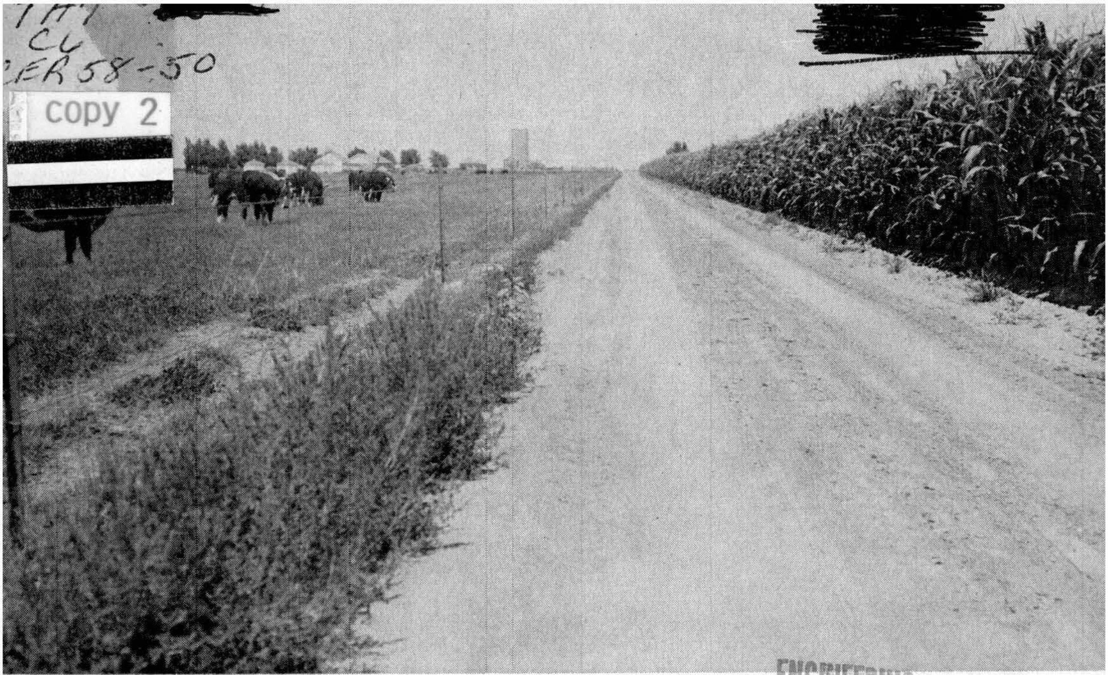

Ground Water and the Bijou Valley

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Ground Water and the Bijou Valley

By W. E. Code[1]

Introduction

Material presented in this report is the result of a cooperative agreement among various western states and the U. S. Department of Agriculture. This agreement was activated July 1, 1956. The Colorado project had as its objective an economic analysis of laws and related institutions affecting ground-water use in the Bijou Valley. The work was conducted cooperatively by the Civil Engineering and Economics sections of the Colorado Agricultural Experiment Station, Colorado State University.

An important phase of the project was to be a study of the economic impact on a community dependent upon a diminishing supply of ground water for irrigation. The probable effects of various types of water laws were to be projected upon this situation.

To evaluate the local conditions to which the study was limited, it was considered desirable to determine as nearly as possible the physical aspects of the water supply. Work on this part of the project was conducted by the Civil Engineering section of the Experiment Station and is the substance of this report.

Physical Situation

It was felt desirable to limit this project to a specific area of reasonable size, rather than to make a broad study of various conditions that exist within the state. The Bijou Valley was chosen because conditions there are representative of several Colorado areas, thus giving the study more than local value. Because of personnel, time, and fund limitations, the study area was confined to that part of the valley in Morgan county south of Wiggins.

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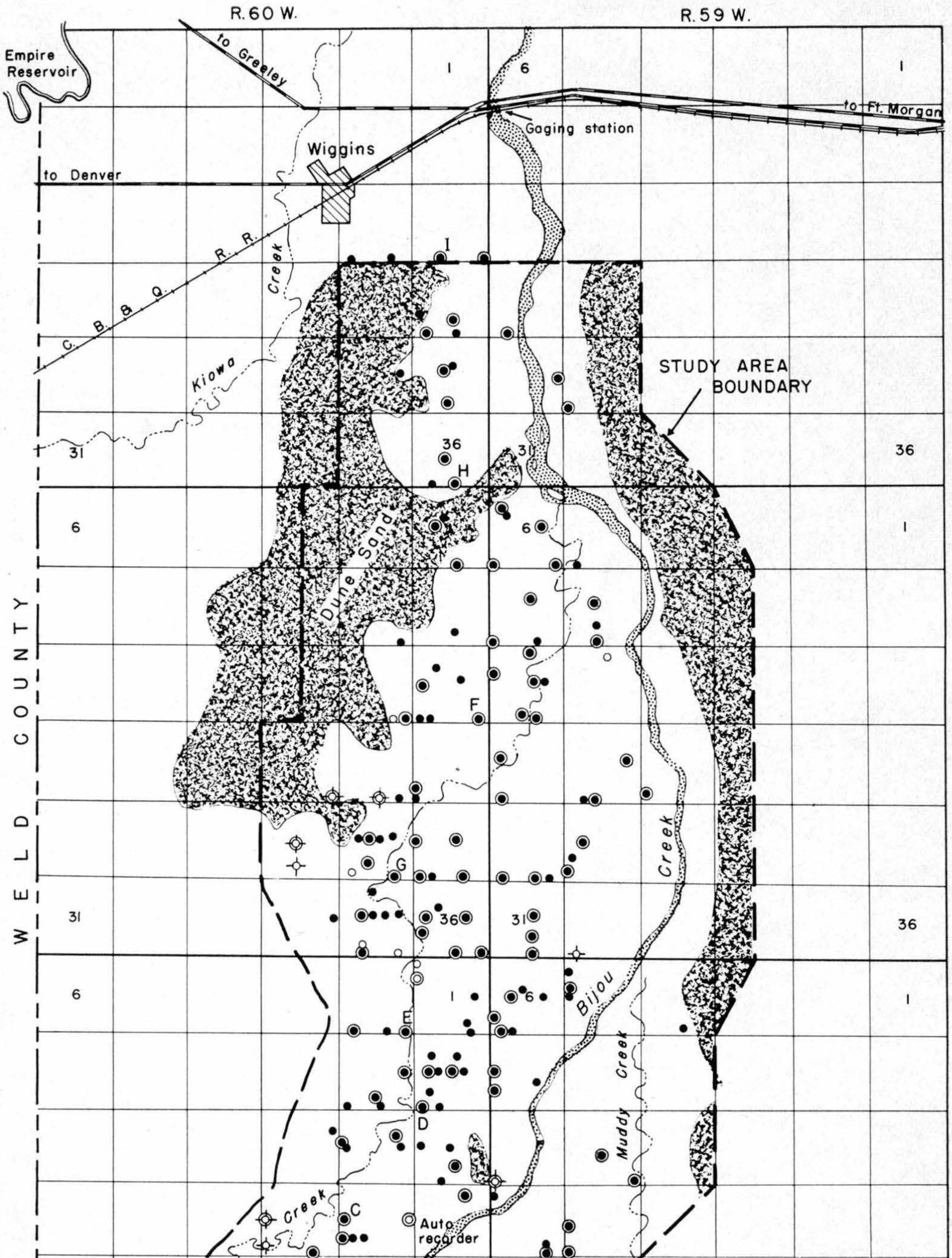

FIGURE 1.—Map of Bijou Valley study area.

Other reasons for choosing this area were:

1. Irrigation water was derived solely from ground-water sources.

2. The water table had been sinking, first slowly and later at a faster rate, since development started in 1935.

3. Pumping had produced no immediate effect upon appropriated surface water flows.

4. Geologic features had been determined and other data obtained by the Ground-Water Branch of the U. S. Geological Survey in 1948.

5. The valley in which the pumping was concentrated had reasonably definable boundaries.

Figure 1 shows a map of the area. The ground-water development continues both north and south of the arbitrary boundaries shown. The western boundary is quite definite in the south half of the valley, since geological exploration revealed that the saturated gravels pinch out. The boundary for the north half was selected arbitrarily to include that area considered to be accociated with Bijou Valley conditions.

The sediments continue west under an overlay of wind-deposited sand hills into the Kiowa Creek drainage. The east boundary follows approximately a line of zero saturation as indicated by the USGS report on the area in 1949.[2] This boundary cannot be precise because of lack of data. The area within these boundaries is 84 square miles, or 53,750 acres.

The ancient channel of Bijou Creek in Morgan county is a trench about 6 miles wide, principally carved out of the Pierre formation.[2] The overlying Fox Hills formation is present on both sides for a few miles north of the Adams-Morgan county boundary. Erosion by Bijou Creek has removed the Fox Hills formation in the valley trench. This channel has been filled with alluvium to a maximum depth of from 100 to 190 feet in the deepest parts of the study area. The greatest depth occurs at the north end. Recoverable ground water in quantities required for irrigation is found only in the alluvium. Wind-deposited soils occur on both the east and west sides of the valley. The soils in general are deep and range from light to heavy loams.

In the study area, depth to water in 1946 varied from 18 feet at the south end to 55 feet at the north. In almost all instances, good irrigation wells were obtainable in the central parts of the trough. Poor soil and topographic conditions have influenced location of ground-water development, especially east of the Bijou. These conditions and the thinning out of the saturated zone have prevented westward development.

Earliest attempts to obtain

[2] L. J. Bjorklund and R. F. Brown, Geology and Ground-Water Resources of the Lower South Platte River Between Hardin, Colo., and Paxton, Nebr. U. S. Geological Survey Water-Supply Paper 1378, 1957.

irrigation wells in Bijou Valley were in adjoining Adams county to the south. Several abandoned wells were found here in 1930 and some may have dated back to about 1910. The earliest year of record for an irrigation well in Morgan county south of Wiggins is 1935.

A 1940 survey of the study area showed 28 operating irrigation wells. At that time a number of pumps still were driven by internal combustion engines although electricity had become available in 1939 through the Morgan county REA. In 1956, 178 wells were found in operation. Four plants used in 1954 or 1955 were not in use in 1956.

Sources of Replenishment

Evaluation of a ground-water supply which is being drawn upon heavily requires knowing the rate of withdrawal and how that rate affects the water table. Several factors operate in varying degree to determine this effect.

For example, a portion of the water applied to the soil is lost in evaporation from ditches and the soil surface. Another portion is lost temporarily through seepage from ditches and, from the fields, by percolation down through the root zone. But this water ultimately reaches the water table and hence is not lost to the ground-water supply.

Net ground-water replenishment in the Bijou Valley is due principally to stream-flow losses from the sandy bed of Bijou Creek. Although usually dry, this creek is subject to great extremes in flow. Floods of more than 100,000 cubic feet per second have occurred in the past 25 years. The channel is wide and extreme floods overflow the banks. The topography of the overflow lands makes them useless for agriculture.

FIGURE 2.—Use of Hoff current meter to measure pump discharge. This method requires a pipe flowing full. When not flowing full, a smaller pipe is inserted as shown.

A second possible source of replenishment is water which may escape from the Fox Hills formation that outcrops under the alluvium in the southern part of the study area. This is conjecture only, as no proof exists for or against such a contribution.

Ground-water movement into the area from the south would be offset by a similar movement out of the area at the north end. In either case, changes in amount of flow would be small. If anything, the flow into the study area has decreased through the years because there has been a greater lowering of the water table due to pumping in Adams county. A steadily receding water table makes it obvious that water is continually being drawn from storage. Part of this storage has been taken from the east and west fringes of the area, the borders of which were fairly well fixed by the 1948 Geological Survey.

Replenishment Considerations

As previously stated, the principal replenishment of the ground water in Bijou Valley is the loss from stream flow in Bijou Creek. A small contribution may occur from precipitation on the sand dune areas immediately adjacent. But this natural replenishment is inadequate and consideration should be given to augmenting ground-water supplies by artificial means.

It is generally true that irrigation based on a surface-water supply is attended by a rise in the water table. Flooding selected and prepared areas to "sink" water has been pursued successfully for many years in southern California.[3] Using large pits has produced encouraging results in several Mississippi Valley locations. More recently, injecting water through wells in Texas, Arkansas and California has been under test. All these methods have potential.

In the Bijou Valley, irrigation is solely from wells. This means that seepage losses from ditches and irrigation water that percolates down through the root zone *do not add new water* to the ground-water supply. They merely return to that supply a portion of what was pumped out originally.

Sinking flood waters by spreading them over low-value lands seems the obvious thing to investigate and the Colorado Agricultural Experiment Station now has such a study in progress. However, several possible deterrents to the successful use of this method should be noted.

Long and substantially built diversion structures will be necessary to pass the occasional great floods. The cost may be prohibitive in terms of benefits obtained. These large floods carry tremendous loads of suspended sediments. From 1950 to 1954, U. S.

[3] Muckel, Dean C. Replenishment of Ground Water Supplies by Artificial Means. USDA Tech. Bulletin 1195, 1959.

Geological Survey samplings at the engaging station near Wiggins showed sediment loads of 10 percent by weight were common. Loads as high as 25 percent were recorded.

At a 10-percent concentration, an acre-foot of flood water contains enough sediment to cover an acre of land six-tenths of an inch deep. Before such water could be used on a spreading ground, most of this sediment would have to be settled out in a detention reservoir. Such a reservoir obviously would have a short life.

For the same reason, whether pits and wells can be used effectively to sink recharge water is questionable and needs additional research. This technique requires water which is almost clear, and even clear water contains bacteria which produce a clogging action. Preparatory treatment of recharge water may be necessary to halt or minimize this action. In addition, in the case of pits, periodic drying out would be necessary to permit peeling off or stirring up pit bottoms to maintain a reasonably adequate sinking rate.

The most encouraging approach appears to be a soil and water conservation plan which includes building many small detention reservoirs on small tributaries. These would help reduce flood crests and prolong stream flow. Keeping the main stream flowing longer would add greatly to recharge possibilities. Potential benefits from such a plan warrant further study.

Volume of Water Pumped And Effect on Water Table

In the Bijou Valley study, an attempt was made to determine how much water was removed by pumping in 1956 and 1957. Measuring distance to water in wells at the beginning of each pumping season gave some idea of the amount of water taken from storage.

The only definite information that the survey could yield was the volume of "unwatered" sediments, or formerly saturated sediments now occurring above the water table due to the drop caused by pumping. How much water had been removed had to be figured on the basis of an estimated specific yield[4] of these sediments, since no data were available or obtainable to evaluate this factor. This estimate of specific yield was 0.24 or 24 percent.

On this basis, further estimates were made on replenishment from Bijou Creek floods; losses of pumped water from ditches and fields; an estimate of the possible underground discharge from the Fox Hills formation; and a rough estimate of the lateral inflow from the sides of the valley. No account was taken of

[4] Specific yield is the ratio of the volume of water that will drain out of a soil by gravity to its own volume.

inflow and outflow northward in the valley trough, as it was assumed that these would just about balance out.

Admittedly, much of the evaluation of influencing factors is based on estimates. They are unknowns that could be evaluated only by costly and time-consuming means.

Volume of water removed by pumping and the attendant effect on the water table were evaluated fairly accurately in 1956 and 1957. Volume of water pumped in 1956 was determined by field measurements (Figure 2) on 163 pumps out of the 178 operated in the area. Of the 15 wells not measured, 8 were used for only a small part of the season. Estimates on quantities pumped from those wells not measured were made from power use data or area of crop irrigated.

When a flow was measured, power use was also observed. Total power use for the two seasons was furnished by the power supplier[5] operating in the area. From these data it was possible to calculate with reasonable accuracy the number of acre-feet pumped for the season.

Farmers in the southern part of the area where measurements were made late in the 1956 season indicated such measurements were definitely less than average for the season. To compensate for such error, an estimate of 1,500 acre-feet was added to the computed data which were based on a few spot measurements made in July, 1957.

Total volume pumped in 1956, computed in the manner described, was 38,700 acre-feet.

Weather during 1957 was much more favorable than 1956. Much more moisture fell during the winter and spring and this delayed the start of pumping considerably. An estimate of 24,500 acre-feet was made for 1957, based on 1956 water measurements and 1957 power use.

First water-table measurements by the Colorado Agricultural Experiment Station within the study area were made in the fall of 1940. Depth to water table was measured in only four wells at that time. More observation wells were added later and by 1955 the group consisted of nine. In the spring of 1956, measurements on 10 additional wells were made in anticipation of their use in this study. In the spring of 1957, the pumped area was covered thoroughly by measurements in 127 wells. Spring of 1958 saw 89 of these wells measured again.

Hydrographs for those wells having the longer periods of record are shown in Figure 3. The jagged appearance of an apparent recovery between the fall and the following spring measurement is due to a residual effect of the season's pumping. A plane of approximate equilibrium is not established until the following spring; hence the spring measurements are more indicative of actual conditions.

Following the 1956 measurements, changes for 1957 and 1958

[5] The Morgan County Rural Electric Association.

were plotted on a work map of the area for each observation well. Using a section (640 acres) as a unit, a value of the rise or lowering was assigned, based on the included and adjoining wells for that section. Fringe area changes were inferred where no wells were available. The area east of Bijou Creek had few wells and hence became the most uncertain.

For 1956, gross volumetric reduction of water in the alluvium was thus computed as 76,900 acre-feet. For 1957, the figure was similarly figured at only 3,100 feet.

This extreme variation cannot be accounted for solely by differences in amount pumped. Rather, there must have been a substantial replenishment which could not have come from any source other than flood flows in Bijou Creek. Plottings of water-table changes revealed a rise along the entire course of the creek, whereas all the lowering occurred on the west side of the valley. An algebraic summation of the areal changes indicated a slight average lowering of about three-fourths of an inch.

Flows in Bijou Creek occur almost entirely in the spring and summer as a result of intense storms. At the time the Ground Water Branch of the U. S. Geological Survey was surveying the lower South Platte Valley, the Surface Water Branch established a gaging station at a bridge on U. S. Highway 6, east of Wiggins. Table 1 gives run-off as provided by that source through 1950-55.

An estimate was made for 1956, since that station was abandoned July 1 of that year. The 1957 discharge was estimated from a study of the differential flows in the South Platte River between the gaging stations at Weldona and Fort Morgan. These two stations are above and below the junction point. Since there are no other gaging stations on the Bijou, there can be no measure of the water losses from flood flow that can be credited to replenishment.

Ground-Water Inventory

If one were to divide the volume of water pumped in 1956 by the total volume of unwatered sediments, the resulting specific yield would be:

$$\frac{38,700}{76,900} = 0.50 \text{ or } 50 \text{ percent}$$

This ratio is much larger than possible[6] and hence replenishment obviously was taking place. A table was prepared to list all factors considered present and a reasonable value was given to them. The sum of these factors had to add up to total water pumped.

[6] Specific yields for sands and gravels may be as high as 30 percent. When clays are present as in the case of Bijou Valley, the specific yield will be less. Calculations for Prospect Valley, made by the author in 1945 for Technical Bulletin 34, resulted in a value of 17 percent for specific yield.

TABLE 1. Discharge of Bijou Creek Near Mouth in Acre-Feet

Year	May	June	July	August	Sept.	Total
1950	--------	12	349	141	195	697
1951	--------	146	192	23,000	768	24,100
1952	--------	--------	--------	3,750	--------	3,750
1953	2	1	899	288	--------	1,190
1954	--------	--------	1,560	802	7	2,370
1955	34	858	100	1,170	264	2,430
1956[1]	--------	17	5,600	650	--------	6,270
1957[2]	30,700	--------	4,470	--------	--------	35,200
				Average		9,500

[1] Flows for July and August estimated by U. S. Geological Survey.
[2] Estimated by the author by comparing discharges at Weldona and Fort Morgan on the South Platte.

Values given are intelligent guesses and the only defense given for such a tabulation is the need for a reasonable evaluation of the influence of Bijou Creek. Its influence can also be detected in 1951 hydrographs of wells when the water-table decline was less than in the drier years following.

As previously stated, volume of saturated sediments unwatered in the study area was 76,900 acre-feet in 1956 and 3,100 in 1957. For purposes of inventory, a specific yield of 24 percent has been taken to arrive at figures under item 5 in Table 2. Although rather high, this estimate of specific yield is still possible.

To check on volume of unwatered sediments, a calculation was made covering the period 1948 to 1957. The base for 1948 was taken from the U. S. Geological Survey report previously mentioned. Depth-to-water measurements therein shown were made at various times, beginning in 1947 and extending into 1949. These were adjusted arbitrarily to represent conditions in the spring of 1948.

This method indicated that during the nine-year period 1948-57 the volume of unwatered sediments increased by 660,000 acre-feet. Thus, during each year of the 1948-57 period, an average of 73,300 acre-feet of sediments which had been below the water table and hence classified as "watered" sediments were now above the water table and classified as "unwatered."

Using 24 percent as the estimated specific yield from 73,300 acre-feet of sediments, about 17,600 acre-feet of water was the net annual withdrawal from the ground-water supply. This is in reasonable agreement with 1956 findings.

Losses from irrigation were based on estimated crop requirements. Principal crops grown in this area are corn, alfalfa and sugar beets. Total water requirement of alfalfa and sugar beets,

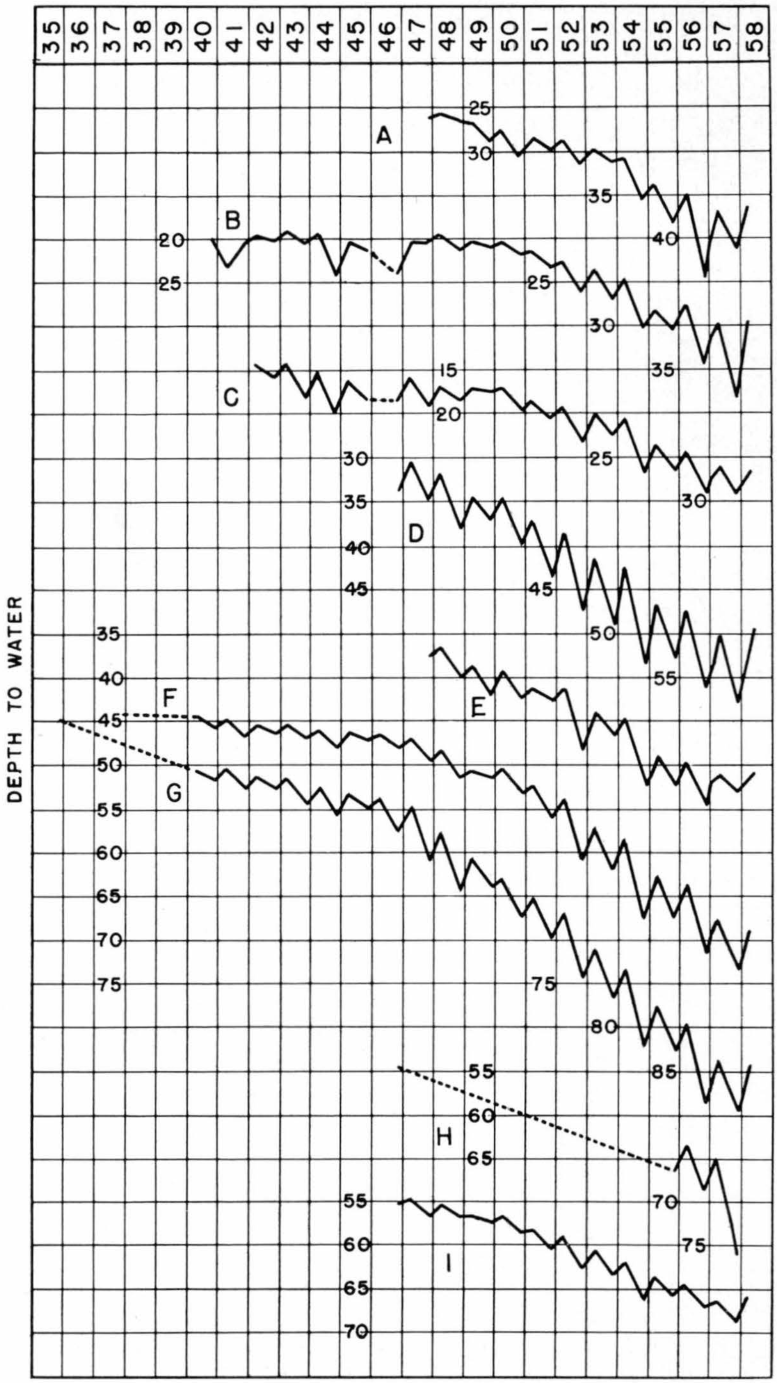

FIGURE 3.—Hydrographs of observation wells in study area.

TABLE 2. Proposed inventory of factors influencing water table in Bijou study area.

Factors considered	1956 Acre-Feet	1957 (Estimated)
1. Losses from flows in Bijou	3,700	12,100
2. Ground-water inflows from sides	2,000	2,000
3. Ground-water escape from Fox Hills	1,500	1,500
4. Losses to water table from irrigation	13,000	8,200
5. Water taken from storage	18,500	700
Total removed by pumping	38,700	24,500

including evaporation, is about 28 inches; corn, 20 inches; and cereals and sorghums, about 14 inches.[7]

Normally, only about 8 inches of total annual precipitation received is effective in growing crops in this area. In 1956, there was little effective precipitation—perhaps one-half the normal amount, or 4 inches. Reasonable average irrigation use by crops in the valley must have been around 20 inches in 1956. On 15,500 irrigated acres the net irrigation use in the study area for 1956 would thus be about 25,500 acre-feet. This figure subtracted from 38,500 leaves 13,000 acre-feet lost, presumably in large part to the ground water.

At planting time in the spring of 1957, excellent soil moisture conditions reduced irrigation requirements by at least one irrigation, compared to 1956. Effective precipitation could have been 11 or 12 inches, well above the 4 inches of effective precipitation in 1956.

Considering 24 inches as the total requirement, 12 to 13 inches would have to be supplied from wells in 1957. Thus, approximate irrigation requirements on 15,500 acres would be 16,000 acre-feet. This figure subtracted from 24,500 acre-feet actually pumped leaves 8,500 acre-feet presumably lost to ground water.

There was no way to measure losses or gains from flows in the Bijou, ground-water inflows from the valley's sides, and ground-water escape from the Fox Hills formation. Hence items 1, 2, and 3 in Table 2 are estimates. Items 2 and 3 are small and not vital to the problem. Item 4 is based on long experience of irrigation engineers on such losses. Item 5 has an error possibility of 4,000 acre-feet in 1956 and 200 acre-feet in 1957. However, if 4,000 acre-feet were added to item 1 in 1956, that quantity would become 7,700 acre-feet. This is improbable since the figure exceeds the total creek discharge as given in Table 1. In 1957, item 5 becomes insignificant and item 1 accordingly becomes reasonably probable.

Note from Table 1 that the

[7] Blaney, H. F. and Criddle, W. D., Consumptive Use and Irrigation Water Requirements of Crops in Colorado, U.S.D.A., S.C.S., 1949.

8-year average discharge at the gaging station is 9,500 acre-feet. Such a period is not nearly enough to establish an average, but is an indication. Net withdrawals from storage were about 18,000 acre-feet annually from 1948 to 1957. Had all the water passing the gaging station in this period been returned to the underground water supply along with that which was actually sunk, there still would have been a deficit.

Probable Life of Water Source

As a study in economics, it would be desirable to project the life of the water resources into the future. If the saturated depth of the alluvium were the same over the entire area, and if the water table receded at the same rate, a reasonable prediction would be possible.

Neither of these conditions prevails. There will be no sudden exhaustion of ground water and no abrupt change in farming methods. But wells will become constantly less productive until they can no longer be operated economically, with the southern region first to be so affected. Deeper wells will survive for a longer period, hence those in the northern part will be abandoned last. This will occur many years later.

In storage in 1948 were about 1.0 million acre-feet of water contained in approximately 4.3 million acre-feet of saturated sediments. In the nine years following, the volume of saturated sediments was reduced 660,000 acre-feet (157,000 acre-feet of water). This left in storage in 1957 about 870,000 acre-feet of water contained in 3.6 million acre-feet of saturated sediments. Assuming that only a third of the total actually could be used, and that average volumetric depletion of saturated sediments would be 70,000 acre-feet a year, the ground-water resource for irrigation probably would last 15 to 20 years more.

Well hydrographs (Figure 3) back up this prediction. These hydrographs, projected on the basis of performance of the last 18 to 20 years, suggest a further water-table decline of 20 or more feet in a similar length of time. In about half the study area, this decline would make most of the irrigation wells useless. As previously noted, however, abandonment would be gradual and localized. As the wells are progressively abandoned, a dwindling demand will prolong the life of the remaining wells.

How changing lift conditions affect pump efficiency should not be overlooked. Most pumps in the Bijou Valley were selected for a lower lift than now exists. Many have been changed at considerable expense to meet the new conditions. It has been common to see pumps surging—that is, pumping part time because

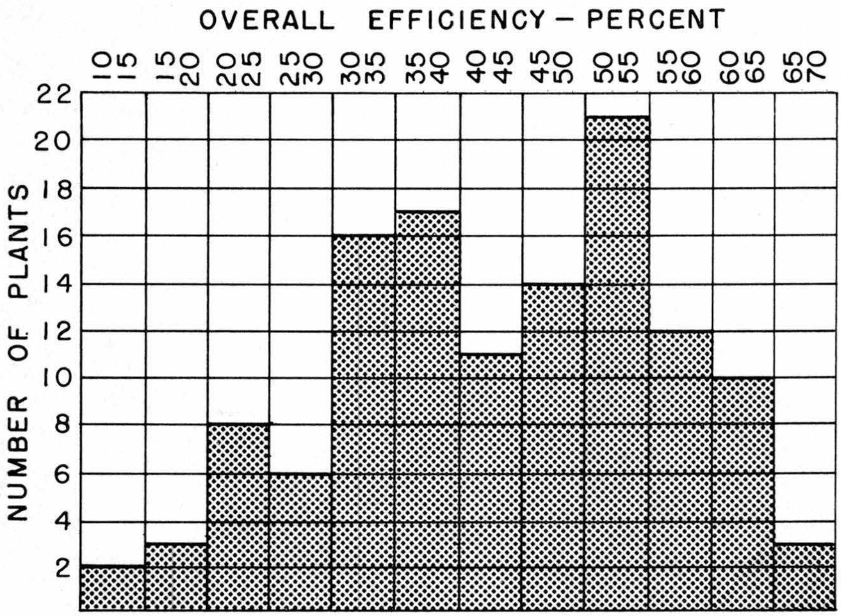

FIGURE 4.—Distribution of overall efficiency values of pumps tested.

they were capable of lifting more water than the wells could supply.

The relation of water produced to amount of power required is illustrated in Figure 4, which shows that about 63 percent of the pumps were operating at a measured overall efficiency of less than 50 percent.

Summary and Conclusion

Pumping for irrigation within the arbitrary study area in Bijou Valley began in 1935. Within this area of 53,750 acres, 173 operating irrigation wells were serving some 15,500 acres of crop lands in 1956.

Initially, there was a small annual decline of the water table. But beginning about 1949, the decline accelerated in much of the area, reaching the rate of about one and a half feet each year. The saturated thickness of the sands and gravels at the beginning of pumping varied from 80 feet at the south end to 150 feet at the north end of the study area. It is obvious that a large proportion of well capacity already has been lost. Well depth is strictly limited by thick shale deposits and no improvement in capacity is possible by deepening.

Water is being withdrawn from storage continually under present conditions. Replenishment from flood flows in Bijou Creek occurs in substantial amounts very infrequently and the downward trend of the water table is expected to continue. The yield of wells will continue to decline and abandonment will occur progressively, starting where conditions are poorest.

Because abandonment will slow the rate of water-table decline, the present rate cannot be projected far into the future. However, it is possible that within 15 or 20 years half or more of the area now irrigated will be back to dry farming.

Such change will have a severe effect on the economy of the community.

The Need for Legislation in Colorado

Colorado residents should be particularly concerned about ground water, since it plays such an important role in their lives. Everywhere it is becoming more and more apparent that water is the limiting factor of population growth.

Extent of surface supplies can be measured reasonably well, and the West particularly has learned to abide by rules pertaining to its use. Ground water is not so easily measured, and applying rules for its use is more difficult.

The complexity of the ground-water problem and lack of understanding about it has resulted in much confusion as to extent of supply.

Developing ground water involves a modest investment, compared with the cost of developing present surface-water supplies. Because of this difference in cost, ground-water use in Colorado has reached a very considerable magnitude. That being the case, ways in which its fair and equitable use might be achieved should be considered.

Ground-water legislation can assume one of several regulatory forms. Each should be examined to determine the impact it may have in a given situation. Colorado ground-water conditions vary widely in geologic occurrence and in relation to surface-water use. A satisfactory rule of law must therefore be broad and sufficiently flexible to meet these conditions if it is to be equitable and enforceable throughout the state.

A workable law would have to clarify possible rights among ground-water users in the same basin and should protect the resource from total exhaustion. The statute would also have to resolve the very real conflict of interest between ground-water and surface-water users.

At present, the only recourse in settling disputes is through the courts. These courts must employ rules intended for another purpose and their decisions are influenced by precedents of dubious value when related to the current situation.

Water removed from the ground may be replaced by natural or artificial means in whole or in part at varying rates. It is, therefore, a renewable resource. The balance between extraction and replacement is reflected in the vertical movement of the water table.

This balance or imbalance is of utmost importance in the proper use of the resource.

One of the basic considerations under any regulatory system, aside from those of a legal character, is that of degree of conservation to be applied. Extreme conservation could result in little use of the resources.[8] The opposite extreme would exhaust the water supply in a comparatively short time.

In the first instance, the water supply would be preserved for future generations, possibly for a higher priority use than that of agriculture.

Orderly development would permit the ground-water hydrologist to determine the limit or duration of the resource. The economy of the area under consideration would thus be subject to no great change.

In the second instance, much new wealth would be produced currently to be enjoyed by those now occupying the land. During development, the community would invest in improvements such as power and telephone lines, roads, schools, and private buildings.

Upon exhaustion of the ground water, much of this investment would be greatly depreciated. The effect of such a change upon the economy of a community would be serious.

Rules of Law Relating to Ground Water

Two principal rules of law govern the use of water. One is that of riparian rights, which is a non-consumptive use right. As laid down in the old English law relating to surface waters, it could be exercised by owners of abutting land only. This rule also gives ownership to all that lies below the land surface.

Several variations of the riparian rule have appeared in the United States. One, the American rule of reasonable use, was promulgated in 1862.[9] The other, an extension of the first is called the correlative rights doctrine, as adopted by California courts. Reasonable use, however, is difficult to define and must be left to the judgment of the courts.

The correlative rights doctrine has not entered into ground-water consideration in Colorado. This rule was developed in the California courts for application to irrigation. There, it holds essentially that each land owner is entitled to his proportionate share of the underlying water. That share is based on size of the land owner's surface area, as compared with size of the entire overlying area which can be irrigated from the underlying ground-water supply.

Under the correlative rights doctrine, a pumper can be enjoined from pumping water to

[8] A state engineer of New Mexico has suggested a rule to the effect that a ground water basin need not be expected to last more than 40 years.

[9] Bassett v. Salisbury Mfg. Co. 43 N.H. 569, 82 Am. Dec. 179 (1862).

a point outside the basin unless there is a proved surplus. Prescriptive rights are recognized. Loosely stated, a prescriptive right is one gained through use without legal procedure. A court can take over jurisdiction of a basin and determine the rights of the ground-water users.

The second principal rule of water law is that of priority of appropriation. In this, riparian rights are set aside as being untenable in an area where water is consumed or removed to points remote from a stream for irrigation of crops, or other purposes. It holds that the first appropriator who puts the water to beneficial use has a better right to that water than those who follow. Thus, when a surface stream becomes reduced in volume and there is not enough water for all, appropriators are denied water in the reverse order of their dates of appropriation.

The rule of prior appropriation evolved from requirements of early gold miners in California and Colorado. Its roots are in United States land laws which were extended to include use of water in placer mining. Colorado was the first state to adopt this rule in its constitution and statutes. It was soon followed by nearly all the western states. In each case, the result was a body of laws covering administration of surface waters.

In the beginning, surface-water statutes were extended, or interpreted by the courts to cover ground water. Now, however, many western states have adopted specific ground-water laws because of the growing demand on that resource.

New Mexico was the first state to draft ground-water legislation. Its statutes cling closely to the prior appropriation doctrine. With the exception of Arizona, those adopted by the western states also follow this rule. However, deviations from its strict application are notable, particularly in Wyoming.

In general, courts had to feel their way into this new subject of ground water. Two conditions ordinarily were recognized. One was where ground water was flowing within an ascertainable bed and banks. The other was where water was moving in a broad stream in no discernible direction. This was called percolating water.

The rule of prior appropriation usually was applied to the first condition and the common-law riparian rule to the second. Ground-water hydrologists regard this distinction of occurrence as unfortunate and unwarranted.

Rules as Applied in Colorado

The American rule of reasonable use, a modification of the English or Common law, embraces the concept that the owner of the overlying land should use ground water in a way that will not intentionally injure the rights of adjacent land owners.

It was employed in the case of *Ivan M. Thomas et al* v. *John*

J. and Frank Brady in the San Luis Valley in 1953. In this case, the plaintiffs contended that operation of the Brady well caused numerous nearby domestic artesian wells to cease flowing. The judge of the district court ruled in favor of the defendants on the premise that the plaintiffs still had reasonable access to a water supply by employing pumps in their wells.

William R. Kelley, an experienced Greeley, Colorado, attorney on water matters, has expressed his concurrence in applying the American rule of reasonable use to non-tributary ground water.[10] Others do not agree with this concept.

In Colorado, courts early adopted a rule that any groundwater tributary to a flowing stream was subject to the same rule of law as surface waters. Further, the presumption has been established that ground water is tributary unless proved otherwise.

This means that although tributary ground water may be appropriated, such appropriations will necessarily follow in order of time all other appropriations from the stream in question. The courts have not been called upon to adjudicate along these lines. Hence it is an unsettled question and neither surface- nor ground-water users have pressed for any clarifying action. The foregoing statement needs some qualification.

In 1952, the District Court in Larimer County adjudicated a large group (not all) of irrigation wells in the Cache la Poudre drainage. This adjudication was independent of surface-water appropriations, it being assumed by the court that the ground water was "not tributary" to a natural stream. However, this statement was qualified by further wording that such water ". . . if left undisturbed in its natural condition would not *appreciably* augment the flow of any natural stream . . ." The decision was not supported by expert testimony; neither has it been contested.

Without doubt, expert testimony would have demonstrated that this water was technically "tributary." The adjudication produced considerable confusion in the minds of ground-water users and the legal profession.

The condition under which ground water is not tributary to a stream has not been passed upon by the Supreme Court, except as to some waters developed in mine tunnels. However, a district court in 1946 made an adjudication in the Grand Junction artesian basins wherein expert testimony was to the effect that the water in that basin was not tributary to stream flow. The decision is now being contested.

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[10] W. R. Kelley, Colorado Ground-Water Act of 1957. Rocky Mountain Law Review, Vol. 31, No. 2, February, 1959.

Colorado's Ground-Water Law

Colorado's present ground-water law, passed in 1957, follows none of these rules. It does provide certain police powers as to reporting of wells drilled and their logs. It is silent on the matter of ground-water ownership.

Ownership of surface waters is fixed by the constitution as vested in the State. The constitution also states that the right to appropriate unappropriated water shall never be denied.

The ground-water law permits designation of a pumping area as a "tentatively critical district" when, upon findings by a commission, through investigations or hearings, "the withdrawal of ground water appears to have approached, reached or exceeded the normal annual rate of replenishment." When a decision is made, boundaries are established and the election of a District Advisory Board of five is authorized. The essence of the law is expressed in these three paragraphs:

The Commission shall at any time after the designation of a Tentatively Critical Ground-Water District upon its own initiative, or at the unanimous request of the Local Advisory Board, or upon petition of two-thirds of the resident landowners, using ground water not exempted in Section 8 within the district, remove any restrictions, modify any restrictions, or remove the designation of the area as a Tentatively Critical Ground-Water District.

District Advisory Boards shall have the duty and responsibility to consult with the Commission on all ground-water matters affecting their respective districts, to determine in conjunction with the Commission and the State Engineer whether a critical area should be enlarged or contracted, to cooperate with the Commission and the State Engineer in the assembling of data on the ground-water aquifers in the area and the enforcement of regulations or restrictions which may be imposed thereon, and to assist the Commission and the State Engineer to the end of conserving the ground-water supplies of the area for the maximum beneficial use thereof.

It is expressly provided, however, that the consent of a majority of the members of a District Advisory Board of an area shall be necessary before an initial designation of Tentatively Critical as to such area may be kept in effect for more than 12 months. After such initial designation, subsequent designations and accompanying restrictions may be imposed by the Commission with the consent of the District Advisory Board for the area, to extend for 12 month periods prior to further review.

Application of Rules to Bijou Valley

The American rule of reasonable use has possibilities for application to conditions such as those which occur in Bijou Valley. It already has been used in the San Luis Valley where ground water was considered as percolating water and not tributary to a stream.

To adapt this rule to a control program might meet with more difficulties than with the priority-permit system. However, it seems conceivable that a reasonable use law could be so drawn as to include regulatory features. Machinery would have to be set up making it possible to prevent overdraft or halt overdraft in progress. Means of pro-rating the remainder of a diminishing supply would be essential. Since prescriptive use already has been established, rights which may have accrued would need to be recognized without reference to the time of their initiation.

It would appear feasible that a law based on the American rule could recognize the difference in the degree of effect on stream flow where ground water is technically tributary. Location of a ground-water development has a profound differential effect on stream flow. It might not be too far-fetched to say that a well 4 or 5 miles from a stream would have no significant effect on flow of that stream.

Most pumping in Bijou Valley would have very little effect on flow in the South Platte River. Any influence would be greatly delayed and might be eliminated during a replenishment period. For practical purposes, the ground water could be considered not tributary. As such, it could be treated legally by rules that apply to that type of occurrence.

As with any other rule, the American rule would need adequate authority for administration to be effective. The idea of a commission to advise an administrator is desirable. A representative group should be available to confer with the administrator before any important decision is made on problems as complex as those involving ground water.

If features mentioned could be incorporated under this rule, "mining" ground water might be prevented in such valleys as the Bijou. Many difficulties that lead to litigation might be anticipated and avoided. With proper management the economy of a basin could be sustained over a long period of time.

A ground-water law which follows the strict rules laid down for use of surface water by the priority of appropriation doctrine would not be realistic or equitable for ground-water users in Bijou Valley.

Development here followed no systematic plan. Some early wells were drilled in the least advantageous locations and many were affected seriously as the water table dropped. Many wells drilled later in deeper parts of the valley were of higher capacity. In operating these wells their owners, collectively and individually, caused injury to the earlier appropriators.

This was not done willfully, but rather in the light of what was considered to be the rights of those who owned the wells of higher capacity.

Bijou Valley is long and relatively narrow. A stream channel which is normally dry but subject to large floods winds along its entire length. Losses from stream flow are the major source of replenishment for the valley's ground-water supply. This replenishment takes place locally. Hence, ground water can be withdrawn from one place without affecting other locations along the stream course.

Had the early appropriators sought to enjoin those who came later, development would have been greatly retarded. Litigation would have joined nearly all residents in the valley and proving who was injuring whom would have been difficult and costly.

To apply the surface water rule of maintenance of a previous condition of diversion to avoid injury to others would not be practical.[11] Neither would substitution be workable, in most cases. The simple inclusion of a system of permits to regulate development already established is not sufficient.

Provision must be made to recognize prescriptive rights in some degree, to prorate limited supplies and possibly to cut back use.

The matter of wells materially and adversely affecting stream flow is a very knotty one. It must be disposed of eventually, but it should not enter the kind of situation presented by the Bijou Valley.

From the standpoint of consistency in water law, it is desirable that a ground-water code be based on a modified rule of prior appropriation. This rule has been modified by other states to meet the entirely different physical conditions in which ground water occurs. With proper modifications, it should be entirely possible to frame a law which would be equitable and satisfactory in areas such as Bijou Valley.

It is apparent from reactions of past legislatures and students of the problem that the district feature including an elected advisory board is desirable and politically necessary.

Colorado's Ground-Water Act of 1957 first was applied to a major part of Bijou Valley in January, 1958, when the Ground-Water Commission designated this area as "tentatively critical."

At subsequent hearings, both lay and expert testimony was to the effect that the water table under a large part of the district was declining annually at a serious rate. The area treated in this report was a part of the district.

Opposition to the "tentatively critical" designation immediately formed. Since the District Advisory Board had the power to revoke the Commission's decision, the attitudes of its individual members became very important.

Candidates for election to the advisory board were required to announce for or against the district. Those announcing against the district received the majority of votes and voted unanimously to override the decision of the commission.

Thus the first effort to put the new ground-water code into effect resulted in defeat.

This test of Colorado's ground-water code indicates its ineffectiveness as a conservation measure. It could well be, however, that other areas in a plight sim-

[11] This includes maintenance of lift conditions.

ilar to that of the Bijou Valley could initiate organization of a ground - water district. Several fall into this category. Although the act does not follow any of the doctrines previously described, the machinery is provided for voluntarily agreed-upon conservation measures to be adopted.

It remains to be seen whether the law can be useful under conditions where the land owners seriously wish to invoke such measures.

Conclusions

Colorado's Ground-Water Act of 1957 has possibilities of solving some of the difficulties that exist in such valleys as the Bijou. But it is permissive legislation and thus any implied controls can be easily avoided. The original bill was framed around the priority-permit doctrine but was greatly altered by the legislators. Being a compromise measure, many of the fundamental controversial features of a complete code were avoided.

The idea of Colorado departing from the priority of appropriation doctrine is abhorrent to water lawyers. However, in its present form, this doctrine is not suitable for application to ground water. Extensive alteration of many of its basic features is necessary to meet the peculiar requirements of ground-water occurrence and development. Presumably, with such changes, it would be acceptable in such already developed areas as Bijou Valley. If this can be effected, the priority of appropriation doctrine would be preferable to any other rule.

If a way cannot be found to frame a sensible ground-water law under the priority system, an exploration of the American rule of reasonable use is indicated. The courts have accepted this rule in Colorado and other states when applied to percolating water. Conditions in Bijou Valley might be considered as falling into the category of percolating or non-tributary water. The question arises: Can this rule be applied to tributary water? The rule has a number of aspects that could make it practicable for application to ground-water problems.