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CHARACTERIZATION OF THE STUDY AREAS FOR THE PILOT STUDY: AGRICULTURAL CHEMICALS IN RURAL, PRIVATE WELLS IN ILLINOIS

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CHARACTERIZATION OF THE STUDY AREAS FOR THE PILOT STUDY: AGRICULTURAL CHEMICALS IN RURAL, PRIVATE WELLS IN ILLINOIS

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EXECUTIVE SUMMARY

The Illinois Groundwater Protection Act of 1987 (PA 85-863) mandated that the impact of pesticides on groundwater be evaluated. Because pesticide use is widespread in rural areas and groundwater is the major source of drinking water in rural areas, the Illinois State Geological Survey (ISGS) and the Illinois State Water Survey (ISWS) developed recommendations for a statewide survey of agricultural chemicals in rural, private water wells in Illinois (McKenna et al. 1989).

This pilot study was undertaken to develop and evaluate field, analytical, and database management methodologies that would be applied in a statewide survey. Such an evaluation of the research design would assist in streamlining and making more economically feasible the statewide survey recommended by McKenna et al. (1989). Specifically, the pilot study evaluated the validity of using the potential for contamination of shallow aquifers as the stratification variable by assessing the occurrence of agricultural chemicals in rural, private wells in representative hydrogeologic settings in Illinois (McKenna et al. 1989). Additional objectives included field testing well selection procedures; conducting well user interviews; training Illinois Department of Agriculture (IDOA) and Illinois Department of Public Health (IDPH) personnel in sampling procedures; and establishing and evaluating techniques for database management, laboratory management, and quality assurance/quality control. The results of the pilot study could be used in a statewide survey to determine the number of wells necessary for characterizing the quality of water pumped from rural, domestic wells, while at the same time maintaining an acceptable level of statistical reliability and analytical precision.

This report summarizes the land use, agricultural, geologic, and hydrologic characterizations of the five representative settings in the pilot study. A companion report, *Pilot Study: Agricultural Chemicals in Rural, Private Wells in Illinois* (Schock et al. 1992), discusses the project design, sampling methodology, and statistical analysis and interpretation of the chemical analyses. Schock et al. (1992) also present recommendations for conducting a statewide survey and propose modifications in the sampling and chemical analysis protocols. The volume of the characterization material warranted publication as a separate document. Both reports should be reviewed concurrently to fully understand the objectives, methodologies, and results of the pilot study.

Characterizing the geologic materials of target areas is a major component in assessing the potential for contamination. McKenna et al. (1989) identified four hydrogeologic settings that occur in Illinois on the basis of their interpretation of the stack-unit geologic map of Illinois (Berg and Kempton 1988). The distance from the land surface to the top of the uppermost deposit of aquifer material was used to differentiate the four groups.

The four study areas chosen for the pilot study represent these four hydrogeologic groups and are located in the following counties: (1) Mason (aquifer material within 5 feet of land surface), (2) Kankakee (between 5 and 20 feet of land surface), (3) Livingston (between 20 and 50 feet of land surface), and (4) Piatt (aquifer material greater than 50 feet from land surface). A fifth study area in Effingham County was chosen because large-diameter, dug or bored wells are the predominant well type and no well-defined significant aquifer system is present within 50 feet of land surface. The other four areas contain predominantly small-diameter, drilled or driven wells.

For each study area, all available topographic, geologic, and soil survey maps were used to create a database on the Geographic Information System (GIS). Selected cultural, topographic, geologic, hydrologic, and soil survey information was digitized and used to provide the data for various base maps produced using the GIS. The location of each water well in each study area was verified, and the available drillers' logs for each well were interpreted. For each area, a number of maps was produced, including a stack-unit map to a depth of 50 feet, and bedrock

topography, drift thickness, parent materials/soils, and terrane maps. Because some of these maps are quite similar to one another, not all individual maps are presented for each area. In some cases, a single map could convey the necessary information for a given study area. Such streamlining to eliminate redundancy was desirable because one of the objectives of the pilot study was to evaluate the economic feasibility of a statewide survey.

The land use, agricultural, geologic, and hydrologic maps produced for the pilot study serve dual purposes. First, the process of producing them provided the researchers the opportunity to assess the quality and quantity of the database. Because the pilot study areas are generally representative of the status of the statewide database, knowledge of problems arising during this stage of the project will aid in the evaluation of the economic feasibility of the recommended statewide survey. Second, these maps are important in interpreting the chemical and statistical results presented in the companion document (Schock et al. 1992), which presents the sampling protocols and statistical analyses of the chemical data and summarizes the results of the pilot study.

Because the characterization part of the pilot study was designed to test procedures and methodologies that would be applied in a statewide survey, emphasis was placed on using all available databases (e.g., soil, stratigraphic, geographic, topographic, and hydrologic). No additional fieldwork was conducted other than the actual water sampling and selected trips to identify industrial, commercial, and agricultural activities, and to interview residents. Existing drinking-water wells were used for sampling. This design required interpretation of the existing geologic database, which consists of drill logs from private, municipal, and commercial water wells; drill logs from coal and gas borings; drill logs from highway and bridge borings; and reports, maps, and unpublished data housed at the ISGS and the ISWS. Additional information was obtained from the county soil reports of the U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS).

Because the selection of the five study areas was made on the basis of their hydrogeologic classification and not the amount of information currently available, the quality and quantity of data varied considerably. Some of the study areas (Mason and Kankakee) are within or near the boundaries of recently completed research projects and, therefore, more information was available concerning the hydrogeologic characteristics of the area. Conversely, considerably less geologic and hydrologic information was available for the Livingston and Effingham County study areas, and the data that are available are either dated or presented on very small-scale maps.

An additional problem was caused by the different map scales used in the original sources. Source map scales ranged from the large-scale, 1:15,840-scale soil survey maps (where 1 inch equals 0.25 miles) to the small-scale, 1.250,000 state stack-unit map (where 1 inch equals 4 miles). The pilot study used 1:24,000-scale topographic maps for preliminary geologic mapping, whereas the GIS maps presented in this report range in scale from about 1:62,000 to 1:100,000. Map detail and readability are concerns because the level of detail that can be presented is directly related to map scale (larger scale maps show more detail than smaller scale maps). Because small-scale maps require more data generalization than large-scale maps of the same area, less information can be shown. The physical size of the map also controls its use because it affects scale and readability. With few exceptions, all of the working maps produced for this project were at scales larger than the final published version.

Although in some cases considerable detail was generalized for the final map, all five study areas exhibited a need for additional, accurate geologic information. The most common problem encountered was the lack of detailed, verifiable, drill logs for water wells in the study area. Often, the verifiable wells were either clustered in a small area or lacked the information necessary for a detailed geologic interpretation of the sediments.

Overall, the problems encountered in the characterization part of the pilot study appear to be representative of the problems that would be encountered in a statewide survey. For some study areas, there was a lack of information that would have allowed a more detailed hydrogeologic interpretation. Extrapolating from the ISGS regional glacial stratigraphic framework into areas lacking detailed geologic information assisted in identifying the geologic units present and their hydrogeologic characteristics. The accuracy and detail of the extrapolation is obviously related to the level of detail of the previous research, but sufficient information appears to be available in the current geologic database to allow for regional geologic mapping and interpretation of the geologic sediments and the potential for contamination of groundwater resources by agricultural chemicals. Due to the variability in the quality and quantity of geologic data, however, some areas selected for the recommended statewide survey may require interpretations that are based on marginal data and are, therefore, more likely to be in error. Because geologic complexity varies across Illinois, data with similar quality, quantity, and spatial density may be adequate in some areas and not in others. Neither the pilot study nor the proposed statewide survey will replace the need for detailed, site-specific studies.

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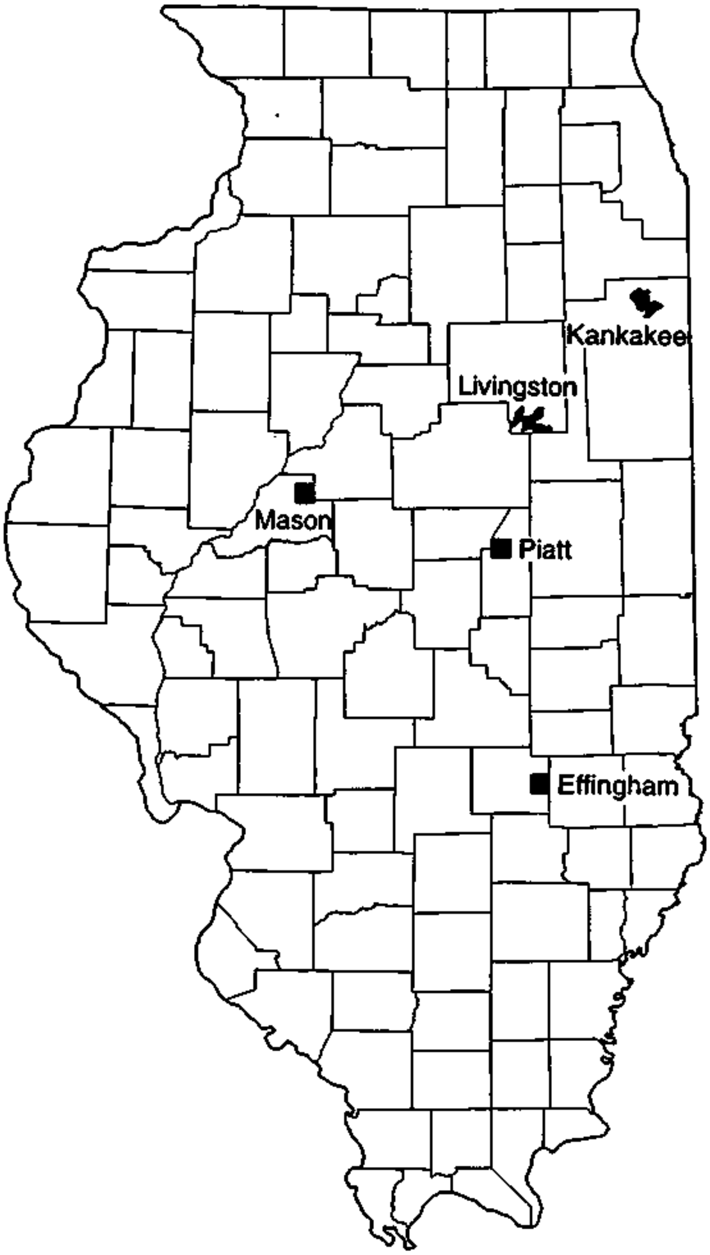

Figure 1.1 Location of study areas.

1 INTRODUCTION

E. Mehnert and M. L. Bamhardt

The Illinois Groundwater Protection Act of 1987 (PA 85-863) mandated that an evaluation of the impact of pesticides on groundwater. Because pesticide use is widespread in rural areas and groundwater is the major source of drinking water in rural areas, the Illinois State Geological Survey (ISGS) and the Illinois State Water Survey (ISWS) developed recommendations for a statewide survey of agricultural chemicals in rural, private water wells in Illinois (McKenna et al. 1989).

This pilot study was a cooperative effort of the ISGS and the ISWS, with assistance from the Illinois Department of Agriculture (IDOA). The purpose of the study is to examine the significant aspects of the proposed statewide survey (McKenna et al. 1989). For this study, agricultural chemical was defined as pesticides (e.g., herbicide, insecticide, fungicide, and nematocide) and nitrogen fertilizer.

The impact of agricultural chemicals applied at the surface on groundwater resources is directly related to several factors. These factors include the hydraulic properties of the soils and underlying geologic materials, attenuation capacity of the soils and geologic materials, terrane characteristics, depth below land surface of the shallowest aquifer, rate and direction of water movement through the materials surrounding the aquifer, and surface leakage into the aquifer by way of abandoned wells and improperly sealed or constructed wells.

A major goal of the pilot study and the specific purpose of this report was to characterize the land use, agricultural practices, hydrology, and geology of the five study areas, located in Effingham, Kankakee, Livingston, Mason, and Piatt Counties (fig. 1.1). Data and data summaries developed during the characterization process served two functions. The characterization process provided information necessary to analyze the occurrence of agricultural chemicals in wells from the study areas. Also, it allowed the geologists characterizing the areas to evaluate the availability and quality of existing data and to develop an economical characterization methodology to be used for the proposed statewide survey.

Because of the volume of material generated during the characterization of the study areas, this characterization portion of the pilot study is being published as a separate report. Details regarding the design, analysis, and results of the pilot study are discussed in a companion report, *Pilot Study: Agricultural Chemicals in Rural, Private Wells in Illinois* (Schock et al. 1992). Both documents should be reviewed to fully understand the pilot study.

The study areas range in size from 35 to 49 square miles. The areas in Kankakee, Livingston, Mason, and Piatt counties represent four distinct hydrogeologic categories in Illinois. McKenna et al. (1989) interpreted the stack-unit map of Illinois (Berg and Kempton 1988) to define the depth to the uppermost aquifer material and divided the state into four categories on the basis of this parameter. These four categories are (1) aquifer material within 5 feet of land surface (Mason County study area), (2) aquifer material between 5 and 20 feet of land surface (Kankakee County study area), (3) aquifer material between 20 and 50 feet of land surface (Livingston County study area), and (4) no aquifer material within 50 feet of land surface (Piatt and Effingham County study areas).

The Effingham County study area is similar to Piatt County with respect to depth to the uppermost aquifer material; however, the two areas may be differentiated by the predominant type of well. The predominant well type in Piatt, Kankakee, Livingston, and Mason Counties is a small-diameter, drilled or driven well. The predominant well type in Effingham County is the large-diameter, dug or bored well. In Effingham County, these large-diameter wells derive water from non-aquifer materials such as fractures in till or small sand lenses or seams.

Data used in the characterization process were obtained from available records, including ISGS and ISWS publications, maps, open-file reports, and computer databases. Because it would be prohibitively expensive to conduct field investigations for the proposed statewide survey with its broader geographical scope, only limited field investigations were conducted in the pilot study. The only fieldwork conducted was the initial reconnaissance to locate and classify households and commercial and industrial facilities, as well as an interview with 48 randomly selected residents to obtain detailed information regarding land use around the wellhead.

Several types of maps are presented in this report. A Geographic Information System (GIS) was used to produce maps depicting various cultural, economic, and physical databases. Soil survey maps were digitized, and the resulting database of soil survey information was used to produce maps of soil types and geologic materials. The information on these maps was then combined with additional subsurface geologic data to create stack-unit maps. It was also combined with topographic information to produce terrane maps. Although each of the five sections of this report on the individual study areas presents several of these maps, all types of maps are not included for each study area because the parent material, stack-unit, and terrane maps are occasionally similar. In such cases, only the map(s) providing unique information are presented.

2 METHODOLOGY

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LAND USE

Land use was characterized across each study area and, in greater detail, around the sampled wells to identify potential sources of and pathways for groundwater contamination. Land use directly determines the type of chemicals that might be used and, consequently, the possible sources of groundwater contamination.

Data Sources

The ISGS and ISWS are repositories for geologic and hydrologic data, respectively. Data from published or unpublished reports, maps, and articles were combined with information derived from two interviews with owners and/or users of study area wells. (For convenience, the term "well user" will be used in place of "well owner and/or user" in this report.) Field trips to the study areas were conducted to locate and identify commercial and industrial facilities and large-scale, animal-housing operations, and to locate and classify rural residences as either farmed or nonfarmed. Roads, railroads, towns, forested areas, pipelines, quarries, churches, and cemeteries were delineated on the most recent topographic maps. Some of these areas were field checked during well-sampling trips.

An initial interview with well users in the study area provided information concerning well type, dwelling type (farm versus nonfarm), method of well construction, and siting of the well. This interview and field reconnaissance also provided information on the number of households, information necessary to estimate the population of each study area for water-consumption calculations. A second, more detailed questionnaire was employed to obtain additional information from 48 randomly selected well users in each study area. Information gathered included data on pesticide use and livestock operations. In particular, data were gathered regarding topographic setting of the well, location of any septic tanks or animal-housing facilities near the well, ground cover within a 50-foot radius of the well, and manure and pesticide use in fields adjacent to the well.

Potential sources of groundwater contamination were located from field inspections made during the course of the project. The potential sources mapped included large industries, commercial operations, animal-housing facilities, and irrigation wells. Irrigation wells are present in only two of the study areas. Some farmers use irrigation systems to supply fertilizer to the crops. In Mason County, where irrigation is widespread, a selected number of the irrigation wells mapped by Rockford Map Publishers, Inc. (Winnebago County, IL) were field checked. In Kankakee County, the irrigated areas were mapped by study personnel.

HYDROLOGY

Hydrology, as applied in this study, comprises the surface water and the (subsurface) groundwater as they are linked through the local geology. The surface water component includes precipitation, runoff, infiltration, and temperature. Intensity and duration of precipitation, local topography, antecedent soil moisture, season, and hydraulic properties of the near-surface materials affect the proportion of precipitation that runs off the land surface or enters the soil. Temperature and wind speed are key components in evapotranspiration, which greatly influences the volume of water in the soil profile. The subsurface component of hydrology deals mainly with the movement of groundwater through the geologic materials. Groundwater moves from recharge areas to discharge areas through local, intermediate, and regional flow systems. The fate of any agricultural chemicals in groundwater is tied to which flow system it enters.

Interpretation of the potential for agricultural chemicals to migrate from the land surface to groundwater is enhanced when land-use information is examined with respect to the surface and subsurface hydrology.

Data Sources

Topographic relief and general slope directions and gradients were determined from topographic maps. The gradient, width, and depth of creeks and drainage ditches in selected areas were obtained from published reports (Herndon and Rogers 1972, Lockart 1969). Climatic records for stations in close proximity to the study areas were available from the ISWS Midwestern Climate Center.

Published reports and drillers' logs of wells were used to describe geologic formations. The hydraulic properties of aquifers and pumpage information were obtained from published pump-test results, the aquifer properties database files, and other records of the Water Inventory Program at the ISWS. However, no specific field effort was undertaken to determine the hydraulic properties for any of the study areas. Water-level data were obtained from other recently conducted field studies and the records from the Water Inventory Program.

Groundwater Recharge Estimates

The rates of groundwater recharge in the study areas were obtained from published and unpublished reports of the ISWS. Various methods were used for calculating recharge.

In Mason County, the rate of recharge was determined using flow-net analysis. In this method, the net increase in the quantity of water flowing through a flow tube is estimated to be equivalent to the recharge on the land surface directly above (Walker et al. 1965).

The rate of recharge for the Kankakee County study area was determined using the value calculated by Cravens et al. (1990) for their 414-square-mile study area, southeast of the study area. To calculate the rate of recharge to the Silurian dolomite aquifer, they used a flow-net analysis of the potentiometric surface map in spring 1987 and a diversion-area analysis for groundwater use in 1987 and 1988.

The rate of recharge for the Livingston County study area was estimated using the data of Visocky and Schicht (1969) and Walton (1965). They considered groundwater recharge to be the sum of groundwater evapotranspiration, subsurface underflow, and groundwater runoff plus (or minus) the change in storage. Groundwater runoff is defined as the portion of precipitation that infiltrates the soil or water table and then percolates into the stream channels (Walton 1965). A portion of the groundwater recharge flows to the deeper aquifer; the amount depends on the permeability of the confining units and head differential between the shallow and deep aquifer.

For the Piatt County study area, the recharge calculation for the Goose Creek watershed around DeLand, Illinois, was used (Schicht and Walton 1961). A major portion of the Piatt County study area was covered by their study. They used a complete groundwater budget from January 1955 to September 1958 to calculate recharge, but the rate of recharge calculated in their study was for the shallow system (source beds) and not for the deeper aquifers. The rate of recharge for the deeper aquifer would be considerably smaller.

No groundwater runoff or recharge studies have been conducted for the Effingham County study area. However, Walton (1965) estimated the groundwater runoff for the nearby Little Wabash and Embarras River basins, and Walton and Csallany (1965) assessed the yield of the aquifers in the Embarras River basin.

Groundwater Use Calculations

Rates of groundwater use for irrigation were compiled from recently completed studies in Mason-Tazewell (Bowman et al. 1991) and Kankakee-Iroquois Counties (Cravens et al. 1990). Water withdrawal for public water supplies was obtained from the records of the Water Inventory Program of the ISWS.

On-farm and domestic-water use were estimated using the 1986 water withdrawal records of Illinois (Kirk 1987). Specifically, each household was estimated to have 3.5 residents, each using 70 gallons of water per day. Daily livestock demand for cattle and hogs was estimated at 35 gallons and 4 gallons per head, respectively (Kirk 1987). Livestock numbers were estimated from the township agricultural statistics (IDOA 1979) and the most recent county summaries (IDOA 1989) because township agricultural statistics have not been available since 1979.

AGRICULTURAL PRACTICES

Several recent studies have evaluated the effects of agricultural practices on groundwater quality (McKenna et al. 1990, Brach 1989, University of Wisconsin 1989). Pesticide selection and application (rates, timing, and methods), tillage practices, and crop rotations are among the agricultural practices affecting the potential for groundwater contamination from pesticides and nitrate. In addition, water-management practices, including irrigation, drainage, and conservation measures, can affect soil properties, water infiltration, and runoff. Consequently, these practices can affect the movement of pesticides and nitrate into and through the soil. Management practices of livestock and their waste can influence the potential for groundwater contamination by nitrate, as can management of human waste.

Data Sources

Data were obtained from interviews with users of the sampled wells about the nature of agricultural activity within a 500-foot radius of the wellhead. In addition, agricultural practices in the five study areas were examined and similarities and variations among the practices were noted. Data were also collected from interviews and written communications with county U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS) agricultural agents, IDOA agricultural statistics and annual farm census data, field observations, and published literature, especially University of Illinois Agricultural Experiment Station bulletins and circulars.

GEOLOGY AND HYDROGEOLOGY

Characterizing geologic materials by hydrogeologic, engineering, and other properties is important when addressing land-use questions and potential groundwater contamination. Once the nature and extent of the geologic deposits are known, a variety of models can be applied to address the specific research questions of the project. Several data sources are available. A variety of data display and handling techniques can be used, depending on the project goals.

A measure of caution must be taken when using any small-scale map or graphic generated from these sources because data sources often consist of borehole logs of variable detail and quality, previously prepared maps of different scales, and documents produced for projects with different research objectives. The spatial continuity and quality of data may inhibit various interpretations. The users of maps produced from these sources must be aware of these limitations.

Data Sources

The vertical and horizontal distribution of geologic materials in the five study areas is presented in a series of figures and maps, including the parent material, stack-unit, and terrane maps. The geologic complexity of the study areas ranges from rather simple for the Mason County study area to increasingly more complex for the study areas of Piatt, Kankakee, Livingston, and Effingham Counties, respectively. The complexity is a function of variability in depth to bedrock, drift thickness, geologic-material sequence, slope, and hydrogeologic characteristics of materials.

Drill logs For each study area, all available well logs for private water wells were obtained from the Geologic Records Unit of the ISGS and Groundwater Information Office of the ISWS. Also included were logs for structural tests (gas and oil), bridge and highway cores, municipal water wells, and irrigation wells. The location of each well was verified by checking the name on the well log against that in the county plat books and/or a house or farm building at the location given. It was then plotted on 1:24,000- or 1:62,500-scale U.S. Geological Survey (USGS) topographic maps. Selected well logs were used to construct cross sections and verify the stratigraphic column for each area. A buffer zone 3 miles wide was mapped around each study area in order to place the study area into a broader, more regional framework; however, only the study areas are presented on the final maps.

The capability of a map or diagram to accurately portray the surface and subsurface geology is directly related to the detail available in the database from which the information is compiled. It may be very difficult, if not impossible, to confidently separate geologic units using only well log description data in areas where multiple deposits with similar physical characteristics occur in the vertical sequence. If laboratory data and descriptions of core samples by trained geologists are available, the stratigraphy can be delineated with greater ease; geologic materials with contrasting physical characteristics are easier to identify and differentiate in well log records, and a greater degree of confidence in vertical and horizontal correlation with other well logs in the area is possible. A common problem associated with well log data is that the available wells are often not located in the most advantageous positions relative to the problem under investigation. In addition, the irregular spacing of wells and the level of detail provided by the driller in the well log report introduce a degree of inconsistency that affects the interpretation.

Soil survey reports Modern soil survey reports are available for most counties in Illinois. They contain a great deal of information on land use, crop productivity, drainage, engineering, and soil characterization. Large-scale, air-photo base maps (scale 1:15,840) present the distribution of soil map units from which information such as parent material, hydrologic class, erosion class, slope, texture, organic content, infiltration data, engineering limitations, and chemical properties can be interpreted. Of the five study areas, only Kankakee County had a published soil survey report. Soil mapping has been completed, however, in Mason, Effingham, Livingston, and Piatt Counties and prepublication soil maps were available (SCS, in press a, b, c, d). Soil survey reports from neighboring counties with similar soils were also available.

Geographic Information System and Map Production

A GIS is a computer-based system designed for the storage, manipulation, retrieval, and portrayal of geographic data. Features are digitized into a computer database as locational data that identify regions, points, or lines in terms of x and y coordinates. Features are also digitized as descriptive data that identify the characteristics of an item. For example, a well location might be stored as having the coordinate "2,4," and descriptive characteristics, such as "irrigation well," "95" feet deep, with an "8" inch casing. A soil location might have descriptive characteristics, such as soil map unit name, slope class, hydrologic group, runoff loss, and other soil properties. In this study, the particular GIS software package employed was ARC/INFO running on a minicomputer. (Please note that the use of trade names is for the purpose of description only and does not imply endorsement by either the ISWS or ISGS.)

Map scale A definition of large-scale and small-scale maps is necessary here to delineate between the technical, cartographic meaning and the colloquial usage. Map scale refers to the ratio of geographic space (land) that is represented by a unit of map space. For example, a large-scale map is one that depicts a small geographic area such as a soil map with a scale of 1:15,840. A small-scale map would depict the same geographic area in less map space so that the area would be smaller in size on the map and less readable. A map with a scale of 1:62,500 depicts about 1 mile of geographic distance in 1 inch of map distance, and a map with a scale of 1:15,840 depicts only about 0.25 mile of geographic distance in 1 inch of map distance. Therefore, large-scale maps are able to show more detail because they allocate more map space for a given unit of geographic space.

Location, sources of potential contamination, and drainage maps Locations of features such as towns, cemeteries, roads, railroads, pipelines, and surface drainage features (streams, ditches, and ponds) were digitized directly from USGS topographic maps (scale 1:24,000), whereas the locations of livestock areas and agricultural-chemical facilities were added to the database after field checking. The resulting surface drainage and potential sources of contamination maps were used to interpret the laboratory and statistical results presented in Schock et al. (1992).

Parent material/soils map Soil maps, due to their scale, are usually the most precise representation available of surface geologic materials. They are good base maps from which to construct parent material and stack-unit maps. Individual map sheets in the county reports (scale 1:15,840) were first photo-reduced to a scale of 1:24,000 to match the topographic map scale and then digitized for entry into the GIS database from which the various project maps were generated. Soil maps for each study area were used initially to identify the soil and parent materials (geologic materials). However, the proportion of each study area that is covered by each soil map unit, parent material group, stack-unit, or terrane unit was calculated by the GIS.

The individual soil map units were initially grouped according to their geologic parent materials. This procedure produced a surficial geologic map for each study area in which sequences of materials to a depth of 5 feet (the depth of soil mapping) were depicted. This map has fewer classes or groups than the soil map because several soil types are often developed in the same parent material; soil types are differentiated on the basis of drainage class or some other subordinate characteristic in the soil profile. Because a soil survey examines the sediment to a depth of approximately 5 feet, the parent material map represents an interpretation of both the lateral and vertical changes in geologic materials.

Various logs for structural test wells and foundation borings and other available stratigraphic information were used to identify the sequence of geologic materials (i.e., construct a stack-unit map) to the project mapping depth of 50 feet, following the method of Kempton (1981) and Berg and Kempton (1988). However, these wells were often not located in optimal positions or easily verified within the five pilot study areas. Consequently, the amount of reliable information was occasionally at a minimum, and the geologist was left to interpret the stratigraphy between' widely spaced datum points. For this reason, geologic maps for this project (e.g., the stack-unit map) retain the original soil map unit configurations.

Stack-unit map By integrating the soil-geologic map with the sequence of geologic materials to a depth of 50 feet, a stack-unit map is produced that represents the vertical sequences of sediment to that depth across the study area. This map can be much more complex than the parent material map because the sequence and thickness of unlithified deposits and the nature of the bedrock surface can change rapidly from place to place. The more complex the geologic history of a site has been, the more complex the stack-unit map may be. For example, in the northern part of the Kankakee County study area, near the moraine, the presence of till, outwash, lacustrine sediments, alluvial and colluvial deposits, and windblown sand and silt over an wavy bedrock surface creates numerous combinations of materials that must be represented on the stack-unit map. Other areas, such as Mason and Piatt Counties, exhibit basically the same sediments to depths exceeding 50 feet, so the map shows less complexity. The quantity and quality of available data, however, influences the confidence of the interpretation; for example, generalizing a large amount of data is very different from depicting a small amount of data. The complexity of the map, however, is not directly related to that area's susceptibility to contamination by agricultural chemicals. Complexity does suggest that extra caution should be exercised when using agricultural chemicals because the different units within each stack unit could have varying capacities to accept, transmit, restrict, or remove contaminants in the groundwater (Berg and Kempton 1988).

Terrane map Topographic and landscape information can be added to the stack-unit map to produce a terrane map (Kempton 1981). Kempton and Cartwright (1984) defined terranes as specific physiographic features underlain by a predictable sequence of geologic materials having both topographic and lithologic predictability. This map is generally less complex than the stack-unit map because variables such as slope, landscape position (e.g., upland or lowland), and other landscape characteristics are commonly continuous over fairly large areas. As such, they generally homogenize and simplify the map. A terrane map can provide additional insight to potential problem areas because it combines slope and landscape factors. In some cases, however, the terrane map cannot provide depth information and the stack-unit map or parent material map is more useful for identifying areas with high risk of contamination. For some study areas, unpublished maps or work maps constructed for previous publications were available and used in the development of the stack-unit and terrane maps (Lineback 1979, Berg and Kempton 1988).

Bedrock topography and drift thickness maps A contour map depicting the depth to bedrock can be constructed when a sufficient number of boreholes in an area penetrate to the top of the bedrock. A drift thickness map can be developed by subtracting the elevation of the bedrock surface from the elevation of the ground surface. Bedrock topography and drift thickness maps often mirror each other because deep bedrock valleys are commonly filled with thick sequences of unlithified sediments. These maps are crucial for interpreting the potential for aquifer recharge and contamination, understanding groundwater movement, and helping to delineate the boundary conditions of a potential aquifer.

Limitations of Data

It must be emphasized that no fieldwork on geologic characterization specific to this project was conducted, and that all interpretations were made on the basis of analysis of published and unpublished data. Ideally, additional boreholes should be drilled and fieldwork designed to provide detailed subsurface data should be conducted. A need for additional information is demonstrated in each of the five study areas. Because of the scope and purpose of this pilot study, however, all interpretations and analyses in the pilot study were based on current databases. A statewide survey would experience a similar situation. It must also be emphasized that small-scale maps are more generalized than large-scale maps, and they should not be used to make individual, site-specific interpretations. The purpose of these maps is to provide information and interpretations that are as detailed as possible, given the limitations of the data set and the scale of the map. Individuals should use them only as guides or indicators of potential problems; they do not replace the need for site-specific investigations.

3 CHARACTERIZATION OVERVIEW

M. L. Barnhardt, C. Ray, and W. S. Dey

INTRODUCTION

This section presents an overview of the study area characteristics for land use, hydrology, agricultural practices, and geology. The five areas were selected on the basis of their potential for contamination of shallow aquifers from agricultural chemicals. The study areas were chosen such that the depth from the land surface to the uppermost aquifer material varied between each area (McKenna et al. 1989). Specifically, the depth to the aquifer material is less than 5 feet in the Mason County study area, between 5 and 20 feet in the Kankakee County area, between 20 and 50 feet in the Livingston County area, and more than 50 feet in the Piatt County area. The Effingham County study area also has no significant aquifer material within the uppermost 50 feet, but it was chosen to represent an area in which large-diameter dug and bored wells are the predominant well type. Drilled wells predominate in the other four study areas.

For this study, aquifer materials are distinguished from aquifers in that aquifer materials may not be saturated, even though they have the hydrogeologic characteristics to be classified as aquifers (McKenna et al. 1989). The water table in Illinois generally occurs 5 to 15 feet below the ground surface. Below this depth, aquifer materials are generally saturated, but these materials may not be saturated in areas mapped as having aquifer materials within 5 feet of ground surface. Highly permeable materials such as sands, gravels, fractured carbonate rocks, and sandstones generally allow rapid migration of contaminants. Less permeable materials such as loess, diamicton (glacial till), shale, cemented sandstone, and unfractured carbonate rocks generally restrict contaminant migration. Because the movement of agricultural chemicals would not be significantly restricted by highly permeable materials, areas having these materials were interpreted to have a high potential for contamination. Sand and gravel greater than 5 feet thick, sandstone greater than 10 feet thick, and fractured carbonates greater than 20 feet thick are considered to be aquifer materials (McKenna et al. 1989).

LAND USE

The five study areas are rural areas with urban populations less than 2,500. They contain no individual nonrural or forested area larger than 1 square mile (McKenna et al. 1989). Rural areas with community water supplies were excluded. Selected areas met the criteria of well density (2 wells/sq mi) and percentage of dug wells (not exceeding 33%, except in Effingham County). In addition, corn and soybeans are the predominant crops grown in these areas (table 3.1). The irregular boundaries of the Kankakee, Livingston, and Piatt study areas are the result of using the above criteria, in addition to depth to the uppermost aquifer in the area.

The sandy soils of Mason County are extensively irrigated (table 3.1). Approximately 11,000 acres are currently under irrigation in the study area, and expansion is underway. Specialty vegetables, seed corn, and popcorn are the major irrigated crops. The Kankakee County study area has approximately 1,000 acres of irrigated land in vegetable crops and turf grass. No irrigation occurs in the study areas in Livingston, Piatt, and Effingham Counties.

Study area selection criteria generally precluded locations with significant industrial and commercial operations. However, a substantial number of such activities occur in areas adjoining the Kankakee County study area, and a large agricultural-chemical facility is located 1 mile north of the Mason County study area. Other study areas have small agricultural-chemical facilities to serve the needs of the farmers. Some industrial and commercial activity occurs on the northern edge of the Livingston County study area in the towns of Fairbury and Forrest.

Table 3.1 Major crops harvested and chemical treatments by county.

	Mason	Kankakee	Livingston	Piatt	Effingham
Number of farms	581	1,086	1,760	604	1,228
Avg. farm size (acres)	517	358	368	453	210
Total acres harvested	223,222	304,175	511,868	214,577	186,170[a]
Com	90,236	151,488	224,823	98,964	67,460
Soybeans	97,028	135,383	277,466	112,477	88,056
Wheat	17,295	4,061	1,567	899	19,476
Hay	4,203	4,014	6,909	1,692	13,073
Vegetables	3,132	3,423	—	—	0
% Cultivated acres in com and soybeans	83.9	94.3	98.1	98.5	83.5
Irrigation (acres)	59,962	7,822	635	111	98
% Cultivated acreage receiving chemical treatment					
Fertilizer	72.6	76.1	62.5	58.4	86.3
Herbicide	78.7	73.6	87.0	76.9	64.5
Insecticide	23.2	22.1	11.5	10.1	23.4
Nematocide	2.7	0.6	0.9	0.9	0.6

[a] Double cropping of soybeans and hay is common; this may cause total acres harvested to be less than sum of crops harvested.
Source: U.S. Dept. of Commerce, 1987 Census of Agriculture (1987)

Table 3.2 Mean monthly temperature and precipitation for the study areas.

	Mason		Kankakee		Livingston		Piatt		Effingham	
Month	Temp (° F)	Precip. (in.)	Temp (° F)	Precip. (in.)	Temp (° F)	Precip. (in.)	Temp (° F)	Precip. (in.)	Temp (° F)	Precip. (in.)
Jan.	23.6	1.32	20.5	1.50	22.2	0.86	23.1	1.79	26.2	1.97
Feb.	28.1	1.31	24.8	1.52	27.2	1.29	27.8	1.71	30.5	2.23
Mar.	41.1	2.79	38.1	2.85	38.7	2.95	39.9	3.11	**41.8**	3.74
April	53.7	3.29	49.9	3.77	52.2	2.99	52.5	3.81	54.5	3.52
May	64.0	3.77	61.0	4.58	62.8	3.57	63.2	3.82	63.8	3.93
June	72.7	3.24	70.7	4.29	72.0	3.17	72.0	3.64	72.9	4.15
July	76.1	3.52	75.1	3.95	75.4	3.13	75.2	4.65	76.8	4.08
Aug.	73.6	3.39	72.6	3.31	73.2	3.16	72.8	4.21	74.7	2.67
Sept.	66.9	3.36	65.1	3.42	66.8	3.13	66.3	3.49	68.0	3.07
Oct.	55.4	2.82	52.3	2.45	54.9	2.80	54.9	2.68	55.9	2.68
Nov.	42.3	2.64	40.9	3.27	42.2	3.66	42.1	3.17	44.0	3.55
Dec.	29.4	2.54	27.3	2.62	28.0	2.56	29.5	3.08	31.6	3.40
Year (mean)	52.2		49.9		51.3		51.6		53.4	
Year (total)		34.01		37.54		33.26		39.17		38.99

Source: Midwestern Climate Center, Illinois State Water Survey, Champaign, IL, 1960-1989.
Stations used:

Mason:	Mason City 1 NW (precip. and temp.)
Kankakee:	Kankakee (precip. and temp.)
Livingston:	Fairbury (precip.) and Pontiac (temp.)
Piatt:	Monticello No. 2 (precip.) and Farmer City (temp.)
Effingham:	Effingham (precip. and temp.)

Each study area also has small- to medium-scale cattle and hog operations, and the Livingston County study area has several large, commercial poultry operations.

Surface Water Hydrology

General topography in the study areas ranges from nearly flat in Mason and Kankakee Counties to somewhat undulating in Effingham County to rolling in Livingston County. Surface drainage in Mason County is mostly through manmade drainage ditches; natural channels predominate in the Piatt and Effingham Counties. Streams in certain areas of the Kankakee and Livingston study areas appear to have been straightened to facilitate drainage. Drainage density is high in Effingham County because of less permeable soils and more topographic relief than in the other study areas. It is very low in Mason County because of the predominance of coarse-textured sediments and minimal topographic relief.

Climate

A review of the climatic data in table 3.2 indicates that the range in temperature and precipitation between the five study areas is minimal. The difference in mean annual temperature between Effingham and Kankakee, the most southern and northern areas, respectively, is only 3.5° F. The major difference occurs during the winter. In general, the late spring and summer months are the wettest because of the predominance of moist, tropical air masses. January and February are the driest months in each of the study areas.

AGRICULTURAL PRACTICES

The selection criteria for areas sampled in the pilot study assured a certain amount of homogeneity of agricultural practices. The pilot study was conducted throughout the corn- and soybean-producing areas of Illinois, as shown by farm income (table 3.3) and percentage of harvested acres in corn and soybeans (table 3.1). The fertile soil and humid, temperate climate of Illinois are particularly conducive to the production of high-yield corn and soybeans. Interviews with farmers and county agricultural extension agents indicate that most farmers rotate between corn and soybeans, use some form of tillage (rather than no-tillage), and apply 100 to 200 lbs/acre of nitrogen fertilizer on com (as well as phosphorus and potash). Farmers in the study areas typically use chemical and mechanical weed control on corn and soybeans and occasionally use chemical control of insects, more commonly on corn (table 3.1). Pesticides are purchased in premixed containers or custom applied, but 33% to 78% of farmers in the study areas mix their own chemicals (table 3.4). Corn and soybean yields average from 110 to 170 and 35 to 42 bushels per acre, respectively, across all five areas.

Agroclimatic and General Soil Conditions

With the exception of Effingham County, the study areas are located within a narrow latitudinal range that produces similar climatic conditions and timing for planting and harvesting. The average number of growing degree days ranges between 2,950 and 3,100 for May 1 through September 30 (Anderson et al. 1987). Each study area has several small livestock operations, but the main emphasis of agriculture is corn and soybean production (tables 3.1 and 3.3).

In the Effingham County study area, the percentage of farms with livestock and small-grain production is greater than the other four areas (tables 3.1 and 3.3) and more closely approximates its countywide average. The Effingham County study area is about 100 miles south of the other four sites; it averages 3,250 growing degree days and double cropping is more common, particularly with small grains and soybeans. The soils in this study area are almost exclusively light-colored (low organic content) forest soils (Alfisols), as opposed to the other four study areas, which have predominantly dark-colored (high organic content) prairie soils (Mollisols). Low permeability subsurface horizons in the Alfisols preclude the use of tile drainage in Effingham County, but farmers in the northern four study areas use tiles to some extent to control excess soil water.

Table 3.3 Comparison of livestock operations on countywide and study area basis.

	Mason		Kankakee		Livingston		Piatt		Effingham	
	County	Study	County	Study	County	Study	County	Study	County	Study
Number of farms	581	21	1,086	20	1,760	40	604	21	1,228	27
with cattle	146	10	194	1	312	12	92	6	537	10
avg. no. cattle	54	50	47	—[a]	42	115	42	47	46	74
% with cattle''	25	48	18	5	18	30	15	29	44	37
with hogs	91	4	113	0	225	12	30	2	165	10
avg. no. hogs	248	44	213	0	498	606	685	7	215	700
% with hogs	16	19	10	0	13	30	5	10	13	37
with poultry	25	9	44	2	43	3	4	2	27	1
avg. no. poultry	59	46		10	5,127	4,077	39	40		4
% with poultry	4	43	4	10	2	8	1	10	2	4
with sheep or horses	43	4	112	4	146	3	52	5	180	3
% with sheep or horses	7		9		9		9		13	
% with any livestock[b]	25-52	38	18-41	30	18-42	65	15-30	52	44-72	70
Source of farm receipts for agricultural products										
Total value[c]	51.1	—	93.7	—	139.8	—	63.0	—	61.4	—
% from livestock[d]	16.0	—	14.1	—	24.5	—	8.9	—	50.8	—
% from crops[e]	84.0	—	85.9	—	75.5	—	91.1	—	49.2	—

Sources: Countywide data from U.S. Department of Commerce, 1987 Census of Agriculture (1987); study area data from interviews (1989).

[a] —denotes data withheld or not collected.

[b] The range gives the minimum and maximum possible distribution of livestock on farms. The smaller number assumes that any farm with livestock has cattle and some other type of livestock; thus, the percentage of farms with cattle equals the minimum distribution. The larger number assumes no farm has more than one type of livestock; thus, the percentages of each type of livestock are summed to yield the maximum distribution.

[c] Market value of agricultural products sold (millions).

[d] Livestock, poultry, and their products.

[e] All crops, including nursery and greenhouse crops.

Table 3.4 Classification of study area well users.

	Mason	Kankakee	Livingston	Piatt	Effingham
Number of households interviewed	48	48	48	48	48
Active farms	15	18	32	14	25
Farm residences	6	2	8	7	2
Non-farm residences	27	26	8	27	18
Unclassified	0	2	0	0	3
Number of farms with livestock currently	8	6	26	11	19
Number of farms with livestock in past[a]	6	26	15	21	8
Manure use[b]	8	12	22	5	15
% Farmers mixing chemicals	33	78	47	36	39

Source: Compiled from interviews with randomly selected well users in the study areas.
[a] Number of households that formerly had livestock, but not at present.
[b] Number of households that have manure spread within 500 feet of wellhead.

Tillage and Conservation Practices

Interviews with farmers in the five study areas indicate that most corn acreage in the four northern areas is treated with conventional tillage. Less than 10% of corn acreage is treated with no-till, but soybeans are predominantly no-till or chisel plowed. Ridge tilling has limited application in the northern areas, but is more common in Effingham County, where it is applied to an estimated 10% to 15% of corn and soybean acreage. Chisel plowing is the primary tilling method in the Effingham County study area, where no-till accounts for less than 2% of all acreage.

Dredged and channelized streams are evident in the four northern study areas, but incised streams dominate surface hydrology in Effingham County. Grassed waterways are in use in all five areas. Conservation terraces were observed only in Piatt and Livingston Counties and only in very small areas.

Unique Characteristics of the Study Areas

The predominantly sandy soils of Mason County are ideally suited to irrigation. Interviews with county agricultural extension agents revealed that only an estimated 10% of cultivated acres in Mason County is tile drained because sandy soils in this area are naturally well drained. Kankakee County ranks a distant second in irrigation (table 3.1). Some agricultural chemicals are applied through irrigation systems, a process known as chemigation. Fertilizers, insecticides, herbicides, fungicides, and nematocides can all be applied through chemigation. In Illinois, nitrogen fertilizer is applied to corn through irrigation by almost 80% of the farmers using center-pivot systems (McKenna et al. 1990). This method of applying nitrogen fertilizer may result in a smaller amount of nitrogen being applied per acre, although it is applied in more mobile forms that may result in a higher potential for nitrate leaching (McKenna et al. 1990). Also, in Mason and Kankakee Counties, commercial vegetable crops are more common, as are their associated aerial applications of insecticides.

The Livingston and Effingham County study areas produce considerably more livestock than the other areas; Livingston County contains a significant poultry industry (table 3.3). The Piatt County study area has the highest percentage of acreage in corn and soybeans (table 3.1). Alfisols dominate the Effingham County study area. Their lower fertility, relative to the Mollisols that cover most of the other study areas, results in lower yields for corn and soybeans. Consequently, more acreage is in small grains and hay, and more livestock is raised in this area (tables 3.1 and 3.3).

Table 3.5 Average nitrogen content from different manures.

	Dairy cattle	Beef cattle	Poultry	Swine	Sheep	Humans[a]
Animal wt. (lb)	1,000	1,000	5	100	100	150
Manure (tons/yr)	11.86	10.95	0.046	1.46	0.73	13.69
Moisture (%)	85	85	72	82	77	99.7
Nitrogen (lb/ton)	10.0	14.0	25.0	10.0	28.0	0.83
Total nitrogen (lb/yr)	118.6	153.3	1.15	14.6	20.44	11.36

Sources: Tisdale and Nelson (1975) and Baumann et al. (1978).
[a] Waste water entering septic system per person per year.

Potential Sources of Contamination

Pesticides Pesticides in the environment originate from practices or accidents induced by humans; therefore, their sources are finite. Both point and nonpoint potential sources of pesticides are considered in the characterization of agricultural practices. Applications of pesticides covering all or part of a field are considered nonpoint sources. Pesticides entering the environment from an accidental discharge associated with transporting, loading, mixing, or storing pesticides are considered point sources. Also, discharges of pesticides from disposal of excess pesticides or pesticide containers are considered point sources. In rural areas, pesticides are used for commercial agriculture, noncommercial gardens, and fruit trees, as well as home insect control.

Nitrate There are natural sources of nitrate in groundwater, but agricultural activities may influence the presence and levels of nitrate by introducing different forms of nitrogen into the soil environment. Current high yield corn production depends on supplementing the natural levels of nitrogen in the soil with nitrogen fertilizer, legumes, and/or manure. It would not be economically viable to grow corn in Illinois without supplements of nitrogen to the soil (Swanson et al. 1978).

Soil nitrogen occurs in several forms. The four most common are nitrogen gas (N_2), ammonium (NH_4^+), nitrate ($N0_3^-$), and organic nitrogen. These forms can be transformed repeatedly from one form to another, depending on the soil environment. Nitrogen can be removed from the soil by volatilization, plant uptake, runoff, erosion, or leaching. Nitrate is the form of nitrogen most susceptible to leaching. Usually, when groundwater contamination is considered, nitrate is the predominant form of nitrogen. Because of transformations, all forms of nitrogen may be sources of nitrate (Alexander 1977, Welch 1979). Soybeans, alfalfa, clover, and other legumes in symbiosis with rhizobium bacteria can fix atmospheric nitrogen into immobile organic nitrogen. Humans and livestock produce waste that contain varying amounts and forms of nitrogen (table 3.5). Nitrogen fertilizer is commonly applied to land planted in corn and other nonlegume crops.

In addition to current practices, past agricultural practices may have a persistent effect on the present quality of the soil and water environment. Examining farmsteads in southern Illinois where livestock and human waste were applied, Dickey and Lembke (1978) found that 24 years after waste incorporation and crop production had ceased, nitrate levels were still higher than they were in heavily fertilized surrounding fields. They attributed the persistent and high levels of nitrate to low permeability soils that hindered leaching, minimal runoff, and a low degree of volatility.

GEOLOGY AND HYDROGEOLOGY

Introduction

The susceptibility of rural, private water wells to contamination by pesticides is governed by a variety of factors, including the geologic materials in which a well is constructed, type and concentration of pesticides applied, thickness and character of geologic material, technique of well construction, and condition of the well with respect to its annular seal. Pesticides are applied to two out of three acres in rural Illinois each year (McKenna et al. 1989). The vast majority of the rural population of Illinois uses groundwater for drinking, and approximately 40% of the rural land is underlain by aquifers within 50 feet of land surface (McKenna et al. 1989, 1990). Thus, there is a considerable potential for groundwater contamination, and a significant segment of the rural population may be at risk. Although insufficient data are now available to assess the statewide impact pesticides may have on groundwater quality in Illinois, sampling of wells indicates that shallow aquifers are most vulnerable to contamination (Schock et al. 1992).

Potential Contamination of Shallow Aquifers

Figure 3.1 shows the potential for contamination of shallow aquifers by agricultural chemicals (McKenna et al. 1989, McKenna and Keefer 1991a, 1991b) and illustrates the differences between the five study sites. Extensive areas of Mason and Kankakee Counties are classified as having a high to moderate potential for contamination. Piatt, Livingston, and Effingham Counties exhibit lower potential. Areas that have high potential for infiltration and recharge are considered to possess high potential for groundwater contamination because pollutants (e.g., pesticides) can migrate downward with the percolating water. The rate and depth to which the pesticides migrate is controlled by a variety of factors, including groundwater flow, type and concentration of pesticide, and physical and chemical characteristics of the geologic materials.

In areas, like the Mason County study area, where the aquifer is very close to the land surface, shallow sandpoint wells are often installed in the highly permeable sand and gravel. In areas, such as the Effingham County study area, where low permeability materials are present, large-diameter dug and bored wells are common. Both well types are usually shallower than drilled wells. Dug and bored wells achieve the needed well yield through their large diameter. They can draw groundwater from thin sand seams, lenses, and fractures in diamicton, but because they are shallow, they are more susceptible to chemicals applied at the surface than deeper wells in the same sediment. Well construction can also play more of a role in the contamination potential for these wells.

Drift Thickness and Bedrock Topography Maps

Maps depicting the bedrock elevation and topography and drift type and thickness are helpful in determining aquifer elevation, thickness, and distribution. If the uppermost aquifer is shallow and of sufficient thickness to sustain yield to domestic wells, and the thickness of unlithified sediments is great, few wells will be completed in bedrock. Therefore, information available for constructing drift thickness and bedrock topography maps will be limited. This is the case in Mason and Piatt Counties, where the study areas overlie or adjoin major bedrock valleys that are filled with Quaternary glacial sediments (figs. 3.2 and 3.3).

In general, depth to bedrock in the five study areas ranges from shallow (less than 25 feet) in Kankakee County to deep (greater than 200 feet) in Mason County. Only the Kankakee County study area exhibits significant near-surface bedrock (fractured Silurian dolomite) that is considered to be an aquifer. The remainder of the study areas are underlain by Pennsylvanian rocks, primarily shales.

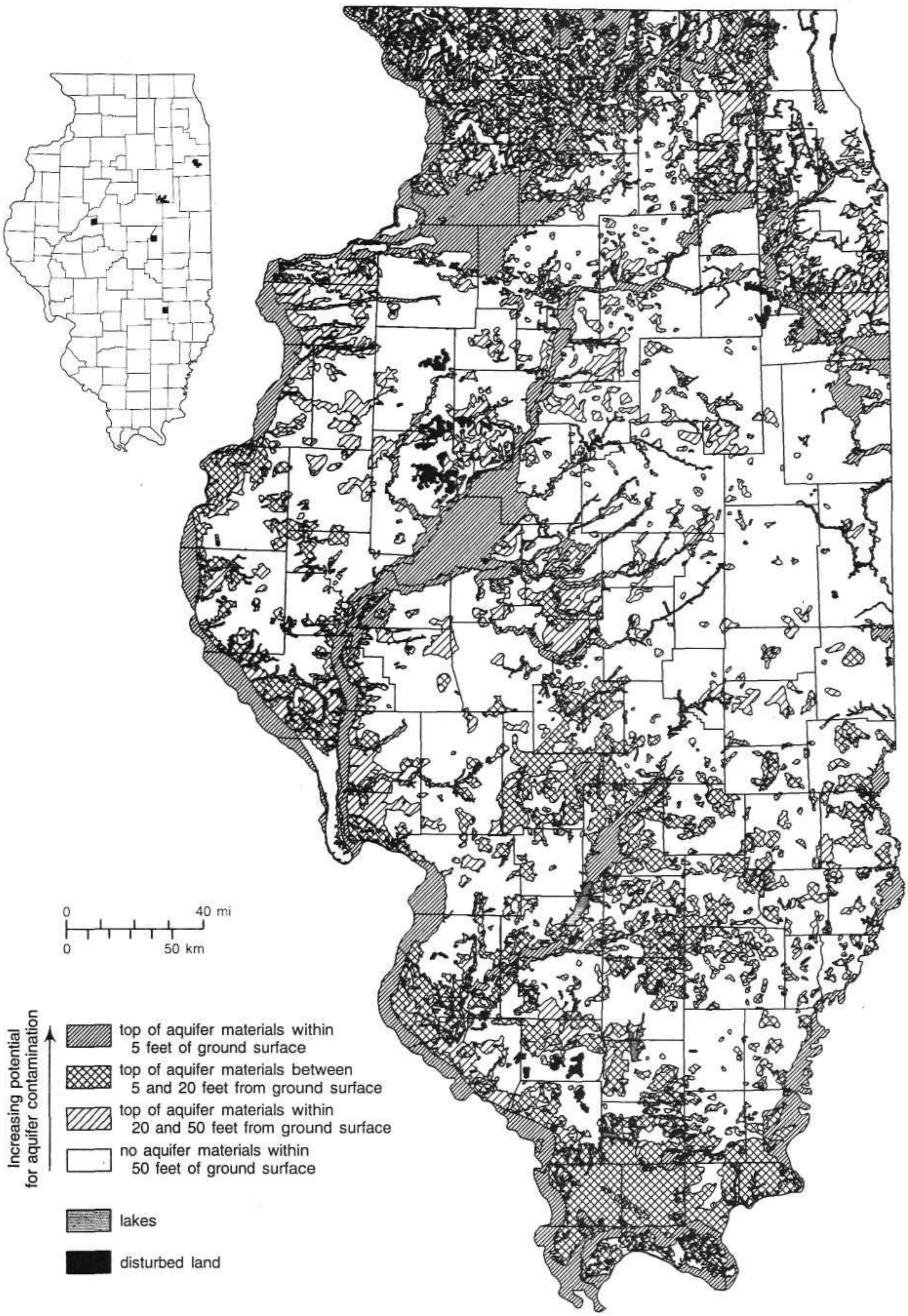


Figure 3.1 Potential for agricultural chemical contamination of aquifers.

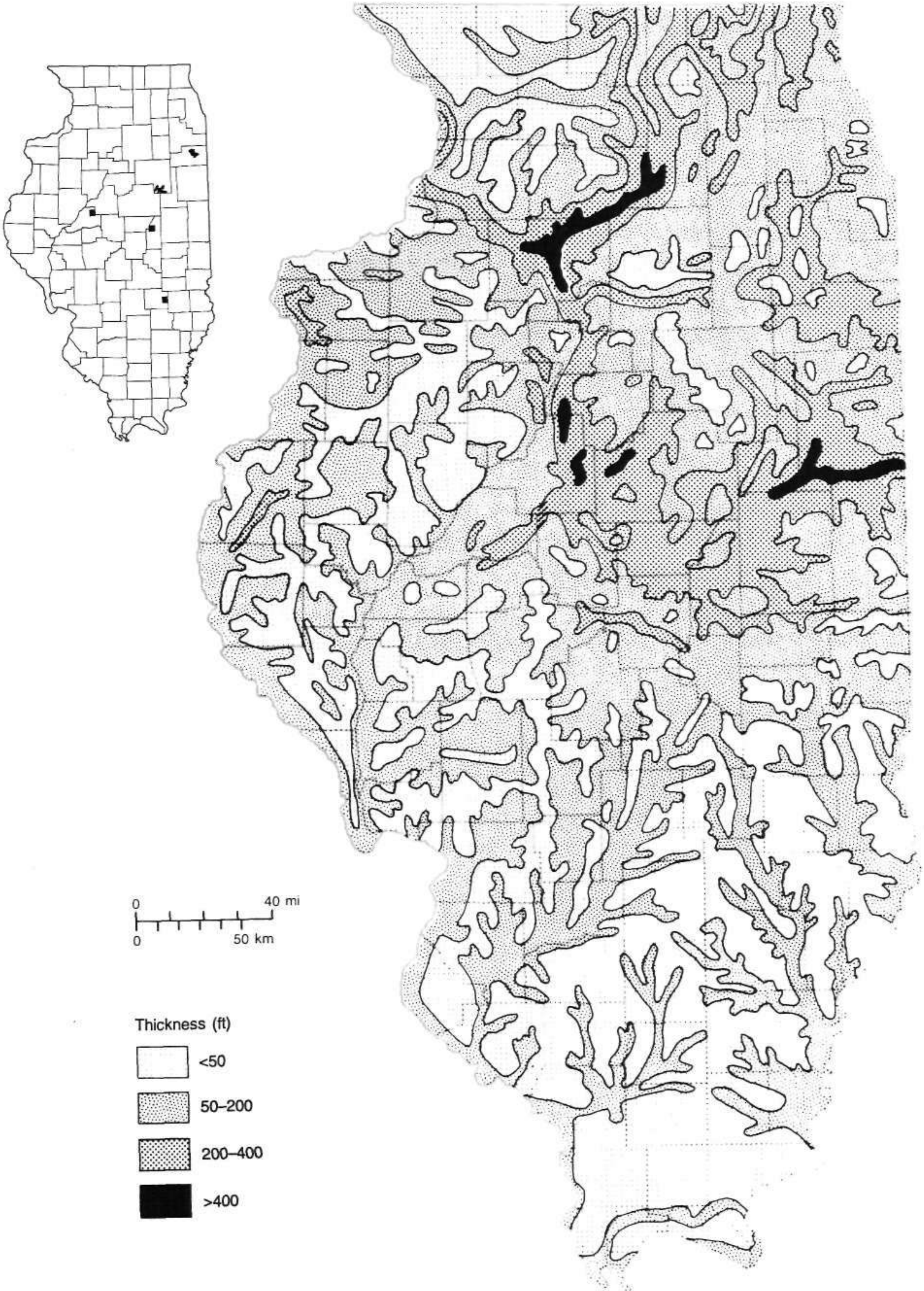


Figure 3.2 Thickness of Pleistocene deposits of Illinois.

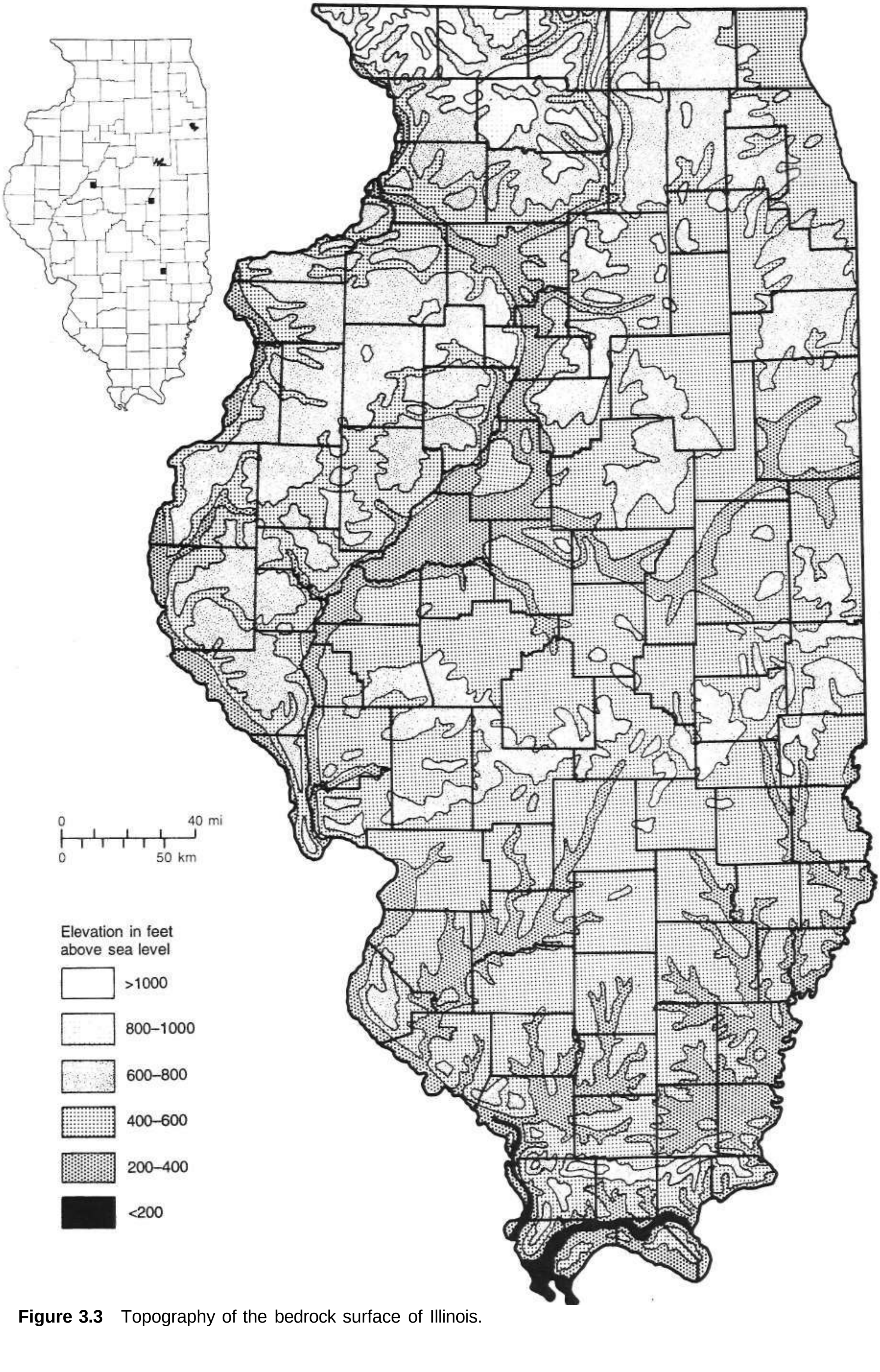


Figure 3.3 Topography of the bedrock surface of Illinois.

Variety of Geologic Materials

In addition to various types of bedrock sources used for groundwater supplies, high permeability unlithified sediments are the principal geologic materials that may become contaminated. The majority of Illinois is covered by glacigenic sediments (fig. 3.4) that can be, because of depositional processes, highly variable in physical and chemical characteristics over short distances. Ice-contact sediments, lacustrine deposits, outwash sands and gravels, deltaic materials, colluvial and alluvial deposits, and eolian silts and sands are often interspersed. Local textural variations in the form of lenses, irregular and discontinuous layers, and fractures vary in importance, depending on whether they are in a position to affect groundwater recharge or allow agricultural chemicals access to an aquifer. These local variations also make interpretation more difficult because the lateral and/or vertical extent of a variation may not be completely defined. Tills vary in texture, permeability, thickness, compactness, and other characteristics that influence their effectiveness as aquitards.

The five study areas contain a variety of glacial sediments. Mason County has thick, coarse-textured outwash. Kankakee has a mixture of thin, coarse-textured outwash and thick, fine-textured till. Livingston, Effingham, and Piatt Counties contain moderate to thick sequences of fine-textured tills with intermixed sand and gravel lenses. These three study areas pose problems because they outwardly appear to contain thicknesses of fine-textured sediment adequate to protect near-surface aquifers. The presence of intermixed sand and gravel lenses of variable lateral and vertical extent, however, introduces the possibility of contaminant transmission to the aquifer.

Need for Geologic Characterizations

Geologic characterizations can be used to evaluate the initial suitability of an area for landfilling, resource utilization, or as in this case, the potential for aquifer contamination by agricultural chemicals. More detailed site analysis is always necessary, however, before any specific location can be evaluated for its susceptibility to or its potential for adverse effects from a particular land use or activity.

Although the characterizations are generalized on maps (because of map scale and the number and spatial density of datum points), the characterizations provide a useful summation of the geologic conditions that can affect the movement of groundwater and mobility of agricultural chemicals toward an aquifer. Potential problem areas of high permeability or transmissivity can be mapped with sufficient accuracy to provide residents and other well users with an indication of the susceptibility of their water to contamination.

A stack-unit map represents the vertical succession of geologic materials to a specified depth (Kempton and Cartwright 1984). This three-dimensional perspective is useful because it presents a considerable amount of information in a relatively compact format. Once the geologic units in an area are identified, additional information regarding their permeability, transmissivity, texture, hydraulic conductivity, erodibility, chemistry, and other variables can be used in the various interpretations and analyses to achieve the project objectives.

GROUNDWATER HYDROLOGY

Water for domestic use in the Effingham County study area is obtained primarily from dug wells finished in the glacial drift, and public water supply wells tap water from isolated sand and gravel lenses in the drift. The extensive surface sand and gravel deposits in the Mason County study area contribute to the abundance of sandpoints for domestic use. Irrigation wells pump from the lower parts of this unconfined aquifer. Almost all the domestic, public water supply, and irrigation wells in the Kankakee County study area pump water from the fractured dolomite

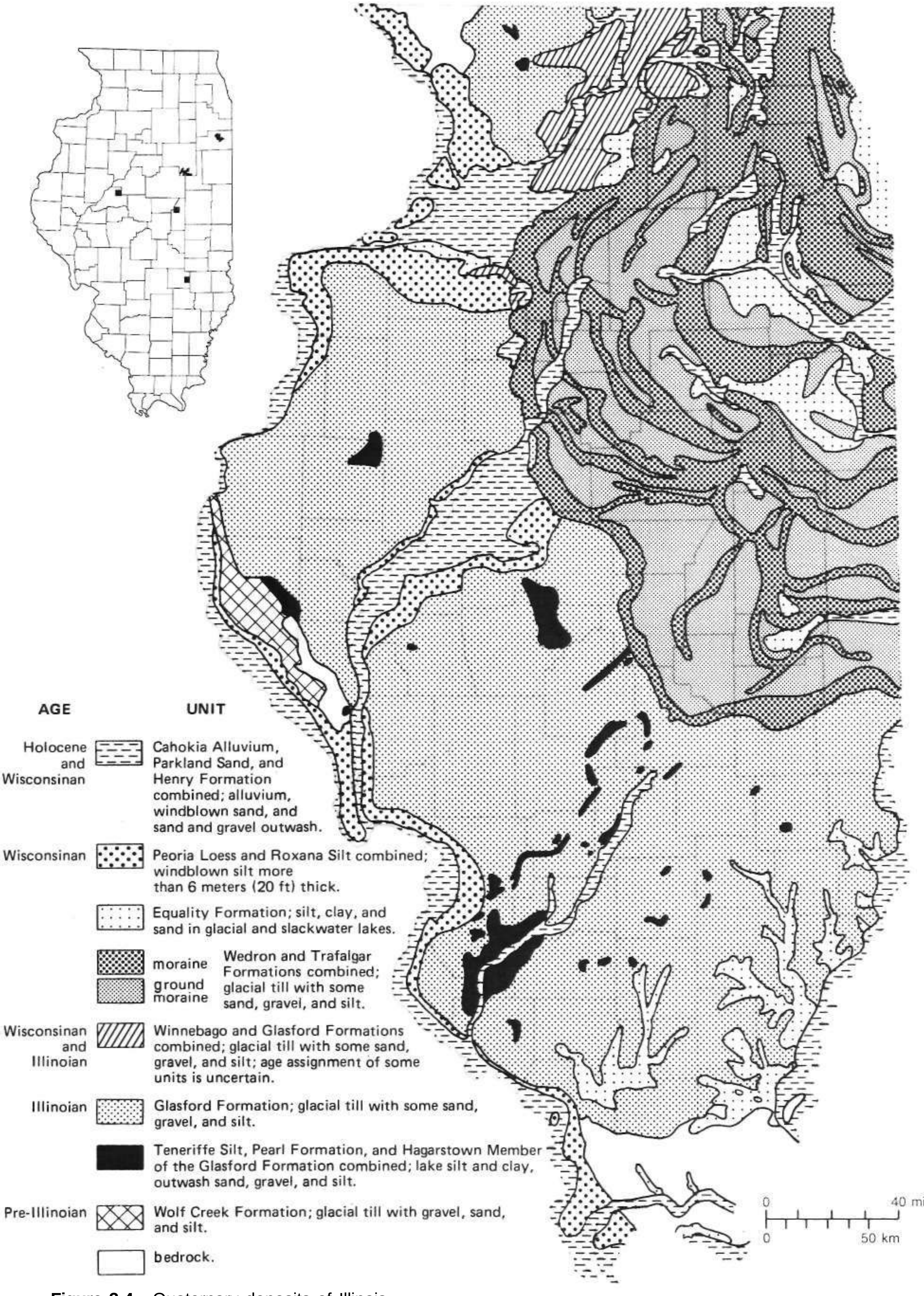


Figure 3.4 Quaternary deposits of Illinois.

aquifer. Some of the drilled wells in the Livingston and Piatt County study areas draw water from aquifers within deep, buried bedrock valleys. Most wells in these areas, however, range in depth from 30 to 150 feet.

Aquifer Properties

Significant differences in aquifer hydraulic properties occur across the study areas. In general, public water supply and irrigation wells tap productive parts of the aquifers (i.e., zones with high transmissivities) and screen a larger part of the aquifer thickness than private wells. Furthermore, public and irrigation wells are often constructed better and have been developed more extensively during installation than private wells. Domestic wells generally tap the upper part of an aquifer and have smaller screen lengths. Information in the ISWS aquifer properties database suggests that the hydraulic conductivities are highest for irrigation wells in Mason County, and lowest for public water supply wells at DeLand (Piatt County study area) and Dieterich (Effingham County study area).

Withdrawal Rates

Water withdrawal for public supply within any of the study areas is negligible. Areas with heavy pumpage, however, exist adjacent to the Mason, Kankakee, Livingston, and Piatt County study areas. The Jake Wolf State Fish Hatchery at the Sand Ridge State Forest, located approximately 6 miles northwest of the Mason County study area, pumped an average of 9 million gallons every day from seven wells (Visocky, personal communication, 1991). In 1988, the yearly pumpage was 2.9 billion gallons. Irrigation use within the Mason County study area was estimated to be an additional 2.8 billion gallons per year.

Detailed records of supplemental irrigation in the Kankakee County study area are not available. Cravens et al. (1990) note, however, that application of irrigation water varies with crop type and on a seasonal basis. In an average precipitation year, vegetables will receive an additional 5 inches of water, and turf grass an additional 40 inches. Irrigation withdrawal, averaged for vegetables and turf grass at an estimated application rate of 20 inches per year in the Kankakee County study area, was calculated to be 500 million gallons per year. In addition, ISWS records indicate that the municipal wells of Manito and Momence pump nearly 126 and 296 million gallons per year, respectively.

Public water withdrawal within or in the vicinity of the Livingston County study area by the towns of Strawn, Forrest, and Fairbury totals 200 million gallons per year. Similarly, the towns of DeLand and Monticello in Piatt County pump 280 million gallons per year and the Village of Dieterich draws 16 million gallons per year within the Effingham County study area.

Recharge Rates

The recharge rates in the five study areas are also variable. Because the amount of precipitation across the five areas is similar, annual recharge to the aquifers is dependent upon pumping stresses and the permeability of the material near the land surface and overlying the aquifers. The Mason County study area has the highest recharge rate, and the Effingham County study area has the lowest (Walker et al. 1965, Walton 1965, Walton and Csallany 1965).

Hydrology, land use, and geology affect the transport of agricultural chemicals from the land surface to groundwater. Hydrogeologic characterizations of the five pilot study areas presented in the following sections provide an understanding of this transport process.

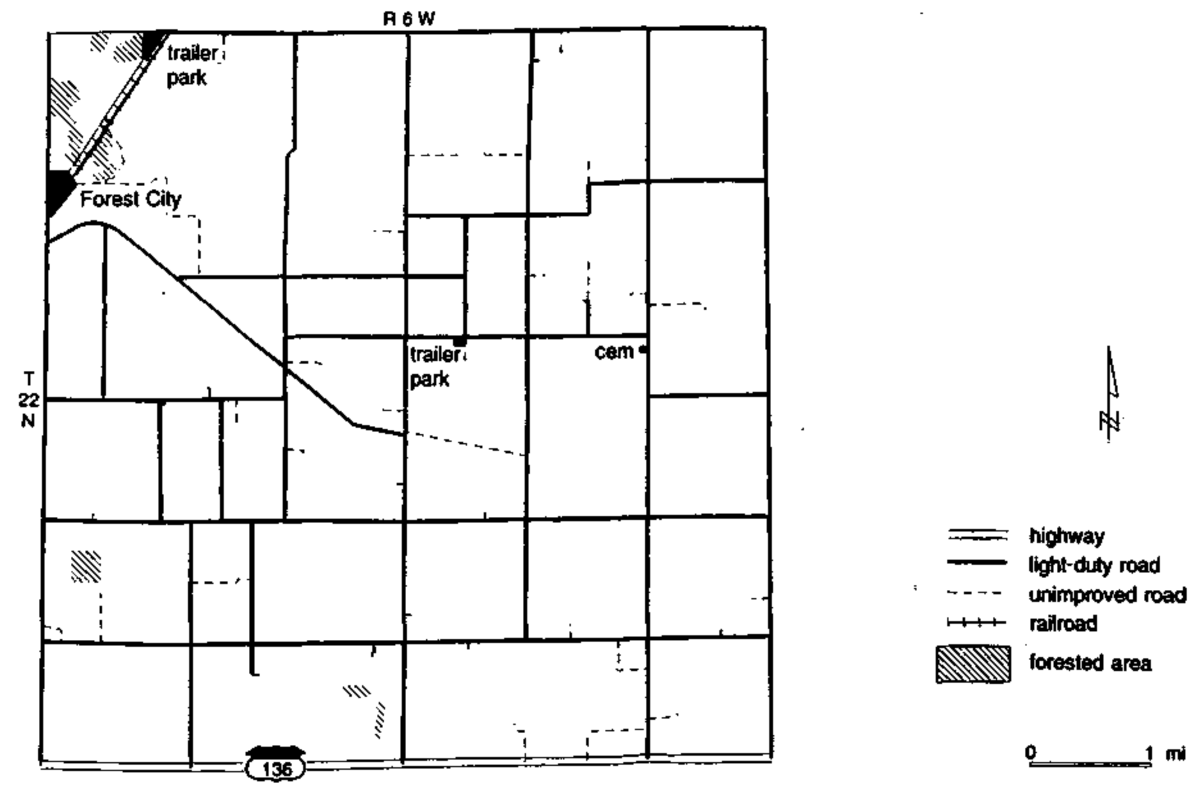


Figure 4.1 Mason County study area.

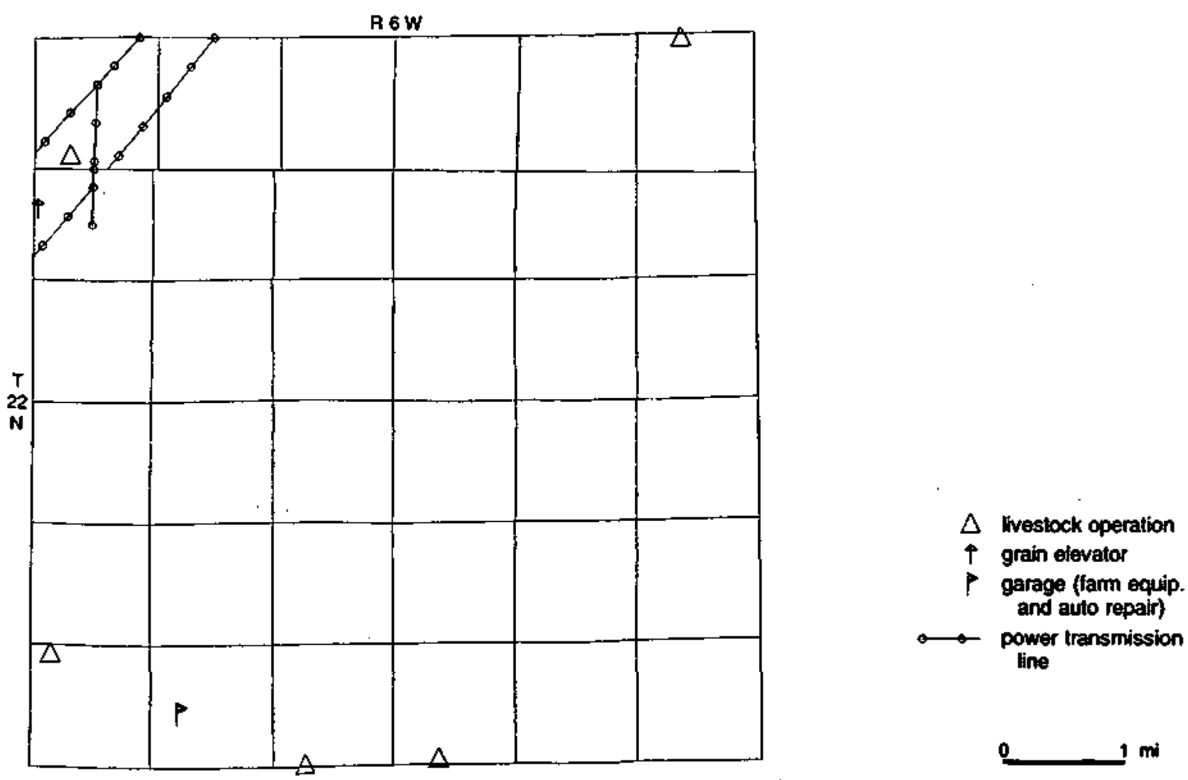


Figure 4.2 Potential sources of contamination in the Mason County study area.

4. CHARACTERIZATION OF THE MASON COUNTY STUDY AREA

M. L. Barnhardt, C. Ray, and M. R. Greenpool

LAND USE

Description of the Study Area

The study area in Mason County, encompassing the entire 36-square-mile Forest City Township (T22N, R6W), is primarily agricultural. Only Forest City, at the northwest comer of the study area, has any significant commercial activity. The major transportation features are U.S. highway 136, which forms the south boundary of the study area, and Forest City-Manito Road (County road 461), which traverses the study area's west boundary (fig. 4.1). The Chicago and Illinois Midland railroad passes through the northwest corner of Forest City.

A total of 162 rural households was located in the study area. Forty-nine (30%) were farmsteads, 69 (43%) were rural residents, and 44 (27%) were unclassified. Detailed interviews with 48 randomly selected well users indicated that 15 (31%) of the households were active farms (table 3.3).

Industrial and Commercial Operations

Figure 4.2 illustrates the industrial and commercial operations present in the study area. A grain elevator is located along the Chicago and Illinois Midland railroad at Forest City, and a pipeline passes nearby. A distribution center for agricultural chemicals is located 1 mile north of the study area, and a sewage disposal pond is located about 700 feet southeast of the southeast corner of the study area.

GEOLOGY AND HYDROGEOLOGY

Introduction

The Mason County study area was selected to represent areas in which the top of the shallowest aquifer material occurs within 5 feet of land surface. The aquifer, composed of Wisconsinan and possibly pre-Wisconsinan sand and gravel, is at the land surface throughout more than 70% of the study area. A thin (<5 feet thick), discontinuous, loamy textured cover of sand and silt mantles the sand and gravel throughout the remainder of the township. The sand and gravel is between 150 and 170 feet thick in the study area, and it overlies Pennsylvanian shales.

Previous Studies

Specific information for the area includes the study of groundwater resources of the Havana Region (Walker et al. 1965), and the study of the sand and gravel resources of Mason County (Labotka and Hester 1971). Hajic's (1990) work on the geomorphology and stratigraphy of the lower Illinois River valley is significant because it offers a reinterpretation of the age, development, and sedimentology of the Manito and other terraces in the Havana Lowland, **a** region that includes the study area. A number of statewide mapping projects have examined the Quaternary stratigraphy of the area (Berg and Kempton 1988, Berg et al. 1984, Keefer and Berg 1990, Lineback 1979, Piskin and Bergstrom 1975, Willman and Frye 1970, Willman et al. 1975).

Physiography and Drainage

Forest City Township is located about 10 miles east of the Illinois River and 4 miles south of the Mackinaw River. The coarse-textured sediments that dominate the surficial materials have inhibited the development of a significant drainage network in the study area (fig. 4.3). Natural drainageways have been channelized to promote drainage of farm fields. The major drainage channels—Main Ditch, Red Oak Ditch, North Quiver Ditch, and Mason Tazewell Drainage Ditch—are located in the Illinois River basin. The relatively flat topography produces a slight

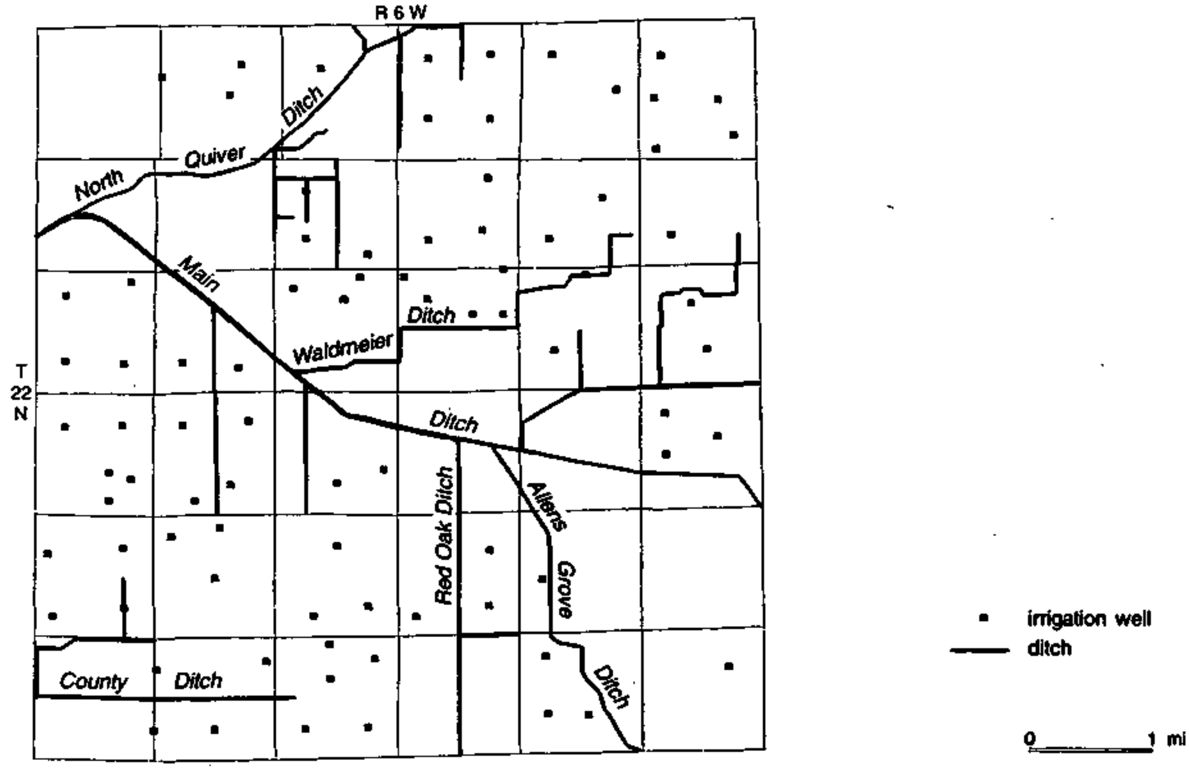


Figure 4.3 Drainage of the Mason County study area.

gradient from the southeast to the northwest of about 5 feet per mile. Approximately 20 miles of drainage ditches occur within the Forest City Township, and Main Ditch serves as the major collector. Its 17-foot-wide channel has an average gradient of about 3.3 feet per mile and drains into North Quiver Ditch and then toward the Illinois River via the Mackinaw River (Herndon and Rogers 1972).

Kankakee Flood A series of geomorphic events affecting the topography of the study area occurred between 16,000 and 15,500 years B.P. (before the present) when glacial-lake outburst floods filled the Illinois River valley and eroded into the outwash forming the Manito Terrace. These floods appear to be responsible for most of the flood-related features found throughout the Illinois River valley (Hajic 1990). Earlier work by Wanless (1957) suggested that two high terraces (Manito and Havana) were cut during this time, but a reexamination by Hajic (1990) found no erosional scarps or other evidence to confirm the presence of the separate deposition-erosion sequence expected in the formation of a terrace. Hajic suggested that only one terrace exists, and the lower surfaces attributed to the Havana Terrace are actually sluiceways used for drainage. Formation of sand dunes on the Manito Terrace in the lower middle Illinois River Valley was probably facilitated by the exposure of fresh sand surfaces by the Kankakee Flood (Hajic 1990).

Manito Terrace Elevation across the township in general ranges from about 490 feet above mean sea level (msl) along North Quiver Creek to 550 feet in the northwest corner, north of Forest City. Local relief is minimal, ranging between 500 and 505 feet; higher elevations (550 feet) occur where sand dunes punctuate the Manito Terrace. The Manito Terrace is the highest of several terraces in the Havana region and constitutes the dominant geomorphic feature in the township. The Manito Terrace surface formed on late Wisconsinan outwash when the lower Illinois River Valley was the principal course for meltwater discharge from the Lake Michigan Lobe (Hajic 1990). By the time the Woodfordian glacial advance terminated north of the study area and began depositing the Bloomington Moraine near Peoria (about 20,000 years B.P.), thick deposits of sand and gravel had accumulated in the bedrock valleys formerly occupied by the ancient Mississippi River (Hajic 1990). As the Lake Michigan Lobe downwasted and retreated, extensive reworking and incision of the outwash occurred, thus creating the terrace.

Sand dunes Dunes are most common in the west-central part of the study area, but they occur throughout the areas dominated by the Manito Terrace. The largest dunes occur directly south of Forest City, along the study area's west boundary and in the south-central part along the south boundary. Large dune-fields also occur just west and east of the study area. The sand dunes represent eolian reworking of sands (Parkland Sand) derived from the extensive outwash deposits that constitute the Manito Terrace.

Bedrock Geology and Topography

The Havana region is underlain by undifferentiated Pennsylvanian System rocks that are not an important source of groundwater (Walker et al. 1965). Log records from 18 deep borings in and around the study area indicate that these rocks are mainly shales, with occasional sandstone, coal, and limestone (fig. 4.4).

The elevation of the bedrock surface decreases from more than 360 feet above msl in the eastern part of the study area to less than 340 feet in the southern part (fig. 4.5), where the buried bedrock Mahomet Bedrock Valley runs east-west toward a confluence with the bedrock valley underlying the Mason Tazewell Drainage Ditch (see also fig. 10 in Walker et al. 1965, for a more regional perspective; Kempton et al. 1991).

Thickness of Quaternary Deposits

The presence of buried bedrock valleys in the western and southern parts of the township is important because they contain thick deposits of sand and gravel that are the medium for groundwater storage (fig. 4.6). The sand and gravel deposits of the Sankoty Sand Member (Banner Formation) and Mackinaw Member (Henry Formation) constitute the major aquifers in the study area, as well as in Mason County in general (Walker et al. 1965). Drift thickness generally ranges from 150 to 170 feet. The lack of verified wells penetrating bedrock within the study area precludes the presentation of a more detailed map and discussion. The drift thickness map of Walker et al. (1965), however, suggests that drift thicknesses of greater than 200 feet may occur just southeast of the study area.

Lithostratigraphy

The stratigraphic relationships of the Parkland Sand, Mackinaw Member, and Sankoty Sand deposits and the underlying Pennsylvanian bedrock surface are illustrated in figure 4.7. The buried bedrock channel is evident in cross section A-A'. Walker et al. (1965) located a major bedrock valley to the west of the study area, but a lack of deep wells prevents an accurate depiction of the subsurface geology. This area was a major drainageway for glacial meltwaters, and these bedrock valleys were preferred avenues for the deposition of coarse-textured sediment (Hajic 1990).

Banner Formation The Sankoty Sand Member of the Banner Formation underlies the Parkland and Mackinaw deposits throughout the study area and is the major aquifer (Walker et al. 1965), although many wells are finished in the overlying Mackinaw Member. It is a mineralogically distinct, well-sorted, medium- and coarse-grained sand that is easily identified by its pink quartz grains (Willman et al. 1975). The Sankoty Sand ranges from 40 to 100 feet thick in the township and directly overlies the bedrock. The cross sections (fig. 4.7) indicate that the Sankoty Sand occurs at depths of 50 to 70 feet below the ground surface. Most of the rural wells examined in this study area probably penetrate the upper part of this unit.

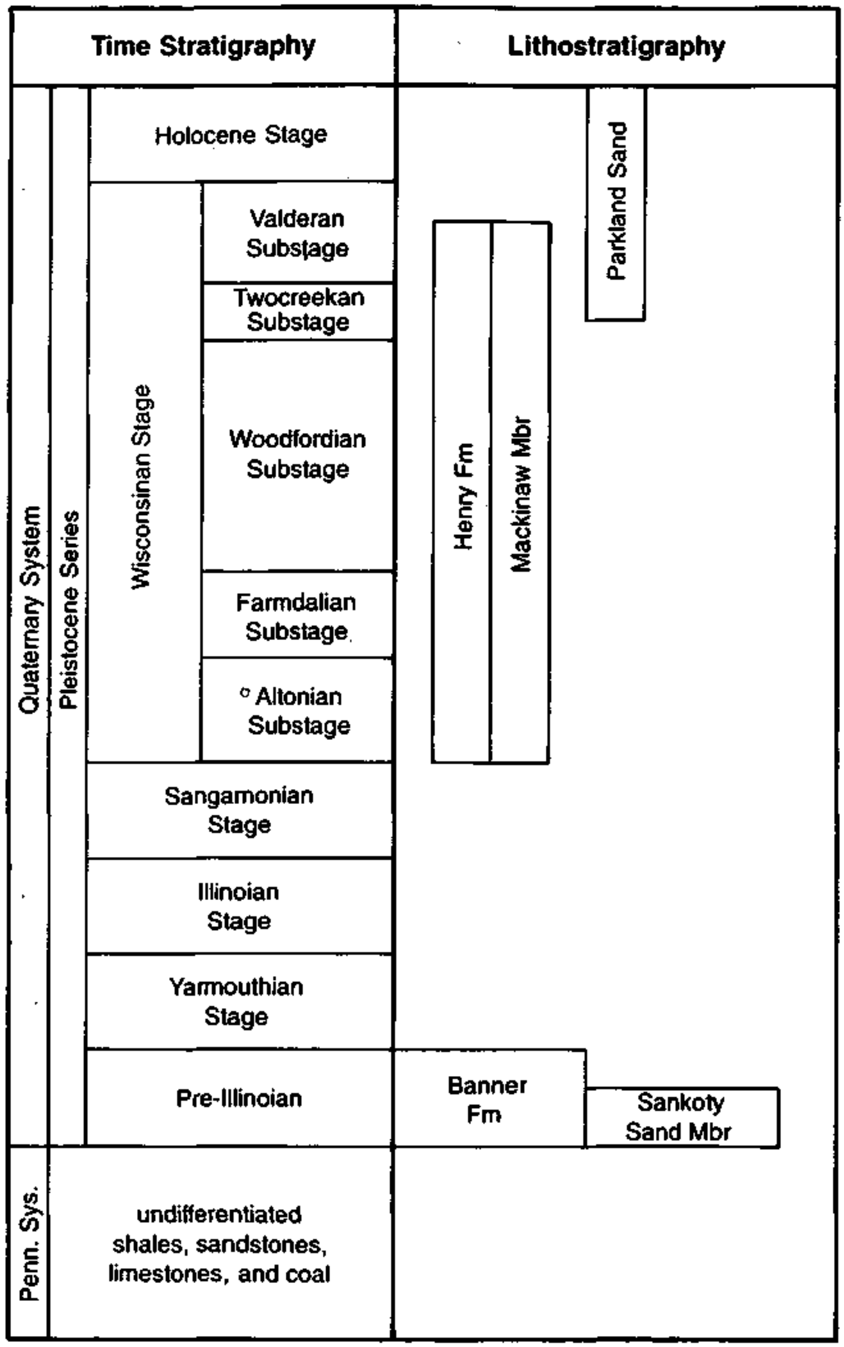


Figure 4.4 Lithostratigraphy of the Mason County study area.

Henry Formation The Mackinaw Member of the Henry Formation consists of sand, pebbly sand, and gravel (Willman et al. 1975). In the study area, it underlies the Parkland Sand and is the surficial deposit underlying most of the terrace surfaces and floodplains where sand dunes are not present. Hajic (1990) suggested that much of the sand and gravel underlying the Manito Terrace is Farmdalian or early Woodfordian and that most of the sediment had been deposited by the time glacial ice terminated at the Bloomington Moraine. The Mackinaw Member ranges from 35 to 70 feet thick, but it increases to more than 100 feet over bedrock valleys. Shallow sandpoint wells are usually finished in this sand and gravel unit (Labotka and Hester 1971).

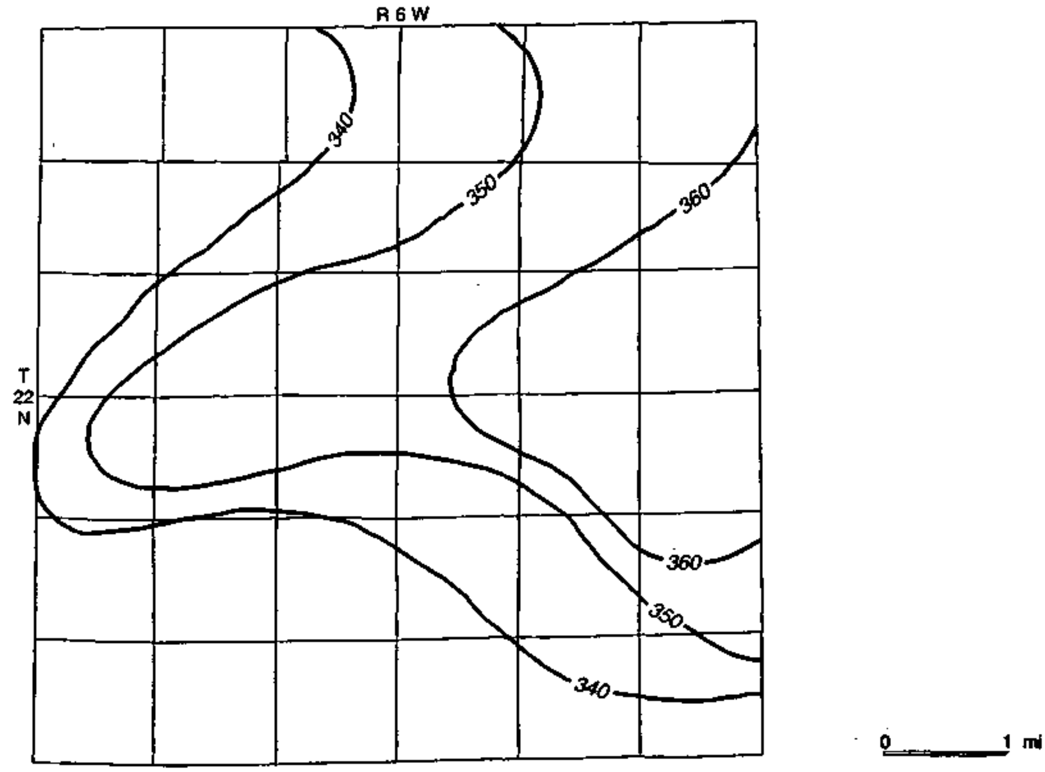


Figure 4.5 Topography of the bedrock surface in the Mason County study area. Elevation is in feet above msl, and contour interval is 10 feet.

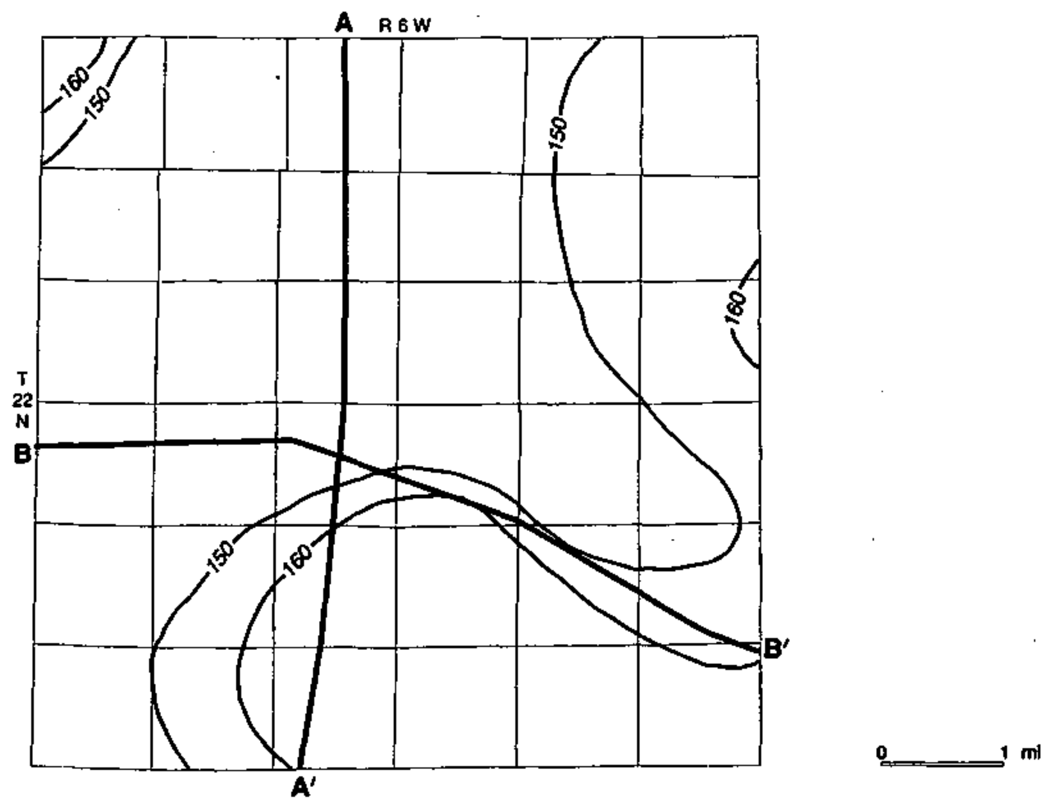


Figure 4.6 Thickness of drift deposits in the Mason County study area. Thicknesses are in feet, and contour interval is 10 feet. Location of transect lines is shown for cross sections A-A' and B-B'.

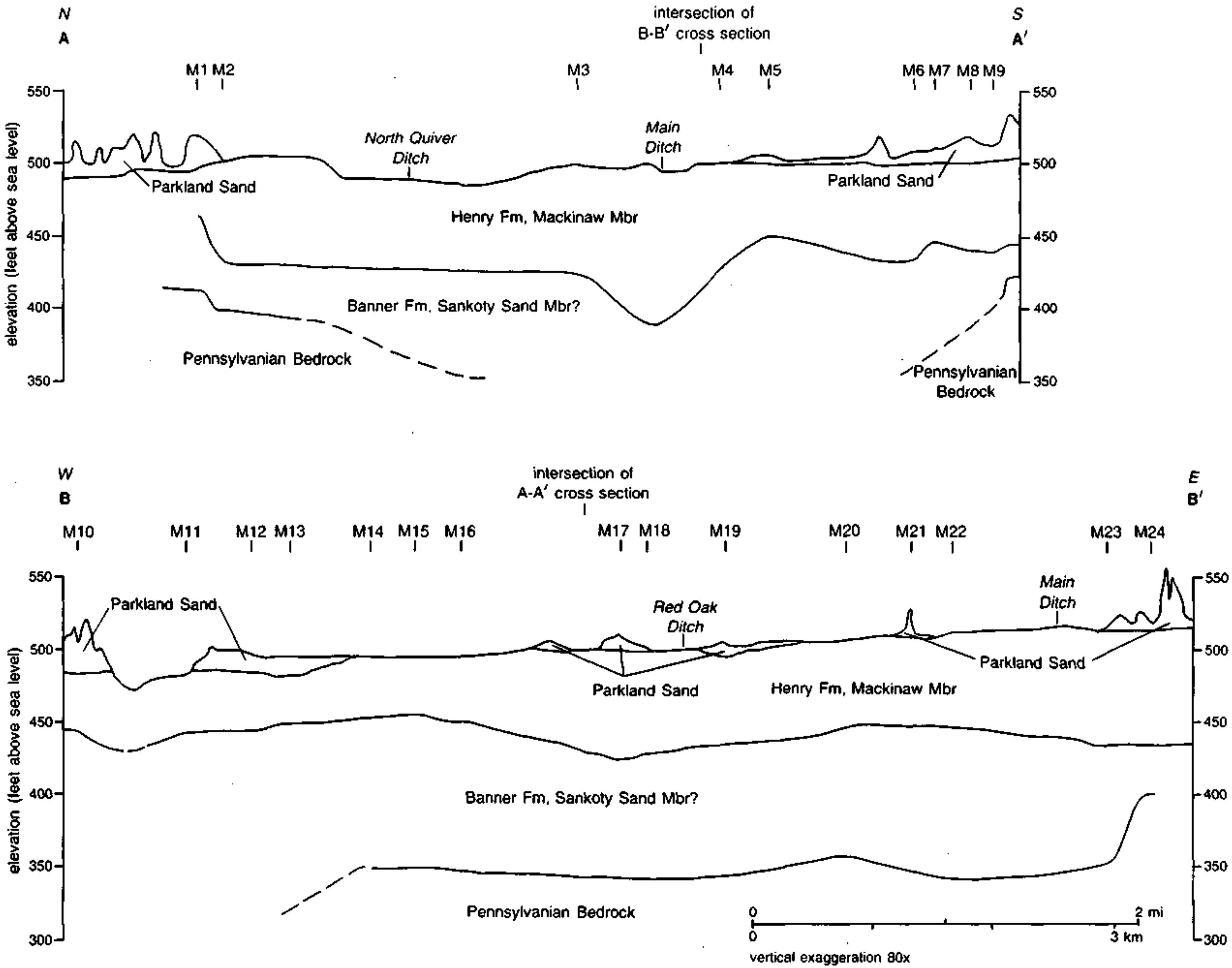


Figure 4.7 Cross sections A-A' and B-B' for the Mason County study area.

Parkland Sand The Parkland Sand (ranging from 20-40 ft thick) comprises the sand dunes and sheet-like deposits in the study area (Willman et al. 1975). The sand is derived from local Woodfordian outwash deposits that extend over the township. The highest dunes in the study area have a height of about 55 feet. They are generally characterized by steeper slopes and high relief. Minimal erosion occurs, however, because high infiltration rates inhibit runoff. The drainage characteristics, texture, and parabolic morphology of the sand dunes create unique patterns on the landscape. The patterns are easily discernable on topographic maps and soil survey maps because a distinctive assemblage of soils dominates the dune and interdunal surfaces. Major dune fields occur immediately west of the study area and again just east of the study area in Tazewell County. The individual dune fields (fig. 4.8) are generally separated by larger drainageways (fig. 4.3).

Soils and Parent Materials

Parent materials in the study area have similar physical and hydraulic characteristics because all are part of the extensive sand and gravel outwash deposits that cover much of Mason County (fig. 4.8). The reworking of finer sand fractions into morphologically distinct sand dunes and/or the redeposition of finer sand and silt (possibly some loess) along modern drainages has little effect on the overall geologic and hydrologic characterization of the township. Organic matter content varies primarily with drainage conditions in the study area. Poorly drained soils along drainageways exhibit slightly lower permeabilities and higher organic contents in their surface horizons than do the better drained sand dunes (table 4.1).

Calculations using the GIS indicate that about 43% of the soils in the study area are characterized as having moderate to high infiltration rates (low runoff potential) and moderate to high rates of water transmission (Hydrologic Groups A and B). Group A soils are generally associated with sand dunes or interdunal areas on the Manito Terrace (SCS, in press c).

Organic matter content (organic carbon) is important because it affects pesticide adsorption and, therefore, pesticide leaching potential. Organic matter is concentrated near the soil surface, and its distribution is directly affected by tillage practices (McKenna et al. 1989). Under otherwise identical conditions, soils with higher organic content will usually provide a greater potential for pesticide adsorption than soils with lower organic content. High infiltration rates, however, can offset the advantages of high organic content because of the rapid downward movement of water under saturated conditions (McKenna et al. 1990). The soils in Forest City Township are very permeable. The coarser textured parent materials exhibit high permeabilities and, generally, low organic matter contents (table 4.1). The finer textured sediments have slightly lower permeabilities than have the coarser sand and gravels that mantle this region. Most of the parent materials contain a moderate (3%) organic content, and the more poorly drained soils along drainageways exhibit higher values than the better drained sand dune soils.

Hydrogeology

General hydrogeologic considerations This township is dominated by coarse-textured sand and gravel deposits that have high hydraulic conductivities (Berg et al. 1984). Even though about 30% of the township has loamy textured sediments (generally less than 5 feet thick) overlying the sand and gravel deposits, these more poorly drained areas probably do not impede the infiltration of water. The parent material and stack-unit maps (figs. 4.8 and 4.9) illustrate the position of the fine-textured deposits along the current drainageways (fig. 4.3).

Aquifers The entire sequence of Quaternary sediments is composed of permeable sand and gravel, and it may be considered to be one aquifer. The absence of any barrier to impede groundwater movement increases the probability of agricultural chemical contamination of groundwater, shallow wells, and wells that have developed a significant cone of depression.

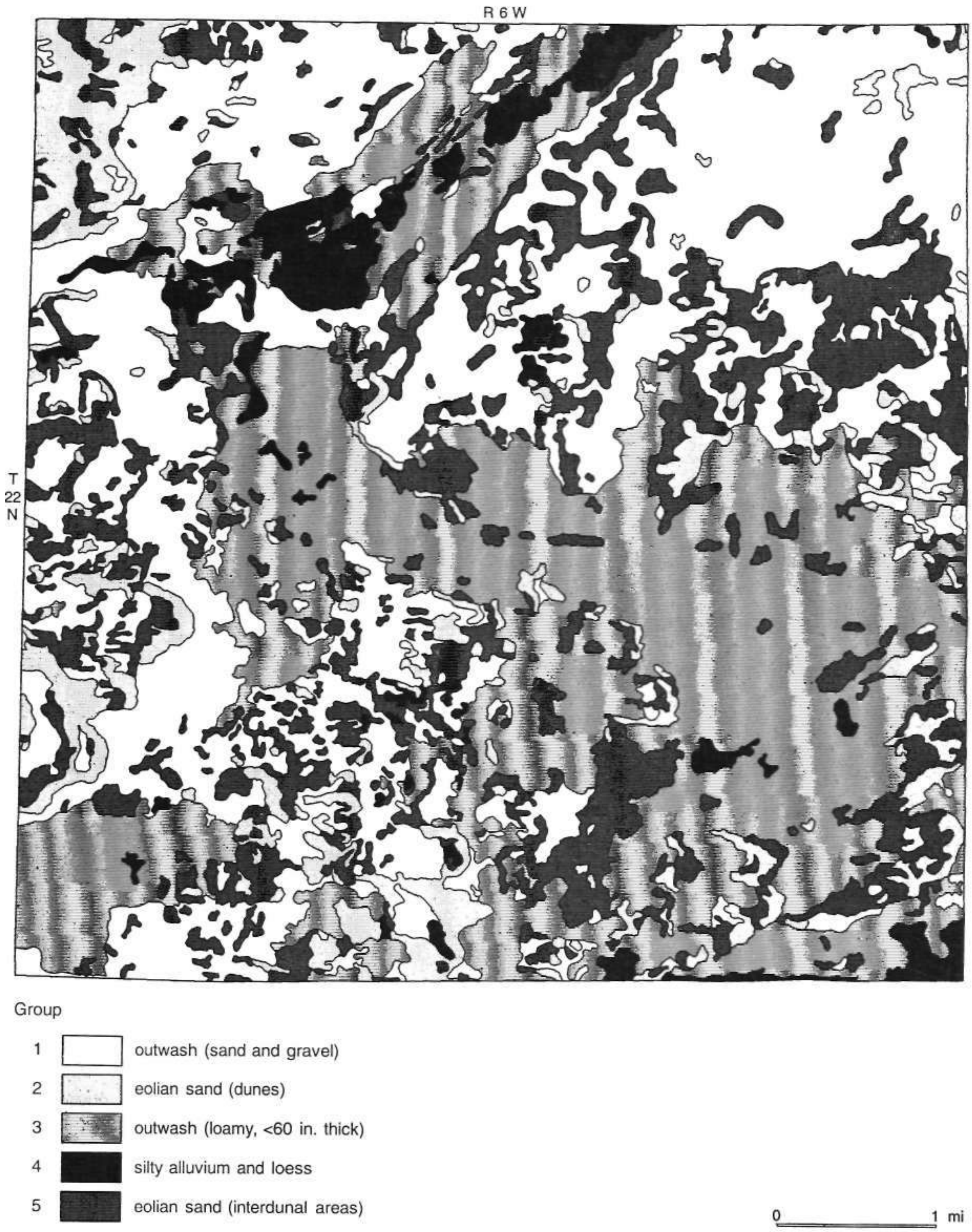


Figure 4.8 Parent materials of the Mason County study area.

Figure 4.9 Stack-unit map of the Mason County study area.

Table 4.1 Soil permeability *i*and surface organic matter content in Mason County study area.

Parent material group[a]	Permeability[b,c] (in./hr)	Organic matter[d] (avg. %/avg. thickness)	% of study area
1—Outwash (sand and gravel)	0.6-2.0 (upper 25 in.) 6-20	3.1 for upper 15.5 in.	34
2—Eolian sand (>60 in. thick)	6-20	1.9 for upper 16.2 in.	9
3—Outwash (loamy, <60 in. thick)	0.6-2.0 (upper 48 in.) 6-20	5.2 for upper 18.7 in.	33
4—Silty alluvium/loess (<60 in. thick)	0.6-2.0	5.6 for upper 17.1 in.	4
5—Eolian sand(<60 in. thick)	0.6-2.0 (upper 35 in.) 6-20	2.8 for upper 17.3 in.	20

[a] See parent material map (fig. 4.8) for distribution.
[b] Data for permeability and organic matter from Soil Conservation Service (in press c).
[c] The second range of values represents permeability for sediments below the initial unit unless another material is identified.
[d] Percentages and horizon thicknesses are weighted by soil series in each group.

The water table in the Havana region slopes from Delavan westward toward Forest City and southwestward toward Beardstown in a configuration similar to the land surface (Walker et al. 1965). Locally, the groundwater moves toward the large drainage ditches in the township and then toward the Mason Tazewell Ditch that overlies the major bedrock valley in the area.

The terrane map (fig. 4.10) depicts major sand dune areas, predominantly sand and gravel terraces, and loamy textured deposits along the drainages. The sand dunes are separated from the sand and gravel areas mainly to indicate where steeper slopes may occur rather than to indicate significantly different material and hydrologic properties. Because the sand dunes are excessively well drained, runoff and water erosion is minimal. Because of the high permeability of the sediments covering the study area, these areas are most likely recharge zones for the aquifer.

The surface or near-surface position of the sand and gravel aquifer throughout the township creates a high risk for contamination by agricultural chemicals. Of the five areas selected for this pilot study, this situation represents the greatest potential for migration of agricultural chemicals. Not only is the aquifer material at or near the land surface, but it is also a coarse-textured sand and gravel deposit into which many shallow sandpoint wells have been emplaced. The deposit has minimal organic matter. Even though the Sankoty Sand may be the aquifer most heavily used in the area (Walker et al. 1965), the overlying Mackinaw Member exhibits essentially identical hydrologic characteristics and is also used as a source of drinking water.

GROUNDWATER HYDROLOGY

A substantial quantity of groundwater is present in the unconsolidated deposits. Walker et al. (1965) reported that the saturated thickness of the unconsolidated deposits ranges from 100 to 180 feet, with porosities ranging from 30% to 40%. In 1960, the elevation of the water table in the study area ranged from 480 to 500 feet above msl (Walker et al. 1965). The water-level contour map of Walker et al. (1965) indicates the flow direction of groundwater was along Quiver Creek toward the Illinois River. Water level contours prepared from measurements recorded in selected irrigation wells in 1989 (Bowman and Kimpel 1991) indicate that the water levels in the township ranged from 478 to 496 feet above msl (fig. 4.11). The flow direction appears to be from southeast to northwest in the west half of the study area and south to north in the east half.

Figure **4.10** Terranes of the Mason County study area.

Aquifer Tests

The unconsolidated deposits have hydraulic conductivities ranging from 4,000 to 7,500 gallons per day per square foot (gpd/sq ft) (Walker et al. 1965). In 1960, a 2-hour pump test at a site in this township, with a constant pumpage of 750 gallons per minute (gpm), yielded a calculated hydraulic conductivity of 7,600 gpd/sq ft and a transmissivity of approximately 1,250,000 gpd/ft. The saturated thickness of the aquifer at the pumping well was 165 feet. Records at the ISWS indicate that six additional short term pumping tests, for periods ranging from 2.0 to 5.5 hours, were conducted in different sections between 1960 and 1967. Pumping rates for these tests

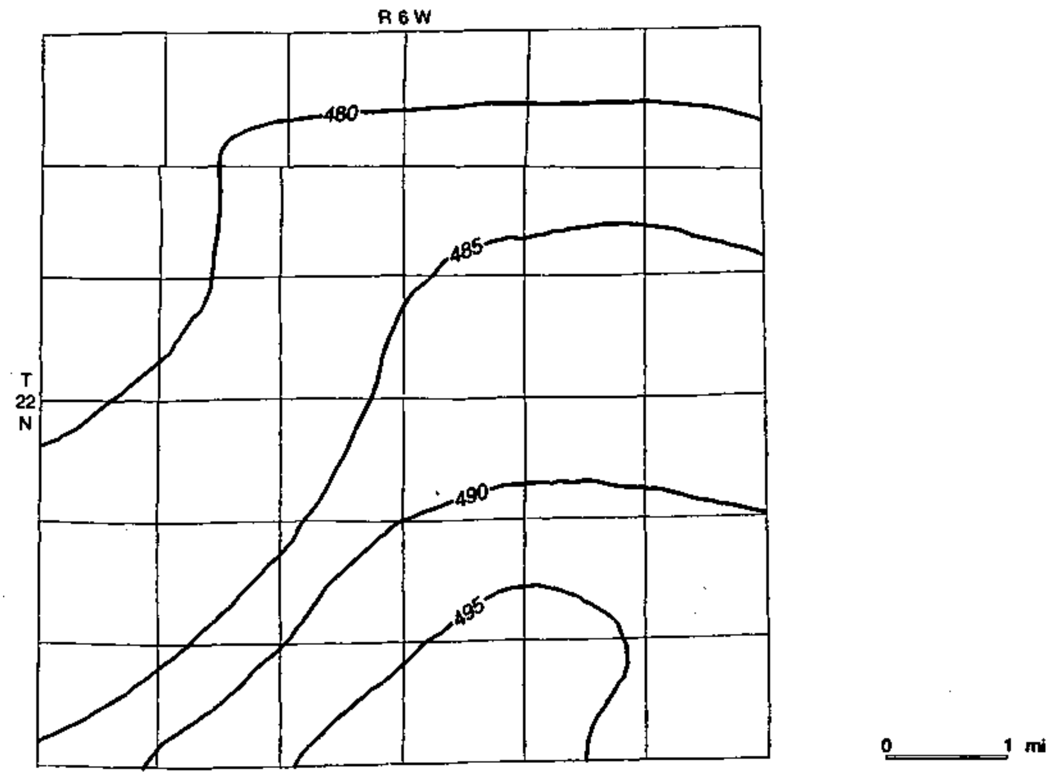


Figure 4.11 Piezometric surface in the Mason County study area. Elevation is in feet above msl; contour interval is 5 feet (from Bowman and Kimpel 1991).

varied from 300 to 1,200 gpm. The calculated hydraulic conductivities and transmissivities ranged from 1,690 to 5,750 gpd/sq ft and 160,000 to 870,000 gpd/ft, respectively.

Groundwater Use

Irrigation Groundwater in the study area is primarily used for irrigation. There is no industrial or municipal water supply system within the study area. Irrigation expansion in the past three decades has been dramatic (Bowman, personal communication, 1991). For example, in the entire Havana Lowland region, 11 irrigation systems were operating in 1960. Now, more than 800 systems irrigate about 100,000 acres (Bowman, personal communication, 1991). The study area is experiencing a similar trend.

Walker et al. (1965) calculated the recharge rate at about 490,000 gpd/sq mi for an area west of Manito, Illinois, approximately 4 miles northwest of the study area. The recharge for the study area, based on this rate, is estimated to be 179 million gallons per square mile per year for a total recharge exceeding 6,439 million gallons per year. Bowman et al. (1991) studied the biweekly water use of 61 irrigators in the Havana Lowland for the 1989 growing season, in addition to reviewing the total water use for 28 other irrigators in the same area. The average application rate in the 1989 growing season was 14.5 inches. During the drought of 1988, however, the average water application in the Havana Lowlands area was 23.5 inches. They also found that the application rates for 14 irrigators in Forest City Township (the study area) during the growing season of 1989 to be between 6.1 and 13.7 inches, with an average of 9.3 inches (only 64% of the average application in the Havana Lowlands). The annual irrigation application for the Mason County study area, based upon this amount of water (9.3 inches), is estimated to be 2,778 million gallons for 11,000 acres. The total estimated water withdrawal for the 11,000 irrigated acres in the study area, based on the application rate of 23.5 inches for the drought year of 1988, is 7,019 million gallons. Thus, for the drought year of 1988, the ratio of use to recharge was about 1.1 to 1 for our study area.

Given a per capita water use of 70 gallons per day, domestic use is estimated to be 14.5 million gallons per year. The livestock water use, determined from 1979 township statistics (IDOA 1979) and the water requirements for livestock (Kirk 1987), is estimated not to exceed 4.5 million gallons per year. Therefore, the total annual use for the study area is only 43% of the recharge volume.

It should be pointed out that in a drought year, the recharge is substantially less than the recharge in a normal year. An overdraft existed in 1988. On a long term basis and in the absence of frequent droughts, however, the use is substantially less than the volume of recharge. During the 1983 drought conditions in Illinois, the pumpage in the growing season from the sand and gravel aquifers exceeded the yield during that period of the year (Bowman and Collins 1987). On an annual basis, however, no overdraft was created. The situation might alter under conditions of extended drought. The high recharge rate is one of the reasons the water level in wells has not declined in the past 30 years.

Expansions in irrigation Total irrigated acreage in the study area is expected to increase. Given a 50% increase, the total average annual application, based on 12 inches of supplemental irrigation, would be 4,200 million gallons. The pumpage-to-recharge ratio would still only be 0.66 on an annual basis. If drought-year applications are assumed to be about 24 inches, the pumpage-to-recharge ratio would be 1.32 on an annual basis. In the absence of prolonged drought, overdraft during a single drought year could easily be replenished by the recharge in the following year(s).

SUMMARY AND CONCLUSIONS

The coarse-textured sediments that mantle Forest City Township vary little in thickness, physical characteristics, and hydrologic properties, although the thickness may vary considerably in areas where bedrock valleys exist adjacent to this township. The predominance of sand and gravel deposits and the minimal thickness and geographic extent of medium- and fine-textured sediments contribute to the lack of variety in the soil parent materials, the simplicity of the vertical sequence of geologic materials (stack units), and the homogeneity of the terranes. The study area contains no significant deposits of fine-textured deposits that could serve to attenuate a contaminant stream before it would reach the sand and gravel aquifer that is at or near land surface over the entire area. The low organic content of the soils and the high hydraulic conductivity of the unconsolidated sediments contribute to the high probability for contamination of aquifers. The number of shallow private water wells coupled with a water table that is close to the surface result in hydrogeologic conditions that appear to indicate a high potential for contamination of domestic water supplies by agricultural chemicals.

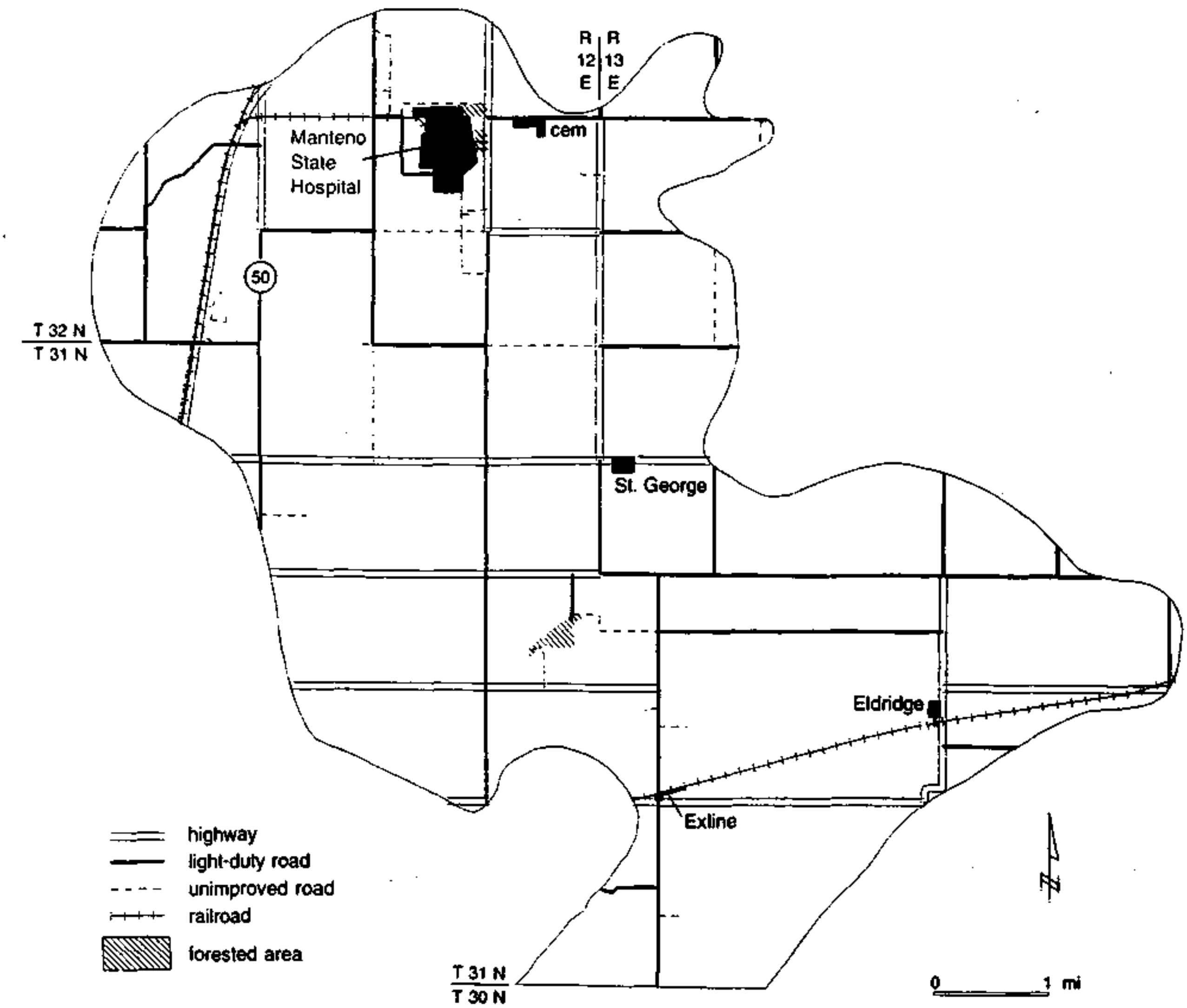


Figure 5.1 Kankakee County study area.

5 CHARACTERIZATION OF THE KANKAKEE COUNTY STUDY AREA

M. L Barnhardt, C. Ray, and M. R. Greenpool

LAND USE

Description of the Study Area

The odd shape of the 36-square-mile study area (fig. 5.1; parts of T31N, R13E; T31N, R12E; T32N, R12E; and T32N, R12E) results primarily from our adherence to the site-selection criterion of aquifers occurring within 5 and 20 feet of land surface. The cities of Bradley and Momence are located just southwest and southeast of the study area, respectively. Interstate highway 57 parallels the west boundary of the study area and Illinois State highway 50 traverses the northwest corner, parallel to the Illinois Central Gulf railroad. The Penn Central railroad crosses east-west along the southern part of the study area. Approximately 18 miles of medium-duty roads, 30 miles of light-duty roads, and 3 to 4 miles of gravel roads are present and generally form section boundaries.

A petroleum pipeline is located in the northwestern part of the study area, and another passes through the center of the study area in a northeast-southwest direction (fig. 5.2). Other smaller natural gas pipelines, which supply suburban Chicago customers, are present in the area.

Of the 188 households in the study area, 120 (64%) were active farms, 43 (23%) were rural residents, and the remaining 25 (13%) were unclassified. Of the 48 randomly selected well users, 18 (38%) were farmers (table 3.3).

Industrial and Commercial Operations

The study area is adjacent to the urban areas of Bradley, Kankakee, Manteno, and Momence, and there are several industrial and commercial operations in these urban areas. A large sand and gravel quarry and an asphalt plant are located in the western part of the study area (fig. 5.2). The study area has two general repair shops, but no gas stations. A grain elevator, an agricultural chemical facility, and a discontinued sewage treatment facility located at the former Manteno State Hospital site make up most of the remaining commercial structures.

GEOLOGY AND HYDROGEOLOGY

Introduction

This study area represents a hydrogeologic setting in which the depth to the top of the uppermost aquifer is within 5 to 20 feet of the land surface. The area is characterized by thin drift overlying permeable bedrock. The fractured Silurian dolomite is a significant local aquifer. Deposits of sand and gravel overlying the dolomite provide avenues for groundwater recharge and discharge; they are also a significant source of groundwater for low volume users. Fine-textured glacial tills and lacustrine sediments provide a greater degree of protection for the permeable dolomite aquifer from infiltrating agricultural chemicals than sand and gravel deposits, but their lack of thickness and lateral continuity may limit their effectiveness.

Previous Studies

A variety of research related to landfill siting (Kempton, unpublished map) and groundwater-resource assessment (Cravens et al. 1990) has been conducted in the Kankakee and Iroquois County region. Kempton's maps were part of a geology-for-planning project for Kankakee County. Cravens et al. (1990) used Kempton's geologic maps and additional unpublished maps by Smith and Dey to aid in their assessment of the groundwater resources of Kankakee and northern Iroquois Counties with respect to future development, especially the effects of

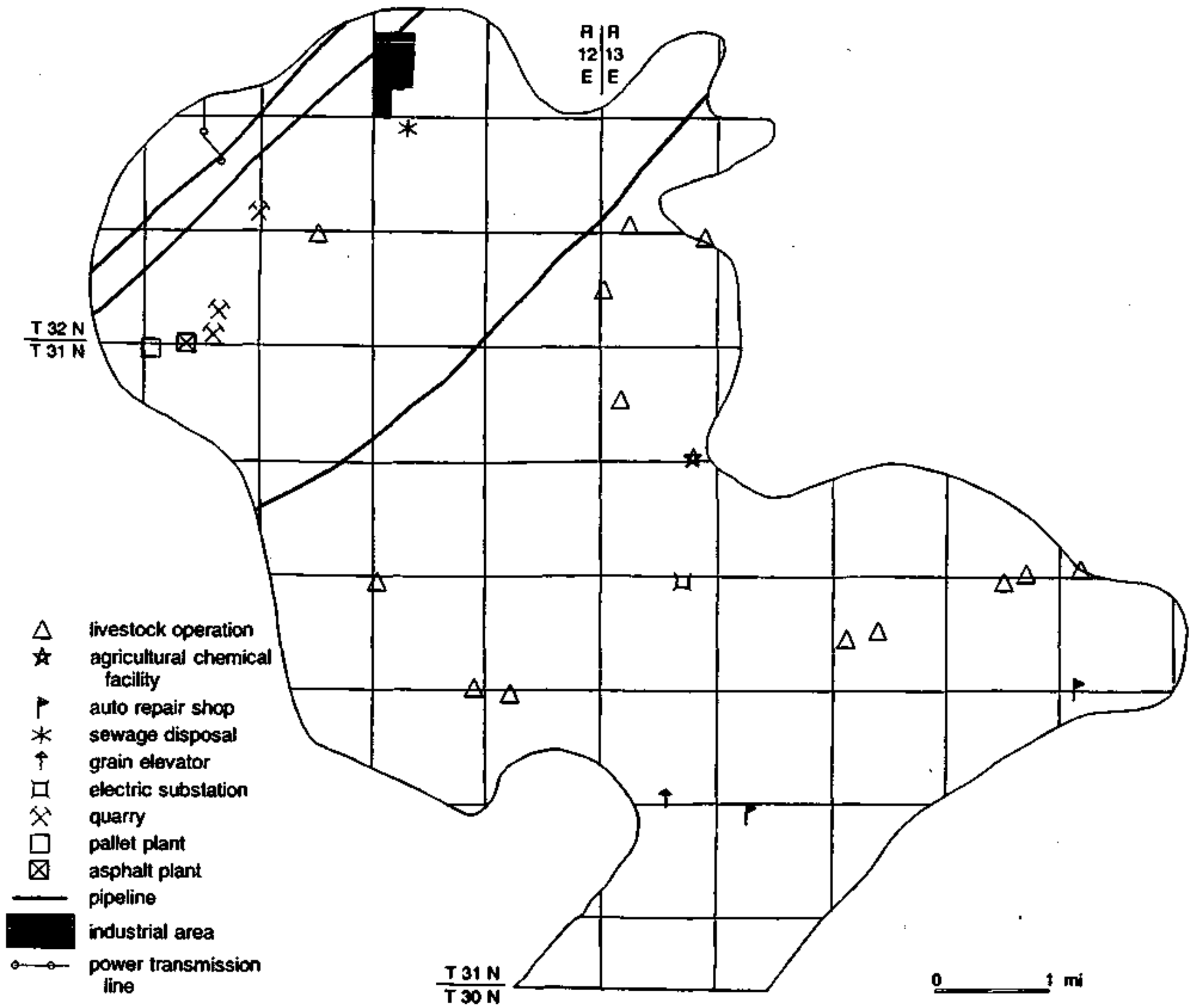


Figure 5.2 Potential sources of contamination in the Kankakee County study area.

increased irrigation. A considerable amount of research has been conducted on the glacial history of the area (e.g., Willman and Frye 1970) and the geology in the vicinity of the Kankakee River (Carnaghi 1979, Gross and Berg 1981).

Physiography and Drainage

The elongated study area (fig. 5.1) ranges in elevation from a low of around 610 feet above msl along the south boundary, near the Kankakee River, to a high of about 690 feet along the northwest and northeast boundaries. The study area's proximity to a melting Wisconsinan ice sheet contributed to an abundance of landforms, including moraines, deltaic aprons, lacustrine basins, and sand dunes. The combination of local relief, fine-textured tills and lacustrine deposits, and coarse-textured outwash deposits has led to an abundance and variety of floodplain, slopewash, and accretion deposits.

The drainage network (fig. 5.3) is part of the Kankakee River basin. Tower Creek, Farr Creek, Exline Slough, and Soldier Creek drain southward toward the Kankakee River, and the south branch of Rock Creek flows along the northwest edge of the study area. Some human modification of the channels in their lower reaches has occurred for drainage purposes. The topo-

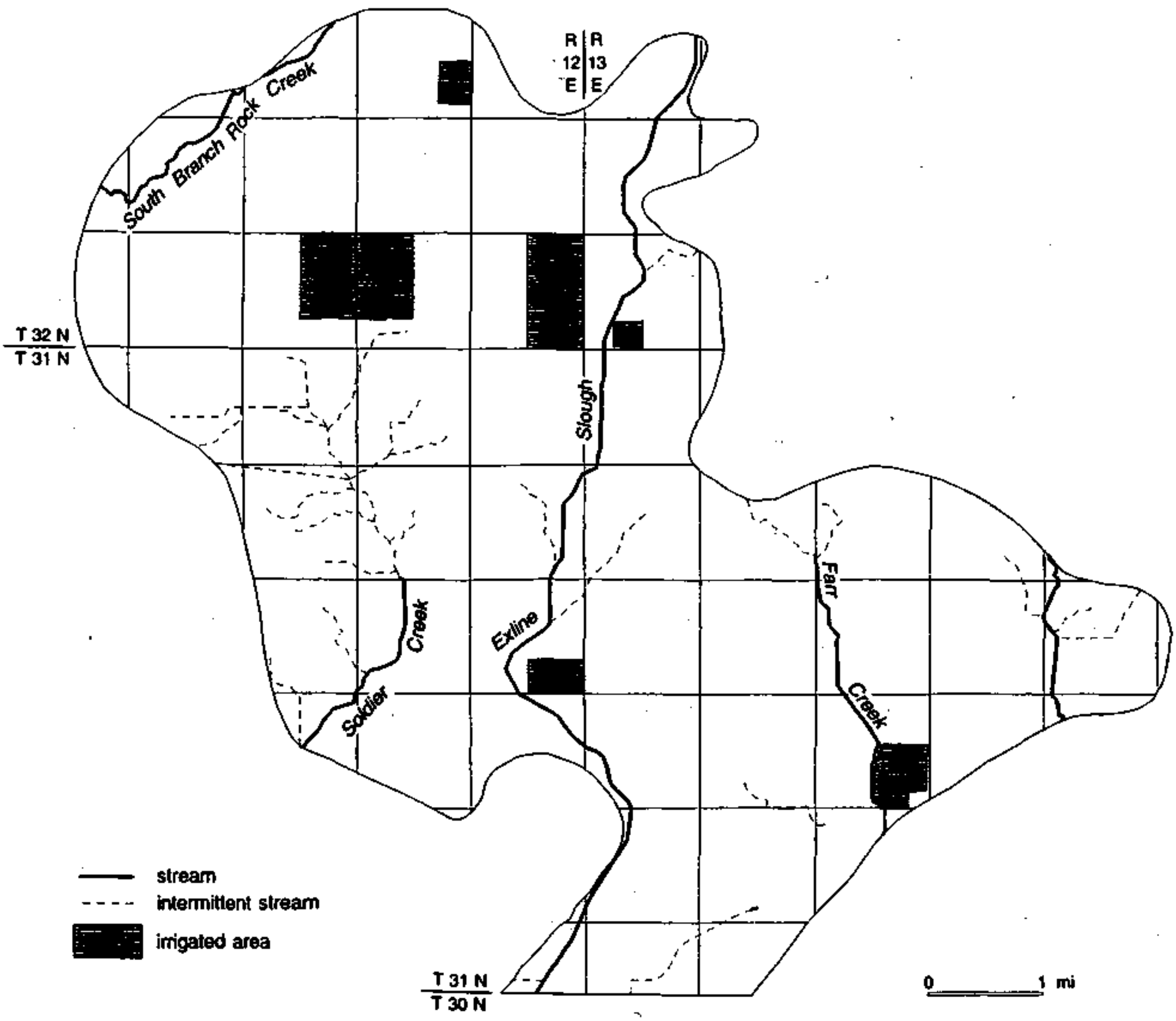


Figure 5.3 Drainage of the Kankakee County study area.

graphic gradient is generally from north to south, with a relief of about 60 feet in the center part of the study area. The abundance of fine-textured sediments with low permeabilities creates a potential for runoff. Less than 1% of the soils in the study area are classified in Hydrologic Group A (high infiltration, low runoff potential, and high water transmission rate), about 32% are classified as Group C (slow infiltration when wet), and 16% are in Group D (very slow infiltration, high runoff potential, and very slow water transmission).

Bedrock Geology and Topography

In the Kankakee County study area, bedrock generally occurs between 5 and 25 feet of land surface. The principal aquifer in this region is fractured Silurian dolomite (Cravens et al. 1990, Smith and Dey, unpublished map). The stratigraphic position, topography, and depth below the land surface of the bedrock aquifer are illustrated in figures 5.4, 5.5, and 5.6, respectively. The bedrock surface generally dips southward toward the Kankakee River where, in places, the river flows over bedrock (Gross and Berg 1981). Two narrow, buried bedrock valleys enter the study area along the east-central boundary and along the south boundary. Their location coincides with the thickest Quaternary sediment in the study area (fig. 5.6).

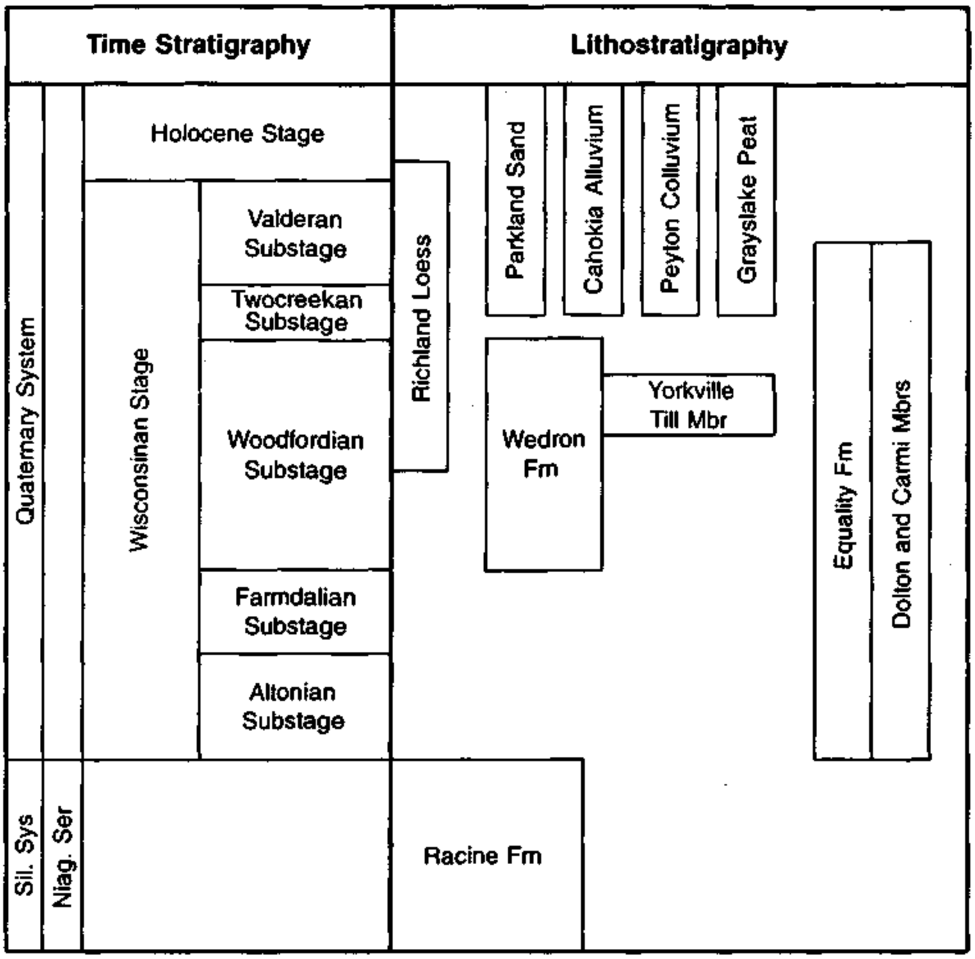


Figure 5.4 Lithostratigraphy of the Kankakee County study area.

Thickness of Quaternary Deposits

Although the thickness of the Quaternary deposits is generally uniform across the study area, bedrock occurs at or near the land surface in some areas. Drift thickness is generally less than 25 feet. It is thicker in the east-central area, where it overlies a buried valley and drift thickness exceeds 75 feet, and in the southernmost area, where it exceeds 50 feet (figs. 5.6 and 5.7). Drift thickness increases toward the northeast close to the Wilton Center Moraine; it increases again to the south of the study area, where accumulations of Parkland Sand occur. The variable thickness of the unconsolidated deposits throughout the study area is illustrated by the cross sections (fig. 5.7). The distribution of thin, loamy outwash or loess over limestone bedrock (i.e., bedrock within 5 feet of land surface) is shown in fig. 5.8. Sediment thickness is also quite variable along drainageways.

Lithostratigraphy

Silurian System Fractured dolomite of the Racine Formation (Niagaran Series) lies below **a** thin, discontinuous mantle of glacial sediments (figs. 5.4, 5.5, 5.6, and 5.7). It is the principal aquifer in the township (Cravens et al. 1990) and the unit in which most wells are finished. Lower Silurian Alexandrian Series rocks are thin in the study area, and the Niagaran rocks make up the bulk of the Silurian in central arid eastern Kankakee County (Kempton, unpublished data). Textural variability in the overlying unconsolidated sediments produces **a** range of conditions in this aquifer. Within a small geographic area, it can be mantled by either fine-

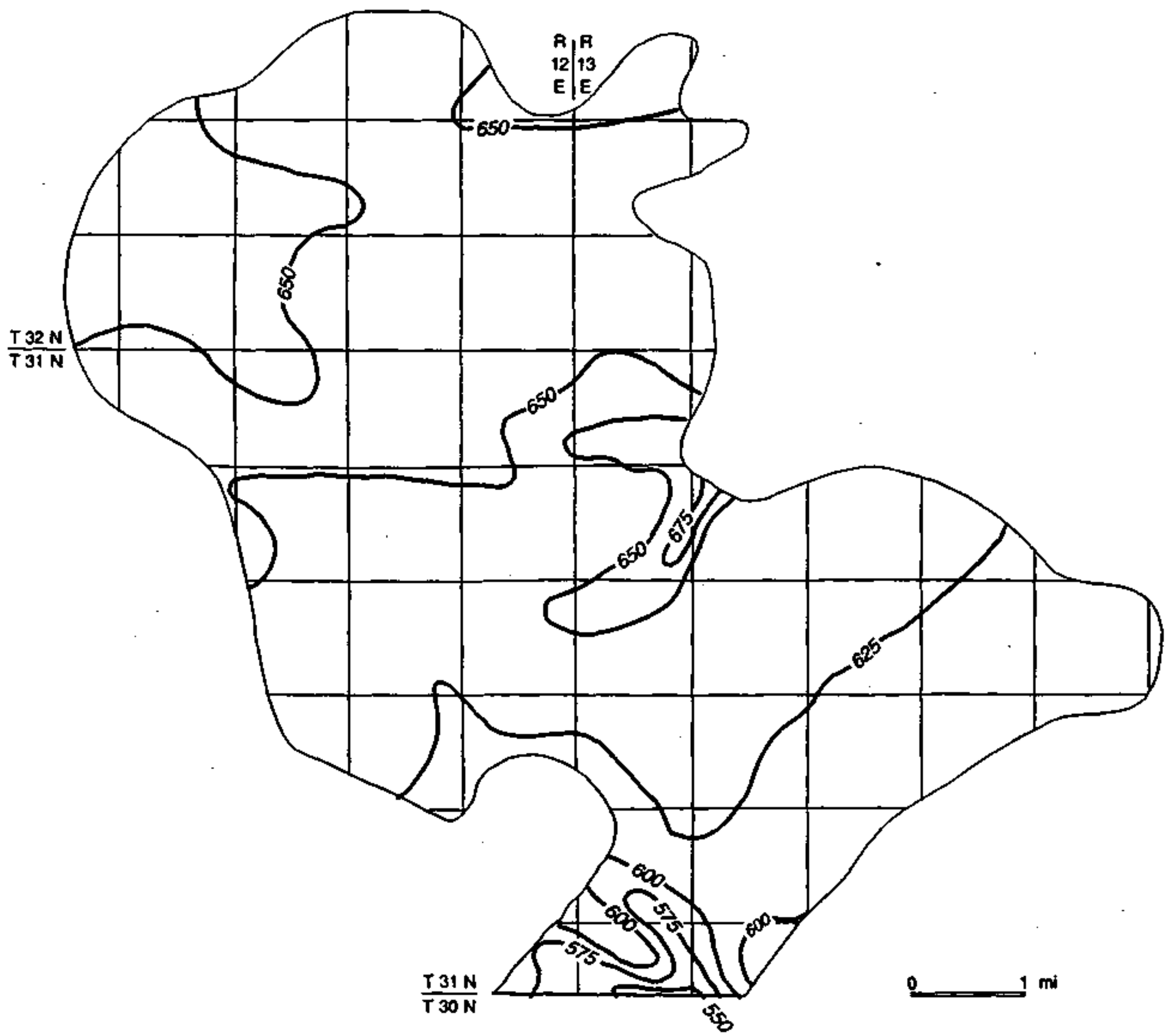


Figure 5.5 Topography of the bedrock surface in the Kankakee County study area (modified from unpublished maps by Kempton). Elevation is in feet above msl; contour interval is 25 feet.

textured till and lacustrine sediment or coarse-textured outwash. The shallow depth to bedrock is reflected in the parent materials that are influenced by bedrock (fig. 5.8).

Quaternary System All of the deposits overlying the Silurian dolomite in the study area are unlithified Quaternary sediments (fig. 5.7). Wisconsinan Stage deposits (till, outwash, loess, and lacustrine deposits) are the dominant units, but they are capped by alluvial, colluvial, eolian, and peat deposits locally. The geographic location, spatial variability in thickness, and stratigraphic position of these sediments have created a variety of parent material combinations for soil development and complexity of stack-unit mapping (figs. 5.7, 5.8, and 5.9).

Wedron Formation The major glacigenic deposit in the study area is a clayey diamicton recognized as the Yorkville Till Member. Other than a thin loess cover, this till is the surficial deposit over 40% of the area (fig. 5.9). It comprises the morainic uplands that dominate the northern part of the area, where the till overlies bedrock (figs. 5.7 and 5.9). These moraines are part of the Valparaiso Morainic System deposited by the Lake Michigan Lobe near the end of the Woodfordian Subage (Gross and Berg 1981).

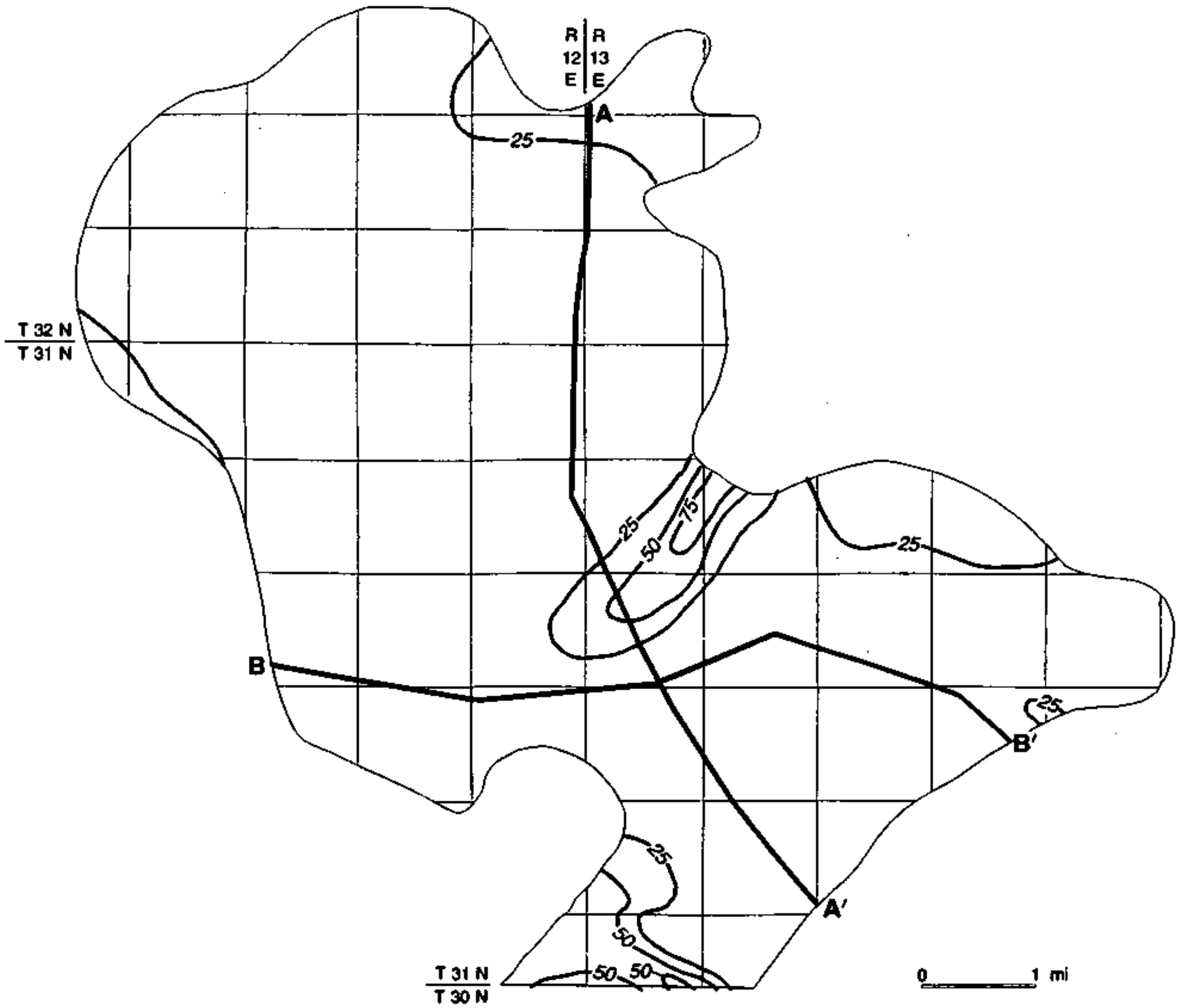


Figure 5.6 Thickness of drift deposits in the Kankakee County study area (modified from unpublished maps of Kempton, and those of Berg and Kempton). Contour interval is 25 feet. Location of transect lines is shown for cross sections A-A' and B-B'.

Equality Formation Related to the development of the Valparaiso Morainic System was the deposition of vast quantities of poorly sorted sands, gravels, and boulders by meltwater and the deposition of finer silts and clays in proglacial lakes. Drainage from the Lake Michigan Lobe discharged westward through the Kankakee River Valley. Extensive lakes formed throughout the study area as discharge increased along the Lake Michigan, Saginaw, and Erie Lobes. The Carmi Member (lacustrine silts and clays) and the Dolton Member (lacustrine sand with some silt and gravel) represent those deposits (Willman et al. 1975). The Carmi Member has limited extent in the study area and is found only in the northern part. The Dolton Member covers almost 40% of the study area, predominantly in the southern half (fig. 5.9). The Kankakee Flood shaped the most of the landscape in the Kankakee River Basin (Gross and Berg 1981, Willman and Frye 1970), as well as the landscape along much of the Illinois River Valley (Hajic 1990).

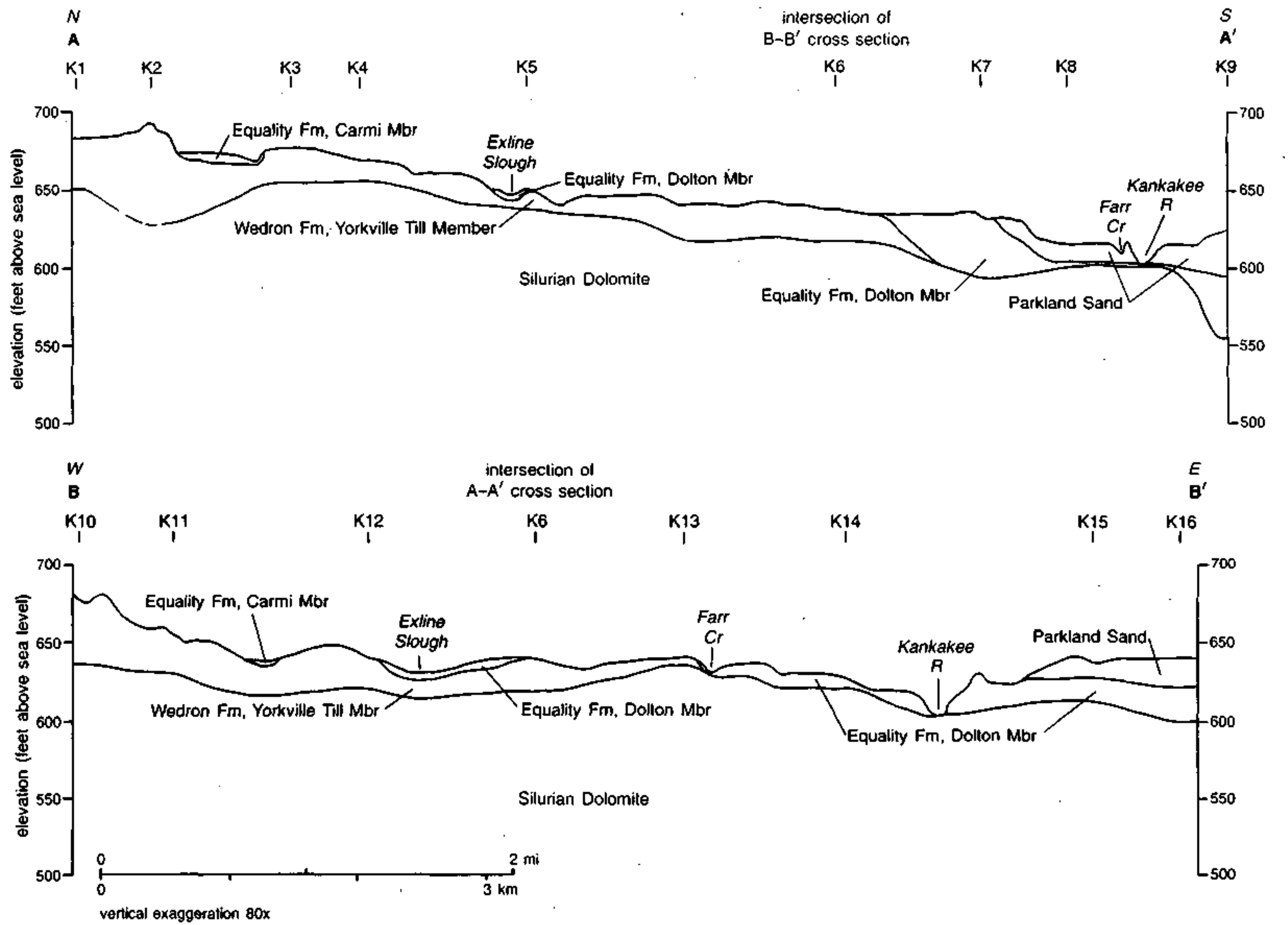


Figure 5.7 Cross sections A-A' and B-B' for the Kankakee County study area.

Figure 5.8 Parent materials of the Kankakee County study area.

Group

1 thin loess or silly lacustrine overlying silty clay till

2 thin loess or silty lacustrine overlying clayey till

3 loamy lacustrine

4 loamy and sandy deposits

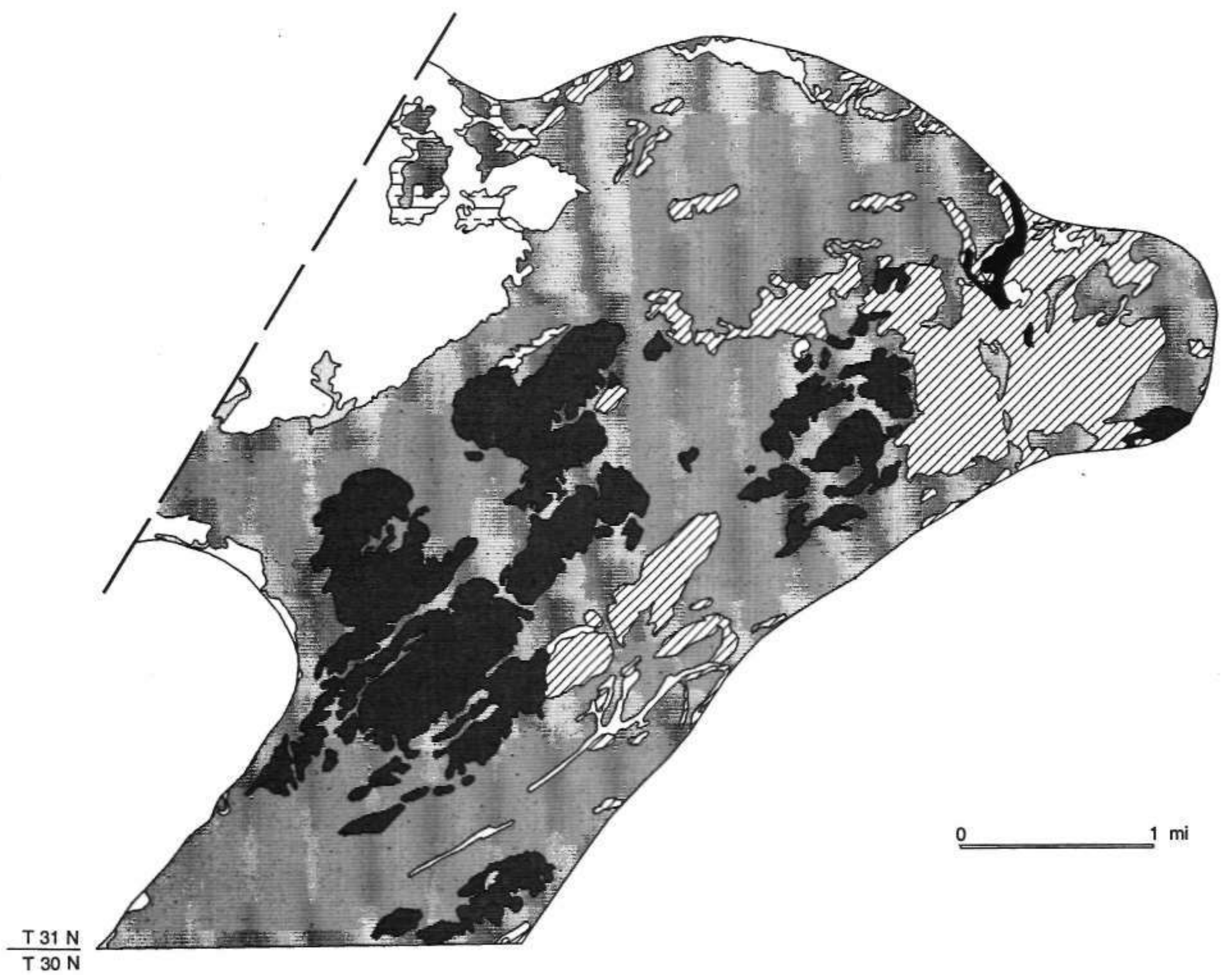
5 thick, sandy deposits

6 thin, loamy deposits or loess overlying dolomite bedrock

7 alluvium

8 organics (muck)

Q quarry



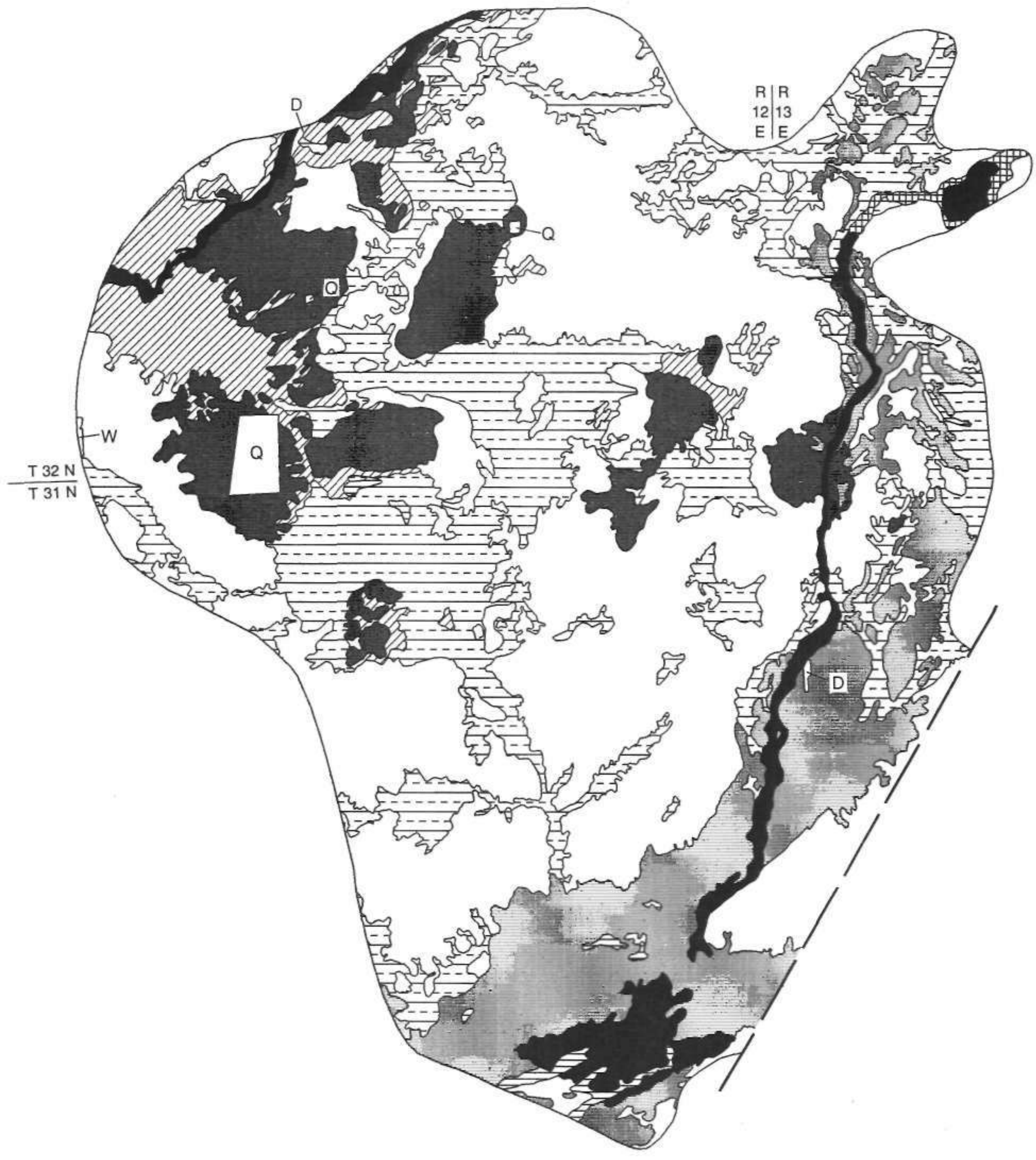
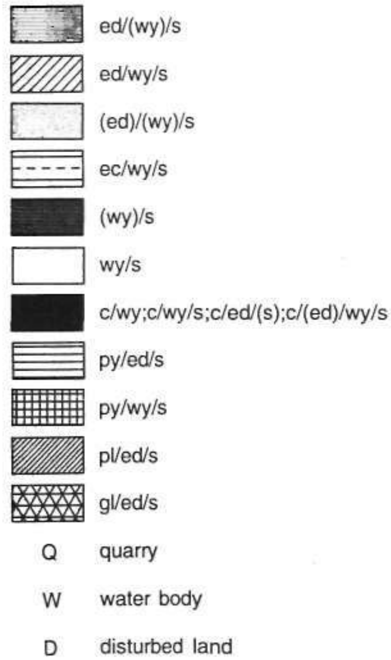
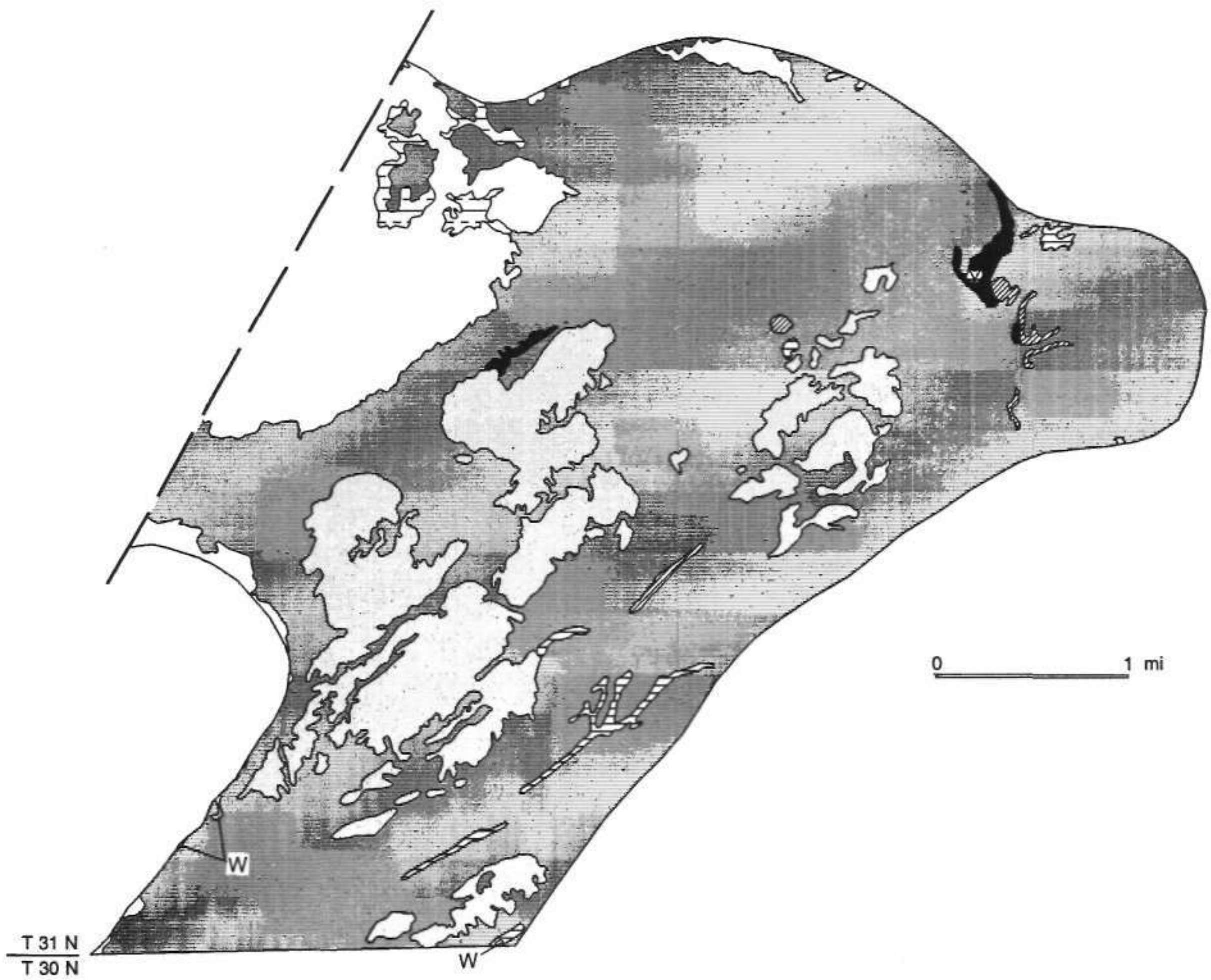


Figure 5.9 Stack-unit map of the Kankakee County study area.

gl Grayslake Peat
py Peyton Colluvium
c Cahokia Alluvium
pl Parkland Sand
ec Equality Formation, Carmi Member
ed Equality Formation, Dolton Member
wy Wedron Formation, Yorkville Till Member
s Silurian Dolomite
( ) continuous throughout map area but less than 20 ft thick in some areas





Richland Loess This deposit is generally less than 2 feet thick throughout the study area and is modified by the Modern Soil. Where it overlies silty lacustrine deposits, it is difficult to differentiate from the underlying materials.

Cahokia Alluvium This formation consists of poorly sorted silt, clay, and silty sand deposited along modern floodplains and stream channels (Willman et al. 1975). It is mainly Holocene in age, but it may be Woodfordian in some places (Willman et al. 1975). In the study area, it overlies Yorkville Till in the northern part, where higher slope gradients and lower infiltration rates promote runoff and soil erosion. In the southern areas, where Dolton sand dominates the surficial sediments, Cahokia Alluvium is less abundant. About 15% of the study area is covered by Cahokia Alluvium (fig. 5.9).

Parkland Sand The Parkland Sand is a windblown sand, mostly late glacial in age. After the Kankakee Flood, wide expanses of sand were exposed to the wind, allowing the finer sand to be reshaped into extensive sand dune deposits. This formation covers less than 1% of the study area, near the south boundary (fig. 5.9). Immediately south of the Kankakee River, however, thick and extensive deposits of Parkland Sand are found (Gross and Berg 1981).

Peyton Colluvium and Grayslake Peat Less than 1% of the study area (fig. 5.9) is covered by slopewash (Peyton) and peat or muck deposits (Grayslake). The Peyton Colluvium is found overlying both the Dolton Sand and Yorkville Till, but it is located primarily in the northern part of the study area, where steeper slopes occur. This formation consists of poorly sorted sediment of slopewash, creep, and mudflow processes (Willman et al. 1975). The Grayslake Peat is found sporadically overlying the Dolton Sand, where poorly drained conditions promote the accumulation of organic material.

Soils and Parent Materials

A combination of multiple parent materials (fig. 5.8) with varying textures has led to the development of 43 soil series in the county. Of these, 34 occur within the study area (Paschke 1979). Moraines, lacustrine deposits, outwash, sand dunes, and bedrock (occurring at or near land surface) provide a wide variety of topographic, textural, and drainage combinations. Several soil associations are important in the study area because of their widespread occurrence and effects on infiltration and drainage.

The Beecher-Milford association covers about 31% of the study area. This association of deep, slowly and moderately permeable soils occurs on flat to gently sloping surfaces on fine-textured lacustrine (Carmi) and glacial till (Yorkville) parent materials in the north half of the study area (fig. 5.9). The Selma-Darroch-Jasper association covers about 27% of the study area. These deep, moderately permeable soils occur on flat to gently sloping upland surfaces in sandy deposits (Dolton, Parkland). They are found mainly in the south half of the study area (fig. 5.9). About 12% of the study area is covered by the Rockton-Plattville-Selma (bedrock) association, which consists of deep or moderately deep, moderately permeable soils developed in medium-grained (sandy silty) deposits over Silurian limestone. The Elliott-Varna-Ashkum association covers about 9% of the study area and consists of deep, moderately permeable soils developed in moderately fine-textured glacial till (Yorkville) on uplands. They are spatially associated with the Beecher-Milford association and together cover more than 40% of the study area.

In addition to permeability, organic matter content (organic carbon) plays a role in pesticide migration because it affects pesticide adsorption (McKenna et al. 1990). The eight parent material groups found in the study area are generally high in organic matter and low in permeability, but differences are apparent across the various glacial sediments (table 5.1). More than 95% of the soils developed in these sediments are rated as high in organic matter. Values range from 3.6% to 5.3% within the upper 12 to 25 inches. Only the soils developed in sandy outwash or eolian sand exhibit high permeabilities. Overall, the great majority of soils in this study area can be characterized as being high in organics and low in permeability. The general

Table 5.1 Soil permeability and surface organic matter content in Kankakee County study area.

Parent material group[a]	Permeability[b,c] (in./hr)	Organic matte[d] (avg. %/avg. thickness)	% of study area
1—Thin loess or silty lacustrine overlying silty clay till	0.6-2.0 (upper 14.3 in.) 0.2-0.6 (silty clay till)	3.7 for upper 13.6 in.	32
2—Thin loess or silty lacustrine overlying clayey till	0.6-2.0 (upper 33.0 in.) 0.06-0.2 (clayey till)	5.2 for upper 12.5 in.	1
3—Loamy lacustrine	0.6-2.0 (upper 15.3 in.) 0.2-0.6	5.3 for upper 15.3 in.	15
4—Loamy and sandy deposits	0.6-2.0	4.1 for upper 14.0 in.	33
5—Thick, sandy deposits	2.0-6.0 (upper 30.0 in.)	2.5 for upper 14.3 in.	5
6—Thin loamy deposits or loess overlying dolomite bedrock	0.6-2.0	3.6 for upper 14.1 in.	12
7—Alluvium	0.2-2.0	5.0 for upper 25.6 in.	1
8—Organics (Muck)	—	65+	<1

[a] See parent material map (fig. 5.8) for distribution.

[b] Data for permeability and organic matter from Paschke (1979).

[c] The second range of values represents permeability for sediments below the initial unit unless another material is identified.

[d] Percentages and horizon thicknesses are weighted by soil series in each group.

lack of thickness of the parent materials in which the soils have formed, however, may decrease the potential of the soils to protect the shallow bedrock aquifer in this area.

Hydrogeology

General hydrogeologic considerations About two-thirds of the study area can be characterized as medium- and coarse-textured sediments with moderate to high infiltration rates and permeability. The thickness of unconsolidated deposits is generally less than 25 feet throughout most of the study area and bedrock is within 10 feet of the land surface in many places (figs. 5.6, 5.7, 5.8, and 5.9). The thickness and texture of overlying sediments contribute to the potential protection an aquifer will receive from those deposits. Thick, compact, fine-textured sediments will offer greater protection than thick, coarse-textured sediments.

Aquifers and groundwater movement In their investigation of the groundwater resources of Kankakee and Iroquois Counties, Cravens et al. (1990) noted that the groundwater flow through the Silurian dolomite of this area is affected by discontinuities, such as vertical joints and horizontal separations occurring predominantly within the upper 100 feet. The recharge to the dolomite is derived primarily from vertical leakage of groundwater from overlying unconsolidated deposits. Using flow-net analysis, they estimated the recharge to the aquifer through layers of clay or till to be from 86,000 to 126,000 gpd/sq mi and recharge through coarse-grained sediments to be from 245,000 to 285,000 gpd/sq mi.

All of the well log records examined indicate that the water wells are completed in bedrock rather than in the overlying sand and gravel. Shallow sandpoint wells are present but make up a small proportion of the total number of rural water wells. Even where the finer textured till and lacustrine sediments exist, their thickness and lateral continuity is variable, especially in the southern parts of the study area. This variability limits their capability to protect the shallow aquifer. Furthermore, any fracturing in the till or intermixed sand and gravel lenses will increase the probability of contaminants infiltrating downward to the bedrock aquifer.

The regional topographic slope is toward the Kankakee River, which runs westward along the south border of the study area. Along the slope, the geologic deposits become coarser and the dolomite bedrock is nearer the land surface. These conditions make the bedrock aquifer vulnerable to contamination.

GROUNDWATER HYDROLOGY

Groundwater movement within the dolomite aquifer occurs primarily in secondary permeability features such as joints, fissures, solution channels, and bedding planes. Vertical and horizontal flow paths, both irregular in space (Csallany and Walton 1963), constitute the predominant water-yielding capacity of the aquifer. Cravens et al. (1990) delineated surface lineaments in two areas approximately 6 miles south of the study area, where bedrock underlies less than 25 feet of sand, and concluded that the lineaments may be surface expressions of fractures in bedrock.

Calculated Transmissivities for the Bedrock Aquifer

Given the directions of lineaments and presence of secondary porosities, the flow in the dolomite aquifer system may respond anisotropically at a local scale (Cravens et al. 1990). The anisotropy may be averaged out, however, at a regional scale. Results from six aquifer tests southeast of the study area (Cravens et al. 1990) yielded transmissivities ranging from 14,000 to 122,500 gpd/ft and storativity values ranging from 0.00004 to 0.0006. Test results indicated that directional variation of transmissivity is insignificant (Cravens et al. 1990).

Cravens et al. (1990) analyzed published discharge and corresponding drawdown (specific-capacity) data for 885 wells from drillers' logs. They assumed an aquifer thickness of 100 feet (because most of the fractures are in the upper 100 feet) and a storage coefficient of 0.0001. A computer program written by Bradbury and Rothschild (1985) was used to estimate transmissivity from the specific-capacity data. The specific-capacity data and calculated transmissivity values were found to have a log-normal distribution. The median transmissivity was 7,244 gpd/ft. The minimum and maximum calculated transmissivity values were 18 and 244,881 gpd/ft, respectively. Figure 5.10 shows the areal distribution of the log-normal transmissivity values across the Kankakee County study area.

Transmissivities determined from aquifer tests of high-capacity municipal or irrigation wells appear to have a narrower range of values than those determined by the specific-capacity method. Cravens et al. (1990) reported that the specific capacity of bedrock-penetrating wells decreases as well depth increases. The mean specific capacity for wells penetrating 100 to 400 feet of fractured bedrock (based on the analysis of industrial, irrigation, and public water wells) was 19.9 gpm/ft, but it decreased to 5.1 gpm/ft when the well depth exceeded 400 feet (up to 600 feet).

Calculated Transmissivities for the Sand and Gravel Aquifer

A review of the records of water well logs and the initial interviews with residents indicate that only a limited number of residents use water from the shallow deposits of sand and gravel above the bedrock aquifer for domestic and livestock use (these wells were initially inventoried, but they were not used for sampling in the pilot study). In their study, Cravens et al. (1990) determined that only 71 out of 2,434 documented wells (less than 3%) obtained water from unconsolidated deposits. Suction-type pumps are often used where the depth to water is shallow. An aquifer test near Hopkins Park indicated that the shallow aquifer has a transmissivity of 11,600 gpd/ft and a hydraulic conductivity of 232 gpd/sq ft. (Cravens et al. 1990). Using a specific yield of 0.1, a saturated thickness of 40 feet, and hydraulic conductivities of 490 and 690 gpd/sq ft, they calculated the transmissivity of 20,000 and 31,000 gpd/ft, respectively, for two high capacity wells in the same area.

Cravens et al. (1990) monitored the water levels in eight shallow observation wells in the Hopkins Park area from November 1987 to September 1988. At six of the seven localities at which a clay or till confining layer separates the bedrock aquifer from the shallow sand and gravel aquifer, the observation well data indicated that pumping of water in high capacity bedrock wells does not cause substantial drawdown in the shallow wells screened above the confining layer. They calculated the vertical hydraulic conductivity of the clay or till aquitard on

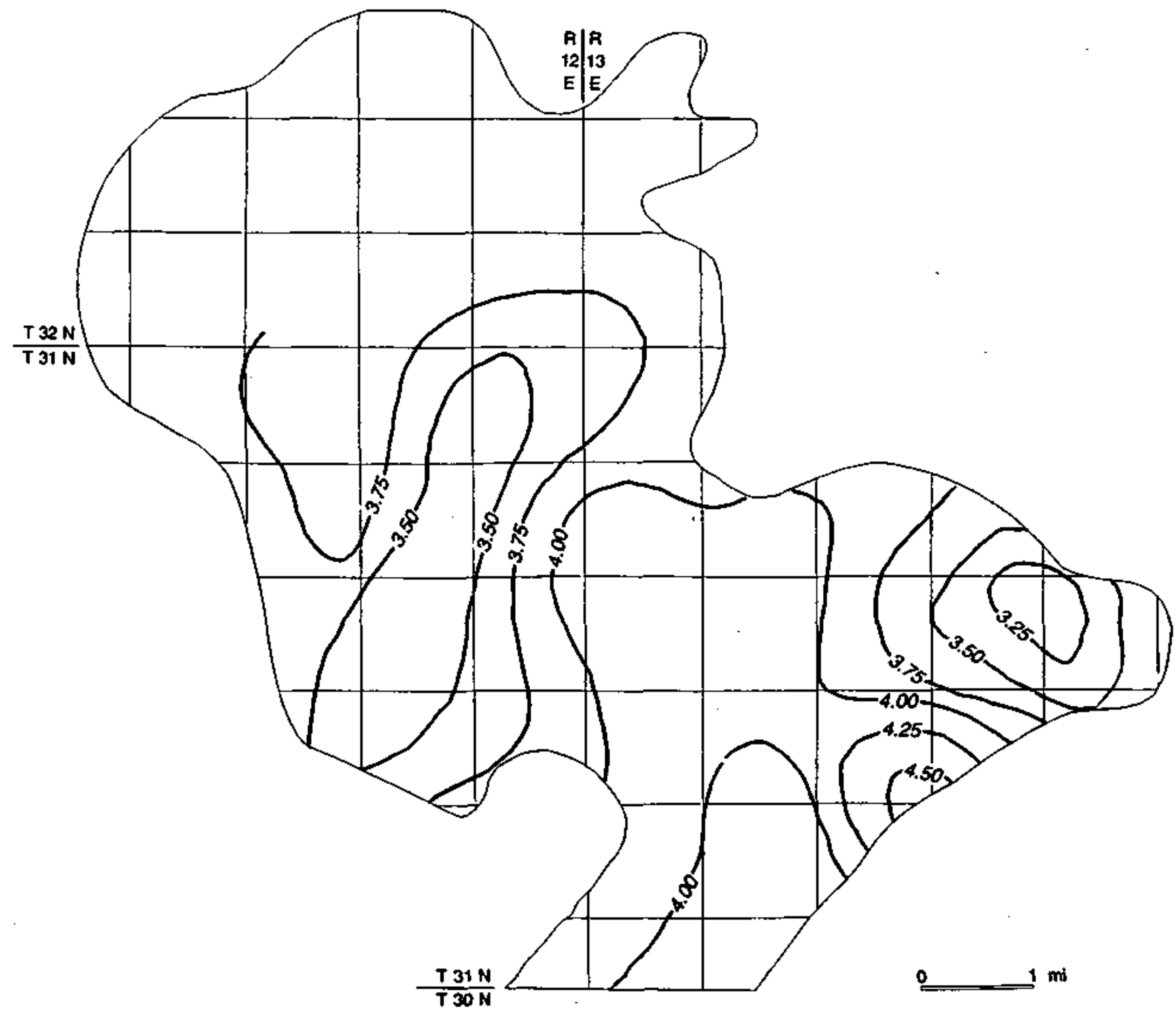


Figure 5.10 Transmissivity distribution of the dolomite aquifer in the Kankakee County study area (Cravens et al. 1990; no data are available for the northern part of this study area). Contour interval is 0.25 $\log_{10}$ transmissivity.

the basis of recharge data, aquitard thickness, and differences in hydraulic head across the aquitard. The vertical hydraulic conductivity of clay or till ranged from 0.007 to 0.031 gpd/sq ft.

Recharge of Bedrock Aquifer

Downward movement of soil water and leakage from influent, or losing, stretches of rivers and creeks recharge the bedrock aquifer (Cravens et al. 1990). The low vertical hydraulic conductivity of fine-textured sediments slow recharge. Approximately one-half of the study area is covered by fine-textured sediments over bedrock. Recharge to the bedrock aquifer also varies, depending on the head gradient between the shallow aquifer and the bedrock aquifer. The higher the head differential, the greater the vertical flux and recharge. Pumping of the bedrock aquifer would increase the vertical head gradient. Continued pumping could cause the artesian condition in the dolomite to change to water table conditions, thereby reducing yield.

Water levels measured in wells along the Kankakee and Iroquois Rivers from May 3 to 5, 1988, indicate that both of the rivers receive groundwater in some areas, but the Kankakee River recharges the bedrock aquifer in other areas (Cravens et al. 1990). For the Kankakee River between Momence and Aroma Park (southeast of the study area, where the bedrock is near land surface), the head of shallow groundwater was 0.42 to 4.98 feet above the river stage. This indicates that groundwater is discharged to the river in this reach. For 1985 to 1987, Cravens et al. (1990) estimated rates of groundwater runoff from both surficial and bedrock aquifers at the Momence and Chebanse gaging stations on the Kankakee and Iroquois Rivers. They calculated mean and median base flows of the Kankakee River at Momence to be 0.83 and 0.75 cubic feet per second (cfs)/sq mi, respectively.

Water Use

Given an estimated application rate of 20 inches of water per year for turf grass, corn, and vegetables in the Kankakee County study area, the irrigation water withdrawal was calculated to be 500 million gallons per year. This is about 62.5% of the annual groundwater withdrawal for the study area. The Kankakee County study area has no pumpage for public water supply and has no industrial use. There is limited pumpage from a well used by Manteno Municipal Golf Course. The nearby towns of Manteno and Momence pump 126 and 296 million gallons per year, respectively. Annual domestic use is estimated to be 17 million gallons. Records for water consumption by livestock are available only on a countywide level since 1979. The livestock population in the study area is small, however, and the annual water use for livestock is estimated not to exceed 5 million gallons. The total annual withdrawal of groundwater within the study area is estimated to be 800 million gallons.

Irrigation

A limited number of farms in the study area practice irrigation agriculture. The database is not complete for irrigation wells in the Kankakee County study area; however, the current number of irrigation wells is not expected to exceed six. It was also observed that some irrigation farmers pump water from creeks during the year. Major crops grown under irrigation are vegetables (onions, cabbage, lettuce, peas), corn, and turf grass. Estimated irrigated acreage in the study area ranges from 800 to 1,000; most irrigation systems use the sprinkler method. Weather influences annual application rates. Cravens et al. (1990) reported that the average water application for vegetables in 1987 was 5.5 inches, whereas the total was 23.3 inches in 1988 because of an unusually dry summer. For sod farms, the water use was 39.5 inches in 1987 and 47.7 inches in 1988. They also reported that, for the irrigated land in their study area, the groundwater use-to-yield ratio of the dolomite aquifer was 2.00 for 1987 and 4.54 in 1988. For their entire study area, however, the total use-to-yield ratios were substantially less than 1, indicating no overdraft on a regional basis.

SUMMARY AND CONCLUSIONS

The variability in sediment thickness and texture throughout the study area creates a series of conditions that provide varying degrees of protection to the underlying dolomite aquifer. The fine-textured tills and lacustrine deposits of the Yorkville and Carmi Members provide a greater degree of protection to the aquifer than do coarse-textured sediments in the study area because the tills and lacustrine sediments have a higher clay and silt content and are generally thicker. The remaining two-thirds of the study area is dominated by the fractured Silurian dolomite and coarse-textured sediments of the Dolton Member and Cahokia Alluvium. These materials exhibit high hydraulic conductivities and will offer minimal resistance to the downward percolation of contaminants. Thick till deposits on uplands should offer greater protection to subsurface aquifers than do areas of sand over bedrock. Even though the Silurian bedrock is the primary aquifer, surficial sand and gravel are also at risk from contamination.

6 CHARACTERIZATION OF THE LIVINGSTON COUNTY STUDY AREA

U. Vaisanen, J. P. Kempton, M. L. Barnhardt, C. Ray, and M. R. Greenpool

LAND USE

Description of the Study Area

The 49-square-mile study area in Livingston County (fig. 6.1) contains the town of Strawn, population 150, in the southeastern part of the study area (parts of T25N, R6E; T25N, R7E; T26N, R6E; and T26N, R7E). Fairbury and Forrest (population 3,544 and 1,246, respectively) are located within 2 miles northeast and northwest of the study area, respectively. In the eastern part of the study area, Illinois highway 47 traverses north-south, parallel to the abandoned Norfolk and Western Railroad. U.S. highway 24 and the AT. & S.F. Railroad pass less than 1 mile north of the study area. The less frequently used Illinois Central Gulf Railroad track runs west of Strawn. Several petroleum and natural gas pipelines pass through study area (fig. 6.2). Most of the approximately 80 miles of paved roads run along section boundaries.

A total of 164 households with private water wells was located in the study area. Of the 145 residences contacted, 100 (69%) were farms and the rest were rural residences. Of the 48 randomly selected well users, 32 (67%) were located on farms.

Industrial and Commercial Operations

Two agricultural chemical distribution centers are located in the study area with another located within 1 mile of the boundary. Other operations include a grain elevator in Strawn, an auto repair facility, and an inactive gravel pit. A number of chicken and turkey farms are located in the area (fig. 6.2).

GEOLOGY AND HYDROGEOLOGY

Introduction

This area in southeastern Livingston County is representative of areas in which the top of an aquifer occurs between 20 and 50 feet of the land surface. This area is directly underlain by Quaternary glacial sediments up to 200 feet thick (locally less than 50 feet); the sediments average about 100 feet thick. These sediments are composed predominantly of glacial tills capped by windblown silt (loess) but contain buried interbedded layers of sand and gravel, the principal source of groundwater to wells in the area. Surficial sand and gravel deposits, up to 50 feet thick along Indian Creek (fig. 6.3), are the source of groundwater to wells at Fairbury. The present topography of the area has been shaped primarily by the deposits left by the melting of the last glacier to cover the area.

Previous Studies

Although no detailed geologic or hydrogeologic studies have been made of the study area, considerable general information is available in numerous regional and statewide studies. Regional information on the bedrock topography and drift stratigraphy were obtained from Nelson (1981, 1982), Kempton et al. (1991), Willman and Frye (1970), Horberg (1950, 1953, 1957), unpublished work maps of Kempton, miscellaneous ISGS/ISWS unpublished data, and inference of regional patterns. McKay (1975) and Johnson et al. (1986) provide information on the character of surficial (Wedron Formation) tills, and soil maps (SCS, in press b) present the distribution and character of the surficial material to a depth of 5 feet. Engineering borings (some with samples) near the study area confirmed the general character of tills within 20 to 50 feet of the surface (see also Berg and Kempton 1988, for a more generalized distribution).

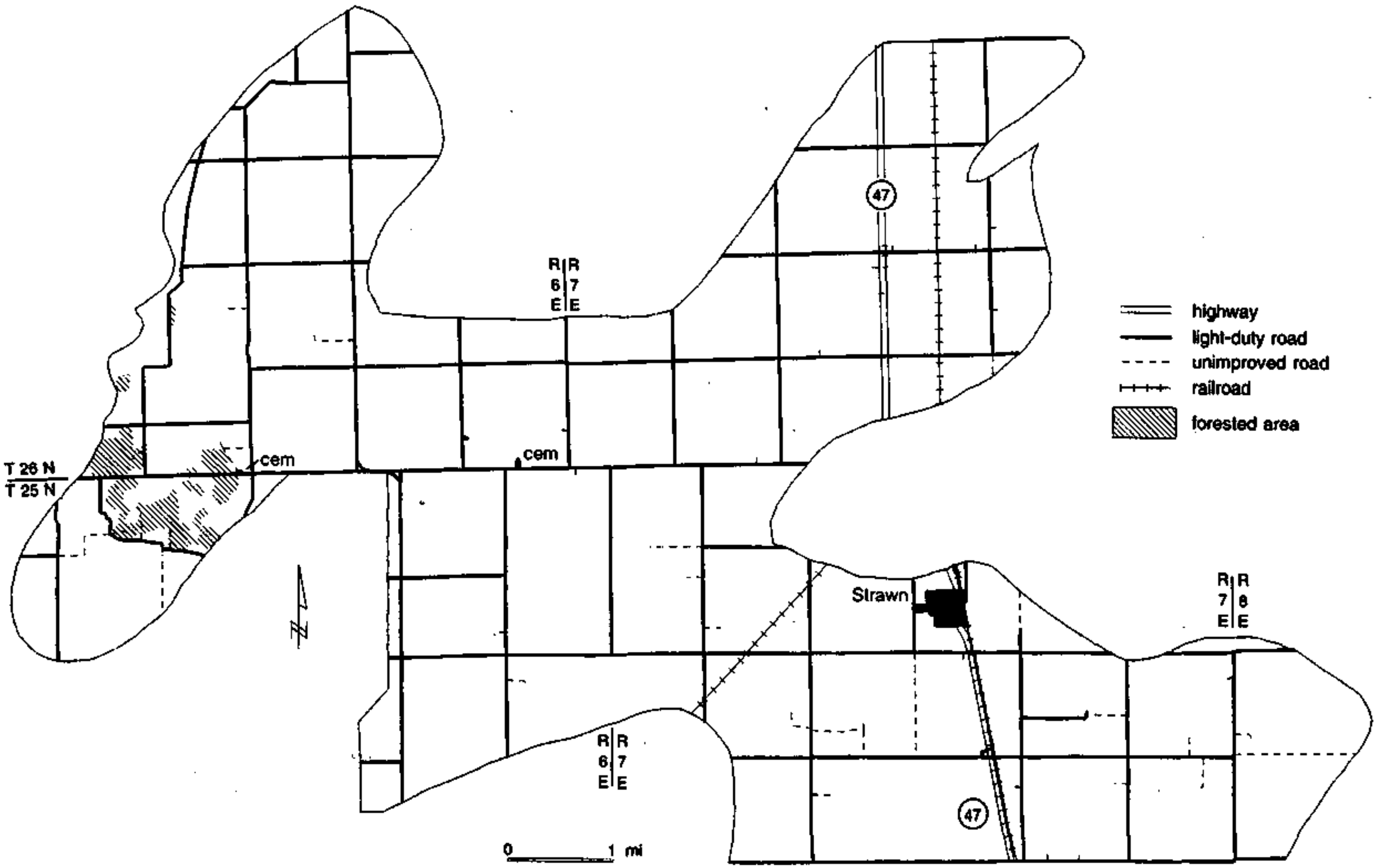


Figure 6.1 Livingston County study area.

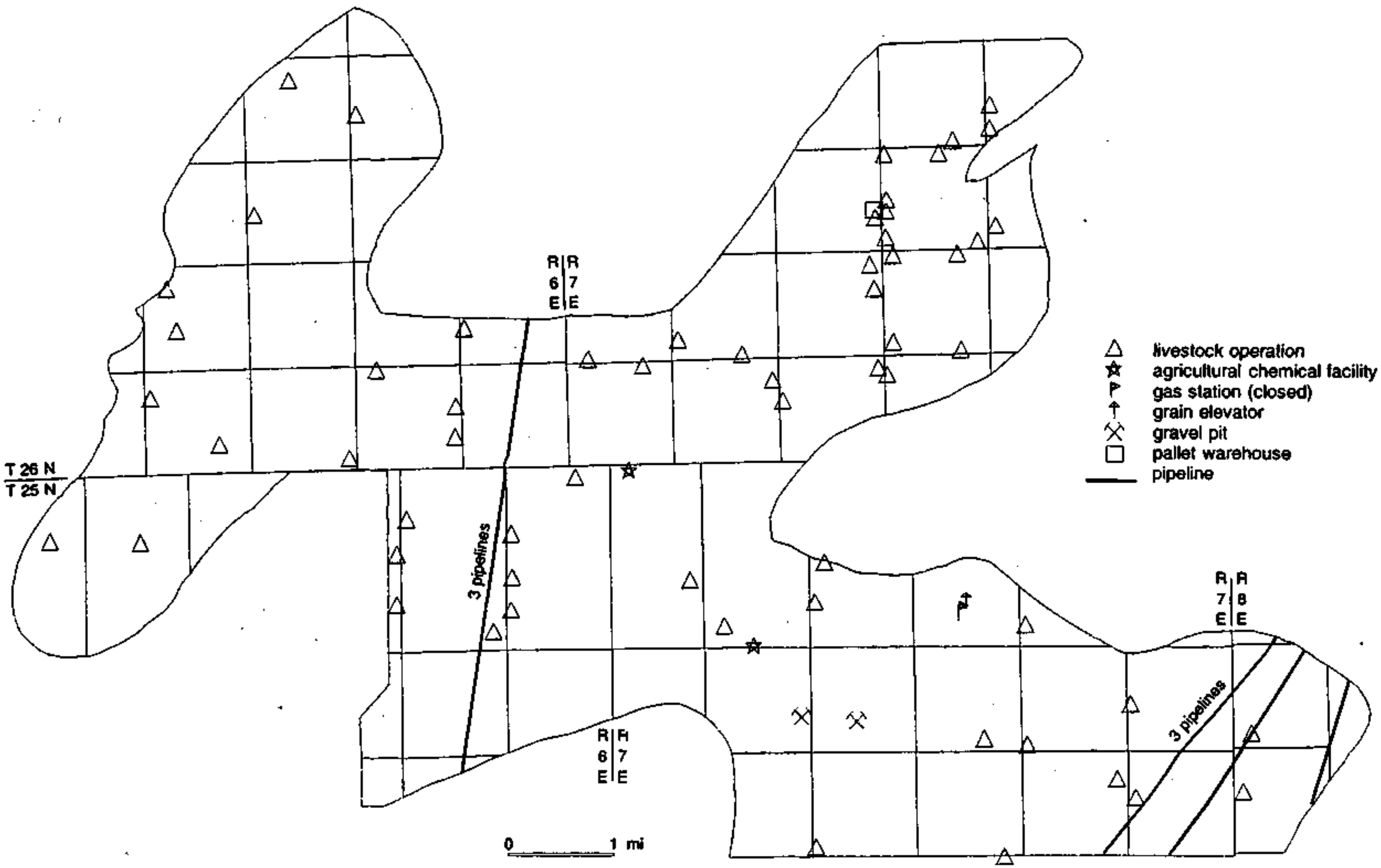


Figure 6.2 Potential sources of contamination in the Livingston County study area.

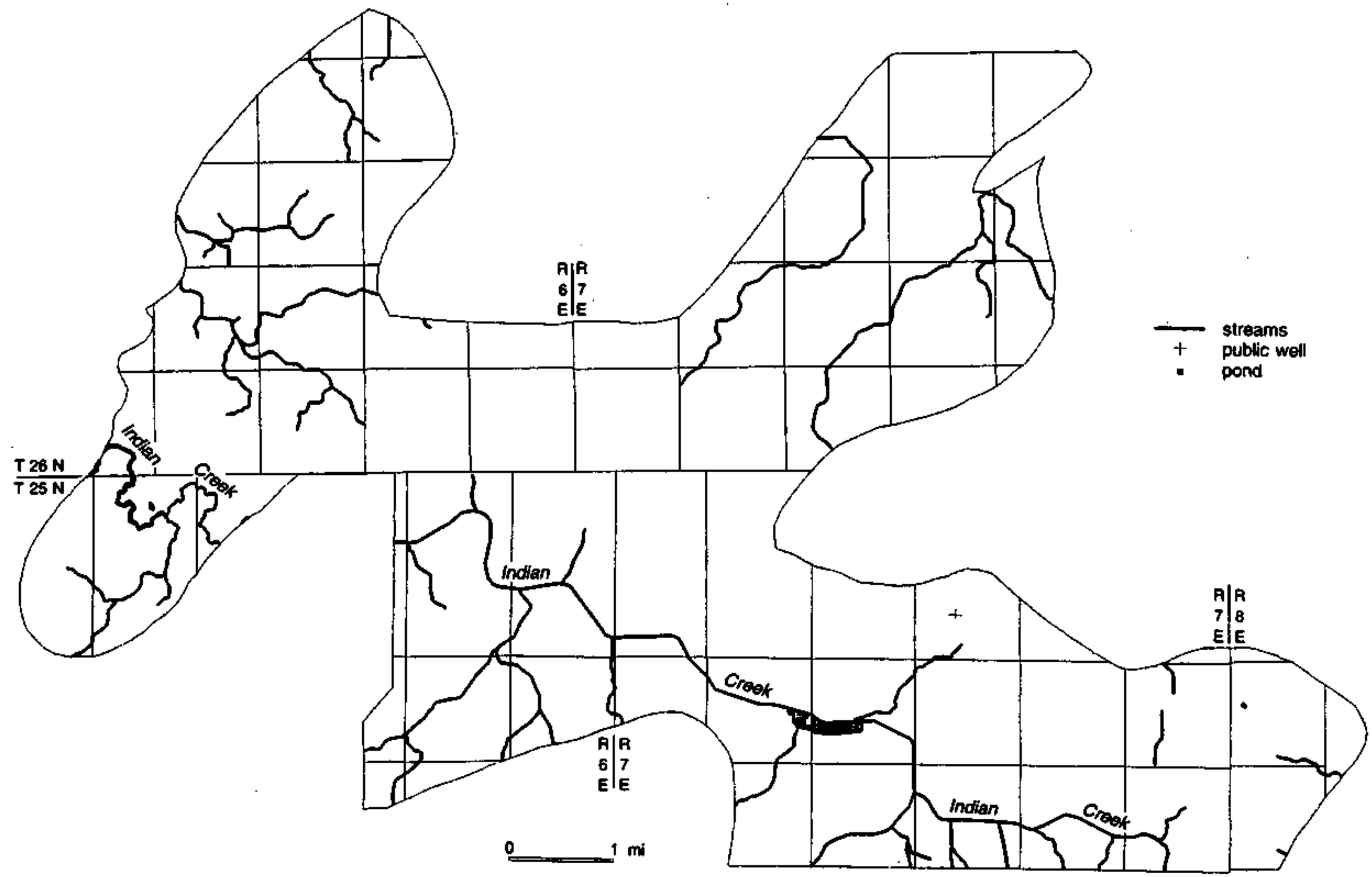


Figure 6.3 Drainage of the Livingston County study area.

Physiography and Drainage

The landscape is characterized by broad, rolling hills and has a maximum local relief of about 40 feet. Elevations range from about 680 feet above msl along Indian Creek near Fairbury to a maximum of about 820 feet in the southeastern part of the area. Elevations generally rise from north to south and southeast from about 700 to 800 feet. Drainage is primarily toward the north, with Indian Creek forming roughly the west boundary of the area and tributaries to the South Fork Vermilion draining northeastern parts of the area (fig. 6.3). Both Indian Creek and the South Fork Vermilion are tributaries of the Vermilion River.

Bedrock Geology and Topography

The Livingston County study area is directly underlain by a sequence of glacial sediments that range from a few feet to more than 200 feet in thickness. These unlithified sediments overlie Pennsylvanian bedrock that consists predominantly of shale; locally, there are thick beds of limestone and sandstone and a few relatively thin coal beds (Lamar 1929, Jacobson 1983). The bedrock surface was eroded prior to glaciation, leaving a preglacial surface of hills and valleys. The numerous glacial advances have left layers of deposits that now cover the bedrock surface, and give little hint of the original configuration of that surface.

The present land surface is a result of the deposits left by the melting of the last of the Wisconsinan glaciers that advanced over the area. The deposits are composed predominantly of glacial till deposited directly by the melting glacier ice. During melting of the ice, meltwater streams deposited sand and gravel in the low valley areas of the emerging landscape and silts and clay in small lakes and ponds. Because the glaciers advanced in a lobate pattern out of the Lake Michigan basin, arcuate ridges of till were left at the margins of the glaciers. The ridges formed end moraines or end moraine complexes. The entire area has since been unevenly blanketed by up to 5 feet of loess (fig. 6.4).

The bedrock surface—its elevation and configuration—has a direct influence on the thickness and character of the overlying glacial deposits (fig. 6.5). The bedrock surface of the Livingston County study area ranges from an elevation of about 690 feet above msl south of Fairbury, where exposures have been reported along Indian Creek (an abandoned quarry is reported by Lamar (1929) in SE Section 16, T26N, R6E), to below 500 feet east and southeast of Forrest, along the Chatsworth Bedrock Valley. Except for the area along the Chatsworth Bedrock Valley (Horberg 1950), the bedrock surface generally lies above 600 feet elevation; it is above 650 feet in much of the northern portion of the study area (fig. 6.5). Figure 6.6 provides a generalized map of the drift thickness, using the known configuration of land surface from the topographic maps and drift thickness data available from wells that do penetrate bedrock,.

Thickness of Quaternary Deposits

Willman and Frye (1970) established a stratigraphic framework for the Quaternary deposits that blanket nearly all of Illinois. The deposits identified as present or likely to be present in the study area are shown in figure 6.7. Figures 6.8 and 6.9 show the elevation and distribution of the Robein Silt position, as well as its relationship to the other deposits in the area. These cross sections (fig. 6.9 a, b) and other regional information (e.g., Horberg 1953, Nelson 1981, 1982, Kempton et al. 1991) indicate that deposits of pre-Illinoian, Illinoian, Wisconsinan, and Holocene age are present in the study area.

The glacial drift consists principally of a sequence (from bottom to top) of glacial tills (deposited directly from melting ice), outwash sand and gravel (deposited from high energy meltwater streams), and lacustrine sediments (low energy lake sediments), as well as some organic sediments, and loess (up to 5 feet locally).

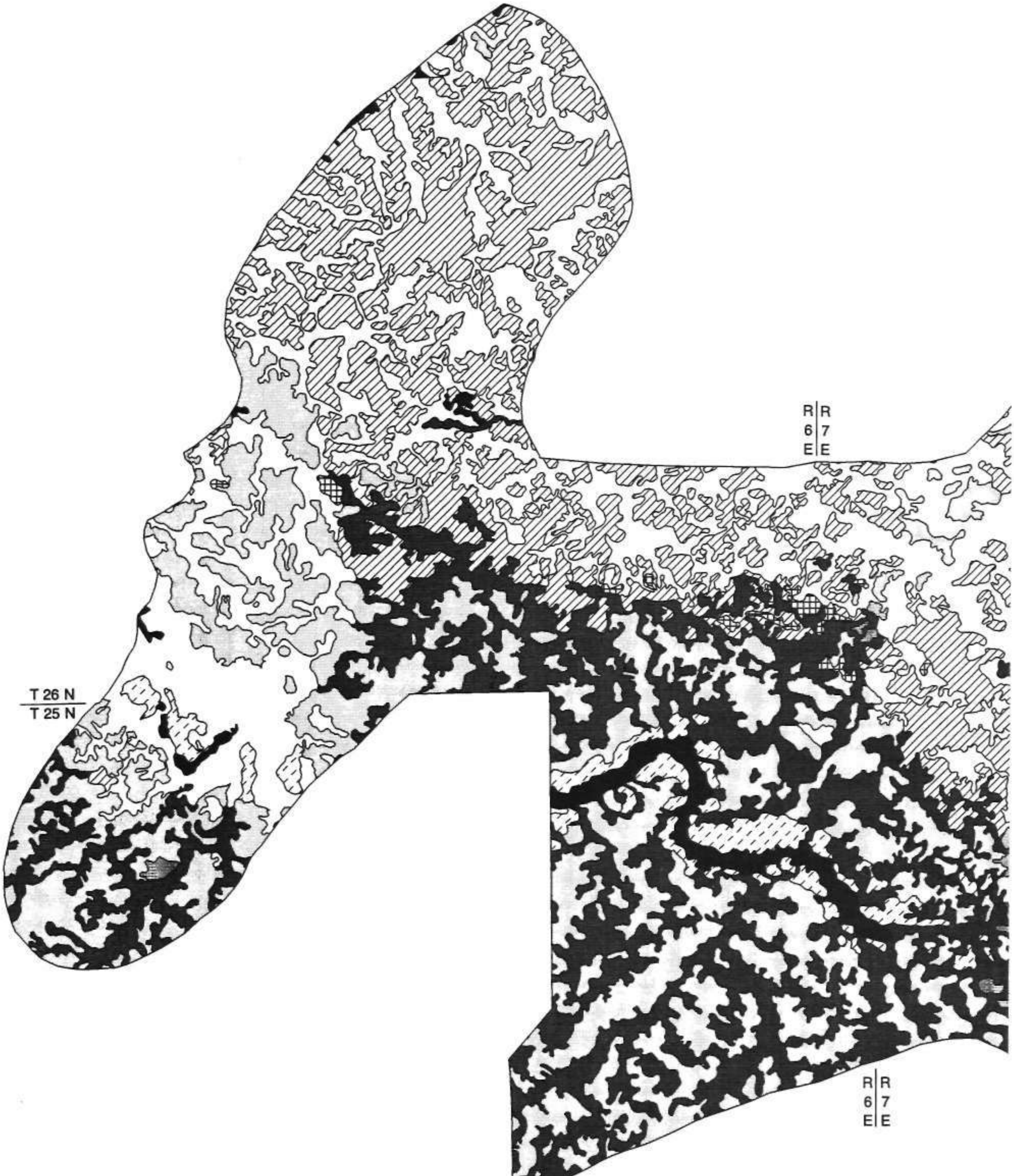
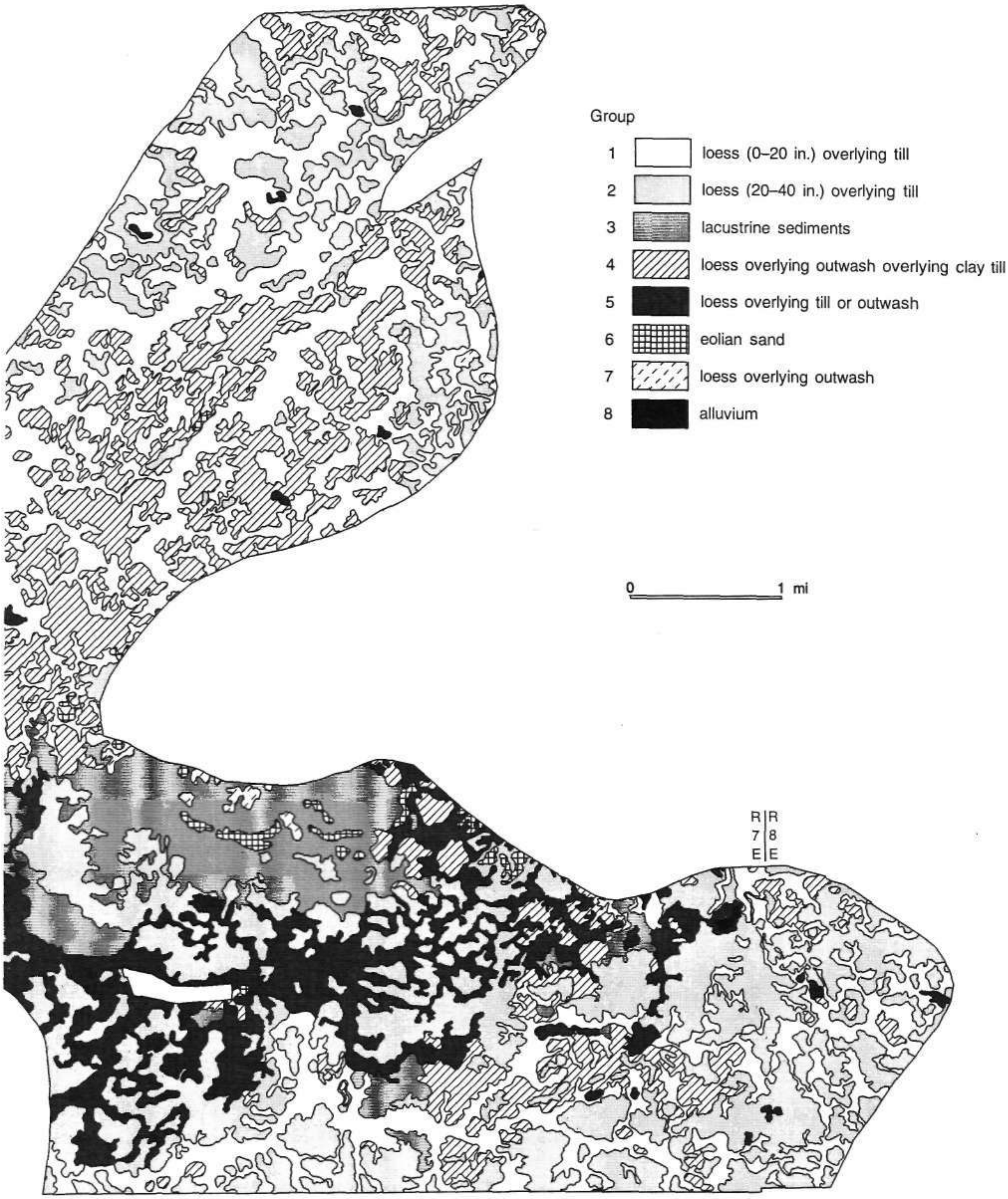


Figure 6.4 Parent materials of the Livingston County study area.



Group
1 loess (0–20 in.) overlying till
2 loess (20–40 in.) overlying till
3 lacustrine sediments
4 loess overlying outwash overlying clay till
5 loess overlying till or outwash
6 eolian sand
7 loess overlying outwash
8 alluvium
0 1 mi
R 7 E
R 8 E

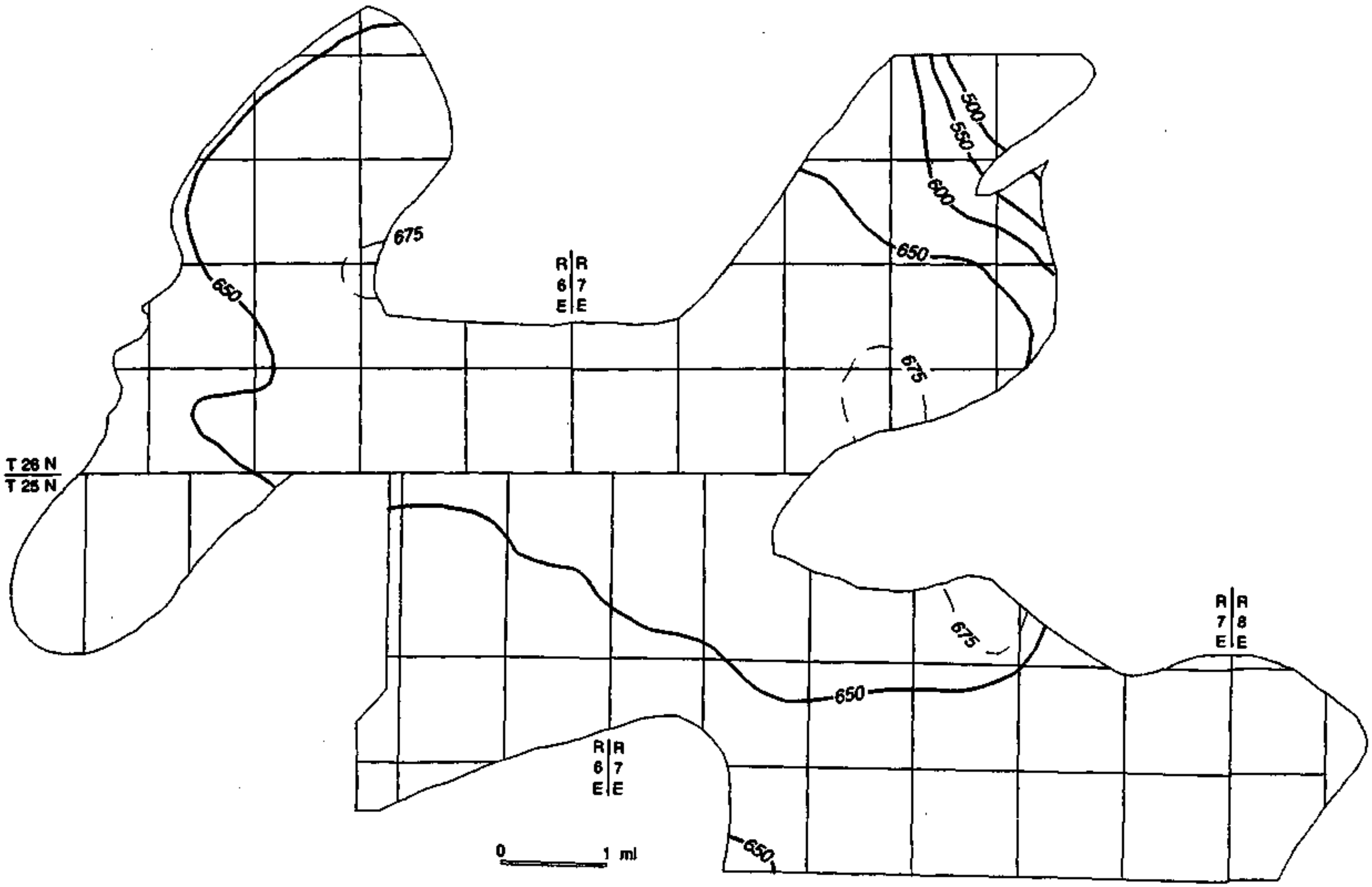


Figure 6.5 Topograph of the bredrock surface in the Livingston County Study area. Elevation is in feet above msl; contour interval is 50 feet.

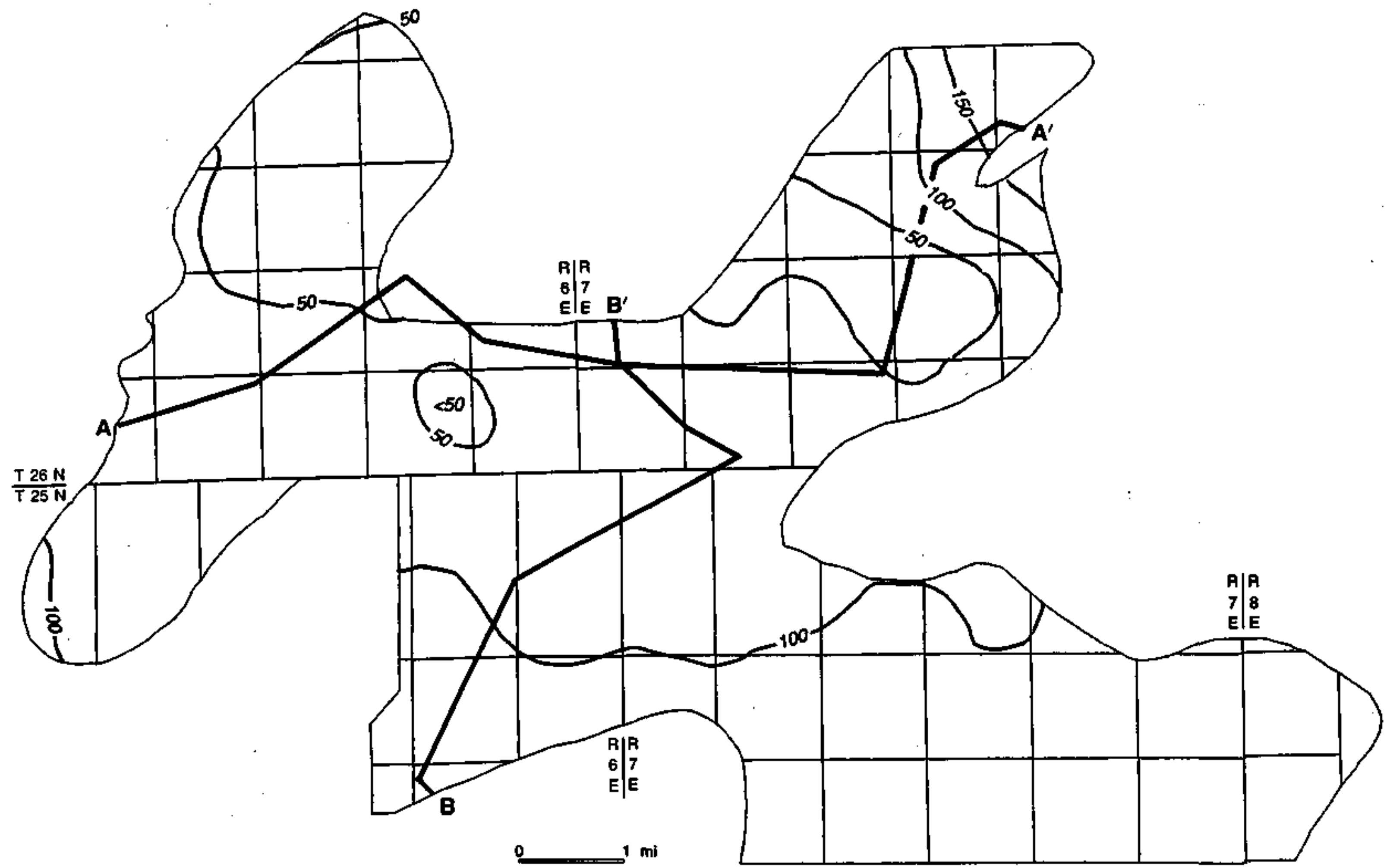


Figure 6.6 Thickness of drift deposits in the Livingston County study area. Contour interval is 50 feet. Location of transect lines is shown for cross sections A-A' and B-B'.

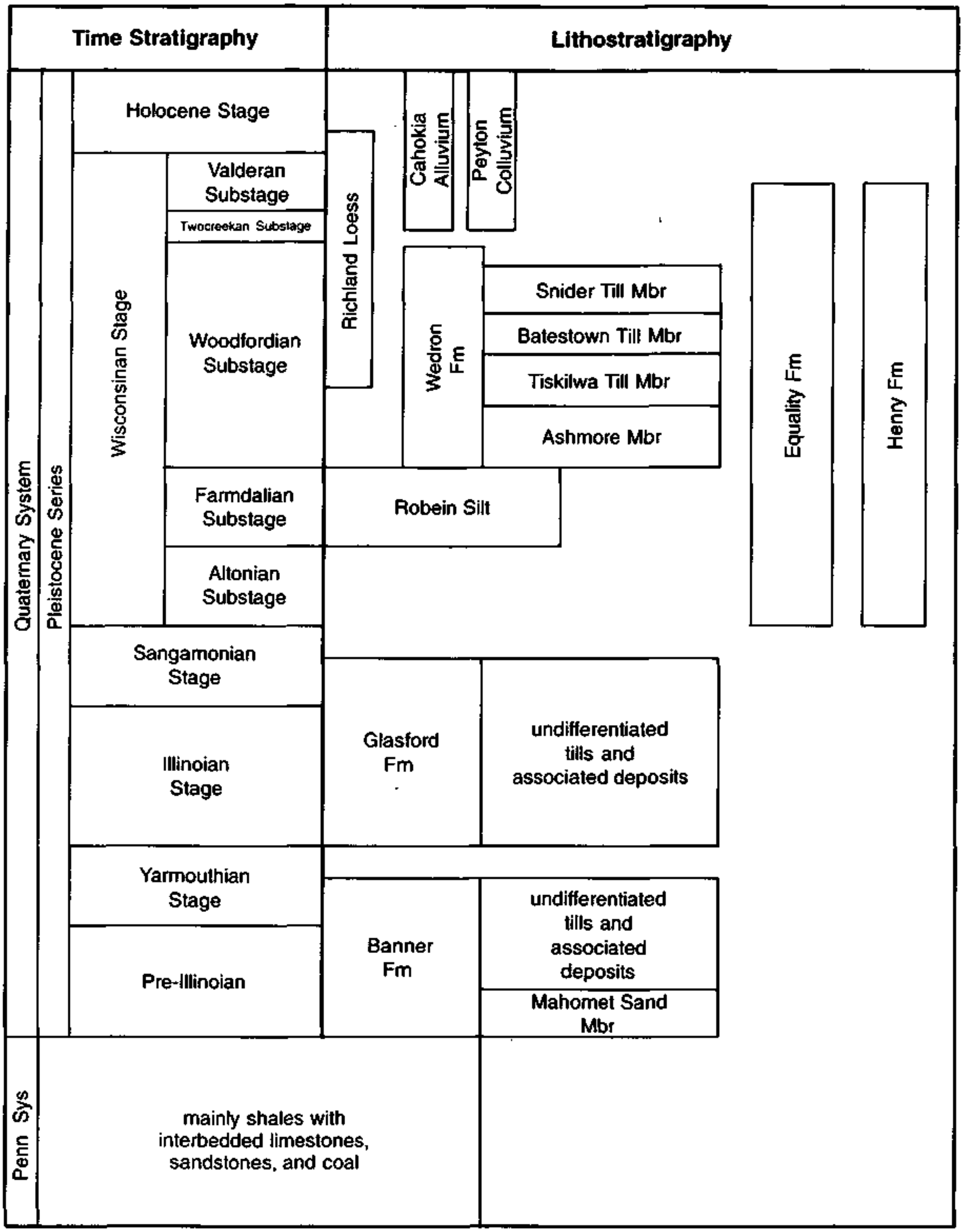


Figure 6.7 Lithostratigraphy of the Livingston County study area.

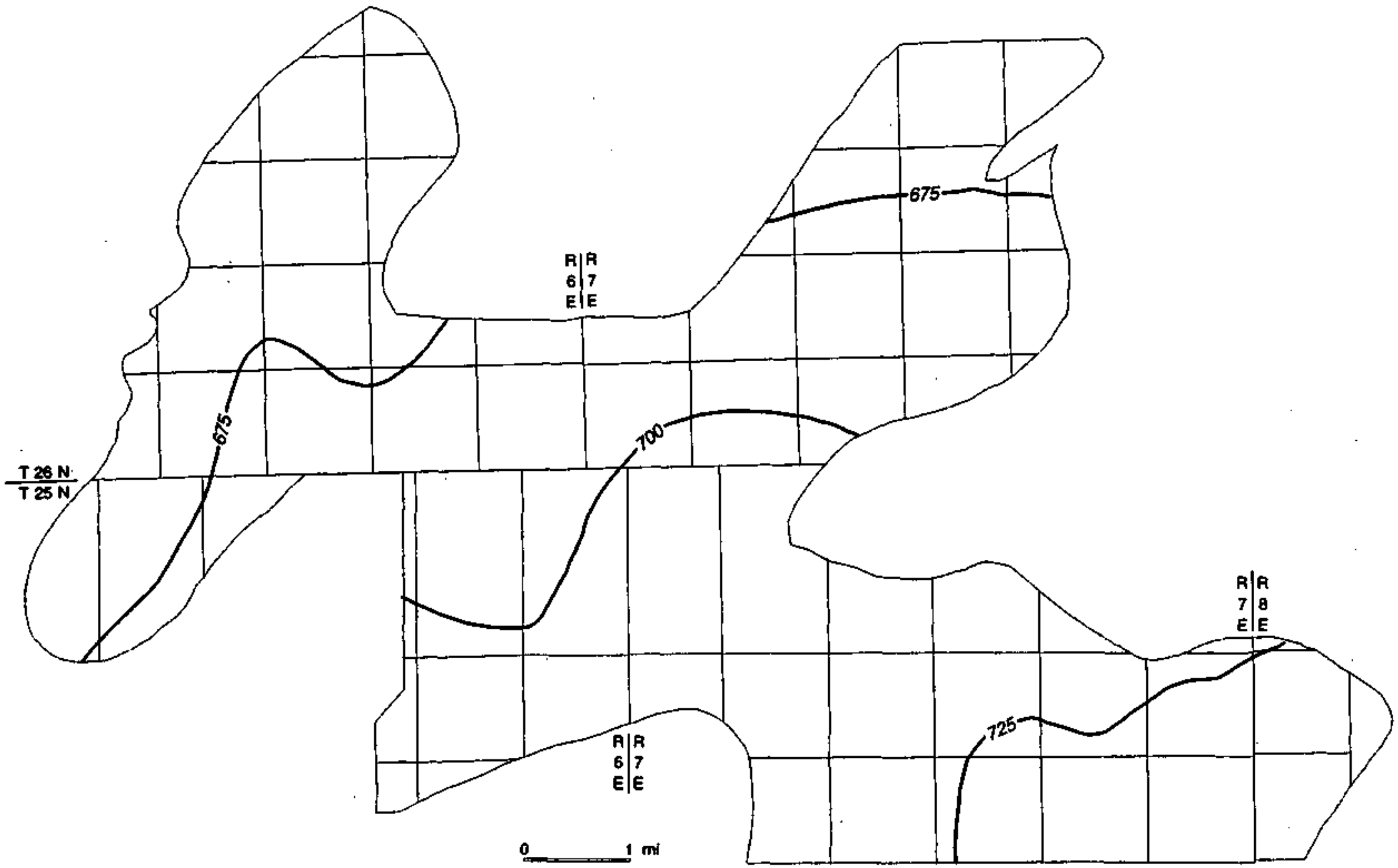
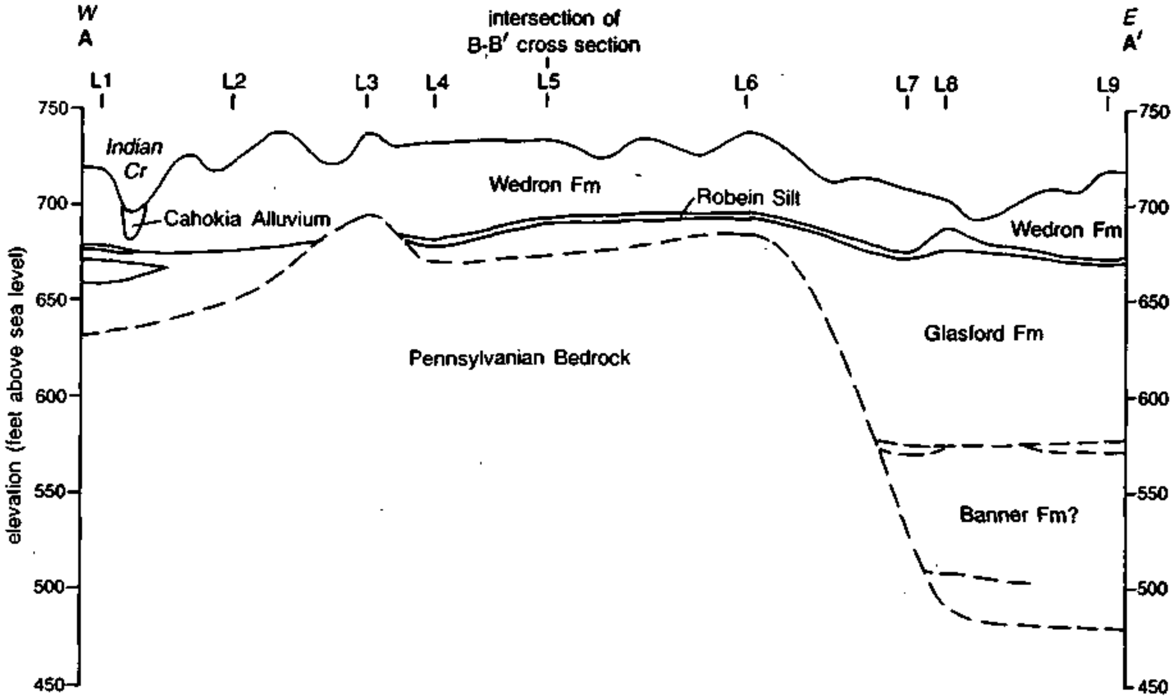


Figure 6.8 Topography of the Robein Silt surface in the Livingston County study area. Elevation in feet above msl; contour interval is 25 feet.



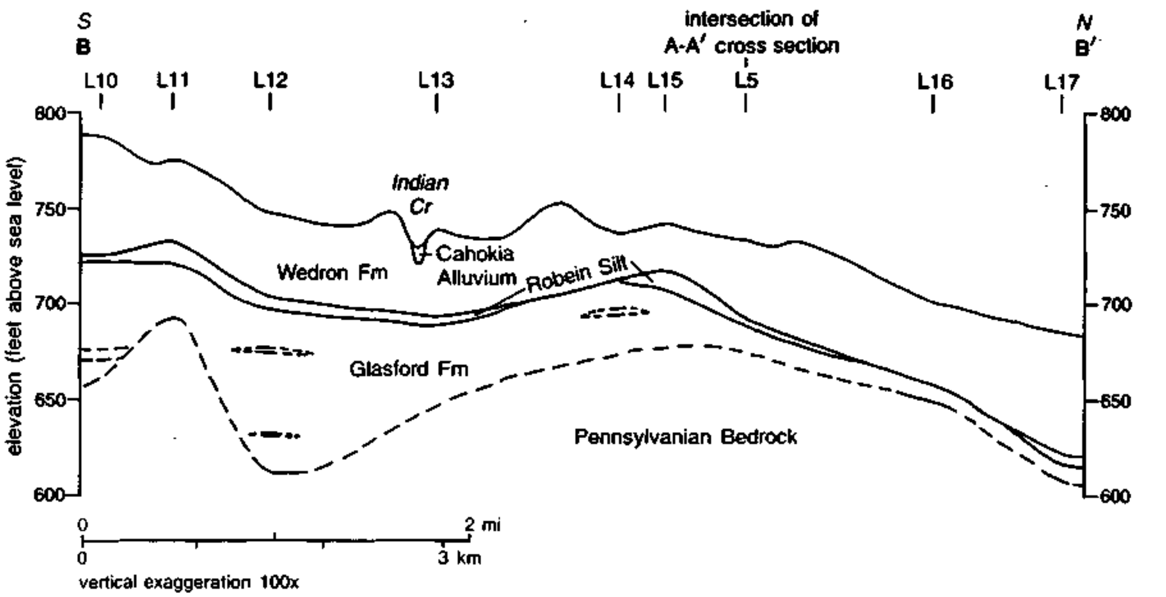


Figure 6.9 Cross sections A-A' and B-B' for the Livingston County Study area.

Lithostratigraphy

Evidence of at least three major episodes of glaciation—from oldest to youngest (bottom to top), pre-Illinoian, Illinoian, and Wisconsinan—are found in the study area. They are represented by the Banner, Glasford, and Wedron Formations, respectively (figs. 6.7 and 6.9). The glacial episodes were separated by interglacial episodes, the Yarmouthian and Sangamonian, dominated by erosion and weathering of the earlier sediment. Locally, windblown silt was deposited, and water-laid and organic sediments also occur. Some intraglacial erosion, weathering, and deposition also occurred (e.g., Robein Silt; fig. 6.7).

Banner Formation The oldest sediments encountered in the Livingston County study area are present at the base of the drift in the eastern and northeastern parts of the study area in the Chatsworth Bedrock Valley (Horberg 1950). These are assigned to the Banner Formation by extrapolation from adjacent areas, particularly from the east and southeast. Horberg (1953) and Kempton et al. (1991) identified pre-Illinoian deposits within the Mahomet Bedrock Valley, of which the Chatsworth Bedrock Valley is a tributary. In the Mahomet Bedrock Valley, the Banner Formation consists of two main units, a basal sand and gravel (the Mahomet Sand) and an upper unit composed predominantly of a sequence of till(s). The top of the Banner Formation in the Mahomet Bedrock Valley rarely exceeds an elevation of about 580 feet above msl, and the top of the Mahomet Sand occurs at about 550 to 520 feet.

In the Chatsworth Bedrock Valley, a "basal" sand is encountered at an elevation of about 510 feet. About 40 to 60 feet of "clay" (till?) above the sand is interpreted to be Banner Formation (fig. 6.9). Sufficient data are lacking to indicate the thickness of the "basal" sand or whether it continues to the bottom of the bedrock valley. The total thickness of the Banner Formation probably does not exceed 100 feet. It does not appear to overlie the bedrock uplands through the rest of the study area, although it may occur in low areas of the bedrock surface.

Glasford Formation The Glasford Formation appears to be present through most of the study area, except where the bedrock is above about 690 feet elevation, as suggested by figure 6.9. The Glasford Formation through much of Illinois, except to the north and northeast of the study area, is composed of a sequence of several named tills, associated with interbedded outwash, sand and gravel, and silt beds (Willman and Frye 1970, Kempton et al. 1981).

Because adequate stratigraphic information is not directly available for southeastern Livingston County, no substantive basis for identifying individual units exists. The available logs of all water wells and those used for the cross sections (fig. 6.9) do suggest a continuity of Glasford deposits across the area. A relatively thin upper till unit, with a basal sand and gravel occurs locally; a lower, somewhat thicker till unit with a thin basal sand and gravel also occurs locally. Both sand and gravel beds occur primarily on the east side of the study area.

The maximum thickness of the Glasford Formation may be as much as 100 feet over the Chatsworth Valley, although it generally ranges from about 40 to 80 feet thick and is locally absent in areas of high bedrock. The top of the Glasford Formation may be locally identified by the presence of weathering (fig. 6.7, Sangamonian Stage) or organic sediments (figs. 6.8, Farmdalian Substage (Robein Silt), and 6.9). This surface has been mapped regionally (Horberg 1953, Nelson 1981, 1982) and is shown on figure 6.9. It is generally highest (elevation about 700 feet) in the southwestern part of the study area and lowest (elevation about 650 feet) in the northeastern parts.

Wedron Formation Glacial tills and interbedded sands and gravels of the Wedron Formation compose the bulk of the materials directly underlying the land surface in southeastern Livingston County (figs. 6.7 and 6.9). These tills and sands and gravels were deposited during the Woodfordian Substage of the Wisconsinan Stage. The base of the Wedron Formation directly overlies tills of the Glasford Formation through most of the area, although scattered occurrences of the Robein Silt (Farmdalian Substage) are reported. Although available water well records do not provide a basis for definitive identification of specific till members, regional information and a detailed study of the surficial tills, particularly those in the current study area (McKay 1975), provide a basis for description and characterization of these deposits. McKay used surface exposures and shallow boreholes to study and describe the tills. Regionally, several members of the Wedron Formation have been recognized (Willman and Frye 1970, Lineback 1979). Figure 6.7 indicates the members present or likely to be present in the study area. Only the Tiskilwa Till Member has not been definitely recognized as present.

Ashmore Member Kempton et al. (1981) identified a basal Wedron Formation sand and gravel with interbedded silt as a well developed unit in the southern part of east-central Illinois; it is informally called the Ashmore Member. A similar unit at the same stratigraphic position has been noted in numerous areas throughout the area covered by the Wedron Formation. Although quite variable in distribution, thickness, and character, it is locally significant in southeastern Livingston County (fig. 6.10). Although not encountered in every well penetrating the Glasford Formation, the Ashmore does appear to be present over most of southeastern Livingston County in thicknesses ranging from less than 1 foot to as much as 15 feet. Actual maximum thickness may be greater because many wells do not penetrate the entire thickness, but 6 to 8 feet of sand and gravel are commonly reported.

Because the Ashmore directly overlies the Glasford Formation or the Robein Silt (where present), its base can be generally predicted unless it fills valleys eroded into the surface of the Glasford Formation. The depth to and therefore the elevation of the top of the Ashmore can be fairly accurately portrayed. Through most of the area, the top of the Ashmore lies within 50 feet of the land surface (fig. 6.10). It occurs at depths of greater than 50 feet, mainly in the western part of the study area. The map showing the depth to the top of the Ashmore is used in lieu of the stack-unit map in this area.

Tiskilwa Till Member Although not specifically identified in southeastern Livingston County, the Tiskilwa Till Member is likely to be locally present directly above the Ashmore, particularly where the total Wedron thickness is greater than 50 feet. The Tiskilwa Till can often be identified by its characteristic reddish gray to grayish brown color. It typically has a loamy to silty and loamy texture. Because it may be only 3 to 5 feet thick through most of the area, it could easily be missed in drill cuttings.

Batestown Till Member Three tills within the Wedron Formation cover the land surface in this study area. McKay (1975) correlated the oldest of these with the Batestown Till Member, which is the surface till just a few miles to the south of the Livingston County line. McKay described the Batestown as typically a gray, silty till that is distinguished from other tills in the area primarily by its texture. It frequently contains lenses of silt and sand in its upper part, but becomes more uniform with depth. *

The Batestown Till Member overlies the Tiskilwa Till or Ashmore Member and is overlain by the Snider Till, Richland Loess, Henry Formation, or Cahokia Alluvium. It probably averages about 30 feet thick, although it thickens to the east. It is possibly exposed along the valley sides adjacent to Indian Creek, where later erosion has removed the overlying till.

Snider Till Member The Snider Till Member is the predominant surface till throughout southeastern Livingston County. McKay (1975) described the Snider Till Member as typically a gray, silty, clayey till, which lies stratigraphically above the Batestown Till Member. It is variable in textural composition, but the variations appear to be laterally gradational. The mean matrix texture has somewhat less sand and more clay than has the Batestown (McKay 1975). With lateral variations in texture, the Snider Till coarsens westward across the study area (McKay 1975).

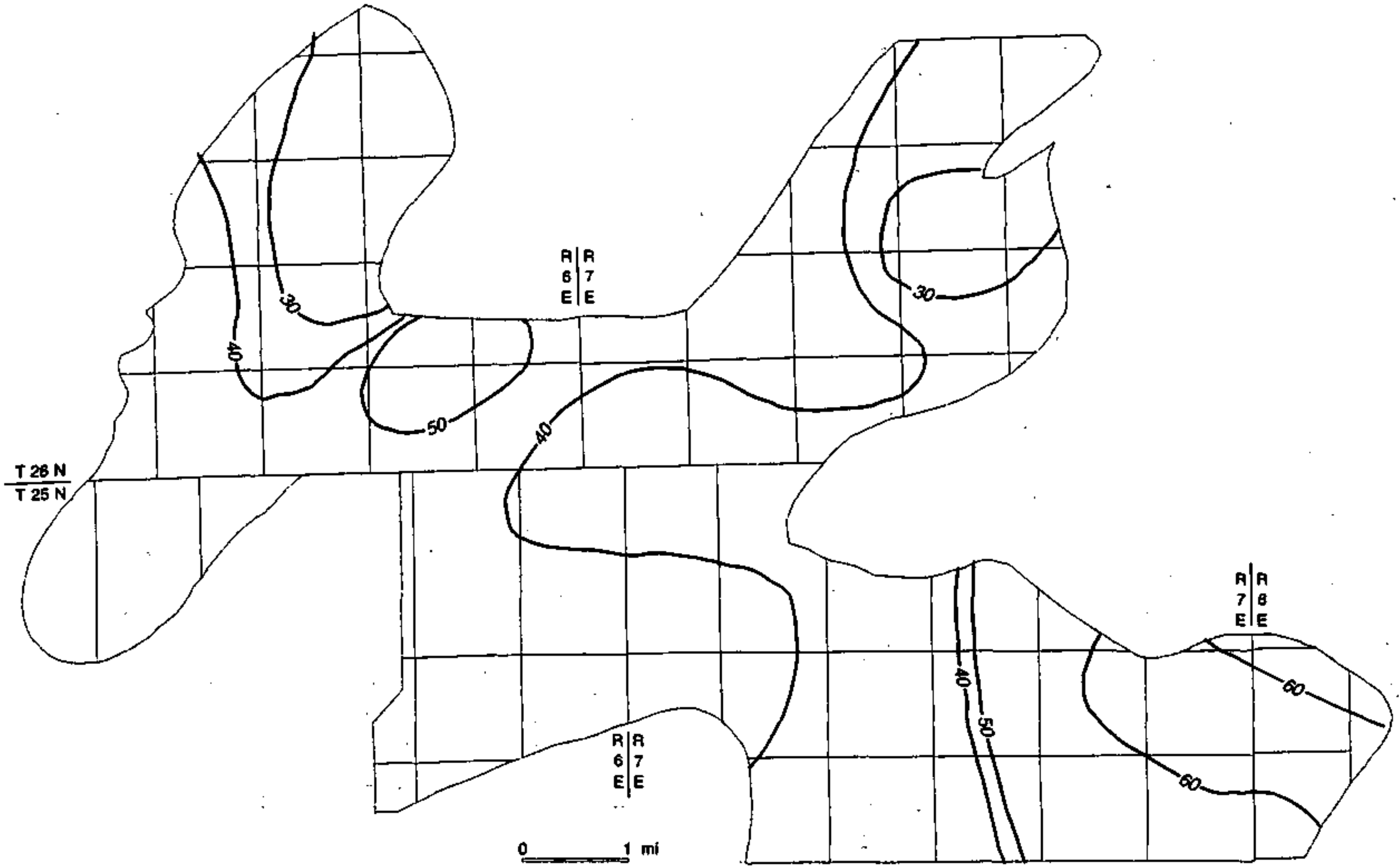


Figure 6.10 Depth to the top of the Ashmore Member.

Data from foundation borings at Risk (about 1 mi northwest of Strawn) and at Weston (about 5 mi northwest of the study area) show about 20 feet of gray till similar to Snider Till overlying till having typical Batestown textures. Also, McKay (1975) described a borehole about 4 miles south of the Livingston County line where about 22 feet of till correlated with the Snider overlies the Batestown, although the two tills are separated by 3 feet of sand. A similar sequence is occasionally described in well logs in the study area (fig. 6.9, cross section B-B', borehole 8). The Snider may be locally absent, particularly along the Indian Creek Valley, where erosion has been active.

Equality Formation The Equality Formation consists of generally fine-textured lacustrine sediments in the study area (Willman and Frye 1970). These sediments were deposited in lakes formed in low areas on the landscape during melting of the last glaciers. The fine-textured deposits occur in the headwater area of Indian Creek in the southeastern part of the study area, as indicated by the soil parent material map (fig. 6.4). There are no data on the thickness of these deposits, and they may be no more than a few feet thick.

Henry Formation The Henry Formation (Willman and Frye 1970) is composed of glacial outwash that is predominantly sand and gravel; the outwash occurs at the land surface principally in the Indian Creek Valley (figs. 6.3 and 6.4). No well data indicate the thickness of these deposits in most of the study area. Wells in the village of Fairbury, however, penetrate these deposits adjacent to the northwestern part of the study area, where up to 50 feet of sand and gravel has been encountered below land surface in the Indian Creek Valley (fig. 6.9).

Richland Loess The wind-deposited Richland Loess (Frye and Willman 1960), a yellow tan silt up to 5 feet thick, caps much of the upland till in the study area. It has been modified by weathering in the Modern Soil. Where the loess is only a few feet thick, the soil has also modified the underlying till. The loess is generally thinnest on upland slopes and slopes along stream valleys.

Cahokia Alluvium Cahokia Alluvium consists of a silty or clayey deposit derived from the erosion of loess and till, and it is present along all streams in the area (Willman and Frye 1970). The alluvium began to accumulate in many valleys as soon as they were free of ice. The deposits range from Woodfordian to Holocene in age.

Parkland Sand and Peyton Colluvium Within the study area, several other surficial deposits of limited distribution and thickness are present. These include colluvial (slope wash) sediments that accumulate at the base of slopes or in shallow depressions and eolian (wind deposited) sand. These deposits are described by Willman and Frye (1970) and are named the Parkland Sand and Peyton Colluvium. In many cases, small areas of these deposits, particularly the eolian sands, have been mapped with larger units (e.g., fig. 6.4).

Soils and Parent Materials

Almost all of the study area (98%) is covered by Mollisols; Alfisols, Inceptisols, and Entisols cover the remaining 2%. Of the 32 soil series represented, the Drummer (15%), Ashkum (15%), Reddick (12%), and Andres (12%) dominate the loess-covered landscape (Soil Conservation Service, in press b). Thin loess overlying till or outwash and loess overlying outwash dominate the parent material combinations (fig. 6.4), covering 56% and 37% of the study area, respectively. The study area is, in part, dominated by low permeability soils because of these loess-till combinations. In their upper 5 feet, almost 80% of the soils are classified as moderate to moderately slow or moderately slow in permeability (table 6.1). Low permeability coupled with sufficient slope can lead to increased runoff and a higher potential for soil erosion.

Because organic matter is concentrated near the surface, its distribution is directly influenced by tillage practices and erosion. Mollisols are characteristically high in organic matter. The soils in the study area average about 4.7% organic matter, distributed through an average depth of

Table 6.1 Soil permeability and surface organic matter content in Livingston County study area.

Parent material group[a]	Permeability[b,c] (in./hr)	Organic matter[d] (avg. %/avg. thickness)	% of study area
1—Loess (0-20 in.) overlying till	0.2-0.6	5.6 for upper 12.6 in.	28
2—Loess (20-40 in.) overlying till	0.6-2.0 0.2-0.6	3.7 for upper 12.3 in.	29
3—Lacustrine sediments	0.2-0.6	5.0 for upper 12.9 in.	4
4—Loess overlying outwash overlying clay till	0.6-2.0 0.2-0.6	4.1 for upper 14.0 in.	19
5—Loess overlying till or outwash	0.6-2.0	6.0 for upper 16.9 in.	16
6—Eolian sand	2.0-6.0	3.1 for upper 10.6 in.	1
7—Loess overlying outwash	0.6-2.0	3.8 for upper 14.2 in.	2
8—Alluvium	0.6-2.0 0.2-0.6	4.6 for upper 16.4 in.	1

[a] See parent material map (fig. 6.4) for distribution.

[b] Data for permeability and organic matter from Fehrenbacher et al. (1984).

[c] The second range of values represents permeability for sediments below the initial unit unless another material is identified.

[d] Percentages and horizon thicknesses are weighted by soil series in each group.

13 inches. The presence of soils rated as either moderate or high in organic matter throughout the area is favorable for controlling pesticide leaching. The combination of high organic matter content and slow permeability should inhibit the downward movement of pesticides. The presence of tills with high clay content containing fracture planes, however, may provide avenues for rapid downward translocation of surface water (Williams and Farvolden 1967). If fracturing is common in the oxidized zone of the tills, the inhibiting factors of high organic content and low permeability may be offset by the presence of macropores, which can rapidly transmit water downward. The water may thus move into aquifer units that are otherwise somewhat protected from direct input of surface water.

Relationship of Materials to Topography

The combination of topography and geologic materials information necessary to produce a terrane map requires knowledge of the occurrence of geologic materials on the landscape and evaluation of land use and resource characteristics. The terrane map for the study area (fig. 6.11) differentiates the major upland and lowland. Although material boundaries are often coincident with terrane boundaries, distinguishing these boundaries in this area is more often a topographic determination. For example, the headwater of Indian Creek and its valley is substantially on an eroded till surface, with only limited areal distribution of Henry Formation and Cahokia Alluvium. Therefore, an arbitrary upland-lowland boundary must be determined primarily on the basis of topography, and these relationships are not always clearly determined.

Hydrogeology

Several factors have particularly important effects on the impact of agricultural chemicals applied at the surface on groundwater resources. These include the (1) properties of the surficial materials, specifically the surficial till, (2) depth of the shallowest aquifer, and (3) terrane characteristics and aquifer recharge.

Properties of surficial materials The Snider Till Member, the surficial till through most of the study area, is a silty clay loam till that locally has amounts of clay up to 44%. The loess cap ranges from 20 to 40 inches thick, and the permeability is generally rated as moderate to moderately slow (table 6.1, Groups 1 and 2). Although the till matrix can significantly inhibit downward movement of water, these clay-rich tills may also contain vertical or nearly vertical

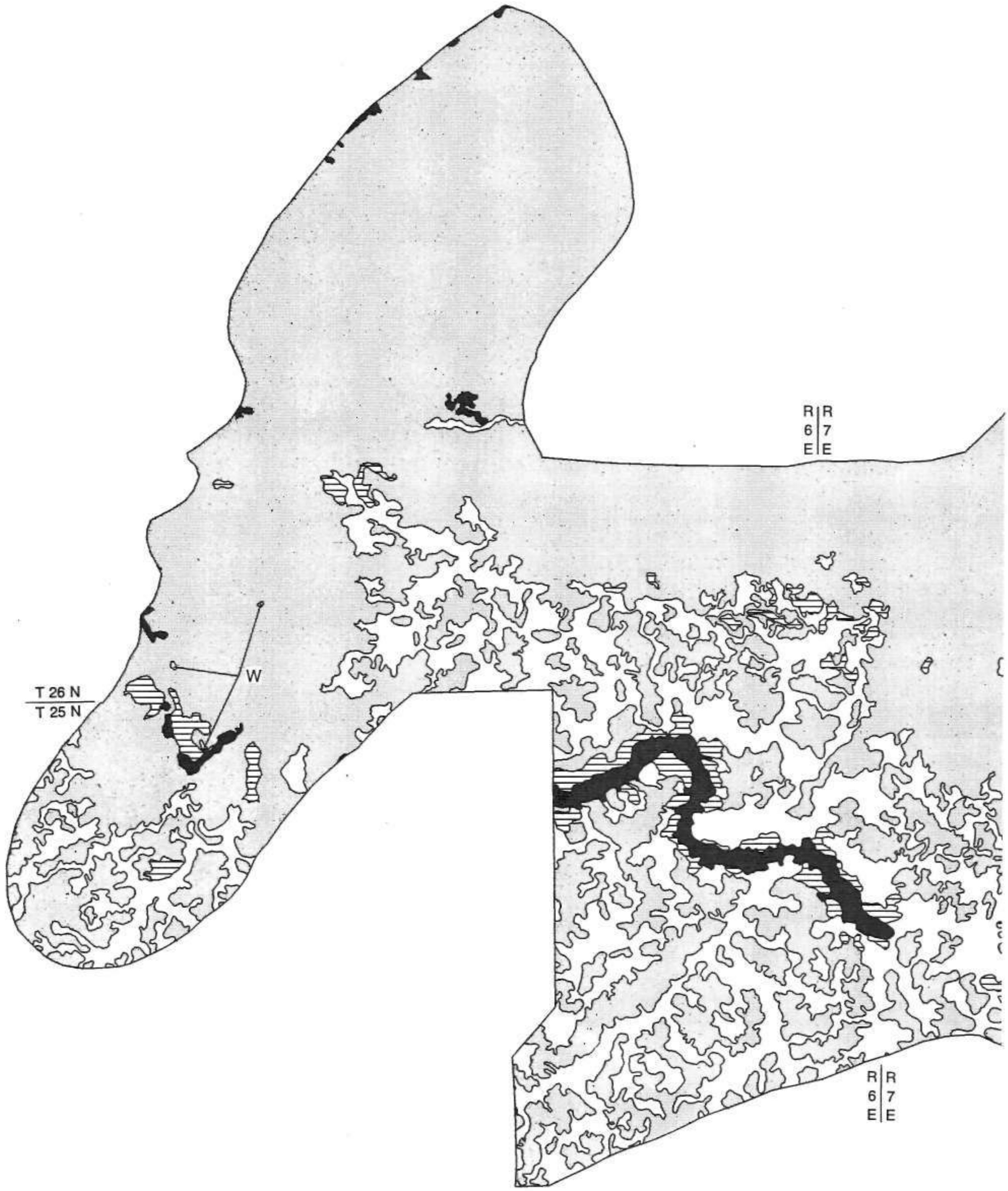
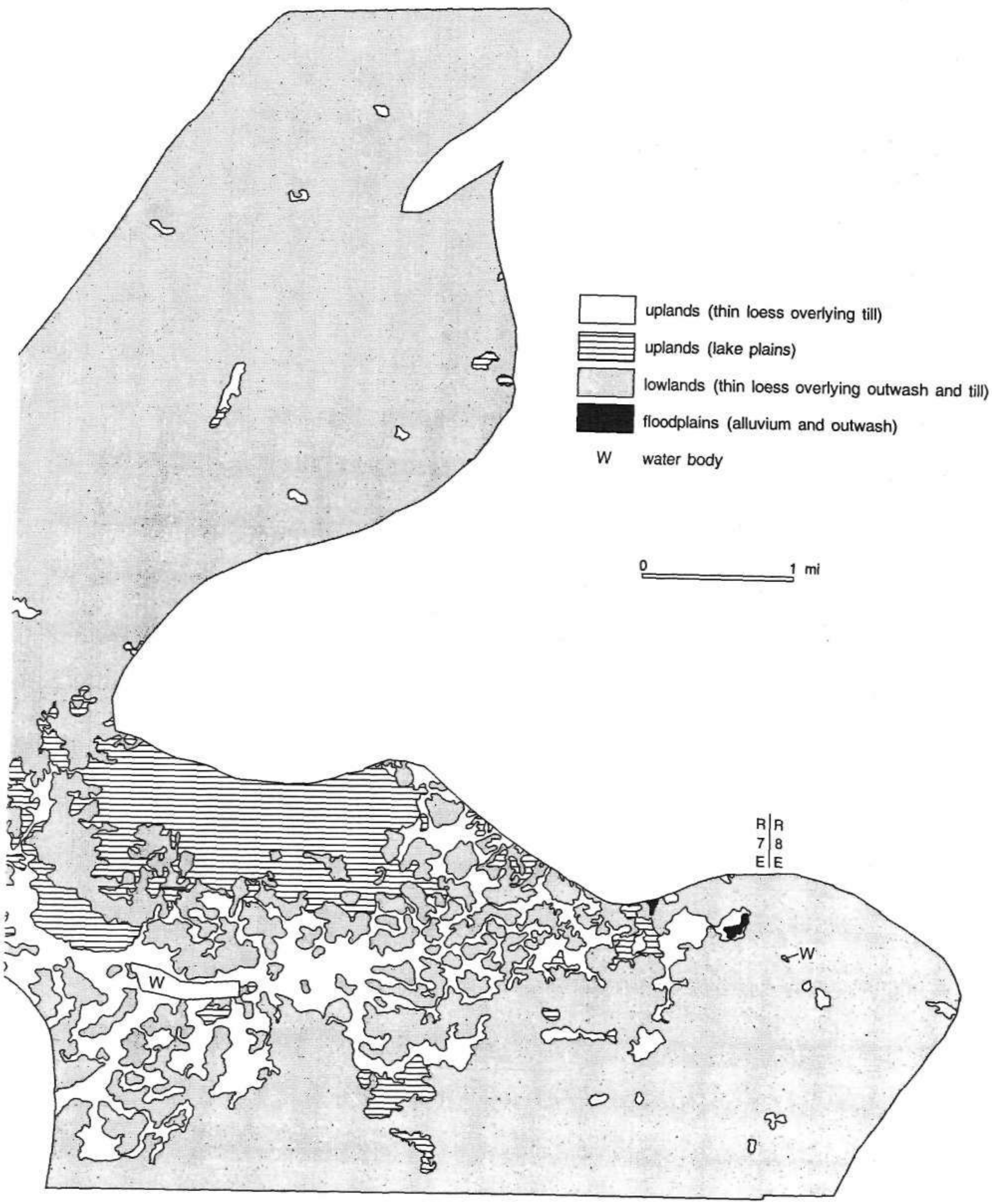


Figure 6.11 Terranes of the Livingston County study area.


uplands (thin loess overlying till)
uplands (lake plains)
lowlands (thin loess overlying outwash and till)
floodplains (alluvium and outwash)
W water body
0
1 mi
R 7 E
R 8 E
W
W

fractures in the oxidized zone, and these fractures may allow for more rapid downward movement of water (Williams and Farvolden 1967). Either the local presence of a sand layer separating the Snider from the Batestown Till Member, or the contact of the Snider with the Batestown at depths of about 20 to 25 feet, suggests the greatest depth to which fractures may be present in the Snider.

Where the Henry Formation is present (table 6.1, Group 7), permeability is moderate. Where the Henry Formation is used as an aquifer, the moderate permeability of the overlying loess and the high hydraulic conductivity of the sand and gravel make this deposit particularly susceptible to contamination from surface sources.

Depth to aquifers Four geologic units in the study area contain five locally significant sand and gravel units that are aquifers. The deepest of these is the sand and gravel at or near the base of the Banner Formation. It occurs near the easternmost part of the study area at a depth generally greater than 200 feet (fig. 6.9).

Also, several wells in the eastern part of the study area are reported as finished at depths ranging from 120 to 140 feet. These are probably finished in the basal Glasford Formation sand and gravel. A few wells are reported to be finished at shallower depths (90 to 115 feet). These are probably within the Glasford Formation and may be screened in discontinuous sand and gravel layers in the upper part of the formation, although this interpretation is supported by little stratigraphic evidence.

The most frequently used aquifer is the sand and gravel of the Ashmore Member of the Wedron Formation. This aquifer occurs at depths ranging from less than 30 feet in the northwestern and northeastern parts of the study area to greater than 50 feet in the southeastern part of the area (figs. 6.9 and 6.10). Although locally absent, the Ashmore aquifer does appear to occur through most of the study area. Most of the wells of record do not indicate that the entire thickness of the aquifer has been penetrated, but the Ashmore Member only locally exceeds 10 feet in thickness. This aquifer appears to satisfy the minimum needs for farm and domestic use.

A number of large-diameter, concrete-cased, bored wells are used within the study area, mainly where no significant development of the Ashmore has occurred. These wells have large-diameter (24 inches) casings to store water that slowly moves into the wellbore from fractures in the till. Water also moves in from thin sand lenses within or between the tills of the Wedron Formation or the upper part of the Glasford Formation. Bedrock has been encountered in a few of these large-diameter wells, which may obtain water from the uppermost fractured bedrock. Probably the most productive aquifer in Livingston County is the sand and gravel of the Henry Formation just outside the northwestern part of the study area along Indian Creek. Wells at the village of Fairbury and a few industrial wells have penetrated as much as 40 feet of sand and gravel. The maximum yield of these wells has been reported as 200 gpm. No other well records exist that indicate the Henry Formation has been used as an aquifer where present in the south-central part of the study area.

Terrane characteristics and aquifer recharge Southeastern Livingston County is composed predominantly of a rolling upland terrane bisected by the east-west trending lowland occupied by the Indian Creek drainage. From a hydrogeologic perspective, it is assumed that the uplands are principally areas of groundwater recharge and the lowlands are discharge areas. Therefore, groundwater movement is generally downward through the loess-capped Snider Till Member, toward the Ashmore aquifer. The top of the zone of saturation (water table) generally closely parallels the land surface. In the fine-textured Snider Till, the water table is generally within 5 to 10 feet of the land surface. Because of the rolling topography and frequent shallow depressions and drainageways, local discharge areas occur on the uplands.

Lowland terranes commonly contain alluvial or glacial outwash sediments that can readily be used to distinguish the boundaries of upland terranes. In the study area, the topographic lowland containing the Indian Creek drainage appears, in part, to have been formed by erosion of the till uplands. In some areas, little or no alluvium or outwash has been identified in the lowland. These areas within the lowland, along with the areas that contain coarse-textured sediments, are assumed to be areas of groundwater discharge, with the water table generally within 5 feet of land surface.

Impact of surface sources of contamination. The geologic and terrane characteristics of southeastern Livingston County, along with the depth of the aquifers, provides both protection and potential for contamination of aquifers in the area. Although the Banner and Glasford Formation aquifers are buried by more than 100 feet of mainly fine-textured glacial till, the Ashmore Member and Henry Formation, which serve as aquifers, are at relatively shallow depth or directly below land surface, respectively.

The Ashmore aquifer, at depths ranging from less than 30 feet to greater than 50 feet, is variable with respect to the potential for contamination from agricultural chemicals applied at the surface. In the areas where the aquifer occurs within 30 feet of land surface, the contamination potential would appear to be greatest. Although the clayey nature of the Snider Till Member would generally inhibit and attenuate contaminants from reaching the Ashmore, the potential for fractures transmitting contaminants to the aquifer is high. Also, problems may occur in wells located along slopes or in shallow depressions because surface runoff may concentrate contaminants. In those areas where the Ashmore aquifer is between 30 feet and 50 feet below the surface, the thicker Batestown Till Member below the Snider may help to decrease the potential for contamination of the Ashmore.

Wells finished in the Henry Formation aquifer, particularly just at the northwest edge of the study area, are probably the most likely to be contaminated. There are two potential sources of contamination to this aquifer: infiltration directly into the aquifer and induced infiltration of contaminated surface water in Indian Creek. Intensive pumpage of the aquifer by municipal and industrial wells can induce recharge into the aquifer. Also, rainfall on the sand and gravel can carry contaminants downward by infiltration.

GROUNDWATER HYDROLOGY

Aquifer Tests

Records at the ISWS indicate that the only municipal well in the study area is a 60-foot-deep well with a pumping capacity of 50 gpm in the town of Strawn. No aquifer test results are available. A number of aquifer tests, however, are available for the municipal wells in the towns of Fairbury and Forrest, 1 mile north of the study area. The wells are most likely finished in the sand and gravel of the Ashmore Member.

The town of Fairbury has five wells, ranging from 39 to 57 feet deep. Their screen lengths range from 10 to 20 feet. The reported static-water levels vary from 5.5 to 19 feet below ground surface. The wells were pumped, during aquifer tests, for short durations (1 to 3 hours) at rates of 88 to 500 gpm. Reported transmissivities range from 29,000 to 128,000 gpd/ft, and the corresponding hydraulic conductivities range from 800 to 3,900 gpd/sq ft. Short term specific capacity of these wells ranges from 10 to 155 gpm/ft. An aquifer test for one reserve well, pumped at a rate of 200 gpm for 24 hours, yielded the lowest transmissivity and hydraulic conductivity (29,000 gpd/ft and 800 gpd/sq ft, respectively). The specific capacity for this well was 19.9 gpm/ft.

The town of Forrest has three municipal wells, ranging from 105 to 114 feet deep. They have screened lengths of 18 to 25 feet. Two of the wells were pumped at 250 and 300 gpm, respectively, for 3 hours each. The two pump tests gave similar transmissivities of 24,000 gpd/ft, hydraulic conductivities of 1,200 gpd/sq ft, and specific capacities of 10.5 gpm/ft. The third well was pumped at 245 gpm for one-half hour. Transmissivity and hydraulic conductivity values of 39,000 gpd/ft and 1,560 gpd/sq ft, respectively, were derived from the test. Because the test duration was short, these values cannot be compared with those of the other two wells. Another well, 130 feet deep, located at a nearby industrial facility was pumped at 62 gpm for 3 hours. The reported transmissivity and hydraulic conductivity are 6,300 gpd/ft and 250 gpd/sq ft, respectively. This well is located within 0.5 mile of the wells in Forrest. Thus, over short distances, a range of values for hydraulic conductivity can be expected.

Groundwater Use

In the study area, the 164 households that rely on wells have an estimated population of about 574 and use about 40,200 gallons daily. Strawn pumps an additional 38,000 gpd. Livestock water use is estimated at about 100,000 gpd. The total daily pumpage for the study area is about 178,000 gallons, and the total yearly pumpage is approximately 65 million gallons.

Aquifer Recharge

Groundwater runoff in the study area is estimated to range from 64,600 to 129,000 gpd/sq mi (Visocky and Schicht 1969). The portion of groundwater runoff that recharges the deep aquifer depends upon till thickness and its vertical permeability and pumping stress. Zeizel and others (1962, quoted by Visocky and Schicht 1969) indicated that 60% of groundwater runoff could be diverted into cones of depressions in deeply buried valleys. Visocky and Schicht (1969) also reported that recharge rates calculated by Walton (1965) for the middle aquifer (Glasford Formation) at Urbana-Champaigri show that the recharge rate is nearly one-half of the estimated groundwater runoff. Because there is no pumping stress in the Livingston County study area, a conservative estimate of groundwater recharge to the deep aquifer is 35% of the total groundwater recharge. At this rate, the deep aquifer recharge per square mile, based on the groundwater runoff data, can be estimated to range from 22,000 gpd to 45,000 gpd. Thus, the average annual recharge to deeply buried bedrock valley aquifers in the study area is about 600 million gallons.

SUMMARY AND CONCLUSIONS

The geologic setting of southeastern Livingston County does not provide for an abundance of available groundwater. Although groundwater is obtained from five aquifers in the study area, none has either the areal extent or thickness to yield large groundwater supplies over extended periods of time. The most widespread aquifer throughout the study area, the Ashmore aquifer, is locally within 30 to 50 feet of the land surface and is the only aquifer present in most of the central part of the area. Where it is within 30 feet of the surface, it has the greatest risk of contamination from surface sources.

Although not known to be used as an aquifer within the immediate study area, the Henry Formation is the groundwater resource for the village of Fairbury and some industries just at the northwest edge of the study area. Because this sand and gravel aquifer directly underlies land surface along Indian Creek and carries surface drainage from the study area, contaminants can enter the aquifer both by recharge from the creek near pumping wells or from infiltration of rainfall through the unsaturated zone and into the aquifer. Therefore, the greatest risk in the use of farm chemicals is in those areas where the Ashmore aquifer is within 50 feet of land surface or in areas where the Henry Formation is an aquifer or potential aquifer.

7 CHARACTERIZATION OF THE PIATT COUNTY STUDY AREA

J. P. Kempton, M. L. Barnhardt, C. Ray, and M. R. Greenpool

LAND USE

Description of the Study Area

The study area in Piatt County (T19N, R5E) covers about 35 square miles of Goose Creek Township; the extreme southeast corner of the township, located on the Goose Creek floodplain, is not included in the study area (fig. 7.1). The village of DeLand, with a population of about 500, is the largest town. The Illinois Central Gulf railroad runs parallel to Illinois route 10 through DeLand, and Interstate highway 72 passes within 1 mile of the southeast corner of the study area.

A total of 104 households was located in the study area. Of the 87 considered suitable for sampling, 36 (41%) were active farms, 42 (48%) were rural residents, and the remaining 9 (11%) were unclassified. Of the 48 randomly selected well users, 14 (29%) were farmers (table 3.3).

Industrial and Commercial Operations

There are only a limited number of commercial operations in the study area (fig. 7.2). One grain elevator is located in the study area, and only one agricultural chemical facility is currently in operation. A second closed in March 1991, soon after sampling ended. Three pipelines cross the eastern part of the study area in a general north-south direction. One gas station is located in DeLand on Illinois route 10. A closed gas station is located east of the present gas station.

GEOLOGY AND HYDROGEOLOGY

Introduction

Goose Creek Township was selected as representative of an area in which the top of the shallowest aquifer is greater than 50 feet below the land surface. This section defines the geologic framework of the study area and emphasizes the sand and gravel bodies that are aquifers.

Previous Studies

A review of previously published work established the general geologic framework of the region. Lineback's (1979) map of Quaternary deposits of Illinois (fig. 3.4) provides the regional and surficial glacial geologic setting of the study area within the area of Illinois covered by the most recent major glaciation (the Wisconsinan). Also useful for information on the general geologic setting and stratigraphy are the work of Stephenson (1967) on the hydrogeology of the Mahomet Bedrock Valley (a portion of which underlies the southeastern part of the township), as well as that of Horberg (1950, 1953) on bedrock topography (fig. 3.3) and pre-Wisconsinan deposits of northeastern Illinois. Kempton et al. (1980) studied the stratigraphy and regional distribution of Illinoian and pre-Illinoian glacial deposits in east-central Illinois, and Willman and Frye's (1970) study of Pleistocene stratigraphy of Illinois provided the geologic names used in the figures and text. Hunt and Kempton's (1977) study of the geology of De Witt County, which neighbors Piatt County on the northwest, provided useful information on regional stratigraphy and correlation. Kempton et al. (1991) described the geology, hydrogeology, and bedrock topography of the entire Mahomet Bedrock Valley in Illinois.

Physiography and Drainage

Goose Creek Township is generally flat to gently rolling. The elevation of the till plain ranges from a maximum of about 715 feet above msl in the northwestern part of the township to 680 to 700 feet in the southeastern part. The lowest elevation in the township is about 640 feet along

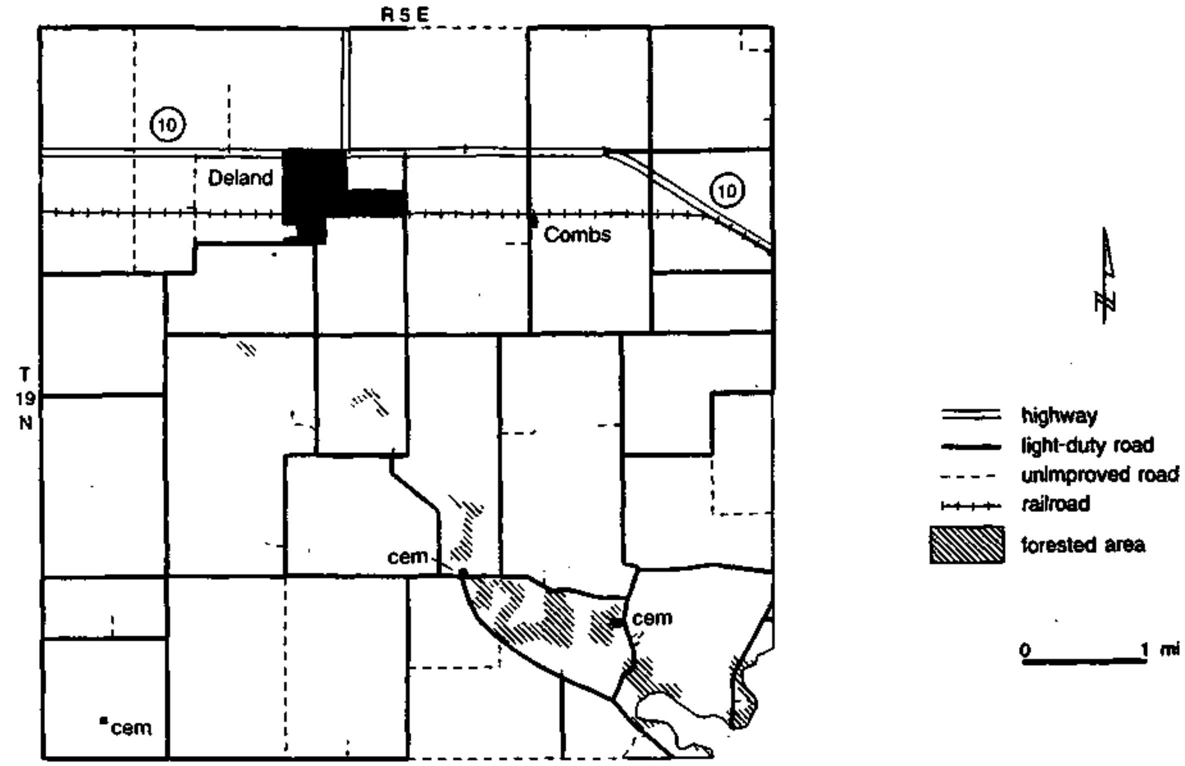


Figure 7.1 Piatt County study area.

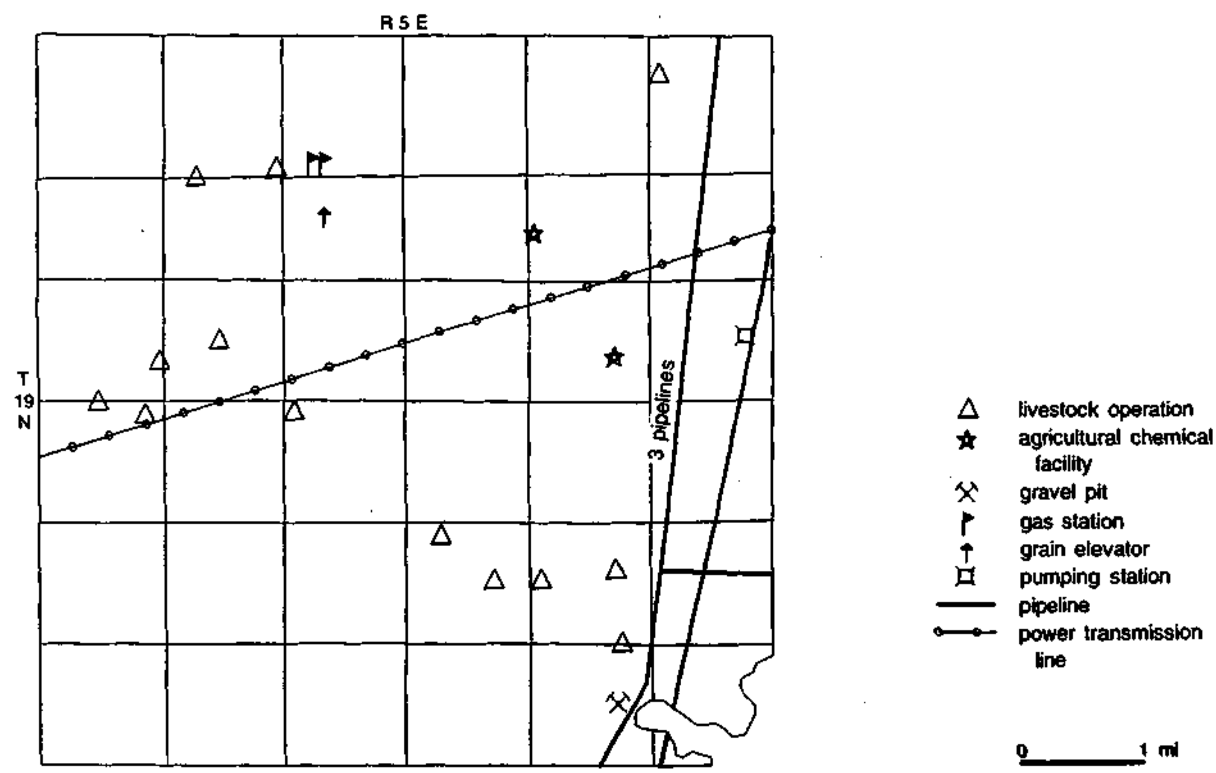


Figure 7.2 Potential sources of contamination in the Piatt County study area.

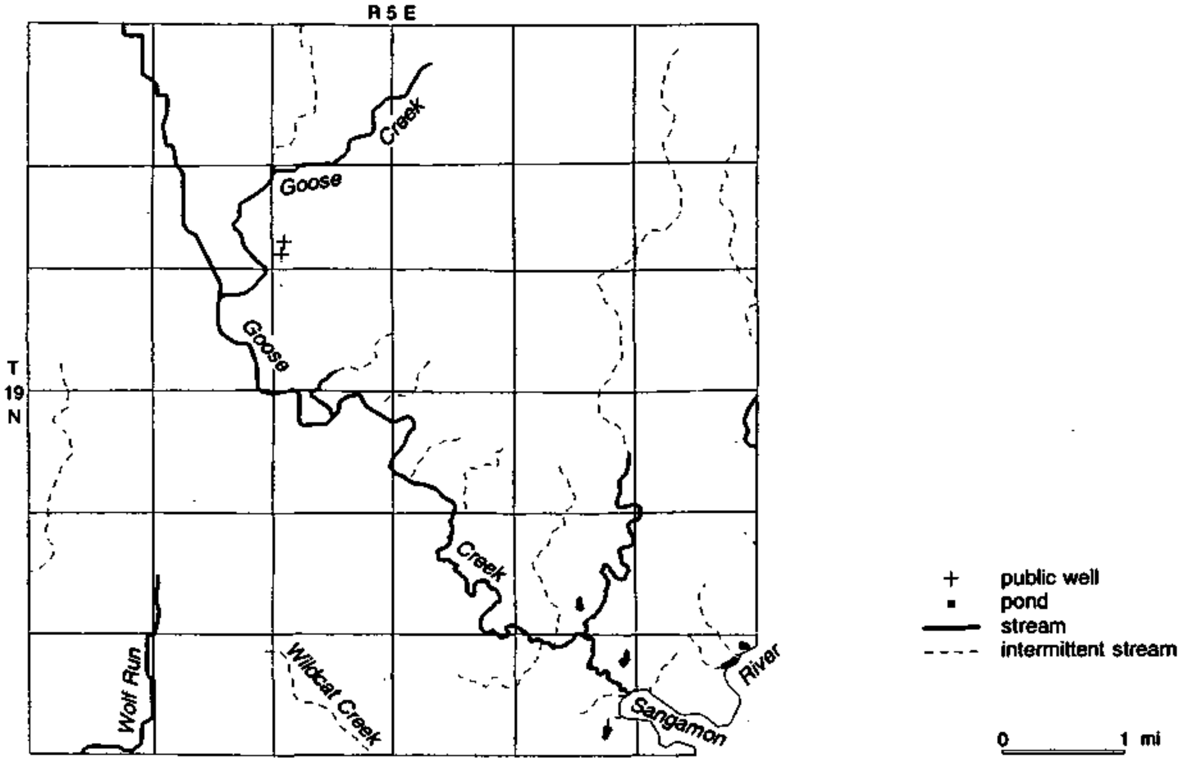


Figure 7.3 Drainage of the Piatt County study area.

Goose Creek, near its confluence with the Sangamon River. Maximum local relief is about 50 feet between the till-plain upland areas and the bottomlands along the lower reach of Goose Creek. The general slope of the land surface is to the south.

The main drainage of the area is via Goose Creek to the Sangamon River, although smaller drainageways such as Wolf Run and Wildcat Creek drain to the south directly into the Sangamon (fig. 7.3). Numerous shallow depressions on the relatively flat land surface indicate that drainage is not yet well integrated across the region, which is subject to erosion mainly adjacent to Goose Creek and the Sangamon River, as well as locally along the smaller creeks in the central and southeastern part of the township.

Bedrock Geology and Topography

The characteristics of the land surface in Goose Creek Township, including the topography and the nature of the unlithified surficial materials, are mainly the result of the action of glacial ice and flowing water (fig. 7.4). The surface of the stratified bedrock underlying the surficial deposits at depths ranging from 150 to 300 feet does not reflect the present landscape. The topography of the buried bedrock surface, however, has a direct bearing on the thickness of the drift deposits (figs. 7.5 and 7.6). Where the elevation of the bedrock surface is low along major ancient bedrock valleys, the glacial deposits are thick and contain substantial amounts of sand and gravel. Where the bedrock surface is high, the drift deposits are generally thin and contain less sand and gravel.

Directly beneath the glacial deposits are the Bond and Modesto Formations of the Pennsylvanian system. They are composed primarily of shale and sandstone, as well as some thin but significant beds of limestone and coal (Willman et al. 1967). Below the Pennsylvanian rocks, which range in thickness from about 400 to 800 feet, is a thick sequence (about 5,000 feet)

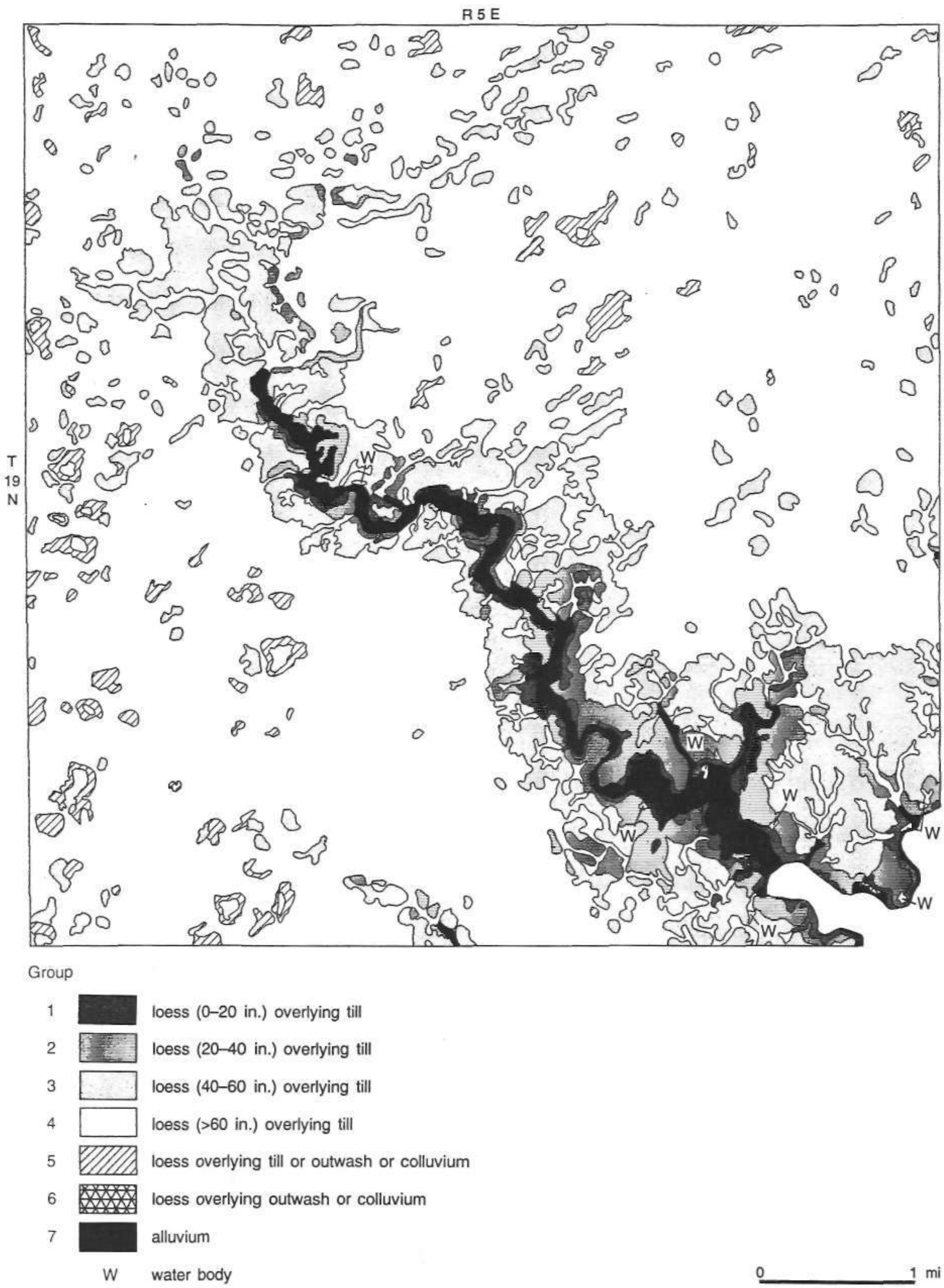


Figure 7.4 Parent materials of the Piatt County study area.

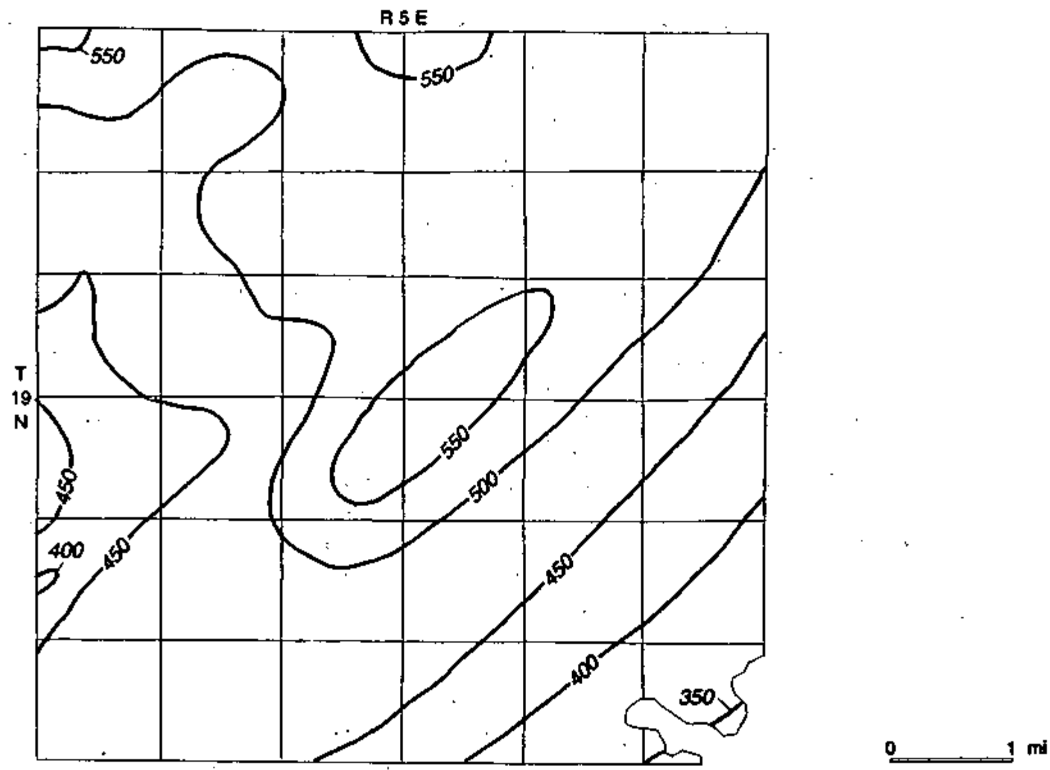


Figure 7.5 Topography of the bedrock surface in the Piatt County study area. Elevation in feet above msl, and contour interval is 50 feet.

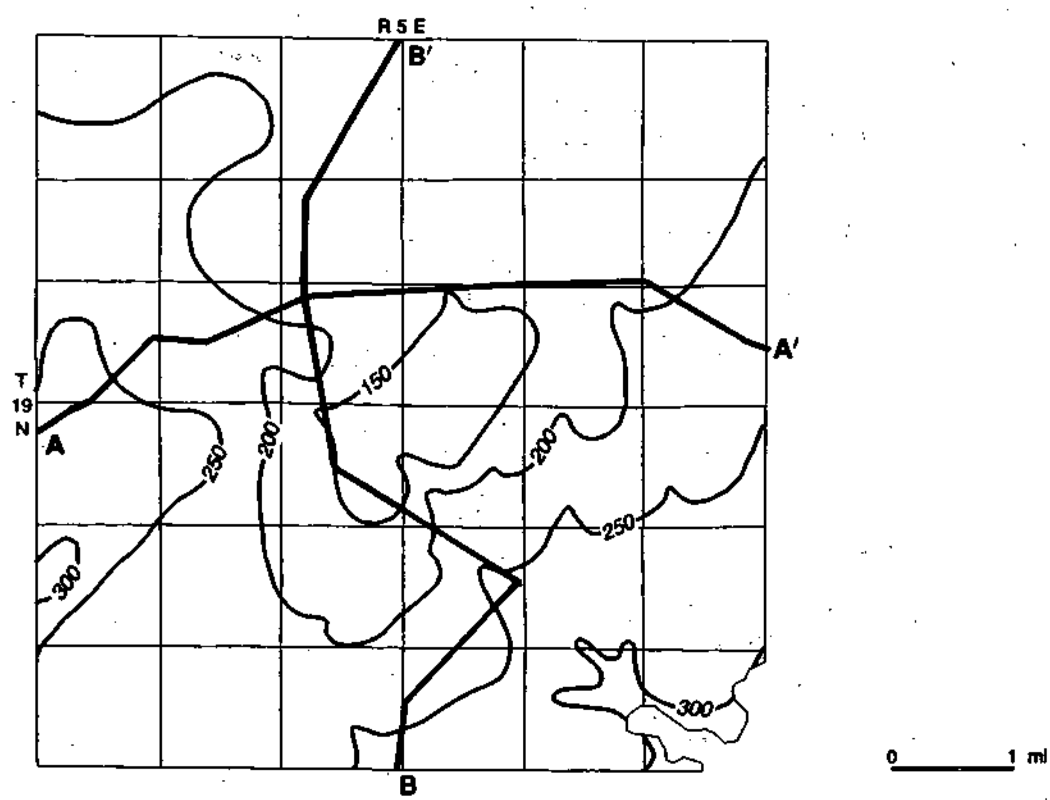


Figure 7.6 Thickness of drift deposits in the Piatt County study area. Contour interval is 50 feet. Location of transect lines is shown for cross sections A-A' and B-B'.

that represents all earlier Paleozoic periods. The sequence consists of interbedded shales, sandstones, limestones, and dolomites. The Pennsylvanian system was buried under an estimated 3,000 feet of younger strata that subsequently eroded. The result was a landscape with deep valleys incised into the bedrock. A portion of one of the major bedrock valleys in Illinois, the Mahomet Bedrock Valley (Kempton et al. 1991), underlies the southeastern part of Goose Creek Township. Figure 7.5 shows the bedrock topography.

Thickness of Quaternary Deposits

The surficial deposits that overlie the bedrock range in thickness from slightly more than 150 to more than 300 feet (fig. 7.6). Most of these materials are glacigenic deposits of the continental glaciers that covered the area during the last million years. The drift is composed mainly of glacial till or diamicton and interbedded sand and gravel. The sand and gravel layers are scattered and discontinuous in the shallow drift in the study area, but a thick, basal sand and gravel deposit fills the bedrock valleys (Kempton et al. 1991). Boreal peat or soils, which frequently separate the deposits of individual glacial advances, have been found in the study area. Loess, ranging in thickness from less than 2 feet to more than 5 feet (with small amounts of windblown sand), covers most of the study area and is the primary parent material for the Modern Soil (SCS, in press d). The most recent deposits not directly related to glaciation are the floodplain deposits (alluvium) found adjacent to streams (fig. 7.4).

The surface features of Goose Creek Township were formed during the most recent stage of glaciation, the Wisconsinan. The farthest advance of the Wisconsinan terminated approximately 20 miles to the west and buried tills and sand and gravel deposits of Illinoian age (fig. 7.7). Buried beneath the Wisconsinan and Illinoian deposits overlying the bedrock are the pre-Illinoian tills and sand and gravel. Figure 7.8 presents the distribution of the geologic materials present from the land surface to a depth of 50 feet. The figure illustrates the spatial and vertical relationships of the deposits representing two of the three main stages of glaciation (from oldest to youngest): the Banner Formation (pre-Illinoian), the Glasford Formation (Illinoian), and the Wedron Formation (Wisconsinan). The Banner Formation does not appear on figure 7.8 because it is found at depths greater than 50 feet; the Glasford Formation and the Wedron Formation make up the bulk of the sediments in this area. The Wedron Formation dominates the surface deposits throughout the study area, but it is generally the thinnest of the three formations (fig. 7.9).

Banner Formation Although nowhere present within 50 feet of land surface, the Banner Formation is significant because it includes the Mahomet Sand Member, a thick outwash sand and gravel deposited during one or more of the earliest glacial advances into the area. The Mahomet Sand Member, which reaches a maximum thickness of about 150 feet just to the south of the study area, fills the deepest part of the Mahomet Bedrock Valley.

Glasford Formation The Glasford Formation consists of several individual tills that are commonly separated by thin, discontinuous layers of sand and gravel. The uppermost of the tills, the Radnor Till Member, is a compact, gray silty till that may be locally found within 50 feet of the land surface within the study area. The Vandalia Till Member is a sandy till with thin lenticular bodies of silt, sand, and gravel (Willman et al. 1975).

Robein Silt The Robein Silt (fig. 7.7), an easily recognized marker horizon, separates the Glasford Formation from the Wedron Formation and occurs extensively in the area. The Robein Silt is an organic sediment, often containing twigs and logs, composed of dark, brown to black, highly organic silt. The age of this material ranges from 22,000 to 28,000 B.P. and marks **a** major period of ice withdrawal during the Wisconsinan Stage of glaciation (Willman et al. 1975). Where present, the Robein Silt averages about 2 to 3 feet thick, although it may reach thicknesses of 5 or 6 feet. Where thin, it probably represents an old wet prairie soil; where thick, it may have accumulated in bogs or marshlands. Although other organic deposits are

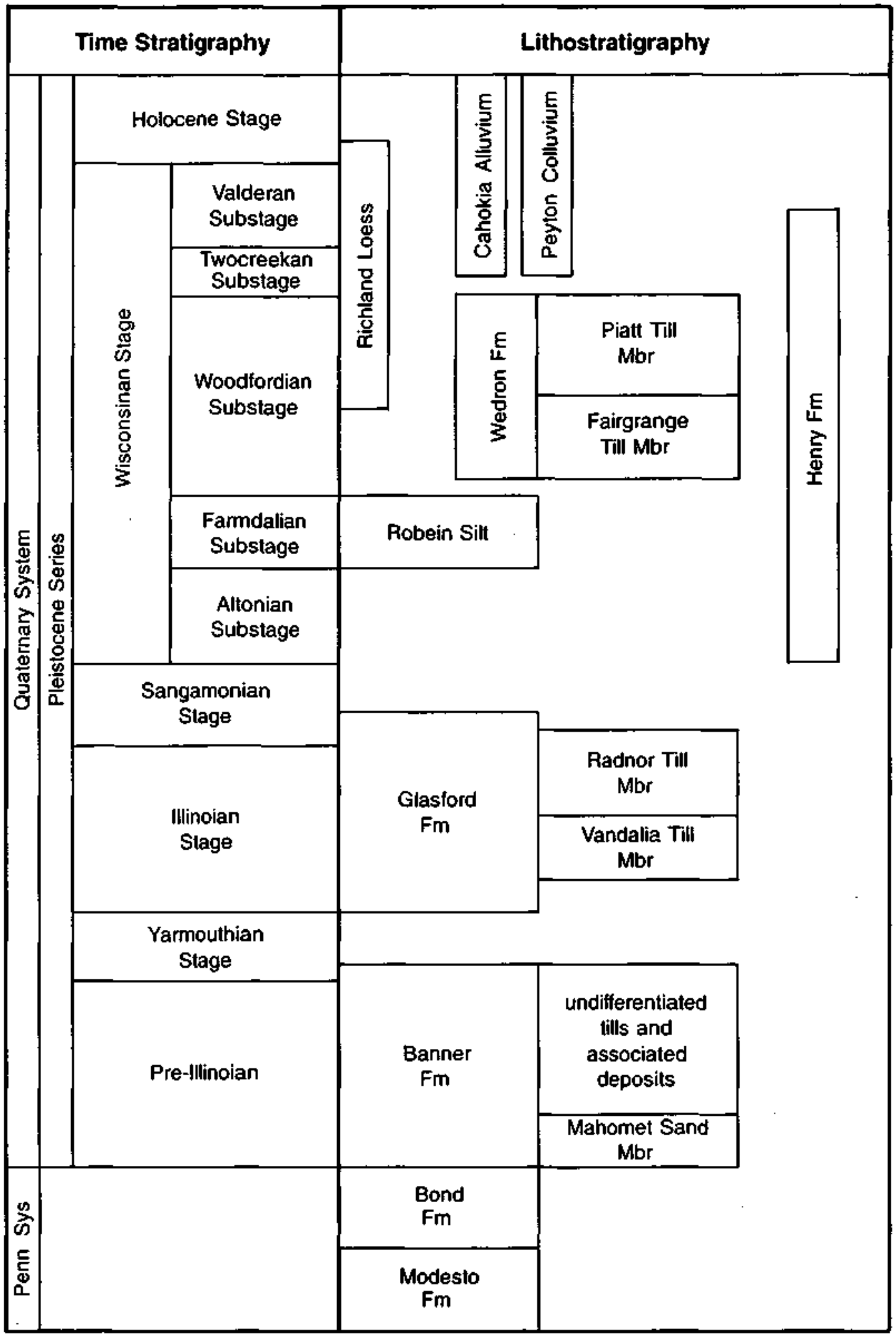


Figure 7.7 Lithostratigraphy of the Piatt County study area.

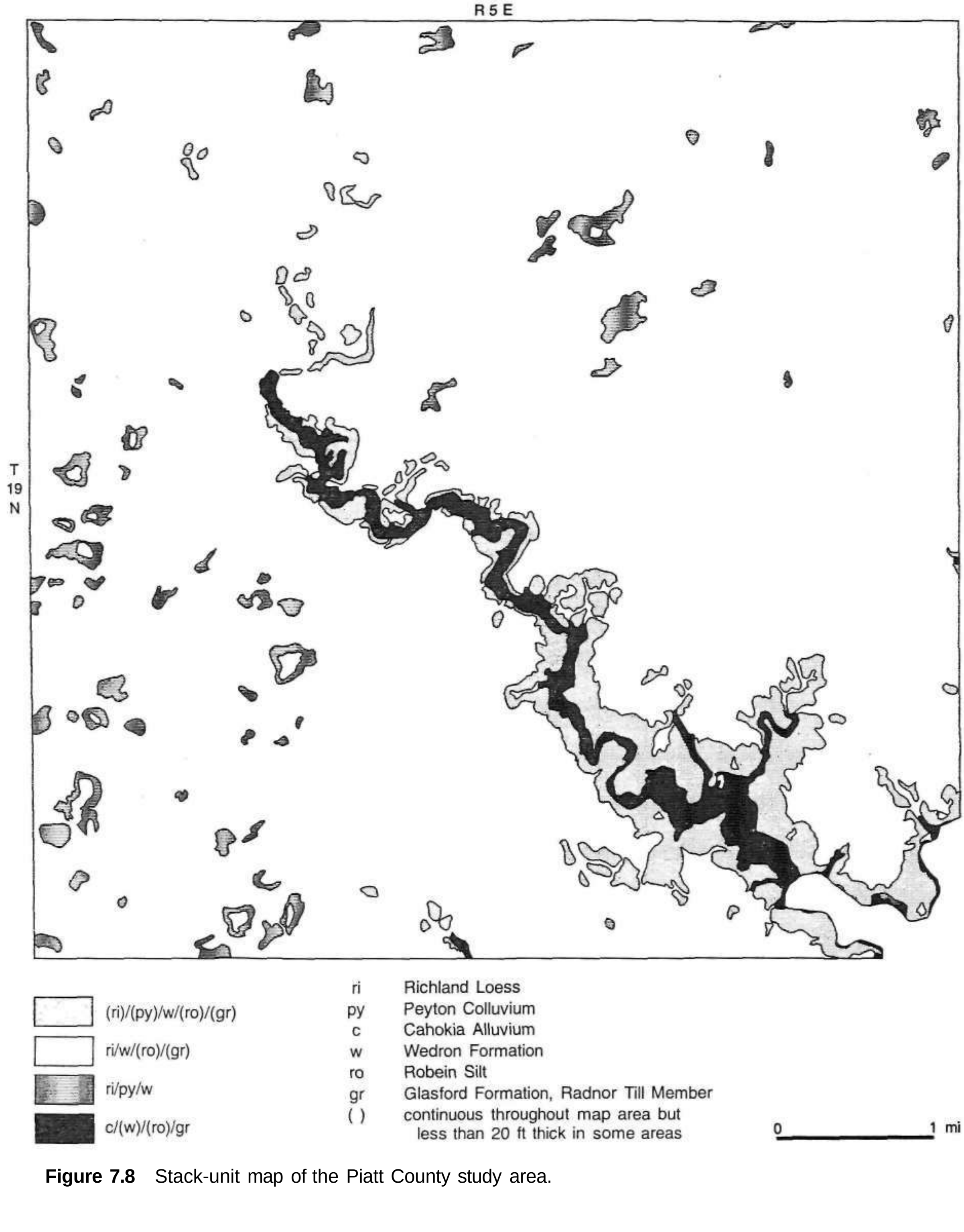


Figure 7.8 Stack-unit map of the Piatt County study area.

encountered locally within the older sequence of glacial deposits, the Robein Silt is by far the most persistent. Its surface is at a relatively constant elevation of about 650 feet across the township (fig. 7.10). These organic units generate methane gas, which is frequently present in water wells in the area (Meents 1960).

Wedron Formation The Wedron Formation, deposited during the Wisconsinan glaciation, consists of two till members. The Fairgrange Till Member is a gray brown silty till (Lineback 1979), and the Piatt Till Member is a gray, sandy, silty till (Wickham 1979) that forms the upland surface till of the entire township. The Fairgrange Till is likely to be found within 20 feet of the surface and below the upper Piatt Till, but it may be absent in areas where the Piatt Till rests directly on the Robein Silt or on the Glasford Formation.

Henry Formation The surficial sands and gravels of Wisconsinan age are glacial outwash deposits belonging to the Henry Formation, and they occur only along the Sangamon River and Goose Creek. In Goose Creek Township, the Henry Formation deposits consist of the Mackinaw Member, which is a fairly well sorted, medium sand to gravel found in terraces along the Sangamon River and beneath the modern alluvium in the Sangamon River and Goose Creek valleys.

Richland Loess The tan to yellowish tan Richland Loess covers almost the entire surface of Goose Creek Township. It is generally 3 to 5 feet thick and may thin to the east and northeast across the study area.

Cahokia Alluvium As the youngest deposits mapped in the county, the Cahokia Alluvium consists of alluvial deposits ranging from 5 to 20 feet thick along the major valleys, but they are generally no more than 2 or 3 feet thick along smaller tributary valleys. The Cahokia Alluvium is Holocene (recent) in age and consists of silts and sands with some organic material. It may include reworked sand and gravel of the Henry Formation or the products of erosion and slopewash (Peyton Colluvium) from the till and loess deposits on uplands.

Soils and Parent Materials

A relatively uniform coverage of loess and till occurs across the township. There is little relief on the land surface except along stream channels. Twenty soil series are recognized in Goose Creek Township (SCS, in press d). About 95% of the area is covered by Mollisols and the remainder by Alfisols. Major soils in the study area are the Sable silt loam (44% of the map area), Ipava silt loam (27%), Flanagan silt loam (8%), and Catlin silt loam (7%). Loess is the surficial parent material throughout the study area, except along streams, where alluvium is the uppermost parent material. The loess varies from less than 20 inches to more than 60 inches in thickness (table 7.1 and fig. 7.4). Where the loess cover is thin, the underlying glacial till and outwash is also a parent material for the Modern Soil. The till has slightly lower permeability than the loess, and the outwash exhibits considerably greater permeability. Overall, 80% of the soils in the study area are rated as moderately permeable, and the remaining 20% are rated as moderate to moderately slow in permeability.

Soils in the study area, based on estimates from the SCS, average about 4.7% organic matter throughout an average thickness of 17.5 inches. The range in organic matter is 1.4% to 5.5% (table 7.1). More than 98% of the soils contain more than 2% (moderate) organic matter, and more than 92% of the soils contain more than 4% (high). Soils developed in thin loess over till and in thin loess over outwash contain the smallest amounts of organic matter (table 7.1). One of the factors influencing pesticide leaching potential is organic matter content (McKenna et al. 1989). The predominance of soils with high organic content in the study area is a positive factor in the prevention of pesticide migration.

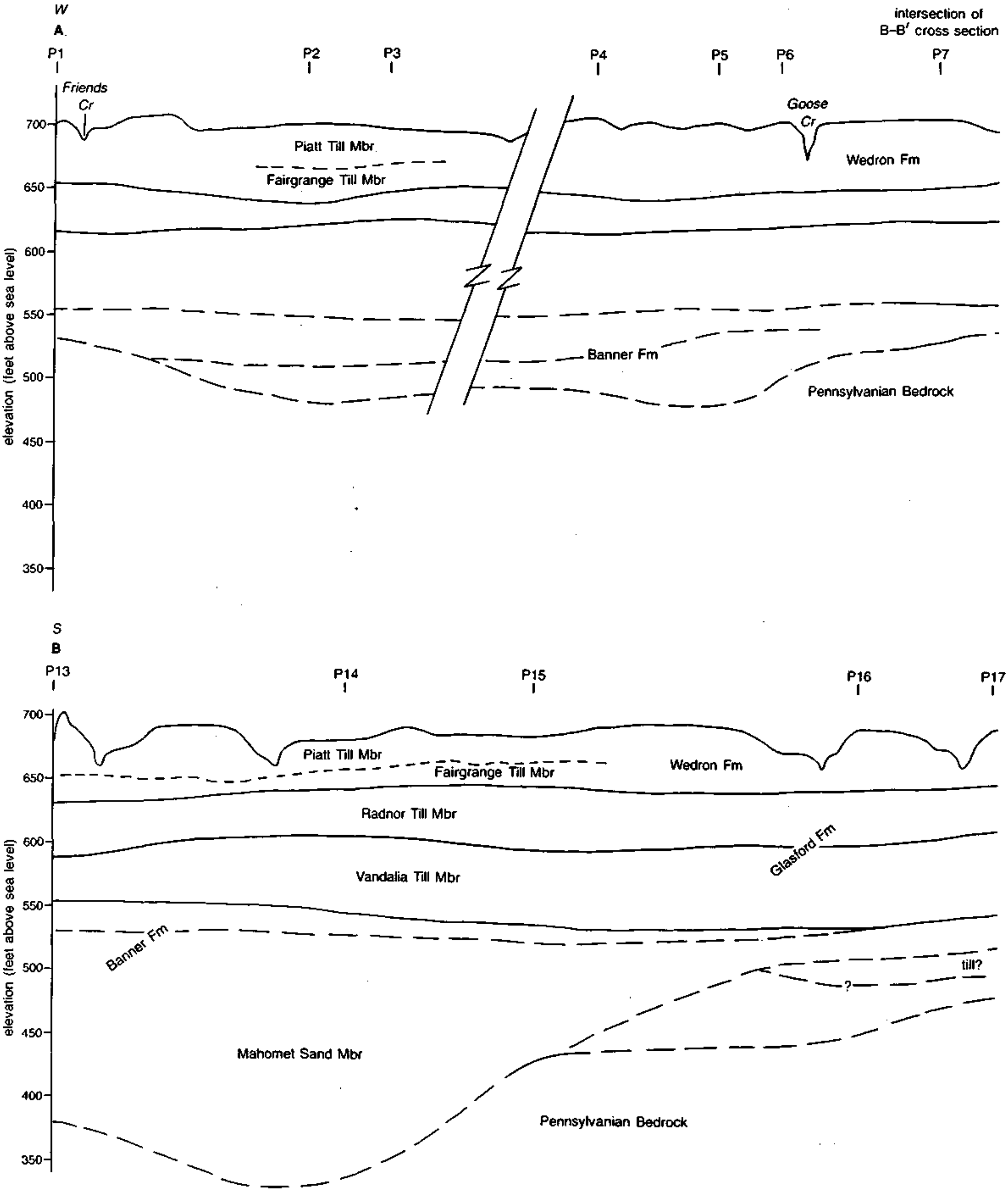
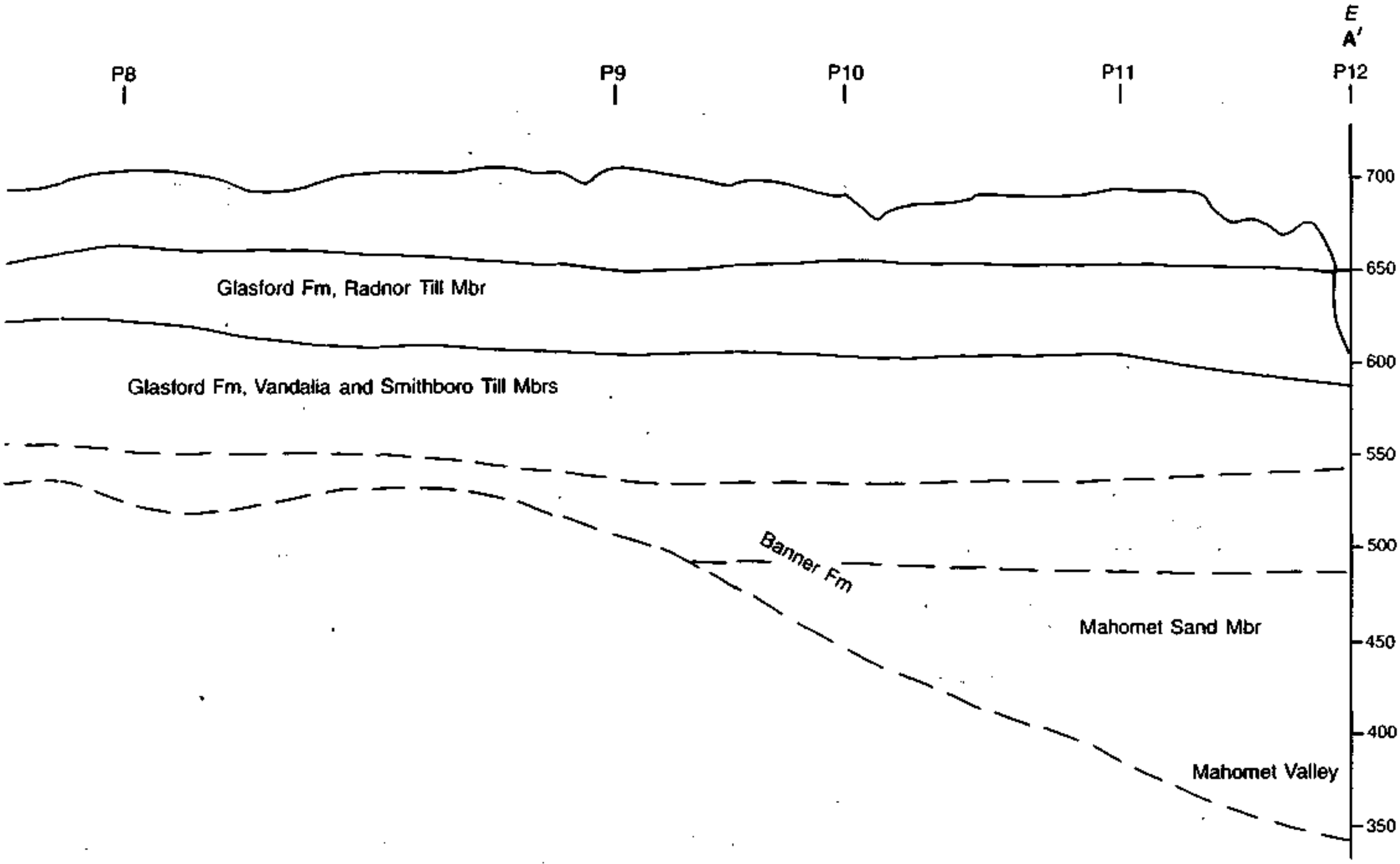
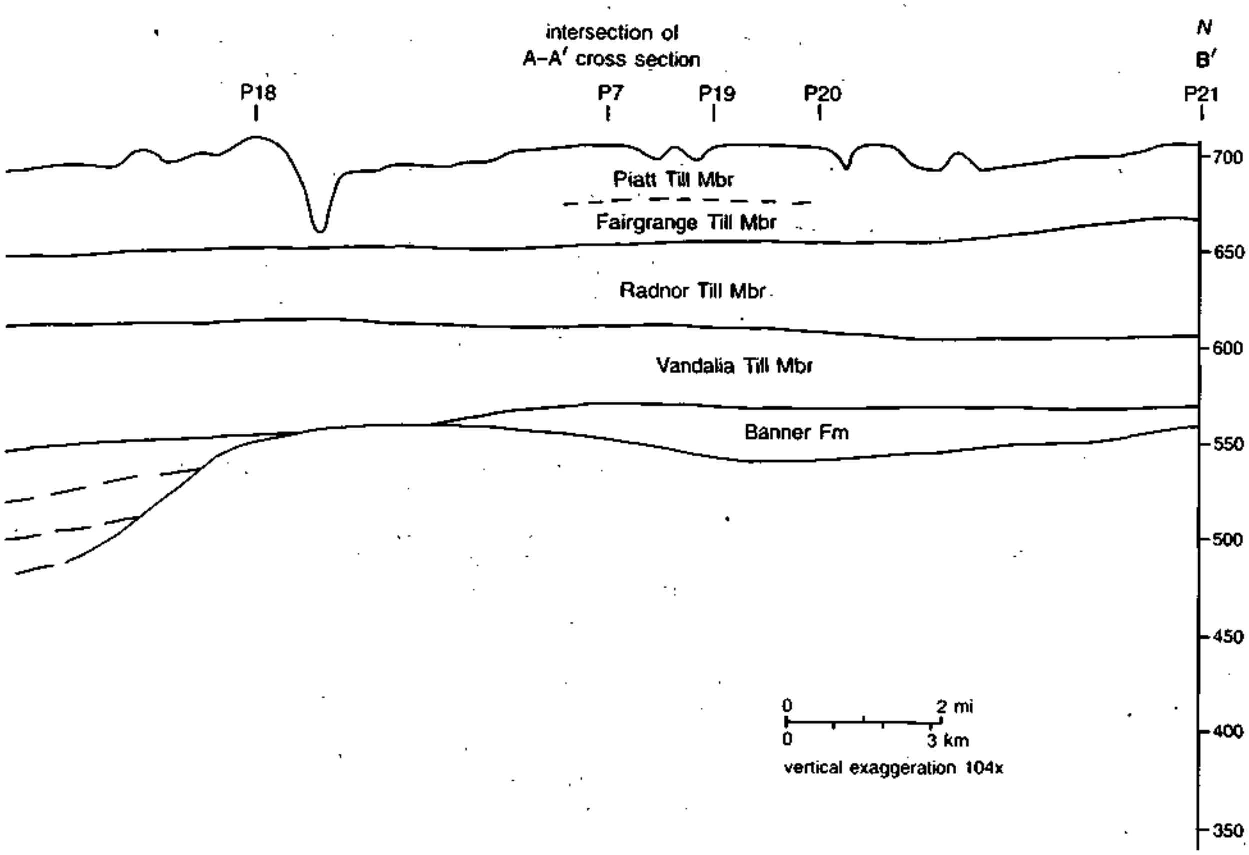


Figure 7.9 Cross sections A-A' and B-B' for the Piatt County study area.


E
A′
P8
P9
P10
P11
P12
700
650
600
550
500
450
400
350
Glasford Fm, Radnor Till Mbr
Glasford Fm, Vandalia and Smithboro Till Mbrs
Banner Fm
Mahomet Sand Mbr
Mahomet Valley


intersection of
A–A′ cross section
N
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P18
P7
P19
P20
P21
700
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Piatt Till Mbr
Fairgrange Till Mbr
Radnor Till Mbr
Vandalia Till Mbr
Banner Fm
0
2 mi
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3 km
vertical exaggeration 104x

Table 7.1 Soil permeability and surface organic matter content in Piatt County study area.

Parent material group[a]	Permeability[b,c] (in./hr)	Organic matter[d] (avg. %/avg. thickness)	% of study area
1—Loess (0-20 in.) overlying till	0.6-2.0	1.4 for upper 8.1 in.	2
2—Loess (20-40 in.) overlying till	0.6-2.0 0.2-0.6	2.1 for upper 11.1 in.	4
3—Loess (40-60 in.) overlying till	0.6-2.0 0.2-0.6	4.0 for upper 15.5 in.	15
4—Loess (>60 in.)	0.6-2.0	5.1 for upper 18.4 in.	74
5—Loess overlying till or outwash (colluvium)	0.6-2.0	5.5 for upper 11.1 in.	2
6—Loess overlying outwash	0.6-2.0	1.5 for upper 14.0 in.	~0
7—Alluvium	0.6-2.0	4.0 for upper 23.3 in.	3

[a] See parent material map (fig. 7.4) for distribution.
[b] Data for permeability and organic matter from Fehrenbacher et al. (1984).
[c] The second range of values represents permeability for sediments below the initial unit unless another material is identified.
[d] Percentages and horizon thicknesses are weighted by soil series in each group.

Terranes

The terranes of Goose Creek Township consist of a widespread, nearly flat to gently rolling upland. The upland is underlain mainly by loess-capped till of the Wedron Formation and bisected by a narrow lowland that trends northwest to southeast and is outlined by the Cahokia Alluvium of Goose Creek (fig. 7.11). The principal relief is concentrated along Goose Creek valley and its small tributaries, where the loess has been eroded. The margins of the upland adjacent to the Goose Creek lowland and the Sangamon River valley may have as much as 50 feet of local relief. The valley sides are locally steep, but more often they have gentle slopes.

The lowland is sinuous and narrow, averaging no more than 1/4 mile in width, except in the southeast corner of the township, where it broadens into the Sangamon River valley. The lowland extends to just southwest of the village of DeLand, where two tributaries enter Goose Creek. The lowland is only about 25 feet below the highest upland level near DeLand but lowers to about 60 feet below the upland in the southeast corner. Therefore, in this area, the alluvium may rest directly on till of the Glasford Formation, and the valley may actually truncate the Robein Silt.

Hydrogeology

General hydrogeologic considerations The soils, geologic, and topographic (terrane) setting of Goose Creek Township control the infiltration rate, aquifer distribution, and groundwater availability in the area. The widespread upland till surface capped by loess provides for generally slow to moderate infiltration rates. The predominantly silt loam tills have relatively low permeability. Although these tills allow significant but slow, long term recharge to the deeper aquifers, they generally inhibit downward movement of contaminants.

The shallowest aquifers in the study area are associated with sands and gravels within the Radnor Till Member at depths of 50 feet or greater. They are covered by a minimum of 40 to 50 feet of silt loam and loam till. Although some of the oxidized clayey tills have a tendency to develop fractures, such features are not as common in sandy and silty tills. The top of the zone of saturation in the upland areas is generally within 5 to 10 feet of the land surface. Static-water levels in the shallower (Radnor Formation) aquifers are reported at about 50 feet below the upland surface (elevation 650 feet above msl), and those in the Mahomet Sand are at about 600 feet.

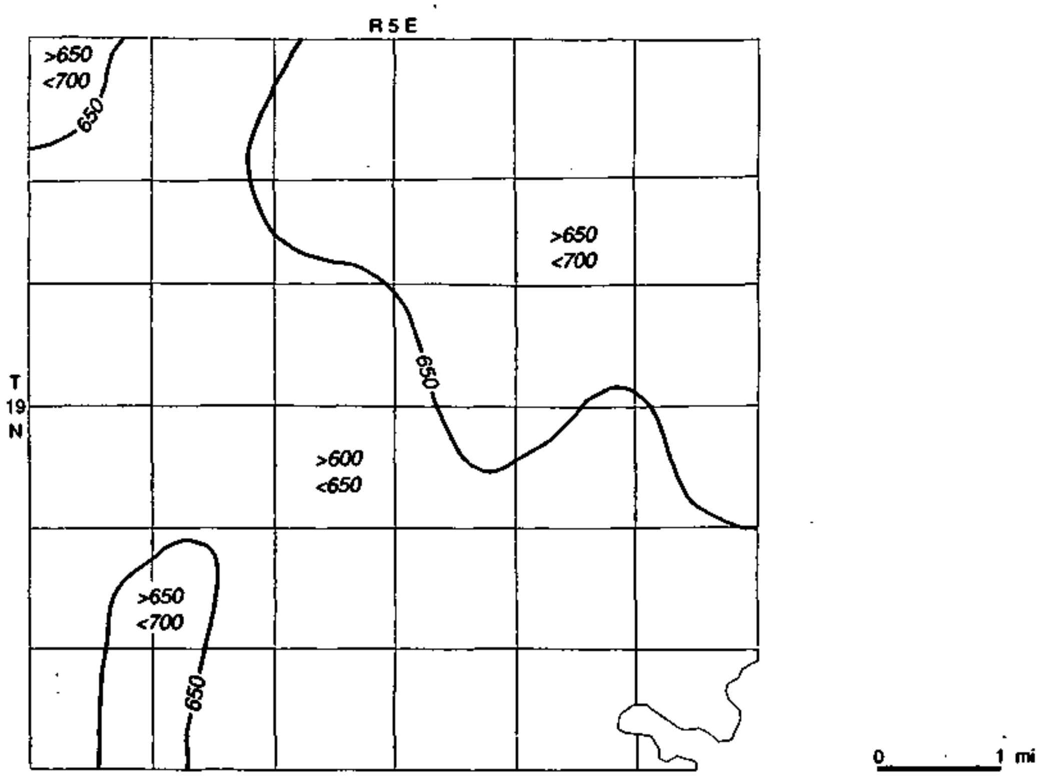

Figure 7.10 Topography of the Robein Silt surface in the Piatt County study area. Elevation is in feet above msl.

Groundwater resources The bedrock in Goose Creek Township is not a favorable source of groundwater. The shallow Pennsylvanian rock is composed of tight shales and thin, interbedded limestones, sandstones, and coal. The deeper bedrock aquifers, the sandstones and limestones in particular, contain water that is too highly mineralized for use. A few wells yield small quantities of water from the upper 20 to 30 feet of the Pennsylvanian bedrock. The water is drawn from fractures in the shale and limestone or from sandstones that are locally present; however, the Pennsylvanian rocks are usually considered as a source of water only if adequate supplies cannot be obtained from the drift.

The possibility of developing small supplies of groundwater for farm and domestic use from wells finished in the drift is generally good. The potential for development of moderate to large groundwater supplies from the drift ranges from poor, as in most of Goose Creek Township, to extremely favorable in the southeast, where the Mahomet Sand Member is present. Figure 7.9 illustrates the vertical sequence of deposits in Goose Creek Township, including the thick Mahomet Sand Member in the Mahomet Bedrock Valley. The figure also illustrates the discontinuity of the interbedded sand and gravel deposits within and between the Glasford Formation and the upper half of the Banner Formation. Where the Mahomet Sand Member reaches its maximum thickness in the southeastern part of the township (fig. 7.9), the uppermost zone is neither as permeable nor as productive as the underlying zone, which generally contains sand and fine to medium gravel. The Mahomet Sand Member is less favorable as an aquifer where the bedrock surface is at elevations of 450 feet or higher (figs. 7.5 and 7.9) and where only the upper, finer portion of the sand is present.

Sand and gravel deposits found in the Cahokia Alluvium or in the Henry Formation of creek valleys may yield small to moderate amounts of groundwater. Wells finished in these deposits must be constructed in a manner that prevents pollution of the groundwater by surface water during periods of high water or flood. In areas where the Mahomet Sand Member is not

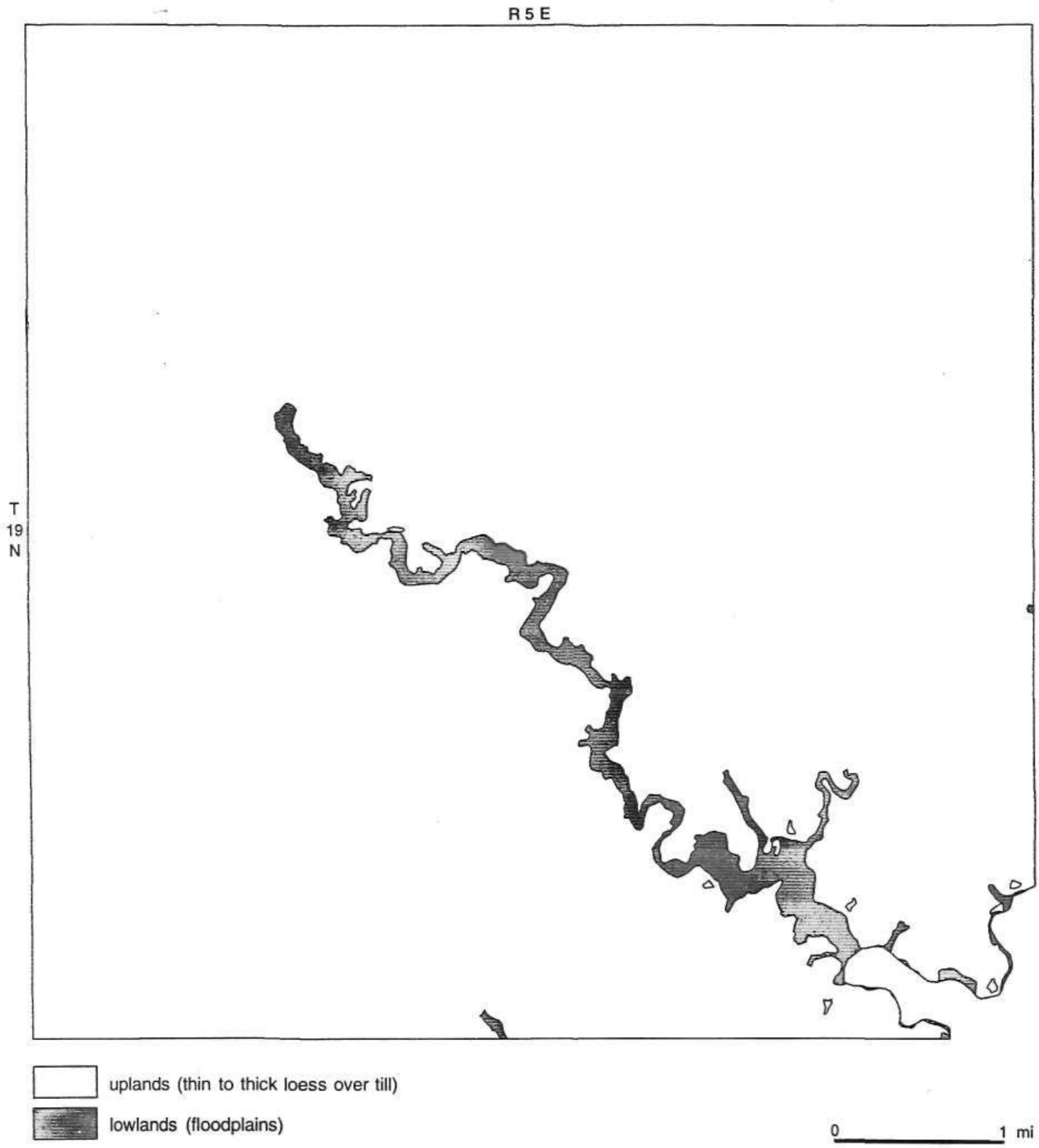

Figure 7.11 Terranes of the Piatt County study area.

present, most wells are finished in thin, discontinuous beds of sand and gravel within the Radnor and Vandalia Till Members. In these areas, however, test drilling is usually necessary to locate a source of groundwater for a supply larger than that needed by the average farm. Data on the extent of the shallow aquifers are insufficient for predicting where and at what depth the aquifers will be encountered in the drift.

Potential for aquifer contamination The principal aquifers used for domestic and farm groundwater supplies are those within the Glasford Formation at depths ranging from 50 to 120 feet. In the southern quarter of the area, the deeper Mahomet Sand Member (Banner Formation) is also used at depths below 150 feet. The shallowest of the Glasford Formation aquifers

Table 7.2 Summary of results from aquifer tests at DeLand, Illinois.

Well	Owner	Depth (ft)	Screen length (ft)	Saturated thickness (ft)	Pumping rate (gpm)	Test duration (hr)	Transmissivity (gpd/ft)	Hydraulic conductivity (gpd/sq ft)	Storativity
1	DeLand	83	9	8	65	7.5	2,950	370	
4	DeLand	79	3	11	20	0.5	1,690	150	
6	DeLand	82	7	7	46	3	1,600	229	0.0004
7	DeLand	79	8	8	45	3	1,900	238	0.0004
	Private	84	8	8	45	unknown	2,250	280	

Source: ISWS aquifer properties database.

All wells are finished in unconsolidated glacial deposits. The static water level for well 1 was 18 feet; it was approximately 30 feet below ground surface for the remaining wells.

are generally covered by at least 50 feet of silt loam till and a loess cap of up to 5 feet. No significant fracturing occurs in these tills to any significant depth. Given the relative thickness and generally low permeability of these tills, it would appear that proper use of agricultural chemicals should pose no serious threat to these aquifers.

GROUNDWATER HYDROLOGY

Aquifer Tests

Several aquifer tests were performed in Section 9 near DeLand for wells ranging in depth from 79 to 82 feet (table 7.2). All of the wells are finished in sand and gravel within the Glasford Formation. Aquifer hydraulic conductivity ranged from 150 to 370 gpd/sq ft, and the average storativity value was 0.0004.

Aquifer Recharge

Schicht and Walton's (1961) 3.5-year study of water budgets in the Goose Creek basin included a significant part of the study area. Constructing monthly water budgets for January 1955 to September 1958, they calculated annual groundwater recharge for 1955, 1956, and 1957 to be 6.40, 3.57, and 10.40 inches, respectively. This amounts to an annual recharge rate of 305,000, 170,000, and 496,000 gpd/sq mi, respectively. The precipitation in these 3 years was 31.80, 27.26, and 37.18 inches, respectively. The precipitation during 1955 and 1956 was well below the long term average value of 37 inches. This is reflected in the amount of groundwater recharge.

Groundwater Use

Groundwater use in the study area is primarily for domestic and livestock use. The village of DeLand, serving about 500 people through its municipal water system, annually pumps about 11.6 million gallons. The total number of rural households in Goose Creek Township is 104, with an estimated population of 364. The annual domestic use, determined from **a** water use of 70 gallons per day, is 9.3 million gallons. The livestock water use is estimated to be 3.6 million gallons. Thus, the total groundwater use within the township is 24.5 million gallons per year.

Although groundwater withdrawal within the boundaries of the study area is small compared with the estimated recharge, large amounts of water are pumped by four municipal wells of the town of Monticello, located less than 2 miles from the southeast corner of the study area. Well records at the ISWS indicate total pumpage from the wells in 1988 was 270 million gallons. The Sangamon River flows between these wells and the study area, but the contribution of the river and the adjoining wetlands to this pumpage is not clear and requires additional analysis.

SUMMARY AND CONCLUSIONS

Goose Creek Township is directly underlain by about 150 to 300 feet of glacial deposits containing interbedded sand and gravel deposits that are used as aquifers. The most widespread of these sand and gravel aquifers are within the Glasford Formation of Illinoian age and occur at 50 to 150 feet below a relatively flat upland surface. Although somewhat discontinuous in occurrence, the shallower aquifers are used for domestic and farm supplies throughout the township. The deeper Mahomet Sand aquifer at about 200 feet is present only in the southern quarter of the township. The shallower aquifers underlie about 50 feet of relatively impermeable Wedron Formation tills that should provide protection from contamination from properly applied farm chemicals.

8 CHARACTERIZATION OF THE EFFINGHAM COUNTY STUDY AREA

B. B. Curry, C. Ray, M. L. Bamhardt, and M. R. Greenpool

LAND USE

Description of the Study Area

The study area in Effingham County (fig. 8.1) covers the entire 36-square-mile Bishop Township (T7N, R7E). The village of Dieterich (population approximately 650) is located near the eastern edge of the study area. The Illinois Central Gulf (ICG) railroad crosses the area from northwest to southeast through Dieterich (fig. 8.1). Two petroleum pipelines traverse the study area in a general northeast-southwest direction, and three natural gas pipelines pass through the center of the study area in a north-south direction (fig. 8.2). Illinois route 33 parallels the ICG railroad track.

A total of 136 households (potential well sites) was inventoried in the study area. Personal contacts were made at 105 of these. One house was vacant. Of the 136 households, 74 (54%) were active farms, 47 (35%) were rural residences, and the remaining 15 (11%) were unclassified. Of the 48 randomly selected wells, 23 (48%) were on active farm sites.

Industrial and Commercial Operations

A limited number of commercial operations are found in the study area (fig. 8.2). A seed company and a grain elevator are located in the village of Dieterich along the ICG railroad. In addition, two gas stations and a major supplier of farm chemicals are located in the area. A sewage disposal facility is located in Section 13 of the township.

GEOLOGY AND HYDROGEOLOGY

Introduction

Bishop Township is representative of areas in which no highly permeable materials occur within 50 feet of land surface. Bored and large-diameter dug wells are the dominant well types. The generally flat-lying study area is dissected by several stream valleys (fig. 8.3).

The Quaternary stratigraphy may be subdivided into four groups: (1) pre-Illinoian sediments, (2) Illinoian sediments, (3) Sangamonian weathered sediment and Wisconsinan loess, and (4) Wisconsinan and Holocene alluvium (fig. 8.4). The pre-Illinoian deposits are composed of glacigenic sediment (e.g., till, sediment flow deposits, and outwash) that possesses an upper Yarmouthian (pre-Illinoian) weathering profile (geosol). They are overlain by three members of the Illinoian Glasford Formation (Smithboro Till, Mulberry Grove, and Vandalia Till Members) and Pearl or Hagarstown Formation. These units are mantled by pedogenically altered Sangamonian sediment and Wisconsinan loess, which are collectively about 11 feet thick.

Previous Studies

The most significant data sources are (1) descriptions of outcrops just west of the study township (Kettles 1980), (2) engineering borings from Dieterich, (3) water well logs, and (4) unpublished soil survey maps (SCS, in press a). Multiple corroborating logs suggest that the description of units is reliable in two areas: in Dieterich and in the SW Section 9 and SE Section 8. Numerous borehole logs exist for coal tests, but the descriptions of the Quaternary units are poor, and the locations and depths to bedrock indicated by these logs are unreliable. No other logs for bridges, highways, or structural tests are available. Unpublished soil survey maps were used to assess drainage characteristics on the uplands and to map Holocene alluvium. Subsurface profiles of western Clark County (Curry et al. 1991) provide a model for depicting the geometry of certain units.

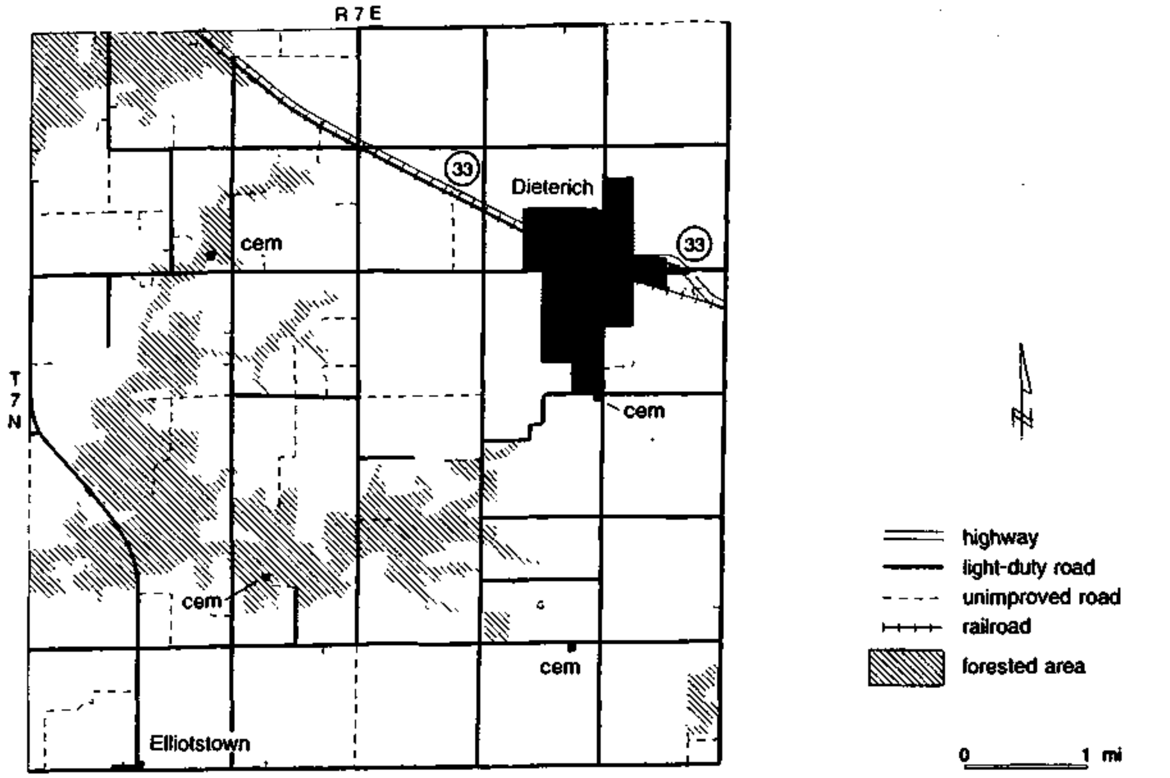

Figure 8.1 Effingham County study area.

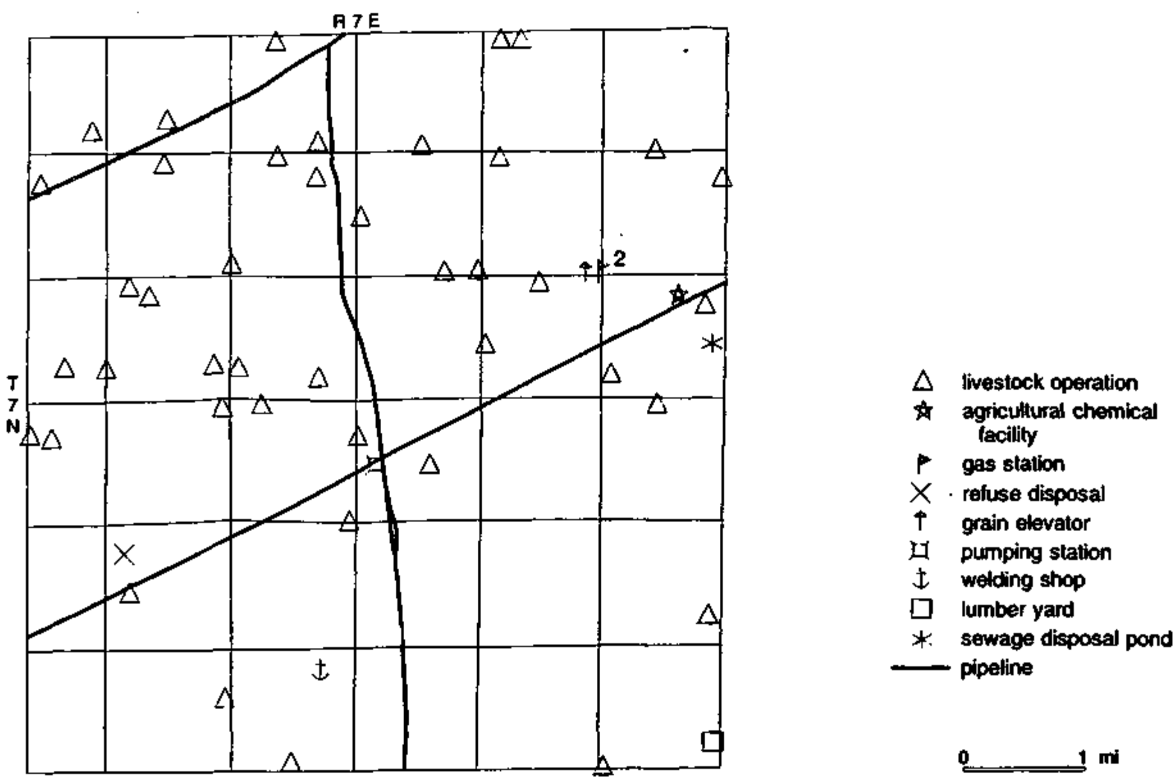

Figure 8.2 Potential sources of contamination in the Effingham County study area.

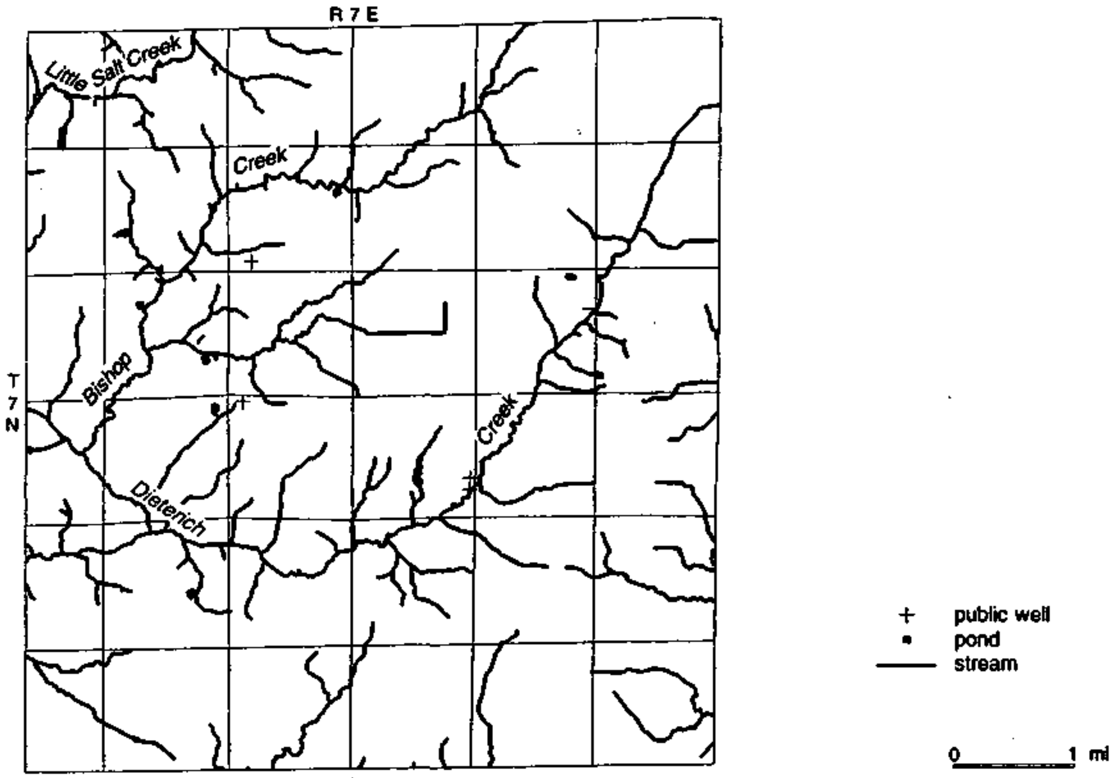

Figure 8.3 Drainage of the Effingham County study area.

Physiography and Drainage

The study area is characterized by broad, flat-lying uplands that are dissected by several streams, including Bishop Creek, Dieterich Creek, and Little Salt Creek (fig.8.3). A broad ridge trending roughly northeast to southwest occurs on the eastern half of the study area. The highest ground surface elevation (about 607 feet) occurs on the ridge where both Bishop Creek and Dieterich Creek originate. The average gradient of Bishop Creek is 6.5 feet per mile and the average width is 13.7 feet (Lockart 1969). The lowest elevation in the study area is 510 feet where Bishop Creek exits to the southwest. Total relief in the study area is about 97 feet. The drainage network is dendritic on the west and trellis-like on the east, where Bishop Creek and Dieterich Creek flow on the west slope of the ridge (fig. 8.3).

Bedrock Geology and Topography

The study area is underlain by the Pennsylvanian Mattoon Formation, which is composed of cyclothemic strata, including sandstone, siltstone, limestone, mudstone, and coal. Details of the local lithology are unknown. No significant structural features occur in Bishop Township (Treworgy 1981).

The buried bedrock topography of Bishop Township (fig. 8.5) is generally characterized by a westward-dipping slope. A buried bedrock valley is located just west of Bishop Township, although it may pass below the northwest corner of the township. The buried valley is a tributary to the Little Wabash Buried Valley, initially mapped by Horberg (1950). Elevation of this valley floor is between 400 and 450 feet above msl (Horberg 1950), which agrees with data interpreted from the well logs in western Bishop Township.

Thickness of Quaternary Deposits

The thickest drift (fig. 8.6) occurs in northwest Bishop Township. It overlies the lowest portion of the buried bedrock surface. The thinnest drift is less than 15 feet thick. The drainage texture of

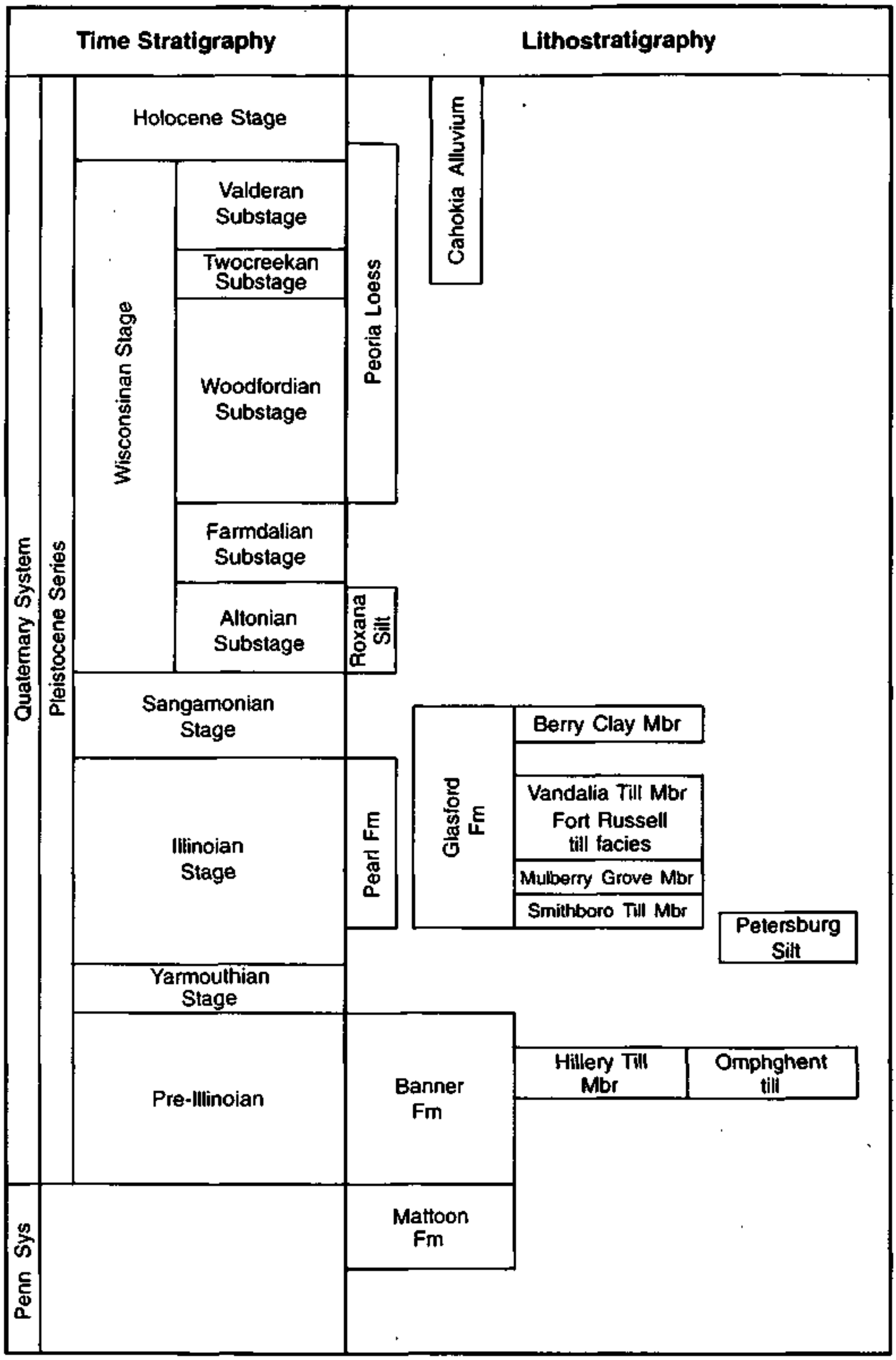

Figure 8.4 Lithostratigraphy of the Effingham County study area.

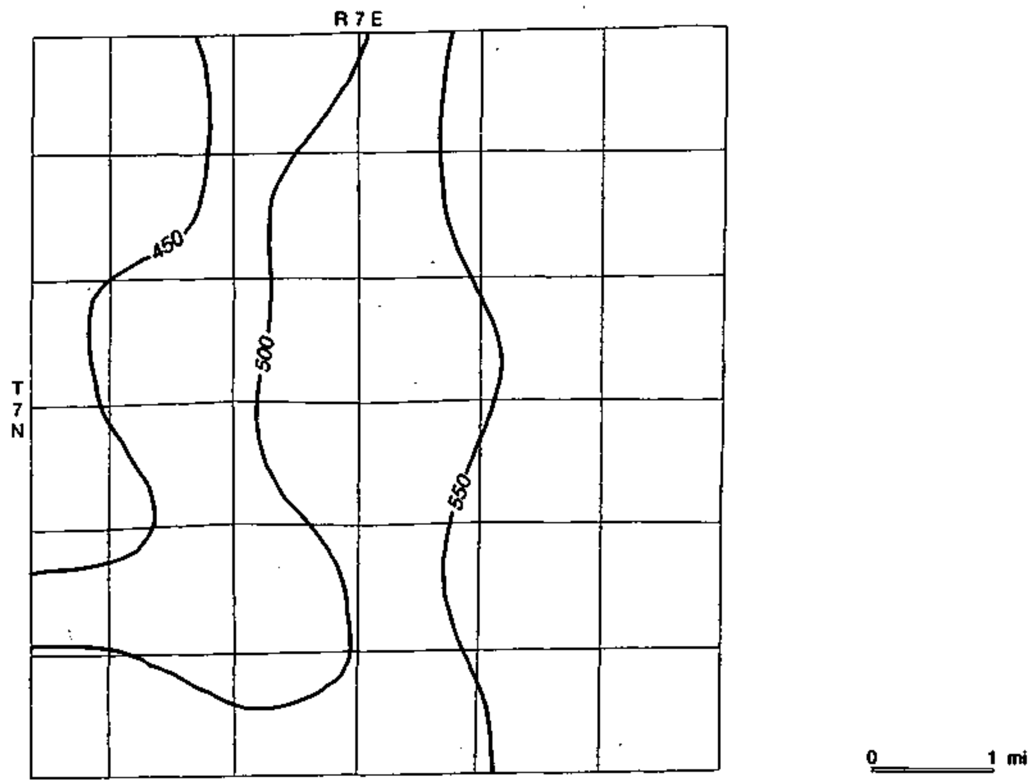

Figure 8.5 Topography of the bedrock surface in the Effingham County study area. Elevation in feet above msl, and contour interval is 50 feet.

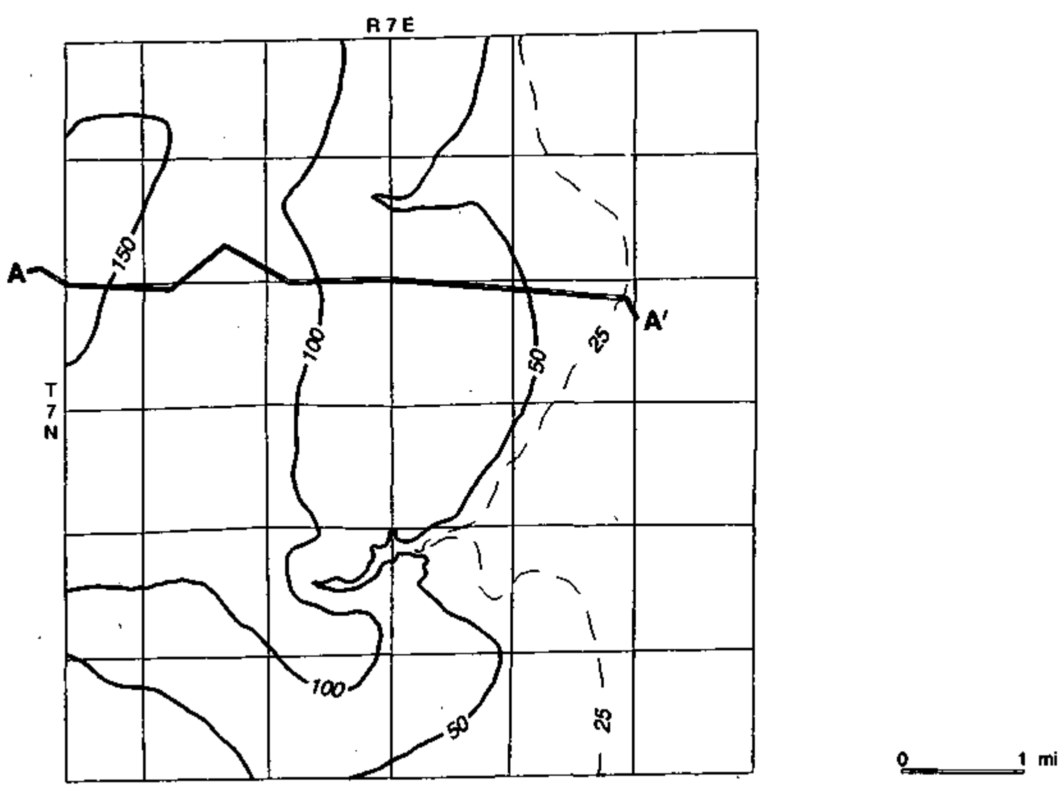

Figure 8.6 Thickness of drift deposits in the Effingham County study area. Contour interval is 50 feet. Location of transect line in shown for cross section A-A'.

present-day tributaries of Bishop and Dieterich Creeks indicates that bedrock may crop out locally along the creeks. The thickness and physical relationship of the Quaternary deposits in Bishop Township are depicted in cross section A-A' (fig. 8.7). They are also depicted as a stack-unit map to a depth of 50 feet (fig. 8.8).

Lithostratigraphy

Banner Formation Kettles (1980) identified and correlated pre-Illinoian deposits just west of Bishop Township with the Hillery Till Member of the Banner Formation (fig. 8.4). If this interpretation is correct, pre-Illinoian sediment in Bishop Township may be as much as 80 feet thick (fig. 8.7). Pre-Illinoian deposits are probably composed of glacigenic sediment, such as coarse-grained outwash, fine-grained lacustrine sediment, and diamicton or till. The outwash sediments, and other lithologies as well, are likely to be thickest and most continuous where buried bedrock valleys occur.

Petersburg Silt This silty sediment (Willman and Frye 1970) was probably primarily deposited in proglacial slackwater lakes. The thickness of this unit varies greatly because it was eroded by overriding Illinoian glaciers, especially the earliest advance, which deposited the Smithboro Till Member (Curry et al. 1991). Although not described by Kettles (1980), this unit may be present in Bishop Township, especially in buried bedrock valleys.

Glasford Formation The Glasford Formation overlies the Yarmouth Geosol, pre-Illinoian sediment, or bedrock in the study area (Willman and Frye 1970). The formation is composed of the following members (from base to top): Smithboro Till, Mulberry Grove, Fort Russell till facies of the Vandalia Till, and Berry Clay (fig. 8.4)

Smithboro Till Member The Smithboro Till Member is composed of silt loam to loam diamicton (Jacobs and Lineback 1969, Curry et al. 1991) that generally is less than 10 feet thick, or is absent (Kettles 1980); it may be much thicker, especially over buried bedrock valleys (Curry et al. 1991).

Mulberry Grove Member The Mulberry Grove Member is composed of a lithologically heterogenous complex of sediment, including sand and gravel, silt, and diamicton (Curry et al. 1991). Although the Mulberry Grove was not identified adjacent to Bishop Township by Kettles (1980), it is depicted in figure 8.7 as a potential aquifer.

Vandalia Till Member The Vandalia Till Member is composed of heterogeneous loam diamicton with subordinate sand and gravel and silt (Jacobs and Lineback 1969, Willman and Frye 1970). The Fort Russell till facies of the Vandalia Till Member has lithic parameters (such as particle size distribution, carbonate content, and clay mineralogy) intermediate to that of the Smithboro and Vandalia Till Members. Kettles (1980) described at least 23 feet of Fort Russell till in an outcrop just west of the study area. This facies of the Vandalia Till Member is probably the dominant, uppermost Glasford till unit underlying most of Bishop Township (figs. 8.7 and 8.8).

Berry Clay Member The Berry Clay Member, a sticky, soft, leached diamicton to clay, has not been described in the immediate area. It probably is present, however, in Bishop Township and may be locally exposed along valley slopes. The thickest Berry Clay will probably be found in the upland areas, where soil drainage is poorest (Follmer 1982).

Pearl Formation The Pearl Formation has not been described in the immediate area, but it is probably present in Bishop Township (fig. 8.7). Typical upland profiles may be underlain by thin Pearl Formation (less than 5-10 ft thick), as in western Clark County (Curry et al. 1991). The lack of well drained soils in the study area, however, suggests that the Pearl Formation is likely to be less than 10 feet thick, and its lateral extent is probably quite variable (Follmer, personal communication, 1991).

Roxana Silt This unit is composed of loam, clay loam, or silt loam diamicton with a grain size distribution intermediate to that of Peoria Loess and Berry Clay. The sandy silt facies of the Roxana Silt probably occurs throughout much of the upland areas of Bishop Township, underlying the Peoria Loess and overlying the Berry Clay and Pearl Formation. Fehrenbacher et al. (1986) found that the Roxana Silt is less than 15 inches thick in the region, but others have found it to be up to about 36 inches thick in places (Follmer 1982, Curry et al. 1991).

Peoria Loess Peoria Loess is composed of leached, pedogenically altered, silty clay loam to silt loam, and it is the uppermost unit in the upland sequences. Peoria Loess is 20 to 40 inches thick in the region (Fehrenbacher et al. 1986) and the Modern Soil has modified the whole unit.

Cahokia Alluvium Cahokia Alluvium underlies the present-day valley floors, and is composed of stratified material dominated by silt and clay. The thickness and lithology of the Cahokia has not been described in detail in an area such as Bishop Township, in which all drainages head on the Illinoian Till Plain.

Soils and Parent Materials

The poorly drained uplands in the study area are dominated by the Cisne-Ebbert-Hoyleton and Bluford-Hickory-Wynoose soil associations (Fehrenbacher et al. 1986). These soil associations are characteristic of the Illinoian Till Plain, where soil catenas are developed in thin loess (less than 40-60 in. thick) over a paleosol developed in clayey till. Stratified silty sediment is the characteristic parent material in the alluviated valleys.

Bishop Township, covered almost entirely (>99% from GIS calculations) by Alfisols, contrasts sharply with the other four study areas, covered primarily by Mollisols. These Alfisols are characterized by B horizons with a high clay content and some fragipan development, conditions that generally restrict the downward movement of soil water. The characteristic low permeabilities and organic contents are shown in table 8.1. As a group, the soils in the study area average less than 2% organic matter through an average surface thickness of less than 15 inches.

Hydrogeology

Aquifers A review of water well logs for this area suggests that there are two primary aquifers. The stratigraphic position of aquifers in the study area is inferred from other studies. Most well logs list completion depths between 25 and 40 feet. The most likely sediments at this depth are the Pearl Formation and upper Fort Russell facies of the Vandalia Till Member (fig. 8.7). In the Fort Russell unit, the porosity and permeability probably decrease with depth. The upper part of this till unit is fractured and supplies water to shallow, large-diameter wells.

Isotopic studies of groundwater age by radiocarbon and tritium methods in western Clark County show that the groundwater in the Pearl Formation is essentially "modern" (Battelle Memorial Institute and Hanson Engineers, Inc. 1990). These data suggest that groundwater in the Pearl Formation would be susceptible to contamination by agricultural chemicals applied to the soil. Groundwater from the melange facies of the Vandalia Till Member in western Clark County is older than about 50 years (the maximum detection limit for the tritium method). Numerical modeling of this unit in western Clark County suggested a horizontal hydraulic conductivity of approximately 0.3 gpd/sq ft and a vertical hydraulic conductivity of approximately 3 gpd/sq ft (Battelle Memorial Institute and Hanson Engineers, Inc. 1990). If conditions are similar in this aquifer/till in the Effingham County study area, groundwater from an equivalent horizon in the Fort Russell till facies of the Vandalia Till Member in Bishop Township probably would be less susceptible than the Pearl Formation would be to contamination by pesticides.

Table 8.1 Soil permeability and surface organic matter content in Effingham County study area.

Parent material group[a]	Permeability[b,c] (in./hr)	Organic matter[d] (avg. %/avg. thickness)	% of study area
1—Loess or alluvium on uplands	0.2-0.6 (upper 17 in.) 0.06-0.2	3.0 for upper 20 in.	1
2—Loess (30-70 in.) on paleosol in Illinoian till	0.6-2.0 (upper 19 in.) 0.06-0.2	2.0 for upper 12.7 in.	26
3—Loess (30-70 in.) on paleosol in Illinoian till or local wash	0.2-0.6 (upper 19 in.) 0.06-0.2	1.9 for upper 16.4 in.	53
4—Loess (0-20 in.) on slopes	0.2-0.6 (upper 35 in.) <0.06	1.5 for upper 9.7 in.	16
5—Loess (silty material) overlying outwash	0.6-2.0	2.0 for upper 12 in.	4

a See combined stack-unit and terrane map (fig. 8.8) for distribution.

[b] Data for permeability and organic matter from Fehrenbacher et al., Soils of Illinois (1984); Await, Soil Survey of Clark County, IL (1979).

[c] The second range of values represents permeability for sediments below the initial unit unless another material is identified.

[d] Percentages and horizon thicknesses are weighted by soil series in each group.

Two wells in the inventory indicate the presence of an aquifer at a depth of about 80 to 90 feet. This aquifer probably correlates to either the Mulberry Grove Member of the Glasford Formation (fig. 8.7), earliest Illinoian alluvium, or pre-Illinoian alluvium. If the elevation of the contact between the pre-Illinoian Banner Formation and the Fort Russell till, as described by Kettles (1980), is more or less level across Bishop Township, the lower aquifer is probably composed of pre-Illinoian sediment. Additional aquifers may be deeper in the buried bedrock valley, but there are no reliable data to test this idea.

Isotopic and geochemical studies in western Clark County suggest that the groundwater in the deeper aquifer is much more geochemically evolved than that in the upper aquifer (Battelle Memorial Institute and Hanson Engineers, Inc. 1990). Deep aquifers within buried bedrock valleys and covered by thick diamicton would be less likely to be affected by pesticide contamination. Water in the deeper aquifers, however, may be of poorer quality (e.g., greater total dissolved solids or dissolved iron and organic carbon).

Assessing the aquifer properties of Cahokia Alluvium without additional data is difficult. The unit is probably composed primarily of sediment eroded from Peoria Loess and probably does not contain aquifers where it is less than about 20 feet thick.

Inferred groundwater movement A generalized description of groundwater movement through the Quaternary materials is given below. The groundwater movement is inferred from previous work in western Clark County (Battelle Memorial Institute and Hanson Engineering, Inc. 1990). Figure 8.8 integrates the stack-unit map and the terrane map. Virtually all soils mapped in Bishop Township are poorly drained to very poorly drained. There are three primary map units: upland sequences (groups 1, 2, and 3), a slope sequence (group 4), and an alluvial sequence (group 5).

Groups 1, 2, and 3 are underlain by virtually the same sequence of materials: the Peoria Loess, Roxana Silt, discontinuous Pearl Formation, Berry Clay, Fort Russell till fades of **the** Vandalia Till Member, and potentially, the Hillery Till Member. Groups 1, 2, and 3 are differentiated on the basis of soil associations'that indicate differences in drainage characteristics, although **the** entire upland surface in Bishop Township is poorly drained. The most poorly drained areas on the uplands (group 1) are probably local, shallow zones of groundwater discharge during wet periods and groundwater recharge during drier periods. Pedogenically altered sediment is probably thickest in group 1 (Follmer 1982) and may store more near-surface groundwater than other parts of the landscape. Group 1 has soils with moderate to high organic matter content, but it is also the smallest area. Group 2 is more common on the uplands and is characterized by poorly drained soils with intermediate permeability, such as the Cisne and Wynoose. The somewhat better drained Hoyleton soil dominates group 3. Group 3 covers a large area underlain by glacial drift less than 50 feet thick (fig. 8.8). Drift aquifers are less likely to be present in this group simply because the drift is thinner. The soils associated with groups 2 and 3 contain little organic matter (table 8.1).

Group 4 is composed of soils typical of valley slopes (Hickory, Atlas, and Ava). The stack-unit sequence is similar to groups 1, 2, and 3, although more Hillery Till might be encountered at lower elevations along the valley slope. The hydrogeology of this group is affected by the position along the valley slope at which permeable units are exposed and whether those units are covered by colluvium at that location. Seepage may issue from these slopes, especially from (1) the base of the Peoria Loess, (2) the Pearl Formation, and (3) the sand and gravel layers within the Fort Russell till facies of the Vandalia Till Member. The soils in group 4 contain little organic matter.

Group 5 is composed of alluvium that overlies thin Fort Russell till and relatively thick Hillery Till. The characteristics of this group are greatly dependent on the thickness and lithology of Cahokia Alluvium, both of which are largely unknown. Presumably, this unit would be able to absorb some overland flow and shallow groundwater issuing from seeps on adjacent slopes. In addition, there may be some groundwater input from upward flow ultimately derived from adjacent uplands. The soils associated with group 5 have moderate organic matter contents.

Topography is probably the most important factor governing groundwater flow in Bishop Township. The thickness and distribution of the Pearl Formation and sand and gravel facies of the Fort Russell Till Member of the Glasford Formation probably exert local control on relatively shallow groundwater flow paths. More detailed subsurface information is needed to infer paths of groundwater flow along the deeper aquifer units, shown as sand and gravel bodies within the Hillery Till Member of the Banner Formation in figure 8.7.

GROUNDWATER HYDROLOGY

The upper bedrock units consist of shale with negligible water-yielding capacity and of small amounts of limestone, sandstone, and coal of the Pennsylvanian Mattoon Formation. The dissolved solids concentration of groundwater increases with depth in the bedrock. According to Visocky et al. (1978), wells finished below depths of 130 to 150 feet produce water unfit for most uses.

Discontinuous sand and gravel deposits form the major source of groundwater supply for Dieterich. These deposits are 5 to 27 feet thick and contain material ranging from silty sand to gravel. The width of these deposits is 100 to 600 feet, and the maximum lengths are less than 1,400 feet (Visocky et al. 1978). A limited number of aquifer test data are available for Bishop Township. The village of Dieterich drilled nine boreholes along Dieterich Creek, ranging from 25 to 100 feet in depth (table 8.2). The hydraulic conductivities from well tests in Dieterich ranged from 68 to 375 gpd/sq ft. All of these wells are finished in sand and gravel, and the test durations ranged from 0.5 to 3 hours. The aquifer appears to have a low to very low hydraulic conductivity.

Domestic Groundwater Use

There are no industrial or irrigation withdrawals of groundwater within the study area. The only major municipal withdrawal is by Dieterich, which pumped 16.3 million gallons from four wells in 1989 and served an estimated population of 610. The 136 rural households, with an estimated population of 476, use about 33,300 gallons daily for domestic use and about 12.2 million gallons yearly.

Table 8.2 Results of aquifer tests for the Dieterich municipal wells in Bishop Township

Well location	Depth (ft)	Saturated thickness (ft)	Pumping rate (gpm)	Transmissivity (gpd/ft)	Permeability (gpd/ft^2)	Test length (hr)	Type of analysis
9.7A	100	32	10	12,000	375	3.0	T
14.1F	28	14	12	950	68	0.5	S
21.7H	67	6	30	1,680	280	0.5	T
22.1 B	25	7	35	1,500	215	M	T
22.1C	32	23	10	4,800	209	3.3	S

Source: ISWS aquifer properties database.
M = missing data
T = time-drawdown method
S = specific capacity method

Groundwater Use for Livestock

In 1987, Effingham County had 12,000 cattle and 119,000 hogs (IDOA 1989). Because no township data are available, the marketed livestock in 1989 in Bishop Township was estimated at 17,000 hogs and pigs and 1,500 cattle. Given a daily use for cattle and hogs of 35 and 4 gallons per head, respectively (Kirk 1987), total daily livestock use is estimated to be 120,500 gallons. Water use for poultry is estimated to be small. Thus, the annual withdrawal for all uses within the township is about 72.5 million gallons.

Aquifer Recharge

Aquifer recharge data for this area are not available. Walton and Csallany (1965), however, studied the yields of aquifers in the nearby Embarras River basin. They suggested that, under heavy pumpage, the rate of recharge through the till varies from 60,000 to 150,000 gpd/sq mi. Because the pumping stresses are low in the study area, the actual rate of recharge most likely is substantially lower. A conservative estimate of 50% of the lower range of recharge is 30,000 gpd/sq mi. Therefore, with an estimated annual recharge in this township of about 394 million gallons, water use (72.5 million gallons) is only about 18% of the recharge.

SUMMARY AND CONCLUSIONS

Although the geology of this township is most likely representative of the Illinoian Till Plain, additional data are needed to locate, identify, and confidently correlate aquifer units to the stratigraphic framework (Jacobs and Lineback 1969, Willman and Frye 1970, Johnson et al. 1971, Curry et al. 1991).

Most of the wells reported in the inventory are shallow (20 to 40 feet deep) and are probably tapping groundwater from the Pearl Formation and upper Fort Russell till facies of the Vandalia Till Member. Groundwater is less available in the thin glacial drift on the eastern part of Bishop Township than in the western half of the study area, where thicker glacial drift is associated with a buried bedrock valley. Deeper aquifers are not used as frequently as the shallow aquifers, even though they are less likely to be contaminated by pesticides; however, overall groundwater quality is likely to be poorer than in shallow aquifers.

9 REVIEW AND ASSESSMENT OF STUDY AREA CHARACTERIZATION

M. L Barnhardt

This document presents the results of the land use, agricultural, geological, and hydrogeological characterizations for the five pilot study areas and documents the methodologies and data sources used to produce the characterizations. The pilot study was designed to use current databases, and it did not include any well drilling or other geologic fieldwork because the intent of the study was to evaluate the capability of developing hydrologic and geologic characterizations using existing reports, maps, and data in ISGS and ISWS files. Because a statewide survey of agricultural chemicals in rural, private water wells would involve considerable expense, one goal of the pilot study was to assess the quantity and quality of existing data sources used to characterize the geologic materials. The geologic and hydrologic characterizations conducted for this study followed modified procedures established by numerous previous projects, including those for urban planning, glacial stratigraphic correlation, potential for groundwater contamination, landfili siting, and assessment of groundwater supplies. A companion report (Schock et al. 1992) presents the results of the chemical and statistical analyses in addition to a discussion of the sampling protocol and recommendations for a statewide survey of rural, private water wells.

The knowledge and experience gained from the pilot study characterization can be used to identify the most efficient procedures and useful materials for assessing the potential for contamination in a statewide study of rural, private water wells. The experience acquired during the previously mentioned projects made this characterization easier because many of the methods were tested and modified before being applied in the pilot study. Many previous projects included systematic drilling and geophysical testing that were hot available to the pilot study. Consequently, the majority of the difficulties encountered during the geologic and hydrologic characterization for the pilot study involved the evaluation of data reliability, location of datum points, and lack of data. Data were needed for groundwater modeling and for identifying and correlating stratigraphic units. Given the lack of site-specific data, the regional glacial stratigraphic framework was used to correlate, the sediments described in verified drillers' logs to established lithostratigraphic units. The correlation was possible only because of the extensive research base in mapping and characterizing glacigenic sediments in Illinois. Correlating the sediments to specific lithostratigraphic units using the regional stratigraphic framework did not, however, ensure that the materials were well characterized with respect to specifics, such as the extent of till fracturing or the number of clays beds occurring in sand and gravel units.

LAND USE AND AGRICULTURAL DATA

Interviews and fieldwork were the primary data sources for characterizing wellheads and local land use and agricultural practices. Because most topographic maps are dated with respect to recent changes in land use and offer little information on small commercial facilities, fieldwork by survey personnel was required to update and complete the database. An efficient, accurate interview form and questionnaire will be necessary if a statewide survey is to be conducted because the increased number of and distances between sample sites would greatly affect the cost of a statewide survey. The cooperation of county extension agents would be critical for acquiring accurate and timely information concerning livestock facilities, pesticide application, and crop information. The countywide agricultural database used in the pilot study would still be a source of information for.comparison with the much smaller (section-sized) study areas proposed in the statewide survey.

GEOLOGIC DATA

Quantity of Data

Probably the overriding concern to the characterization effort was the variability in quantity, quality, and location of subsurface geologic information. A major source of subsurface information is the drillers' logs from rural, domestic water wells in each study area. Borings from bridge construction and other engineering projects, in addition to oil and gas wells, are locally available but have limited distribution. Because the pilot study was conducted in rural areas, few major highways or freeways traversed the study areas.

Quality of Data

The quality of the information recorded in the drill logs varied considerably within and between the study areas. Because wells were constructed by different drillers over several decades, the descriptions of the materials encountered during drilling varied considerably. Some drillers provided detailed information that was easily correlated with stratigraphic units, and others only provided minimal information. In either case, there was no way to check accuracy, regardless of the level of detail presented in the log.

Location of Data

Some well locations could not be verified because of incorrect coordinates or incomplete records. Many of these wells could have been verified by field checking, but this was cost prohibitive. Mason County had numerous well locations that had been verified during previous research projects. Verified wells were not, however, necessarily located in the most advantageous positions with respect to interpreting the stratigraphic units for constructing stack-unit maps or cross sections. Occasionally, the most detailed drill logs were for wells that either could not be verified or were located in close proximity to other verified wells with high quality drill core descriptions. Overall, the difficulties encountered in verifying the locations of wells were probably representative for most areas in Illinois that would be studied following the constraints of this project.

DEVELOPING A GEOGRAPHIC INFORMATION SYSTEM

The pilot study relied heavily upon a GIS to quickly produce a variety of maps at low cost. The initial investment in labor to develop the database was justified because the production of stack-unit, terrane, and other maps is an iterative process. Also, the increasing availability of digitized databases for soil survey maps would significantly reduce the time-consuming task of digitizing individual soil maps. This entire procedure would significantly reduce costs for a statewide survey. Maps displaying different combinations of geologic units, soil series, or parent materials can be reviewed to better visualize the surface/subsurface geologic sequence. Maps depicting units with similar combinations of physical, chemical, or hydrological characteristics assist in hydrogeologic modeling. Additional development and refinement of the GIS should provide researchers with the ability to quickly select which map or combination of maps best display the geologic and hydrologic conditions in a region.

A continuing point of concern is the selection of the appropriate map scale for work maps and presentation. A similar problem exists in the vertical exaggeration used for cross sections. Some generalization is necessary because only selected information is needed for modeling. If these maps are to become part of the expanding GIS database, however, they should retain as much of the original detail as possible (i.e., remain as close to their original scale as possible) so that they will have value for future researchers seeking information for other purposes. The GIS should serve not only the current pilot study and the recommended statewide survey, but it should also serve as a data source to expedite future research projects. It should be more economically viable to balance these needs than to streamline and specialize to the point where only the needs of a specific project are met. The GIS is a tool and methodology that can assist many projects. If properly used, it can provide valuable information to future projects.

A number of maps were produced for each study area, including cultural, transportation, potential contaminants, land use, drainage, soils/parent materials, stack-unit, and terrane maps. For most of the study areas, one or more of the maps were sufficiently similar such that one was omitted for economical or editorial reasons. For example, in the Livingston County study area, the stack-unit map and a map depicting the position of the Ashmore Sand provided similar information. Because the map showing the depth to the Ashmore Sand was more direct and easier to interpret and portray, it was selected for inclusion rather than the stack-unit map.

Considerable range existed in the number of stratigraphic units present in the different study areas. For example, the Effingham, Piatt, and Livingston County study areas each contain glacial deposits that have limited extent and variable thickness and require considerable interpretation. Given the limited stratigraphic control in these study areas, the resulting maps need to be interpreted with care. The number of stratigraphic units also required that they be described in as much detail as possible to assist individuals interpreting the maps. The greater number of stratigraphic units presented in some maps should not be interpreted as greater accuracy; in some cases, the opposite may be true.

HYDROLOGIC DATA

The availability of aquifer test data was closely related to the presence of towns within or near the study areas. Even though municipal wells were not included in the pilot study, these wells were often the only wells for which pump test records were available. Data were also more likely to be available if the study area was part of a previous study, such as in the cases of Mason and Kankakee Counties, where irrigation is significant.

WELLHEAD CONTAMINATION

If the wellhead seal is not adequate, a potential pathway for contamination is through the annulus of the well. The pilot study addressed this problem indirectly by examining the wellhead and collecting data on the method of well construction and age of well. No tests were performed, however, to ensure that the seal was secure because this would have been an extremely expensive process with limited value in a statewide survey. The statistical sampling of wells assumes that random occurrences will be incorporated. It is reasonable that some wells will experience contamination at the wellhead due to transmission through the annulus. The extensive statistical testing applied in this study, however, would probably identify wells that should be secure but still experience contamination. If additional analyses failed to identify likely sources of contamination, problems at the wellhead would become a possible factor. Abandoned or improperly sealed wells may be important conduits for groundwater contamination. This issue should be carefully addressed in any study.

Stratifying the sample population using the potential for contamination map does not necessarily provide accurate information for identifying the type of well. For example, in the Livingston County study area, many well owners described their well as drilled, although the wells were actually bored. If the drill log is not available, it will require significant field time by survey personnel to determine the type of the well. The cost of such a determination will be prohibitive in a statewide survey. Also in the Livingston County study area, the aquifer material is indicated as occurring between 20 and 50 feet by the state stack-unit map, but no aquifer material occurs within 100 feet of land surface in the eastern part of the study area. In addition, the depth to bedrock is very shallow in the central part of the study area where one of the sampled wells is drilled into limestone. In counties such as Piatt, Livingston, and Kankakee, there are areas where wells tap shallow sand lenses. Technically, these wells do not meet the depth criterion for aquifer materials. Because these wells will have a higher susceptibility to contamination, special notice of them must be taken in the statistical analysis and interpretation.

Stratifying the sample population using the potential for contamination model of McKenna et al. (1989) is a viable method as long as the inherent variability in the groupings is accepted. As noted previously, within-group variability in geology can affect well type, well depth, and potential susceptibility to contamination. In effect, this creates a subpopulation within the hydrogeologic group, a fact that must be considered during the statistical analysis and interpretation of the chemical data. The proposed statewide survey would identify sections (1 sq mi) instead of townships (36 sq mi) for the unit of study. This would not appreciably affect the method of geologic characterization because most published studies cover considerably greater areas. The section-sized study area could be too small, however, because the verifiable well logs are too few for interpretation. The small size could, however, possibly decrease the potential for within-group geologic variability. The complexity of the geology affects the quantity and distribution of the data necessary to produce a characterization with a specific level of confidence. An area with less complex geology will generally require less information than an area with more complex geology.

This document is the companion to Schock et al. (1992), which presents the sampling methodology, chemical analyses, and results of the statistical analyses of the pilot study. Schock et al. also present recommendations for evaluating and streamlining the proposed statewide survey, and propose modifications in the sampling and chemical analysis, protocols. This document deals only with the land use, agricultural, geologic, and hydrologic characterizations of the study areas and the GIS developed from them. It is intended to enhance the reader's understanding of the companion report (Schock et al. 1992) by presenting the information necessary to understand the different hydrogeologic regions that were used as the stratifying variable. It also illustrates the similarities and differences between the study areas with respect to land use and agricultural characteristics. Readers should review both documents to fully understand the pilot study.

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