Tertiary and of Quaternary age and from one to the other. Therefore, these saturated deposits are considered to form a single hydrologic unit which hereinafter is referred to as the "ground-water reservoir."

Depth to water table

The depth to water in wells, as measured during the field studies, ranged from 1 to 120 feet below the land surface. (See table 4.) It is estimated, however, that the water table is as much as 225 feet beneath some of the higher hills between Mira Valley and the North Loup River valley. In general, as shown by patterns on plate 1, the water table is less than 5 feet below the flood plain of the North Loup and Loup Rivers, and is 5 to 40 feet below the terraces bordering the flood plain. In much of the upland part of Valley County, including parts of Mira Valley, the depth to water exceeds 60 feet, but only in a relatively small part of the upland is the depth to water greater than 150 feet. The principal tributaries to the North Loup River in Valley County have cut their valleys to within 20 feet of the water table throughout much of their length.

Recharge

The water in the ground-water reservoir beneath the report area is derived in part by subsurface inflow from adjacent areas and in part by the infiltration of precipitation and irrigation water. Subsurface inflow occurs along the northwest, west, southwest, and south margins of the upland area in Valley County, the inflowing water entering from a west-southwest direction. (See pl. 1; the ground water is moving at right angles to the water-table contour lines.) Subsurface inflow to the report area occurs also along the northeast margin of the North Loup River valley in Valley County and along both sides of the North Loup River and Loup River valleys downstream from Valley County. Without additional information on the thickness and permeability of the ground-water reservoir along the margins of the area, it is impossible to compute the amount of recharge due to subsurface inflow. Because the areal extent of the area described in this report is small in relation to the length of the boundaries across which inflow occurs, inflow probably is the most significant source of recharge to the ground-water reservoir underlying the report area.

Sniegocki (1959), on the basis of records of stream discharge during periods of insignificant overland runoff, computed the average annual recharge from precipitation in the loess-mantled part of the Loup River drainage basin to be about $1\frac{1}{4}$ inches, or between 5 and 6 percent of the average annual precipitation. The amount of recharge from infiltrating precipitation undoubtedly varies widely from year to year. Generally, it is not directly related to the amount of precipitation because it is governed not only by the amount but also by the intensity and duration of the rainfall and by soil-moisture conditions, season of the year, and other factors. Under favorable conditions melting snow can be a source of considerable recharge. The hydrograph of well 15-9-9aal, near Cushing, for the period 1949-51 shows a significant period of recharge in each of the 3 years. (See fig. 3.) The largest rise of the water level began in March 1949 and continued through July of that year. The early part of that rise was due to the melting of an unusually heavy snow cover, whereas the later part was due to infiltrating spring rains. If it is assumed that the specific yield of the material that became saturated is about 20 percent, the rise of nearly 2 feet would reflect recharge amounting to about $4\frac{1}{2}$ inches of water, or roughly 250 acre-feet per square mile, or 80 million gallons per square mile. The lesser rises in 1950 and 1951 were due largely to infiltrating spring rains.

In the irrigated parts of the area, seepage from the distribution system of canals and laterals and from water applied to cropland is an added source of recharge. No estimates have been made of recharge in the irrigated areas, but the 8- and 10-foot rises of the water level during the period 1934-56 in wells 19-14-6dc and 18-13-23dd, respectively, which are in irrigated parts of Valley County, suggest that infiltrating irrigation water locally is a source of significant recharge to the ground-water reservoir. (See table 3.)

Movement

In all parts of the report area, water in the ground-water reservoir is percolating slowly (at a rate estimated to average about 3 feet per day) toward either the North Loup River or the Loup River. (See pl. 1.) In the upland part of the area the movement is east-northeastward or eastward, whereas in the valleys of the North Loup and Loup Rivers ground water moves from the valley sides in a downstream direction toward the river. In the valleys, the average angle between the line of ground-water flow and the general course of the river is about 60°.

Discharge

Unless withdrawn through wells, or discharged by evapotranspiration in places where the water table is near the land surface (principally on the flood plain), all ground water percolating toward the rivers eventually enters them and is conveyed out of the area as surface flow. Because the natural flow in the North Loup and Loup Rivers within the report area is affected by diversions for irrigation, by ground-water withdrawals for irrigation, and by return flow from irrigated areas, the records of discharge at gaging stations in the area do not provide an adequate basis for computing the quantity of ground water being discharged as surface flow.

Of the 115 irrigation wells in the area in the spring of 1957 (table 4), about one-third were on the upland in Valley County and the others were in the valleys of the North Loup and Loup Rivers. Most of those on the upland are 300 to 400 feet deep, were drilled 200 feet or more into saturated material, and yield 600 to 1,000 gpm (gallons per minute), whereas most of those in the valleys are less than 200 feet deep, were drilled 60 to 150 feet into the zone of saturation, and yield 250 to 900 gpm. The water yielded by most wells on the upland is derived in large part, and by some is derived wholly, from the Ogallala formation; that yielded by wells in the valleys is derived either wholly from the deposits of Wisconsin age or partly from those deposits and partly from the underlying Ogallala formation. In 1956, about 8,000 acre-feet of water was pumped for irrigation.

Water pumped from wells supplies the residents of all towns in the area except Ord, which obtains water from the North Loup River. The villages of Elyria, Cotesfield, and Cushing do not have publicly owned water systems, each dwelling and business establishment being equipped with a privately owned well. Water for the village of North Loup is obtained from two wells (18-13-25ccl and -25cc2). Well -25ccl is south of the water tower and is used as a standby for emergencies; well -25cc2 is a block west of the railroad station. Scotia is supplied with water from 2 wells (17-12-4dc and -9ba) in the city hall, and Elba is supplied from 1 well (15-11-10bc) in the northwest corner of town. The city of Fullerton is supplied from 9 wells (16-6-11dbl-9) which are connected by siphons in series of 3, with a pump to each series. Fullerton has 4 other wells not now in use.

In rural areas nearly all the water used for domestic purposes is obtained from wells. Stock ponds are frequented by cattle grazing the rough lands between Mira Valley and the valley of the North Loup River in Valley County, but elsewhere in the area water supplies for livestock are obtained from wells. Several of the rural domestic and livestock wells were visited in obtaining water-level data needed for the construction of plate 1; pertinent data regarding these wells are included in table 4.

Where the capillary fringe (zone above the water table into which ground water rises by capillarity) is within the reach of plant roots, large quantities of ground water are transpired by plants; and where the capillary fringe extends up to or within a few inches of the land surface, ground water is evaporated also. The amount of ground water discharged by evaporation and transpiration (commonly referred to as evapotranspiration) is governed by such factors as temperature, wind movement, relative humidity, precipitation, and type of vegetation. According to data collected by the Conservation and Survey Division of the University of Nebraska, various types of vegetation common in northern Nebraska consumed 2 to 4 feet of ground water between July 9 and September 20, 1937, where the water table was 3 to 6 feet below the land surface. Thus, in the 14,000 acres of the report area in which the water table is less than 5 feet below the land surface, about 42,000 acre-feet of ground water would be discharged in a year if an average of 3 feet of ground water were transpired by plants growing there. Because the roots of some plants, among them alfalfa, penetrate to a depth of 20 feet or more, ground-water discharge by transpiration can be significant also in areas where the water table is deeper than 5 feet.

Chemical quality

By Lester R. Petri

Chemical analyses of ground water from deposits of Tertiary and Quaternary age are listed in table 1. The analyses indicate that the water is uniform both in type and in amount of mineralization. The water is of the calcium bicarbonate type and has moderate concentrations of dissolved minerals (specific conductance, 236 to 859 micromhos). The most highly mineralized water was from a well (18-13-25ccl) located between a large irrigation canal and the river, and the relatively high mineralization is probably the result of recharge by irrigation water that has been concentrated by evaporation and transpiration.

The ground water is of good quality for irrigation. Because the concentrations of dissolved minerals are moderate, high salinity in the soil is not likely to develop if drainage is adequate. The concentrations of sodium are low; therefore, the structure of the soil is not likely to deteriorate from use of the water for irrigation. Concentrations of boron are so low that even boron-sensitive crops should not be affected adversely by use of the water.

The water is of good quality for domestic use and most industrial uses except that it is hard and highly siliceous. Locally, the water from shallow deposits may contain enough iron to cause discoloration of fabrics, utensils, and fixtures and to impart an unpleasant taste. The nitrate content of a few samples was high enough to suggest that locally the water may not be safe for infant feeding. The temperature of the water ranged from 48° to 58°F.

The ground water is similar in type to the water in the North Loup River but has about twice as much mineral material (table 2). The greater mineral content probably is the result of the long period of contact of the ground water with the minerals in the rocks through which it has moved.

CONCLUSIONS

The observed productiveness of the water-bearing deposits and the present wide scattering of the irrigation wells indicate that small to moderately large supplies of ground water are obtainable in much, if not all, of the area described in this report. Because the average discharge of the wells in Valley County and in the western parts of Greeley and Howard Counties is somewhat greater than that of wells in the remainder of the area, it is believed that the capacity of the ground-water reservoir to yield water to individual wells decreases eastward. East of central Howard County the Ogallala formation apparently is too thin and its permeability is too low for it to yield much water; consequently, the deposits of Quaternary age are the principal source of the water discharged by wells in that part of the area. Because the Ogallala contains a high proportion of very fine grained material, wells tapping it are likely to yield silt and fine sand with the water unless they are properly designed and installed and are carefully developed by surging or other effective methods.

Water-level measurements made to date do not indicate that withdrawals of ground water have caused any significant lowering of the water table. However, if the rate of withdrawal were to be increased considerably, the water levels eventually would decline and pumping lifts would increase correspondingly. The establishment of a gravity irrigation system in the immediate vicinity of the wells would result in an increase in recharge to the ground-water reservoir and thus tend to offset any water-level decline caused by pumping. A close watch on water levels in wells would reveal at an early date if, in places, the water table is rising sufficiently to threaten waterlogging or is declining to the extent that pumping costs are increasing appreciably; remedial measures then could be taken. Because both the ground water and the surface water are highly suitable for use in irrigation, no water-quality problems are expected to occur unless the water table rises in places to a level high enough for the ground water to be raised by capillarity to the root zone or to the land surface.

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Table 1.--Chemical analyses of ground water in the North Loup Division of the lower Platte River basin

[Results in parts per million except as indicated]

Well	Depth (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25°C)	pH
15-6-2bb......	19	6- 2-51	49	46	1.4	33	3.8	6.1	5.0	115	11	2.5	0.2	12	.....	188	98	4	11	0.3	236	7.7
15-8-17dd.....	14	6- 2-51	48	35	....	66	9.6	16	6.1	249	42	3.0	.3	.9	.....	311	204	0	14	.5	450	7.7
15-9-5cc......	150	9-11-56	55	61	.02	100	7.4	9.9	5.2	343	19	4.0	.2	6.8	0.07	380	280	0	7	.3	565	7.4
15-10-16aa....	65	12- 1-43	53	.....	....	....	......	7.8		340	6.0	7.0	.....	9.6	.....	....	285	6	6	.2	539	7.9
15-11-9.......	46	11-30-43	53	.....	....	....	......	16		331	5.0	4.0	.....	1.0	.....	....	249	0	12	.4	511	7.6
15-11-10bc....	79	11-30-43	.....	.....	<.02	81	13	16		327	11	4.0	.0	6.4	.04	....	256	0	12	.4	511	7.6
16-7-35ab.....	97	9-11-56	53	51	.01	98	17	14	7.4	356	24	7.5	.2	33	.08	428	315	23	9	.3	652	7.3
16-11-7cb.....	38	11-30-43	53	.....	....	....	......	22		390	10	8.0	.....	.0	.....	....	294	0	14	.6	620	7.6
16-11-8ab.....	185	11-30-43	54	.....	.02	89	11	19		347	9.3	5.0	.0	8.0	.06	....	267	0	13	.5	545	7.6
16-11-18bc....	......	9-13-56	55	60	.15	88	8.4	7.7	4.9	317	14	3.0	.2	3.1	.04	341	254	0	6	.2	505	7.6
17-11-31ba....	100	8-29-56	53	60	.01	98	12	7.8	7.5	361	13	4.0	.2	5.4	.05	388	292	0	5	.2	583	7.3
17-12-4dd.....	93	8-29-56	55	62	.08	105	14	14	6.9	384	33	2.5	.2	4.6	.08	435	318	3	9	.3	641	7.3
17-12-9ba.....	74	11-30-43	52	.....	<.02	102	15	23		390	28	7.0	.0	9.0	.06	....	316	0	14	.6	639	7.5
18-12-19ca....	264	8-29-56	56	61	.03	90	9.6	12	6.5	326	25	3.0	.1	3.3	.04	376	264	0	9	.3	547	7.4
18-13-20db....	100+	11-30-43	52	.....	....	....	......	20		395	35	5.0	.....	6.6	.....	....	330	6	11	.5	665	7.5
18-13-23dd....	83	11- 6-36	.....	.....	....	81	15	25		322	27	5.0	.7	22	.....	....	264	0	16	.7	....	
18-13-25ccl...	93	11-29-43	53	.....	<.05	122	22	47		444	77	20	.0	31	.07	....	395	31	21	1.0	859	7.5
18-13-33bc....	257	8-28-56	55	63	.08	98	8.1	8.2	6.6	332	26	3.5	.2	2.9	.07	391	278	6	6	.2	562	7.3
18-13-36ad....	125+	11-30-43	53	.....	.02	96	14	14		362	23	5.0	.0	.0	.07	....	297	0	9	.4	584	7.6
18-14-31ad....	354	8-28-56	58	64	.02	100	13	11	6.5	369	29	4.0	.2	1.8	.06	415	305	2	7	.3	610	7.4
18-15-12bb....	120	8-29-56	53	60	.01	93	12	7.9	6.3	329	26	2.5	.2	3.4	.06	377	280	10	6	.2	558	7.5
18-15-15dd....	158	11-29-43	53	.....	....	....	......	4.6		318	10	10	.....	8.4	.....	....	282	21	3	.1	553	7.6
19-13-35cc2...	85	11-29-43	54	.....	<.02	40	6.3	11		154	5.6	2.8	.0	16	.04	....	126	0	15	.4	277	7.6
19-14-8da.....	42	11-29-43	52	.....	....	....	......	33		385	12	9	.....	38	.....	....	300	0	19	.8	663	7.6
19-16-13db....	305	8-28-56	56	60	.02	100	13	8.6	7.2	329	55	3.0	.1	.6	.09	416	301	31	6	.2	604	7.5
20-15-10da2...	100	11-29-43	52	.....	.02	62	9.2	15		261	4.1	1.0	.1	5.6	.04	....	192	0	14	.5	409	7.7