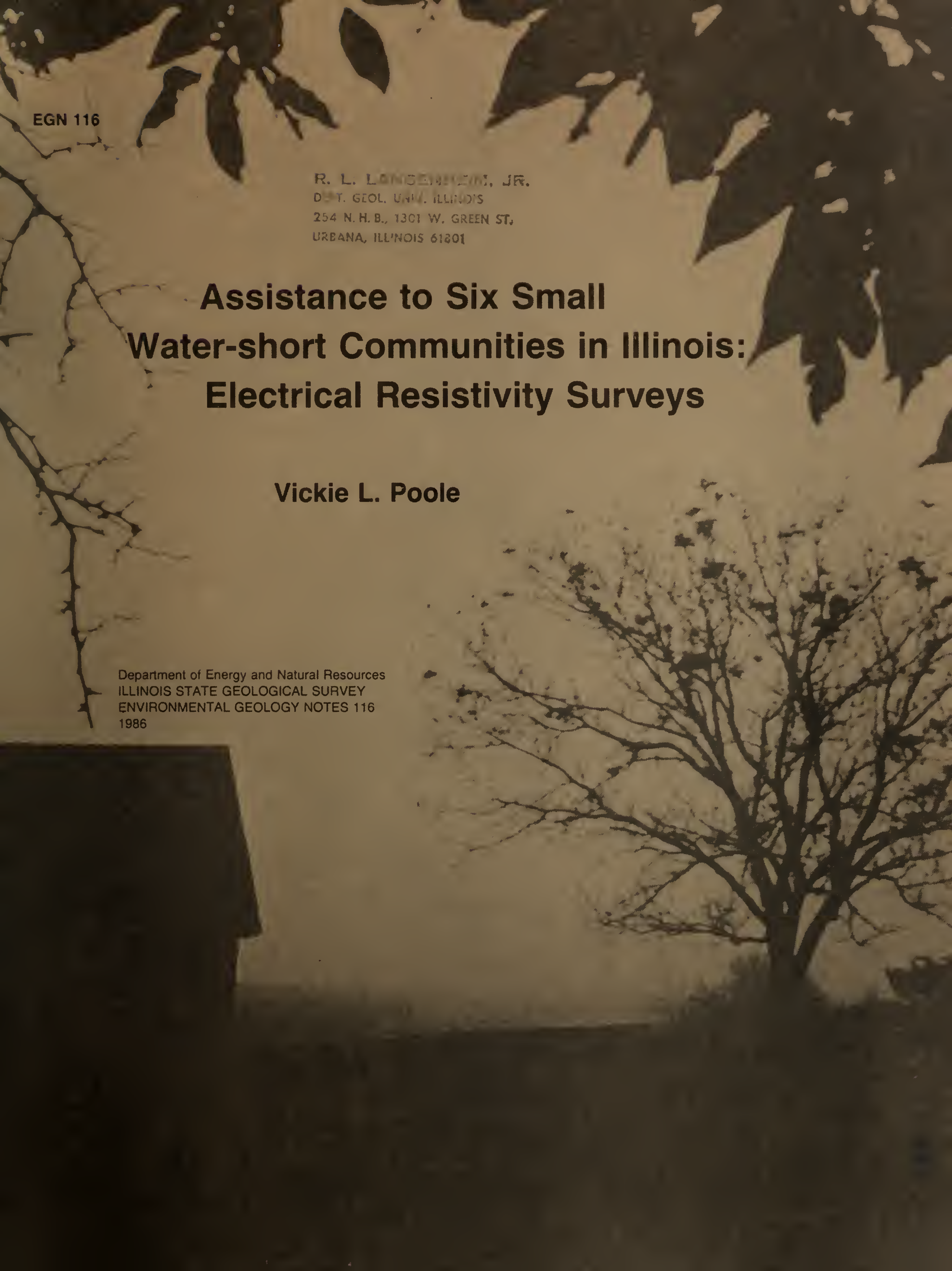

EGN 116

Assistance to Six Small Water-short Communities in Illinois: Electrical Resistivity Surveys

Vickie L. Poole

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
ENVIRONMENTAL GEOLOGY NOTES 116
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Assistance to Six Small Water-short Communities in Illinois: Electrical Resistivity Surveys

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Prepared in cooperation with the Illinois Department of
Transportation, Division of Water Resources

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FIGURES

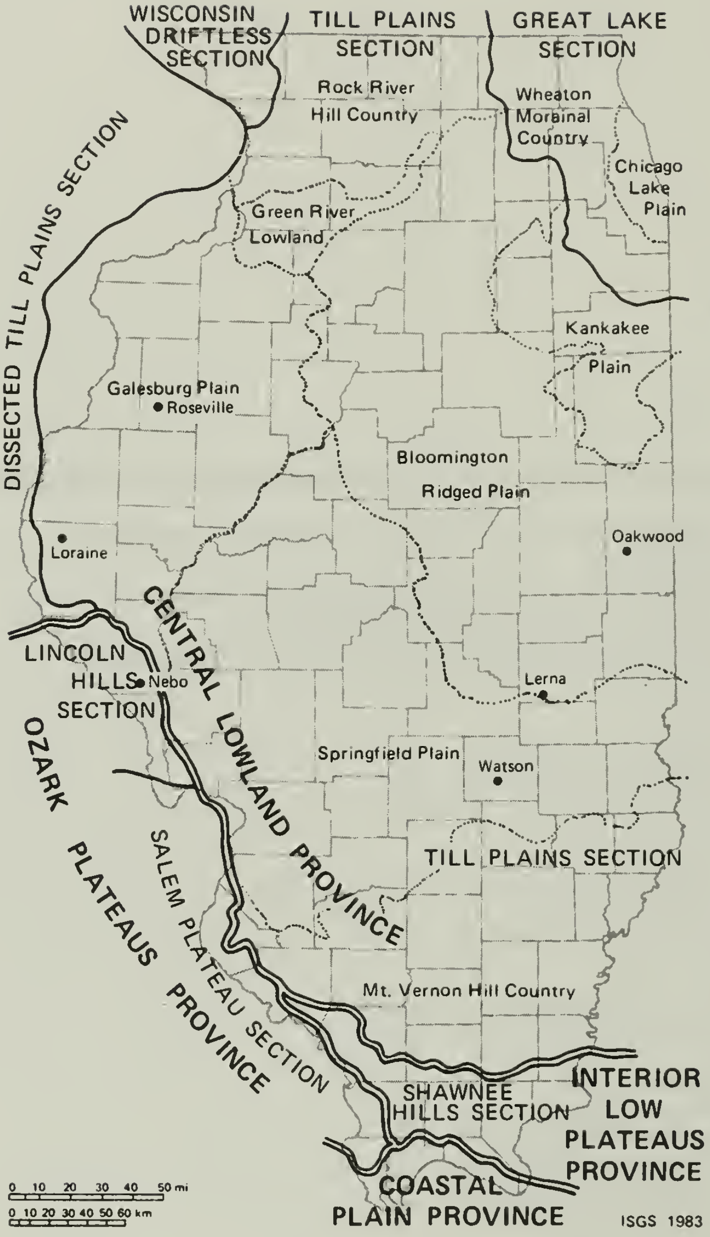


Figure 1. Physiographic divisions of Illinois (after Leighton, Ekblaw, and Horberg, 1948) and locations of communities studied for this report.

ABSTRACT

Six small central Illinois communities that experienced water supply problems during the drought conditions of 1976-1977 were selected as sites for electrical earth resistivity (EER) exploration programs as an aid to siting new municipal wells. The six communities were chosen on the basis of a history of past shortages, estimated future water demand, and the possibility of obtaining a greater water supply from the glacial drift. Information available on the geologic framework of the study area was used in conjunction with the EER data to delineate favorable portions of each study area for test drilling.

INTRODUCTION

Beginning in 1976 and continuing into 1978, drought conditions in Illinois resulted in water shortages and hardship for numerous communities, especially in the central portion of the state. As a result, the Illinois Department of Transportation, Division of Water Resources, in cooperation with the Illinois State Geological and Water Surveys, assessed all public groundwater supplies in the state to gauge the extent of the water supply problem. The hydrogeologic background of 42 communities identified as having marginal or deficient groundwater supplies was reviewed in two studies (Visocky et al., 1978; Wehrmann et al., 1980). Because a number of the water-deficient communities were concentrated in east-central Illinois, a regional evaluation was made of sand and gravel aquifers that could provide municipal groundwater supplies (Kempton et al., 1982). Following this preliminary phase, 20 communities were selected for which an electrical earth resistivity (EER) survey (a geophysical exploration technique) would be helpful in delineating possible municipal well sites. Fourteen of these communities were studied previously (Poole and Heigold, 1981; Poole and Vaiden, 1985). The six remaining communities, Lerna, Loraine, Nebo, Oakwood, Roseville, and Watson, are included in this report (fig. 1). Generalized stratigraphic relationships of geological formations in the vicinity of these communities are illustrated in figures 2 and 3.

When fresh water is present, the resistivities of coarse-grained sands and gravels are higher than those of finer-grained sediments such as silts and clays (fig. 4); the EER procedure used in this study is a quick, relatively reliable method of locating sand and gravel deposits. In this procedure, an electric current is applied into the ground through two current electrodes, and the potential difference is measured across a pair of potential electrodes. Apparent resistivity is calculated on the basis of the measured

AGE		ROCK UNITS			
SYSTEM	SERIES	FORMATION		DOMINANT MATERIALS	
PENNSYLVANIAN	VIRGILIAN	Mattoon Formation		shale, siltstone, sandstone	
	MISSOURIAN	Bond Formation		shale, sandstone, limestone	
	DESMOINESIAN	Modesto Formation Carbondale Formation Spoon Formation		shale, sandstone shale, sandstone, coal shale, siltstone	
	ATOKAN	Abbott Formation		sandstone, shale	
	MORROWAN	Caseyville Formation (south)		sandstone, shale	
MISSISSIPPIAN	CHESTERIAN (south)				
	VALMEYERAN	Ste. Genevieve Limestone St. Louis Limestone Salem Limestone		limestone, shale, sandstone limestone limestone, shale	
		(west)	(east)	(west)	(east)
		Warsaw Shale Keokuk Ls Burlington Ls Fern Glen Fm	Borden Siltstone	shale, limestone limestone limestone limestone, shale	siltstone
	KINDERHOOKIAN	Chouteau Limestone Hannibal Shale	New Albany Shale Group	limestone shale, siltstone	
DEVONIAN	UPPER	Saverton Shale Grassy Creek Shale Sweetland Creek Shale		shale, gray shale, black shale, gray	
	MIDDLE			limestone	
	LOWER (south)			limestone, dolomite, chert	
SILURIAN		(west)	(south)	(west)	(south)
	NIAGARAN	Racine Fm Joliet Fm	Moccasin Springs St. Clair Ls	dolomite dolomite	limestone, dolomite limestone
	ALEXANDRIAN	Kankakee Fm Edgewood Fm	Sexton Creek Ls Edgewood Fm	dolomite dolomite	limestone limestone
ORDOVICIAN	CINCINNATIAN	Brainard Shale Ft. Atkinson Ls Scales Shale	Maquoketa Shale Group	shale limestone, dolomite shale	
	CHAMPLAINIAN	Galena Group Platteville Group Joachim Dolomite St. Peter Sandstone		dolomite, limestone limestone, dolomite dolomite sandstone	

Figure 2. Generalized stratigraphic column of bedrock formations that underlie communities studied for this report (after Willman, 1973 and Willman et al., 1975). Not all formations are named. (E = east, W = West, S = south)

potential drop, applied current, and electrode spacing (Freeze and Cherry, 1979). The apparent resistivity is a weighted average of the resistivities of the earth materials that exist in the region between the potential surfaces (P_1 and P_2) that intersect the surface of the earth at the potential electrodes (fig. 5). As the distance of the electrode pairs from the center stake is systematically increased, changes in apparent resistivity can be related to variation in resistivity of earth materials with depth. Values of resistivity are recorded in ohm-meters.

Basic equipment for this study included an AC current instrument (a Bison 2350B), insulated single-conductor electrical cable, two steel stakes implanted a few inches into the ground to introduce the current, two copper stakes implanted a few inches into the ground to measure the potential differences, and four short lengths of insulated wire, with alligator clips on both ends, which were used to connect the electrical cables to the electrodes (Gilkeson, 1984). In the Schlumberger electrode configuration used in this study, the electrodes were laid out in a line with the current electrodes positioned at the outside ends and the potential electrodes forming the inner pair (see fig. 5). The distance between the two outer electrodes was maintained at ten times the distance between the inner electrode pair. The method of expanding the electrode configuration systematically around a center stake, measuring the potential

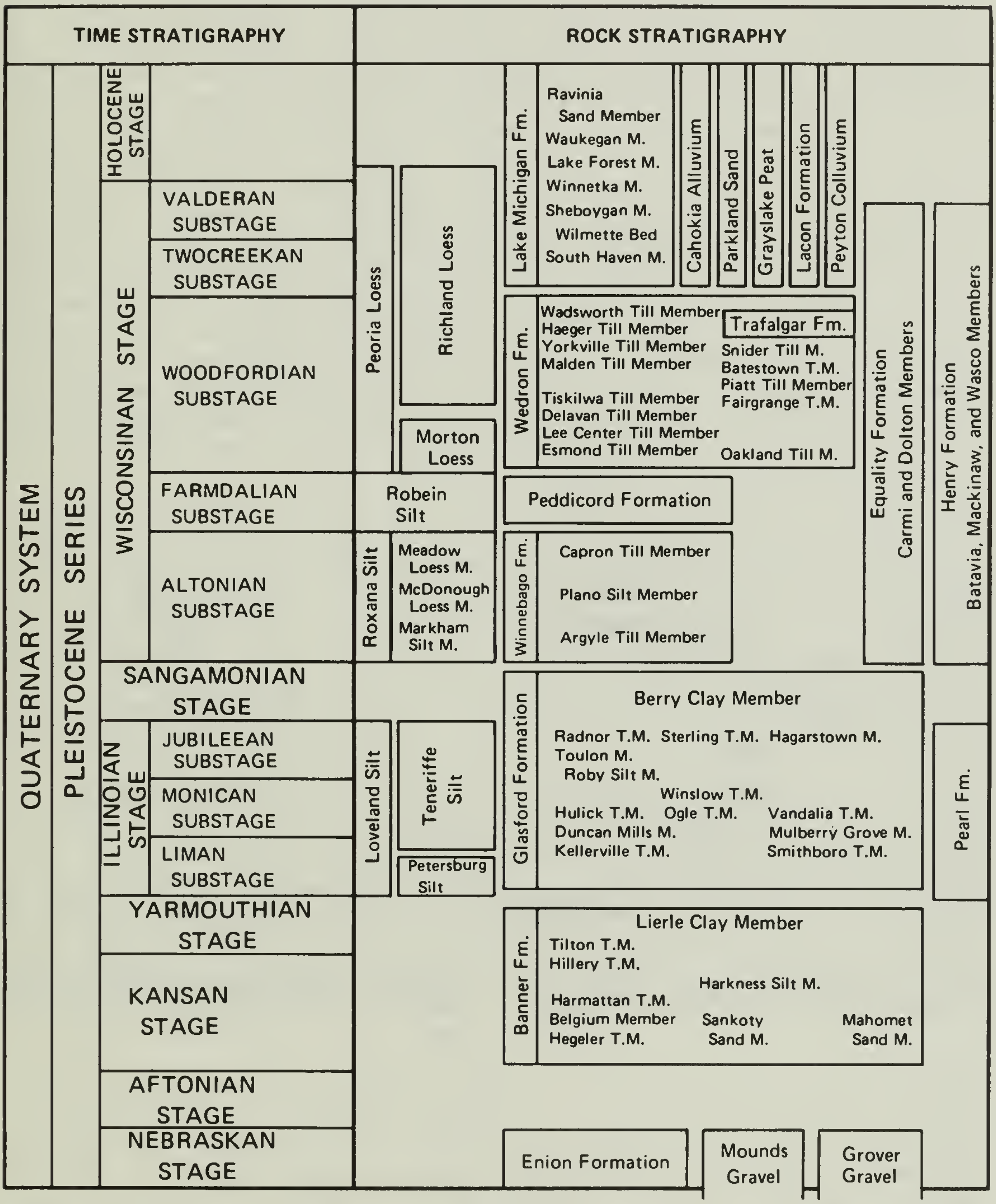


Figure 3. Stratigraphic classification of the Pleistocene deposits of Illinois (after Willman et al., 1975; Lineback, 1979, and Killey, 1982).

differences, and calculating apparent resistivity values of the earth materials below the center stake is termed vertical electrical sounding (VES). A plot of apparent resistivity values versus electrode spacings is a VES curve (Heigold et al., 1984).

The VES data obtained during this study were analyzed qualitatively and quantitatively. Qualitative interpretation was based on examination of the maxima, minima, inflection points, and apparent resistivity values of the VES curves. In the quantitative analysis the weighted average apparent resistivity values used to construct the VES curves were converted into a sequence of layers representing types of earth materials of varying thickness and calculated "true" resistivity. These "true" resistivities and thicknesses are referred to as layering parameters. The quantitative interpretation (inversion technique) in this study was developed by Zohdy (1973), and uses the method of convolution (Ghosh, 1971) and modified DarZarrouk functions (Zohdy, 1973, 1975). This technique provides only one of many geoelectrically equivalent layering parameters solutions for a given VES curve (Heigold et al., 1984). Information available on the geologic framework of the study area was used in conjunction with the EER data to delineate portions of each study area that exhibit the most favorable VES data. Cross sections through these "most favorable areas" illustrate the layering parameters or "true" resistivity (in ohm-meters) and "true" thicknesses determined by quantitative analyses for the earth materials below the center stake of each VES profile. Discussions of these cross sections and recommendations for future test drilling sites are provided for each community studied.

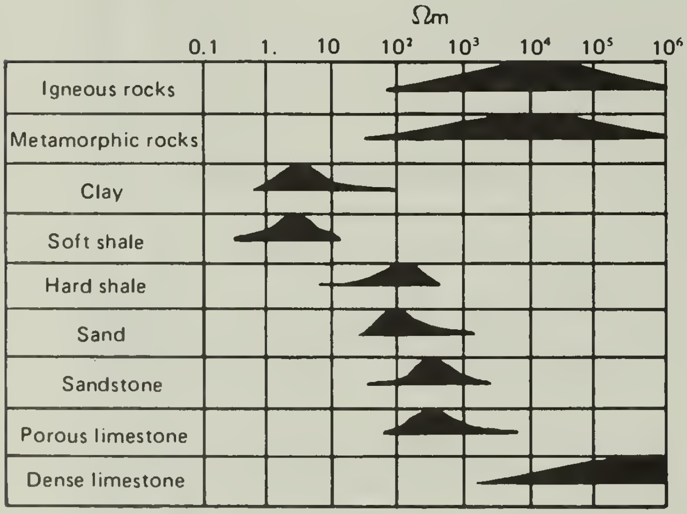


Figure 4. Approximate resistivity ranges of some rock types (adapted from Griffiths and King, 1965).

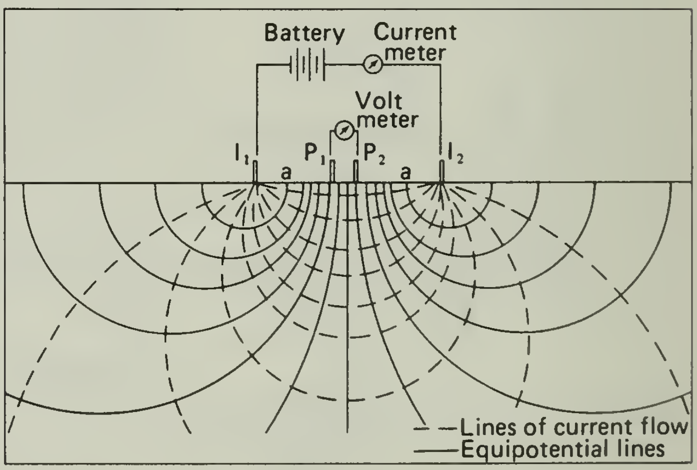


Figure 5. Basic elements of an earth resistivity meter and the Schlumberger electrode configuration.

LERNA

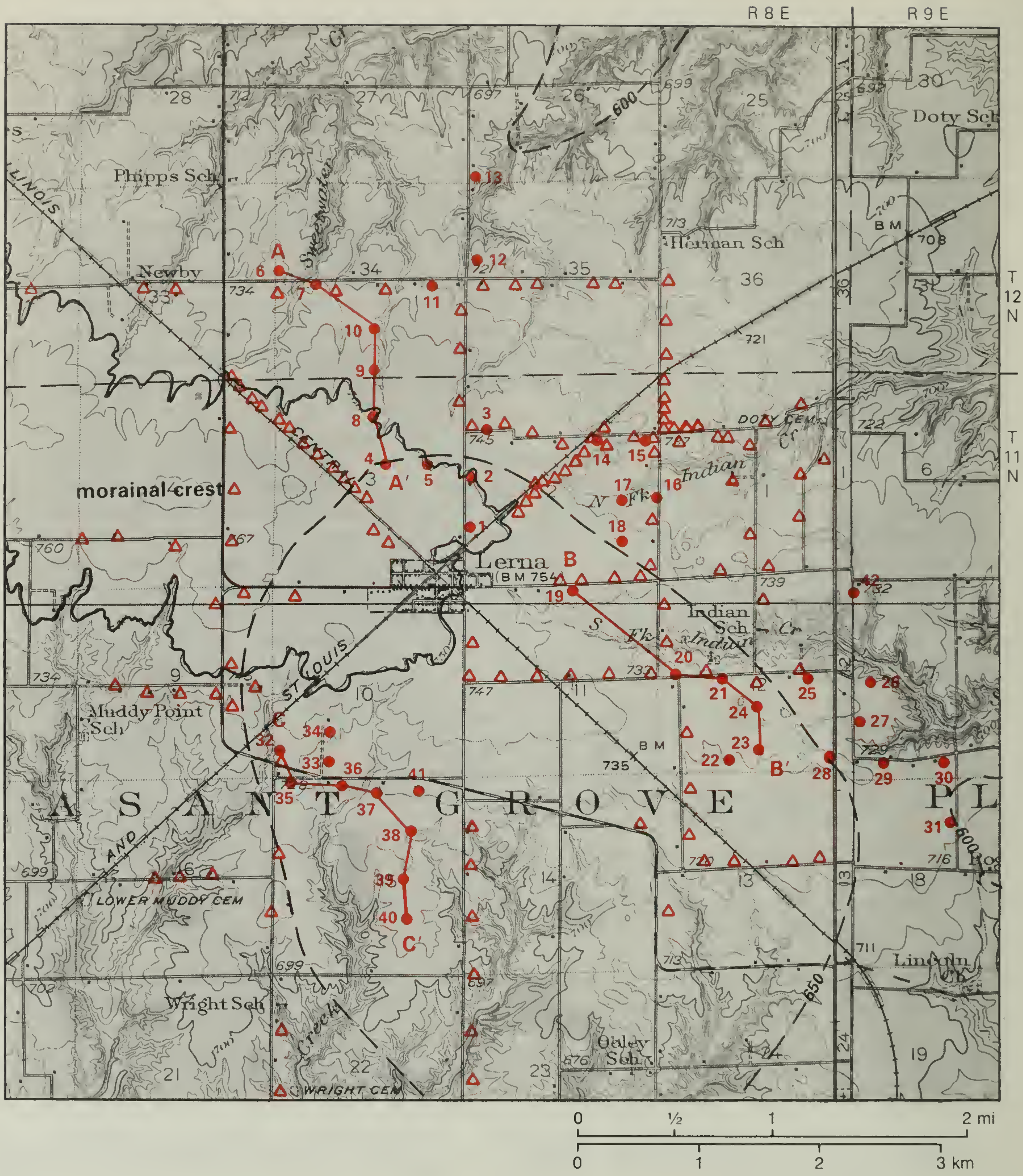
The community of Lerna (population 386) is in southern Coles County in portions of Sections 2, 3 and 10, T 11N, R 8E (see p. 6), approximately 7 miles east of Lake Mattoon and approximately 6 miles west of the Embarrass River. The population of Lerna increased 34 percent between the 1970 and 1980 census periods and is expected to increase slightly by the year 2,000. Average water demand by the year 2,000 is also expected to increase slightly (Wehrmann et al., 1980).

The Lerna area is physiographically situated on the southern edge of the Bloomington Ridged Plain of the Till Plains Section of the Central Lowland Province (fig. 1). The Bloomington Ridged Plain is characterized by generally low, broad moraines separated by flat to gently rolling ground moraines (Leighton et al., 1948). Lerna is located at the southern boundary of the Decatur Sublobe of the Woodfordian Erie Lobe of Wisconsinan glaciation and lies on a crest of the east-west trending Shelbyville (undifferentiated) Morainic System.

Topography in the vicinity of Lerna ranges from almost flat, on the plains, to gently rolling, on the crest of the moraine system, to ridged, where streams have developed across and on the flanks of the moraine. Surface elevations range from approximately 780 feet above mean sea level (msl) on the morainal crest northwest of Lerna to approximately 650 feet above msl along stream valleys. Drainage is to the north, south, and east from the crest of the moraine at Lerna, to eastward-flowing tributaries of the south-flowing Embarrass River.

The uppermost bedrock in the Lerna area consists primarily of intercalated shale, siltstone, sandstone, limestone, and coal of the upper Pennsylvanian Mattoon Formation. Elevation of the bedrock surface in the study area generally ranges from 580 to 680 feet above msl (see plate, p. 6). Elevations decrease to less than 400 feet above msl in the north-south trending Embarrass Bedrock Valley, approximately 8 miles to the east. An east-west trending tributary to the Embarras Bedrock Valley is present approximately 4 miles southeast of Lerna.

Several water wells, including Lerna municipal wells, are completed in sandstones of the upper bedrock. Yields range from 2 to 25 gal/min, but are usually less than 10 gal/min. Small domestic supplies of water have also been developed in fractured limestone occurring near the surface of the bedrock. Water from deep bedrock (below a depth of approximately 300 ft) is generally too mineralized for most water supply uses.



● 1984 VES profile

△ previous VES profile

bedrock elevation (ft), dashed where approximate

LERNA STUDY AREA

Glacial drift in the Lerna area consists mostly of clay and till (pebbly clay) with some sand of pre-Illinoian (possibly), Illinoian and Wisconsinan age, and windblown silt (loess) of Wisconsinan age (Wehrmann et al., 1980, Kempton et al., 1982). Drift thickness ranges from 70 to 125 feet (Wehrmann et al., 1980). The blanketing loess may be as much as 4 feet thick.

Sand and gravel deposits are generally thin and discontinuous. Wehrmann et al. (1980) distinguished two sand units, an upper and a lower. Upper sand deposits are usually less than 5 feet thick; lower sand deposits are slightly more extensive but seem limited to the flanks of the moraine. These sand deposits support numerous domestic water wells and tend to be sensitive to prolonged dry spells. In a regional evaluation of sand and gravel aquifers for municipal groundwater supplies in east-central Illinois (Kempton et al., 1980), Lerna was identified as being in an area where no extensive sand and gravel aquifers have been reported. The probability of obtaining a moderate to large municipal supply of groundwater from sand and gravel deposits of the glacial drift appears low.

Historically, Lerna has obtained its public water supply from a combination of wells completed in sand deposits of the glacial drift and in shallow bedrock sandstones. Municipal wells 1 and 2 were completed in the drift and wells 3, 4, 5, and 6 were completed in sandstone bedrock. Within the last 10 years, both drift wells were shut down and water withdrawals have been met essentially by sandstone wells 3, 5, and 6. In 1975, water demand was at or near the estimated sustained yield of 20,000 gal/day of the sandstone aquifer (Wehrmann et al., 1980). In 1980, the Division of Water Resources (Wehrmann et al., 1980) estimated that water demand in Lerna by the year 2,000 would reach 23,700 gal/day.

Wehrmann et al. (1980) recommended three areas for further exploration and test drilling that could help provide for future needs. One area was the southeast side of the Norfolk and Western tracks, northeast and southwest of Lerna, which had been recommended for test drilling on the basis of results of a previous resistivity survey. The other two were areas where sand and gravel had been found at or near the base of the drift along the flanks of the moraine: the NE 1/4, Section 3, T 11N, R 8E, through the south half of Section 34, T 12N, R 8E, and 1 mile east of Lerna in Sections 11, 12, and 14, T 11N, R 8E. Beginning July 2, 1981, Lerna began purchasing water from the Clear Water Service Corporation (Michael Broten, personal communication, 1984).

During the EER survey conducted in 1984, 42 vertical electrical sounding (VES) profiles were located on the flanks of the Shelbyville Morainic System in the areas just north, east, and south of Lerna, including the areas recommended by Wehrmann et al. (1980). Locations of the 1984 survey profiles, as well as past EER survey profiles, are shown on page 6. Qualitative interpretation of VES data consisted of construction and examination of all 1984 VES curves. Quantitative evaluation utilized the inversion technique of Zohdy (1973) to produce layering parameters ("true" resistivities and thicknesses) for the sediments below the center stake of the corresponding VES profiles. Three lines of VES profiles, AA', BB', and CC' (figures 4a, 4b, and 4c), were selected to illustrate the layering parameters associated with the areas of most favorable VES profiles.

Line AA' of VES profiles (fig. 6) traverses the south half of Section 34, T 12N, R 8E, and the north half of Section 3, T 11N, R 8E, one of the areas recommended by Wehrmann et al. (1980). Interpretation of scattered well data indicates that the bedrock surface in the area of this cross section are shale and sandstone. Most VES profiles along this line exhibit resistivity values of 50 ohm-meters or more above the estimated elevation of the bedrock surface. Depth ranges of these relatively high resistivity values are shown with a stipple pattern on VES profiles 4, 6, and 8 to 10 in figure 6. All relatively high resistivity values of this line of VES profiles fall at the low end of the approximate resistivity range of sand (fig. 4) and may therefore reflect the presence of sandy clay rather than discrete sand layers in clay till. Test drilling would be necessary to confirm the presence of sand and/or gravel at the base of the glacial drift. The locations of VES

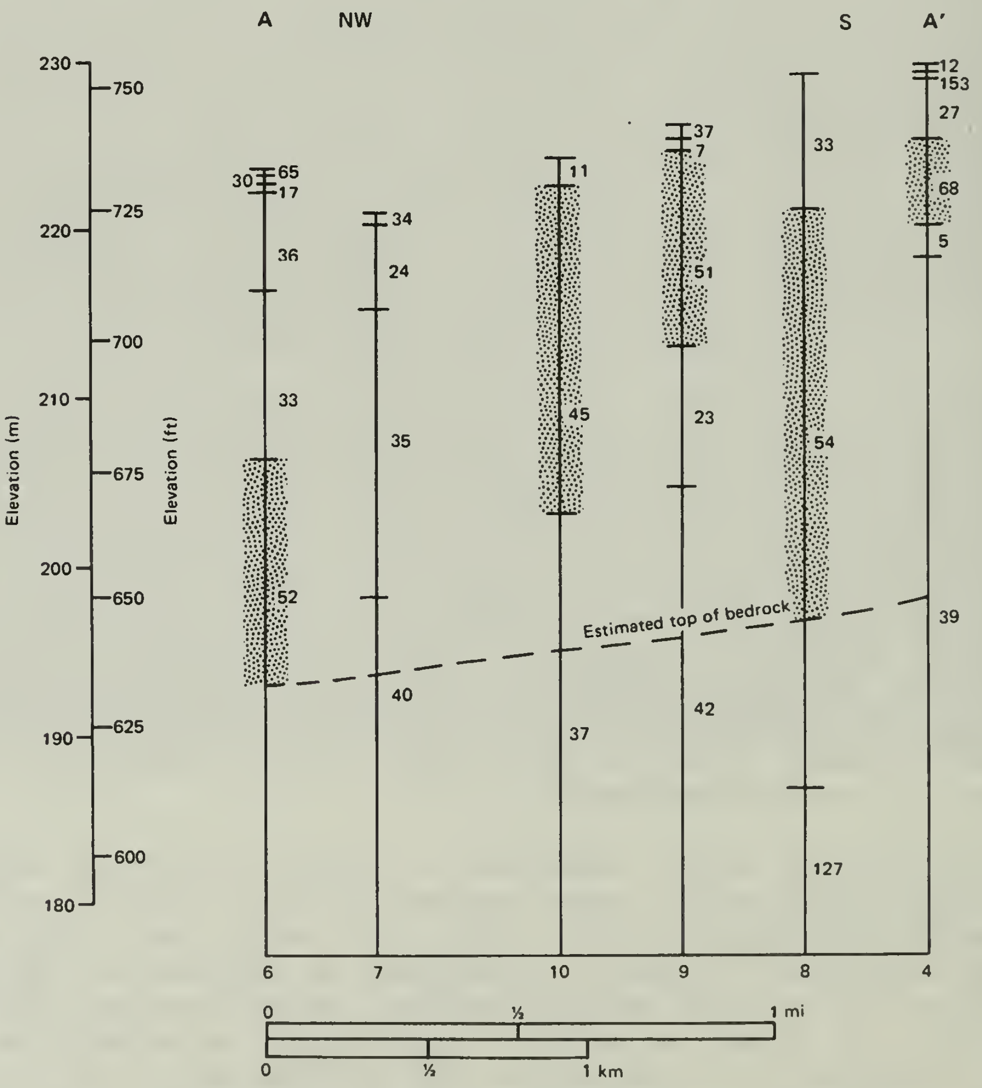


Figure 6. Layering parameters ("true" resistivities and thicknesses) along line A-A', Lerna study area. "True" resistivity values are in ohm-meters.

profiles 6 and 8 are considered the most favorable sites for test drilling.

Lines BB' and CC' of VES profiles (fig. 7 and 8) illustrate layering parameters associated with sediments on the flanks of the moraine to the east and south of Lerna, respectively. "True" resistivity values are generally lower than those of profiles along AA'. Again, the relatively high "true" resistivity values of 40 to 50 ohm-meters of VES profiles along these two lines may reflect the presence of either sandy clay or thin sand deposits within the till. Along the

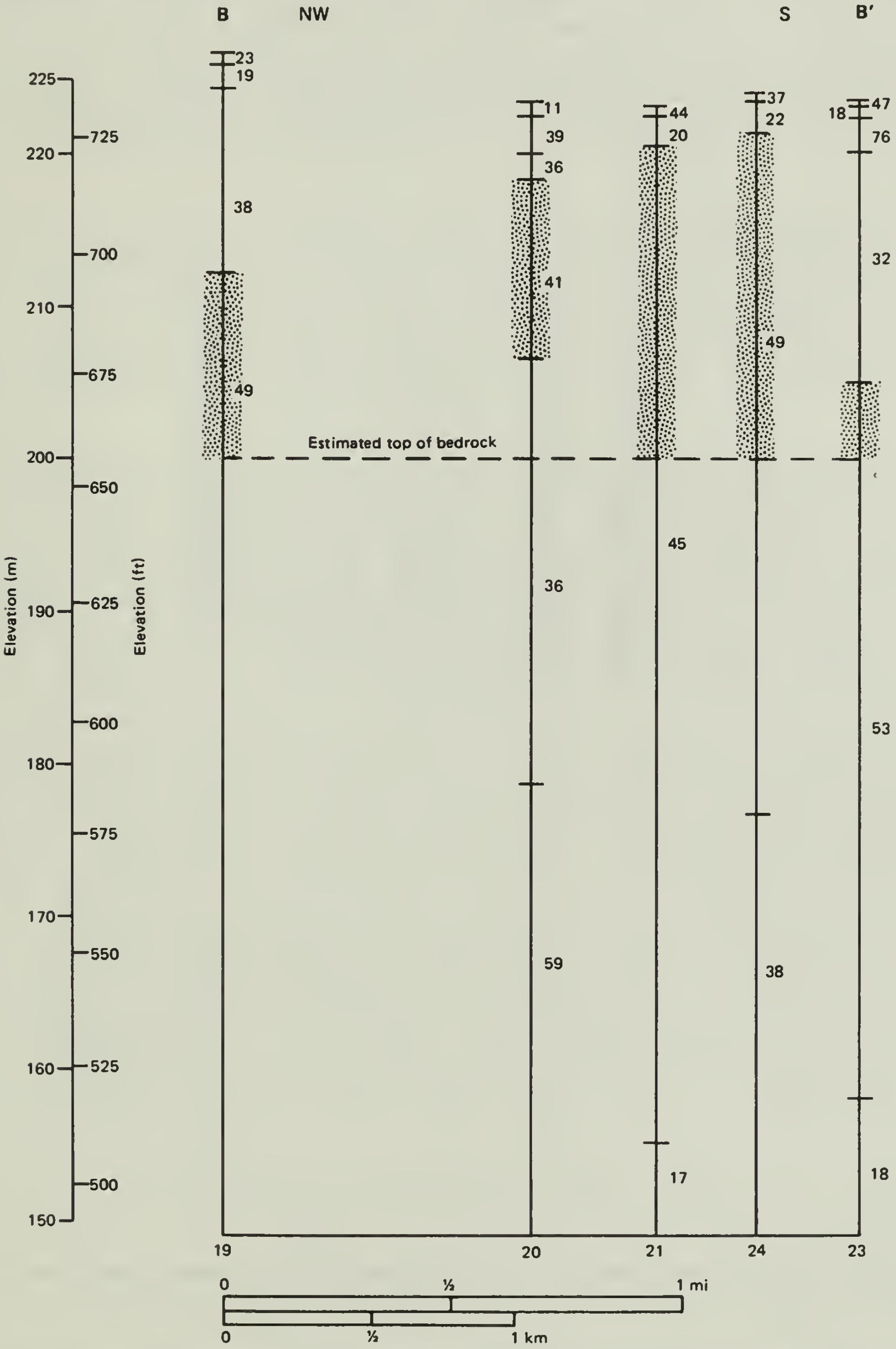


Figure 7. Layering parameters ("true" resistivities and thicknesses) along line B-B′, Lerna study area. "True" resistivity values are in ohm-meters.

two lines, the locations of VES profiles 19 and 24 of BB' appear to be the most promising locations for test drilling.

To summarize, although deposits of sand and gravel may exist along the flanks of the moraine at Lerna, these deposits are apt to be thin and discontinuous and may contain a high percentage of clay. In general, resistivity values measured during this survey were, at their best, at the low end of the approximate resistivity range of sand. The locations of VES profiles 6 and 8 appear to be the best sites for test drilling should Lerna decide to resurrect its own water supply system. However, considering the low probability of developing a moderate municipal water supply from the drift, the population size, and the cost of undertaking such a program, the community's decision to purchase its water supply from the Clear Water Service Corporation is the most reasonable alternative at this time.

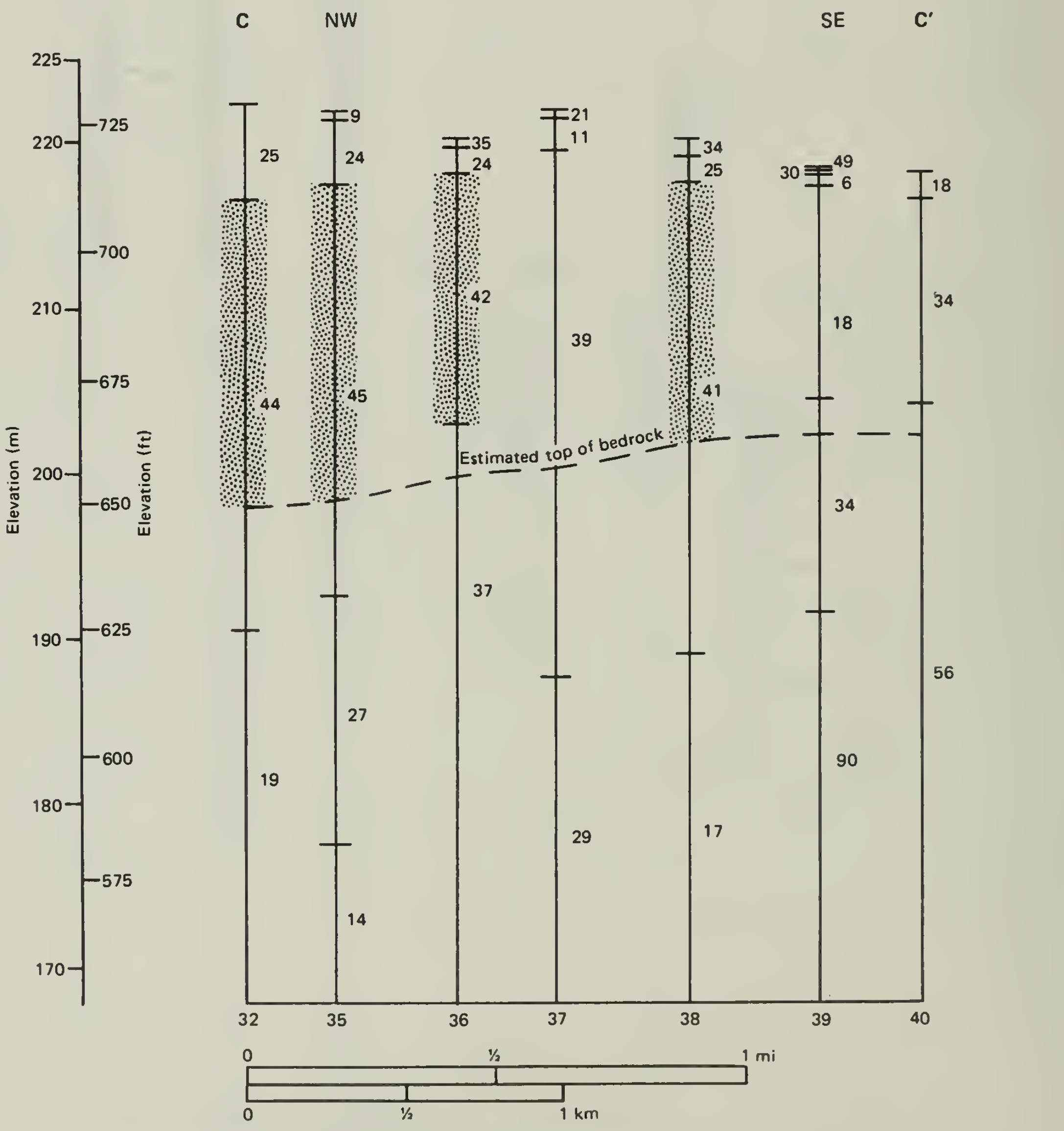


Figure 8. Layering parameters ("true" resistivities and thicknesses) along line C-C′, Lerna study area. "True" resistivity values are in ohm-meters.

LORAINE

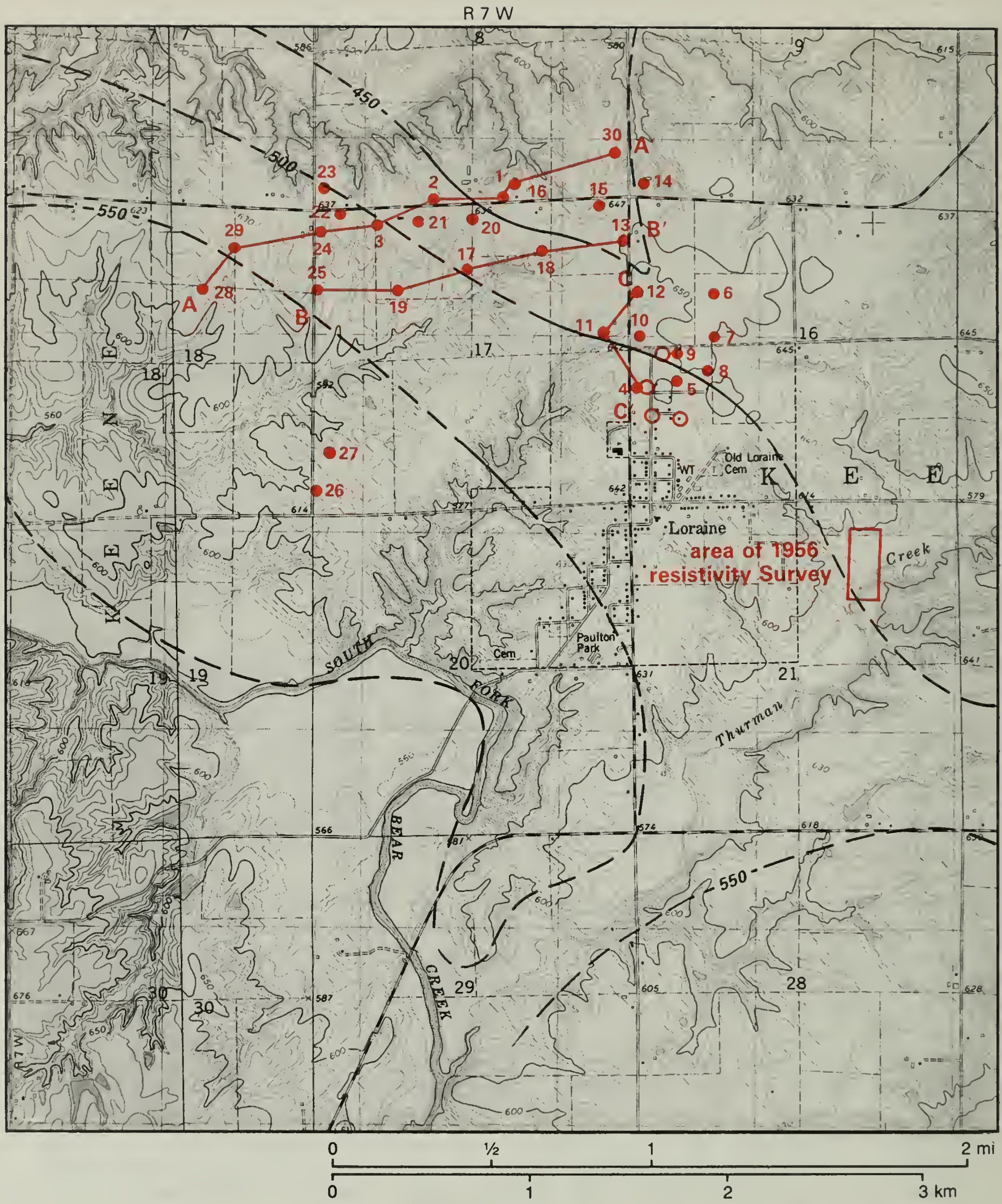
The community of Loraine (population 382), is in western Illinois in portions of Sections 16, 17, 20 and 21, T 2N, R 7W, of northern Adams County (see plate, p. 12). The population increased approximately 3 percent between the 1970 and 1980 census periods and is expected to increase only slightly by the year 2,000. Average water demand by the year 2,000 is also expected to increase proportionately (Wehrmann et al., 1980).

Loraine is near the southwest edge of the Galesburg Plain of the Till Plains Section of the Central Lowland Province, very close to the western boundary of Illinoian drift (fig. 1). Loraine lies on a highly dissected upland of Illinoian and pre-Illinoian till deposits approximately 6 miles east and southeast of the Illinoian moraine associated with the Kellerville Till Member of the Glasford Formation.

Topographic elevations in the Loraine area range from approximately 650 feet above mean sea level (msl) on the north side of town to slightly lower than 550 feet above msl west and southwest of town in the South Fork of Bear Creek bottomlands. The upland area drains to tributaries of the predominantly westward-flowing Bear Creek and South Fork of Bear Creek (including the southwest-flowing Thurman Creek), which are tributaries of the Mississippi River. The Mississippi River valley is approximately 10 miles west of Loraine.

Uppermost bedrock lithologies in the area of Loraine consist predominantly of limestone and shale with some thin sandstone of the Warsaw Formation and the Keokuk and Burlington Limestone Formations of Middle Valmeyeran (Mississippian) age. The Keokuk and Burlington Limestones underlie the Warsaw Formation and are in turn underlain by the non-water-yielding black, gray, and green shales of the Middle and Upper Devonian to Kinderhookian (lower Mississippian) New Albany Shale Group. Municipal wells presently operated by Loraine are completed in cherty intervals of the Keokuk and Burlington Limestones (Wehrmann et al., 1980); all other bedrock wells in the Loraine study area for which logs are on file at the Illinois State Geological Survey (ISGS) also obtain water from the limestones.

Elevations of the bedrock surface in the immediate vicinity of Loraine range from less than 450 feet above mean sea level (msl) approximately 1 mile north of town to a little more than 550 feet above msl west and southwest of town (see p. 12). Low bedrock surface elevations north of Loraine are related to a buried bedrock valley that was a tributary of the ancient Carthage Bedrock Valley. The Carthage Bedrock Valley trends northeast-southwest approximately 3 miles northwest of Loraine and is coincident with the present-day Bear Creek in its lower reaches.



● 1984 VES profile

○ municipal well

bedrock elevation (ft), dashed where approximate

LORAINE STUDY AREA

Glacial drift in the study area is composed primarily of clayey and silty tills with some thin, intercalated and discontinuous sand and gravel lenses of Illinoian and pre-Illinoian age, and windblown silt (loess) of Wisconsinan age. Drift is absent in the South Fork Bear Creek bottomlands in Section 29 south of Loraine, but its thickness increases to more than 170 feet over the buried bedrock valley tributary north of town (Piskin and Bergstrom, 1970; Wehrmann et al., 1980). The blanketing loess is generally less than 10 feet thick. In places, the predominantly thin, discontinuous sand lenses of the glacial drift may be capable of supporting large-diameter wells for small domestic water supplies. Records of only two wells completed in sand and gravel deposits in the study area are on file at the ISGS. These wells, approximately 1 mile northwest of Loraine near the center of the south line of Section 8 and near the center of the east half of the north line of Section 17, T 2N, R 7W, indicate sand deposits greater than 20 feet thick at depths of more than 100 feet below the surface. These sand deposits are in the region of the buried bedrock valley north of Loraine and are probably associated with it. However, no information is available concerning the extent of these deposits or what their maximum yield might be.

Loraine currently operates four municipal wells in the NW 1/4 SW 1/4 of Section 16, T 2N, R 7W, on the north edge of town (p. 12). The wells are finished at depths of 300 to 354 feet and are open opposite the approximately 200-foot interval of the Keokuk and Burlington Limestones. Reported yields of Village Wells 1, 2, and 3 in 1978 were 11, 8, and 22 gal/min, respectively (Wehrmann et al., 1980). Wehrmann et al. (1980) noted that some loss of well yield had occurred because of a lowering of regional static water levels and possible clogging of the limestone fractures and pore spaces in the vicinity of the wells due to mineral precipitation.

Village Well No. 4 was subsequently drilled in 1984, possibly to meet increased needs, but also to offset continued decreases in yields of the first three village wells. About 40 feet south and 600 feet east of the northwest corner of the southwest quarter of Section 16, T 2N, R 7W, the 6-inch diameter well is 345 feet deep and cased with steel to 153 feet. No screen was installed. The static water level of 113.5 feet was lowered to 325 feet during a 2-hour pump test at 20 gal/min. The pump installed has a capacity of 14 gal/min and is set at 315 feet. Because combined pumpage of Village Wells 1, 2, and 3 has already reached the estimated 20,000 gal/day sustained yield of the aquifer (Wehrmann et al., 1980), the addition of Well No. 4 in the same aquifer tapped by the other municipal wells is not expected to significantly increase the sustained yield of the well system. In 1980, the Division of Water Resources (Wehrmann et al., 1980) estimated that water demand in Loraine by the year 2,000 would be 24,900 gal/day.

In the 1980 report, Wehrmann et al. (1980) recommended three exploration alternatives: (1) drilling another well into the Keokuk and Burlington Limestones far enough from the existing wells to prevent interference; (2) exploring to attempt to define the relatively thick sand and gravel deposit north of Loraine in

Sections 8 and 17; or (3) test drilling at a possible sand and gravel site located by a resistivity survey conducted by the ISGS in 1956 (see p. 12). Although a new well has been drilled into the Keokuk and Burlington Limestones, it is too close to the old well field to add significantly to the sustained yield of the well system.

In late summer, 1984, 30 vertical electrical sounding (VES) profiles were located north and west of Loraine, including the area in Sections 8 and 17 recommended by Wehrmann et al. (1980). The plate (p. 12) shows locations of these profiles, the area of the 1956 resistivity survey, and the location of the current municipal wells. VES data were evaluated qualitatively and quantitatively. Qualitative interpretation of the VES data included construction and examination of the VES curves. The inversion technique of Zohdy (1973) was used in quantitative evaluation of the VES data. Inversion of a VES curve provides layering parameters ("true" resistivities and thicknesses) for the earth materials below the center stake of the corresponding VES profile. Lines AA', BB', and CC' of VES profiles on page 12 traverse or trend toward the known thick sand and gravel deposit in Sections 8 and 17, and illustrate the layering parameters associated with that area.

The northernmost line of VES profiles, AA' (fig. 9) extends from north-central Section 8, T 2N, R 8W, across the northwest portion of Section 17 and the southeast quarter of Section 8, T 2N, R 7W. Relatively high resistivity values above the estimated bedrock surface along this line are shown as a stipple pattern on profiles 3, 16, and 30. The layer of 149 ohm-meters shown on VES 3 may represent one of the thin, discontinuous sand lenses within the drift. VES profiles to either side do not indicate continuity of the possible deposit, at least in the east-west direction. VES profiles 16 and 30 illustrate favorable layering parameters that strongly indicate the possible presence of coarser-grained sediments such as sand and gravel above the bedrock surface. All other profiles along this line exhibit "true" resistivity values of less than 30 ohm-meters for sediments above the estimated bedrock surface. The presence of extremely thin, multiple layers at the surface of many of the profiles is indicative of a very dry ground surface. The locations of VES profiles 16 and 30 are consistent with the presence of known sand and gravel deposits and the buried bedrock valley tributary north of town. These areas are considered the most favorable sites for test drilling.

Line BB' of VES profiles (fig. 10) roughly parallels line AA' approximately 1/4 mile to the south. The trend in "true" resistivity values along this line is similar to that of AA'. The most favorable layering parameters are those of VES 13, in the vicinity of the southeasternmost extent of the buried bedrock valley tributary. The significance of the extremely high (322 ohm-meter) "true" resistivity value of this profile is ambiguous. The bedrock surface elevation may be higher than estimated and sand and gravel may directly overlie limestone bedrock at this location, this could cause an increase in the value of the layering parameters associated at that depth of the profile. Test drilling would be necessary to confirm the presence of a sand and gravel deposit or unexpectedly high limestone bedrock surface. VES profile 13 is considered the most favorable site for test drilling along BB'.

North-south line CC' (fig. 11) is immediately north of Loraine and extends from approximately 1/8 mile south of VES 13 of line BB' to the center of the current municipal well field. High resistivity values (stippled intervals) along this line of profiles are generally less than those of AA' and BB'. "True" resistivity values of 75 ohm-meters and 56 ohm-meters of profiles 12 and 4 may reflect sandy till or stringers of sand within the till. Layering parameters at VES 11 are the most favorable of line CC', but the relatively high resistivity value (160 ohm-meters) at VES 11 may be influenced by the higher resistivity of limestone formations at or near the bedrock surface.

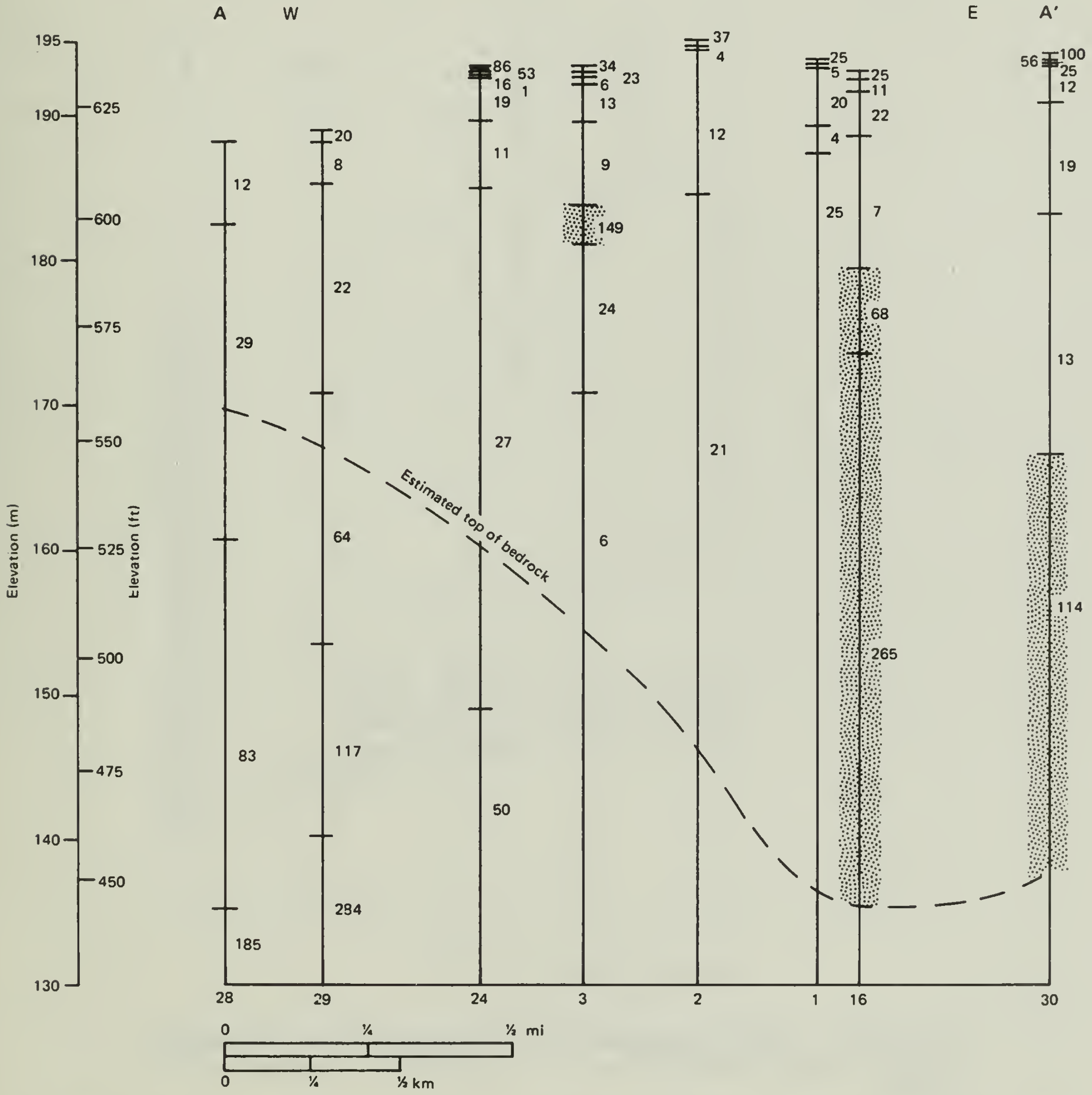


Figure 9. Layering parameters ("true" resistivities and thicknesses) along lilne A-A′, Loraine study area. "True" resistivity values are in ohm-meters.

To summarize, the community of Loraine may be able to expand its municipal well system to include development of a supplementary water supply from sand and gravel deposits of the glacial drift. However, results of the 1984 resistivity survey indicate that sand and gravel deposits associated with the buried bedrock valley tributary north of town probably extend no closer than approximately 1/2 mile north of the center of the current well field. Therefore, developing and laying pipeline for a new well field a mile or more from the current one may not be economically feasible for the community. Should Loraine wish to investigate this option, the locations of VES profiles 16 and 30, or a location between the two, are the most favorable sites for test drilling. Additional exploration would be necessary to determine possible boundaries of the sand and gravel deposits to the north.

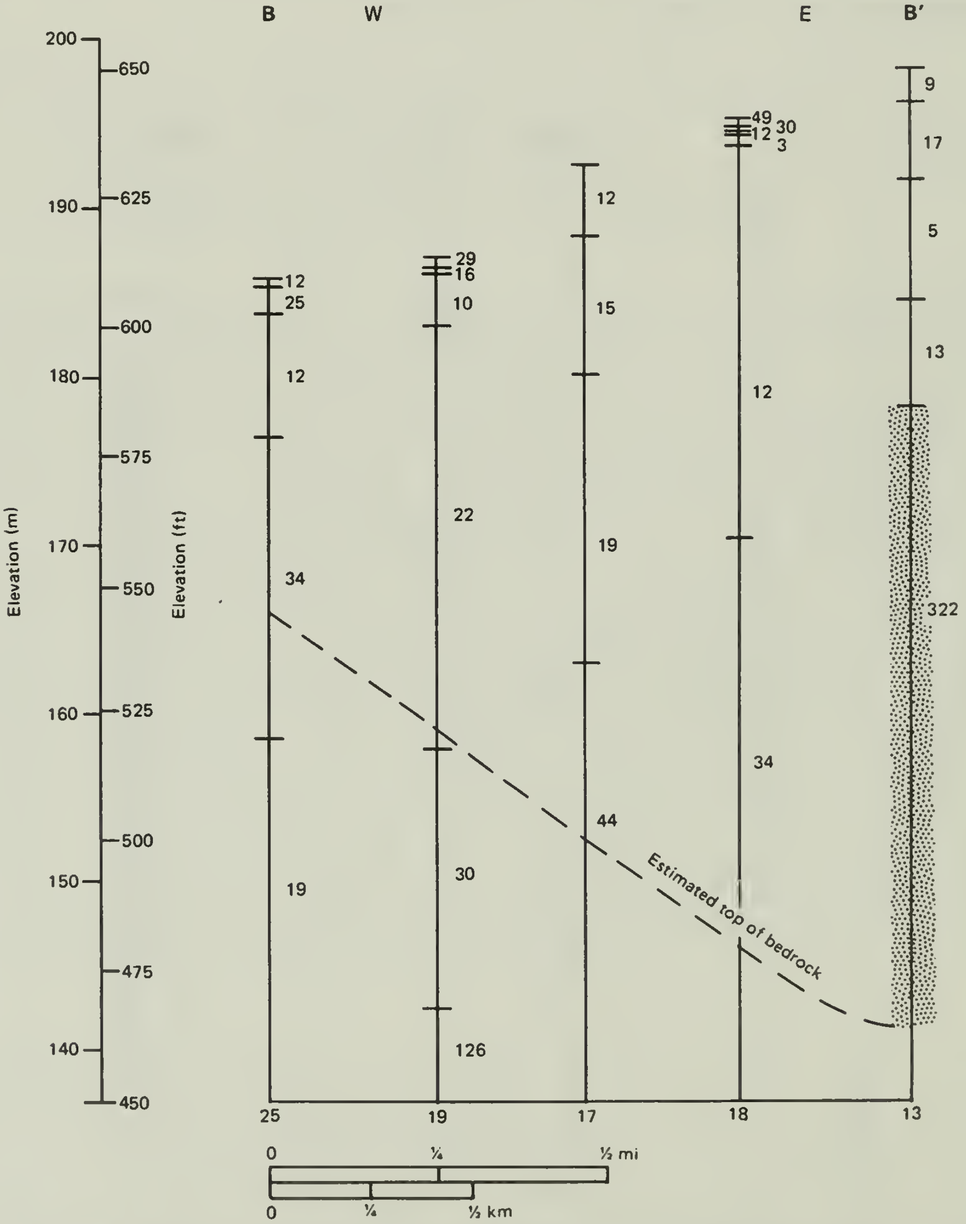


Figure 10. Layering parameters ("true" resistivities and thicknesses) along line B-B′, Loraine study area. "True" resistivity values are in ohm-meters.

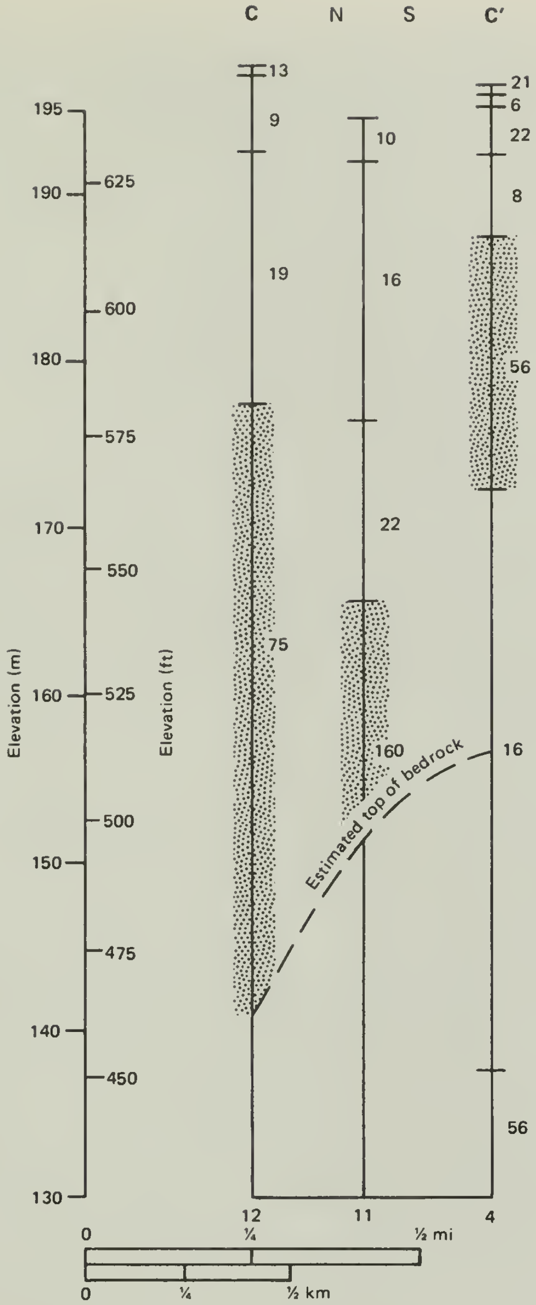
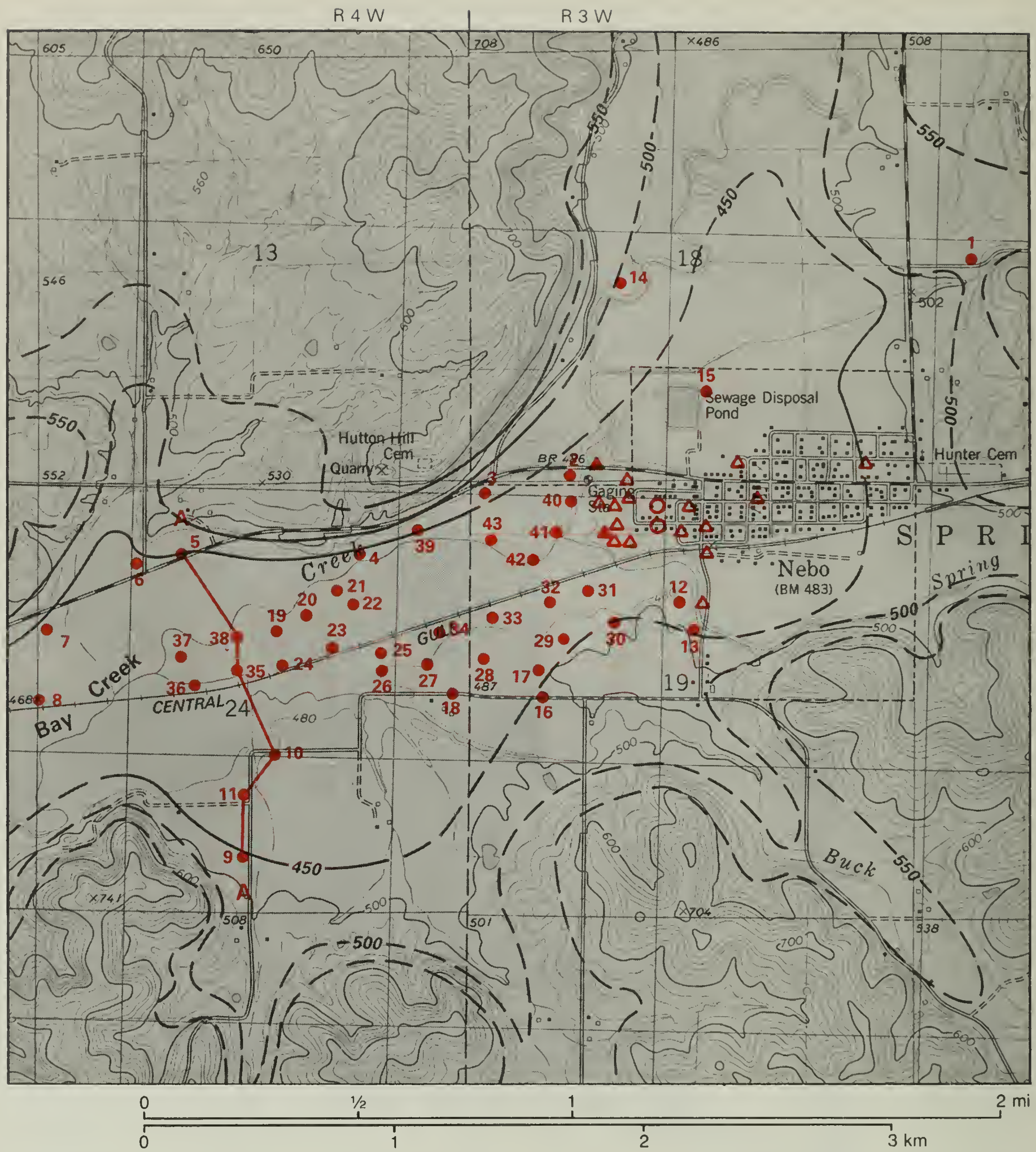


Figure 11. Layering parameters ("true" resistivities and thicknesses) along line C-C′, Loraine study area. "True" resistivity values are in ohm-meters.



NEBO STUDY AREA

NEBO

The community of Nebo (population 487) is in southeastern Pike County in portions of Sections 18 and 19, T 7S, R 3W, on the floodplain of Bay Creek and approximately 3 miles northeast of the Mississippi River valley bottom (see p. 18). The population of Nebo increased approximately 7 percent over the 1970-1980 census period; it is expected to remain approximately the same or increase slightly by the year 2,000. Average water demand by the year 2,000 is also expected to remain near current levels (Wehrmann et al., 1980).

The Nebo area is in the extreme eastern portion of the Lincoln Hills Section of the Ozark Plateaus Province, less than 10 miles west of the Galesburg and Springfield Plains of the Till Plains Section of the Central Lowlands Province (fig. 1). The Ozark Plateaus Province is characterized by shallow limestone bedrock, continental-type climate, dendritic drainage pattern, and upland areas either broad and rolling or narrow irregular ridges (Hunt, 1967, revised 1974). Uplands surrounding Nebo are highly dissected and form narrow irregular ridges.

Ground surface elevations in the study area range from a little less than 480 feet above mean sea level (msl) along Bay Creek to slightly more than 700 feet above msl on the uplands. Nebo is built on the creek bottomlands at elevations ranging from 480 to approximately 500 feet. Drainage is predominantly west and northwest via Spring Creek and Buck Branch to the southwest-flowing Bay Creek and eventually to the Mississippi River approximately 8 miles to the west.

Nebo is directly underlain by the Grassy Creek Shale of the Upper Devonian. Silurian and/or Devonian limestone separate the Devonian shales from the underlying thick, non-water-yielding Maquoketa Shale Group of the Ordovician. The Maquoketa is in turn underlain by limestones of the Galena and Platteville Groups and by the St. Peter Sandstone. Bluffs of the uplands surrounding Nebo are formed from the non-water-yielding shales of the Kinderhookian Series and the overlying limestones of the lower part of the Valmeyeran Series of the Mississippian. Elevation of the bedrock surface ranges from approximately 400 to 500 feet above msl in the creek bottoms (from west to east), to 650 feet or more above msl in the uplands (p. 18) (Horberg, 1950).

Water-yielding capacity of the shallow Silurian and/or Devonian limestones is low. Only one log of a water well completed in the shallow limestones near Nebo is on file at the Illinois State Geological Survey. The reported yield of the well was 2 gallons per minute (gal/min). Higher yields may be possible in places where the limestone is fractured. Water may be obtainable from deeper bedrock formations, such as limestones of the Galena and Platteville Groups and the St. Peter Sandstone, but this water is likely to be too mineralized to use as a public water supply (Wehrmann et al., 1980).

Nebo lies in the western Driftless Area of Illinois. Pleistocene till deposits have not been recognized in the immediate vicinity of Nebo, although pre-Illinoian till sediments of the Banner Formation are present less than 2 miles to the west and Illinoian till deposits are present approximately 8 miles to the northeast. Pre-Illinoian, Illinoian, and Holocene alluvium is present in the creek floodplains surroundng Nebo. Alluvial deposits average 35 to 65 feet thick (Wehrmann et al., 1980); the blanketing Illinoian and Wisconsinan windblown silt (loess) averages 12 to 25 feet thick.

Water-yielding capacity of the sand and gravel alluvial deposits (12 to 50 gal/min) is greater than that reported for the shallow limestones. Yields will vary depending on thickness of the aquifer and amount of silt or clay present.

Nebo operates two municipal wells on the west side of the town near the center of the north edge of Section 19, T 7S, R 3W (see p. 18). The wells are completed in sand and gravel alluvial deposits 12 to 14 feet thick in the Bay Creek floodplain. Wells 1 and 2 are 43 and 52 feet deep; they encounter the sand and gravel aquifer at depths of 29 and 40 feet, respectively. The wells are operated at 50 gal/min (Wehrman et al., 1980).

Pumpage of the Nebo municipal wells averaged 75,000 gal/day in 1980 and 65,000 gal/day in 1983 (Mike Broten, personal communication, 1984). Pumpage for all years since 1970 has averaged 71,500 gal/day. The total sustained yield of the Nebo municipal wells has been estimated to be 100,000 gal/day during years of normal precipitation. Reductions in possible yield are inevitable during periods of prolonged drought.

Wehrmann et al. (1980) recommended that if new or additional supplies of water were sought, development of the current well field could be extended to the west; specifically, two previously recommended locations delineated by resistivity data collected in 1952 should be investigated. If those sites would fail to provide the desired water supply, Wehrmann et al. (1980) suggested that additional sites west of the current well field be chosen on the basis of existing or supplemental resistivity data.

In accordance with these recommendations, 43 vertical electrical sounding (VES) profiles were taken in the creek bottomlands near Nebo during late summer of 1984. The locations of these soundings are shown on page 18. Qualitative interpretation of the resistivity data consisted of plotting and examining all VES curves and evaluating them with respect to well log data. Quantitative interpretation utilized the inversion technique of Zohdy (1973) to produce layering parameters ("true" resistivities and thicknesses) for the sediments below the center stake of the corresponding VES profiles.

A map of apparent resistivity values (fig. 12) for the electrode spacing $\overline{AB}/2$ = 14.67 meters (48.1 ft) was constructed to aid in defining areas of favorable resistivity values. Line AA' (fig. 13) of VES profiles illustrates the layering parameters associated with the areas of most favorable VES data.

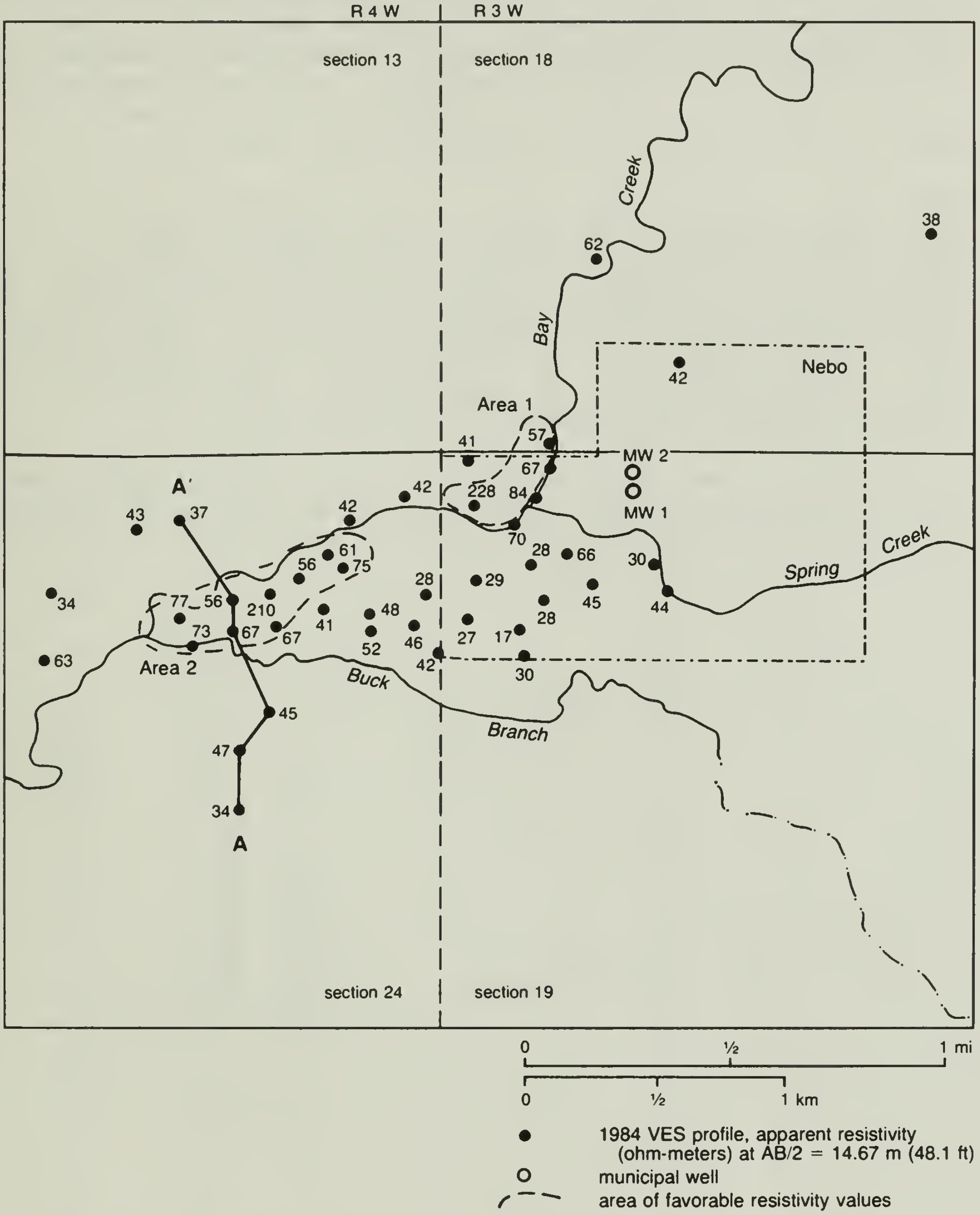


Figure 12. Map of apparent resistivity (in ohm-meters) in the Nebo area for electrode spacing $\overline{AB}/2$ = 14.67 m (48.1 ft).

Two areas of relatively high apparent resistivity values are delineated in figure 12. Area 1, closest to the current municipal wells, is the field just west of Bay Creek and south of the highway, where Bay Creek bends to the west. This area includes the locations of VES profiles 2 and 40-43. Area 2 is the triangular section formed by the confluence of Bay Creek and Buck Branch, approximately 1/2 mile west of the corporate boundary of Nebo. The area includes the locations of VES profiles 19-22, 24, and 35-38. Apparent resistivity values at the $\overline{AB}/2 = 14.67$ meters (48.1 ft) electrode spacing in these two areas exceed 50 ohm-meters, which is near the lower limit of the approximate resistivity range of sand (fig. 4).

North-south line AA' (fig. 13) is in the center of Section 24, T 7S, R 4W, approximately 1 mile west of the center of Nebo. This line traverses the westernmost area of high apparent resistivity values and includes VES profiles 5, 9-11, 35, and 38. VES profiles 35 and 38 are in the area of high apparent resistivity. "True" resistivity values of these profiles for the geoelectric layer at the estimated base of the alluvium are approximately 100 ohm-meters, which strongly suggests the presence of sand and gravel.

To summarize, the 1985 resistivity survey confirms data from previous resistivity surveys, which indicated that further groundwater development could take place west of the current well field at least

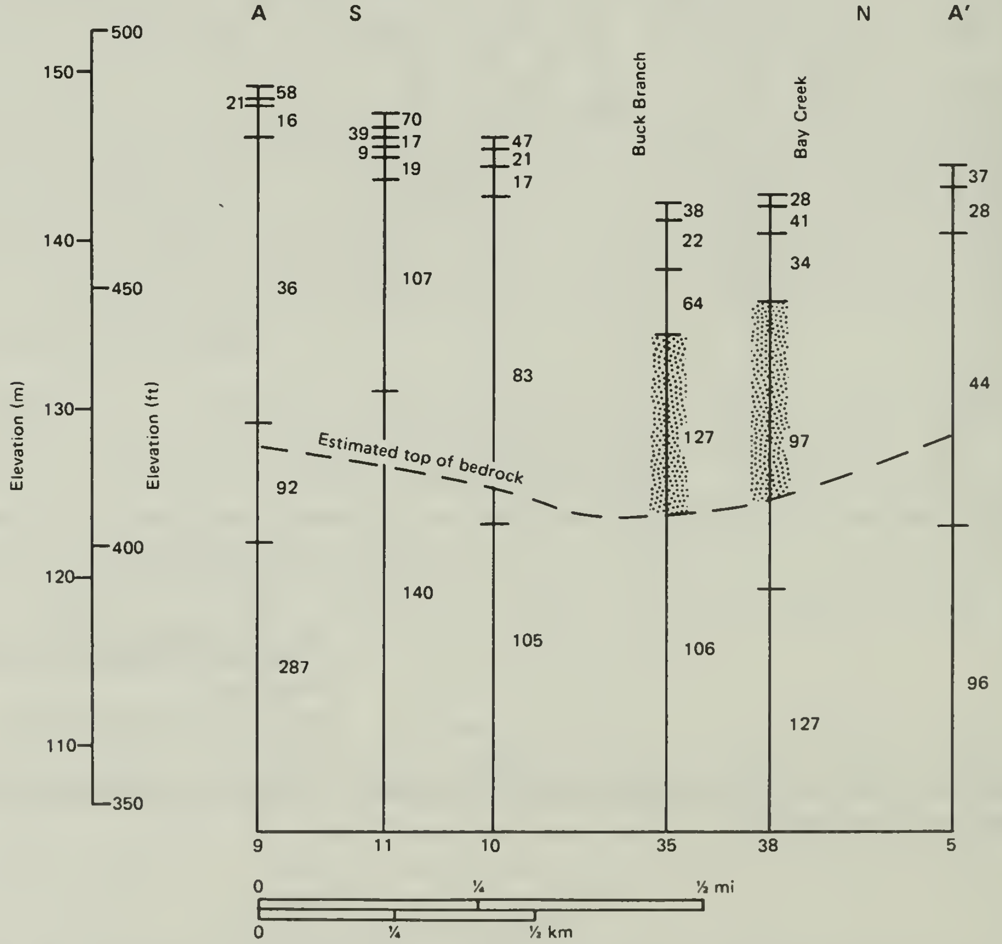
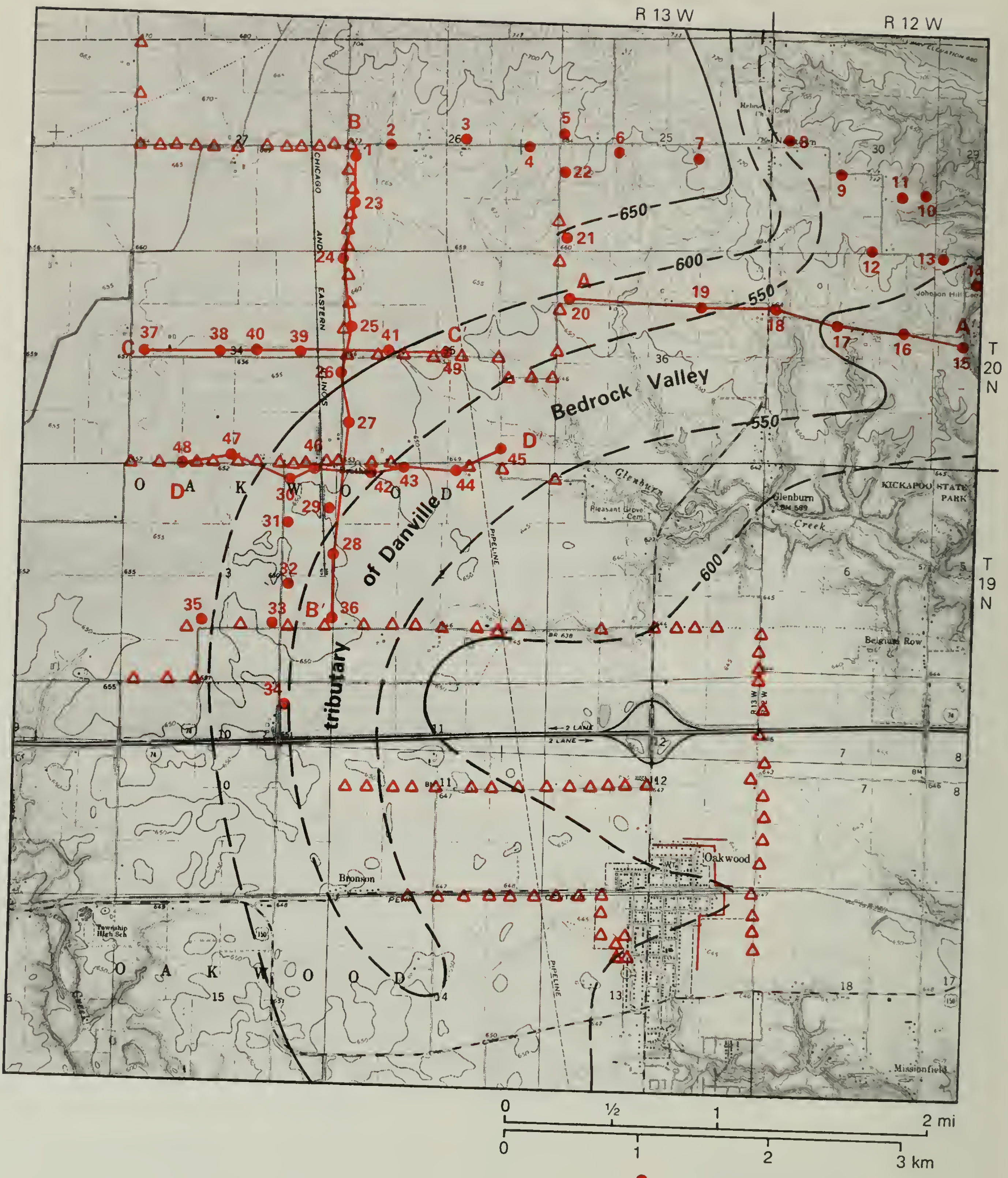


Figure 13. Layering parameters ("true" resistivities and thicknesses) along line A-A', Nebo study area. "True" resistivity values are in ohm-meters.

as far as the northwest corner of Section 19, T 7S, R 3W (area 1, fig. 12). Another area with favorable resistivities is in the triangular area just east of the confluence of Bay Creek and Buck Branch in the north-central portion of Section 24, T 7S, R 4W (area 2, fig. 12). If an additional groundwater supply is sought, two previously recommended locations (see p. 18) should be tested first because they are closer to town and wells would therefore be more economical to develop. Area 1 should be tested before Area 2 for the same reason.



OAKWOOD STUDY AREA

OAKWOOD

The community of Oakwood (population 1,627) is in central Vermilion County (p. 24) in portions of Sections 12 and 13, T 19N, R 13W. The population of Oakwood increased nearly 20 percent over the census period 1970-1980 and is expected to continue to increase. Water demand has also steadily increased and will probably increase significantly by the year 2,000. Although currently dependent on surface water for its municipal water needs, Oakwood used groundwater resources in the past, and may need them to augment their surface water supply in the future.

The Oakwood area is in the east-central portion of the Bloomington Ridged Plain of the Till Plains Section of the Central Lowland Province (fig. 1). The Bloomington Ridged Plain is characterized by morainic ridges separated by flat to gently rolling ground moraine (Leighton et al., 1948). Oakwood lies on ground moraine of the Batestown Till Member of the Wedron Formation of Wisconsinan age. It is 1½ to 2 miles south of the Newtown Moraine, the outer moraine of the Illiana Morainic System (Willman and Frye, 1970), and 3¼ to 4 miles north-northeast of a portion of the Urbana Moraine. The ground moraine has a general surface elevation of 645 to 650 feet above mean sea level (msl). Surface elevations range from 760 feet above msl on the crest of the Newtown Moraine 4½ miles north of Oakwood to 545 feet along the Salt Fork southeast of town. Drainage is east and southeast to the west-flowing Salt Fork of the Vermilion River.

The uppermost bedrock in the Oakwood area is composed primarily of non-water-yielding shales with some limestone and sandstone of the Pennsylvanian Modesto Formation. Several domestic water wells in the study area have been completed in intercalated limestone-shale and sandstone-shale intervals as well as individual limestone and sandstone beds. Yields of these wells are generally sufficient for domestic water needs; the upper bedrock is not considered a possible source of moderate to large municipal supplies of groundwater.

In the study area, elevation of the bedrock surface is variable because of the presence of unnamed bedrock valleys that are tributaries of the buried Danville Bedrock Valley. The Danville Bedrock Valley is in turn a tributary of the Mahomet Bedrock Valley, located at the extreme northern edge of Vermilion County. The major unnamed bedrock valley in the study area trends north from beneath the Salt Fork, just over a mile south of Oakwood, through the study area 1 to 1¼ miles due west of town. It then turns east, exits the study area approximately 2 miles north of town, and shortly thereafter joins the Danville Bedrock Valley (see p. 24). A tributary of this unnamed bedrock valley is believed to extend beneath Oakwood (p. 24). Elevations of the bedrock surface range from approximately

520 feet above msl in the portion of the bedrock valley north of town to a little over 650 feet above msl at the northernmost extent of the 1984 resistivity survey north of town.

Glacial drift in the vicinity of Oakwood consists primarily of deposits of Wisconsinan age, with some deposits of Illinoian and possibly pre-Illinoian age (Wehrmann et al., 1980). The deposits form a complex of till, sand and gravel outwash and alluvium, and windblown silt (loess). Drift is absent along the Salt Fork, but increases to a thickness of more than 150 feet where the bedrock valley north of town is present beneath the Newtown Moraine. Drift thickness is commonly 25 to 50 feet. Thickness of the blanketing loess averages 2 to 4 feet.

Sand and gravel deposits of the glacial drift support numerous domestic water wells in the study area as well as Oakwood's three former municipal wells. These deposits occur in three general forms: (1) thin, discontinuous stringers of sand or sand and gravel -- at various elevations within the glacial drift -- consisting of thin outwash deposits in front of the Newtown Moraine, (2) thicker sand and gravel deposits at the base of the drift, and (3) sand and gravelly sand deposits within the bedrock valleys. Sand and gravel deposits of the bedrock valley that extends beneath Oakwood are generally thinner and less continuous than those of the larger bedrock valley to the west and north.

Oakwood does not currently operate any municipal wells completed in the glacial drift or in bedrock formations. Three former municipal wells were completed in sand and gravel deposits of the bedrock valley beneath the northeastern portion of town. Wells 1 and 2 have been abandoned, but Well 3 has been capped and is still available for emergency or supplemental use (Wehrmann et al., 1980). Well 3 was operated until late 1978 or early 1979 when expanded surface water treatment facilities were completed (Michael Broten, 1984, personal communication). Today, the total water needs of Oakwood are met by pumpage from the Salt Fork River south of town. In 1980, water demand in Oakwood was 135,000 gal/day (Wehrmann et al., 1980). The Division of Water Resources has estimated that water demand in Oakwood by the year 2,000 will reach 172,000 gal/day, an increase of 27 percent over 1980 demand estimates.

Wehrmann et al. (1980), made two recommendations for meeting future water needs if present sources prove inadequate. The first recommendation was for exploration to define the extent of sand and gravel deposits associated with the bedrock valley north of town. The second possibility involved damming a tributary to the Salt Fork, approximately 3/4 mile southeast of town. In response to the first recommendation, 49 vertical electrical sounding (VES) profiles were taken in the Oakwood area in the summer of 1984. Locations of these profiles as well as locations of previous VES profiles are shown on page 24. VES data were evaluated qualitatively and quantitatively. Interpretation of the data consisted of plotting, examination, and inversion of VES curves for the VES profiles. The inversion technique of Zohdy (1973) was used to derive layering parameters ("true" resistivities and thicknesses) for the sediments below the center stake of the corresponding VES profile. Four lines of VES profiles (AA', BB', CC', and DD') illustrate layering parameters obtained in the area north of Oakwood.

Line AA' of VES profiles (fig. 14) trends east-west across a portion of the bedrock valley approximately 2½ miles north of town. At this point, the bedrock valley appears to be constricted in width. High "true" resistivity values of VES profiles along this line are generally between 50 and 60 ohm-meters; these values are at the low end of the range for sand and at the high end of the range for clay (fig. 4). None of the layering parameters along AA' strongly indicate sand and gravel deposits. No location along AA' is recommended as a future test-drilling site.

The north-south line of VES profiles BB' (fig. 15) extends south to the north edge of the bedrock valley, where the valley turns south

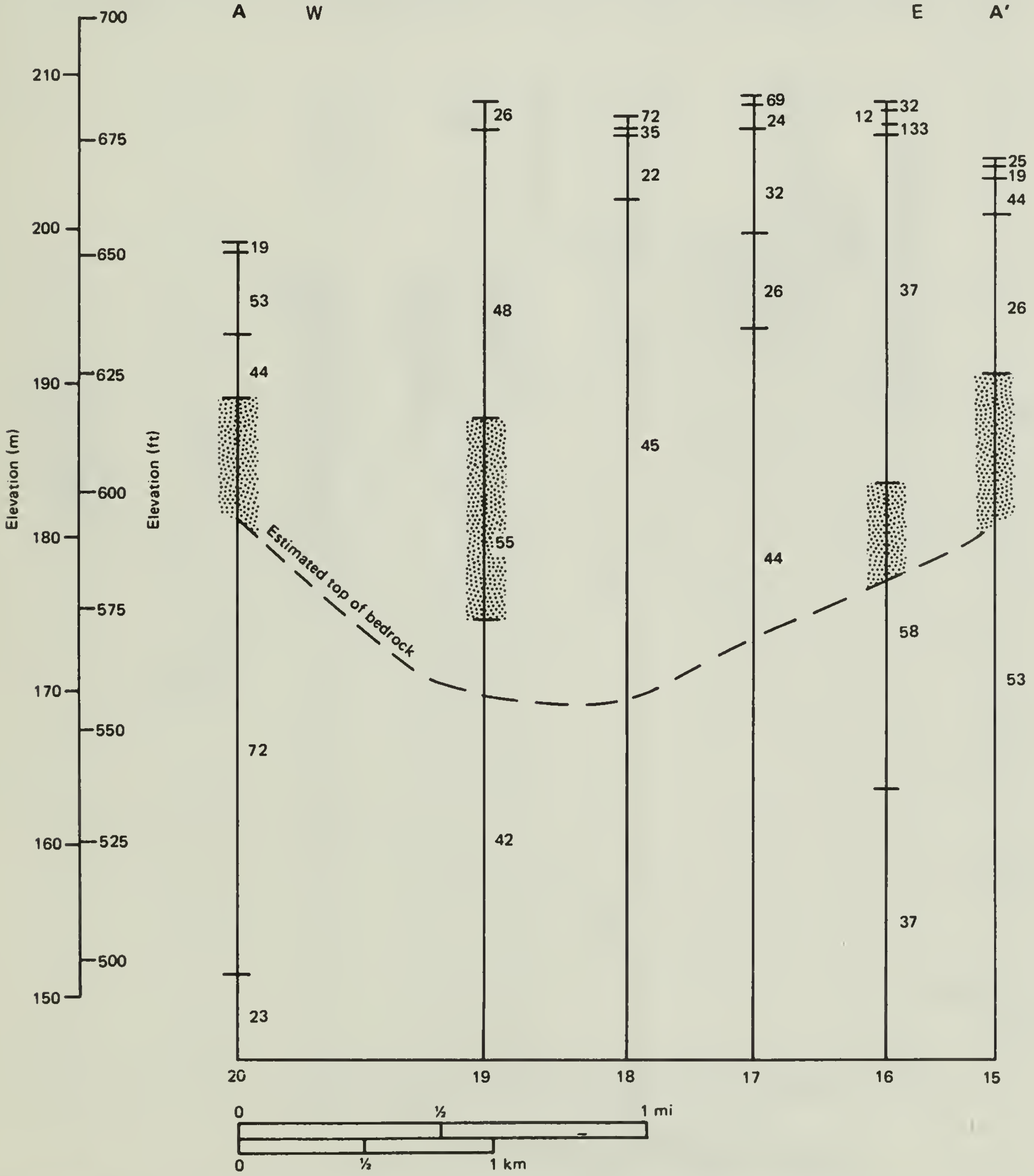


Figure 14. Layering parameters ("true" resistivities and thicknesses) along line A-A', Oakwood study area. "True" resistivity values are in ohm-meters.

to pass west of Oakwood. Well control is scarce in this area and the elevation of the bedrock surface (and therefore the position of the deepest part of the bedrock valley) is largely inferred from well data to the north and southwest of Oakwood. High "true" resistivity values for sediments above the estimated bedrock surface range from 56 to 226 ohm-meters. In some profiles (1, 24, and 25), the calculated high resistivity layers show little to no correlation with the estimated position of the bedrock surface. Two possible reasons for this are that the position of the bedrock surface is not known in sufficient detail, or, more likely, deposits of sand and gravel may overlie bedrock formations that include several thin sandstones and/or limestones, which makes it difficult to differentiate the resistivity of sand and gravel from that of the bedrock formations. Drift thickness at VES profiles 1, 23, 24, 25, and 26 is estimated to be 25 to 30 feet or less. Although high resistivity values at these profiles may indicate the presence of sand and gravel, the deposits may be too thin (depending on the position of

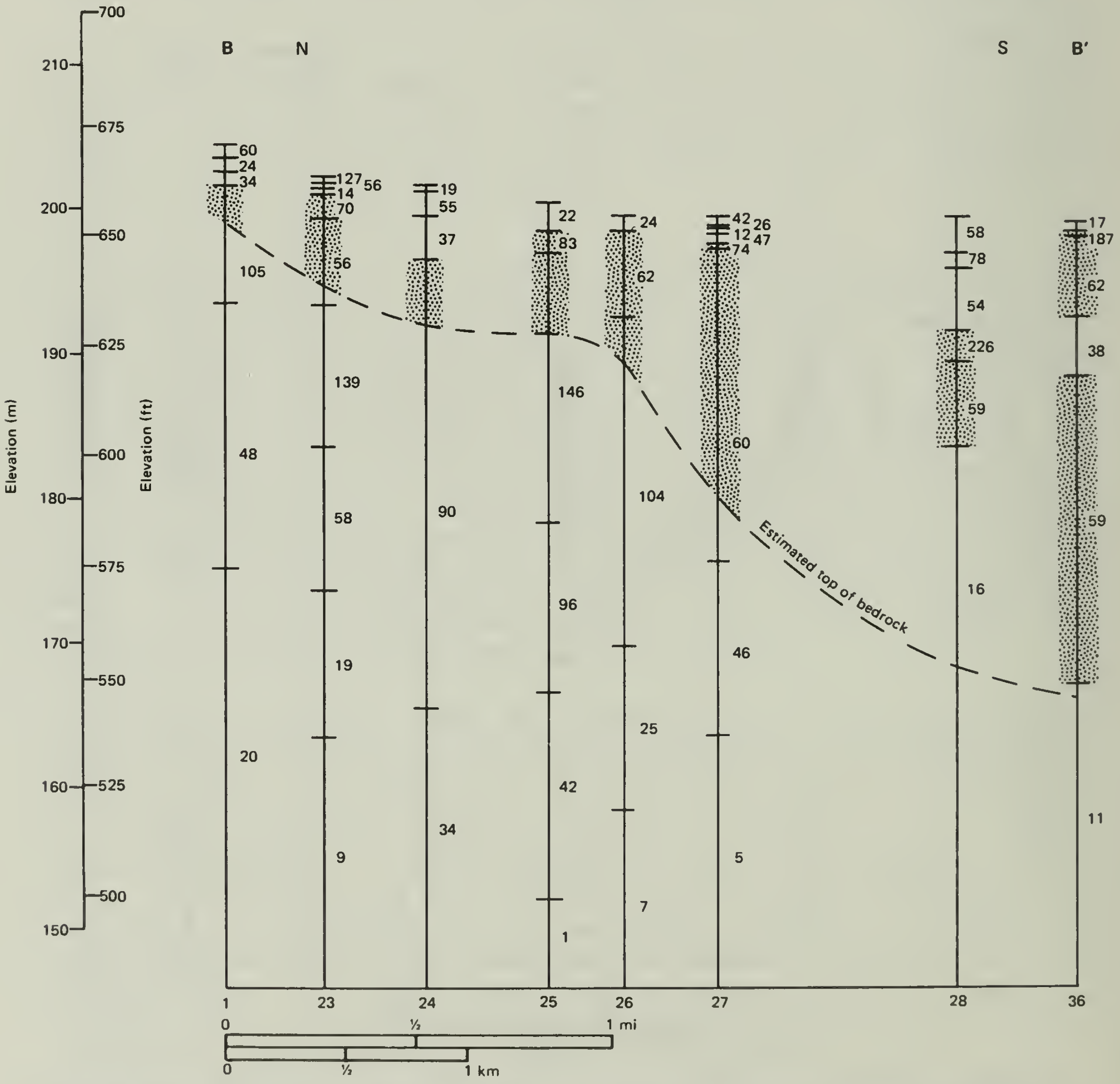


Figure 15. Layering parameters ("true" resistivities and thicknesses) along line B-B′, Oakwood study area. "True" resistivity values are in ohm-meters.

the bedrock surface) and water levels too sensitive to drought conditions for them to be utilized for a supplemental municipal water supply. Resistivity values at VES profiles 27, 28, and 36 are in general slightly lower than those at the north end of the profile, but estimated drift thickness is much greater as the line extends over the north edge of the bedrock valley. The location of VES profile 27 is considered the most favorable as a possible test-drilling site along this line of profiles.

East-west trending lines of VES profiles CC' and DD' (figs. 16 and 17) are roughly parallel; they are located approximately 2½ miles northwest of Oakwood (see p. 24). These lines of VES profiles exhibit the most consistently favorable layering parameters of the 1984 Oakwood resistivity survey. Because the bedrock valley is trending northeast-southwest in this area, line DD' probably extends

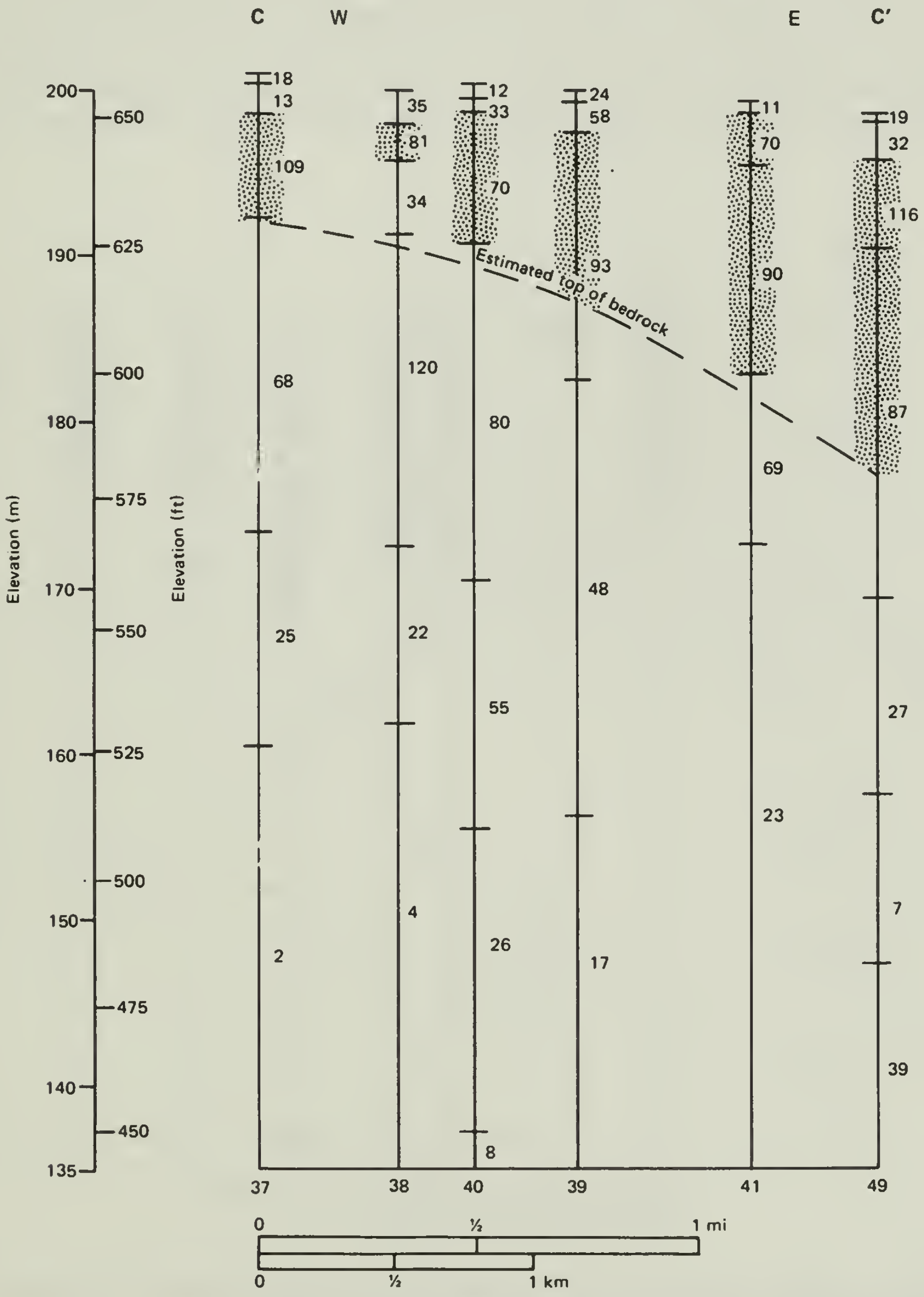


Figure 16. Layering parameters ("true" resistivities and thicknesses) along line C-C', Oakwood study area. "True" resistivity values are in ohm-meters.

farther over the center of the valley than CC'. Absence of favorable layering parameters at the east end of line DD' suggest that deposits of sand and gravel occur on the sides of the bedrock valley rather than in the deepest part of the channel. VES profiles 40, 39, 41, and 49 of line CC' and profiles 30, 46, 42, and 43 of line DD' exhibit the most favorable layering parameters (high "true" resistivities and reasonable layer thicknesses) of these two lines. Values also suggest that the sand and gravel deposit, if present, is fairly continuous. The most favorable locations for future test drilling appear to be at or near VES profiles 41 and 49 of line CC' or in the vicinity of VES profile 42 along DD'.

To summarize, the possibility of developing a supplemental municipal water supply from the glacial drift near Oakwood is fair. Outwash or valley-train deposits associated with a bedrock valley approximately $2\frac{1}{2}$ miles northwest of town may be able to support a supplemental well system. Test drilling would be necessary to confirm the presence, extent, and degree of continuity of the sand and gravel deposits. Sand and gravel deposits of the glacial drift are not considered capable of supporting the total water needs of the

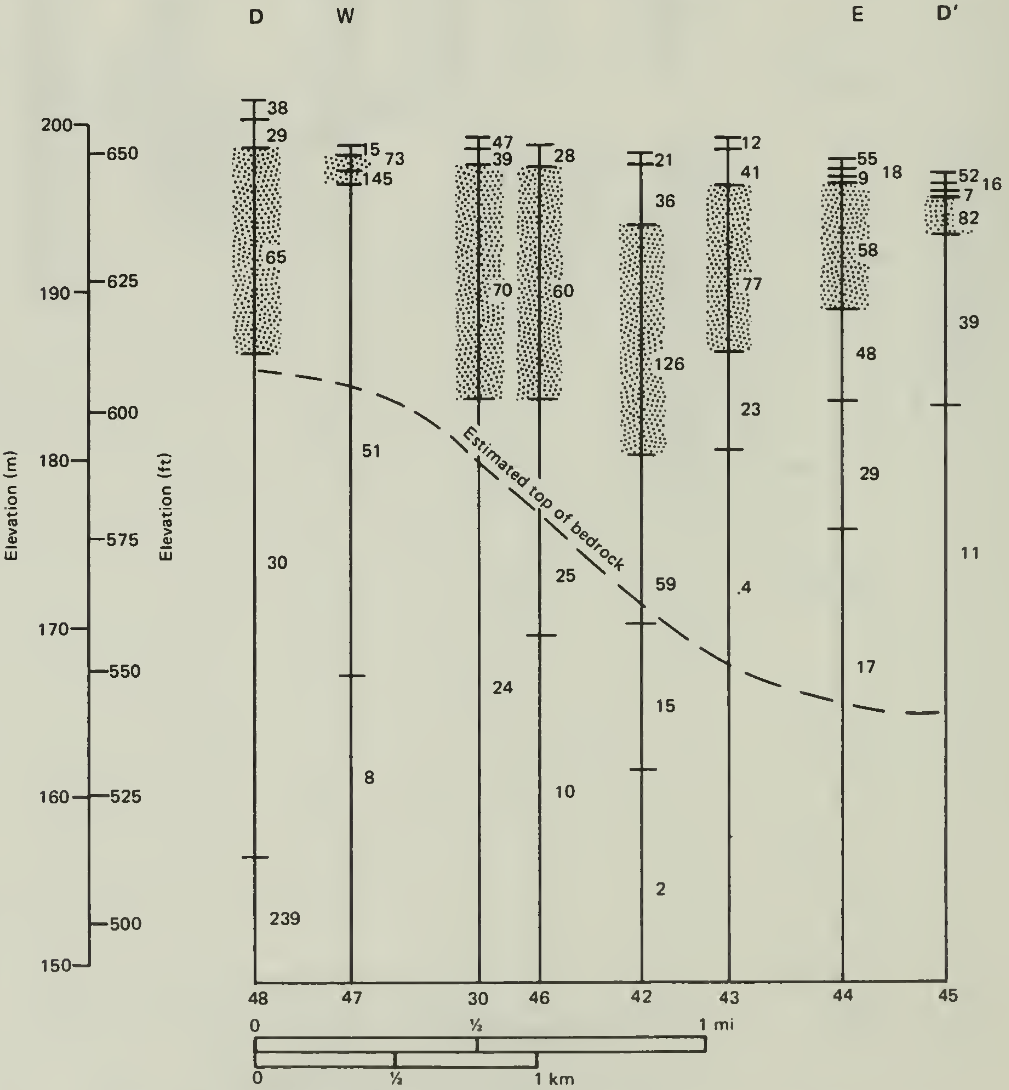
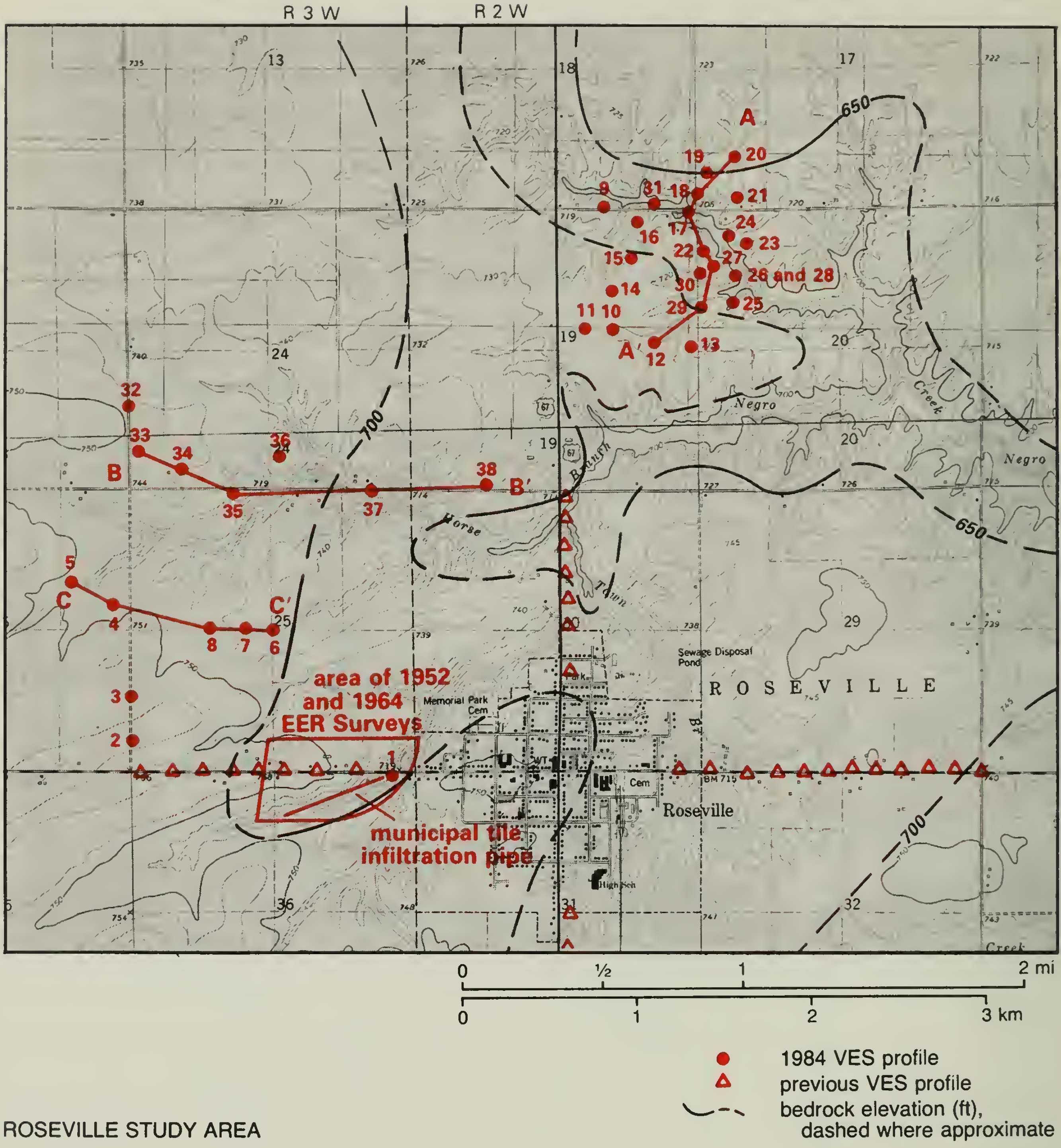


Figure 17. Layering parameters ("true" resistivities and thicknesses) along line D-D', Oakwood study area. "True" resistivity values are in ohm-meters.

community. Should additional water resources be sought, the primary choices for test-drilling sites in the glacial drift are at VES profile locations 41 and 49 of CC' and profile location 42 of DD'. The community could also investigate the second recommendation made by Wehrmann et al. (1980), to dam a tributary to the Salt Fork approximately 3/4 mile southeast of town.



ROSEVILLE STUDY AREA

ROSEVILLE

The community of Roseville (population 1,254) is in south-central Warren County in portions of Sections 30 and 31, T 9N, R 2W. The population of Roseville increased approximately 13 percent during the 1970-1980 census period and is expected to continue to increase slowly. The groundwater source currently utilized by Roseville is sand and gravel at a very shallow depth; therefore, available yield from the aquifer can be cut sharply during prolonged periods of drought. In 1980, the average daily water demand at Roseville exceeded the 1980 Division of Water Resources estimates for the community for the year 2,000. The Illinois State Water Survey estimates that withdrawals from the aquifer are at or near its practical sustained yield. It is likely that additional water resources will be required.

Roseville lies in the central portion of the Galesburg Plain of the Till Plains Section of the Central Lowland Province (fig. 1). The till plain is fairly level to gently rolling; stream valleys tend to be narrow, and cut deeply (up to 40 ft) into the upland surface. Surface elevations of the till plain at Roseville are 740 to 750 feet above mean sea level (msl). Surface elevations in the study area range from 780 feet above msl on several small hills west and south of town to 680 feet along Negro Creek 1½ miles northeast of Roseville. Roseville is approximately 1 mile east of the drainage divide for the Mississippi River to the west and the Spoon River to the east. Drainage in the immediate vicinity of Roseville is to the east and northeast via Horse Branch, Town Branch, Negro Creek, and Little Negro Creek, to Swan and Cedar Creeks, and eventually to the south-flowing Spoon River 25 miles to the east.

The uppermost bedrock lithologies in the Roseville area are predominantly shales with thin limestone, sandstone, and coal of the Pennsylvanian Spoon and Carbondale Formations, underlain by the Burlington and Keokuk Limestones of Lower Valmeyeran (Mississippian) age. Bedrock outcrops are common along stream beds, and have been mapped by Horberg (1950) and Piskin and Bergstrom (1975) in the west half of Section 30, T 9N, R 2W, and 1 to 1½ miles northeast of town. A small, narrow (less than 1/2 mile in width) buried bedrock valley extends into the northern portion of the study area, in portions of Sections 17, 18, and 20, T 9N, R 2W. This small valley is a tributary to an east-west trending ancient buried bedrock valley approximately 6 to 7 miles north of town, which was in turn a tributary to the ancient Mississippi River. Elevation of the bedrock surface ranges from 630 feet above msl in the buried bedrock valley north and northeast of town in the vicinity of Horse Branch and Negro Creek, to a little more than 700 feet above msl just southwest of town (see p. 32). Numerous water wells have been completed in limestone of the Burlington and Keokuk Formations as well as some in the thinner limestone and sandstone of the overlying Pennsylvanian formations.

Roseville lies on the early Illinoian (Liman) ground moraine of the Kellerville Till Member of the Glasford Formation. The glacial drift is composed of deposits of pre-Illinoian, Illinoian, and Wisconsinan age. These deposits are primarily silty till with a few discontinuous sand and gravel beds and windblown silt (loess). Drift thickness is commonly 25 feet but ranges up to a little more than 80 feet over the small, narrow bedrock valley in portions of Sections 17, 18, and 20, northeast of town. Thickness of the blanketing loess averages 8 to 10 feet. Sand and gravel deposits of the glacial drift are generally scattered and limited in extent (Wehrmann et al., 1980). Only two domestic wells, in Section 19, T 9N, R 2W, are known from water well logs to be completed in sand and gravel deposits besides Roseville's current municipal well system, which is developed in alluvial sand and gravel deposits located just west of town.

Roseville currently operates one horizontal well (Well 9), which roughly parallels the southern side of the intermittent stream in the northern half of Section 36, T 9N, R 2W, at the west edge of town. The well is actually approximately 1,400 feet of infiltration pipe that is gravel packed and buried 12 to 14 feet below ground. Discharge from the pipe is pumped into the distribution system by one of two 146 gal/min pumps (Wehrmann et al., 1980). This well replaced a system of eight shallow, large-diameter wells, just to the north, completed in the same alluvial sand and gravel aquifer. Thickness of the aquifer, as determined from the eight former municipal wells, ranges from 9 to 45 feet and water is obtained from an average depth of 14½ feet (Wehrmann et al., 1980).

Pumpage of the Roseville municipal well system averaged 135,000 gal/day in 1980 (Michael Broten, 1984, personal communication). The Division of Water Resources previously estimated that water demand in Roseville by the year 2,000 would be 131,000 gal/day. Taking into consideration recent population trends, it is likely that future demand will continue to exceed the current average demand of 135,000 gal/day. On the basis of typical rates of recharge to shallow sand and gravel aquifers, the total sustained yield of the Roseville well field is thought to be at or near the current withdrawal of 135,000 gal/day (Wehrmann et al., 1980). Significant reductions in yield can be expected during periods of prolonged drought because the sand and gravel deposits are shallow. Therefore, additional water resources may be necessary to meet future water needs of the community.

Wehrmann et al. (1980) listed four alternatives if Roseville should need additional water resources: (1) lengthen the infiltration pipe of Well 9 (however, the system will still be limited and susceptible to drought); (2) drill an additional well in the old well field just north of the infiltration pipeline (but do not overpump the aquifer); (3) use an electrical earth resistivity (EER) survey to explore and possibly delineate the sand and gravel deposit located near the northeast corner of Section 19, T 9N, R 2W; and/or (4) drill one or more wells into the Burlington and Keokuk Limestones and/or St. Peter Sandstone, making sure that the wells are properly constructed and cased. During the summer of 1984 (see p. 32), 38 vertical electrical sounding (VES) profiles were located northwest, north, and northeast of Roseville (the third alternative).

Interpretation of the resistivity data consisted of construction, examination, and inversion (according to the inversion technique of Zohdy, 1973) of VES curves for all VES profiles. The inversion technique provides layering parameters ("true" resistivities and thicknesses) for the sediments below the center stake of the corresponding VES profile. Three lines of VES profiles (AA', BB', and CC') illustrate the layering parameters associated with the areas of most favorable resistivity values.

Line AA' of VES profiles (fig. 18) extends roughly north-south from the southwest corner of Section 17, through the northwest and northeast quarters of Sections 20 and 19, respectively. This line of profiles traverses the area specifically recommended by Wehrmann et al. (1980), where at least one well is known to be completed in 9 feet of sand and 2 feet of gravel at a depth of 60 to 71 feet. This

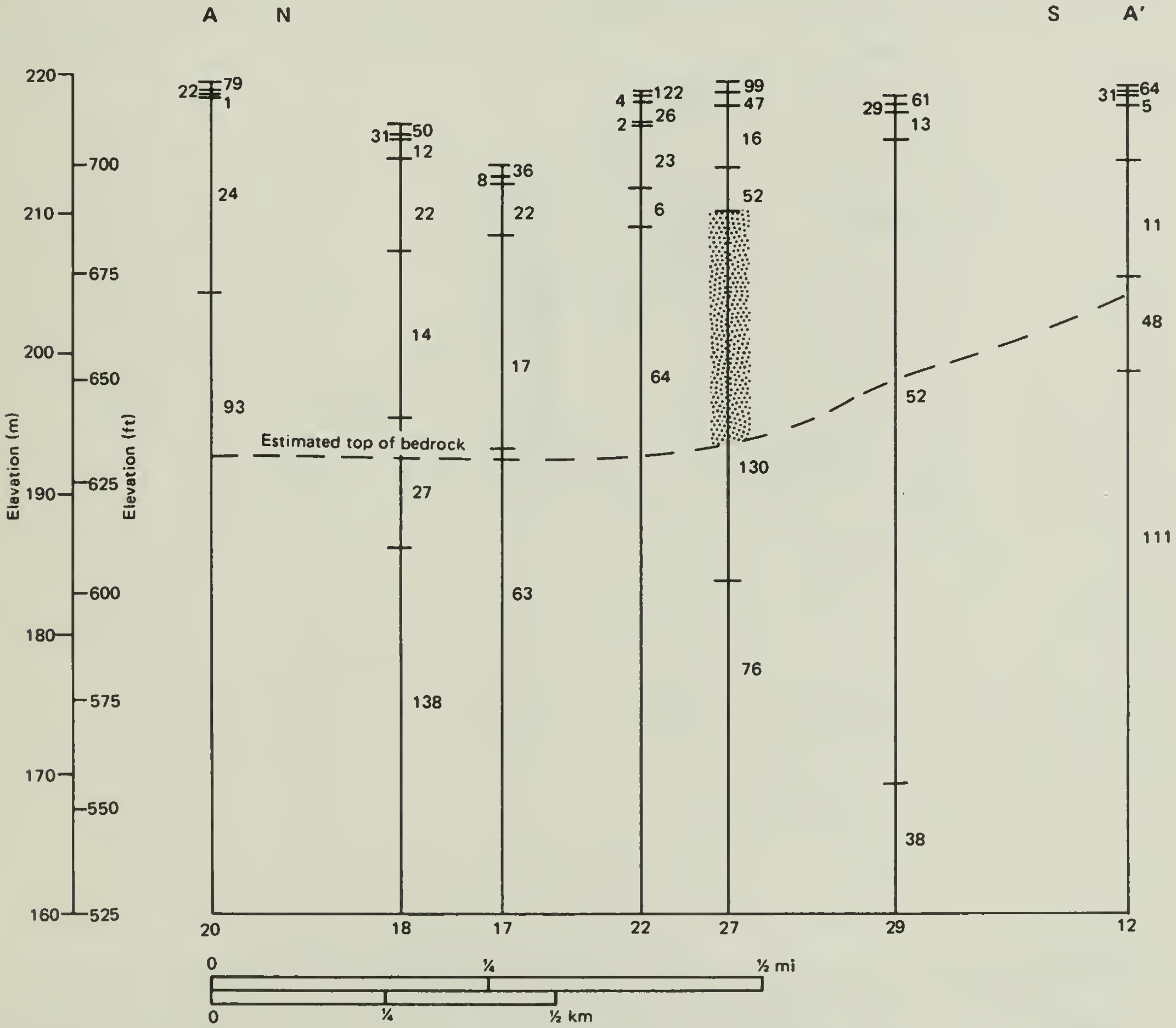


Figure 18. Layering parameters ("true" resistivities and thicknesses) along line A-A', Roseville study area. "True" resistivity values are in ohm-meters.

well is located in the vicinity of VES profile 17. "True" resistivity values at profile 17 are low for the interval above the estimated bedrock surface. The resistivity of the sand and gravel deposit, if present at profile 17, is apparently not significantly different from that of the calculated 63 ohm-meter resistivity layer that encompasses the entire shallow bedrock interval. A similar situation may exist at the locations of profiles 20 and 22. The most favorable location for a possible test-drilling site along AA' appears to be at profile 27, where an interval that spans the estimated position of the bedrock surface has a calculated resistivity value of 130 ohm-meters. Test drilling would be necessary to determine whether the high resistivity value was due to sand and gravel, and whether that sand and gravel deposit might be continuous with the sand and gravel deposit near profile 17.

The east-west line of VES profile BB' (fig. 19) is roughly 1 mile northwest of Roseville along the north line of Section 25 and northwest corner of Section 30, T 9N, R 2-3W. Estimated drift thickness at all profile locations except profile 38 is less than 40 feet. Resistivity values at profiles 33 and 35 suggest the presence of very sandy till or sand and gravel (60 to 90 ohm-meters). If present, the sand and gravel does not appear to be continuous

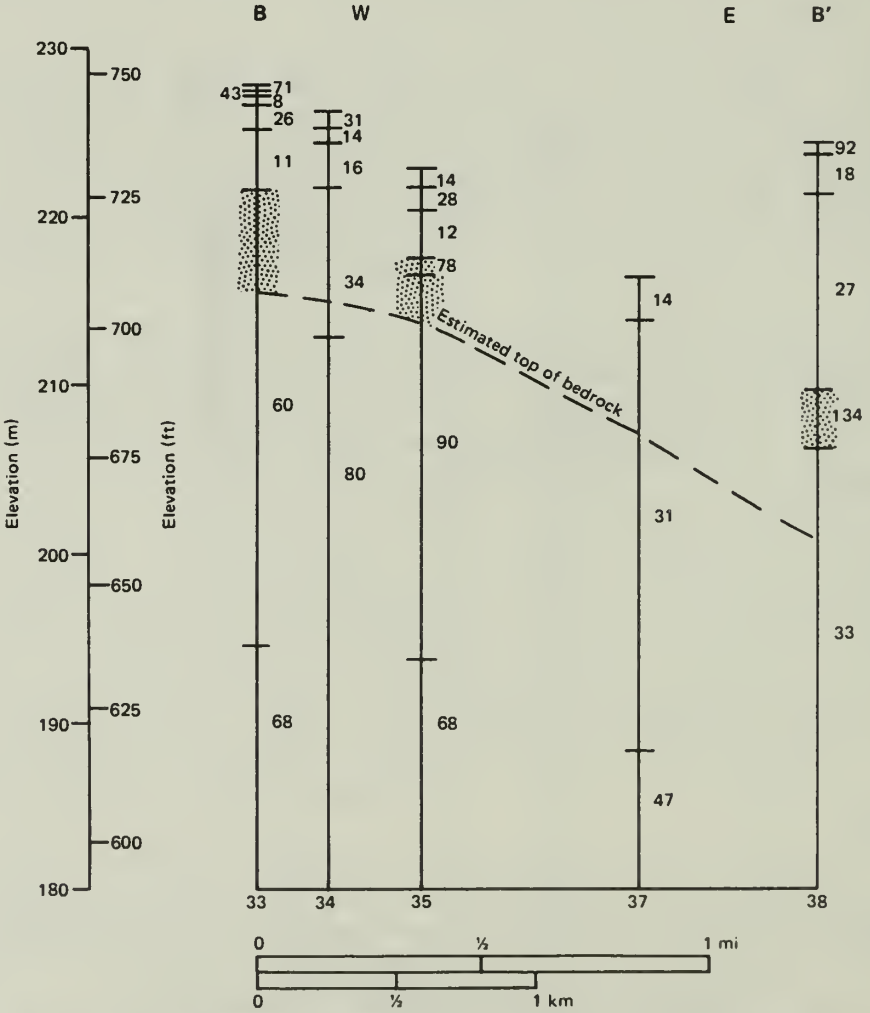


Figure 19. Layering parameters ("true" resistivities and thicknesses) along line B-B', Roseville study area. "True" resistivity values are in ohm-meters.

between the two profiles because resistivity values above the estimated bedrock surface at profile 34 are low (34 ohm-meters or less). The calculated high resistivity layers at profiles 33 and 35 are thin above the estimated bedrock surface. The thinness of the layers and their shallow depths (less than 40 ft) would make any sand and gravel deposit present in those intervals very sensitive to drought. Estimated drift thickness at VES profile 38 of line BB' is 75 feet. The calculated resistivity layer of 134 ohm-meters at profile 38 is the most favorable indication of a sand and gravel deposit along BB'. Test drilling would be necessary to confirm the presence of the sand and gravel deposit, its possible continuity, and the elevation of the bedrock surface.

The third line of VES profiles, CC' (fig. 20), trends east-west through the center of the east half of Section 26 and the center of the west half of Section 25, T 9N, R 3W. Calculated resistivity values for the interval above the bedrock surface along this line are generally low, 50 ohm-meters or less, except at profile 4. At VES profile 4, a calculated resistivity value of 60 ohm-meters spans the estimated position of the bedrock surface. A resistivity of 60 ohm-meters is at the low end of the range for sand and at the high end of the range for clay (fig. 4). Layering parameters at profile 4 may or may not indicate a possible sand and gravel deposit. Test drilling at this location is recommended only after the other recommended areas have been tested.

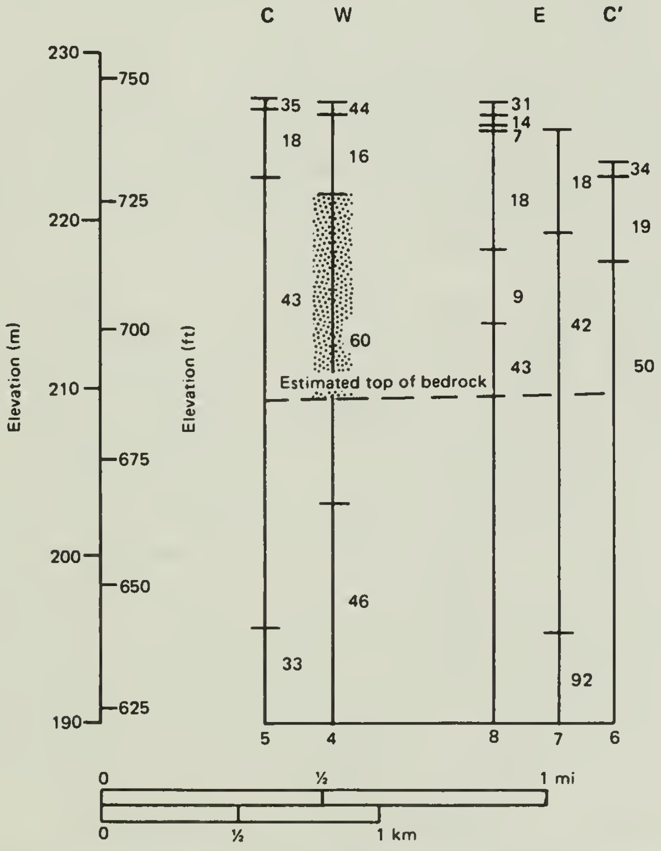


Figure 20. Layering parameters ("true" resistivities and thicknesses) along line C-C', Roseville study area. "True" resistivity values are in ohm-meters.

To summarize, test drilling will be necessary to confirm the presence and extent of the possible sand and gravel deposit at the location of profile 27 of line AA' and determine whether the deposit is continuous with the sand and gravel present near profile 17. The location of profile 27 is considered the most favorable as a possible test-drilling site. The location of VES profile 38 of line BB' may be considered as a secondary test-drilling location. Test drilling at the location of VES profile 4 of line CC' is only recommended after all other areas have been tested.

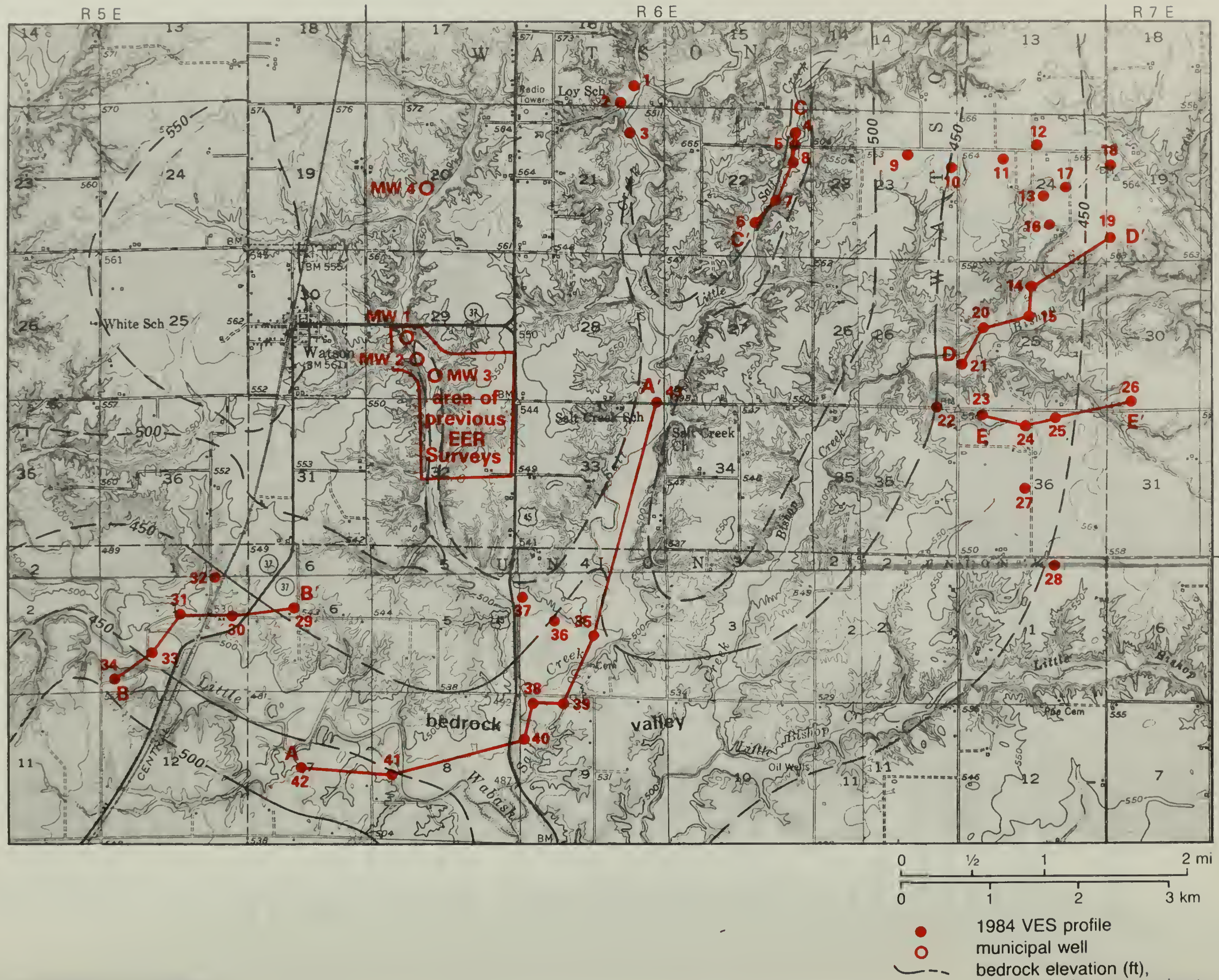
If supplemental water supplies become necessary, the other three alternatives listed by Wehrmann et al. (1980) may also be considered. Certainly, lengthening the infiltration pipe or drilling a new well in the old well field north of the infiltration pipe may be more economically feasible for the community than drilling a well into the Burlington and Keokuk Limestones or the St. Peter Sandstone or doing exploratory drilling for a new well field up to 2 miles from town. However, the last two alternatives are more likely to insure adequate water supplies during drought.

WATSON

The community of Watson (population 551) is in south-central Effingham County in Section 30, T 7N, R 6E (see p. 40). Watson experienced a rapid growth in population over the 1970-1980 census period; the population increased by nearly 100 percent. The population is projected to continue increasing by the year 2,000, although not at such a high rate. Water demand may be expected to increase proportionately.

Watson is in the east-central portion of the Springfield Plain of the Till Plains Section of the Central Lowland Province (fig. 1). It lies on the nearly flat glacial ground moraine of the Vandalia Till Member of the Glasford Formation which is Illinoian in age. Watson is located on a fairly level upland at an elevation of approximately 560 feet above mean sea level (msl). The upland area is dissected by numerous small streams. Surface elevations in the study area range from slightly more than 570 feet above msl on the uplands north and northeast of town to approximately 480 feet above msl in the major valleys of the Little Wabash River, Salt Creek, and Bishop Creek. Drainage in the vicinity of Watson is predominantly east to a north-south trending tributary to Salt Creek. This tributary joins Salt Creek about 1 mile north of its confluence with the Little Wabash River approximately 2½ miles south of town. One-half mile west of town drainage is south and west to the Little Wabash River which is 2 miles west of town in that direction.

The uppermost bedrock in the Watson area consists predominantly of non-water-yielding shales with some sandstones and thin limestones and coals of the early Pennsylvanian Mattoon Formation. General thickness of the Mattoon Formation ranges from 100 feet in northwestern Effingham County to a little more than 500 feet at the eastern edge of the county; average thickness in the vicinity of Watson is between 300 and 400 feet (Willman et al., 1975). Water from bedrock formations below a depth of 200 to 300 feet is generally too mineralized for most uses. A few domestic water wells, primarily west and south of Watson, have been completed in sandstone of the shallow bedrock. Yields are usually 5 gal/min or less, so the shallow bedrock cannot be considered as a possible source of moderate to large municipal supplies of groundwater in this area. Elevation of the bedrock surface is between 500 and 550 feet above msl in the area of Watson (see p. 40). In two nearby bedrock valleys, elevation of the bedrock surface may be slightly less than 450 feet above msl. One valley, approximately 1½ miles south-southeast of town, is a roughly east-west trending ancient tributary of the Little Wabash Bedrock Valley, located 4½ to 5 miles east of town. Bedrock outcrops are frequent in the area halfway between Watson and the buried Little Wabash Bedrock Valley.



WATSON STUDY AREA

Components of the glacial drift in the study area include clayey till, sandy till with sand and gravel, sand and gravel outwash and alluvium, and water-laid and windblown silt (loess). The glacial deposits are pre-Illinoian, Illinoian, and Wisconsinan. Thickness of the drift varies from less than 25 feet in the north to more than 160 feet over the buried Little Wabash Bedrock Valley to the east. Thickness of the blanketing loess averages from 2 to 4 feet. Nearly all water wells in the study area are completed in sand and gravel deposits of the glacial drift. Reported yields vary from 1 to 40 gal/min. In general, greater yields are obtained from wells completed in alluvial sands and gravels. Other sand and gravel deposits of the drift tend to be more discontinuous and too variable in thickness and position within the drift to make them easy to find or delineate (Wehrmann et al., 1980).

Watson currently operates four municipal wells completed in alluvial sand and gravel of the north-south trending Salt Creek tributary just east of town (p. 40). Municipal Wells 1, 2, and 3 are in the stream valley in the south half of Section 29 and Well 4 is located near the center of Section 20, T 7N, R 6E. Depths of the wells are 28, 34, 50, and 65 feet, respectively, and thicknesses of the aquifer tapped are, in order, 9, 7, 20, and 35 feet (Wehrmann et al., 1980). Reported yields range from 15 to 40 gal/min. Completion details for Wells 1 and 2 are given in Wehrmann et al. (1980). Wells 3 and 4 have been completed since that report. Well 3 was added in September 1980 (Michael Broten, 1984, personal communication), and Well 4 was added in June 1984. It is currently unknown whether either of the two original wells has been retired from the municipal well system. In 1980, the estimated total sustained yield of the original two-well system was 50,000 gal/day (Wehrmann et al., 1980). The current average daily demand in 1981 was 31,000 gal/day (Michael Broten, 1984, personal communication). Peak summer demands may be difficult to meet if yields of the shallow sand and gravel aquifers are significantly reduced because of drought conditions. Although the addition of Wells 3 and 4 may have helped alleviate this problem, additional water supplies may be needed if the population continues to increase.

Should additional water supplies be needed, Wehrmann et al. (1980) offered four alternatives for consideration: (1) test drill at the locations recommended in a 1978 EER survey (location 27 of Section 29 and locations 47 and 57 of Section 32, T 7N, R 6E (figure 79, Wehrmann et al., 1980); (2) explore the valley flats of the Little Wabash River upstream and downstream of the heavily drilled area in Sections 1 and 12, T 6N, R 5E, and Section 7, T 6N, R 6E; (3) explore the valley flats of Salt Creek east and southeast of town; and/or (4) explore the Little Wabash buried bedrock valley 4½ to 5 miles east of town. Accordingly, 43 vertical electrical sounding (VES) profiles were located in those areas during an EER survey conducted in the summer of 1984. The distribution of these profiles, the area covered by previous EER surveys, and the locations of the municipal wells are shown on page 40.

VES data were evaluated qualitatively and quantitatively. Qualitative interpretation of the data included construction and examination of the VES curves in conjunction with well log data. The inversion technique of Zohdy (1973) was used in quantitative evaluation of the VES data. Inversion of a VES curve provides layering parameters ("true" resistivities and thicknesses) for the sediments below the center stake of the corresponding VES profile.

Five lines of VES profiles, AA', BB', CC', DD', and EE' (p. 40), illustrate the calculated layering parameters associated with portions of the areas recommended by Wehrmann et al. (1980).

Line AA' of VES profiles (fig. 21) trends roughly southwest-northeast from the center of Section 7 to the northwest corner of Section 9, T 6N, R 6E, and then to the southeast corner of Section 28, T 7N, R 6E. This line of profiles follows a portion of the Little Wabash River valley to its confluence with Salt Creek and trends north along a portion of the Salt Creek valley, an area recommended by Wehrmann et al. (1980). High resistivity values of calculated layers above or spanning the estimated position of the bedrock surface (shown as a stipple pattern) are generally favorable

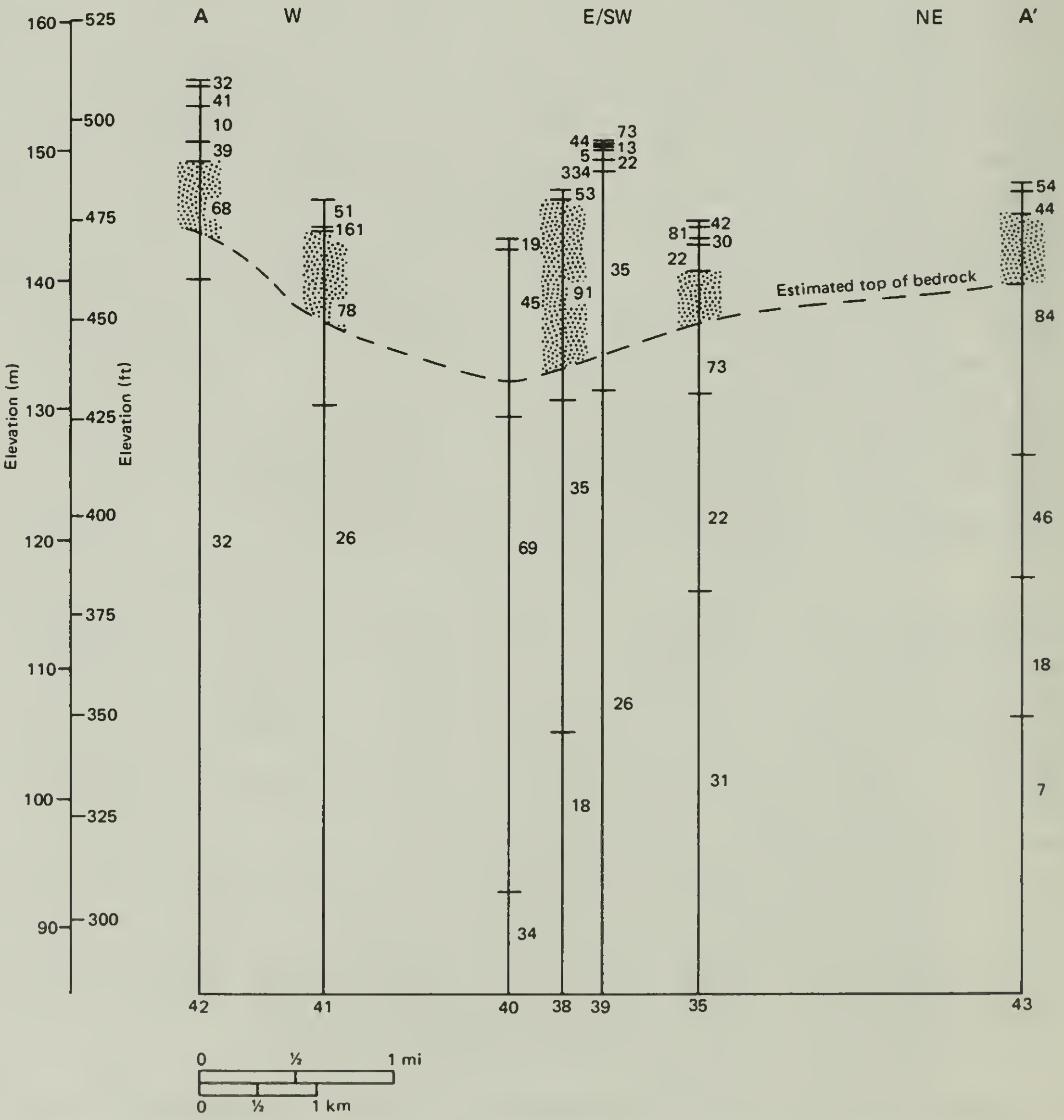


Figure 21. Layering parameters ("true" resistivities and thicknesses) along line A-A', Watson study area. "True" resistivity values are in ohm-meters.

indicators of the presence of sand and gravel deposits along this line of profiles. The possible sand and gravel deposits appear to occur at depths of 50 feet or less depths comparable to those of the current municipal wells. The thin, extremely high "true" resistivity layer at VES profile 39 (334 ohm-meters) most likely reflects the presence of a very dry sand lens. The location of VES profile 38 near the confluence of Salt Creek and its unnamed tributary which flows south just east of Watson is considered the most favorable site for possible future test drilling.

A second line of profiles, BB' (fig. 22), crosses a portion of the Little Wabash River valley from the southwest corner of Section 1, T 6N, R 5E, to the upland area on the north side of the river in the northwest quarter of Section 6, T 6N, R 6E. The stipple pattern shown on figure 22 highlights the depth ranges of the most favorable resistivity layers. The relatively thin, shallow, high-resistivity intervals of VES profiles 33 and 34 may represent sand and gravel deposits or sandy till. The values border those of sand and clay. If the values do represent sand and gravel, the deposits would be too thin, shallow, and too sensitive to drought conditions to support municipal wells. The locations of VES profiles 31 (74 ohm-meters) and 29 (109 ohm-meters) are considered more favorable as possible test drilling sites. There is a possibility that the high "true" resistivity value of 109 ohm-meters at profile 29 may result from the influence of sandstone near the bedrock surface.

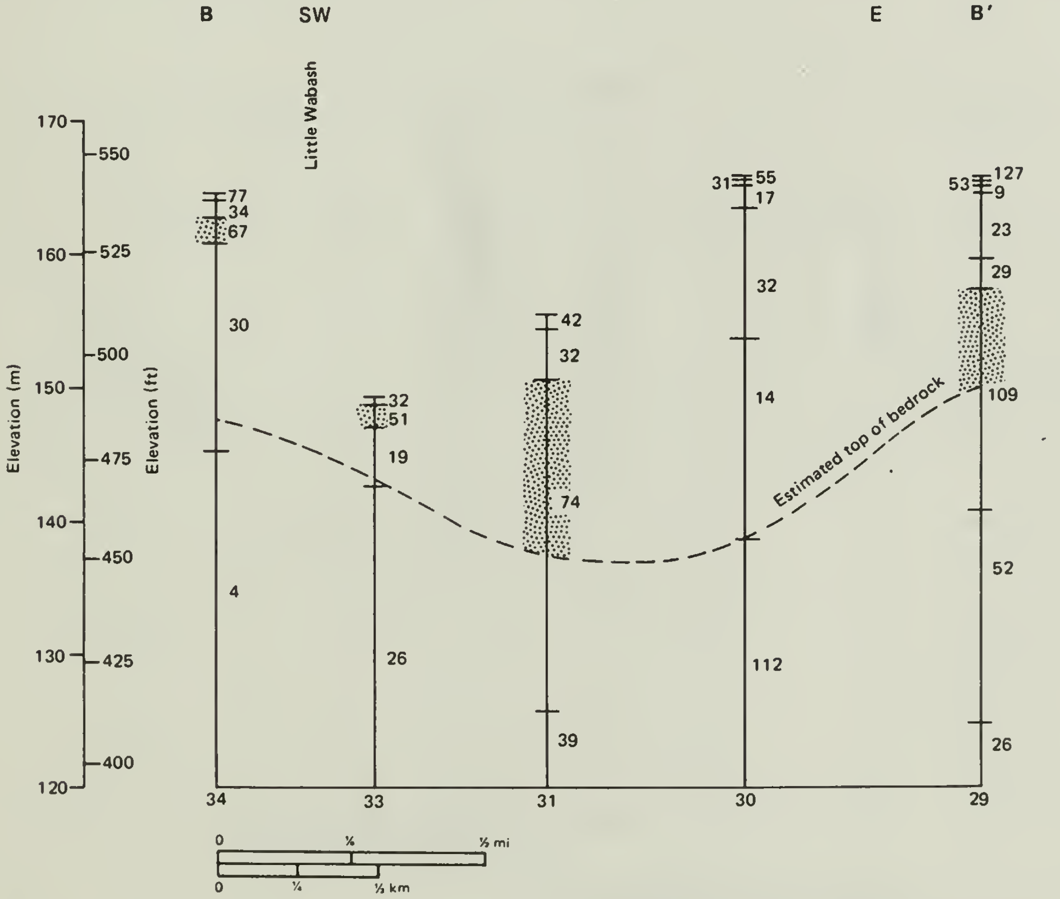


Figure 22. Layering parameters ("true" resistivities and thicknesses) along line B-B′, Watson study area. "True" resistivity values are in ohm-meters.

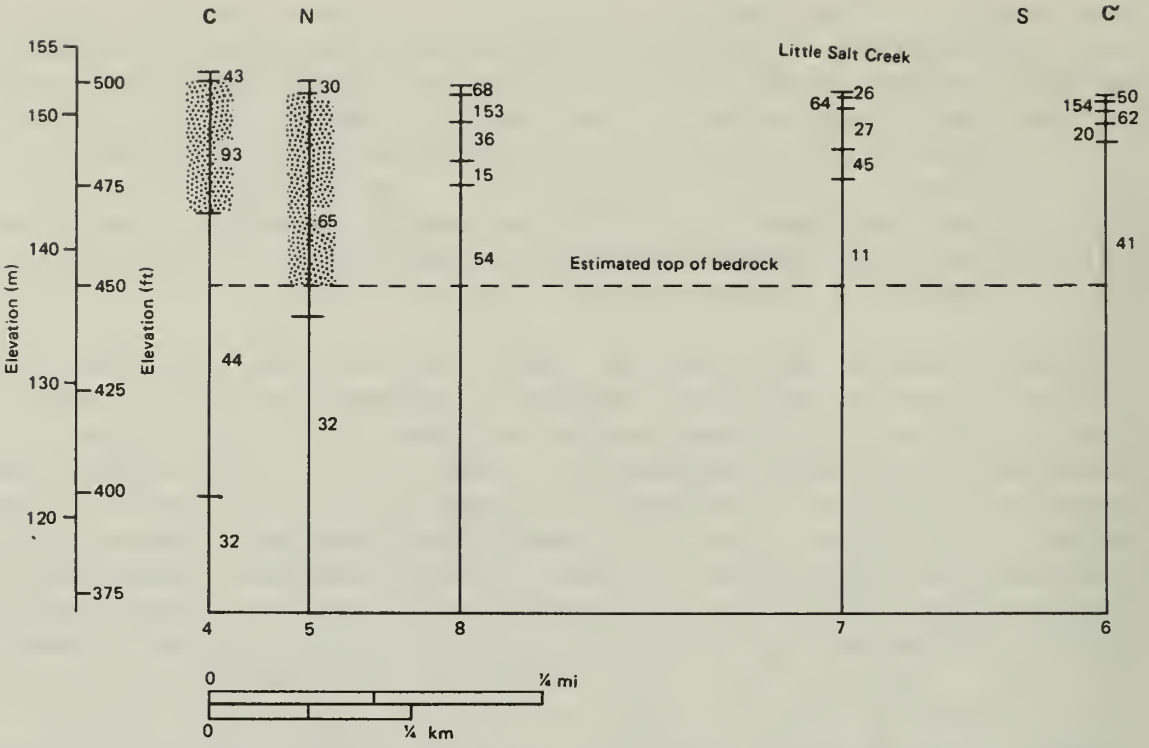


Figure 23. Layering parameters ("true" resistivities and thicknesses) along line C-C′, Watson study area. "True" resistivity values are in ohm-meters.

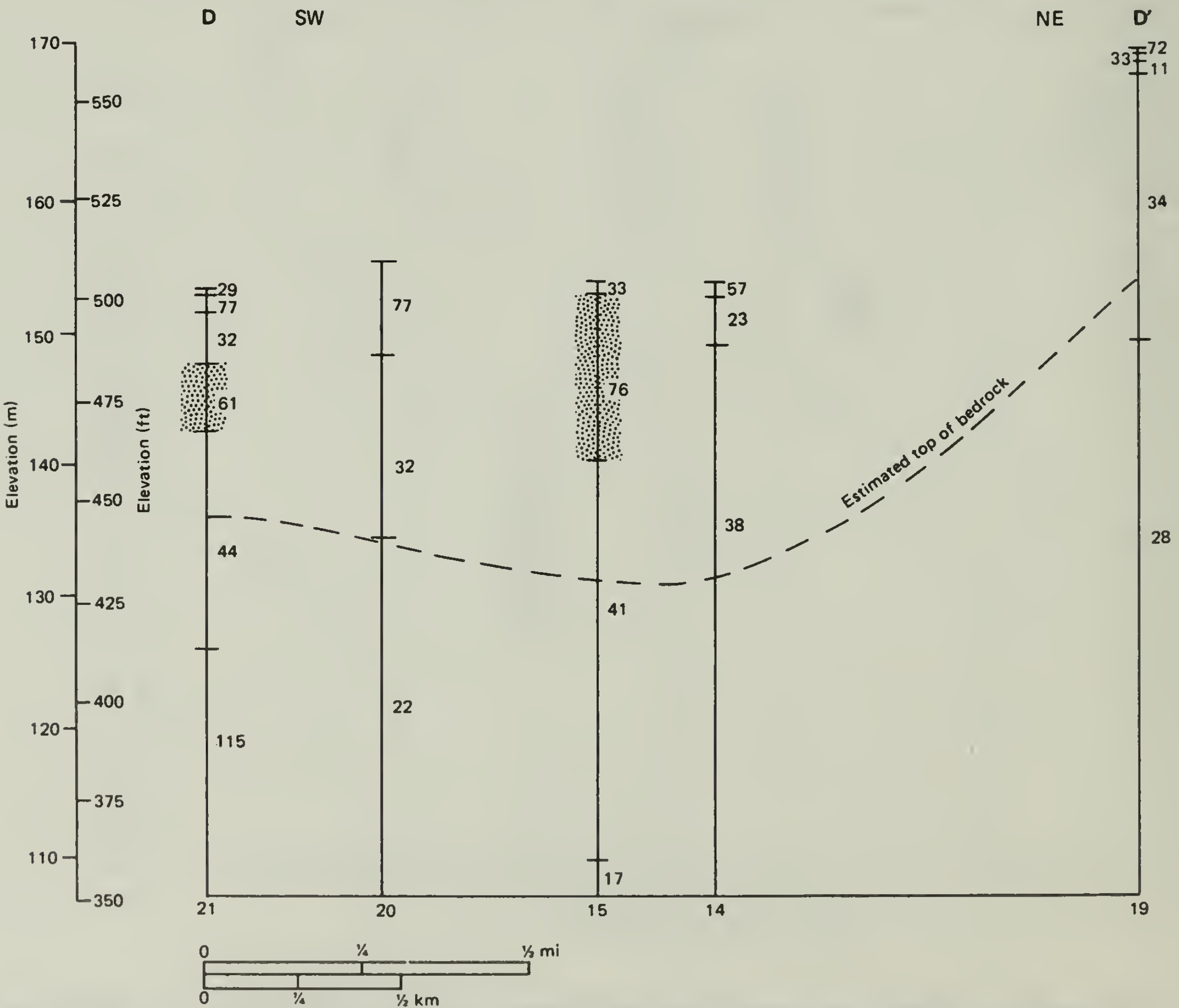


Figure 24. Layering parameters ("true" resistivities and thicknesses) along line D-D′, Watson study area. "True" resistivity values are in ohm-meters.

North-south line CC' of VES profiles (fig. 23) is located along the valley of Little Salt Creek in the east half of Section 22, T 7N, R 6E. Twelve feet of sand and gravel have been reported in a well near the north end of CC'. The high "true" resistivity values of VES profile 4 (93 ohm-meters), and to a lesser extent profile 5 (65 ohm-meters), support possible continuity of the deposit slightly to the south. Calculated resistivity values of VES profiles 6, 7, and 8 are generally indicative of till or sandy till. The location of VES profile 4 is considered the most favorable as a possible test drilling site along this line of profiles.

Lines DD' and EE' of VES profiles (figs. 24 and 25) traverse the estimated location of the buried Little Wabash Bedrock Valley. Line DD' trends northeast-southwest from the southwest quarter of Section 26, T 7N, R 6E, to the southwest corner of Section 19, T 7N, R 7E. East-west line EE' is just south of DD', roughly paralleling the north line of Section 36, T 7N, R 6E. Calculated resistivity values of VES profiles along DD' and EE' are in general lower than AA', BB', and CC'. High "true" resistivity values of profiles from both lines are at the low end of the range for sands and gravels and at the high end of the range for clays (fig. 4). Sand and gravel deposits may be present, but the values are more indicative of sandy till. Depth ranges of the most favorable resistivity values are shown as a stipple pattern on figures 24 and 25. VES profile 15 is considered the most favorable location along DD'; VES profile 25 is the most favorable location for test drilling along EE'.

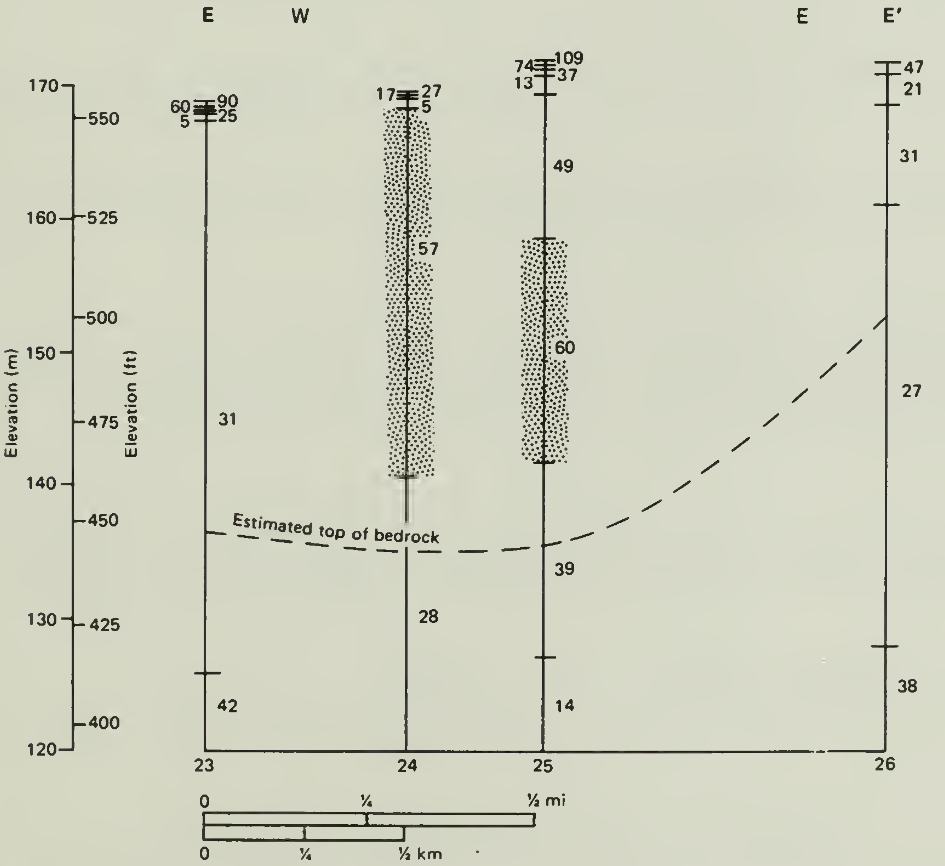


Figure 25. Layering parameters ("true" resistivities and thicknesses) along line E-E', Watson study area. "True" resistivity values are in ohm-meters.

To summarize, the potential is good for developing additional municipal water supplies for the community of Watson from alluvial sand and gravel deposits of the Little Wabash River, and Salt Creek and its tributaries. Because the deposits tend to be discontinuous and their water-yielding characteristics vary laterally, test drilling is necessary prior to siting new municipal wells. Although sand and gravel deposits exist in association with the Little Wabash Bedrock Valley 4½ to 5 miles east of town, development of a municipal well system in that area would require an extensive exploration program as well as several miles of pipeline. Such a program is not economically feasible or reasonable for this small community, given the favorable groundwater conditions of the river, creek, and stream valleys closer to town. It is likely that Watson will prefer to continue developing sand and gravel deposits of the unnamed Salt Creek tributary just east of town as long as possible. In the event that exploration a greater distance from the community becomes more desirable, the location of VES profile 38, near the confluence of Salt Creek and its unnamed tributary in Section 9, T 6N, R 6E, is recommended as the most favorable test drilling site based on the results of this study.

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