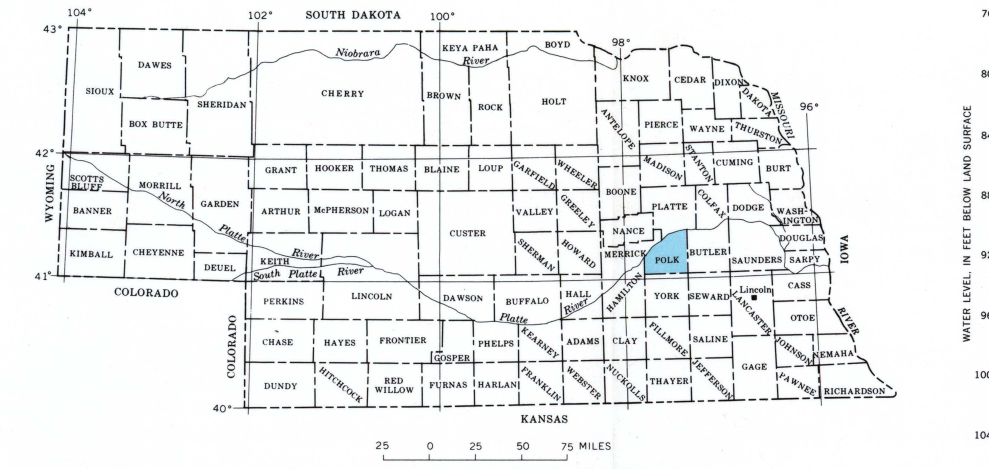
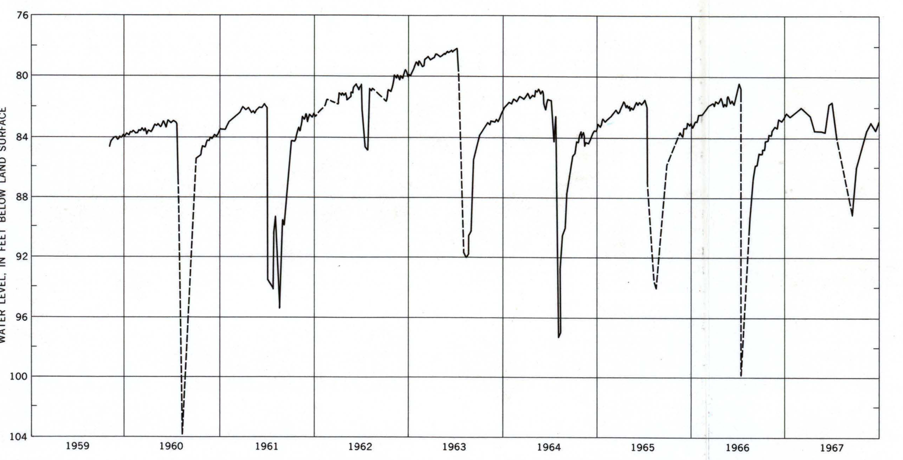
PREPARED IN COOPERATION WITH THE
CONSERVATION AND SURVEY DIVISION
OF THE UNIVERSITY OF NEBRASKA



INDEX MAP SHOWING LOCATION OF POLK COUNTY



HYDROGRAPH OF WELL AT OSCEOLA, NEBRASKA

Introduction.—This report was prepared to describe the ground-water conditions in Polk County in east-central Nebraska and to indicate some of the effects of withdrawals of ground water for irrigation. The study is part of a long-term cooperative program of ground-water investigations begun in 1930 by the U.S. Geological Survey and the Conservation and Survey Division of the University of Nebraska.

Polk County, an area of 430 square miles, is situated in the east-central part of Nebraska. (See index map.) Topographically, Polk County comprises two distinct areas. The southern two-thirds of the county is an eastward-sloping, smoothly rolling upland plain. Although the Big Blue River and several of its tributaries have incised valleys below this surface to a depth of as much as 75 feet, about a third of the upland plain drains to depressions having no outlet to a stream. The northern third of the county is mostly 125 to 150 feet lower than the upland plain and consists of the present flood plain on the south side of the Platte River, remnants of earlier flood plains at higher levels, and the steep slope rising to the north border of the upland plain; this lowland widens from less than 1 mile at the Hamilton County line to about 6 miles at the Butler County line. As several streams tributary to the Platte River have cut ravines into the north border of the upland plain and thus drain small parts of that surface, the topographic divide separating the Big Blue and Platte drainage basins lies south—from a fraction of a mile to as much as 4 miles—of the north border of the upland plain. The average eastward slope of the upland plain is about 5.2 feet per mile and the average northeastward slope of the Platte River flood plain is about 6.4 feet per mile. The altitude of the highest point on the upland (SE¼ sec. 31, T. 14 N., R. 4 W.) is about 1,781 feet and of the lowest point on the Platte River flood plain about 1,444 feet; thus the maximum topographic relief within the county is 337 feet.

The economy of the county is based almost wholly on agriculture. Crops—principally sorghum, corn, and wheat—are grown on 70 percent of the area and much of the remainder is used as pasture. About 3,000 acres of the more steeply sloping land has been terraced to retard runoff and to increase its capacity for crop production. In 1967, about 65,000 acres, or 34 percent of the land in crops, was irrigated with water pumped from 883 wells. As much of the land that is dry farmed or used for pasture is classed as irrigable, the number of irrigation wells is likely to increase. Water for all purposes is derived from ground water, but except for irrigation water use is very small.

Climate.—Annual additions to ground-water storage and annual withdrawals from storage are both related to variations in climate from season to season and from year to year. For example, a prolonged rainy period when vegetation is dormant and the ground unfrozen may result in large quantities of water infiltrating to the zone of saturation, whereas an equally long rainy period during the growing season or when the ground is frozen may result in little or no water being added to storage. For another example, well-distributed and ample precipitation during the growing season obviates the necessity for irrigation and thus greatly reduces withdrawals from storage whereas poorly distributed or scanty precipitation during the growing season results in large quantities of water being pumped for application to crops.

According to ESSA-Weather Bureau, normal annual precipitation at Osceola, near the center of the county, is 24.35 inches. However, within the period of record, annual precipitation has ranged from as little as 13.21 inches (1936) to as much as 41.89 inches (1903). For crop production on nonirrigated land, the total quantity of annual precipitation is less important than distribution of precipitation during the spring and summer. High yields have been obtained in some years of normal or less-than-normal precipitation because rain fell at propitious times during the growing season; conversely, low yields have characterized some years of above-normal precipitation because the root zone contained too little or too much moisture at crucial stages of plant growth. Summer precipitation usually occurs as local thundershowers rather than as a widespread rain and only rarely is so well distributed in time that yields from nonirrigated crops such as sorghum and corn are as great as from irrigated. That growing-season precipitation ordinarily is not dependable is borne out by data compiled by the State-Federal Division of Agricultural Statistics for 1962–66. During that 5-year period, per-acre yields from irrigated sorghum and corn were, respectively, 22 to 64 and 56 to 140 percent greater than those from nonirrigated sorghum and corn.

The mean annual temperature at Osceola is 50.8° F. Afternoon temperatures in summer exceed 90° F. on an average of 45 days and early morning temperatures in winter are below freezing on an average of 145 days. At times, hot winds are very damaging to crops. Similarly, extremely low temperatures coupled with high winds can ruin winter wheat that is not protected by a snow cover.

Growing seasons range in length from about 135 to 185 days and average about 160 days. Occasionally, when soil conditions necessitate a delay in planting or the first freeze in the fall is unusually early, the season is too short for maturation of corn and sorghum.

How large a part of the precipitation is returned to the atmosphere through direct evaporation and through transpiration of vegetation, how large a part is added to ground-water storage, and how large a part runs off to streams is determined by a variety of climatic factors, by topography, and by man's attempts to promote infiltration and retard runoff. As none of these factors are measured directly, they can only be estimated.

During a year of near-normal precipitation, the volume of precipitation on the county is about 560,000 acre-feet. Of this amount about 375,000 acre-feet falls on the upland plain and about 185,000 falls on the Platte River lowland. The part returned to the atmosphere from the upland plain is estimated at 315,000 acre-feet (84 percent), the part added to ground-water storage at 45,000 acre-feet (12 percent), and the part of runoff to streams leaving the county at 15,000 acre-feet (4 percent). Disposal of precipitation on the Platte River lowland differs markedly. There, although possibly as much as 40,000 acre-feet (22 percent) may infiltrate to ground-water storage, the quantity returning to the atmosphere probably is nearly as great or possibly even greater than the quantity of precipitation on the lowland area. The seeming discrepancy is explained by the following: overland runoff to Clear Creek and the Platte River is almost negligible in an average year; water returning to the atmosphere is derived in large part from ground-water storage; the source of some of the ground water stored beneath the Platte River lowland is underflow from beneath the upland plain; and virtually all water leaving the area as streamflow is derived from ground-water storage.

During years of less-than-normal precipitation the amounts infiltrating to ground-water storage or leaving as streamflow generally would be less and, conversely, during years of more-than-normal precipitation the amounts generally would be greater than those indicated. However, various combinations of weather and soil conditions can affect the disposition of precipitation from individual storms so markedly that the proportionate parts annually returning to the atmosphere, infiltrating to ground-water storage, or running off to streams cannot be defined in other than general terms.

Soil infiltration characteristics.—The parent materials on which the soils of Polk County have developed are loess (wind-deposited silt), colluvium (slope-wash deposits), alluvium (stream deposits), and dune sand. The loess-derived soils are the most extensive, coinciding in extent with the upland plain; the other soil types are limited to the deeper valleys incised into the upland plain and to the Platte River lowland.

Because the upland is the oldest surface extant in the county, its soils have had a longer time to develop. Infiltrating precipitation has removed much of the clay fraction from the upper soil and concentrated it in the subsoil to the extent of forming a hardpan; it also has leached calcium carbonate from the upper soil and concentrated it in the more compact subsoil. Decomposition of prairie vegetation has added organic matter to the top 6–14 inches, changing the original light-brown or yellowish-brown loess to a dark brown or dark brownish gray. Classified as silty loam, the loess-derived soil ordinarily absorbs water readily. However, most of the absorbed water is retained by the soil and is returned to the atmosphere by evapotranspirative processes. Only when the retentive capacity of the soil is exceeded in precipitation likely to penetrate to depths where it will escape return to the atmosphere and thus eventually be added to ground-water storage.

Where the loessial soil has never been plowed it has a columnar structure and, on drying, the soil columns shrink and pull apart. The spaces between columns greatly increase the ease of penetration by water, remaining open until the soil columns become thoroughly moistened and swell to their original size. Now that most of the upland plain is under cultivation, a greater part of the precipitation probably is held in the soil zone and a smaller part reaches the zone of saturation than was the case before the columnar structure of the loess was destroyed.

Depressions on the upland surface are sites for accumulation of runoff from the surrounding slopes and must contain water for a time after heavy precipitation. The soil in such depressions generally is higher in organic matter and highly calcareous, and the subsoil generally is very compact. As the very compact subsoil beneath the depressions is virtually impervious to penetration of moisture, little or no water seeps downward from them.

Erosion along the drainageways that are incised into the upland plain has exposed the parent loess in several places where slopes are steep. Soils on the lower slopes and on the narrow terraces and bottomland within these drainageways are developed on colluvial and alluvial silts derived from the upland plain. These soils tend to be well watered by runoff from the adjacent slope and are drained by seepage into the stream channel.

Along the escarpment at the north border of the upland plain, the loess is being actively eroded by stream action. There, the loamy topsoil together with much of the lower soil profile has been removed and unweathered loess is within a few inches of the surface. Slopes along the escarpment are so steep that precipitation rapidly runs off affording little time to infiltrate the soil.

Ordinarily, material eroded from the upland margin by slope wash is transported only a short distance out onto the Platte River lowland before it comes to rest. Soils on such colluvial-alluvial deposits tend to be less loamy and to be less retentive of moisture than the upland soils, but they receive water that runs off the slopes, much of which soaks into these deposits. Under such conditions infiltration to ground-water storage is somewhat greater here than on the upland.

Other soils in the Platte River lowland have developed mostly on alluvial deposits but locally have developed on dune sand. These generally sandy soils range widely in loaminess. As the less loamy have little capacity to retain water, a comparatively high fraction of precipitation infiltrates to ground-water storage. Even the more loamy permit faster infiltration of precipitation than do the silty loams. On the average, the fraction of annual precipitation added to ground-water storage probably is 4–5 times greater in the Platte River lowland than on the upland plain.

Geologic conditions.—The available ground water in Polk County is stored in unconsolidated deposits that range in thickness from about 35 to a little more than 400 feet and rest on bedrock of Cretaceous age.

The general configuration of the bedrock surface on which the water-bearing deposits rest is known from logs of 31 test holes drilled along three north-south lines, from logs of 10 irrigation wells and 2 test holes for irrigation wells, and from observations at 2 gravel pits. As shown by the contour lines on the bedrock geologic map, the bedrock surface is characterized by eastward-trending valleys and ridges. The altitude of the highest known point on that surface is 1,514 feet (sec. 19, T. 14 N., R. 4 W.) and of the lowest point 1,249 feet (sec. 24, T. 13 N., R. 3 W.). A north-south relief of about 200 feet is indicated by the difference between the lowest and highest bedrock altitudes along the lines of test holes passing through the center of the county.

Two formations—the Carlile Shale and the Niobrara—are transected by the erosional surface on the bedrock. These Cretaceous rocks are nearly flat lying, having a west-northwestward dip of less than 10 feet per mile.

The unconsolidated sediments that are saturated are of Quaternary age and consist principally of ancient interbedded stream alluvium, deltaic deposits, and lakebed deposits of glacial till, and of wind-deposited silt. Of these, only the stream alluvium, deltaic deposits, and lakebed deposits underlie the entire county. Glacial till underlies an area of about 35 square miles near the center of the county, whereas wind-deposited silt, which generally is above the zone of saturation, underlies the entire upland plain but is not present beneath the Platte River lowland.

Derived mostly from sources to the west, the alluvium comprises deposits laid down during the Pleistocene age by a succession of streams whose transporting ability was decreased in this part of Nebraska by the damming effect of at least two continental ice sheets that expanded westward into the State. Possibly some of the alluvial sediment may have been deposited by melt water from glacial ice or by streams flowing southward along the glacial margin. The ice sheets presumably were bordered by lakes that were fed by streams from the west and by melt water from the ice. On entering these lakes, streams formed deltas and their finer sediment load settled to the bottom beyond the delta margin. In Polk County, the sequence of interbedded stream alluvium, deltaic deposits, and lakebeds that escaped later removal ranges from 35 to 200 feet beneath the Platte River lowland and from 150 to 350 feet beneath the upland (see geologic sections). The fraction that consists of sand or of sandy gravel ranges from about one-fourth to one-half or a little more. These coarser grained materials freely transmit water to wells whereas the finer grained deposits (fine-grained alluvium and lakebeds) hinder or even prevent transmission of water.

The glacial till underlying the central part of the county consists of scattered pebbles in a matrix of rock flour. Where penetrated in test drilling its maximum thickness is about 35 feet. It is both underlain and overlain by coarse-grained water-bearing material and is a barrier to vertical movement of the water.

The wind-deposited silt (loess) that overlies the other types of Quaternary deposits throughout the upland plain is 35 to 80 feet thick, and all water added to ground-water storage beneath the upland must filter through it. Some of the silt has washed down into and has been redeposited as alluvium in the valleys that are incised into the upland plain; some also has washed or slumped down onto the Platte River lowland where it now constitutes a band of alluvial and colluvial deposits along the lowland margin.

Availability and use of the ground water.—An estimated 5-5.5 million acre-feet of fresh water is stored in the Quaternary deposits underlying Polk County. This value was derived by determining, from the geologic sections, the average thickness of saturated material, multiplying that value by the area of the county, and dividing the result by 5 on the assumption that 1 cubic foot of saturated material contains 0.2 cubic foot of water. Under the natural conditions that prevailed before large withdrawals for irrigation began, the quantity in storage remained almost constant because the long-term natural additions to the supply were balanced by the long-term natural losses. Now, however, the quantity in storage is decreasing slowly because the natural additions plus infiltration of applied irrigation water are exceeded by the natural losses plus withdrawals for irrigation.

Part of the ground water in the Quaternary deposits occurs under water-table conditions and part under artesian conditions. Both conditions exist beneath most of the upland. The artesian conditions exist because the water in the lower sands and gravels is confined by a layer of fine-grained sediments. The water in the upper zones is under water-table conditions and, so far as could be determined, ground water beneath the Platte River lowland is mostly under water-table conditions.

The configuration of the water table, or upper surface of the water above the confining layer, and of the potentiometric surface of the confined water (that is, the imaginary surface defined by the static water level in wells that tap the confined ground water) are indicated by the contour lines on the water table-potentiometric surface map. Because ground water moves in the direction of the steepest hydraulic gradient—that is, downslope at right angles to the contour lines—the following can be inferred from the map: ground-water movement is generally eastward in the southern half of the county and northeastward in the northern half; ground water enters the county by underflow from Hamilton County on the west and northwestern York County on the south and leaves the county by underflow into Butler County on the east and northeastern York County on the south; some of the ground water beneath the Platte River lowland is derived by underflow from beneath the upland plain; the only discharge of ground water into a stream channel occurs near the confluence of Clear Creek with the south channel of the Platte River in the northeastern corner of the county. As the average natural rate of ground-water movement under the conditions existing in Polk County is only a few feet per day at best, the minimum time required for a molecule of water to travel the full width of the county is more than a century. The confined water moves even more slowly.

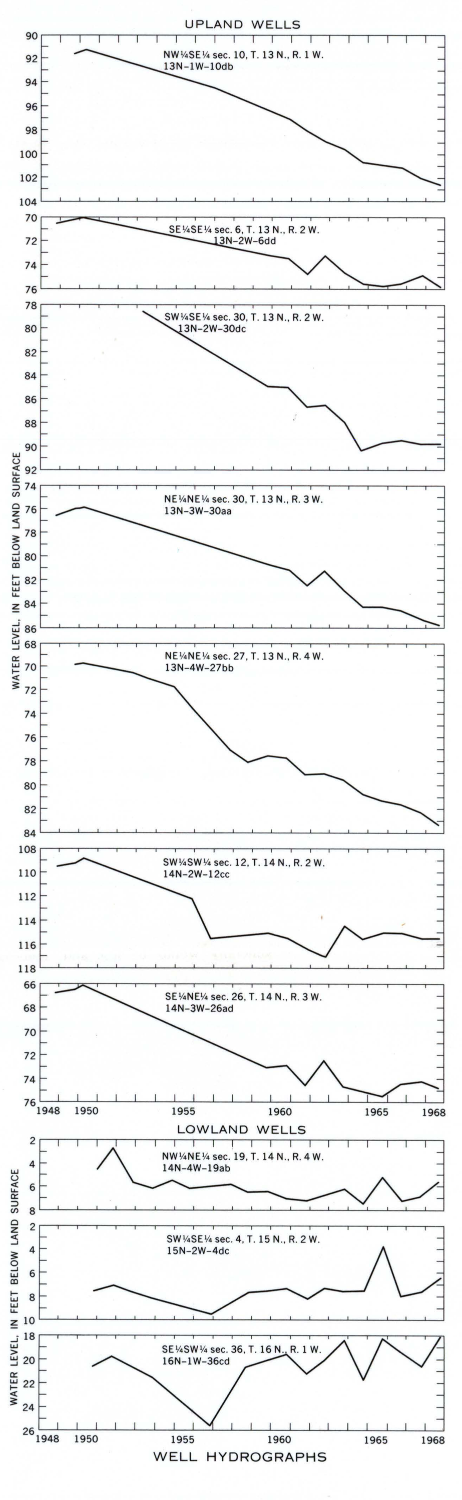
Pumping from irrigation wells that tap the confined water results in high initial and widespread reduction in artesian pressure. Thus simultaneous pumping from several wells in the same general area results in mutual interference and a greater water-level drawdown than would occur if the water occurred under water-table conditions. However, with cessation of pumping at the end of the irrigation season, water levels recover much more rapidly than they would if the water were unconfined.

The effect of pumping water that is under artesian pressure is illustrated by the hydrograph for a water-level observation well at Osceola. Although this observation well is more than a quarter of a mile from the nearest pumping for irrigation, the water level declines markedly in response to that pumping and recovers promptly when pumping stops. Such effects have caused considerable consternation to some irrigators because wells that were drilled and tested when most pumps are dormant yield less during the irrigation season when irrigation pumps are in use. A partial remedy to this problem would be to schedule pumping, so that wells less than 1,000 feet apart would not be pumped at the same time. Wells tapping unconfined water generally are not mutually interfering if more than 600 feet apart, as is now required by State law.

Because the water table is not parallel to the land surface, the depth to water ranges considerably from place to place in the county. Depths to water are least in the Platte River lowlands, ranging from less than 5 feet near the river to as much as 60 feet at the base of the slope between the lowland and upland. On the upland the depth to water generally ranges from 75 to 115 feet but is less than 60 feet where valleys are incised deep into the upland plain and is as much as 178 feet in a well 5 miles north and 1 mile west of Shelby.

Well yields greater than 1,000 gpm (gallons per minute) can be obtained throughout all but about 30 square miles, or 7 percent, of the county area. In about 70 percent of the county the water-level drawdown is less than 15 feet in wells yielding 1,000 gpm and in about 23 percent it is more than 15 but less than 40 feet. The largest yield recorded by Weakly (Smith and Weakly, 1968) when inventorying irrigation wells in 1966 was 1,800 gpm from well 13N-4W-26CCD and the drawdown at that rate of yield was 18 feet. Irrigation-well locations and possible well yields as related to transmissivities of the water-bearing sediments are shown on the ground-water availability map. The transmissivity of water-bearing material at any given location is equal to the product of the average coefficient of permeability and the thickness, in feet, of the material at that location. The coefficient of permeability is defined as the rate of flow, in gallons per day, through a cross-sectional area of 1 square foot under a hypothetical water-level slope of 1 foot per foot. Values for the coefficient of permeability were estimated from test-hole samples according to a method devised by E. C. Reed (Keech and Dreeszen, 1959) and from computations by E. C. Reed from yield and drawdown data on file in the office of the Conservation and Survey Division, University of Nebraska.

Withdrawals of ground water for irrigation began in 1936. Development proceeded at a slow pace until 1953 at which time a total of about 100 irrigation wells were in use. Then in the years 1954–57 a flurry of drilling activity resulted in an increase to about 600 wells. As of January 1, 1969, the number of irrigation wells had grown to 925. Other large-yield wells are those supplying the towns of Osceola, Polk, Shelby, and Stromsburg, but these total only 14.



WELL HYDROGRAPHS

Withdrawals for irrigation and public supply are slowly diminishing the quantity of water in storage beneath the upland area but are having virtually no effect on storage beneath the Platte River lowland. As shown by the hydrographs for 10 observation wells, the water level in each of the 7 located in the upland plain is lower in 1968 than at the beginning of the record; the maximum decline shown by the hydrographs for upland wells is 13 feet in 20 years. No significant water-level trends are indicated by the lowland wells.

The progressive decline of water levels beneath the upland area shows that withdrawals are not balanced by either an increase in the rate of additions to storage or a decrease in the rate of natural discharge from storage. Thus, the quantity of water in storage there is slowly being depleted. Large-scale pumping on the upland plain will become impossible first where the coarse-grained water-bearing sediments are the thinnest; that is, generally speaking, where the bedrock surface is highest. Currently, withdrawals in the Platte River lowland area are being balanced at least partly by a decrease in natural losses due to evapotranspiration. Moreover, opportunity for recharge may have increased somewhat because pumping now creates storage space which, under conditions of no pumping, would have been rejected because the aquifer was already filled to capacity.

The future rate of water-level decline beneath the upland plain will depend partly on climatic conditions and partly on the number of new irrigation wells installed. For example, growing-season droughts not only would prompt irrigators to pump more but also would persuade dryland farmers that development of supplemental water supplies is an economic necessity. On the other hand, years of nearly ideal growing conditions would obviate the necessity for irrigation and thereby discourage the installation of new wells. Probably the number of irrigation wells in the Platte River lowland could be doubled before any problem of overdevelopment would appear.

Chemical character of the ground water.—Water in the Quaternary deposits is of the calcium bicarbonate type (see water-quality map). It is suitable for irrigation and most industrial uses and for use by humans and livestock. Analytical results for samples from 7 irrigation and 2 public-supply wells are given in the accompanying table.

Criteria used in evaluating water for irrigation use include salinity hazard, sodium hazard, residual sodium carbonate, and boron hazard.

If moderate leaching occurs, there is no salinity hazard if the specific conductance of the water is less than 750 micromhos per centimeter. Conductance ranged from 379 to 723 micromhos in the 9 samples analyzed.

The sodium-adsorption-ratio (SAR), an index that expresses the relation of the concentration of sodium to the concentration of calcium and magnesium, is a measure of the sodium hazard. For water having a specific conductance of less than 750 micromhos, little or no hazard is present if the SAR is less than 5.0. As the maximum SAR value among the samples analyzed was 1.0, the ground water in Polk County has a very low sodium hazard.

"Black alkali" conditions are likely to develop if irrigation water contains too great an excess of bicarbonate over calcium and magnesium. Termed "residual sodium carbonate" (RSC), this excess generally should be less than 1.25 me/l (millequivalents per liter). The maximum RSC in the 9 samples analyzed was 0.27 me/l, or well below the recommended limit.

Although boron is an essential plant nutrient, it is toxic when present in excess of certain tolerance levels. For example, plants highly sensitive to boron have a tolerance level as low as 0.33 mg/l (milligrams per liter). As the maximum boron concentration in the 9 samples analyzed was 0.04 mg/l, use of ground water for irrigation in Polk County presents no boron hazard.

In addition to being bacterially safe, water for human consumption should not contain excessive amounts of harmful dissolved mineral substance. Standards pertaining to certain of these chemical constituents have been established by the U.S. Public Health Service for use in evaluating public supplies. Six of the analyzed samples met these standards, but one contained slightly more than the recommended standard for both iron (0.3 mg/l) and manganese (0.05 mg/l) and two others contained slightly more than the recommended level for manganese alone.

Hardness in water is caused principally by calcium and magnesium which contribute to scale formation in boilers and pipes and combine with soap to produce an insoluble curd. No limits for hardness have been established, but according to generally accepted standards 8 of the 9 samples would be described as very hard (>200 mg/l hardness) and 1 as hard (121–200 mg/l hardness).

Evaluation of the ground-water resource.—An estimated 5-5.5 million acre-feet of water is stored in the Quaternary deposits underlying Polk County. The immensity of this supply is appreciated better if it is compared to the estimated current average withdrawal rate of 52,000 acre-feet per year, about 1/100 of the stored water supply. According to data compiled by K. E. Logan for the years 1962–66 (State-Federal Division of Agricultural Statistics, 1964–68), water pumped from this supply for irrigation of 65,000 acres boosted the return from all crops in the county an average $2,550,000 per year, or nearly $40 per acre of irrigated land.

Recent studies by the Conservation and Survey Division and the Agricultural Extension Service of the University of Nebraska revealed that the total cost of pumping ground water for irrigation on the upland part of Seward County, Nebr., where hydrologic conditions are similar to those in upland part of Polk County, is about $20 per acre-foot (J. M. Jess, oral communication, March 1969). Costs of pumping for irrigation in lowland areas similar to the northern part of Polk County have not been evaluated but obviously are considerably less. If it is assumed that costs per acre-foot ranged from $10 to $20 in the county and that an average of 0.8 acre-foot of water was applied per acre of cropland, the cost of irrigating an acre ranged from $8 to $16. The direct benefits from irrigation then, may have been as much as $24 to $32 per acre of irrigated crops. If it is assumed further that about half the stored supply of ground water could be withdrawn before pumping costs increased excessively, the value of the county's ground-water resource in terms of increased crop yields at current crop prices is computed to be $65,000,000 to $92,000,000. Accretions to storage while depletion is in progress would, of course, add to that worth. So, too, would application of water to only those crops whose increases in yield have the greatest dollar values.

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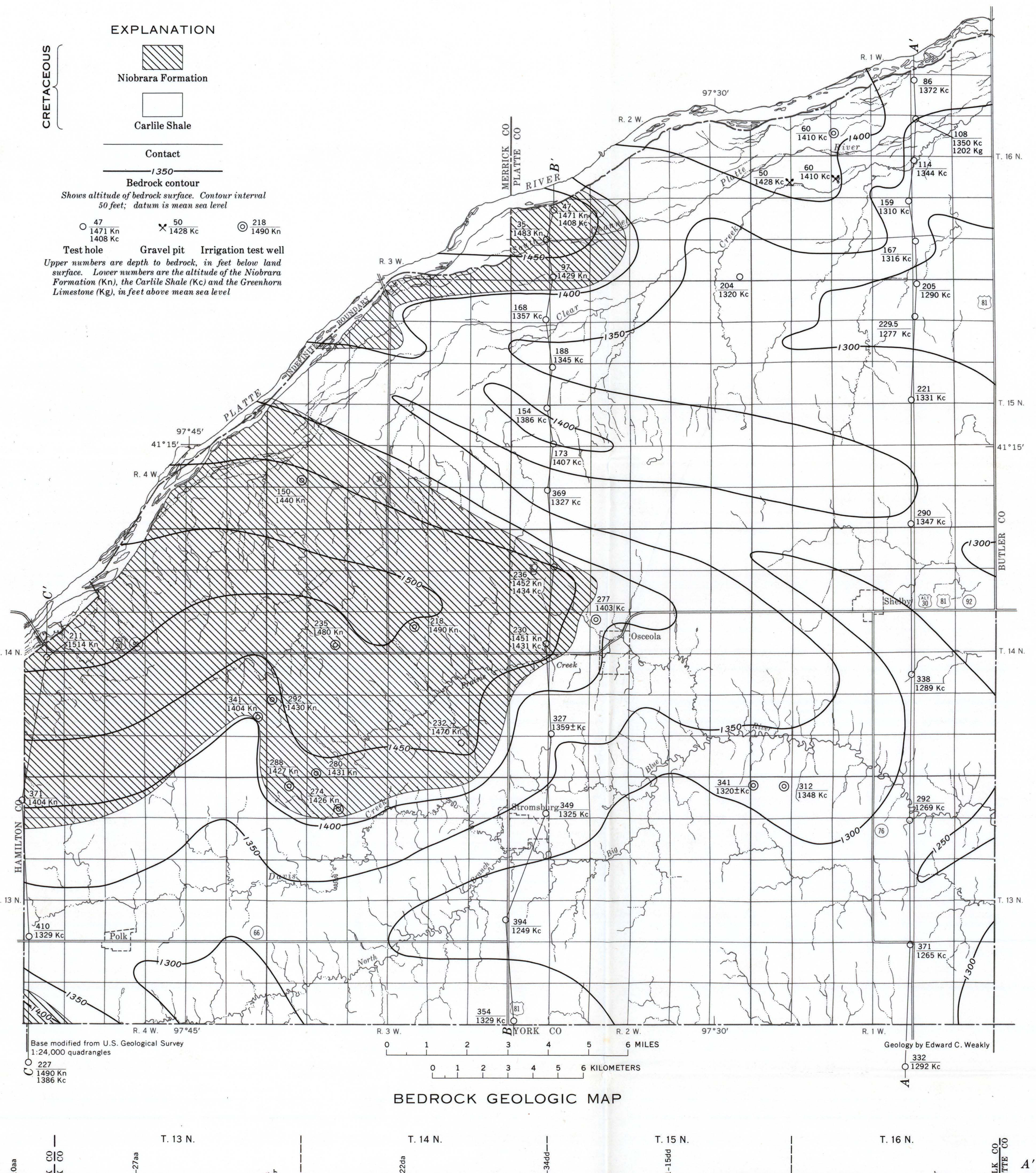
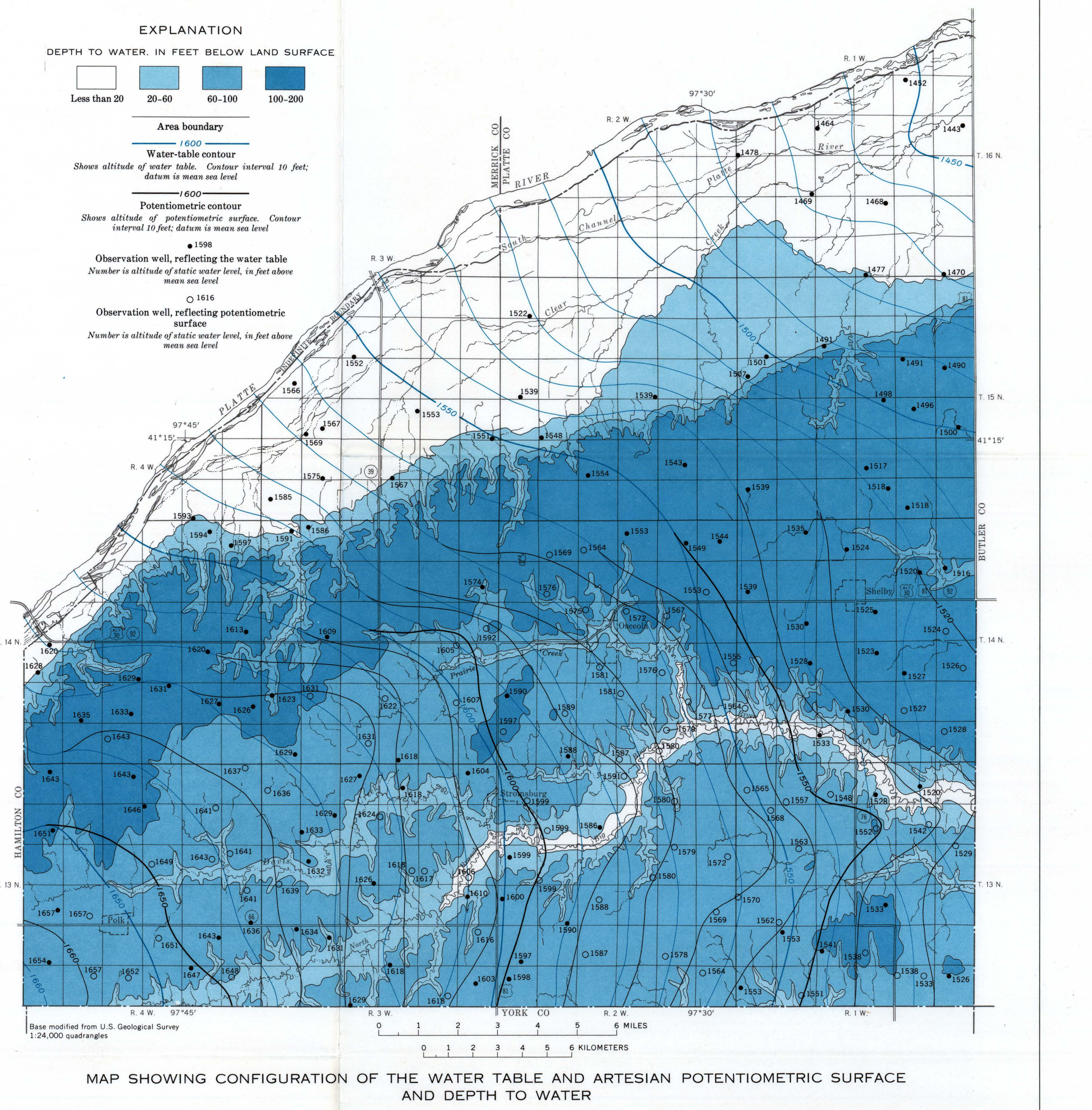
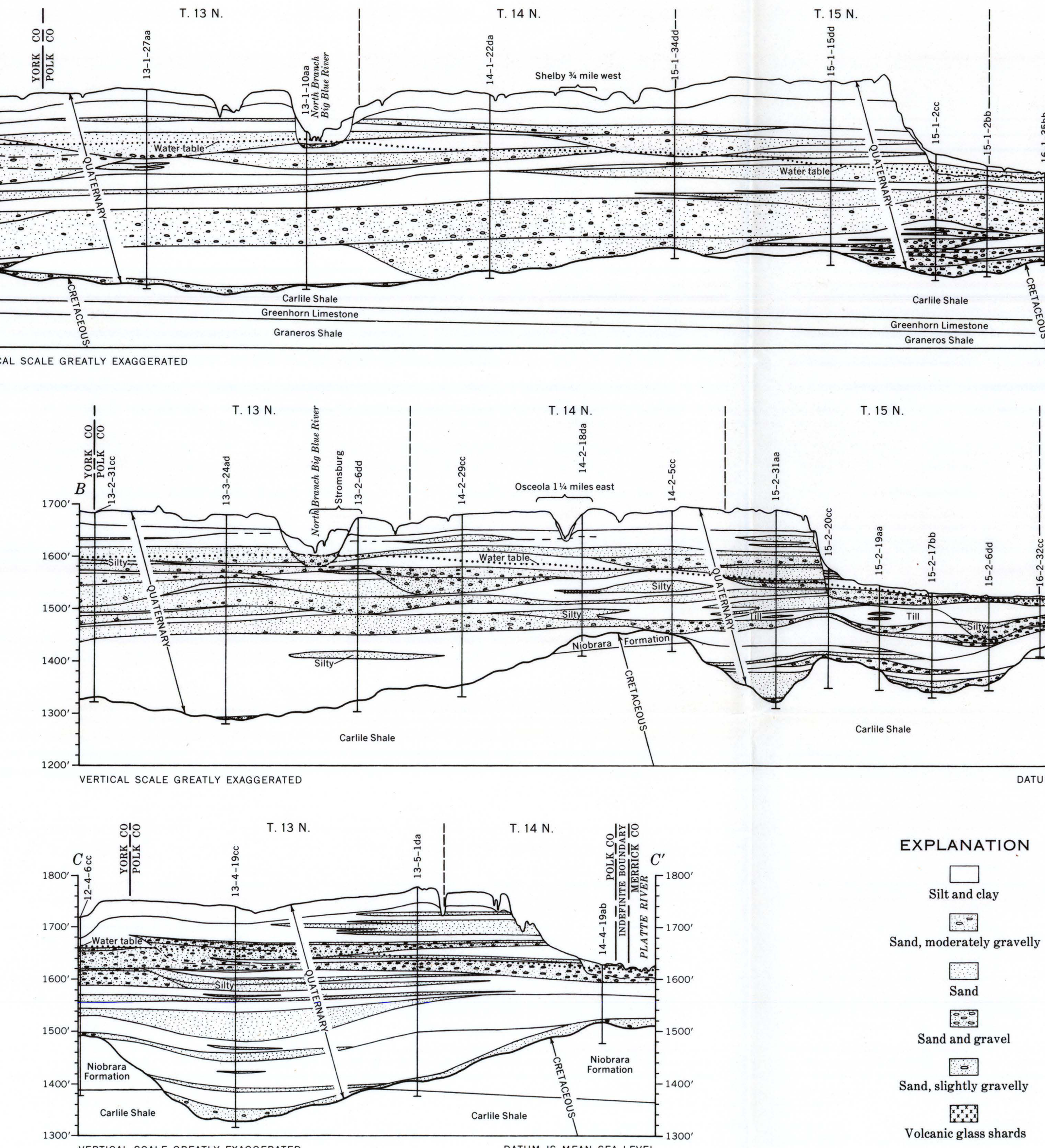


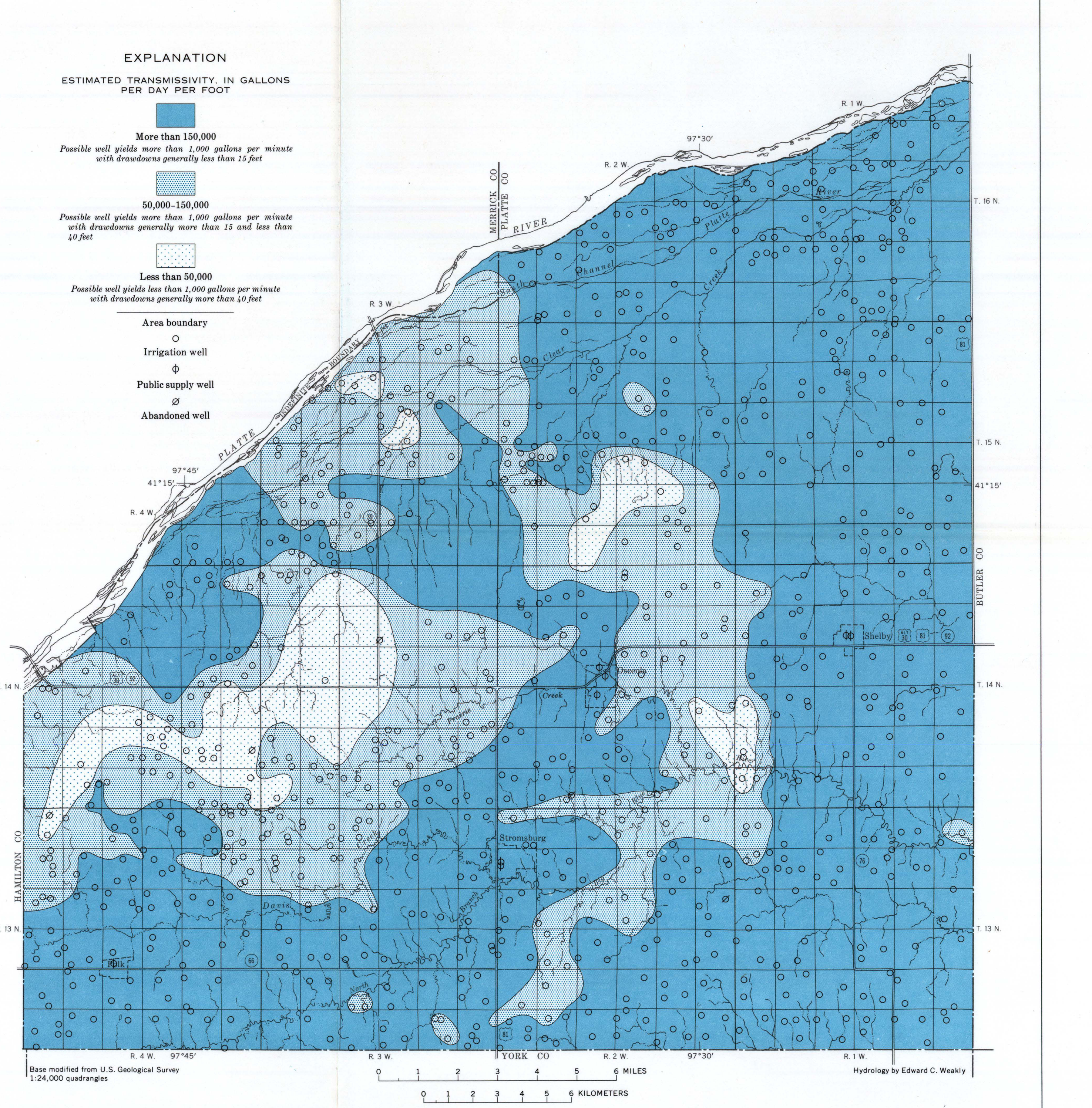
BEDROCK GEOLOGIC MAP



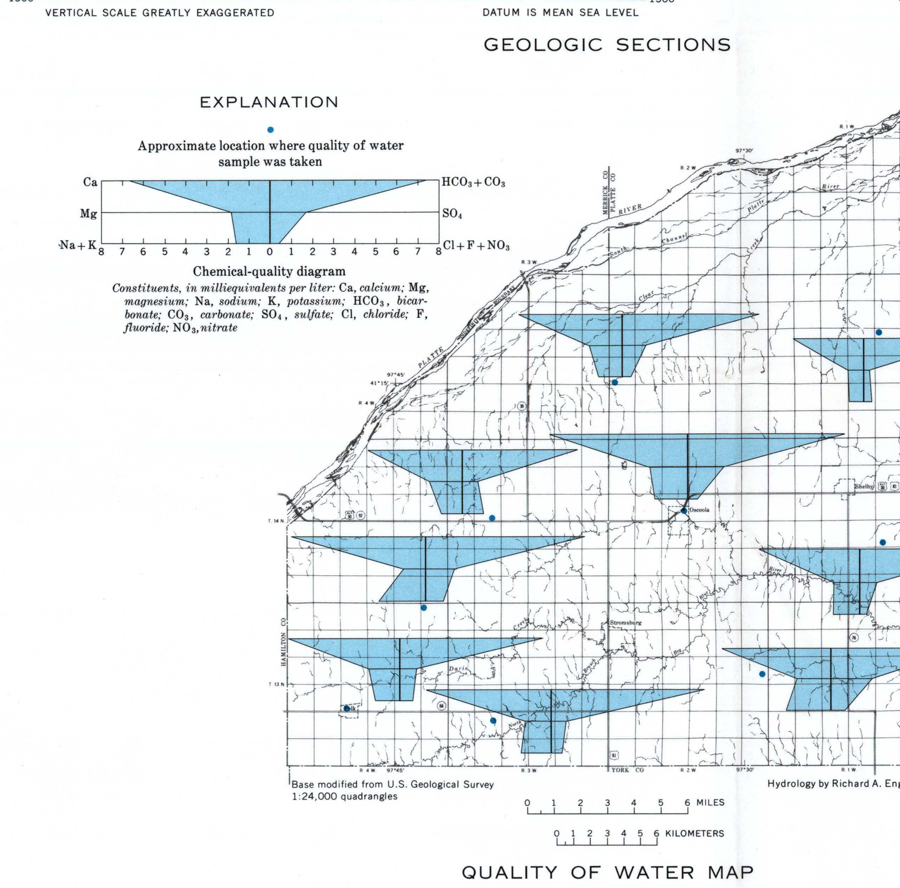
MAP SHOWING CONFIGURATION OF THE WATER TABLE AND ARTESIAN POTENTIOMETRIC SURFACE AND DEPTH TO WATER



GEOLOGIC SECTIONS



MAP SHOWING AVAILABILITY OF GROUND WATER



QUALITY OF WATER MAP

Chemical analyses of ground water in Polk County, Nebraska
(Results in milligrams per liter except as indicated. Use of water: I, irrigation; P, public supply)

Well location	Use of water	Well depth (feet)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	RSC	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH	Temperature (°C)	Temperature (°F)
NW¼SE¼NE¼ sec. 13, T. 13 N., R. 2 W	I	200	8–18–66	38	0.07	0.06	84	15	34	8.8	305	0	74	4.4	0.2	24	0.03	439	271	21	0.00	0.9	648	7.7	12	53
NE¼SW¼NE¼ sec. 29, T. 13 N., R. 3 W	I	233	8–18–66	43	.08	.01	94	12	23	6.3	347	0	25	5.8	.3	12	.02	395	283	0	.01	.6	604	8.0	13	55
NW¼NW¼NW¼ sec. 1, T. 13, N., R. 4 W	I	130	8–18–66	32	.08	.03	98	10	37	7.6	365	0	49	7.2	.5	27	.04	453	287	0	.27	1.0	701	7.8	13	55
SW¼SW¼ sec. 21, T. 13 N., R. 4 W	P	145	9–26–52	30	.02	.02	83	12	24	6.6	328	0	28	11	.2	10	.04	372	258	0	.25	.6	579	7.2	13	55
NE¼SW¼SW¼ sec. 23, T. 14 N., R. 1 W	I	291	8–18–66	39	.38	.09	80	12	23	5.1	305	0	30	2.4	.2	9.5	.03	350	247	0	.02	.6	536	7.7	13	55
NE¼SW¼ sec. 16, T. 14 N., R. 2 W	P	190	3–10–53	38	.01	.03	106	17	25	6.9	373	0	67	7.5	.1	9.4	.04	477	333	27	.00	.6	723	7.2	13	55
NE¼SW¼SE¼ sec. 17, T. 14 N., R. 3 W	I	258	8–18–66	34	.24	.05	74	17	18	4.9	284	0	24	9.4	.4	23	.04	344	253	20	.00	.5	536	8.1	13	55
NE¼NW¼NW¼ sec. 14, T. 15 N., R. 1 W	I	90	8–18–66	48	.04	.04	56	7.7	12	5.3	223	0	8.2	2.2	.5	5.9	.02	259	171	0	.23	.4	379	7.7	12	54
SE¼SW¼SW¼ sec. 19, T. 15 N., R. 2 W	I	100	8–18–66	42	.07	.07	78	16	18	8.4	312	0	34	5.4	.3	7.1	.04	367	260	4	.00	.5	557	7.7	13	55

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By
C. F. Keech

1972