Ground-Water Resources of the South Platte River Basin in Western Adams and Southwestern Weld Counties Colorado

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about 23 feet per mile south of Hudson, but it decreases to about 18 feet per mile and is nearly uniform northward from Hudson. In the vicinity of sec. 11, T. 4 N., R. 64 W., however, there is a flattening of the slope, probably due to an increase in the permeability of the sedimentary rock. Depths to water and the shape of the water table show that Box Elder Creek was not gaining water from the ground-water reservoir in November 1957. The creek is dry during much of the year but is a source of recharge to the ground-water reservoir when it flows and especially so when it is at flood stage. Other sources of recharge are surface water that is spread for irrigation and precipitation that falls within the basin. Immediately after a flood, when water from Box Elder Creek is recharging the ground-water reservoir, a ridge probably is formed on the water table beneath the bed of the creek. The contours around Horse Creek, however, indicate that the creek is gaining ground water, probably by seepage from Horse Creek Reservoir. Recharge from the Ireland Reservoir No. 5 apparently is causing the mound in the water table downstream from the reservoir. The contours in the area where the valleys of the Beebe Draw and Box Elder Creek valley merge show that some of the ground water in Box Elder Creek valley is moving into the valley-fill deposits in Beebe Draw. The slight inward movement of ground water along the edges of the valley probably is caused by the slope of the bedrock surface.

Depths to water in the valley range from less than 5 feet to about 40 feet and average 22 feet. Hydrographs of the U.S. Geological Survey's observation wells (figs. 11, 12, and 13) show that the maximum annual fluctuation in well B1-65-12ccd2 was about 13 feet, part of which was due to the pumping of a nearby irrigation well. The records of the long-term observation wells, except well B2-64-30cbc, show a pronounced downward trend in the water levels since 1950 (fig. 10). In the vicinity of this well, ground-water underflow from Ireland Reservoir No. 5 probably recharges the ground-water reservoir. Although the water levels had risen by the spring of 1958, they still were far below the average of record in most of the wells. The only surface water available for irrigation in the district is that diverted from the few reservoirs and from Box Elder Creek when it is at flood stage. Therefore, irrigation is largely dependent on water pumped from wells. All the large withdrawals of ground water from the valley-fill deposits, except from the Hudson municipal wells, are used for irrigation. Code's well-location map (1943) shows only 70 irrigation wells in 1940; by the end of 1957 there were 210. The number of wells per section ranges from 0 in several to 12 in secs. 12 and 13, T. 1 N., R. 65 W., and the average is three. Locally, however, the irrigation wells are too closely spaced, and as a result mutual interference decreases yields and increases drawdowns. Most of the wells are drilled to bedrock, are lined with metal casing, and are equipped with electrically driven turbine pumps. A few of the wells are dug and lined with concrete casing. Only two wells are equipped with centrifugal pumps and only one pump is driven by an internal-combustion engine.

Hudson (population 430) is supplied with water from two drilled metal-cased wells that obtain water from the valley-fill deposits. The wells, which are outside the city limits, are equipped with electrically driven turbine pumps that force water into a 44,000-gallon elevated steel tank. An average operating pressure of about 35 psi is maintained in the city distribution system. About 125,000 gpd, or about 140 acre-ft per year, is pumped from the wells for municipal use.

Pumping from the irrigation wells in this district has been very heavy during recent years. Yields from the wells that were measured by the U.S. Geological Survey ranged from 85 to 1,090 gpm and averaged 550 gpm. Drawdowns ranged from 7 to 32 feet and specific capacities ranged from 5 to 135. The coefficients of permeability and transmissibility are relatively low (table 5) compared to those in the rest of the report area. The water levels in many of the wells south of Hudson declined to the pump intakes during the 1957 pumping season, and some wells were not used. The largest yields generally are obtained from wells near the axial part of the valley; the slope-wash deposits along the edges of the valley fill are poor producers. The comparatively small average yields of wells in the district probably are due to the declining water table and to the lower permeability of the valley-fill deposits, which contain a large percentage of clay and silt. Heavy pumping eventually could lower the regional water table below the intakes of some pumps.

It is estimated that about 20,000 acre-feet of ground water is pumped from the valley-fill deposits during a normal year. The estimated quantity of recoverable ground water in storage in November 1957 was about 320,000 acre-ft. Declining water levels indicate that ground water is being taken from storage; that is, recharge is not balancing discharge. The decline of the water table in this district is the most marked in the report area.

In the southern part of this district, the water generally has a specific conductance of less than 1,400 micromhos per cm and is of the calcium bicarbonate type. In the northern part, the water generally has a specific conductance of more than 1,800 micromhos per cm and is of the calcium sulfate type.

CONCLUSIONS

Unconsolidated valley-fill deposits of sand, gravel, cobbles, and boulders of Quaternary age are the important water-bearing formations in the report area. These deposits are the principal source of ground water in the stream valleys and, locally, they yield as much as 2,000 gpm to wells, although the average yield is about 700 gpm. The low to moderate yield of some wells probably is due to poor construction of the wells, and that of others to low transmissibility of the aquifer. The ground water in the valley-fill deposits is unconfined, except locally, and the depth to water ranges from 0 to about 80 feet. Ground water enters the area by underflow. The ground-water reservoir in the area is recharged also by precipitation and by seepage from irrigated tracts, reservoirs, canals, and streams. Ground water is discharged within the area by evapotranspiration, seepage into streams, springs and seeps, and pumping from wells. The remainder of the ground water leaves the area by underflow through the valley-fill deposits.

The South Platte River gains water from the ground-water reservoir throughout its course in the area. Beebe Seep at some times and places is a gaining stream and at others a losing stream. Water from Box Elder Creek infiltrates into the underlying unconsolidated deposits, especially during flood stage.

Development of ground-water supplies from the valley-fill deposits has been rapid since 1940; the number of large-capacity wells increased from about 700 in 1940 to about 1,700 at the end of 1957. Ground water is used principally for irrigation, but large amounts are used also for municipal and industrial supplies, and most of the water for domestic and stock use is obtained from wells. It is estimated that about 250,000 acre-ft of water in 1956 and about 100,000 acre-ft in 1957 was pumped from the large-capacity wells, and that about 500 acre-ft is pumped from domestic and stock wells annually. It is estimated that about 2 million acre-ft of recoverable ground water is stored in the valley-fill deposits in the report area.

Further ground-water development may be feasible in some parts of the area but not in others. The insignificant net change in ground-water levels between 1929 and 1958 in the South Platte River valley between Denver and the northern boundary of T. 3 N. indicates that ground-water withdrawals during that period did not deplete the supply in storage. Even during the period 1954–57, when precipitation was subnormal and pumpage was correspondingly greater, the net change in water levels was very slight. Apparently, ground-water withdrawals through 1957 in this part of the area have resulted in the salvage of water that otherwise would have been discharged by natural processes. In places where the water table is shallow, water now lost through evapotranspiration could be salvaged through an increase in pumping. Heavy pumping near the river, however, might induce recharge from the river and compete with surface-water use. In parts of the district between Denver and the base line, wells are so closely spaced that when pumped for long periods the water level declines to the pump intake; additional large-capacity wells in other parts of the district should be spaced farther apart so as to avoid mutual interference and a subsequent local lowering of the water table.

There appears to be a danger of overdevelopment of the ground-water supply in the South Platte River valley in T. 4 N., R. 66 W. Although the net change in water levels during the period 1929–50 was relatively small, a pronounced steady decline, due partly to increased pumping and partly to subnormal precipitation, has occurred since 1950. Water levels in the area immediately north of Lower Latham Reservoir do not show a marked long-term decline, probably because seepage from the reservoir is recharging the ground-water reservoir. Little is known about the net change in water levels in the rest of the district between the northern boundary of T. 3 N. and Kuner because long-term records of water-level fluctuations are not available.

Although long-term records of water-level fluctuations in Beebe Draw are incomplete, they indicate a net decline of ground-water levels, at least locally. High coefficients of permeability and transmissibility of the valley-fill deposits, however, indicate that the district may be able to support additional well-planned ground-water development. An estimated 20,000 acre-ft of ground water was pumped in 1956, apparently without material interference among wells or noticeable depletion of ground water in storage. If properly spaced, additional wells of large capacity should not seriously deplete the ground-water reservoir.

The maximum development of ground water probably has been reached or exceeded in the Box Elder Creek valley, especially in the stretch between Hudson and the southern boundary of the report area where water in the irrigation wells commonly decline to the pump intake when the wells are pumped during extended droughts, and where the coefficients of permeability and transmissibility of the valley-fill deposits generally are comparatively low. Several instances have been reported of interference among wells. Long-term records show that ground-water levels throughout the valley have declined sharply since 1950, indicating rather rapid depletion of the ground water in storage.

The extent to which development of ground water in the districts can be safely increased and sustained depends on (1) the amount of ground water available, (2) the rate at which it is withdrawn, and (3) the rate at which it is replenished. An indication of the amount of ground water available is the average annual amount of natural discharge from a district; the amount available determines the upper limit for development. In practice, however, feasible development must be less than ground-water discharge because not all the natural discharge can be intercepted, and because of limiting hydrologic and legal factors.

The average amount of water than can be pumped from the valley-fill deposits over a long period without exceeding the rate of recharge and permanently depleting the supply in storage and thus progressively lowering the water table should be determined separately for each district. This amount is the safe perennial yield. Its determination requires records for several years of pumpage, water-level changes, precipitation, runoff, and an analytical appraisal of these data. The hydrologic features of the report area are complex, and the safe yield can be determined only by further study and systematic observations while additional development proceeds.

As new wells are brought into production, water levels will decline, but such a decline alone is not necessarily proof of overdevelopment. Some water-level decline is inevitable if a large amount of water is taken from the ground-water reservoir. The critical point, however, is whether or not the water levels recover after the pumping season, or after several pumping seasons during a series of dry years. In a natural ground-water regimen, discharge is mainly equal to recharge; that is, the system is in dynamic equilibrium. In an artificially altered regimen, such as the report area, discharge will continue to equal recharge only so long as the safe perennial yield is not exceeded.

Much of the ground water discharged from wells in areas where the water table is at or near the land surface is salvaged water, because lowering the water table reduces natural discharge by evapotranspiration. Also, artificial lowering of the water table creates space for storage of additional recharge. The safe perennial yield is not being exceeded in such areas. In other areas, however, large-scale pumping may deplete ground water in storage and reduce the natural discharge into streams to such an extent that surface-water rights are infringed upon and water levels in wells drop below the intake of pumps. Most of the large-capacity wells in the project area reach, or nearly reach bedrock; therefore, the total depth of the well is the maximum depth to which the water table and the intake pipe can be lowered.

Two important factors are involved in the concept of safe perennial yield, one being the hydrologic factors just discussed and the other being the legal factor. Although, strictly speaking, the maximum possible withdrawal of ground water from a district is limited by hydrologic factors alone, the maximum actual withdrawal may be limited by legal factors. It may be decided by competent legal authority to restrict ground-water development to a yearly withdrawal rate that

will provide the greatest long-term benefits for all water users and prevent future controversies. Therefore, it should not be inferred from this report that the report area can safely, economically, and legally support a large additional number of large-capacity wells.

Continued collection and study of data is needed to determine the safe perennial yield of the aquifers in the report area, and to assist orderly and efficient development of the ground water of the valley-fill deposits. Such an investigation should include (1) maintenance of complete and accurate records on additional large-capacity wells that are installed in the area; (2) continued measurement of water levels in a network of observation wells; (3) systematic collection of discharge and power-consumption records for large-capacity wells and from those records, computation of the total yearly volume of withdrawals; (4) evaluation of all sources of recharge to and discharge from the ground-water reservoir; (5) quantitative studies of the relation of streamflow to ground water; (6) collection and evaluation of additional data on the chemical quality of the water.

The collected data should be evaluated periodically in order to detect current or impending overdevelopment of the ground-water resources. Such data and periodic review will make water problems easier to solve, and they may indeed provide the basis for development of an integrated surface- and ground-water irrigation system involving the utilization of artificial recharge and discharge as a means of balancing the effects of wet and dry years.

Water from the valley-fill deposits in most of the report area has a specific conductance of 1,000–1,800 micromhos per cm and is of either the calcium bicarbonate or the calcium sulfate type. The water is suitable for irrigation in most places but has a high or very high salinity hazard and in some places has a high leaching requirement. It is of poor quality for public-supply and domestic use because it is very hard. In a few sections in T. 2 S., R. 67 W., near Derby, the water has a specific conductance of more than 4,000 micromhos per cm and is of the calcium chloride type, a type found nowhere else in the report area. The high specific conductance and the water type indicate contamination of the ground water by waste from the arsenal. In the downvalley parts of the South Platte River valley and of most of the tributary valleys, the water has a specific conductance of about 2,250 micromhos per cm and is of the calcium sulfate or sodium sulfate type. Near Denver ground water in the Sand Creek and South Platte River valleys is contaminated by petroleum wastes, but the severity and areal extent of the contamination were not determined.

The quality of the water in the valley-fill deposits in the report area is similar to the quality of the water in the surface streams and is affected by irrigation practices. Use of the water for irrigation tends to increase the mineralization and to change the type of the water from calcium carbonate to calcium sulfate or sodium sulfate.

Water from the bedrock differs widely in mineralization from one stratigraphic unit to another, as well as within units; the specific conductance of ground water that was sampled ranged from 336 to 5,040 micromhos per cm. In most of the units the water is of the sodium bicarbonate type, is soft, and has a relatively high concentration of fluoride. Water from the Dawson arkose was the least mineralized of the water sampled, and water from some strata in the Laramie formation was the most mineralized. Water from the bedrock probably is poor for irrigation and ranges from poor to good for public supply and domestic use.

It would be advisable to study long-term changes in quality of water from key wells, to determine the source and extent of the contamination by petroleum waste in the valleys of Sand Creek and the South Platte River and to determine the extent of and potential for development of the aquifer that produces relatively soft water in the vicinity of Greeley.

LITERATURE CITED

American Water Works Association, 1950, Water quality and treatment: Am. Water Works Assoc. Manual, 2d ed., 451 p.

Back, William, 1957, Geology and ground-water features of the Smith River plain, Del Norte County, California: U.S. Geol. Survey Water-Supply Paper 1254, 76 p.

Bjorklund, L. J., and Brown, R. F., 1957, Geology and ground-water resources of the lower South Platte River valley between Hardin, Colorado, and Paxton, Nebraska, with a section on the chemical quality of the ground water, by H. A. Swenson: U.S. Geol. Survey Water-Supply Paper 1378, 431 p.

Blair, R. W., 1951, Subsurface geologic cross sections of Mesozoic rocks in northeastern Colorado; U.S. Geol. Survey Oil and Gas Inv., Chart OC 42, 2 sheets.

Bryan, Kirk, and Ray, L. L., 1940, Geologic antiquity of the Lindenmeier site in Colorado: Smithsonian Misc. Colln., v. 99, no. 2, Pub. 3554, 76 p.

California Institute of Technology, 1952, water quality criteria: State Water Pollution Control Board Pub. 3, 512 p.

Code, W. E., 1943, Use of ground water for irrigation in the South Platte valley of Colorado: Colorado Agr. Expt. Sta. Bull. 483, 43 p., 1 pl., 17 figs.

——— 1958, Water table fluctuations in eastern Colorado: Colorado State Univ. Expt. Sta. Bull. 500–S, 34 p.

Dane, C. H., and Pierce, W. G., 1936, Dawson and Laramie formations in southeastern part of Denver Basin, Colorado: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 10, p. 1308–1328.

Darton, N. H., 1905, Preliminary report on the geology and underground water resources of the central Great Plains: U.S. Geol. Survey Prof. Paper 32, 433 p.

Eaton, F. M., 1950, Significance of carbonates in irrigation waters. Soil Sci., v. 69, no. 2, p. 123–133.

——— 1954, Formulas for estimating leaching and gypsum requirements of irrigation waters: Texas Agr. Expt. Sta. Misc. Pub. 111, 18 p.

Eldridge, G. H., 1889, On some stratigraphical and structural features of the country about Denver, Colorado: Colorado Sci. Soc. Proc., v. 3, pt. 1, p. 86–118.

Emmons, S. F., Cross, Whitman, and Eldridge, G. H., 1896, Geology of the Denver Basin in Colorado: U.S. Geol. Survey Mon. 27, 556 p.

Hague, Arnold, and Emmons, S. F., 1877, Descriptive geology: U.S. Geol. Explor. 40th Parallel Rept. (King), v. 2, 890 p.

Henderson, Junius, 1920, The Cretaceous formations of the northeastern Colorado plains: Colorado Geol. Survey Bull. 19, p. 7–57.

Hunt, C. B., 1954, Pleistocene and Recent deposits in the Denver area, Colorado: U.S. Geol. Survey Bull. 996–C, p. 91–140.

Jacob, C. E., 1944, Notes on determining permeability by pumping tests under water-table conditions: U.S. Geol. Survey open-file report, 25 p.

——— 1947, Drawdown test to determine effective radius of artesian well: Am. Soc. Civil Engineers Trans., v. 112, p. 1047–1070, paper 2321.

King, Clarence, 1878, Systematic geology: U.S. Geol. Explor. 40th Parallel Rept., v. 1, 803 p.

Lovering, T. S., Aurand, H. A., Lavington, C. S., and Wilson, J. H., 1932, Fox Hills formation, northeastern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 16, no. 7, p. 702–703.

Lovering, T. S., and Goddard, E. N., 1950, Geology and ore deposits of the Front Range, Colorado: U.S. Geol. Survey Prof. Paper 223, 319 p.

Lowry, R. L., Jr., and Johnson, A. F., 1942, Consumptive use of water for agriculture: Am. Soc. Civil Engineers Trans., v. 68, no. 8, pt. 2, p. 1243–1302, paper 2158.

Mather, K. F., Gilluly, James, and Lusk, R. G., 1928, Geology and oil and gas prospects of northeastern Colorado: U.S. Geol. Survey Bull. 796–B, p. 65–124.

Maxcy, K. F., 1950, Report on the relation of nitrate concentrations in well waters to the occurrence of methemoglobinemia: Natl. Research Council Bull., Sanitary Engineering and Environment, app. D.

McLaughlin, T. G., 1946, Geology and ground-water resources of parts of Lincoln, Elbert, and El Paso Counties, Colorado: Colorado Water Conserv. Board, Ground Water Ser. Bull. 1, 139 p.

Meinzer, O. E., and Wenzel, L. K., 1942, Movement of ground water and its relation to head, permeability, and storage, chap. XB in hydrology: Physics of the earth ser., pt. 9: New York, McGraw-Hill, p. 444–477.

Petri, L. R., and Smith, R. O., 1959, Investigation of the quality of ground water in the vicinity of Derby, Colorado: U.S. Geol. Survey open-file report, 77 p.

Powell, S. T., 1954, Water conditioning for industry: New York, McGraw-Hill, 548 p.

Rankin, C. H., Jr., 1933, Study of well sections in northeastern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 4, p. 422–432.

Rohwer, Carl, 1942, The use of current meters in measuring pipe discharges: Colorado Agr. Expt. Sta. Tech. Bull. 29, 40 p.

Schneider, Paul A., Jr., 1962, Records and logs of selected wells and test holes, and chemical analyses of ground water in the South Platte River basin in western Adams and southwestern Weld Counties, Colorado: Colorado Water Conserv. Board, Basic-Data Report no. 9, Ground Water Series.