the lake and the underlying materials. It is not clear how hydrogeochemical processes that occur in the subsurface would affect nitrate concentrations as water moved from Lake Vermilion into the groundwater flow system. Denitrification would most likely occur in the reducing environment of the organic-rich lake bottom sediments and saturated glacial drift underlying the lake. If denitrification did occur, the nitrate concentration in the infiltrating lake water would be reduced as the water moved into the subsurface. The effectiveness of the denitrification processes cannot be properly assessed without further data on the chemistry of the lake water and groundwater as well as on the geochemical environment within the lake bottom and subsurface sediments.

## CONCLUSIONS

The following conclusions were reached concerning the evaluation and development of a supplemental municipal groundwater supply for Danville using aquifers found in the Danville-Lake Vermilion area.

1. There is little potential for developing a supplemental groundwater supply of 3 to 5 mgd from the sand and gravel aquifers in the study area. The sustained withdrawal rate from the basal Harmattan aquifer, the most promising aquifer near Lake Vermilion, is estimated to be only 1.1 to 1.5 mgd, assuming that the groundwater recharge rate is 60% of groundwater runoff (Zeizel et al. 1962).

2. Pumping a high capacity well completed in the basal Harmattan aquifer and located in the vicinity of Lake Vermilion most likely would induce leakage from the basal Hillery aquifer as well as induce infiltration from Lake Vermilion. The induced infiltration of Lake Vermilion

water could carry nitrates from the lake into the aquifers. Nitrates were not found in the groundwater samples collected during the Lake Vermilion aquifer test, but long-term pumping may cause nitrates to appear. An increase in the nitrate levels in the groundwater may reduce the benefit of blending it with lake water to reduce nitrate concentrations in Danville's water supply. The data available are insufficient to permit quantification of either the volume of induced infiltration from Lake Vermilion or the nitrate concentration of the groundwater.

3. The thickest and most transmissive sand and gravel aquifers in the study area, the basal Harmattan and basal Hillery aquifers, are found within the Danville Bedrock Valley. The thickness of these two aquifers varies and their areal extent is limited by the width of the bedrock valley. The aquifers are outwash deposits at the base of the Hillery and the Harmattan Till Members (Banner Formation). Both aquifers underlie the middle part of Lake Vermilion, where they are separated by the Harmattan Till, but there is some uncertainty if both are present under the northern part of the lake. The results of the 1991 test drilling (test holes 2-91 and 3-91) restricted the known extent of the two aquifers north and southwest of Lake Vermilion.

Both aquifers extend as more or less discontinuous deposits of sand and gravel to the northwest along the Danville Bedrock Valley to Snider, then northward to the area between Potomac and Henning. In this area of confluence with an eastern tributary of the Danville Bedrock Valley, the Harmattan Till evidently pinches out. The basal sand and gravel deposits of both the Harmattan and Hillery Till Members thicken northward where they combine and grade laterally into the Mahomet Sand (Banner Formation) in northern Vermilion County.

In the study area, two other sand and gravel units are thick enough to form aquifers that yield sufficient water to supply domestic or farm wells. The first of these units comprises the outwash deposits at the base of the Vandalia Till Member, Glasford Formation (Illinois Episode). The second is the Ashmore sand at the base of the Wedron Group (Wisconsin Episode). The surficial sand and gravel of the Henry Formation may be as much as 60 feet thick locally in the valleys of the North Fork and Middle Fork, Vermilion River, and in the lower reaches of the Stony Creek valley. Where Stony Creek overlies the Danville Bedrock Valley in Danville, several wells penetrate more than 150 feet of nearly continuous sand and gravel with little or no clay (till) reported.

4. The long-term interference drawdown from a single well located at the Lake Vermilion test site pumping 500 to 900 gpm is estimated to be 10 to 19 feet at a distance of 200 feet to less than 1 foot at a distance of 5,000 feet. Although the estimated interference drawdown is relatively small except near the well, the increment of drawdown may result in a decline in water levels as well as affect the performance and efficiency of nearby wells.

## RECOMMENDATIONS

The following recommendations are made, on the basis of the evaluation and interpretation of the information presented in this report, concerning the evaluation and development of a supplemental municipal groundwater supply for Danville, by utilizing the sand and gravel aquifers found in the Danville-Lake Vermilion area.

1. Further testing around Lake Vermilion may refine the estimates of groundwater availability and the potential yield of the sand and gravel aquifers as well as provide additional information on groundwater quality. Additional test drilling in this part of the study area would result in better definition of the character and extent of the basal Harmattan and basal Hillery aquifers.

A 30-day aquifer test at the Lake Vermilion test site would provide data that would allow the leakage of water into the basal Harmattan aquifer to be quantified and the long-term effect of the leakage on groundwater quality, particularly nitrate concentration, to be determined. During the test, water levels should be measured in the pumped well, in nested observation wells located 90 to 180 feet from the test well and as close to Lake Vermilion as possible, and in several other observation wells located at various distances and directions from the test well. For the nested observation wells, one well should be screened in the basal Harmattan aquifer and the other well in the basal Hillery aquifer. The purpose of the shallower observation well is to allow monitoring of water level changes in the well. The analysis of these data could indicate leakage of water from the basal Hillery aquifer and Lake Vermilion. The level of the lake should also be monitored during the test to measure changes in the vertical hydraulic gradient between the lake and the two aquifers. Discharge from the pumped well should be sampled weekly for water quality analyses. Water samples from the observation wells would be collected before and after the test. The water samples should be analyzed for the common cations, anions, and other parameters as well as nitrate.

2. Little information is available on the occurrence, thickness, and potential yield of the sand and gravel aquifers in the triangular area bounded by Lake Vermilion, Rossville, and Potomac. The deeper parts of the main bedrock valleys in this area are most likely to contain the thickest deposits of sand and gravel and have a high potential for the presence of a significant groundwater resource. These parts of the bedrock valleys should be given preference for test drilling.

3. Northern Vermilion County north and northwest of the triangular area has the greatest potential for groundwater development. Resistivity data and water well logs from this area indicate the Mahomet Sand is widespread. Further exploration of this area is also warranted.

4. The possibility of utilizing the sand and gravel deposits found along the Wabash River Valley as a source of groundwater supply could also be investigated. Although this river valley is located in Indiana, it is only a little more than 11 miles east of the water treatment plant at Danville. This distance is slightly less than the distance between the treatment plant and the area of greatest potential aquifer thickness in the Mahomet Bedrock Valley in northern Vermilion County. Obtaining groundwater from this source may be limited by the variable thickness and narrow width of the sand and gravel deposits in the Wabash valley as well as by the location being outside of Illinois.

5. An exploration program should progress systematically northward from Lake Vermilion and focus on the areas considered most favorable for finding the greatest thickness of aquifer. These areas are primarily over the deepest parts of the bedrock valley system. Any test holes that are drilled for exploration purposes should be drilled through the entire thickness of the glacial deposits and into the bedrock to ensure that all sand and gravel aquifers present are penetrated. All test holes should be drilled far enough into bedrock to be reasonably certain that the bedrock encountered is in place.

# REFERENCES

Butler, S.S., 1957, Engineering Hydrology: Prentice-Hall, Englewood Cliffs, New Jersey, 356 p.

Cooper, H.H., Jr., and C.E. Jacob, 1946, A generalized graphical method for evaluating formation constants and summarizing well field history: Transactions of the American Geophysical Union, v. 27, no. 4, p. 526-534

Driscoll, F.G., 1986, Groundwater and Wells, 2nd edition: Johnson Div., St. Paul, Minnesota, 1089 p.

Eveland, H.E., 1952, Pleistocene Geology of the Danville Region: Illinois State Geological Survey Report of Investigations 159, 32 p.

Ferris, J.G., 1959, Groundwater, *in C.O.* Wisler and E.F. Brater, editors, Hydrology: John Wiley and Sons, New York, p. 198-272.

Foster, J.W., 1953, Significance of Pleistocene deposits in the groundwater resources of Illinois: Economic Geology, v. 48, no. 7, p. 568-573.

Freeze, R.A., and J.A. Cherry, 1979, Groundwater: Prentice-Hall, Englewood Cliffs, New Jersey, 230 p.

Gibb, J.P., 1970, Groundwater Availability in Ford County: Illinois State Water Survey Circular 97, 66 p.

Gibb, J.P., 1973, Water Quality and Treatment of Domestic Groundwater Supplies: Illinois State Water Survey Circular 118, 17 p.

Hansel, A.K., and W.H. Johnson, 1996, Wedron and Mason Groups: Lithostratigraphic Reclassification of Deposits of the Wisconsin Episode, Lake Michigan Lobe Area: Illinois State Geological Survey Bulletin 104, 116 p.

Hanson, R., 1950, Public Groundwater Supplies in Illinois: Illinois State Water Survey Bulletin 40, 1036 p. and supplements.

Hantush, M.S., 1956, Analysis of data from pumping tests in leaky aquifers: Transactions of the American Geophysical Union, v. 36, no. 1, p. 95-100.

Hantush, M.S., 1964, Hydraulics of wells, *in* V.T. Chow, editor, Advances in Hydroscience, v. 1: Academic Press, New York, p. 281-432.

Heath, R.C., 1989, Basic Ground-Water Hydrology: U.S. Geological Survey Water Supply Paper 2220, 84 p.

Heiland, C.A., 1940, Geophysical Exploration: Prentice-Hall, New York, 1013 p.

Hensel, B.R., 1992, Natural Recharge of Groundwater in Illinois: Illinois State Geological Survey Environmental Geology 143, 33 p.

Herzog, B.L., B.J. Stiff, C.A. Chenoweth, K.L. Warner, J.B. Sieverling, and C. Avery, 1994, Buried Bedrock Surface of Illinois: Illinois State Geological Survey Illinois Map 5.

Horberg, C.L., 1945, A Major Buried Valley in East-Central Illinois and Its Regional Relationships: Illinois State Geological Survey Report of Investigations 106, 11 p.

Horberg, C.L., 1950, Bedrock Topography of Illinois: Illinois State Geological Survey Bulletin 73, 111 p.

Horberg, C.L., 1953, Pleistocene Deposits Below the Wisconsin Drift in Northeastern Illinois: Illinois State Geological Survey Report of Investigations 165, 61 p.

Illinois Department of Public Health, 1990, Drinking Water Systems Code: Illinois Department of Health, Springfield, Illinois.

Jacob, C.E., 1946, Radial flow in a leaky artesian aquifer: Transactions of the American Geophysical Union, v. 27, no. 2, p. 198-205.

Johnson, W.H., 1971, Old Glacial Drift near Danville, Illinois: Illinois State Geological Survey Circular 457, 16 p.

Johnson, W.H., circa 1980, Unpublished preliminary map of the bedrock topography of Vermilion County, Illinois: Illinois State Geological Survey, scale 1:625,000.

Johnson, W.H., D.L. Gross, and S.R. Moran, 1972a, Till stratigraphy of the Danville region, east-central Illinois: Illinois State Geological Survey Reprint Series 1972-I. Reprinted from R.P. Goldthwait et al., editors, Till—A Symposium: Ohio State University Press, Columbus, p. 184-216.

Johnson, W.H., L.R. Follmer, D.L. Gross, and A.M. Jacobs, 1972b, Pleistocene Stratigraphy of East-Central Illinois: Illinois State Geological Survey Guidebook 9, 97 p.

Jones, D.M.A., 1966, Variability of Evapotranspiration in Illinois: Illinois State Water Survey Circular 89, 13 p.

Kempton, J.P., W.H. Johnson, K. Cartwright, and P.C. Heigold, 1991, Mahomet Bedrock Valley in east-central Illinois; topography, glacial drift stratigraphy and hydrogeology, *in* W. N. Melhorn and J. P. Kempton, editors, Geology and Hydrogeology of the Teays-Mahomet Bedrock Valley: Geological Society of America, Special Paper 258, p. 91-124.

Kempton, J.P., R.W. Ringler, P.C. Heigold, K. Cartwright, and V.L. Poole, 1981, Groundwater Resources of Northern Vermilion County, Illinois: Illinois State Geological Survey Environmental Geology Notes 101, 36 p.

Larson, D.R., and S.C. Meyer, 1993, Summary: Hydrogeological Investigation for a Municipal Groundwater Supply, Danville, Illinois: Illinois State Geological Survey Open File Series 1993-B, 12 p.

Leighton, M.M., G.E. Ekblaw, and C.L. Horberg, 1948, Physiographic Divisions of Illinois: Illinois State Geological Survey Report of Investigations 129, 19 p.

Piskin, K., and R.E. Bergstrom, 1975, Glacial Drift in Illinois; Thickness and Character: Illinois State Geological Survey Circular 490, 35 p.

Poole, V.L., and P.C. Heigold, 1981, Geophysical Assessment of Aquifers Supplying Groundwater to Eight Small Communities in Illinois: Illinois State Geological Survey Environmental Geology Note 91, 61 p.

Poole, V.L., and R.C. Vaiden, 1985, Supplemental Groundwater Supplies for Six Small Communities in Illinois: Illinois State Geological Survey Environmental Geology Note 108, 34 p.

Selkregg, L.F., and J.P. Kempton, 1958, Groundwater Geology in East-Central Illinois; A Preliminary Geology Report: Illinois State Geological Survey Circular 248, 36 p.

Singh, K.P., 1978, Water Supply Alternatives for the City of Danville; prepared for the Division of Water Resources, Illinois Department of Transportation: Illinois State Water Survey Contract Publication 196, 124 p.

Stephenson, D.A., 1967, Hydrogeology of Glacial Deposits of the Mahomet Bedrock Valley in East-Central Illinois: Illinois State Geological Survey Circular 409, 51 p.

Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Transactions of the American Geophysical Union 16th Annual Meeting, part 2, p. 519-524.

Todd, D.K., 1980, Groundwater Hydrology, 2nd edition: John Wiley and Sons, New York, 535 p.

Vaiden, R.C, 1987, Geologic conditions relative to development of a municipal groundwater supply for the City of Danville: Illinois State Geological Survey Preliminary Open File Letter Report, 12 p.

Visocky, A.P., and R.J. Schicht, 1969, Groundwater Resources of the Buried Mahomet Bedrock Valley: Illinois State Water Survey Report of Investigation 62, 52 p.

Visocky, A.P., H.A. Wehrmann, K. Lo. Kim, and R.W. Ringler, 1978, Assessment of Public Groundwater Supplies in Illinois: Illinois State Water Survey Contract Publication 209, 195 p.

Walton, W.C., 1960, Leaky Artesian Aquifer Conditions in Illinois: Illinois State Water Survey Report of Investigation 39, 27 p.

Walton, W.C., 1962, Selected Analytical Methods for Well and Aquifer Evaluation: Illinois State Water Survey Bulletin 49, 82 p.

Walton, W.C., 1965, Groundwater Recharge and Runoff in Illinois: Illinois State Water Survey Report of Investigation 48, 55 p.

Watkins, F.A., Jr., and D.G. Jordan, 1965a, Groundwater Resources of West-Central Indiana, Preliminary Report: Fountain County: Indiana Department of Conservation, Division of Water Resources, Bulletin 28, 91 p.

Watkins, F.A., Jr., and D.G. Jordan, 1965b, Groundwater Resources of West-central Indiana, Preliminary Report: Vermillion County: Indiana Department of Conservation, Division of Water Resources, Bulletin 29, 89 p.

Wayne, W.J., G.H. Johnson, and S.J. Keller, 1966, Geologic Map of the 1°x 2° Danville Quadrangle, Indiana and Illinois, Showing Bedrock and Unconsolidated Deposits: Indiana Geological Survey Regional Geologic Map no. 2, scale 1:250,000.

Wehrmann, H.A., A.P. Visocky, C.B. Burris, R.W. Ringler, and R.D. Brower, 1980, Assessment of Eighteen Public Groundwater Supplies in Illinois: Illinois State Water Survey Contract Report 237, 185 p.

Wenner, F., 1916, A method of measuring resistivity in the earth: U.S. Bureau of Standards Bulletin, v. 12, p. 469-478.

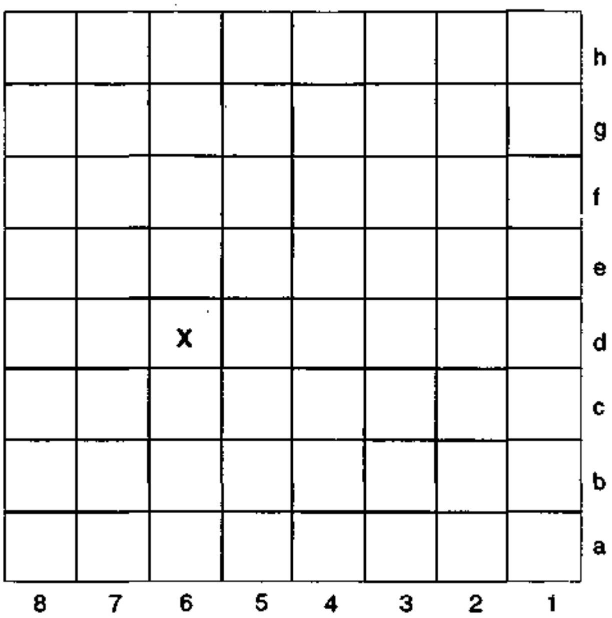
Willman, H.B., and J.C. Frye, 1970, Pleistocene Stratigraphy of Illinois: Illinois State Geological Survey Bulletin 94, 204 p.

Woller, D.M., 1975, Public Groundwater Supplies in Champaign County: Illinois State Water Survey Bulletin 60-15.

Zeizel, A.J., W.C. Walton, R.T. Sasman, and T.A. Prickett, 1962, Groundwater Resources of Du Page County, Illinois: Illinois State Water Survey and Geological Survey Cooperative Groundwater Report 2, 103 p.

## APPENDIX A   Well location scheme

As illustrated below, the system for identifying locations uses numbers to designate township, range, and section. The section is subdivided into quarter-quarter-quarter sections. Each 1/8-mile square is identified by a unique number and letter combination following the section number. The number indicates the east-west position within the section starting from the southeast corner; the letter indicates the north-south position. Irregular sections contain more or less than 64 1/8-mile squares. The location illustrated below is described as Vermilion County, Township 20 North, Range 11 West, Section 19.6d.



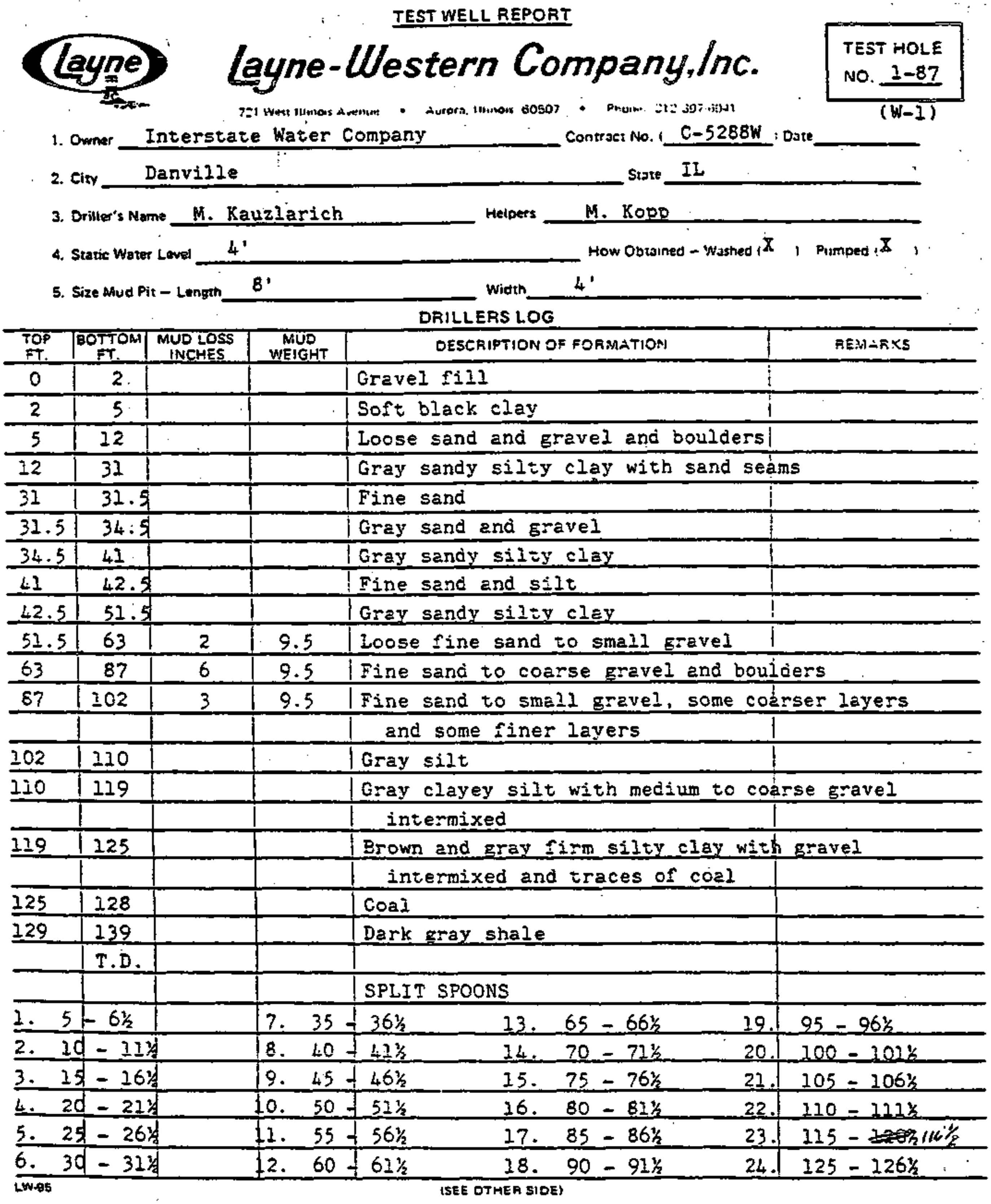
Vermilion County, T20N, R11W, Section 19.6d.

## APPENDIX B List of described sample sets for the study area and location of the wells

| Sample set | Well location | Sample set | Well location |
|---|---|---|---|
| 42057 | T20N, R11W, Section 03.4d | 53260 | T20N, R12W, Section 25.2g |
| 52510 | T20N, R11W, Section 04.8e | 51666 | T20N, R12W, Section 25.6e |
| 67207 | T20N, R11W, Section 07.1c | 49371 | T20N, R12W, Section 27.1b |
| 20839 | T20N, R11W, Section 15.8g | 66555 | T20N, R12W, Section 33.3h |
| 53263 | T20N, R11W, Section 17.8e | 52119 | T20N, R12W, Section 34.6h |
| 26828 | T20N, R11W, Section 18.2c | 53855 | T20N, R12W, Section 36.2h |
| 66442 | T20N, R11W, Section 19.4a | 53853 | T20N, R12W, Section 36.3h |
| 67211 | T20N, R11W, Section 19.4a | 60719 | T20N, R12W, Section 36.3d |
| 52117 | T20N, R11W, Section 20.1d | 58582 | T21N, R11W, Section 01.4h |
| 50173 | T20N, R11W, Section 20.2e | 58398 | T21N, R11W, Section 04.1a |
| 54935 | T20N, R11W, Section 20.6h | 56547 | T21N, R11W, Section 04.8e |
| 66316 | T20N, R11W, Section 28.7a | 20437 | T21N, R11W, Section 05.3d |
| 66317 | T20N, R11W, Section 28.8a | 20442 | T21N, R11W, Section 08.3c |
| 66318 | T20N, R11W, Section 28.8a | 55338 | T21N, R11W, Section 19.7e |
| 66415 | T20N, R11W, Section 28.8a | 62826 | T21N, R11W, Section 20.1e |
| 23548 | T20N, R11W, Section 30.6f | 58584 | T21N, R11W, Section 30.8d |
| 66443 | T20N, R11W, Section 30.3f | 55534 | T21N, R11W, Section 35.4b |
| 66444 | T20N, R11W, Section 30.3f | 58394 | T21N, R12W, Section 02.8a |
| 66445 | T20N, R11W, Section 30.3f | 58585 | T21N, R12W, Section 18.4a |
| 66446 | T20N, R11W, Section 30.3f | 55538 | T21N, R12W, Section 19.2e |
| 67206 | T20N, R11W, Section 30.4d | 54394 | T21N, R12W, Section 34.8d |
| 57020 | T20N, R12W, Section 13.6h | 55533 | T21N, R12W, Section 34.8a |
| 66442 | T20N, R12W, Section 19.4a | 58587 | T21N, R12W, Section 36.1a |
| 55998 | T20N, R12W, Section 24.6h | | |

## APPENDIX C Logs of the 1987,1988, and 1991 test holes drilled by Layne-Western Company

T20N, R11W, Section 28.7a



**TEST WELL REPORT**

**Layne-Western Company,Inc.**

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone 312 897-6941

TEST HOLE NO. 1-87
(W-1)

1. Owner Interstate Water Company Contract No. ( C-5288W ; Date
2. City Danville State IL
3. Driller's Name M. Kauzlarich Helpers M. Kopp
4. Static Water Level 4' How Obtained – Washed ( X ) Pumped ( X )
5. Size Mud Pit – Length 8' Width 4'

DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 2 | | | Gravel fill | |
| 2 | 5 | | | Soft black clay | |
| 5 | 12 | | | Loose sand and gravel and boulders | |
| 12 | 31 | | | Gray sandy silty clay with sand seams | |
| 31 | 31.5 | | | Fine sand | |
| 31.5 | 34.5 | | | Gray sand and gravel | |
| 34.5 | 41 | | | Gray sandy silty clay | |
| 41 | 42.5 | | | Fine sand and silt | |
| 42.5 | 51.5 | | | Gray sandy silty clay | |
| 51.5 | 63 | 2 | 9.5 | Loose fine sand to small gravel | |
| 63 | 87 | 6 | 9.5 | Fine sand to coarse gravel and boulders | |
| 87 | 102 | 3 | 9.5 | Fine sand to small gravel, some coarser layers | |
| | | | | and some finer layers | |
| 102 | 110 | | | Gray silt | |
| 110 | 119 | | | Gray clayey silt with medium to coarse gravel | |
| | | | | intermixed | |
| 119 | 125 | | | Brown and gray firm silty clay with gravel | |
| | | | | intermixed and traces of coal | |
| 125 | 128 | | | Coal | |
| 129 | 139 | | | Dark gray shale | |
| | T.D. | | | | |
| | | | | SPLIT SPOONS | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | 5 - 6½ | 7. | 35 - 36½ | 13. | 65 - 66½ | 19. | 95 - 96½ |
| 2. | 10 - 11½ | 8. | 40 - 41½ | 14. | 70 - 71½ | 20. | 100 - 101½ |
| 3. | 15 - 16½ | 9. | 45 - 46½ | 15. | 75 - 76½ | 21. | 105 - 106½ |
| 4. | 20 - 21½ | 10. | 50 - 51½ | 16. | 80 - 81½ | 22. | 110 - 111½ |
| 5. | 25 - 26½ | 11. | 55 - 56½ | 17. | 85 - 86½ | 23. | 115 - ~~120½~~ 116½ |
| 6. | 30 - 31½ | 12. | 60 - 61½ | 18. | 90 - 91½ | 24. | 125 - 126½ |

LW-85

(SEE OTHER SIDE)

T20N, R11W, Section 28.8a

TEST WELL REPORT

**Layne-Western Company, Inc.**

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

TEST HOLE NO. 2-87

W-2

1. Owner Interstate Water Co. Contract No. (C5288W) Date 12-23-87
2. City Danville State Illinois
3. Driller's Name S. Lumbert Helpers C. Glidewell
4. Static Water Level +5' How Obtained — Washed (X ) Pumped ( X )
5. Size Mud Pit — Length 8 Width 4

## DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 2 | | | Gravel fill and black clay | |
| 2 | 7 | | | Black clay | |
| 7 | 9 | | | Sand and gravel | |
| 9 | 14 | | | Gray sandy clay with gravel | |
| 14 | 16 | | | Sand and gravel | |
| 16 | 39 | | | Gray sandy silty with sand and gravel seams | |
| 39 | 57 | | | Soft gray sandy silty clay | |
| 57 | 68 | 3" | 8.7 | Fine sand to small gravel some coarser layers | |
| 68 | 85 | 7" | 9.5 | Fine sand to coarse gravel with boulders | |
| 85 | 93 | 4" | 9.0 | Fine sand to small gravel with coarser layers | |
| 93 | 98 | | | Gray sandy silty clay with coarse gravel intermixed | |
| 98 | 107 | 4" | 9.0 | Fine sand to medium gravel with traces of coal | |
| 107 | 112 | | | Gray silt | |
| 112 | 126 | | | Gray sandy silty clay with some gravel layers | |
| | | | | and coal seams | |
| 126 | 128 | | | Coal | |
| 128 | 133 | | | Soft gray clay with coal seams | |
| 133 | 145 | | | Gray shale | |
| | 145 | | | T.D. | |
| | | | | Split Spoons: | |
| | | | | 40 - 41.5 85 - 86.5 | |
| | | | | 60 - 61.5 90 - 91.5 | |
| | | | | 65 - 66.5 100 - 101.5 | |
| | | | | 70 - 71.5 107 - 108 | |
| | | | | 80 - 81.5 | |
| | | | | | |
| | | | | | |

LW-95

(SEE OTHER SIDE)

T20N, R11W, Section 28.8a

## TEST WELL REPORT

**Layne-Western Company, Inc.**

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

TEST HOLE NO. 3-87 ~~(W-3)~~

1. Owner Interstate Water Company Contract No. (C5288W) Date 12-31-87
2. City Danville State Illinois
3. Driller's Name S. Lumbert Helpers M. Kopp
4. Static Water Level +2' How Obtained — Washed ( X ) Pumped ( X )
5. Size Mud Pit — Length 8 Width 4

### DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 5 | | | Fill and black clay | |
| 5 | 7 | | | Gray and black clay | |
| 7 | 39 | | | Gray sandy silty clay with gravel intermixed and layered with sand seams | |
| 39 | 55 | | | Gray soft silty clay | |
| 55 | 66 | 2 | | Fine sand to small gravel | |
| 66 | 76 | 3 | | Fine sand to coarse gravel | |
| 76 | 88 | 2 | | Fine sand to medium gravel, some coarse | |
| 88 | 101 | 4 | | Fine sand to coarse gravel and boulders | |
| 101 | 120 | | | Gray soft sandy clay with gravel and coal seams | |
| 120 | 133 | | | Conglomerates of silt, clay and coal | |
| 133 | 144 | | | Soft gray shale, harder at times | |
| | TD | | | | |

LW-95

(SEE OTHER SIDE)

T20N, R12W, Section 19.4a

## TEST WELL REPORT

# Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

TEST HOLE NO. LV-1-8

1. Owner Interstate Water Company Contract No. ( C-5288W ) Date 1-19-88
2. City Danville State IL
3. Driller's Name M. Kauzlarich Helpers M. Kopp
4. Static Water Level 2' How Obtained – Washed ( X ) Pumped ( X )
5. Size Mud Pit – Length 8' Width 4'

## DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 7 | | | Brown clay and gravel fill | |
| 7 | 20 | | | Soft dark gray clay and silt | |
| 20 | 28 | | | Brown sandy silty clay | |
| 28 | 60 | | | Gray sandy silty clay, some gravel | |
| 60 | 76 | 2 | 9.0 | Gray fine sand to small gravel | |
| 76 | 77.5 | | | Gray fine to medium sand | |
| 77.5 | 96 | 1 | 9.0 | Dark gray fine to coarse sand, | |
| | | | | some coarse lavers and finer layers. | |
| 96 | 116 | 4 | 9.0 | Brown fine sand to small gravel. | |
| | | | | some coarser layers and some finer layers | |
| 116 | 118 | | | Black coal and shale with sand and gravel. | |
| 118 | 121 | | | Soft shale and lime | |
| 121 | 130 | | | Gray shale | |
| | 130 | | | T.D. | |
| SPOON SAMPLES | | | | | |
| 10 - | 11-1/2 | | | Set 3" pipe to 129' and backwashed 2 hours. | |
| 15 - | 16-1/2 | 4.5 | | Slotted 100' - 116'. | |
| 20 - | 21-1/2 | 4.0 | | Airlifted 6 hours. | |
| 25 - | 26-1/2 | 4.5+ | | | |
| 30 - | 31-1/2 | 4.5+ | | 75 - 76-1/2 100 - 101-1/2 | |
| 35 - | 36-1/2 | 3.5 | | 80 - 81-1/2 105 - 106-1/2 | |
| 40 - | 41-1/2 | 2.0 | | 85 - 86-1/2 110 - 111-1/2 | |
| 45 - | 46-1/2 | 1.0 | | 90 - 91-1/2 115 - 116-1/2 | |
| 50 - | 51-1/2 | 1.0 | | 95 - 96-1/2 120 - 121-1/2 | |
| 55 - | 56-1/2 | 2.5 | | | |
| 60 - | 61-1/2 | | | | |
| 65 - | 66-1/2 | | | | |
| 70 - | 71-1/2 | | | | |

LW-95

(SEE OTHER SIDE)

T20N, R11W, Section 30.3f

## TEST WELL REPORT

# Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

TEST HOLE NO. LV3-88

1. Owner Interstate Water Company Contract No. ( C-5288W ) Date 1/21/88
2. City Danville State Illinois
3. Driller's Name M. Kauzlarich Helpers M. Kopp
4. Static Water Level 40' How Obtained — Washed ( x ) Pumped ( x )
5. Size Mud Pit — Length 8' Width 4'

## DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 8 | | | Brown clayey sand and silt | |
| 8 | 22 | 25" | 10.0 | Brown sand, gravel and boulders | |
| 22 | 24 | | | Brown sandy silty clay | |
| 24 | 29 | | | Gray sandy silty clay | |
| 29 | 33 | | | Brown and gray sandy silty clay, some gravel | |
| 33 | 56 | | | Gray sandy silty clay, some sand & gravel seams | |
| 56 | 58 | | | Silt | |
| 58 | 61 | | | Dirty brown sand | |
| 61 | 68 | | | Brown silty fine sand | |
| 68 | 72 | | | Brown fine sand to small gravel | |
| 72 | 98 | | | Gray silt with clayey layers | |
| 98 | 103 | | | Gray fine to medium sand | |
| 103 | 117 | 2" | 9.8 | Gray fine sand to medium gravel | |
| 117 | 128 | 6" | 9.8 | Dark gray fine sand to coarse gravel | |
| 128 | 142 | 6" | 9.8 | Gray fine sand to medium gravel, some coarser layers and finer layers | |
| 142 | 157 | 3" | 9.8 | Gray fine sand to small gravel | |
| 157 | 170 | | | Gray shale | |
| | 170 | | | T.D. | |

Set 3" pipe to 170', slotted 155' - 135' and backwashed 2 hours. Airlifted 5 hr.

Spoon Samples:

10' - 11½' 45' - 46½' 4.5+

20' - 21½' 50' - 51½' 4.0

25' - 26½' 4.5+ 60' - 61½' 80' - 81½' 100' - 101½' 120'-121½' 140'-141½'

30' - 31½' 4.5+ 65' - 66½' 85' - 86½' 105' - 106½' 125'-126½' 145'-146½'

35' - 36½' 4.5+ 70' - 71½' 90' - 91½' 110' - 111½' 130'-131½' 150'-151½'

40' - 41½' 4.5+ 75' - 76½' 95' - 96½' 115' - 116½' 135'-136½' 155'-156½'

Didn't take wash samples because of spoons every 5'. 158'-159'

LW-05 (SEE OTHER SIDE)

## TEST WELL REPORT

# Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

TEST HOLE NO. LW4-88

1. Owner Interstate Water Company Contract No. ( C-5288W ) Date 1/27/88
2. City Danville State Illinois
3. Driller's Name M. Kauzlarich Helpers M. Kopp
4. Static Water Level 42' How Obtained — Washed ( X ) Pumped ( X )
5. Size Mud Pit — Length 8' Width 4'

### DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| | | | | Brown clayey sand and silt | |
| 8 | 25 | 8" | 9.5 | Brown sand and gravel | |
| 25 | 27 | | | Brown sandy silty clay | |
| 27 | 29 | | | Gray sandy silty clay | |
| 29 | 32 | | | Sand | |
| 32 | 55 | | | Gray sandy silty clay, some sand and gravel layers | |
| 55 | 80 | 4" | 9.1 | Brown sand with silt layers and gravel layers | |
| 80 | 87 | | | Gray very silty clay | |
| 87 | 99 | | | Grey silt with clayey layers | |
| 99 | 105 | | | Gray fine to medium sand with clay seams | |
| 105 | 120 | 4" | 9.1 | Gray fine sand to medium gravel, some coarser layers | |
| 120 | 148 | 6" | 9.1 | Dark gray fine sand to coarse gravel, some coal | |
| 148 | 159 | 3" | 9.1 | Grey fine sand to small gravel | |
| 159 | 170 | | | Gray shale | |
| | 170 | | | T.D. | |
| | | | | | |
| Spoon Samples: | | | | | |
| 93½' | - 95' | | | Set 3" plastic pipe to 169', slotted 139' - 159', | |
| 159' | - 159½' | | | backwashed 2 hours. Airlifted 4 hrs. | |

LW-95

(SEE OTHER SIDE)

T20N, R11W, Section 30.3f

## TEST WELL REPORT

# Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

TEST HOLE NO. LVS-88

1. Owner Interstate Water Company Contract No. (C-5288W) Date 1/29/88
2. City Danville State Illinois
3. Driller's Name M. Kauzlarich Helpers M. Kopp
4. Static Water Level 40' How Obtained — Washed ( X ) Pumped ( X )
5. Size Mud Pit — Length 8' Width 4'

### DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 7 | | | Brown clayey silt and sand | |
| 7 | 28 | 6" | 9.5 | Brown sand and gravel | |
| 28 | 29 | | | Boulders | |
| 29 | 58 | | | Gray sandy silty clay, some sand | seams |
| 58 | 82 | 2" | 9.0 | Brown fine sand to small gravel, | trace silt seams |
| 82 | 87 | | | Gray silty clay | |
| 87 | 98 | | | Gray silt | |
| 98 | 100 | | | Gray clayey silt | |
| 100 | 107 | 1/4" | 9.0 | Gray fine to medium sand | |
| 107 | 118 | 3" | 9.1 | Gray fine sand to small gravel | |
| 118 | 148 | 3" | 9.1 | Gray fine sand to medium gravel, | some coal |
| 148 | 159 | 1-1/2" | 9.1 | Gray fine sand to small gravel | |
| 159 | 170 | | | Grey shale | |
| | 170 | | | T.D. | |
| | | | | | |
| Spoon Samples: | | | | | |
| 90' - 91½' | | | | Set 8" pipe to 168', slotted 158' - 138'. | |
| | | | | Backwashed 3 hours. Airlifted 7 | hrs. |

LW-95

(SEE OTHER SIDE)

T20N, R11W, Section 30.3g

## TEST WELL REPORT

# Layne-Western Company, Inc.

TEST HOLE NO. LV6-88

721 West Illinois Avenue • Aurora, Illinois 60507 • Phone: 312/897-6941

1. Owner Interstate Water Company Contract No. (C-5288W) Date 2/3/88
2. City Danville State Illinois
3. Driller's Name M. Kauzlarich Helpers M. Kopp
4. Static Water Level 40' How Obtained – Washed ( X ) Pumped ( X )
5. Size Mud Pit – Length 8' Width 4'

### DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 7 | | | Brown clayey sand and silt | |
| 7 | 15 | 3" | 9.0 | Brown sand and gravel | |
| 15 | 17 | | | Brown sandy silty clay | |
| 17 | 53 | | | Gray sandy silty clay, some gravel intermixed | |
| | | | | and an occasional small layer of sand | |
| 53 | 65 | | | Brown sand and gravel | |
| 65 | 78 | | | Fine sand with clay and silt seams | |
| 78 | 92 | | | Gray silty clay with silt layers | |
| 92 | 100 | | | Gray silt | |
| 100 | 102 | | | Gray clayey silt | |
| 102 | 112 | | | Grey fine to medium sand | |
| 112 | 147 | 7" | 9.0 | Grey fine sand to medium gravel, some coarse layers | |
| 147 | 152 | 1" | 9.0 | Grey fine sand to small gravel | |
| 152 | 155 | | | Clay with gravel | |
| 155 | 170 | | | Grey shale | |
| | 170 | | | T.D. | |
| | | | | | |
| Spoon Samples: | | | | Set 3" pipe to 169' and backwashed 2 hours. | |
| 90' – 91½' | | | | Airlifted 7 hours. Pipe slotted 130' – 150'. | |
| 152' – 153' | | | | | |

LW-95

(SEE OTHER SIDE)

Layne

## WELL INFORMATION – DRIFT WELLS

**Layne-Western Company, Inc.**

PROFESSIONAL SERVICES FOR WATER SYSTEMS

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

Name of Job Inter-State Water Co. Date 11/15/91

City or Village Danville State Illinois

Well No.: TWI-91 Drillers: Steve Lumbert

Well Location: App. 1750 ft. ( S ) and 1500 ft. ( W ) of the NE corner of

Section 19 ~~30~~, Twp. 20 ( ~~W~~N ), Range 11 ( W ) County.

Otherwise located as the southeast corner of the County Park parking lot on west bank of Lake Vermillion Reservoir

Work Began: 10/19/91 Work Completed: 11/5/91, Well Depth: 145'

All measurements made from existing ground level at time well was drilled.

Casing Record:

| Amount | Dia. | Wt. or Thickness | Material | | with | | joints from | | to |
|---|---|---|---|---|---|---|---|---|---|
| 27' | 18" | .375W | Steel | with | welded | joints from | 0' | to | 27' |
| 106' | 12" | .375W | Steel | with | welded | joints from | +1' | to | 105' |

Screen Record: Type Johnson Wire Wrap

| Amount | Dia. | Opening | Material | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 40' | 12" | .065 | Stainless | with | T&C | joints from | 105' | to | 145' |
| | | | | with | | joints from | | to | |

Type of Seal at Bottom Steel Plate

Hole Record:

| | | | | |
|---|---|---|---|---|
| 19 | inch from | 0' | to | 27' |
| 17 | inch from | 27' | to | 157' |

Gravel Pack Record:

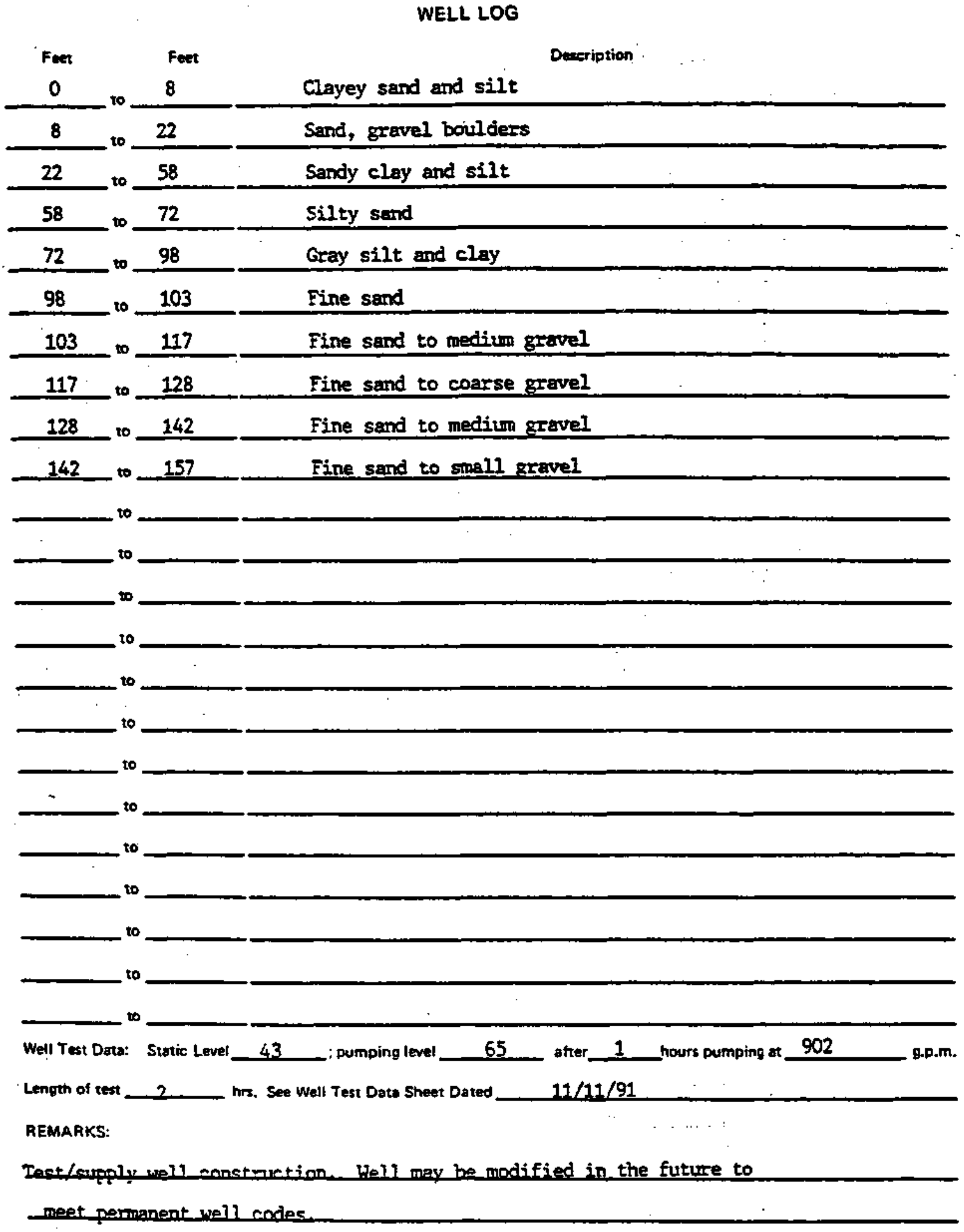
| Amount | Size | Source | From | To |
|---|---|---|---|---|
| 9.75 tons | #2 | Northern Gravel Co. | 157' | 1' |
| | | | | |

Cementing Record: None as of this date.

Backfill Record:

LW-94

SEE OTHER SIDE



**WELL LOG**

| Feet | | Feet | Description |
|---|---|---|---|
| 0 | to | 8 | Clayey sand and silt |
| 8 | to | 22 | Sand, gravel boulders |
| 22 | to | 58 | Sandy clay and silt |
| 58 | to | 72 | Silty sand |
| 72 | to | 98 | Gray silt and clay |
| 98 | to | 103 | Fine sand |
| 103 | to | 117 | Fine sand to medium gravel |
| 117 | to | 128 | Fine sand to coarse gravel |
| 128 | to | 142 | Fine sand to medium gravel |
| 142 | to | 157 | Fine sand to small gravel |

Well Test Data: Static Level 43 ; pumping level 65 after 1 hours pumping at 902 g.p.m.

Length of test 2 hrs. See Well Test Data Sheet Dated 11/11/91

REMARKS:

Test/supply well construction. Well may be modified in the future to meet permanent well codes.

Layne

WELL TEST DATA SHEET

# Layne-Western Company, Inc.

PROFESSIONAL SERVICES FOR WATER SYSTEMS

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

| | | | |
|---|---|---|---|
| Job | Interstate Water Co. | Well No. | TWI-91 |
| | | Date Tested | November 11, 1991 |
| Location | Danville | Tested By | Lumbert-Schierbaum |
| Dia. of Well | 12 | Driver | 353 Detroit |
| Depth of Well | 145 | Pump Used: Column and Shaft | 6 x 1-11/16 |
| Length of Airline | 105 | Bowls | 10 THC 4 stage |
| Non-Pumping Level | 43 62 gauge | Manufacturer | Layne |
| Orifice Size | 6 x 5 | Serial No. | 52305 |

| Time | Piezometer Reading (in.) | G.P.M. | Air Gauge Reading (feet) | Pumping Level | Drawdown | Disch. Pressure Lbs. | Disch. Pressure Feet | Total Pumping Head | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 7:00 | | | 62 | | | | | | |
| 7:15 | 43 | 816 | 48 | 57 | 14 | | | | Cloudy-a little mud |
| 7:30 | 43 | 816 | 46 | 59 | 16 | | | | |
| 7:45 | 43 | 816 | 46 | 59 | 16 | | | | Clearer |
| 8:00 | 52.5 | 902 | 42 | 63 | 20 | | | | Cloudy |
| 8:15 | 52.5 | 902 | 41 | 64 | 21 | | | | Cloudy sand & silt |
| 8:30 | 52.5 | 902 | 41 | 64 | 21 | | | | |
| 8:45 | 52.5 | 902 | 40 | 65 | 22 | | | | Cloudy |
| 9:00 | 52.5 | 902 | 40 | 65 | 22 | | | | Clear |

Sp Cap = 816/16 = 51.0

= 902/22 = 41.0

LW-921 9/91

T20N, R11W, Section 19.4a

TEST WELL REPORT

# layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

TEST HOLE NO. 1-91

1. Owner Interstate Water Company Contract No. ( C-6492W ) Date 10/24/91
2. City Danville State Illinois
3. Driller's Name Marv Michelson Helpers Bill Doyle
4. Static Water Level 40.60' How Obtained — Washed ( X) Pumped ( )
5. Size Mud Pit — Length 10' Width 4'

Page 1

## DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 3 | | | Blacktop, sand fill | |
| 3 | 6 | | | Sand, brown silty clay | |
| 6 | 10 | | | Sand, clay with some gravel | |
| 10 | 15 | 1/2 | | Fine sand and gravel | |
| 15 | 22.5 | | | Brown sandy clay; boulder at 17 ft. | |
| 22.5 | 30 | | | Gray silty clay | |
| 30 | 36.5 | | | Gray silty, sandy clay; boulder at 35 ft. | |
| 36.5 | 41 | | | Gray silty clay with gravel | |
| 41 | 42 | | | Very soft material | |
| 42 | 45 | | | Gray silty clay, trace small gravel | |
| 45 | 50 | | | Gray sandy clay | |
| 50 | 61.5 | | | Gray silty clay with small gravel traces | |
| 61.5 | 62.5 | | | Boulder | |
| 62.5 | 73 | | | Gray silty sandy clay with small gravel | |
| 73 | 81 | | | Gray very sandy, silty clay and gravel | SPLIT SPOONS |
| 81 | 95.5 | | | Gray very sandy, silty clay and gravel | |
| 95.5 | 96 | 1/2 | | Gray sandy, silty clay with gravel layers | Split Spoon (No.1)<br>6" recovery |
| 96 | 102 | 1/2 | | Gravel and sandy, fine; layers of gray silty clay | |
| 102 | 105 | 3/4 | | Fine to medium sand and gravel | |
| 105 | 106.5 | | | Fine to coarse sand | Split Spoon (No.2) |
| 110 | 111.5 | | | Fine to coarse sand | Split Spoon (No.3) |
| 115 | 116.5 | | | Fine to coarse sand | Split Spoon (No.4)<br>no recovery |
| 116 | 117.5 | 1 1/2 | | Collected wash sample | |
| 121 | 122.5 | | | Medium to coarse sand | Split Spoon (No.4) |
| 124 | 125 | 2 | | Trace of coal in gravel and sand | |
| | | 3 | | (Resumed drilling 10/24/91 - overnight 3" mud loss) | |

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(SEE OTHER SIDE)

T20N, R11W, Section 19.4a

TEST WELL REPORT

**Layne-Western Company, Inc.**

TEST HOLE NO. 1-91

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

1. Owner Interstate Water Company Contract No. ( C-6492W ) Date 10/24/91

2. City ______ State ______

3. Driller's Name ______ Helpers ______

4. Static Water Level ______ How Obtained — Washed ( ) Pumped ( )

5. Size Mud Pit — Length ______ Width ______

Page 2

DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 125 | 126.5 | | | Fine to medium sand and gravel | Split Spoon (No.5) |
| 130 | 131.5 | | | Gray fine sand and small gravel | Split Spoon (No.6) |
| 135 | 136.5 | 1-1/2 | | Gray fine sand and gravel | Split Spoon (No.7) |
| 140 | 141.5 | 1 | | Gray fine sand | Split Spoon (No.8) |
| 145 | 146.5 | 1-1/2 | | Medium sand and small gravel; trace of | Split Spoon (No.9) |
| | | | | coal at 148 ft. | |
| 150 | 151.5 | | | Coarse sand and large gravel, trace | Split Spoon (No.10) |
| | | | | of silt | |
| 155 | 156.5 | 1 | | Coarse sand and large gravel, trace | Split Spoon (No.11) |
| | | | | of silt | |
| 158 | 167 | | | Light gray shale | |
| 167 | 170 | TD | | Dark Gray shale | |

LW-95

(SEE OTHER SIDE)

T20N, R11W, Section 30.4d

## TEST WELL REPORT

# Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

**TEST HOLE NO.** 2-91

1. Owner Interstate Water Company Contract No. ( C-6492W ) Date 10/24 & 10/25/9
2. City Danville State Illinois
3. Driller's Name Marvin Michelson Helpers Bill Doyle
4. Static Water Level ______ How Obtained — Washed (  ) Pumped (  )
5. Size Mud Pit — Length 10' Width 4'

## DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 1 | ½" | | Black sandy rocky soil | |
| 1 | 6 | ½" | | Brown sandy & silty clay | |
| 6 | 15 | | | Brown sand & gravel 13'-145' boulder | |
| 15 | 17 | | | Light brown silty & sandy clay | |
| 17 | 30 | | | Gray silty clay | |
| 30 | 42 | | | Gray silty clay with gravel | |
| 42 | 69 | | | Gray sandy & silty clay with gravel | |
| 69 | 110 | | | Gray silty clay with trace of gravel | |
| 110 | 118 | | | Coal | |
| 118 | 130 | | | Light gray clay | |
| 130 | 132 | | | Shale & lime | 450 Lb Pulldown |
| 132 | 157 | | | Light gray shale | 500 Lb |
| 157 | 170 | | | Dark gray shale | 450 Lb |
| 170 | 190 | | | Light gray shale | 450 Lb |

LW-95

(SEE OTHER SIDE)

T20N, R11W, Section 07.1c

# TEST WELL REPORT

## Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

**TEST HOLE NO.** 3-91

1. Owner Interstate Water Company Contract No. ( C-6492W ) Date 10-29-91
2. City Danville State Illinois
3. Driller's Name Marvin Michelson Helpers Bill Doyle
4. Static Water Level ______ How Obtained – Washed ( ) Pumped ( )
5. Size Mud Pit – Length 10' Width 3' SPOONS

Took spoons every 10'

## DRILLERS LOG

| TOP FT. | BOTTOM FT. | MUD LOSS INCHES | MUD WEIGHT | DESCRIPTION OF FORMATION | REMARKS |
|---|---|---|---|---|---|
| 0 | 6 | 1/2" | | Dark silty sandy clay | |
| 7 | 14 | 3/4" | | Sand & gravel 12' boulder | 10' spoon |
| 14 | 17 | | | Brown silty sandy clay | 20' spoon |
| 17 | 19 | 1/4" | | Sand & gravel | 30' spoon |
| 20 | 26 | | | Gray sand samll gravel | 40' spoon |
| 26 | 43 | | | Gray silty sandy clay | 50' spoon |
| 43 | 72 | | | Gray silty clay with trace of gravel | |
| 72 | 82 | | | Gray silty clay & trace of coal | 60' spoon |
| 82 | 84 | | | Coal layer | 70' spoon |
| 84 | 100 | | | Gray silty clay | 80' spoon |
| 100 | 106 | | | Coal layers gray silty clay | 90' spoon |
| 106 | 112 | | | Light gray shale with lime | 100' spoon |
| | | | | 110 run spoon twice - no sample | |
| 115 | 121 | | | Dark gray shale | |
| | | | | 120 run spoon drove for 15 minutes did not move | |
| 121 | 137 | | | Black lime shale | |
| | | | | 130 run spoon would not go | |
| 137 | | | | Light gray shale | |
| | | | | 140 took spoon no sample | |
| 140 | 150 | | | Took spoon no smaple - light gray shale | 500 lbs |
| 150 | 160 | | | Light gray shale 500 lbs | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

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(SEE OTHER SIDE)

# APPENDIX D Results of pumping tests in the study area

| Well location* | Well owner | Depth (ft) | Aquifer* | Land elevation (ft MSL) | Static level (ft) | Pumping rate (gpm) | Specific capacity (gpm/ft) | Analysis method† | Transmissivity (gpd/ft) | Hydraulic conductivity (gpd/ft$^2$) | Storage coefficient[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **T19N-R11W** | | | | | | | | | | | |
| Section 05.2e | Danville Unit School Dist. #118 (Well 2) | 74.5 | B | 605 | 54.4 | 245 | 41.3 | S[a] | 52,000-64,000 | 2,700-3,300 | unconfined |
| 09.8f | Lauhoff Grain Co. (Well 6) | 118 | HB | 560 | 33 | 1,232 | 205 | S | 239,000-317,000 | 2,800-3,700 | unconfined |
| 09.8g | Lauhoff Grain Co. (Well 8) | 108 | HB | 560 | 40 | 1,324 | 265 | S | 313,000-408,000 | 4,600-6,000 | unconfined |
| 15.2f | Vermilion Hills Estates (Well 1) | 74 | B | 550 | 24.5 | 10 | 1.0 | S[a] | 2,000 | 250 | confined |
| 15.3f | Vermilion Hills Estates (Well 2) | 110 | B | 545 | 23.5 | 50 | 7.5 | G | 21,000 | 2,100 | confined |
| **T20N-R11W** | | | | | | | | | | | |
| Section 15.8f | Danville Airport (Well 2) | 35 | W | 655 | 10.1 | 20 | 1.1 | S | 400-1,300 | 40-130 | confined, converted to unconfined during well test |
| 28.7a | Danville Elks Club Golf Course | 88 | B | 635 | 1.2 | 203 | 21.0 | G | 62,000 | 3,000 | confined |
| 28.8a | Danville (Winter Avenue test well) | 100 | B | 611 | 0.6 | 638-720 | 9.5 | G | 30,000-58,000 | 800-1,200 | $3.6\times10^{-4}$-$1.5\times10^{-2}$ |
| 30.3f | Danville (Lake Vermilion test well) | 157 | B | 610 | 39.2 | 715 | 24.2 | G | 41,000-45,000 | 800 | $4.8\times10^{-4}$-$1.8\times10^{-2}$ |
| **T21N-R11W** | | | | | | | | | | | |
| Section 20.1 e | Bismarck Community Water Dist. (Well 1) | 201 | B | 660 | 14.7 | 73 | 0.9 | G | 9,600 | 370 | confined |
| 20.1 e | Bismarck Community Water Dist. (Well 2) | 188 | B | 660 | 19.4 | 116 | 4.9 | G | 30,000-31,000 | 700-800 | confined |

+ See appendix A for explanation of well location scheme.

* H = Glacial outwash of Henry Formation or younger alluvial deposits; W = Wedron Group; G = Glasford Formation; B = Banner Formation.

† S = Specific capacity analysis; G= Graphical analysis of pumping test data.

[a] Transmissivity determination based on specific capacity corrected for well loss.

[b] In the absence of a discrete solution for storage coefficient, hydraulic conditions are characterized as confined or unconfined. The storage coefficient generally ranges from $10^{-5}$ to $10^{-3}$ for confined aquifers and from 0.1 and 0.3 under unconfined aquifers.

# APPENDIX E Results of pumping tests in the region

| Well location[+] | Well owner | Depth (ft) | Aquifer[*] | Land elevation (ft MSL) | Static level (ft) | Pumping rate (gpm) | Specific capacity (gpm/ft) | Analysis method[†] | Transmissivity (gpd/ft) | Hydraulic conductivity (gpd/ft$^2$) | Storage coefficient[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T21N-R11W | | | | | | | | | | | |
| Section 04.8d | Alvin (Well 1) | 103 | G | 660 | 8.3 | 50 | 1.3 | G | 1,700-1,900 | 170-190 | confined |
| **T21N-R13W** | | | | | | | | | | | |
| Section 03.2e | Potomac (Well 4) | 189 | B | 672 | 1.1 | 76 | 36.9 | G | 296,000 | 3,300 | confined |
| 03.2e | Potomac (Well 5) | 178 | B | 660 | 0.3 | 150 | 14.4 | G | 283,000 | 5,300 | confined |
| **T22N-R12W** | | | | | | | | | | | |
| Section 11.1h | Rossville (Test Well 2-72) | 93 | G | 690 | 22.2 | 106 | 7.3 | G | 31,000-85,000 | 500-1,500 | confined |
| 12.7e | Rossville (Well 4) | 127 | G | 710 | 58.5 | 330 | 19.1 | G | 44,000-53,000 | 800-900 | 9.4x10$^{''5}$ |
| **T23N-R12W** | | | | | | | | | | | |
| Section 09.6a | E.F. Trego (Well 1) | 140 | G | 715 | 32.5 | 21 | 2.6 | S[a] | 9,000-12,000 | 500-600 | confined |
| 11.1d | Pillsbury Co. (Well 7) | 115 | G | 715 | 40 | 1,026 | 93.3 | S | 149,000-221,000 | 2,700-3,900 | confined |
| 11.3e | Hoopeston (Well 4) | 110 | G | 710 | 35 | 755-780 | 27.4 | G | 95,000-109,000 | not determined | $2.5\times10^{-3}$ |
| 11.3e | Hoopeston (Well 5) | 104 | G | 710 | 38 | 1,543 | 30.6 | G | 60,000-93,000 | 1,500-2,300 | confined |
| 11.3e | Hoopeston (Well 6) | 98 | G | 705 | 35.3 | 2,030 | 92.8 | G | 101,000-159,000 | 2,500-4,000 | confined |
| **T23N-R13W** | | | | | | | | | | | |
| Section 10.1b | East Lynn Community Water Systems, Inc. (Weill) | 150 | G | 700 | 15.9 | 124 | 21.3 | G | 142,000 | 2,200 | confined |
| **T23N-R14W** | | | | | | | | | | | |
| Section 11.1d | Rankin (Well 1) | 270 | B | 720 | 40.4 | 56 | 1.7 | G | 12,000 | 80 | confined |
| 11.1d | Rankin (Well 2) | 283 | B | 720 | 40.9 | 98 | 14.5 | G | 108,000-144,000 | 700-900 | confined |

+ See appendix A for explanation of well location scheme.

* H = Glacial outwash of Henry Formation or younger alluvial deposits; W = Wedron Group; G = Glasford Formation; B = Banner Formation.

† S = Specific capacity analysis; G = Graphical analysis of pumping test data.

[a] Transmissivity determination based on specific capacity corrected for well loss and partial penetration.

[b] In the absence of a discrete solution for storage coefficient, hydraulic conditions are characterized as confined or unconfined. The storage coefficient generally ranges from $10^{-5}$ to $10^{-3}$ for confined aquifers and from 0.1 and 0.3 under unconfined aquifers.