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WESTERN RESOURCES CONFERENCE
Boulder, Colorado
August 1960

Prepared, Reproduced and Distributed by the

COLORADO GROUND WATER COMMISSION
A DIVISION OF THE
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO

Steve McNichols, Governor

Edward L. Clark, Director DNR

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GROUND WATER SECTION

WESTERN RESOURCES CONFERENCE

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PREPARED, REPRODUCED AND DISTRIBUTED BY

COLORADO GROUND WATER COMMISSION

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GROUND WATER SECTION

WESTERN RESOURCES CONFERENCE - 1960

Presented through the

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GROUND WATER SECTION

WESTERN RESOURCES CONFERENCE - 1960

Steve McNichols, Governor of Colorado, initiated the ground water study out of which grew the idea for the Ground Water Section.

The Ground Water Section of the Western Resources Conference was made possible through the cooperation of Dr. Edward L. Clark, Director, Colorado Department of Natural Resources; Felix L. Sparks, Director, Colorado Water Conservation Board; George W. Colburn, Engineer and Executive Secretary, Colorado Ground Water Commission; Clyde S. Conover, Assistant Director, United States Geological Survey, Ground Water Branch, Denver, Colorado; Wells A. Hutchins, Agricultural Research Service, Department of Agriculture; and the participating states and their agencies.

The Western Resources Conference is sponsored jointly by the University of Colorado, Colorado State University, and Colorado School of Mines.

The Ground Water Section was proposed by Colorado's consultants on ground water. Its purpose was to assemble the officials charged with the administration of ground water programs in all states west of the Mississippi in a cooperative effort to exchange data on ground water resources, their management and optimum use. Invitations to participate were extended to the official water agencies of each of the states, and representatives of the Ground Water Branch of the United StatesGeological Survey, and the Department of Agriculture.

The proposal was accepted by the Western Resources Conference on condition that the consultanta be responsible for the invitations, the program, and the duplication of the papers presented. The cooperating state and federal agencies assumed the expense of the attendance of their representatives.

The State of Colorado expresses its appreciation to the Western Resources Conference, its chairman, Dr. Morris E. Garnsey, and Alan Brown, Director of the Bureau of Continuing Education of the University of Colorado, who were hosts to the conference, the participating states, and especially the speakers who prepared and presented the papers. The experiences of the sister states will assist Colorado in achieving a more workable ground water program. We hope each state participating will benefit from the material presented.

David J. Miller
Samuel Chutkow

Consultants

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WESTERN RESOURCES CONFERENCE - 1960

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GROUND-WATER RESOURCES--DEVELOPMENT AND MANAGEMENT[1/]

By

Clyde S. Conover[2/]

The need for broader appreciation, evaluation, and management of our ground-water resources is becoming more evident every day. Also, as development of our water resources approaches a finite limit, it becomes evident that ground waters and surface waters must be developed and managed as one water supply. This integration, like the solution of many other problems, is easier said than done.

Effective development and management of ground water, whether singly or in conjunction with surface water, requires knowledge and appreciation of its physical environment. Though ground water and surface water are phases of the hydrologic cycle and therefore are interdependent, their prime common denominator is the fact that both are wet. There are other common factors, of course, such as chemical character, but many of the physical situations in which ground water and surface water exist are quite different. It is only because they are different that we have water during dry periods. Mother nature planned it this way, and if man is to make maximum use of ground and surface waters he must fully understand and tailor his actions to take advantage of these different environmental factors.

Take storage, for example. In most areas, the volume of ground water in storage is several times that of surface water. In the United States as a whole, the quantity of water in underground storage, within half a mile of the land surface, is several times that in all the large lakes of the North American Continent and more than 100 times the annual runoff of streams in the United States (Nace, 1960, p. 3). Though the volume of ground water in storage is large, its natural rate of replenishment is small in comparison. For the United States as a

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whole, several hundred years would be required to replenish the stored ground water, whereas streams are replenished seasonally. An outstanding example of large storage and small replenishment is offered by the southern High Plains in Texas and New Mexico. Overall, the ground water in storage in the Texas portion is about 200 million acre-feet, but if exhausted it would take considerably more than 1,000 years to replace (U. S. Senate Select Committee on National Water Resources, 1960a, p. 15).

The rate of movement of ground water also contrasts sharply with that of surface water. Generally, ground water flows inches or feet per day, whereas the flow in streams is measured in feet per second or minute. The contrast in rates of flow is illustrated by the movement of ground water in the aquifer supplying Houston, Tex. Houston, the largest city of the United States dependent mainly on wells for municipal supply, is served by an aquifer having a better-than-average capability for transmitting water. Even so, a cross section of the aquifer 45 miles wide and 600 feet thick is required to transmit 80 mgd (million gallons per day) to the Houston area at a hydraulic gradient of 10 feet per mile. New York City obtains three times as much water from Croton Reservoir through a pipeline less than 14 feet in diameter (Thomas, 1951, p. 98).

The flow in streams is such that water from a large area can be gaged at a single location. Surface reservoirs also can be gaged at a single location. However, permeable earth materials offer significant impedance to flow of ground water, with the result that a ground-water reservoir (aquifer) must be gaged at many points if the status of the resource is to be evaluated. Water-level measurements in a single observation well may indicate conditions in only a small part of an aquifer.

Though stream channels are not simple conduits, they can be easily mapped and measured. The same is not true of aquifers. Aquifers are composed of a wide range of earth materials deposited by many geologic processes. The very nature of geologic processes insures that the materials composing aquifers will vary in character both laterally and vertically. Formations that are water bearing (aquifers) in one locality may change laterally to become nonwater bearing (aquicludes) in another area. Several aquifers may be present in a particular area, separated vertically by aquicludes, and both water-table and artesian conditions may exist. The source of water to and the area of discharge from an aquifer may be distant or nearby. Therefore, aquifers are not easily mapped. However, they must be mapped, their water-bearing characteristics determined, and their hydrologic regimen evaluated before decisions can be made as to optimum development and management of the ground-water resource over a long period of time.

Water is commonly referred to as a renewable resource. Strictly speaking, this is true. However for many ground-water reservoirs, especially those in the arid and semiarid parts of the country, the question of renewability is academic so far as the life span of present water users is concerned. Even in humid areas, ground water withdrawn from wells is renewable by natural recharge only where the wells are so placed that natural discharge is reduced or natural recharge increased by an amount equal to the net consumptive use. If the wells cannot be ideally located--or, even if they are but the net consumptive use of water exceeds the natural discharge (recharge) of the aquifer--then the reserve can be renewed only if the withdrawals are reduced or stopped.

Year-to-year declines in water level are the usual condition in many of the developed aquifers of the West. Persistent declines are evidence of depletion of ground-water resources. Whether the depletion is localized or aquifer-wide, and whether it is temporary or will persist for periods equal to or greater than long-term climatic cycles, depends upon the local geohydrologic situation. Lowering of water levels is a natural consequence of pumping of wells, so that even in humid areas of abundant recharge there are declines of water level.

In areas of shallow-lying ground water, particularly in many stream valleys of the West, rank growths of phreatophytic vegetation consume large quantities of water. The area of phreatophytes in California, Arizona, New Mexico, Nevada, Utah, and Colorado currently is estimated as 7 million acres. These plants consume 10 to 12 million acre-feet a year. The area of phreatophytes in New Mexico and Arizona is almost 1 million acres, and the water consumption is 2½ to 3 million acre-feet per year (U. S. Senate Select Committee on National Water Resources, 1960b, p. 2). Not only do these plants waste large amounts of water, but the water transpired is virtually pure. The chemical character of the water remaining therefore has deteriorated. Salvage of this wasted water by such measures as eradication of the vegetation and construction of drains is only partially effective. However, in many areas capture of this wasted water could be easily accomplished and would be a natural consequence of the lowering of water levels caused by pumping. If wells are located with the objective of salvaging water, then the net usable supply can be increased and the quality improved. However, if wells are installed with water supply as the only objective, then their location may be such that the pumped water comes from ground-water storage or from streamflow. If so, the individual well owner benefits temporarily at the long-term expense of all water users.

Use of ground water may provide an increase in water supply through the medium of recirculation. This is particularly true in irrigated areas, where a significant portion of the water applied to the crops may infiltrate to the ground-water body. It is then pumped to the land surface for reuse by the same individual or his neighbors.

Reuse of surface water is on a downstream basis, each succeeding user receiving a supply diminished in quantity and less acceptable in quality. Recirculation of ground water, though it may take place on the same property, likewise diminishes the quantity and deteriorates the quality. In an aquifer, the continued recirculation of water results in an accumulation of dissolved salts, whereas in a stream the water of diminished quality is flushed downstream. Thus, in many areas of ground-water development, the accumulation of salts in the water poses a more serious threat to the life of the resource than does the decrease of supply. The Wellton-Mohawk area of the Gila River basin in Arizona illustrates such deterioration through recirculation. In 20 years the concentration of salts in the ground water there increased from 7,000 to as much as 16,000 ppm (Thomas, 1951, p. 59).

Development and management of ground-water resources, to provide the optimum use of the water for the benefit of a large segment of the population and for the greatest period of time, therefore should be based upon scientific hydrology and tailored to the geohydrologic characteristics of the particular aquifer in question.

Many aquifers may be classified, with respect to development and management, into two broad categories: those which have large storage but negligible recharge and which are not intimately related to streams, and those associated with streams. By proper management, a dependable supply of water of acceptable quality can be developed on a virtually perennial basis from aquifers of the second class -- that is, those associated with streams. Aquifers of the first class can yield only a small perennial supply once their storage is depleted.

Aquifers under the first category - those having large storage and little recharge - correspond generally to those having "reservoir" problems as discussed by Thomas (1951, p. 35). In such aquifers to limit the use of water to the rate of recharge is not feasible because of (a) the large demand, (b) the very small recharge, or (c) aquifer characteristics such that natural discharge cannot be diverted or stopped feasibly by development. These are the aquifers where water is being mined, and must be mined, if the water resource is to serve a useful purpose. The problem is to recognize the mining situation and to manage the resource for the greatest good over the longest possible time. A large number of developed aquifers in the West fall into this category. Included in the areas of current or potential ground-water mining are the southern High Plains of Texas and New Mexico; the northern High Plains in Oklahoma, Colorado, and Nebraska, and many of the intermontane valleys of New Mexico, Arizona, California, Nevada, and Utah.

Consider the southern High Plains of Texas and New Mexico as an example of a problem of development and management of an aquifer having a large volume of water in storage, but only a small unit rate of replenishment.

The southern High Plains, or Llano Estacado, lies south of the Canadian River in Texas and New Mexico. It has a total area of some 30,000 square miles. Conspicuous escarpments form the east and west borders. The north border is the deep canyon of the Canadian River. The Ogallala formation is the aquifer, and its boundaries are essentially those of the High Plains. The Ogallala is thin or absent in some areas but is more than 600 feet thick in other areas. The total water potentially available from storage in the Texas portion in 1958 was about 200 million acre-feet (Cronin, 1959, p. 11), but the annual average rate of recharge is only about 50,000 acre-feet. Storage and recharge in the New Mexico part of the High Plains are perhaps a third as great. Thus, total storage in the southern High Plains was perhaps 250 to 275 million acre-feet in 1958. About 40 million acre-feet had already been pumped, and the current rate of pumping is more than 100 times the recharge. Obviously, limiting development to the rate of recharge would mean that the large volume of water in storage would not be utilized. Further, even if it were decided so to limit the development, it would be physically almost impossible to carry out the decision if the premise were that doing so would result in a perennial water supply. The only means of developing water from an aquifer on a perennial basis is to locate wells so that, over a long time, the natural discharge can be stopped, and therefore diverted to the pumps, or the recharge can be increased, or both, in an amount equivalent to the consumptive use.

Most of the discharge from the High Plains occurs along or near the eastern escarpment. Originally some discharge occurred from groundwater lakes such as at Portales, N. Mex., and Muleshoe, Tex. Over most of the Plains the water table is more than 50 feet below the land surface, and lowering of water levels in these areas cannot induce more recharge. Therefore, it is not physically possible, except in small areas, to locate wells on the High Plains so that the water pumped will come other than from storage.

The lowering of water levels caused by pumping from a water-table aquifer such as the Ogallala formation is transmitted laterally at a slow rate. The major lowering of water level occurs in the vicinity of the well. The areal spread of the cone of depression is independent of the pumping rate and is a function of time and the hydraulic characteristics of the aquifer. An increase in pumping, or localized heavy pumping, such as caused by many wells in one locality, deepens and steepens the cone of depression. The water can be pumped at such a rate that it is virtually exhausted in the area of heavy pumping, yet water levels are affected only slightly and slowly a few miles away. For example, pumping on the High Plains has been concentrated in the areas where the land is suitable for irrigated farming and where adequate wells can be obtained. As a consequence, water levels have declined more than 100 feet in some of these areas and an average

of more than 50 feet under whole counties (Cronin, 1959, p. 10,) yet in areas of little or no pumping the water levels have not declined, or have declined only a few feet.

The general solution to the problem of optimum development of ground water in areas of mining is therefore twofold: conservative pumping from adequately spaced wells. The exact rate and spacing are a matter of decision which must take into account the aquifer characteristics and which revolve essentially around philosophical and long-term economic considerations. A long-term, stable development permits amortization of capital expenditures for farm equipment, city and highway development, schools, etc. Also of importance, a long-term, stable development permits the economy of the region to evolve to a level such that conservation and rectification measures can be undertaken. In the final analysis, all conservation and rectification measures are economic - a balancing of cost with benefits, either locally, regionally, or nationally. Some conservation and rectification measures require research, and research takes time - time bought by managed development to permit a stable, growing economy to pay for the research.

An example of management that recognizes the two factors of time and spaced development in ground-water mining is afforded by regulatory measures set up by the New Mexico State Engineer in the Lea County portion of the High Plains. Regulation in Lea County is based essentially upon assuring a firm minimum 40-year life of extractable water for agricultural purposes. It is accomplished on a township basis by taking into account the recoverable water under each township.

Such farsighted regulated management of ground-water mining assures a stable development and economy and also allows the time needed to investigate and institute conservation and rectification measures. Such measures could include (a) increasing recharge, (b) improving water-application practices, (c) substituting crops of lower water requirements, (d) changing from an agricultural to an industrial economy, (e) utilizing (perhaps demineralizing) inferior waters for certain industrial processing, (f) importing surface water, and (g) transporting ground water from undeveloped to developed areas.

Transporting ground water from undeveloped to developed areas to alleviate local shortages is a distinct possibility in some areas of the High Plains, especially for municipal and industrial supplies. Amarillo and Lubbock, Tex., are doing so, and Portales, N. Mex., is favorably situated to transport water from the sand-dune area to the north. A significant part of the High Plains is underlain at less than plow depth by cemented sediments called "caliche" which are not suitable for agriculture. The formation of the caliche rocks in these areas may be said to have effectively saved water for the future, and

the rocks therefore may be "worth their weight in water" to the economy of the Plains.

Aquifers of the second category with respect to development and management--that is, those associated with streams - correspond to those having "watercourse" problems and generally to those having "pipeline" problems as discussed by Thomas (1951, p. 36). These are aquifers in which the amount of water that can be developed is sufficiently large to warrant management on a perennial basis. The ground water in these aquifers is related to surface streams, either directly along a stream reach or indirectly through spring flow or other natural discharge.

The prime requisites for development of water from an aquifer on a perennial basis are as follows: (a) the location and character of the discharge areas are such that pumping from wells can effectively reduce the natural discharge from the aquifer, and (or) (b) recharge to the aquifer can be increased in the recharge area or induced in the discharge area. Development can be perennial if the net consumptive use of developed water does not exceed the sum of (a) natural discharge stopped and (b) recharge induced or increased, by virtue of the development or by other artificial means.

Ground-water reservoirs in alluvial valleys of essentially perennial streams, wherein the surface and ground waters are intimately related, fit this category. Examples of such are the Middle, the Rincon, and the Mesilla Valleys of the Rio Grande in New Mexico and the Duncan-Virden and the Safford Valleys of the Gila River in New Mexico and Arizona. In Colorado the South Platte and Arkansas River Valleys and some of their major tributaries also fit this category.

In such valleys, surface water is usually applied to irrigate the lands. A part of the surface water infiltrates to the ground-water body and returns to the stream through drains and by ground-water seepage. The amount of water available for net consumptive use is essentially equal to the difference between the inflow, primarily that brought in by the stream, and the outflow that must be allowed by virtue of prior water needs and rights downstream (and by the necessity of maintaining salt balance). In many such valleys, the valley consumptive use of water exceeds the beneficial consumptive use because of the areas of native phreatophytic vegetation. For example, in 1936 the consumption by irrigated lands in the Middle Valley of the upper Rio Grande was 157,000 acre-feet, whereas the total consumptive use was 583,000 acre-feet (Natural Resources Committee 1938, p. 91).

Streamflow in such valleys is occasionally inadequate for the needs, in spite of regulation by surface reservoirs. Consequently, wells have been installed. As these wells commonly are located at a spot convenient to provide water, evapotranspiration by native vegetation is reduced little if any; accordingly, net consumptive use of the

pumped water results in either diminution of streamflow or reduction in ground-water storage, or both. Before pumping is undertaken in most such stream valleys, ground water feeds the streams. After pumping lowers the water table the ground-water accretion to the streams is reduced or, more frequently, the gradient of the water table is reversed so that the stream loses rather than gains water. Water shortages downstream are thereby increased, and individuals downstream who are able also install wells to satisfy their water needs. Because of this extraction from storage, the stream will continue to lose water even after normal inflow to the valley is resumed. Therefore, pumping will be continued until such time as increased efficiency in water use, reduction of nonbeneficial losses, and inflow of excess surface water result in replenishment of ground-water storage.

A study of the effects of pumping in the Rincon and Mesilla Valleys of the Rio Grande in New Mexico showed that pumping would need to be continued for 4 years after a return to normal surface supply following a 5-year period of 50-percent-normal surface supply. In the absence of excess surface water, pumping there would need to be continued, even in years of normal surface supply, unless the debt to ground-water storage could be gradually reduced by more efficient use of the pumped water and the reduction in pumping that would be made possible. It was shown that ground water obtained by pumping in the Rincon and Mesilla Valleys (where losses from areas of native vegetation are small) does not represent an additional supply or new source of water, but rather a change in method, time, and place of diversion of the supply already available (Conover, 1954, p. 2, 122, 126). During the period of shortage of project water supply in the surface reservoirs, individual farmers utilized the ground-water reservoir by pumping of wells. As a natural consequence the ground-water reservoir was replenished later from project water supply by stream losses and infiltration from irrigated lands. Pumping in such circumstances therefore is, in effect, borrowing on future water supplies.

This unplanned, though somewhat effective, use of the ground-water reservoir in conjunction with the surface stream benefits those who have wells but works a hardship on those who have only surface-water rights. Planned development and management of ground water in stream valleys can increase the water supply by salvaging nonbeneficial losses in areas of shallow water and will facilitate using the ground-water reservoir in conjunction with the surface supply to the maximum benefit of all water users. Such planned development and management necessitates locating and pumping of wells in harmony with the surface system. If such is properly done a perennial water supply can result.

Proper location of pumps includes placing wells in areas of shallow water to capture water used by native vegetation, and spacing of wells so that the storage of ground water can be manipulated. Operation of pumps in conjunction with the surface supply entails pumping during periods of deficient surface supply at a rate such that the ground-water reservoir can be replenished during periods of excess surface supply. A fully managed ground-water and surface-water supply not only will maintain but will increase the firm supply because of (a) the savings in evaporation resulting from storing surface water underground, (b) the capture of floodwaters by surface reservoirs made vacant by storing water underground, (c) the reduction of evapotranspiration losses by phreatophytes, and (d) the recirculation of water by pumping.

Because of the large volume of water in underground storage in many alluvial valleys, as compared with the volume of surface reservoirs, a fully managed integrated system would be capable of providing a firm supply that would span climatic cycles a decade or two long. Theoretically, it is possible to control a supply to the extent that no water would be allowed to flow to the oceans. However, such a system is not desirable or feasible, as the salt content of the water would increase and the economy of the region would suffer. A managed system should therefore provide for flushing out excess salt during periods of excess precipitation and runoff.

The population of the 17 Western States is expected to continue to increase at a rate exceeding the national average. The present 43 million population of these States is expected to reach 108 million in 40 years (U. S. Senate Select Committee on National Water Resources, 1960c, p. 9). The need for industrial, municipal, and agricultural water likewise is expected to increase. Competition for the limited water supply will dictate systematic planning, coordination, and integrated development and management of water supplies.

Integrated development and management of surface and ground water will require a better understanding of our ground-water resources and the nature and extent of the aquifers. The nature of ground-water investigations is changing as the demand for water increases and the limit of the ground-water resources is approached. Only some 30 years ago most ground-water investigations went no further than to determine the occurrence of water--that is, where could wells be drilled, and what might be their expected yield? The concentrated development of wells in some areas of the West brought questions of well interference and the need for quantitative studies of the effects of pumping. Such questions prompted Theis to develop his well-known nonequilibrium formula in 1935. The trend toward full development of ground-water resources and integration with surface-water development is creating a demand for means of analyzing masses of geohydrologic data and parameters to provide a basis for choosing among alternate plans for

aquifer development. Electrical analog models offer promise of providing solutions to complex problems. Development of such equipment for analyzing aquifer systems is now well advanced, and examples of their use are forthcoming. The results will be only as good as the number and quality of data fed into them will permit, however, and in many cases the necessary data will cost a lot of money to acquire.

In summary, optimum development and integrated management of ground waters, singly and in conjunction with surface waters, promises to solve many perplexing water problems of the West. But the solution will be neither easy nor inexpensive. The public, as well as those responsible for water-resource development and management, must be informed and convinced of the need and value of such measures. Large sums will have to be spent to acquire the needed information on the ground-water reservoirs and their relation to the streams, and in many States substantial new legislation will be needed to provide the basis for planned water management.

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Ground Water-Surface Water Relationships

by

Robert E. Glover*

Introduction

Water resources have commonly been considered as falling within one of two separate and distinct categories. These are surface waters and ground waters. As our water supplies are becoming more heavily encumbered, it is beginning to be realized however, that these two categories are not necessarily distinct; and that in irrigation practice, the operations of the surface diverter and the user of ground water may affect each other in very fundamental and important ways. Such possibilities may be brought to attention, for example, by the advent of pumping in an area previously irrigated by surface diversion alone.

The possibility that an established surface diversion right might be adversely affected by pumping operations has led to demands for legal regulation of the pumps. However efforts to frame an equitable ground water law have run into trouble because of the difficulty of evaluating the nature and magnitude of the supposed interferences. Before these relationships can be clarified it will be necessary to evaluate quantitatively the effects of storage and release of ground water. It is the purpose of this paper to describe an analytical procedure by which these evaluations can be made.

Analytical methods

The procedures to be described are an outgrowth of the mathematical methods discovered by Isaac Newton in about the year 1666. (8) Of particular importance are the additional developments of J.B.J. Fourier about 1812. (1) It was in this year that Fourier's methods were presented to the French Academy and stirred up one of the most violent controversies in the history of science. The importance of this in the present connection is that if the budgetary requirement that the rate of rise of the water table within a narrow zone be compatible

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with the rates of flow of ground water into the zone is expressed in mathematical form it leads to differential equations of the type treated by Fourier. This immediately makes it possible to adapt the brilliant developments of Fourier, and his successors, to the calculation of ground water movements. Because of the interest aroused by Fourier's original paper the mathematical resources in this field are exceptionally good. It will be clear that these methods are not new since they represent some 300 years of development by able mathematicians.

The condition of continuity

The types of differential equation described above are obtained if the flow of ground water is computed by the Dupuit-Forschheimer idealization, which applies the surface gradient of the water table, at any point, to the entire saturated thickness below that point and by computing the flow on the basis that the original saturated thickness of the aquifer remains unchanged.

On this basis the requirement that the difference of flow across two planes a distance dx apart in the direction of flow should be compatible with the rate of rise of the water table between the two planes is

$$\alpha \frac{\partial^2 h}{\partial x^2} = \frac{\partial h}{\partial t} \qquad \ldots (1)$$

Where

h represents the height of the water table measured upward from an assumed original stable water table level.

t time

x a distance measured along the path of flow,

and

$$\alpha = \frac{KD}{V}$$

where

K represents the permeability of the aquifer

D the original saturated depth

V the ratio of drainable or fillable voids to the total volume.

Where radial symmetry prevails, as around a pumped well, the basic differential equation takes the form:

$$\alpha \left(\frac{\partial^2 S}{\partial r^2} + \frac{1}{r} \frac{\partial S}{\partial r} \right) = \frac{\partial h}{\partial t} \qquad \ldots (2)$$

Where

s represents the drawdown from an assumed original stable water table level and

r represents the radius.

In order to estimate the rate of ground water movement in any given case solutions of the above differential equations are needed which conform to the appropriate initial and boundary conditions. A few examples are the following:

(1) For the case of a well pumped at the rate Q drawing water from storage in an aquifer of unlimited extent which conforms to the conditions

When $t = 0$, $s = 0$, for $r > 0$

A solution of equation 2 is: (2) (3)

$$S = \frac{Q}{2\pi KD} \int_{\frac{r}{\sqrt{4\alpha t}}}^{\infty} \frac{e^{-u^2}}{u} \, du \qquad \ldots (3)$$

The integral which appears here is a form of the exponential integral. A table of values can be found in reference 5.

When a river runs over the surface of an aquifer and is in contact with the ground water in it the stream depletion q_1 due to a well at a distance x_1 from the river when pumped at the rate Q can be obtained from this expression in the form: (2) (9)

$$\frac{q_1}{Q} = 1 - \frac{2}{\sqrt{\pi}} \int_{0}^{\frac{x_1}{\sqrt{4\alpha t}}} e^{-u^2} \, du \qquad \ldots (4)$$

The integral which appears in this expression has been extensively tabulated. (4) (5) (6) It is called the "Probability Integral". Charts of a general nature can be constructed from such expressions. A sample is given in figure 1.

By integrating this expression with respect to time the total depletion of the river can be obtained in the form:

$$\frac{\int_0^t q_1\,dt}{Qt} = 1 - \frac{2}{\sqrt{\pi}} \int_0^{\frac{x_1}{\sqrt{4\alpha t}}} e^{-u^2} du - \frac{2}{\pi}\left(\frac{x_1^2}{4\alpha t}\right)\sqrt{\pi} \int_{\frac{x_1}{\sqrt{4\alpha t}}}^{\infty} \frac{e^{-u^2}}{u^2}\,du \quad \ldots (5)$$

A plot of this expression is shown in figure 2. The integral

$$\sqrt{\pi} \int_{\frac{x_1}{\sqrt{4\alpha t}}}^{\infty} \frac{e^{-u^2}}{u^2}\,du$$

has been tabulated by Mr. M. W. Bittinger. This table may be found in reference 3. It may be noted that these charts are of a very general nature and can be applied to a wide range of conditions if only the aquifer properties are known.

A solution of equation 1 subject to the conditions

$h = H$ for $0 < x < L$ when $t = 0$

$h = 0$ when $x = 0$ for $t > 0$

$h = 0$ when $x = L$ for $t > 0$

is: (2) (3)

$$h = H \frac{4}{\pi} \sum_{n=1,3,5\ldots}^{n=\infty} \frac{e^{-\frac{n^2\pi^2\alpha t}{L^2}}}{n} \operatorname{Sin}\frac{n\pi}{L}x \qquad \ldots (6)$$

The part of the drainable volume remaining can be obtained from this expression in the form:

$$\frac{\int_0^L h\,dx}{H_o L} = \frac{8}{\pi^2} \sum_{n=1,3,5\ldots}^{n=\infty} \frac{e^{-\frac{n^2\pi^2\alpha t}{L^2}}}{n^2} \qquad \ldots (7)$$

A plot of this expression is shown on figure 3. These expressions may be used to estimate drainage rates to parallel drains a distance L apart, or, since there is no flow across the plane at $x = L/2$ they may be used to estimate the return flow due to deep percolation losses from irrigation in an irrigated river valley of width L with the river in the middle of the valley.

Nature of the solutions

The condition of continuity described above is of a budgetary nature and imposes the requirement that the total flow across the boundaries and the water remaining in storage must equal the volume originally present in the aquifer. This condition is imposed upon the solutions and it follows that the amounts of water involved are exactly accounted for even though the differential equation is an exact expression of the physical conditions only if the rise or fall of the water table is infinitesimally small when compared with the original saturated depth. Whatever inaccuracies there may be will then appear only in the estimate of the time required for the changes to take place. The movements of ground water are treated as transient phenomena by these methods. This idealization will be found to accord well with the conditions to be found in the field.

Comments:

Plans for engineering works to promote the conservation of water and to provide for its effective use have generally been concerned with surface waters only. Such plans are usually based upon studies utilizing the records of runoff

for a series of years. These studies are also of a budgetary nature but generally require no mathematical operations beyond arithmetic. Even though it is recognized that the storage and release of ground water may be an important factor it has heretofore been difficult to include this factor because there has been no means available for accounting for the time delays inherent in ground water movements.* By utilizing the analytical methods described herein this difficulty can be overcome, the factors introduced by ground water movements can be evaluated and the studies can be completed.

Even though specialized mathematical skills are required in this procedure the results of the mathematical work can be incorporated into simple charts, such as the ones shown, and thereafter the inclusion of the ground water factors can become a routine matter requiring no familiarity with advanced mathematical procedures. The charts will not have to be remade for each new case. They are sufficiently general to require only a knowledge of the aquifer characteristics, and its geometry. They can be prepared on either a flow or volume basis. The developments described are adequate to treat the factors of pumpage, return flow from irrigations, canal leakage and seepage from reservoirs. The cases described illustrate a method which can be extended to many other cases. The spreading of water from recharge areas, for example, can also be treated in this way.

Summary

The analytical methods described herein will permit the storage and return of ground water to be included in water budget studies required for the planning of engineering works for water conservation purposes. Charts can be prepared which will permit these factors to be included on a routine basis. Ground water-surface water relationships in existing developments can also be clarified and the effect of future developments can be assessed.

Acknowledgments

The procedures described herein include developments made at the U. S. Bureau of Reclamation and at Colorado State University.

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* Return flows have sometimes been estimated from experience in other areas.

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$$\frac{2}{\sqrt{\pi}} \int_0^x e^{-x^2} dx \Big) .$$

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$$\frac{2}{\sqrt{\pi}} \int_0^x e^{-\beta^2} d\beta \quad \text{and} \int_x^\infty \frac{e^{-\beta^2}}{\beta} d\beta \Big) .$$

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(7) Tables of Functions and of Zeros of Functions. U. S. Department of Commerce, National Bureau of Standards, Applied Mathematics Series No. 37. (Contains a table of

$$E_1(x) = \int_x^\infty \frac{e^{-u}}{u} du \Big) .$$

References - continued.

Note that $\int_x^\infty \frac{e^{-u^2}}{u} du = \frac{1}{2} E_1(x^2)$.

(8) Men of Mathematics by E. T. Bell. Dover

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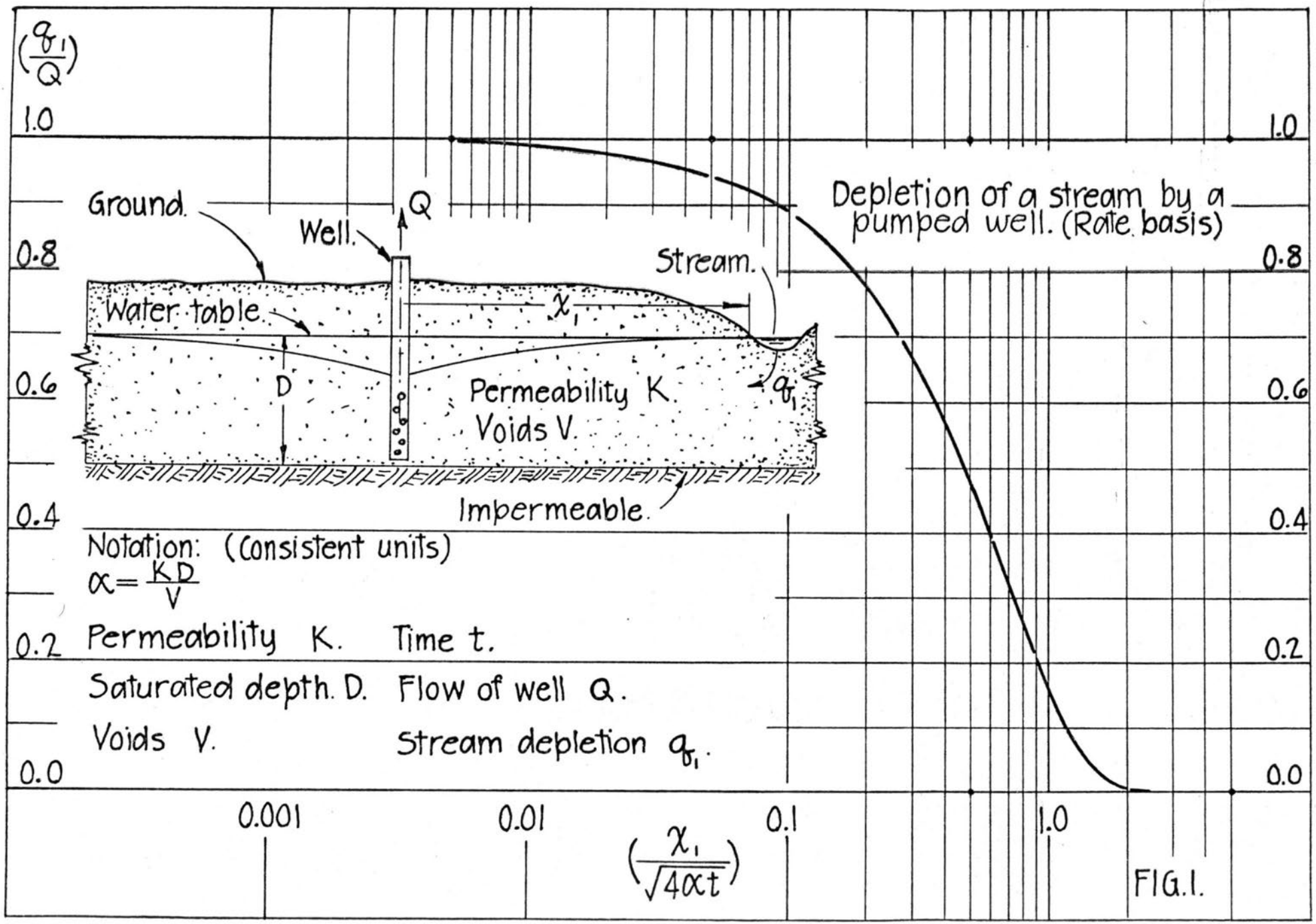
$(\frac{q_1}{Q})$
1.0
0.8
0.6
0.4
0.2
0.0
Ground.
Well.
Q
Stream.
Water table.
x_1
D
Permeability K.
Voids V.
q_1
Impermeable.
Depletion of a stream by a pumped well. (Rate basis)
Notation: (Consistent units)
$\alpha = \frac{KD}{V}$
Permeability K. Time t.
Saturated depth. D. Flow of well Q.
Voids V. Stream depletion q_1.
0.001
0.01
0.1
1.0
$(\frac{x_1}{\sqrt{4\alpha t}})$

FIG. 1.

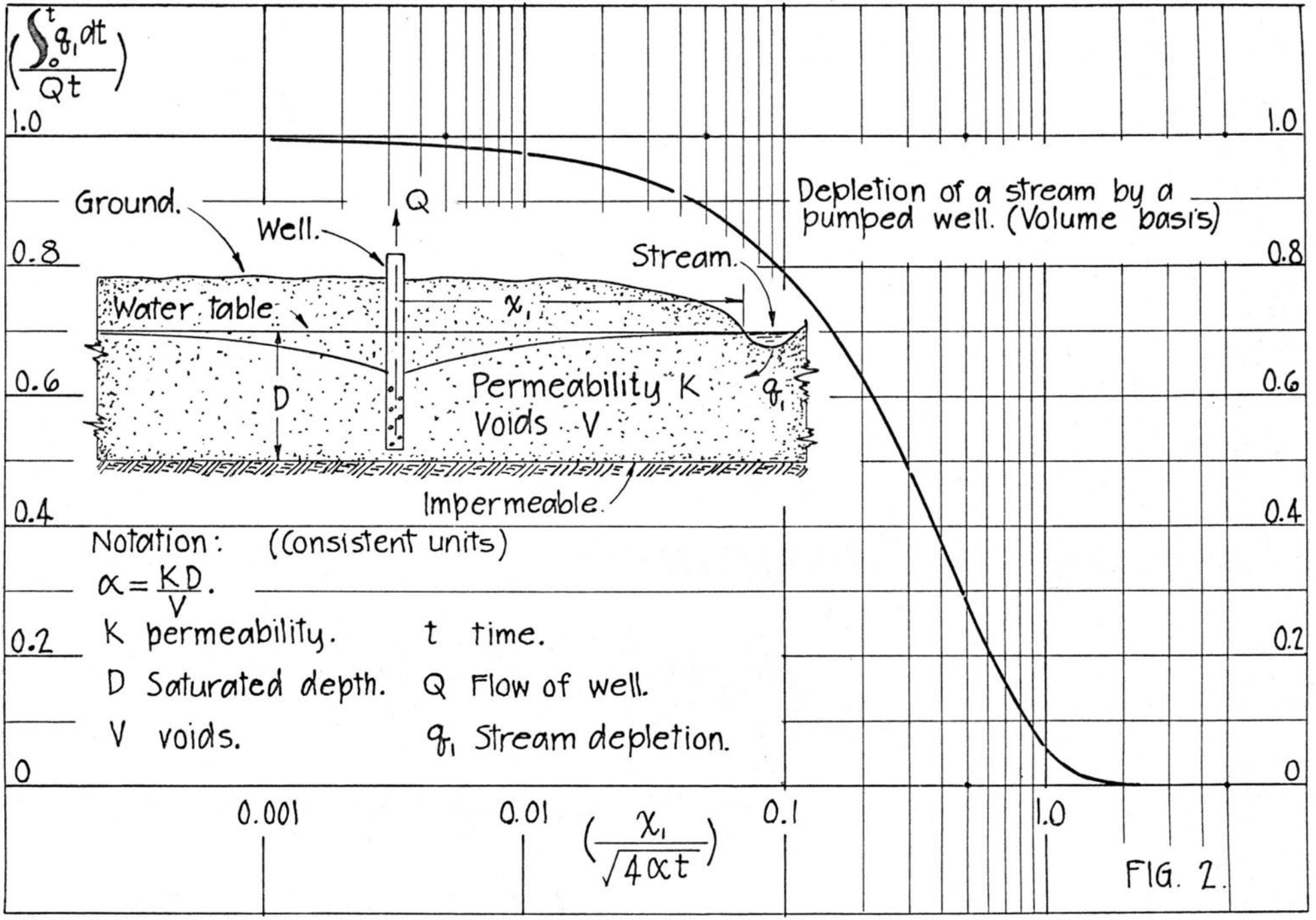
$\left(\frac{\int_0^t q_1 dt}{Qt}\right)$
1.0
0.8
0.6
0.4
0.2
0
Ground.
Well.
Q
Stream.
Water table.
χ_1
D
Permeability K
Voids V
q_1
Impermeable.
Depletion of a stream by a pumped well. (Volume basis)
Notation: (Consistent units)
$\alpha = \frac{KD}{V}$.
K permeability.
t time.
D Saturated depth.
Q Flow of well.
V voids.
q_1 Stream depletion.
0.001
0.01
0.1
1.0
$\left(\frac{\chi_1}{\sqrt{4\alpha t}}\right)$

FIG. 2.

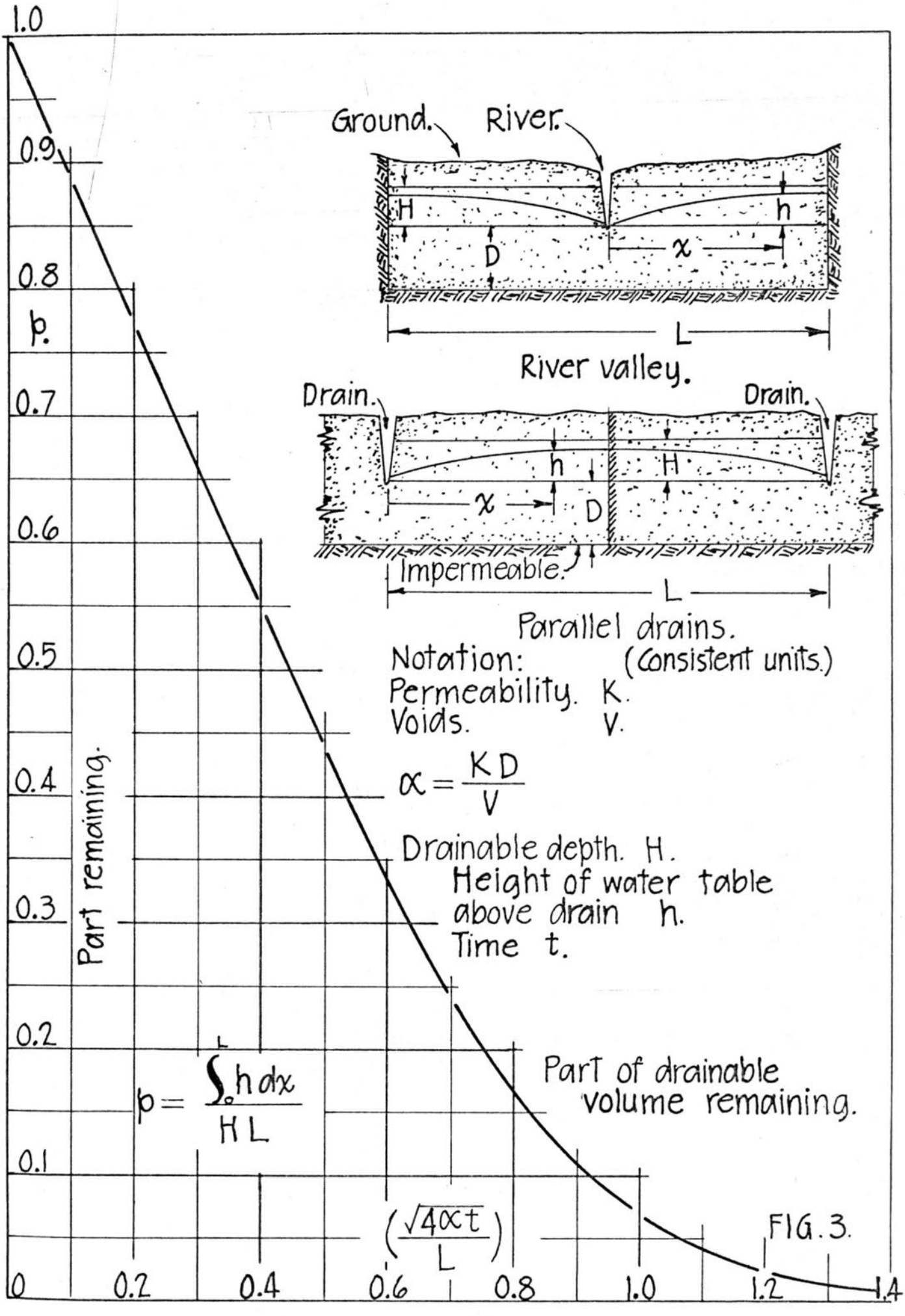
1.0
0.9
0.8
p.
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Part remaining.
$\left(\frac{\sqrt{4\alpha t}}{L}\right)$
Ground.
River.
H
h
D
x
L
River valley.
Drain.
Drain.
h
H
x
D
Impermeable.
L
Parallel drains.
Notation: (Consistent units.)
Permeability. K.
Voids. V.
$\alpha = \frac{KD}{V}$
Drainable depth. H.
Height of water table above drain h.
Time t.
$p = \frac{\int_0^L h\,dx}{HL}$
Part of drainable volume remaining.

FIG. 3.

WESTERN LEGISLATION FOR PUBLIC ADMINISTRATION OF GROUND WATER

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The purpose of this paper is to summarize essential principles of public administration of ground water that appear in statutes of the Western States. Heretofore in discussing water laws of Western States, we have included the 17 States extending from North Dakota to Texas on the 100th Meridian and thence westward to the Pacific Coast. Now that Hawaii has been admitted to the Union, with a ground water statute enacted by its last Territorial legislature, there are 18 States to deal with.

The legislation herein considered deals chiefly with rights to the use of ground water and with measures to protect the quantity and quality of this great natural resource so that it will continue to be available for maximum utilization for beneficial purposes. Included are both artesian and nonartesian waters. In some instances, separate regulation of artesian wells is noted.

I. Classification of Ground Water Administration Statutes

Appropriation statutes

In the ground water statutes of 11 of the Western States, rights of use are based on priority of appropriation. These are Idaho, Kansas, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming. In several, the appropriation statute relates to the whole field of appropriation of water, with insertion of a few provisions relating specifically to ground water. The larger number of legislatures, however, have enacted separate statutes for ground water which are complete in themselves other than incorporation of some features -- such as detailed procedure for making appropriations -- by reference to the general appropriation statute.

Nonappropriation statutes

Statutes of Arizona, Colorado, Hawaii, Nebraska, and Texas provide for certain controls over withdrawals of ground water, but not on a basis of prior appropriation.

Statutory provisions in California relate chiefly (1) to prevention of waste from artesian wells and to reports of installation of water wells generally, and (2) to use of alternate water supplies and to recordation of water extractions and diversions in specified counties. In Montana they relate to prevention of waste of artesian water and to filing of records of water wells.

Exemptions

Most States that impose restrictions upon the exercise of ground water rights or uses provide exemptions therefrom. Although varying in coverage, they relate chiefly, but not exclusively, to small withdrawals of water for domestic purposes and watering of livestock, lawns, and gardens.

II. Ground Waters Affected

Basic classifications

Application of statutory restrictions to all ground waters that are free to move through the soil and are capable of physical control prevails by a large margin in the West.

Exceptions are: (1) Arizona, Oklahoma, and Texas, which exclude definite underground streams and therefore relate to percolating waters only; (2) Washington, which adheres to the classification of bodies of water the existence and boundaries of which may be reasonably established or ascertained; (3) New Mexico, where the main statute refers to underground streams, channels, artesian basins, reservoirs, or lakes, having reasonably ascertainable boundaries, and a 1953 enactment to all ground waters of the State.

Interconnected surface and ground waters

The fundamentally important association and interdependence of surface streams and ground waters, known so well and so long by hydrologists and becoming better known generally, finds expression in statutes of Colorado, Idaho, Oregon, Washington, and Wyoming. In one State or another, legislation includes such matters as recognition of relative rights in the correlated common supply of surface and ground water in a single schedule of priorities, whether a particular diversion be made from a stream or a well; imposition of conditions in a ground water permit to prevent substantial interference with surface water appropriative rights as well as other ground water rights; incorporation of stream and

ground water users in the same administrative area; and provision that in a proceeding to determine water rights in a specified area, all affected appropriators of surface and ground water may be made parties.

Artificially stored ground water

A few statute deal expressly with this subject.

Thus in California, stream water may be appropriated for spreading over lands and later recovery from the ground for beneficial use.

Texas ground water conservation districts are authorized to acquire lands, construct works, and install equipment necessary to recharge ground water reservoirs.

The Washington statute contains procedure by which one may substantiate his claim to water stored in the ground by artificial means, either intentionally or incidentally to irrigation, which otherwise would be dissipated by natural waste.

III. Ground Water Administrators

State level

State administration of ground water control functions is centered wholly or chiefly in the official who performs comparable duties with respect to surface streams. In most cases this is the State Engineer -- the traditional chief in the surface water field -- or a comparable official, department, board, or commission. Colorado has a Ground Water Commission which directs the State Engineer in ground water matters, and is assisted in certain respects by the State Water Conservation Board. Texas has a State Board of Water Engineers of 3 members. In Wyoming, certain functions are vested in the State Engineer and others in the Board of Control of which he is president.

The acts and orders of State ground water administrators are subject to judicial review at the instance of parties aggrieved thereby.

Local administrators

Most of the western ground water statutes provide for officials who work under the direction of the chief State administrator, either at large or in local areas. Usually they are appointed by the chief; in a few States, they are elected locally.

Another method of local administration is through district boards. In some States, such as Texas, the district is an autonomous entity with regulatory powers. In others, it acts chiefly in an advisory capacity.

IV. Ground Water Rights

Character of ground water right

Appropriative. - Rights to the use of ground water by prior appropriation may be acquired under the laws of 11 Western States (as above noted, Idaho, Kansas, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, Wyoming).

Nonappropriative. - The other ground water statutes do not provide for the acquirement of water rights in the sense in which this term is commonly used in the West. The courts of Arizona, California, Hawaii, Montana, Nebraska, and Texas accord rights to the use of percolating water to the owner of overlying land solely because of the relative situations of land and water, and the Texas statute specifically supports the principle. The Colorado Supreme Court recognizes appropriative rights in percolating waters that are tributary to streams, but has not yet had occasion to decide the status of rights in nontributary waters. What the several ground water statutes do is to provide for regulation of existing uses, and some of them impose restrictions upon the initiation of new uses as well.

The Montana statute, which regulates the drilling and use of artesian wells, provides that any landowner may install artesian wells on his land to procure water for domestic, stock, irrigation, or manufacturing purposes.

Preexisting ground water rights

The policy of legislatures in enacting ground water control statutes is to specifically recognize valid preexisting water rights. In some States, these are termed "vested rights." This paves the way for preservation and continuance of ground water uses for beneficial purposes antedating enactment of the statute, under whatever right or claim of right such uses may have been made, and disclaims any legislative intent to avoid providing for due process.

Oregon follows a pattern set by its surface water code in recognizing ground water rights based on actual application of water to beneficial use prior to the effective date of the act, or within a reasonable time thereafter with the use of works then under construction. Provisions to the same effect are included in the Kansas and South Dakota laws.

In North Dakota, a user of water from a source including "underground" for beneficial purposes over a period of 20 years prior to January 1, 1934, is deemed to have acquired a prescriptive right to the use thereof.

In a ground water area designated by the Hawaii Commission on Ground Water Resources as in need of regulation, existing lawful and beneficial uses are "preserved" for the user. The Hawaii Supreme Court has held that

owners of land in an artesian area have rights in the common supply of water. However, the statute declares that a certificate of preserved use is deemed to constitute a description of the use that is preserved, and not an adjudication of property rights in the ground water supply.

Claimants of preexisting rights are required in some States to file declarations of their claims.

Procedure for appropriating ground water

Procedure for acquiring appropriative rights under the ground water statutes follows the familiar pattern which was developed for surface stream water rights before the turn of the century and which is in effect now with respect to surface waters in nearly all Western States. The first step is the filing of an application to appropriate water with the State administrator, who grants the application only if unappropriated water is available and other specified requirements are met. The approved application may constitute a permit to make the appropriation, or a separate documentary permit may be issued. In any event, the grantee has permission to proceed with his intended project under conditions stated in the law and in the permit itself. On completion of construction work and application of water to the proposed use, the permittee receives a license or certificate of appropriation which evidences the State's approval of his appropriation of ground water and its consent that he proceed to exercise his right subject to all prior rights.

In nearly all western ground water appropriation statutes the prescribed appropriation procedure is clearly, or at least by strong presumption, the exclusive method of acquiring a ground water right. Idaho is a definite exception. There an intending appropriator may either follow the statutory procedure, or he may acquire an equally valid right by diversion and application of the water to beneficial use, at his option. A partial exception obtains in New Mexico, where the permit procedure is required only in basins declared by the State Engineer to have reasonably ascertainable boundaries.

A few other variations may be noted. In Idaho and Wyoming, an application in an area not designated as critical is granted if all requirements are met; but in a critical area, notice must be given and a hearing held on objections. An intending appropriator in a designated basin in Nevada must obtain a permit before doing any work; otherwise under nonartesian conditions a permit is unnecessary until the well is installed and water developed, but one must be obtained before diverting the water. The Utah State Engineer may issue a temporary permit to drill a well after the filing of an application to appropriate water therefrom.

Permit limitations and restrictions

Some ground water statutes specifically authorize administrators to include in permits requirements as to proper exercise of the right. For example, the Oregon State Engineer may impose conditions designed

to prevent wasteful use, undue interference with existing wells, or substantial interference with existing rights to appropriate surface water.

Two States -- Kansas and Nevada -- declare that it is an express condition of each appropriation of ground water that the right relates to a specific quantity of water and must allow for a reasonable lowering of the static water level at his point of diversion resulting from later appropriations. A Wyoming declaration is worded differently but expresses the same principle. On the other hand, the Idaho statute declares that early appropriations of ground water shall be protected in the maintenance of reasonable ground water pumping levels as may be established by the State Reclamation Engineer. Washington forbids the issuance of permits to withdraw water beyond the capacity of the formation to yield water within a reasonable or feasible pumping lift in case of pumping developments, or a reasonable or feasible reduction of pressure in case of artesian developments.

The Utah statute accords to a junior ground water appropriator the right of replacement of water, with approval of the State Engineer, in the event that his project may impair a senior right. The nonappropriation statute of Hawaii contains a provision along the same lines.

Preferred uses of water

Preference in use of water is mentioned in some statutes, domestic use being at the head of each list. For example, one of the corrective control provisions that the Oregon State Engineer may include in his order declaring the existence of a critical ground water area is the according of first preference, without regard to priorities, to domestic and livestock purposes, followed by other beneficial uses in such order as he deems advisable under the circumstances.

Changes in exercise of ground water rights

A number of the ground water statutes authorize an appropriator to change the location of his withdrawal of water, place of use, and use of the water without loss of priority, with the approval of the State administrative agency. Changes would be conditioned on no resulting enlargement of the appropriation or impairment of other rights.

Determination of ground water rights

As in the case of surface streams, administration of appropriative rights in the common water supply is facilitated by and under some circumstances dependent upon a determination of relative priorities of the several claimants. Such determinations may be solely court adjudications, or they may be special procedures in which administrative and judicial functions are combined. Surface stream appropriation statutes of most Western States contain procedures in which the State administrative agency is involved in some way.

Some of the States that have separate ground water appropriation statutes have included therein provisions for determining ground water rights in areas designated therefor by the State Engineer. For such purpose, the comparable provisions of the general appropriation statute are adapted to the requirements of ground water appropriations. Final decrees of adjudication include such usual provisions as name of appropriator, priority of right, quantity of water, place of diversion, place of use, and conditions of exercise of right. In addition, some include such features as boundaries of the ground water area, level below which the water may not be drawn down, and safe yield. In Oregon, the determination of a critical ground water area may be included in the proceedings for adjudicating ground water rights. The Washington statute authorizes reservation of jurisdiction for the determination of a safe sustaining water yield necessary from time to time to preserve the water rights and prevent depletion of the ground water supply.

In addition to the general adjudicatory procedure, the Idaho ground water statute provides for administrative determinations of claims by appropriators that their rights are being adversely affected by junior claimants. A local board created for each specific controversy determines the nature and extent of the water rights involved, makes corrective orders, and when it has finally disposed of the claim, ceases to exist.

Loss of ground water rights

Loss of ground water rights by forfeiture for nonuse for prescribed periods of years, and by abandonment, is provided for in some of the separate ground water statutes. In some cases, there is administrative procedure for determining such losses.

In South Dakota, any well not put to beneficial use for a period to be determined by the State Water Resources Commission is declared by statute to be abandoned and is required to be plugged.

Under the nonappropriation statute of Hawaii, a "preserved use" of ground water is extinguished by nonuse for prescribed periods of years unless caused by water shortage resulting from natural conditions.

V. Ground Water Administrative Areas

Practical ground water administration perforce requires for its functioning geographical areas with defined boundaries substantially coterminous with those of the bodies of ground water to which administrative measures are to be applied. The fact that determinations of the existence and characteristics of ground water bodies are feasible represents a great advance over the skepticism exhibited by a Vermont court more than a century ago. That court remarked upon "The secret, changeable, and uncontrollable character" of ground water, which "sometimes rises to a great height, and sometimes moves in collateral

directions, by some secret influences, beyond our comprehension." [Chatfield v. Wilson, 28 Vt. 49, 54 (1855).] Although it is true enough that ground water is still invisible to the naked eye, much of its "secretiveness" and "incomprehensibility" has been removed by the science of ground water hydrology.

Some regulatory measures are not limited to defined local areas. For example, laws and regulations relating to well drilling, or to reports required from ground water users, may be statewide in application. It is the aggregate of many withdrawals of water from given sources of supply, which may or may not be physically interconnected, that cause the greatest concern; hence are the essential factors of specific ground water supply and specific surface area in which withdrawals therefrom are made.

The starting point in designating a ground water administrative area, then, is determination of the body of ground water to which it is to be applied -- variously termed a basin, reservoir, formation, or aquifer. For administrative purposes, a surface area is designated which overlies a ground water body, or a subdivision of it, or possibly more than one distinct formation.

The purpose of a ground water area may be to supervise withdrawals of water according to relative priorities of surface and ground water rights, as in case of watermaster districts in Idaho.

The purpose may be to impose regulatory and corrective measures through the media of autonomous legal subdivisions. Examples are the Nebraska ground water conservation district, the New Mexico artesian conservancy district, and the Texas underground water conservation district.

If the status of the ground water supply in a particular region gives cause for concern and suggests the need of public regulation, either permanently or for the time being, the affected area is designated for this purpose by the State administrator. A favorite term is "critical area," which is used in the larger number of States. Other statutes speak of areas "designated" or "defined" by the administrator.

A critical ground water area, as defined in the Arizona statute, overlies a ground water basin or subdivision in which there is not enough ground water to provide a reasonably safe supply for irrigation of cultivated lands at the then current rates of withdrawal. The same thought is expressed in some other statutes but without limiting the hazard to irrigation uses. Elsewhere an area may be critical if overdraft or pollution is threatened, without waiting for the actual occurrence. For example, the criterion in Colorado is a water supply that appears to have approached, reached, or exceeded the normal annual rate of replenishment. Danger signals in Wyoming include use

of ground water that approaches the current recharge rate, excessive decline in water levels, present or expected conflicts between users, occurrence or probable occurrence of waste. The only requirement for a designated area in either Hawaii or Nevada is a finding that it is in need of administration under the statute.

Designation -- that is, creation -- of a critical ground water area is a means to the end of preventing or correcting serious conditions. It is a step taken by the State administrative agency, not arbitrarily, but sometimes on petition of affected ground water users and in any event after giving objectors an opportunity to be heard. Furthermore, aggrieved parties have the right of judicial review. In the same manner in which it is created, the boundaries of a designated area may be altered; or the designation may be rescinded if and when discontinuance proves justified. However, if development pressures continue in the measure in which they have been exerted in many areas in recent years, restrictive measures therein appear likely to continue for a long time.

VI. Ground Water Regulation

Investigations

Much investigation precedes the determination of a body of ground water and of the related surface area which is the locus of most administration of ground water controls. This is necessarily so. With respect to a natural resource that is hidden from sight but is readily open to scientific inquiry, the necessity for searching investigation before imposing controls is axiomatic.

Authorizations and directions to administrators to make investigations appear in many western ground water statutes. Some contain general authorizations to make studies of ground water supplies of the State, or methods of ground water conservation. Sometimes they specifically authorize administrators to cooperate with Federal, State, and other public agencies and with individuals.

A few examples of authorizations of investigations relating to ground water basins or reservoirs are: Arizona, data on safe annual yield and use made thereof; Colorado, effect of withdrawals on aquifer supply and on surface flow of streams; Nevada, pumping tests to determine whether overpumping is indicated, specific yield, and permeability characteristics; Utah, adequacy of the supply for existing claims in a defined area. In Oregon the State Engineer is directed to investigate, identify, and define tentatively the characteristics of each ground water reservoir in the State; but before making a final determination of boundaries and depth of any ground water reservoir, he is to make a final determination of all ground water appropriative rights therein.

Character of regulation

In general. - Regulation of ground water under a statute based upon priority of appropriation necessarily involves in the first instance recognition and preservation of preexisting rights, procedure for acquiring new rights, and determination or adjudication of water rights, heretofore discussed. Statutes not based on priority of appropriation do not purport to disturb or to enlarge the existing basis of ground water rights in the jurisdiction, but they are concerned with existing uses of ground water and with new uses. Under both appropriation and nonappropriation statutes, regulation of ground water includes protection and conservation of the ground water supply, installation of wells, supervision over withdrawal of water, and prevention or correction of overdraft -- functions that will be dealt with presently. It also includes registration of wells, reports from water users, and promulgation of rules and regulations.

Enforcement of regulation. - Some ground water statutes authorize the State administrator to enter upon private lands in order to examine wells and obtain required data. In a number of States, officials may bring action to enjoin violations of the statute; in 2 of them, they may intervene in court actions to prevent depletion of ground water supplies.

Artesian conservancy districts in New Mexico have concurrent authority with the State Engineer to enforce regulatory provisions of the statute where waters within the respective districts are affected. The State Engineer may intervene in proceedings brought by or against these districts when necessary to protect or adjudicate rights in the public waters.

Violation of any provision of the ground water statute is generally declared to be a misdemeanor.

Protection and conservation of ground water supply

Western ground water legislation is replete with prohibitions against depletion and unnecessary waste and pollution of ground water supplies, and with directions that wasteful practices be brought under control.

There are a number of broad legislative declarations of policy. Among these are that of Hawaii that the ground water resources of all areas must be protected from the threat of exhaustion, depletion, waste, pollution, and deterioration by salt water encroachment; Idaho, directing the State administrator to do all things reasonably necessary to prevent depletion of ground water resources; Nebraska, that conservation and beneficial use of ground water are essential to the future well being of the State; Nevada, that it is the intent of the legislature to prevent waste and pollution of ground water; Oregon, that

depletion of ground water supplies below economic levels, pollution, and wasteful practices be prevented or controlled within practicable limits.

Directions are given to administrators to take specific measures to prevent unnecessary waste of well water both under and on the surface, and losses from storage and conveyance works, as well as pollution of ground waters. These include mechanical devices for control of flowing wells; safe and efficient construction of all wells; abatement of abandoned artesian wells and wasteful or defective wells; insertion of conditions in a permit prohibiting wasteful practices.

Installation of wells

An important part of ground water regulation relates to installation of wells and other works and appliances for withdrawing water from the ground.

Grants of authority to appropriate water and authority to drill a well therefor may or may not be made in one permit issued by the administrator, but they apply to entirely different functions -- one to acquire and exercise a water right, the other to install the physical plant and equipment necessary to draw the water to the surface. In issuing permits to drill wells, the administrator exercises his statutory direction and follows his own rules and regulations in imposing specifications for safe and efficient construction under local conditions. Several statutes expressly include in the required undertaking approved devices for measuring water.

Licensing of water well drillers by the State is required by a considerable number of ground water statutes. This may apply only to persons who install wells for others for compensation, or it may include all who drill wells even for themselves on their own properties. Drillers are generally required to keep logs and to furnish copies to the State administrator. In New Mexico, licensing is required only in ground water areas the boundaries of which have been determined and proclaimed by the State Engineer. Nevada authorizes the State Engineer to appoint a well drillers' advisory board or boards on either a regional or statewide basis for the purpose of determining qualifications of applicants for well drillers' licenses.

In several States, spacing of wells is a feature of control. The Nebraska statute declares that drilling of irrigation wells without regard to spacing is detrimental to the public welfare, and prescribes a minimum distance of 600 feet unless unusual circumstances prevail. Statutes of Oklahoma and South Dakota also make provision for spacing of wells where advantageous; Texas, with respect to ground water conservation districts; Wyoming, in critical areas.

Measures to prevent or correct overdraft

Appropriation statutes. - In the States in which statutes are based on priority of appropriation, two steps are commonly taken when the aggregate of withdrawals of water in a designated or critical area is found to exceed the safe annual yield: (1) closing of the area to the issuance of further permits to appropriate water; and (2) restriction of withdrawals of water to conform to priority rights, withdrawals under the later rights being reduced or prohibited to the extent necessary to satisfy the earlier ones. In a few States the administrator has the option of imposing systems of rotation.

The Oregon State Engineer has a wide discretion in the selection of corrective control provisions. He may order one or more of the following: (1) closing of the area to further appropriations; (2) determination of the permissible total withdrawal and its apportionment among appropriators in accordance with relative priorities; (3) according of first preference despite priorities to domestic and livestock uses and thereafter, in such order as deemed advisable, to agricultural, industrial, municipal other than domestic, recreational, and other beneficial purposes; (4) reduction of permissible withdrawal by any one or more appropriators or wells; (5) if 2 or more wells are used by the same appropriator, adjustment of the total permissible withdrawal by him, or complete prohibition of the use of one or more of such wells; (6) abatement or sealing of any well responsible for pollution of the water supply; (7) imposition of a system of rotation; (8) additional requirements in the public welfare.

Nonappropriation statutes. - In both Arizona and Colorado, critical areas are closed to further development of ground water resources while the critical condition continues, and new permits to drill wells and withdraw waters are limited chiefly to replacement and preservation of existing diversions and uses. The Colorado act provides that permits must be obtained generally for all new wells and for increases and extensions of existing supplies; if located outside the boundaries of a critical district, permits to use ground water will be issued. The Colorado permit does not have the effect of granting or conferring a ground water right upon the user, but it is prima facie evidence of the date and extent of the new use.

The board of directors of a Nebraska ground water conservation district, after conferring with State and University officials and after notice and public hearing, may institute corrective measures to insure proper conservation of ground water in the district. As to the nature of permissible corrective measures, the statute is silent.

A Texas underground water conservation district may provide for the regulation of production of water from nonexempted wells in order to minimize so far as practicable drawdown of the water table or reduction of artesian pressure, or to prevent waste.

The California statute governing court reference procedures for determination of water rights provides that in specified counties, if after the administrative referee report has been filed it appears that unrestricted pumping will induce ocean water intrusion to the irreparable injury of the ground water supply before final judgment, the court may issue a preliminary injunction equitably restricting and apportioning reduction in pumping subject to adjustment and compensation in the final judgment.

The Hawaii ground water use act is an adaptation of the "Model Water Use Act" prepared at the Legislative Research Center, University of Michigan Law School. Withdrawal of water directly from a designated area in which regulation is needed, except for domestic use and preserved uses, requires a permit for a specified period of years, which may be granted if water is available for beneficial use, water resources are not thereby impaired, and no substantial interference with existing uses is indicated. If in such area a water shortage occurs, new wells and uses may be forbidden, existing uses and facilities modified, and water uses apportioned, limited, or rotated. In the event of an emergency in a ground water area, the State administrative agency is authorized to take extraordinary steps to cope with it whether or not the area is designated.

The question of due process. - In States in which the principle that ground water belongs to the public, subject to appropriation, has judicial recognition as well as statutory approval, closing the area to further appropriation in event of an overdraft is comparable to closing a surface stream the waters of which have been fully appropriated. As nobody has a right to appropriate water from a source all of which is needed to satisfy prior rights, an issue of denial of due process does not arise in denying new applications to appropriate water from the insufficient supply.

A different situation exists in a jurisdiction in which overlying landowners are held by the courts to have property rights in waters in their lands, where in case of overdraft the only uses of ground water that are protected are those then existing, and overlying landowners who have not yet made such use are prohibited from doing so while the shortage persists. In such event, a judicial appraisal of statutory restrictions on the exercise of recognized and declared property rights, to be favorable to its validity, must draw a distinction between denial of due process and exercise of the State's police power.

Finally, it is important to note in this connection that the validity of the Arizona restrictive act was sustained by the supreme court of that State. The court took the position that where the public interest is significantly involved, the preferment of such interest over the private interest of an individual is a distinguishing characteristic of exercise of the police power. Under the circumstances presented by a critically overdrawn water supply, the court could not say that invocation of the police power in administering the ground water act involved a denial of due process. [Southwest Engineering Co. v. Ernst, 79 Ariz. 403, 291 Pac. (2d) 764 (1955).]

ADMINISTRATIVE PROBLEMS IN GROUNDWATER PROGRAMS

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Groundwater, as an administrative problem, first came into the picture in Arizona with passage of the Groundwater Act of 1945. This law required the registration of all irrigation wells and the filing of a Notice of Intention to Drill a Well by anyone proposing to drill an irrigation well. Objective of the Act was to accumulate data to be used as a source of information and as a guide in drafting additional legislation.

Three years after the passage of this Act, the Legislature enacted the Groundwater Code of 1948, under which the State Land Commissioner is empowered to designate critical groundwater areas, areas in which no irrigation well can be drilled without first obtaining a permit.

A critical groundwater area, according to this statute, is any groundwater basin, or designated subdivision thereof, not having sufficient groundwater to provide a reasonably safe supply for irrigation of cultivated lands in the basin at the then current rate of withdrawal.

A proposal to create a critical groundwater area can be initiated by the Commissioner or by petition signed by not less than twenty-five users (or one fourth of the users) of groundwater within the exterior boundaries of the proposed basin or subdivision thereof.

A hearing is required at which the proponents and opponents of the proposal may be heard, and notice of such hearing, together with a full disclosure of the proposed critical area, must be published for four consecutive weeks preceding the hearing in a newspaper of general circulation in the county involved.

The first critical area in Arizona, consisting of eleven townships in the lower Santa Cruz Valley, was established in April, 1949. In 1951 three other critical areas were designated, embracing the principal cultivated lands in the central valleys of southern Arizona. Today there are seven such areas, plus additions to some of the early areas. No new critical areas have been set up since 1954, and the last addition to a critical area was in 1956.

A further refinement in the administration of the law came about when a farmer in the Avra Valley, near Tuscon, decided he wanted to irrigate some desert land continguous to his farm, land not previously in cultivation.

The Commissioner objected and the disputing parties went to Court. The farmer won his case in the lower court and, last February, the Supreme Court sustained the lower court. The essence of this decision was that a farmer who owned a well drilled before an area was declared critical could use whatever water he could pump from the well on whatever land he chose.

We have not lived with this latest interpretation of the Groundwater Act long enough to know just what problems we face in enforcement.

Among its enforcements provisions, by the way, the law provides a fine of up to $250 for each day of continuing violation.

So much for the story of our problems in connection with the administration of the GroundwaterAct of 1948.

What are the results ?

In the Salt River Valley, the state's leading agricultural area--an area declared critical in 1951 -- withdrawal of ground water increased 16% between 1950 and 1955. From 1955 to 1960 there was no further increase in withdrawal. However an average drop of 25 feet in the water table between 1951 and 1955 was followed by another drop of 25 feet between 1955 and 1960.

In the lower Santa Cruz and Gila River valleys there was a similar pattern in groundwater withdrawal, that is, a 16% increase between 1950 and 1955, no increase between 1955 and 1960. The drop in the water table was greater, however, averaging 80 feet in the first five years, better than 40 feet in the last half of the decade.

In the Upper Santa Cruz and Avra valleys, where no critical areas was designated until the latter part of 1954, groundwater withdrawal increased 25% between 1950 and 1955, but decreased 10% from the peak firure between the years 1955 and 1960. Despite this decrease in pumpage, however, the static water level continued to drop--about 30 feet in the last five years.

It is interesting to note that the period of lowering water tables took place while our biggest crop and heaviest user of water, cotton, was undergoing a drastic decline in acreage.

It is a widely held belief that an Arizona farmer can't make money producing alfalfa or small grains if he has to lift water more than 275 feet. The pumping lift in many of the wells in the critical groundwater areas already exceeds 275 feet.

I have in mind one recommendation for the next session of our Legislature--an amendment to the Groundwater Act which would stop all irrigation well drilling without a permit immediately upon declaration of a critical groundwater area, that is, eliminating the provision pertaining to substantially commenced wells. This could lead to a general overhauling of the law, making for more effective administration.

INTRODUCTION

Any discussion of the New Mexico water law involves two key phrases--beneficial use and impairment of rights. These are the legislative guide posts and the standards by which the State Engineer administers water rights. In a larger sense, a discussion of these terms involves some discussion of the basic philosophy of water law which, in turn, involves a discussion of the entire philosophy of property law.

It appears to me that the western states, and particularly New Mexico, in developing the law of prior appropriation have been confronted with two diametrically opposed concepts. These concepts are flexibility and security. Probably the fundamental concept of our water law is that of security, that is, "first in time is first in right."

The early court decisions concerning water law in the west and certainly the early legislation was directed toward securing property rights in water. In the case of Yeo v. Tweedy,[1] the New Mexico Supreme Court discussed the alternatives to the prior appropriation doctrine and stated:

> "The preventive for such unfortunate and uneconomic results is found in the recognition of the superior rights of prior appropriators. Invested capital and improvements are thus made only from a supply not already in beneficial use. Non-use involves forfeiture. A great natural public resource is thus both utilized and conserved."

In New Mexico we have been hard put to achieve the idealization of the doctrine of prior appropriation as pronounced by the Supreme Court in 1929. We know now that in many instances our water resources cannot be both utilized and conserved. In most of our groundwater basins such as Lea County, Portales, Mimbres, and Animas basins any appropriation involves mining of water. In other words, once the water is utilized by man, it cannot be at the same time conserved.

Even in 1929, however, the Supreme Court was concerned with the social implications of the use of water. In the same case, the Supreme Court said:

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> "Such bodies of subterranean water are the principal resource of the localities where they occur. Their employment to the best economic advantage is important to the state."

This same idea was expressed in the recent case of State v. McLean, decided in 1957.[2] Chief Justice Lujan stated:

> "All water within the state, whether above or beneath the surface of the ground, belongs to the state which authorizes its use and there is no ownership in the corpus of the water but the use thereof may be acquired and the basis for such acquisition is beneficial use. The state as owner of the water has the right to prescribe how it may be used. This the state has done by the enactment of Sec. 75-11-2, which provides that the beneficial use is the basis, the measure and limit to the right to the use of water."

In the McLean case the Supreme Court went on to hold that the defendant had not made beneficial use of the water for a period of more than four years. In that case the defendant had allowed the water to flow from the artesian well in question, uncontrolled, 24 hours a day, without a constructed irrigation system. However, the defendant claimed that water was absorbed on native salt grass and was used to water livestock and that it was a beneficial use. The Supreme Court held against the defendant, ruling that he had lost the right through continuous nonuser through waste.

This case does not help us much in determining the meaning of beneficial use but the Supreme Court did say that allowing water to waste out on the land without being under the control of an irrigator was not beneficial use. As far as we are able to determine, this is as near to a definition of beneficial use as the Supreme Court has ever given us. The McLean case did say that an appropriator is limited to the use of such water as may be necessary and useful for some beneficial purpose on the land from which it is taken but the law has never defined what beneficial use is.

Query: Does the beneficial use have to be beneficial to the landowner or does it have to be beneficial to the public as a whole? Certainly, the McLean case stands for the proposition that waste will not be tolerated and it further stands for the proposition that the standards of care in preventing waste are greater than the standard required in the early days of irrigation.

It may well be that the trend is toward elimination of wasteful practices. Certainly the technological advances which have enabled appropriators to use underground irrigation systems or concrete-lined ditches have gone a long way toward elimination of waste. It may well be as the shortage of water in the state increases, the public will demand stricter enforcement of the laws prohibiting waste.

PREFERENTIAL RIGHTS

Any discussion of transfer of water rights requires discussion of the legal preferences to use of water, established in New Mexico. The earliest statute giving a preference to the use of water was enacted in 1876, which declared that all waters in springs, rivers and ditches are free in order that all persons traveling in the state shall have the right to take water therefrom for their own use and that of the animals under their charge. Section 75-1-4, N.M.S.A. 1953, Section 75-1-5, N.M.S.A. 1953. This statute evidently gave travelers and livestock an absolute right to the use of water without regard to the doctrine of prior appropriation. While this statute is interesting as setting up an absolute preference, it has not had much importance on the development of water law.

However, in 1953 the Legislature promulgated an amendment to Section 75-11-1 which creates an important preference. This amendment provides that the State shall issue a permit to applicants for domestic use and for livestock water. These permits do not require advertising and hearing as is usually required in applications for appropriations. Neither does the statute provide any grounds upon which the State Engineer can deny an application for livestock or for domestic purposes. The Legislature recited in the 1953 amendment that this statute was enacted for the reason that relatively small amounts of water were consumed in the watering of livestock or for household or other domestic use. However, it can be seen that eventhough the amount of water used is small, that this statute gives to appropriators for domestic or livestock water, an absolute preference over other users, the effect of which is a transfer from prior appropriators by operation of law and without compensation. The constitutionality of this section has not been passed upon by the New Mexico Supreme Court.

The same section also gives a preference to appropriators for the use in prospecting, mining and drilling operations designed to discover or develop the natural mineral resources in the State. The preference given for drilling, prospecting and mining operations is not an absolute one since it is limited to three acre feet of water for a definite period not to exceed one year and the State Engineer is also given the discretion of determining whether or not the proposed use will permanently impair any existing rights. If the State Engineer in a preliminary examination of the application finds that the proposed use will permanently impair existing rights, the statute requires advertisement and hearing as provided in other applications. It can thus be seen that the appropriation of water used in prospecting, mining or drilling operations designed to discover or develop the natural mineral resources of the State of New Mexico have a preference over any other water users except domestic and livestock uses. This portion of Section 75-11-1 has not been passed upon by the Supreme Court, This is another instance of a transfer of water rights by operation of law.

These are the only preferences which we can find in the New Mexico statutes, however, during the last few years important litigation has arisen over the claim of preferential rights for municipal uses. This involves the doctrine of pueblo rights.

Under the California cases, the California Supreme Court has held that the cities of San Diego and Los Angeles were originally formed as pueblos by either the Spanish or Mexican governments and that the original pueblo grants gave to those cities the right to use of waters of the San Diego and Los Angeles rivers respectively, not only for the original pueblos but the right in future to the successors of the original pueblos to use all of the water that was reasonably necessary for the growth of the cities, as in the cases of San Diego and Los Angeles. These cities have the right to take all the water and to drive out of business any other users to their source of water without compensation.

The New Mexico Supreme Court has discussed the pueblo rights doctrine in the case of New Mexico Products Co. v. New Mexico Power Company,[3] but in that case held that Santa Fe never did have a pueblo grant and therefore, the pueblo rights doctrine would not apply.

The most recent decision concerning preferential rights is that of Cartwright v. Public Service Company of New Mexico,[4] 1958. In this case the Public Service Company was taking all the waters of the Gallinas River for use under its franchise to supply the City and Town of Las Vegas with water. The farmers using water from the same stream brought a suit demanding injunction, or, in the alternative, damages for their loss of water. The defendant company countered by claiming it had an absolute right by virtue of a Mexican grant to the pueblo of Las Vegas to take all of the water of the Gallinas River reasonably necessary for municipal uses without compensation to other users on the river.

The state of New Mexico filed a brief amicus curiae and took the positionthat a vested right could be acquired only pursuant to the constitution of New Mexico, i.e., beneficial use is the basis and the measure of the right to use water. Since all of the waters of the river had not been appropriated to beneficial use prior to the times the farmershad appropriated the water, then the city and town of Las Vegas, as successors to the Mexican pueblo, did not have a vested right prior to the acquisistion of New Mexico by the United States.

It was the State's further argument that under the laws of nations and the Treaty of Guadalupe-Hidalgo neither New Mexico nor the United States was obligated to protect imperfect or inchoate rights. The state recited a long list of cases by both the New Mexico Supreme Court and the United States Supreme Court in which the courts have refused to protect non-vested rights acquired before the transfer of sovereignty. Further, the state of New Mexico pointed out that neither the legislature nor the constitutional convention recognized the so-called California doctrine of pueblo rights and that the New Mexico situation should be distinguished from the California cases involving the pueblos of Los Angeles and San Diego.

The California Supreme Court had justification for its promulgation of the California doctrine of pueblo water rights by virtue of special acts by the California legislature. However, the New Mexico Supreme Court disregarded these considerations and held that the California doctrine of pueblo rights prevails insofar as the Las Vegas pueblo is concerned.

It appears that the Supreme Court of New Mexico based its conclusion more on social and philosophical grounds than on any legal analysis. There is no mention of constitutional definition of beneficial use and no mention of the fact that no rights had vested under Mexican sovereignty. Instead, the Supreme Court in a three to two decision, stated:

> "It is not surprising that a doctrine such as the Pueblo Rights arose when we consider the fact that these colonization pueblos to which the right attached were largely, if indeed, not always, established before there was any settlement of the surrounding area. Thus it resulted that there had never been any prior appropriations or use of water of the river or stream, nor any allotment of lands, by the Mexican government prior to the establishment of the Pueblo."

It is interesting that there is no support whatsoever in the record for the above quoted statement and as a matter of fact, the evidence does show that there was a considerable settlement on the Pecos River, of which the Gallinas River is a tributary, prior to the pueblo grant in 1835.

Justice Sadler, speaking for the majority, went ahead to state:

> "It is the claim of plaintiffs (appellants) that constitutional and statutory provisions touching the use of water is contrary to the Pueblo Rights doctrine and that it can find no place in our jurisprudence. They fail, however, to point out in what respect this is true. This Court has long recognized that we have followed the Mexican law of water rights rather than the common law."

Judge Federici, who wrote the dissenting opinion, points out that the California pueblo doctrine of water rights does conflict with the statutes and constitution of New Mexico and also cites the evidence to show that there were settlements and appropriators on the Gallinas River prior to the grant to the pueblo of Las Vegas. Judge Federici also points out that there is absolutely nothing in any law of Spain or Mexico which would grant a pueblo the right to destroy the property of an appropriator from a stream, being his right to the use of the water, with no compensation.

Judge Federici, in his dissent, states that the New Mexico legislature has never delegated or surrendered its power or control over the execution of the trust to the town of Las Vegas.

This writer submits that the majority decision is judicial legislation. This is strikingly pointed out by the majority opinion's rationale of the case:

> "And just as in the case of a private use, so long as he proceeds with due dispatch to reduce to beneficial use the larger area to which his permit entitles him, enjoys a priority for the whole so by analogy and under the rationale of the Pueblo Rights doctrine, growth and expansion, carried with them the torch of priority, so long as there was available water to supply the life blood of the expanded community."

We might question whether Justice Sadler is saying that the community could expand its use of water forever since the Court implies in the above quoted statement that the expanded use in 1958 would relate back and be given a priority of 1835.

It appears that the Court disregarded the separation of powers doctrine and arrogated to itself rather than the legislature the authority to determine the extent of police power as witness the following statement from the majority opinion:

"There is present in the doctrine discussed the recognizable presence of lex supreme, the police power, which furnishes answer to claims of confiscation always present when private and public rights or claims collide. Compare, Middle Rio Grande Conservancy Dist. v. Middle Rio Grande Water Users Ass'n., 57 N.M. 287 (310), 258 P.2d 291. So, here, we see in the Pueblo Rights doctrine the elevation of the public good over the claim of a private right."

After the first decision in the Cartwright case, the Supreme Court of New Mexico granted a rehearing and also granted a second rehearing. At the last rehearing, Justice Sadler was no longer with the Court and the case was finally determined without an opinion by a two to two decision. In both the first rehearing and the second rehearing, Judge Federici, speaking for the dissent, ably answered every argument advanced by the majority decision.

Query: Regardless of how it is worded, does not the California doctrine of pueblo water rights result in confiscation without compensation? The effect of this decision is relatively small insofar as the community of Las Vegas in concerned. But consider for a moment the tremendous problems confronting the State Engineer and the courts of New Mexico if the California doctrine of pueblo rights is applied to the Rio Grande valley. How can New Mexico honor her compacts if all the pueblos, including the Indian pueblos along the Rio Grande, have the absolute right to take all of the waters from the Rio Grande and the valley fill as the pueblos feel they need, without regard to diligence, beneficial use, the statutes on forfeiture or without regard to priority?

The California and New Mexico courts have said that a pueblo use cannot be lost for non-use or abandonment, cannot be sold or transferred. Does this doctrine destroy all security of property rights in the Rio Grande? Who knows how many pueblos in New Mexico and Texas are entitled to absolute rights.

As I have discussed before, the New Mexico Supreme Court and the United States Supreme Court have held that Santa Fe was not a pueblo. The United States Supreme Court also denied the claim of the City of Albuquerque to a pueblo right. But now the City of Albuquerque and the state of New Mexico are engaged in litigation wherein the City of Albuquerque, notwithstanding the decision of the United States Supreme Court, presents new evidence unearthed in the archives in Mexico City purported to show that Albuquerque was in fact a colonization pueblo and that Albuquerque is entitled to all the rights which the pueblo of Las Vegas has won. This litigation has been pending for two years before the districtcourt setting in Albuquerque and, even though Judge Macpherson had indicated on

several occasions that the state of New Mexico would prevail, at the time of the last hearing, on August 11 of this year, the district court ruled from the bench that he would find for Albuquerque and that Albuquerque could take all of the water from the valley fill of the Rio Grande necessary for municipal purposes without regard to the effect on prior appropriators.

The state of New Mexico, when and if judgment is entered for Albuquerque, will undoubtedly appeal this case to the New Mexico Supreme Court. There are several distinctions between the Albuquerque case and the Las Vegas case, one of the distinctions being that Albuquerque submitted to the jurisdiction of the State Engineer and applied to the State Engineer for a permit and that the State Engineer has only such authority as the legislature has granted him. The legislative enactments require the State Engineer to deny the permit in the event it will impair existing rights. No attack has been made upon the finding of the State Engineer that the granting of the present permits would impair existing rights. In addition to arguing that the Cartwright case involving Las Vegas can be distinguished from the Albuquerque case, counsel for the State will undoubltedly argue that the Cartwright case should be reversed.

TRANSFER OF WATER RIGHTS

The surface water statute involving change of place of use or change of purpose of use is Sec. 75-5-23, N.M.S.A. 1953, which provides that the change may be made, provided that no such change may be allowed to the detriment of others having a valid and existing right to the use of the water of said stream system. The underground statute provides that there must be a showing that such change will not impair existing rights.

In the case of Templeton v. Pecos Valley Artesian Conservancy District, decided in 1958,[5] the Supreme Court of New Mexico held that in the case where a ground water user had dried up the Rio Felix, the appropriator from the Rio Felix could follow the source of water and drill wells and thus pump ground water sufficient to take care of his water rights.

This case is a landmark case in New Mexico, since it recognizes the laws of nature in that both surface and ground water in the valley fill are part of the same system. The New Mexico court followed the lead of the Colorado courts in recognizing the relationship between surface and ground water. The State Engineer by his administrative action has administered the Rio Grande Underground Basin in such a way as to give the greatest amount of protection to the base flow of the Rio Grande. In the Roswell Artesian Basin and in the Rio Grande Basin there are many administrative problems connected with the decision of the court in the Templeton case.

The question has not been resolved as to whether appropriators from the small streams tributary to the Pecos River can now regain the amount of water covered in their original appropriation by drilling wells. In many cases the original source of water from springs or streams has been dried up for 20 to 40 years. Have these appropriators lost their right by not exercising diligence in applying for a permit to drill a well? Are they guilty of laches by sleeping on their rights while other appropriators expended money by drilling wells and appropriating water from either the valley fill or the artesian basin?

Some answers may be given by the Supreme Court in the case of Pettett v. State Engineer, Supreme Court Cause No. 6766, now pending before the New Mexico Supreme Court. In the Pettett case, the water user had a priority of 1904 from seeps or springs in Zuber Hollow. By 1922 or 1924, the spring flow had decreased to such an extent that the appropriator supplemented his water by using drainage water and sewage water from the Town of Dexter on his land. By 1938, the source was so inadequate, the appropriator

illegally placed a pump in the Pecos River in order to get his duty of water. In 1954, the State Engineer obtained an injunction against the use of the Pecos River water and shortly thereafter Pettett filed an application with the State Engineer to drill a well to change his point of diversion from Zuber Hollow to the shallow water basin.

The trial court found that appropriation from the shallow basin had dried up the springs and granted the permit. The State Engineer appealed and argued before the Supreme Court of New Mexico that the appropriator has the burden of proving how much water he was taking from the public water source and in this instance the applicant did not meet his burden of proving the amount of public water to which he was entitled. The state further argued that the illegal diversion from the Pecos River could not be consiered as a lawful diversion for beneficial use and that since more than four years had gone by without beneficial use from a lawful source, forfeiture had occurred.

The argument on forfeiture was based upon the case of State v. Mitchell, decided in 1959.[6] In this case, the Supreme Court held that the appropriator could not and cannot change the location of a well used to irrigate a tract with a vested right without following the statutory procedure and the irrigation from the new well for four consecutive years resulted in a legal forfeiture of the water right. Chief Justice Lujan in the opinion stated:

> "Irrigating from an unauthorized well must, insofar as forfeiture is concerned, be considered tantamount to not irrigating at all."

I have pointed out just some of the problems concerning the administration of water rights in New Mexico. Most of these problems are problems with which the administrators of water law in the western states have also faced or probably will face within a short time.

INDEX TO FOOTNOTES

1. Yeo v. Tweedy, 34 N.M. 611, 286 Pac. 970, (1929, 1930)
2. State v. McLean, 62 N.M. 264, (1957), 308 P2d 983
3. New Mexico Products Co. v. New Mexico Power Company, 42 N.M. 311
4. Cartwright v. Public Service Company of New Mexico, 66 N.M. 64 (1958), 343 P.2d 654
5. Templeton v. Pecos Valley Artesian Conservancy District, 65 N.M. 59, (1958), 332 P.2d 465
6. State v. Mitchell, 66 N.M. 212, (1959) 345 P.2d 744

CALIFORNIA'S GROUND WATER PROBLEMS AND THEIR SOLUTION

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I believe it can be stated unequivocally that the economy Californians enjoy today would not have developed, were it not for the availability of water placed in our vast underground reservoirs by nature over the years. Consider, for instance, the great Los Angeles metropolitan area. Could its economy ever have developed to the point where the importation of water from the distant Colorado River could have been financed, without the readily available ground water resources on which to grow? This same situation has been experienced in many areas of the State. It may seem ironical, but it is true that the serious water-deficiency problams now being experienced in California are due to the development in large part made possible by these ground water resources which were once considered virtually inexhaustible.

Since the turn of the century draft on ground water resources throughout California has increased at a phenomenal rate. Today about one-half of the total water supplies put to beneficial use are secured from ground water sources. The bulk of this use is in the Central Valley where the average annual draft exceeds 10 million acre-feet, of which more than 8 million acre-feet are pumped in the San Joaquin Valley. This tremendous development has generally occurred on an uncoordinated individusl basis, with little concern for the ralationship between extraction and recharge, and without progressive action to arrest the steady decline of ground water levels. The results of these practices are plainly evident in many parts of the State, both in quantitative overdrafts, amounting to some 5 million acre-feet per year for the State as a whole, and in degradation of native water supplies by intrusion of saline waters, as is being experienced in many coastal and several inland ground water basins.

The greatest ground water deficiency is found in the San Joaquin Valley, in which the average annual extraction exceeds the safe ground water yield by some 3 million acre-feet. Other areas of serious overdraft include Alameda and Santa Clara Counties in the San Francisco Bay area; Monterey and Santa Barbara Counties in the Central Coastal Area; and Ventura County and the portions of Los Angeles, Orange, San Bernardino, and Riverside Counties in the South Coastal Area.

Taking a brief glance at the future, it is forecast that California's present water requirements of 24 million acre-feet per year will ultimately more than double to some 51 million acre-feet per year. A great portion of this increase in water use will, of course, occur in areas of present or imminent ground water deficiencies. So it can be seen that California not only is experiencing present problems but will be confronted with even greater problems in the future in the management of her vital ground water resources to the end that the overall water requirements can most equitably and efficiently be met.

I propose to center my discussion today primarily around the engineering and legal considerations which have been and will continue to be encountered in the solution of California's present and future ground water management problems. However, it might be well to begin with a brief summary of the history of development of the law governing the use of ground water in California.

History of Ground Water Law in California

In contrast to the use of surface waters, rights to the use of ground water in California are generally not governed by basic statutory law. The doctrines of riparian water rights, attaching to lands contiguous to natural channels; pueblo water rights, the paramount rights of certain cities as successors of a Spanish or Mexican pueblo (municipality); and appropriative water rights, governing the use of water on essentially all other lands, provide full coverage to the development of surface waters of California for beneficial uses. The latter doctrine is of the greatest importance, since most of the rights to the use of water in California have been gained by appropriation. However, present law regulating the use of ground water has stemmed largely from court decrees resolving individual problems as they have developed. Although the doctrine of appropriative rights extends to ground water flowing in "known and definite channels", this doctrine is unimportant in California, as ground waters falling under such a category are insignificant.

The use of ground water in California was first accorded formal recognition by the courts in 1903 in a decision by the California Supreme Court in Katz v. Walkinshaw. This decision established the doctrine of correlative rights in California which holds that owners of land overlying a common ground water basin have mututal and correlative rights to the reasonable beneficial use of the water on the overlying land. Adoption of the "reasonable use" doctrine rejected the former common-law doctrine of absolute ownership in percolating water. As between overlying land owners and exporters for distant use, the rights of the overlying landowners are paramount, but limited only to the

quantity of water necessary for beneficial use on overlying lands. If the supply of percol ting waters is sufficient, the exporter may take the surplus. However, if the supply is limited, all other owners are to have a fair and just portion of the total supply. Court decisions subsequent to Katz v. Walkinshaw on rights to percolating waters have adherred consistently to the principles laid down in the decision in that case.

The case of Pasadena v. Alhambra (1940) added a new concept of "mutual prescription" to the long established correlative rights doctrine. This case has assumed outstanding importance in the ground water law of California, as it applied to a ground water area (Raymond Basin) that had been overdrawn for many years. Briefly the decision of the court found that since the five-year prescriptive period following the first occurrence of overdraft had passed without any proceedings by the earlier pumpers to protect their rights, all pumpers--overlying users as well as exporters--had acquired a prescriptive right as against each other at that time. Each pumper was enjoined from pumping more than his proportionate share of the safe yield of the basin, based upon the ratio of his rights to the total of all rights in the basin. The reduction in this case amounted to about one-third of the tital pumpage. The Raymond Basin decision has widespread implications in California because of the considerable number of overdrawn ground water basins in the State.

The trial court in Pasadena v. Alhambra referred the case to the Division of Water Resources (predecessor to the State Water Rights Board in matters pertaining to water rights) under the "court reference procedure" as set forth in Sections 2001 and 2010 of the California Water Code. Under the court reference procedure, the trial court is authorized to appoint the State Water Rights Board (the Division of Water Resources at the time of the Raymond Basin Reference) to investigate and determine the physical facts and to make recommendation for solution in a report of referee submitted to the court. The court reference procedure was also followed in the case of California Water Service Company v. City of Compton (West Coast Basin Reference).

Pursuant to orders of the trial courts, the Department of Water Resources (and its predecessor agency the Division of Water Resources) is maintaining watermaster service in both the Raymond Basin and West Coast Basin. The court decree in the Raymond Basin case determined the water rights, placed a limit on the pumpage authorized to each holder, and appointed the Department (then Division) of Water Resources as the watermaster to enforce the provisions of the decree through supervision and control of pumping.

In the West Coast Basin Reference, the parties involved entered into an interim agreement pending the final decision by the court. In the agreement all parties voluntarily reduced their pumpage to their prescriptive rights as of 1949, and the Department (then Division) of Water Resources was appointed as watermaster to supervise and maintain accurate records of ground water extraction and of ground water levels.

Another extremely important decision of the California Supreme Court in the case of Los Angeles v. Glendale has added to California ground water law an essential tool in the management of ground water basins. One objective of the case was to establish the validity of the claim by the City of Los Angeles of ownership under its pueblo rights of all water originating in the watershed of the San Fernando Valley. The other objective, and perhaps the more important, particularly as it relates to the implementation of the California Water Plan, was to establish the validity of the claim by the City of Los Angeles to title to waters imported to the San Fernando Valley through the Owens River Aqueduct. The City of Los Angeles spreads a considerable portion of the Owens River water in the upper San Fernando Valley where it commingles with native ground water. The city uses the underlying ground water storage both to provide terminal regulation to the imported water and for conveyance of the waters down the valley to the re-diversion works where it enters the city's municipal water system.

The court held in Los Angeles v. Glendale that the city's pueblo rights do not attach to the imported water, but that since the city imported the water and did not abondon it, it retained title to the water, and that the Cities of Glendale and Burbank had no rights to the imported water. This holding, therefore, constitutes a valuable precedent in support of conjunctive operation in other areas, as for instance, in the San Joaquin Valley under the California Water Plan. I will refer to this case later in a discussion of future problems.

None of these court decrees has accomplished anything toward solving the basic water problem in California--the imbalance between available ground water supplies and the demands thereon; it was not the purpose of these decrees to do so. But they did establish doctrines to facilitate the management of ground water basins, not only under present conditions but under future conditions of their increased use.

Accomplishments Toward Solution of Present Problems

The complete solution to California's present ground water problems, and of course the future problems, lies in an integrated combination of physical or engineering accomplishments to make additional water available, and the legal means of their implementation. Considerable progress has been made thus far through the efforts of various agencies in the construction of physical works to improve their operations, and by enactment

of certain recent legislation.

Substantial accomplishment has been made by many local districts throughout the State in supplementing the natural recharge of ground water basins, either by percolation of local surface water resources or by percolation of surface waters imported from distant sources. These recharge activities may be classed as deliberate or artificial, and incidental. Artificial recharge involves the release of water from surface storage for percolation either in natural stream channels or in any of several forms of spreading basins, or both, or the diversion of unregulated runoff to spreading basins. Under incidental recharge, ground water replenishment is accomplished without specific effort, through the normal conveyance and application of water to irrigated crops. Incidental recharge is practiced more universally than artificial recharge for the simple reason that losses of water by deep percolation from canals and laterals and on irrigated lands are unavoidable. It can be said that nearly every agency utilizing both surface and ground water sources presently acccmplishes incidental recharge.

Bround water recharge, other than that occurring under natural conditions, involves the coordinated or conjunctive operation of surface supplies and underground storage facilities. While the term "conjunctive operation" may be new to some of you, certainly the practice has been long established. Briefly, conjunctive operation involves the supplementing of surface storage with underground storage to increase the conservation of water resources by utulization of greater total storage capacity. Such operation involves the use of cyclic or long-term carryover storage, both surface and underground, but particularly underground. With respect to ground water basins, this will result in a drawdown of ground water levels during drought periods, followed by a recovery during subsequent wet periods. This planned fluctuation, or alternating lowering and recovery of water levels, is necessary to regulate an extremely variable water supply to a relatively uniform yearly demand.

Many water service agencies in California operate surface storage facilities to achieve the fullest control of variable water supply from year to year. These agencies supply the bulk of irrigation water from surgace sources during the wetter years, while individual operators secure the majority of t heir supplies from ground water sources during drier years. This operation permits irrigation of a larger acreage than would be possible under a uniform annual supply from the two sources, if operated independently. In this manner ground water recharge may be accomplished through incidental means or through both incidental and deliberate or planned operations.

Deliberate or artificial recharge is presently being practiced in some 275 artificial recharge projects throughout the State. It is estimated that a total replenishment of 440,000 acre-feet was attained during 1951-52 by operation of these projects. Such recharge has been practiced since 1895 in Southern California. Artificial recharge activities are concentrated largely in the Santa Clara Valley just south of San Francisco Bay, in the southern San Joaquin Valley, and in Southern California. This is readily understandable in light of the extensive exploitation and overdevelopment of ground waters in these areas, coupled with extreme fluctation of runoff, scarcity of suitable surface storage sites, and availability of extensive ground water storage capacity.

In an attempt to solve its water problem the Orange County Water District, in Southern California, has secured special legislation which permits it to levy an assessment on the amount of water pumped for the purpose of purchasing for recharge purposes. In addition, this district has the power of levying a limited ad valorem tax for the purpose of purchasing additional imported water to further replenish the basin. Both the latter district and the Los Angeles County Flood Control District are presently purchasing and spreading Colorado River water to reduce the overdrafts on the ground water basins of the coastal plain on Irange and Los Angeles Counties.

In order to establish a means of financing the replenishment of overdrawn ground water basins with imported water, the California Legislature enacted the Water Replenishment District Act in 1955. This legislation authorizes the formation of ground water replenishment districts in the Counties of Santa Barbara, Ventura, Los Angeles, San Diego, Riverside, San Bernardino, and Orange. The Central and West Basin Water Replenishment District in Los Angeles County, constituted by an election on November 17, 1959, is the first such district formed under this legislation.

An important legislative step was also taken in 1955 when the Ground Water Recordation Act was passed by the Legislature. This legislation requires the recordation of ground water extractions in excess of 25 acre-feet per year in Riverside, San Bernardino, Los Angeles, and Ventura Counties. Those who sponsored the legislation believed that this procedure will help protect water rights and reduce high cost of water litigation by making such records prima facie evidence in court.

While these acts are applicable only to a few counties of the State and to only a portion of the critical area of Southern California, it is probable that similar acts will extend to other areas of the State as the degree of ground water development approaches that now existing in Southern California.

Future Ground Water Problems and Their Solution

California's basic water problem dictates the pattern of solution, as envisioned under the California Water Plan. The bulk of the water resources occurs in the northern part of the State, while the productive land and major urban areas are located in the central and sothern regions. The solution to this basic problem involves the capture and control of surplus waters of Northern California and their transfer to the central and southern areas of deficiency.

Studies made by the Department of Water Resources during the formulation of the California Water Plan strongly indicate that the objectives of the plan--the full satisfaction of water requirements in all parts of the State for all beneficial uses and purposes--cannot be achieved by surface facilities alone. Partially regulated water resources of the Sacramento Valley must receive final regulation in the extensive ground water basins of Central and Southern California, especially in the San Joaquin Valley. This will require full and careful use of our vital underground storage resources. The reason for this is twofold. First, remaining combinations of good dam sites with surface reservoir sites of adequate storage capacity are rare, particularly in the areas which surplus water must be developed; furthermore, the cost of such storage is, in many cases, beyond the present limits of economic feasibility. Secondly, adequate storage capacity is available in the ground water basins to develop at portion of the water resources which would be too costly to develop by surface storage alone.

Under the further development of California's water resources, ground water basins will be utilized for conservation of local supplies, and for seasonal and cyclic regulation of water to be exported from areas of surplus and of imported water in areas of deficiency. This involves not only the correction of present ground water overdrafts but the balanced use of both surface and ground water supplies so as to achieve optimum utility of ground water basins.

Development of local ground water supplies to meet the needs of overlying users does not pose too much of an engineering or legal problem, as it is already in universal practice in nearly all of the ground water basins of the State. Similarly, conjunctive use of underground storage for providing terminal regulation for imported water such as is practiced in the South Coastal Area, is founded upon well-established principles, and does not pose a significant engineering problem. However, there is a need for further development of ground water law to ensure full-scale operation to provide terminal regulation.

Undoubtedly the most formidable engineering problems and probably the greatest legal problems of ground water basin management will be encountered in the planned large-scale use of cyclic ground water storage, as contemplated in the Central Valley under The California Water Plan.

Physical and Engineering Problems

The operation of the Central VAlley under ultimate development assumes the development of local water resources to their full practicable limit. About one-half (8,000,000 acre-feet) of the ultimate seasonal water requirements of the San Joaquin Valley can be developed by conjunctive operation of local resources, while the remainder would be provided by importation of water from northern areas of surplus. Surplus water developed in the Sacramento Valley for export to the San Joaquin Valley would be of three types: (1) water developed conjunctively by major foothill reservoirs and ground water storage on a firm seasonal basia; (2) variable seasonal releases from major footnill reservoirs, depending on the wetness of the particular year ;and (3) variable seasonal pumpage from ground water storage in the Sacramento Valley during drier periods. It is the latter two sources, or "secondary supplies", tnat will require vast underground storage in tne San Joaquin Valley for tneir final regulation.

Ground water recnarge in tne San Joaquin Valley would be accomplisned by: (1) seepage of water from main canals, laterals, and surface distribution systems during tne irrigation season and, if necessary, during tne winter season; (2) percolation of normal excesses of applied irrigation water and of precipitation during wetter years; and (3) water delivered to spreading basins for direct ground water recnarge.

Broadly speaking, tne primary pnysical problems associated directly with the full development and utilization of ground water storage are: the practicability of ground water replenishment, or the transfer of surface water to underground storage; the efficiency of recovery of ground water so stored, including transmission from areas of recharge to areas of use; the effect upon the mineral quality of ground water from such planned operation; and the effects of such utilization on the overlying service areas.

The engineering problems encountered in solving the physical problems are: the conveyance of surplus waters, particularly the large quantities of variable or secondary waters, from the Sacramento Valley to the San Joaquin Valley; the pattern of distribution and disposal of the water imported from the Sacramento Valley, as well as local supplies, through irrigation application and through spreading, if necessary, so as to best utilize the physical percolation characteristics in the San Joaquin Valley service areas; maintanance of satisfactory ; mineral quality

of ground water; provision for drainage facilities; and establishing a balanced use of surface and ground water supplies so as to achieve the optimum utility of ground water storage and to minimize adverse effects on overlying users.

Another problem arises with respect to the manner of treatment of the present ground water overdraft in the San Joaquin Valley during the transitional period from present operation to ultimate conjunctive operation. Water levels in the valley are presently depressed to great depths over large areas. In addition, there is a current annual overdraft amounting to approximately 3,000,000 acre-feet. Conjunctive operations, with the accompanying fluctuation of ground water levels, can be accomplished with the average water level stabilized at almost any depth, dependent upon quality considerations. However, the cost of water recovery will depend, in large measure, on the depth to the average stabilized water level. Recharge of sufficient water to replenish all, or a major part, of the accumulated overdraft will result in sizeable operating economies in the future.

Legal Problems

It has been established that the implementation of The California Water Plan requires the large-scale conjunctive operation or planned management of ground water basins for use on either overlying or nonoverlying lands. The court decree in Los Angeles v. Glendale constitutes a very strong precedent in support of conjunctive operation of surface and underground storage where water is to be stored underground in one area and then withdrawn for use in another area. It still leaves some doubts, however. Under our judicial system, the rights of landowners and an agency engaged in conjunctive operation usually cannot be readily determined in advance of construction of the project. But it is obviously imperative to know for certain that this type of operation can be carried out before spending hundreds of millions of dollars to construct expensive facilities. Even more important than the possible monetary loss, however, is the possible delay of many years which might occur if a determination as to the legality of conjunctive operation is left to the courts under present law.

The only adequate solution to this problem is legislation that specifically authorizes the acts required for conjunctive operation in its broadest aspects. Any such legislation would, of course, provide full protection for vested rights to the use of ground water. Because of the far-reaching changes that planned utilization of ground water basins would cause in relation to the many individual water users, a constitutional amendment to authorize this practice may be desirable. A principal function of such an amendment would be to make sure that the injunctive process would not be used to delay or prevent such programs.

In addition to the cited need for legislation and a constitutional amendment that would clearly authorize conjunctive operation, the following legal steps are considered necessary to the implementation of The California Water Plan.

1. Local districts throughout the State should review their existing authority to determine whether the districts have adequate powers to carry out their role in ground water basin management under The California Water Plan. To the extent that existing districts are inadequate, legislation should be enacted which would enable the formulation of districts with adequate authority for such ground water management.

2. Provisions of the Water Code relating to the filing of records of ground water extraction in five Southern California counties should be expanded to the entire State, with such modifications as experience indicates are necessary.

3. Legislation should be prepared that will streamline, improve, and extend the "statutory adjudication" and "court reference" procedures in order to improve procedures for facilitating adjudication of ground water rights.

4. The Water Replenishment District Act should be extended in the near future to additional areas of the State.

Conclusion

In conclusion, serious ground water problems have developed during the rapid expansion of California's economy. However, through court decrees, operational activities of many organized agencies and districts, and recently enacted legislation, considerable progress has been made toward the minimization of these problems. With respect to the future, formidable engineering problems of long-distance transfer of water and provision of regulatory and terminal storage through planned operation of ground water basins must be solved. Concurrently, legal steps must be taken to permit the effectuation of the physical or engineering plans.

Formidable as these problems appear to be, it must be remembered that they need not be solved today. Our experiences and knowledge will, without doubt, develop as the specific problems take shape, and I am sure these problems can be taken in stride when their solution becomes necessary.

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PUBLIC DISTRICTS IN THE MANAGEMENT OF CALIFORNIA'S GROUND WATER[1]

by

Stephen C. Smith[2]

Public Districts are used as a form of organization in managing California's ground water. They have been organized to execute programs hopefully designed to meet problems facing ground water users. The range of management activities the districts carry on will be outlined in section I. However, the meaning of California's correlative rights doctrine will not be discussed in greater detail than to say that overlying land owners have coequal rights to pump for beneficial use with municipalities and exporters from the basin being appropriators. For a complete review of this doctrine, see Wells A. Hutchins' Law of California Water Rights.[3] Due to the limitations of space, only selected aspects of the relationship of the district to this doctrine will be mentioned.

Experience with the public district in California has been suggestive of factors which are important to the role it plays in ground water management. These will be discussed in section II.

Although the future is uncertain, the time is at hand when problems should be anticipated and questions raised. Some of these questions and problems will be noted briefly in section III.

I

District Programs

The predominant sentiment of California's ground water users has favored the retention of the correlative rights doctrine rather than adopting new ground water legislation with provisions for management. The possibility of such legislation, however, has not been by-passed without being considered by the major interests concerned with ground water problems.[4] Instead, public districts have been used as a form of organization to provide the degree of management decided upon by its constituents.

The problem of increasing depth to water with increasing costs of production was recognized by early ground water users. They readily observed that is some method could be devised for raising the water level savings might accrue depending upon comparative costs. Before long, it was realized that the storage space of the ground water reservoir had a value. Why not capture flood waters in rainy years to build up the reservoirs and then pump them down during the dry years? Or if the secular pattern of draft were declining, its rate might be slowed by such a program.

The management program for these situations was recommended more than half a century ago. The desire was to integrate surface and ground water management and to explicitly recognize and utilize the interdependence of the two. The

program which is practiced most widely was started here in Colorado in 1889 and in California about 1895--artificial ground water recharge. Early efforts in this direction generally consisted of little more than widening the stream bed and throwing a low sack or log dam across a stream to construct an in-stream spreadingpond. Today, this same activity--artificial recharge--is still the most predominant ground water management program executed by districts. Of course, the programs of 1960 are much more complicated and complex; yet the intent of integrating the management of surface and ground water is still paramount and the main function of the district organization.

The particular way the recharge program fits into local water management will depend upon the physical, economic, and historical setting. These all differ from one ground water basin to another. To illustrate the variety of situations which must be met, four case areas will be briefly mentioned. In each, the public district has played a different role.

At the southern tip of San Francisco Bay, the residents of Santa Clara County organized the Santa Clara Valley Water Conservation District in 1929. Then the Valley was mainly rural--today it is becoming urban at an extremely rapid rate. The assessment power of this District to levy against the value of land exclusive of improvements was used as security for issuing bonds from 1934 to date. From the receipts from these bond sales, storage reservoirs have been built in the mountains surrounding the Valley. (The total reservoir capacity is approximately 140,000 acre-feet.) These reservoirs catch the winter flood flows for release into spreading areas along the edges of the Valley floor. In this way, the seasonal run-off is stored in the ground water basin. The stored water may be used for the subsequent summer dry period or during the next drought period. There has been no program for widespread surface delivery of water for irrigation in this valley. The developed water has been distributed through the ground water reservoir.

Today, the boundary of the Santa Clara Valley Water Conservation District approximates the boundary of the northern ground water basin. The desirability of this situation, however, was not self-evident to the County's residents.

In fact, ten years of public debate and organizational effort preceded taking this action. The wisdom of the decision has been demonstrated in their experience and incorporated into later, more specialized legislation--the law enabling the creation of water replenishment districts.[2]

Until recent years, this District was essentially single purpose in character although its powers under its enabling act would permit movement into almost any desired water management activity. But the policy focus as developed in the organizing process has been upon maximum water storage for recharge purposes. However, since the creation of the District in 1929, new water management interests have arisen--flood control, recreation, and municipal water supply via water importation. These were not seen as major problems at the time of organization and subsequently were not incorporated into the operating program of the District. For some issues this has been a satisfactory solution; for example, recreational use of the reservoirs. Early efforts to handle this function by lease were misdirected

largely due to the lack of technical skills within the organization. An internal awareness of the problem and public pressure lead to a cooperative effort to organize a County recreational department. The situation is not so clear-cut for flood control and water importation. New organizations--districts--have been created around these interests with resulting interagency conflict. Working through several functionally organized agencies has made it difficult to develop an integrated plan.

The east side of the large San Joaquin Valley is in contrast to the well-contained Santa Clara Valley. A series of rivers rise in the Sierra Nevada Mountains and flow into the Valley perpendicular to its axis. Many early farmers in this area had both surface and ground water available. Water has been developed by individual farmers, ditch companies, and irrigation districts with both the Bureau of Reclamation and the Corps of Engineers constructing large works in the past decade and a half. As might be expected, few of these surface water management agencies have boundaries which conform to the ground water basin. Yet efforts are being made to integrate surface-ground water management through district organizations.

One such program has been carried out by the Kaweah Delta Water Conservation District since 1927. This is a district which overlies several other organizations--districts and mutual water companies. The function of the District is to carry out an artificial recharge program. The recharge water is run through constituents canals to the specially constructed spreading ponds. Also, some of the stream beds and unlined irrigation canals are used for this purpose. Water from the Kaweah and St. Johns rivers are spread, plus Class II water from the Bureau of Reclamation. The operation is financed by an assessment upon land and improvements. This overlying District integrates the interests of several related organizations.

In Kaweah Delta, as well as in other localities, ground water flow does not stop at the District boundaries. At times well fields are used to capture escaping ground water flow--either to retain it within the District or to capture it from another. The legal issues will not be mentioned, but the point made earlier with respect to district boundaries should be emphasized. Also, as part of an integrated ground-surface water management program, wells are operated by some districts to increase the depth to water, to provide storage space, and to counteract potential drainage problems.

Irrigation districts, likewise, may spread and perform an important related function in setting the toll charged for the surface water delivered to farms. By varyi ng this toll the District can influence whether the farmer uses District delivered surface water or gound water. The relationship between tolls and electric charges for pumping are significant water management tools.

District programs of artificial recharge have also played an important role in integrating ground and surface water management activities in California's southern coastal region. The oldest of these activities has been single purpose similar to that mentioned in Santa Clara County. These programs initially depended upon local surface water, but recently Colorado River water has been purchased for this purpose. Also, special programs of well injection as the Manhattan Beach Project have been initiated to prevent sea water intrusion.

Multifunctional districts also have operated on a large scale. Examples of the former are the newly formed water replenishment districts and the older Orange County Water District. Other districts combine some functions but not all, such as the Los Angeles County Flood Control District which includes functions such as flood control, conventional recharge, and well injection.

One aspect of the Orange County Program should receive elaboration. Their experience may prove helpful to other areas. This District was given the power to levy an excise tax upon the volume of water pumped from each well. The ground water users within the Orange County Water Conservation Distract approved this action so that the District could purchase Colorado River Water from the Metropolitan Water District of Southern California for recharge purposes. Each well is metered with the rate of levy depending upon the volume of water to be purchased. Based, in part, upon this experience enabling legislation was passed to permit the organization of single-purpose water replenishment districts with the power to utilize the pumping tax. Two such districts have recently been formed, but they have not been in operation a year. The size of the levy has varied among these three districts and will vary from year to year, but the range has been between $4 and $8 per acre-foot. Of course, the size of the levy will tend to affect pumping similarly to toll effects previously mentioned although in these situations surface sources are not as readily available.

As corporate entities, public districts have functioned in the California situation to represent the internal interests to interests external to the district. Again, the experience of the Orange County Water District illustrates this characteristic in California's legal setting with the correlative rights doctrine. The Orange County Water District represents the water users overlying the lower basin fed by the Santa Clara River. The upper basin, which feeds the lower basin, is pumped, in particular, by the cities of Riverside, Colton, San Bernardino, and Redlands. The Orange County Water District sought injunctive relief and wanted to limit the volume of water which these cities could pump. Relief was granted and the ability of the cities to pump from the well field was limited according to last year's ruling. Without going into the legal points at issue, the District has been used to define pumping rights through court action. Whether the cities can circumvent the intent of this action by purchasing stock in mutual water companies or by other means is not clear.

Public district management has executed also a strong force in directing water development and use. Of course, programs of public education about good management practices play an important role. And even more effective is the continual counseling to water users--both present and prospective. A good district manager can go a long way in effecting the location and type of installation. Yet effectiveness in this direction is limited by the powers which districts are granted.

II

The Role of Districts

Public districts have been used to organize the activities which have just been illustrated. They have filled a governmental vacuum in the management of California's ground water. Generally, other governmental units had little interest or authority to concern themselves with ground water problems in a management sense. Because of the correlative rights doctrine, the state did not function

in the same capacity as it did for appropriative surface water. Further, federal or state action programs were not as obvious nor legally as feasible. Consequently, legislation began to appear enabling public districts of several kinds to carry on certain ground water management activities.[6]

Before looking at this enabling legislation, I want to make one point which may not be apparent from looking just at the formal institutional structure. The structure does not tell you what went on in the process of drafting the enabling law nor does it tell you about the struggles of organization which frequently took place in attempting to use the enabling law. California has several enabling acts which might be used or special acts can be and have been passed by the legislature; for example, the Orange County Water District Act. During this process of deciding upon an act and of obtaining voters approval, basic policy decisions are made concerning the character of the program, the terms of organization, and the nature of local control and participation. Although this procedure may at times seem laborious in our democratically organized society, it pays in program participation and effectiveness. In a very real sense the district provides a procedure for considering conflicts of interests and reaching a decision.

Two types of enabling acts have been passed by the California legislature--general acts which may be used in any locality in the state and special acts which enable the creation of a specific district. Further, these acts vary from specialized districts empowered to do one or a narrow range of activities to broad multipurpose districts. In the latter case, artificial recharge covers only one item in the range of water management activities. At first the number of enabling acts may appear confusing,but one effect has been to give the local users of ground water a choice in the character of the organization to be used. This flexibility has certain advantages since the problems of integrating surface-ground water management are different in each basin. The burden of responsibility for integration is placed with the overlying water users since their active support and consent is needed to create the district and to approve major programs. However, this potential asset has hazards which may add unnecessarily to the complexity of water management--namely, a fragmentation of the decision-making machinery.

Fragmentation may take place in two ways. Separate districts may be organized around each functional water management interest--irrigation, municipal water supply, flood control, recreational use of water, or others. Or fragmentation may be on a geographic basis. Of course, it will be recognized that under certain circumstances these two types of fragmentation may reinforce each other. On the positive side, such segmentation means that each interest probably will have a watchful opponent ready to do public battle over water issues which are of a competitive nature. I do not deny that the public interest may be served thereby. But a critical examination of the use of public districts for ground water management should not neglect the fact that such fragmentation may make it impossible to develop a coordinated plan of action or to achieve acceptable terms of organization. This problem can be guarded against if the situation is carefully appraised at the time of organization. In fact, the process of organization is fundamental

to creating an institutional structure with both the responsibility and the capacity for action. The decision of what interests to include as internal to the district organization is not susceptible to a general answer but is the result of the organizing process under the particular conditions of the basin. The district form of organization may have this flexibility. It might be suggested that in the organizing process the direction of effort might be to start with the general multipurpose organization and work out restrictions as needed for local purposes.

The question of district boundary has been important and will continue to be significant. The boundary needs to be directly related to interests and program. Where whole basins or separable segments are not included, problems have arisen, some of which were mentioned previously in connection with outflow.

The use of a multipurpose district also may present difficulties in that the geographic areas of water management may overlap in part but not in their entirety. Such situations are not uncommon and have been handled by the creation of submanagement areas with special terms of organization which are not generally applicable throughout the district. Thus, if special pumping equipment is necessary to provide water to a particular locality, this may be done with the cost incident upon that locality. An answer to the boundary question hinges upon a clear decision upon program and based upon sound engineering, geologic, and economic studies. Economically the boundary is important in relating the incidents of benefits to costs.

California districts engaged in ground water management tap three sources of revenue, and each is also a tool for water management--(1) assessment of land, exclusive of improvements; (2) assessment of land and improvements; and (3) an excise levy upon the volume of water pumped. The ad valorem assessment upon land exclusive of improvements has been used where urban communities are within the district and will not accept the assessment of improvements. The use of the pumping tax has been limited so far to districts purchasing water for recharge. In selecting and using the three procedures, careful attention should be given to the purpose which is desired. The method selected should itself be considered as one of the tools of management. These effects are evident; for example, in the experience in Orange County. With the installation of meters and the imposition of a pumping tax, more efficient water use has resulted. Many farmers formerly relying upon traditional experience found they were applying too much water. The use of meters made it feasible to exercise control. It has been reported that the saving in water has more than paid for the $300 meter installation charge in a matter of a year or two. For those areas which have both surface and ground water sources, the use of this tax procedure might be integrated with the surface water toll as effective tools of integrated management--that is, encouraging pumping in some years and discouraging it in other years.

Being corporate entities, districts can own property--including water rights. Also, they can seek injunctive relief as previously noted. This ability is certainly essential to integrating the management of ground and surface water in many situations. A part of this same characteristic is the ability to represent the internal interests in the signing of contracts. This may be particularly important in simplifying the arrangements for using ground water storage in the interregional transfer of water.

The district as a financially capable organization also has been important in integrating the management of ground and surface water in California. The ability to invest in dams, canals, and spreading ponds and to purchase water are dependent upon a revenue source as has been previously illustrated. There are problems connected with all of the methods of financing a discussion of which would call for a separate paper; the three most common methods have been mentioned.

I would like to close this section of my paper with a problem which I think is serious in many situations; namely, plans are proposed and adopted--or should I say sold--without serious study and without having them checked by competent outside, disinterested personnel. The public needs some protection from being sold a "bill of goods." Of course, you may say it is my professional bias, these decisions need economic, engineering, and legal knowledge built right into the planning process. The economists' questions should be raised initially rather than in an effort to make a last-minute appraisal. In saying this, I am cognizant of the added complications which are encountered when the integrated management of surface-ground water is involved.

III

Considerations for the Future

For the future, the demand will be for the integrated management of surface and ground water. If the public district is to play an important function, it will need to encompass the area of activity--both geographically and functionally.

Geographically, the control of the district must encompass the ground water basin. Boundary problems have been discussed and suggestions have been made. Functionally, the district powers should be able to integrate the several purposes of water management necessary to relate surface with ground water management. The multifunctional district needs to provide for a system of representation for each purpose so that decisions will not be one-sided and thus tend toward the creation of new interest groupings. The excess creation of new groupings can lead to undesirable fragmentation in decision making.

The power of the district to make contracts with outside water supplying agencies and with constituents needs careful appraisal. This is particularly true with respect to the affect upon water rights held by these constituents. Relationships within this area may be key factors in achieving integrated management within existing legal systems. The power to contract in conjunction with the police power need further careful study. In fact, this is just one of several avenues for regulating draft which require further research effort. Such an effort would aid the legislative development of adequate district enabling legislation.

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WATER RIGHTS IN KANSAS

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Western Resources Conference
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Kansas will observe the one hundredth anniversary of its admission to the union as a state in 1961. Many changes have taken place during that first century in agriculture, industry, education, transportation, and in all other phases of our day to day life. Our interest in this discussion is in the evolution of state water law, particularly that relating to development and use of ground water.

The constitution of the state is silent in regard to water, and the water policy in Kansas has been made by the legislature and the courts. It was not until 1945 that effective legislation was enacted establishing the appropriation doctrine and providing for its administration at the state level.

In 1886 a law was enacted by the legislature providing for appropriation of water by the procedure of posting a notice at the point of diversion and filing a copy of such notice in the office of the register of deeds. In 1917 the Kansas Water Commission was created and provision was made for the appropriation of water by application to the commission, but no details of procedure were provided. In 1927 the duties and responsibilities of the Kansas Water Commission and the Division of Irrigation were transferred to the Division of Water Resources of the State Board of Agriculture. The 1886 act was repealed in 1941 and shortly thereafter the Kansas Supreme Court found the remaining statutes relating to appropriation of water to be ineffective. In general, court decisions prior to 1945 have followed the common law.

In 1945, as a result of a study and report by a committee appointed by the governor, a law was enacted which provided detailed procedure by which a lawful right to use of water may be established and protected. It applies to all water in the state regardless of source. After some ten years of experience with administration of the law, it became apparent that some of its provisions were inadequate and it was amended by the legislature of 1957. The Chief Engineer of the Division of Water Resources of the Kansas State Board of Agriculture is designated as the state official charged with administration of the provisions of the law.

The act first dedicates all water within the state of Kansas to the use of the people of the state, subject to the control and regulation of the state in the manner provided. It provides that, subject to vested rights, all waters within the state may be appropriated for beneficial use. It defines "vested right" and sets forth the procedure for determining and establishing the vested rights of those who were actually using water for

beneficial purposes other than domestic, on or before the effective date of the act. Determination of vested rights has been essentially completed and no particular difficulties were experienced in that survey and determination.

The law next sets forth procedure for acquiring an appropriation right to use of water. Very briefly, the steps involved are the filing of the application; issuance of the permit by the Chief Engineer; the notice of completion of works and proof of use of water by the applicant; field inspection by a representative of the Chief Engineer; and the issuance of the certificate of appropriation which must be filed with the register of deeds in the county wherein the point of diversion is located. There is also procedure provided for declaring water rights abandoned and terminated if, without good cause, no use is made of the water for three years or more. Procedure is provided for changes in the location of the point of diversion, the place of use and the use made of the water under a water right so long as such change relates to the same local source of supply and will not impair existing rights. The law specifically states that it shall be an express condition of each appropriation of surface or ground water that the right of the appropriator shall relate to a specific quantity of water and that such right must allow for a reasonable raising or lowering of the static water level and for the reasonable increase or decrease of the stream flow at the appropriator's point of diversion.

As amended, the act contains several sections assigning to the Chief Engineer the duty and responsibility for enforcement and administration of the laws of Kansas pertaining to beneficial use of water. Section 82a-706 provides that "The Chief Engineer shall enforce and administer the laws of this state pertaining to the beneficial use of water and shall control, conserve, regulate, allot and aid in the distribution of the water resources of the state for the benefits and beneficial uses of all of its inhabitants in accordance with the rights of priority of appropriation."

Section 82a-706a provides that "The Chief Engineer, subject to the approval of the State Board of Agriculture, shall adopt, amend, promulgate and enforce such reasonable rules, regulations and standards as he shall deem necessary for the discharge of his duties and for the achievement of the purposes of the act pertaining to the control conservation, regulation, allotment and distribution of the water resources of the state."

Section 82a-706b provides that "If any person knowingly prevents, by diversion or otherwise, any waters of this state from moving to a person having a prior right to the same, the Chief Engineer, or his authorized agents, upon the request of the party being injured, shall open, close, adjust or regulate the headgates, valves, or other controlling works of any ditch, canal, conduit, pipe, well, or structure as may be necessary to secure such water to the person having the prior right to its use, and the Chief Engineer, or his authorized agents, may attach to the headgates, valves or other controlling works, a written notice properly dated and signed, setting forth the fact that the headgates, valves, or controlling works have been properly regulated and are wholly under his or their control which notice shall be legal notice to all persons interested in the distribution of water of the ditch, canal, conduit, pipe, well or structure."

Section 82a-706c provides that "The Chief Engineer shall have full authority to require any water user to install meters, gages, or other measuring devices, which devices he or his agents may read at any time, and to require any water user to report the reading of such meters, gages, or other measuring devices at reasonable intervals. He shall have full authority to make, and to require any water user to make periodic water waste and water quality checks and to require the user making such checks to report the findings thereof."

Section 82a-706d provides that "Upon the request of the Chief Engineer, the attorney general shall bring suit in the name of the State of Kansas in courts of competent jurisdiction to enjoin the unlawful appropriation diversion, use of waters of the state, and waste or loss thereof."

These sections of the law apparently give the Chief Engineer a considerable degree of authority over conservation, regulation and distribution of water, but we have some question as to whether there is adequate provision for enforcement of his orders. It is, however, expected that any inadequacies can be readily corrected.

There is specific and detailed procedure provided for appeals from orders by the Chief Engineer to the district court or to the supreme court. In any court action for determination of water rights where the state is not a proper party, the court may order a reference to the Division of Water Resources, or its Chief Engineer, as referee, for investigation of and report upon any of the physical facts involved.

The first order of business following the enactment of the law was to start a survey of the entire state to locate all existing beneficial users of water for purposes other than domestic, and to determine and establish the extent of the vested rights resulting from such users. The survey was completed and orders issued determining and establishing the extent of the vested rights of approximately 2,200 water users. A few appeals from these orders are still pending in the district courts of the state. Vested rights generally are considered as having been acquired under the common law which prevailed prior to 1945 and will be administered accordingly.

Following the enactment of the Act in 1945, applications were received for permit to appropriate water for beneficial use. For a number of reasons new uses of water were developed rather slowly during the first few years. During the period from July, 1945, to July, 1952, only about 900 such applications were received. This was a period of generally above normal precipitation. During the next few years, the state experienced a severe drought and there was a substantial expansion in irrigation development. From July, 1952, to July, 1957, nearly 7,000 applications were received. Since that time the state has again had above normal precipitation and applications have been received at the rate of about 300 each year. A total of approximately 8,500 applications have been filed and nearly one-fourth or slightly more than 2,000 have been abandoned or have failed.

The Kansas law requires that a field inspection be made of each installation before a certificate of appropriation can be issued. The inspections are handled through four field offices each of which is staffed by a water commissioner, a civil engineer, an engineer aide and a stenographer. The

inspection involves a test of the pump or other diversion works to determine the maximum and average rate of diversion, a check of the location of the point of diversion and of the land to be irrigated and the ownership of the land. The water user in each case is required to furnish records of pumping to determine the quantity of water diverted. Approximately 5,500 installations have been reported complete. About 1,500 certificates of appropriation have been issued and there are 4,000 installations awaiting inspection. It is expected that with our present staff it may be five years before this accumulation of field work can be reduced to the extent that it will be on a reasonably current basis.

There have been a few instances where the water commissioners have been called upon to distribute water among the users along a stream. These controversies have usually resulted from a misunderstanding of the relative rights of the users and have been handled without litigation.

The Kansas Law has been in effect for about fifteen years. The emphasis during that time has been on the establishing of vested rights and appropriation rights, and many of the proposed appropriations have not yet been completed to the extent that certificates of appropriation can be issued. The Division of Water Resources, which is the state agency charged with administration of the water laws of the state, has not yet been faced with many problems relating to distribution of water. Many problems of the kind we expect may be encountered have been handled in other states, and we expect to profit a great deal from their experience.

It appears that the most difficult basic question in Kansas will be in the application of the rule of priority to the distribution of ground water, particularly in those areas where there is a substantial quantity of water in storage but where the rate of recharge is very low.

It has been estimated that there is a quantity of some 200 million acre feet of ground water in storage in Kansas. In general, ground water in the eastern and north central parts of the state occurs only in the alluvial valleys of streams. It lies close to the surface and is readily recharged from precipitation on the land surface and in some instances from the stream. The quantity of water in storage is limited. It is believed that there will be no unusual difficulties in administering water rights according to priority in these areas.

In the south central part of the state, areas where ground water occurs are more extensive and there is a substantial quantity of ground water in storage. The water table is near the surface and there is enough precipitation to provide substantial recharge. There will probably be no serious difficulties in these areas in administration of water rights. In these cases it will be possible to define a more or less definite quantity of water which is available and each water user can see whether water may be available to satisfy his right.

A large part of the ground water occurs in the western part of the state in an area comprising approximately one-fourth of the total area of the state. Here the water table is generally at a greater depth below the

surface and, except for limited areas, the rate of recharge is very low. It has been estimated that the average rate of recharge in some areas near the west end of the state may be on the order of one-fourth inch per year. There are large quantities of water in storage. Any extensive development of this valuable resource can only result in its depletion, but it is of value only to the extent it is developed and used for beneficial purposes. Such development should be orderly and should be based on a policy which is understood by and is acceptable to the people in the area who are most affected. Conditions vary considerably throughout this area and any policy should be based on conditions in each particular locality. Surface drainage over much of the area is poorly defined and there is less definition of boundaries of ground water basins.

Strict application of the rule of priority to the extent of limiting withdrawals of water to the estimated recharge in each locality would require abandonment of many existing installations; in some localities such a policy would probably limit withdrawals to those having vested rights. On the other hand, continued unlimited development may be expected to result in accelerated depletion of the ground water supply in some localities. If the best use is to be made of this valuable resource, a definite policy for its development and use will need to be considered in the not too distant future. Any policy which might be considered should be based on general plans for development and use of the water resources of the area being considered and should provide a guide for administration of water rights in accordance with the adopted plan and in accordance with the law.

One approach to the question of administration of water rights is provided in the Water Appropriation Law wherein the Chief Engineer is authorized, subject to approval of the State Board of Agriculture, to adopt, amend, promulgate and enforce such reasonable rules, regulations and standards as he shall deem necessary for the discharge of his duties and for the achievement of the purposes of this act pertaining to the control, conservation, regulation, allotment, and distribution of the water resources of the state.

Each of the water users involved would have an opportunity to participate in the drafting of the rules and regulations. At the same time each would have an opportunity also to fully understand the relationship of his water right to others in the area involved, and the procedure by which the available water would be distributed among the various users. If that full understanding among holders of water rights can be accomplished, it is reasonable to expect that there will be the same mutual respect between owners of water rights as now exists between owners of other property.

A REVIEW OF THE MAJOR GROUND WATER FORMATIONS IN TEXAS

By

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This paper describes the principal water-bearing formations in Texas. The problems of study and development of these formations are the subject of the next two papers which will be presented by Mr. Otha F. Dent, member of the Texas Board of Water Engineers and Mr. William L. Broadhurst, Chief Hydrologist for the High Plains Underground Water Conservation District of Texas.

The occurrence and reliability of ground water supplies in Texas is of particular significance in a state in which climatic conditions range from extreme aridity to semi-tropic humidity. Development of sound principles of ground-water use and conservation in a state encompassing a wide range of climatic conditions, a vast geographic expanse, supplies from ground water aquifers which vary widely in hydrologic characteristics, and wide ranging economic development, presents problems which will be solved ultimately only when adequate information and basic data have been accumulated and evaluated on each of the ground water aquifers.

The significance of ground water in the State's economy can be appreciated when we consider that the value of the State's agricultural production of raw materials of about 1.7 billion dollars per year is second only to the value of the products of the petroleum industry. This agricultural production depends heavily on irrigation water obtained from ground water sources.

The rainfall in the State decreases almost linearly from east to west; from 55 inches per year on the eastern boundary to 8 inches per year at El Paso. The 25-inch rainfall line, which is about the limit of reliable crop production without irrigation, runs nearly north and south, dividing the State approximately in half, and roughly two-thirds of the State receives less than 30 inches of

rainfall per year. Hence, over about half of the State most crops require irrigation, and some crops such as rice in the Houston area, require it even in the areas of heavy rainfall. In 1957, about 9½ million acre feet of ground water was used in Texas for irrigation. The size of this amount can be appreciated by comparing it to about 4 million acre-feet which is the total amount of surface water consumptively used in the State during this same year. Also, the total amount of ground water pumped that year was about 10½ million acre feet. (Texas Board of Water Engineers, 1958, p. 80)

We have illustrated on this map the major ground water producing formations in Texas. In addition to these major aquifers, there are many minor water-bearing formations which yield large quantities of water in small areas or relatively small quantities of water in large areas. These so-called minor aquifers achieve critical local significance where no other source of water supply is available. The general areas in which usable water occurs in the Ogallala formation, the Trinity sands, the Edwards limestone, the Carrizo-Wilcox sands, the Gulf Coast aquifers, and Alluvial deposits, are shown on this illustration. In these formations, we find vast supplies of ground water which are used for a variety of beneficial uses ranging from massive irrigation development on the High Plains to the far-reaching industrial complex on the Gulf Coast.

The High Plains of Texas is an erosional remnant of nearly flat country, ranging from about 2600 to about 4700 feet above sea level, which has been dissected by erosion on the west, south, and east, and which is truncated by the Canadian River. It was the site of some of the very large cattle ranches during the pioneer days, and as recently as 1925 it consisted principally of pasture land with only an occasional patch of cultivation. The population, likewise, was thinly scattered, being distributed among ranches and occasional small towns.

Today, if one drives through the same area, or flies over it, he finds it hardly recognizable. Almost the entire area is in intensive cultivation. The

population density is that of a highly developed agricultural area, and the former small town of Lubbock, in the heart of the area, has become a city of about 129,000 population. The total population of the 18 counties of the Southern High Plains was only about 150,000 in 1925, whereas it has now reached a figure of close to half a million.

This transformation is the consequence of irrigation principally from the Ogallala formation. The Ogallala formation consists of interfingered and intergraded lenses and layers of sand, gravel, silt, clay and caliche ranging in thickness from a feather edge to more than 800 feet. The only source of recharge to the Ogallala formation is precipitation on the High Plains, and of the scanty rainfall in this area only a fraction of an inch per year will seep downward to recharge the underground reservoir.

Pumpage from the Ogallala is far in excess of the rate of replenishment and this heavy pumpage, principally for irrigated agriculture, has resulted in declines of the water table and lowering of well yields in some areas. Water in the Ogallala occurs under water table conditions and the useful life of the reservoir in each locality will be determined principally by water in storage, the rate and distribution of withdrawals, and the character of water-bearing strata. In areas of heavy pumpage, water levels will generally decline at a more rapid rate than in areas of less use, since the rate of movement of water through the Ogallala is only inches per day under natural hydraulic gradients. Water supplies underlying some areas where the Ogallala is relatively thin have already been seriously depleted. Where thicker sections of the Ogallala occur, supplies are available in storage to meet present demands over a period of many years. Water in storage in the entire High Plains area of Texas is estimated to be in excess of 350 million acre feet.

Alluvial deposits consisting generally of interconnected lenticular layers of sand and gravel interbedded with clay and silt occur in various parts of the

State as remnants of once vast alluvial plains, now largely removed by erosion, and as extensive stream deposits along some of the major rivers. Large quantities of water are produced for irrigation from the West Texas alluvial deposits.

For example, in the El Paso area alluvial deposits have accumulated in two large basin-like depressions west and east of the Franklin Mountains. The thickness of these deposits ranges to more than 4,900 feet, but the quality of ground water supplies changes within narrow geographic limits and only in a relatively small part of the El Paso area underlain by alluvial materials are ground water supplies suitable for most purposes.

In the Reeves, Loving, Pecos, Ward and Winkler Counties area, ground water is obtained from alluvial deposits in the Pecos River Valley and in troughs formed by subsidence of older beds, some occurring along the face of deep lying reef deposits. Principal development of the water from alluvium in this area is for irrigation. In 1957 approximately 1,000 wells, mostly in Reeves and Pecos Counties, supplied water for irrigation needs. Many of these wells produced as much as 1,000 gallons per minute. The principal water problem in this area is depletion of supply, as water levels have declined in response to pumpage and will continue to decline as long as withdrawals exceed recharge.

On the Osage Plains region of North Central Texas, island-like remnants of a former alluvial plain make up the Seymour formation which in 1957 supplied water to about 1,600 irrigation wells and was a source of supply for 13 municipalities. These wells range in yield from 50 to 1,000 gallons per minute. Since these alluvial deposits are generally less than 85 feet thick, a serious potential problem of aquifer depletion exists.

In the Edwards limestone reservoir, hydrologic conditions differ greatly from those found in the alluvial deposits and the Ogallala formation. This aquifer is in fact properly described as the Edwards and associated limestones

and extends along the Balcones fault zone from near Brackettville in Kinney County to the vicinity of Kyle in Hays County, a distance of about 180 miles. Municipal, industrial and irrigation development throughout this area is largely dependent upon this aquifer. The Edwards and associated limestone reservoir actually forms two ground water reservoirs - one on the Edwards Plateau where ground water is unconfined and the other an artesian aquifer in the Balcones fault zone. The hydrologic system on the plateau receives and stores as recharge large amounts of water from rainfall and slowly discharges these supplies as spring flow to the perennial streams cutting into or through the plateau. The streams in turn recharge the artesian reservoir in the Balcones fault zone as the entire normal flow and much of the flood flow of many of the streams is lost as they cross stretches in which honeycombed and cavernous Edwards limestone is at or near the surface. The average annual rate of recharge to this ground-water reservoir was about 426,300 acre-feet for the period 1934-1953 (Petitt and George, 1956, p. 1). Although the reservoir underlies three major river basins, the Nueces, San Antonio, and Guadalupe, it obtains about three fourths of its recharge from its western part which is in the Nueces River Basin. The general movement of water in the Edwards is from west to east and most of the discharge occurs in the eastern part of the reservoir.

Much of the discharge is through Comal Springs and San Marcos Springs, the combined flow of the two springs in 1957 being about 210,000 acre-feet (Texas Board of Water Engineers, 1958, p. 42). Irrigation and municipal wells have been extensively developed in recent years and their total withdrawal in 1957 was also about 210,000 acre-feet.

Water moves freely in the reservoir where zones of interconnected cavernous porosity occur, Wells developed in these large cavities are capable of producing large volumes of water, for example, individual well yields of up to

16,800 gallons per minute have been recorded. However, due to the lack of homogeneity in the Edwards, well yields vary greatly.

Because the availability of water in the Edwards depends almost directly upon the rate of recharge, programs for altering or adding to the present rate of recharge will have far-reaching effects upon the economy of the area and of the State as a whole.

In North Central Texas the Trinity sands of Cretaceous age comprise the principal water-bearing formation. These sands are interbedded with layers of shale and thin beds of limestone. The lower sands crop out at the surface along the western edge of the area shown on the accompanying map and dip generally eastward. Recharge from precipitation and surface water sources enters the aquifer in the outcrop and moves downdip to places of discharge. Most of the discharge from the aquifer is by wells. Maximum yields of wells in these sands vary from 50 gallons to as much as 2,000 gallons per minute in the Dallas area. In the Dallas area, where many of the wells are more than 3,000 feet deep, the lowering of water levels has increased the cost of pumping to very near the economic limit of feasibility of production and in many wells the drop in water levels has necessitated well reconstruction to continue production. The principal use of water from the Trinity in North Central Texas is for municipal and industrial purposes. Much of this pumpage is concentrated in the Dallas-Fort Worth area where in 1955 about 34 million gallons of water per day was pumped mostly from the basal sands. In the entire area pumpage from these sands in 1955 averaged about 60 million gallons per day.

The Carrizo-Wilcox sands which supply water for irrigation, municipal and some industrial uses, extend from the Rio Grande northeastward across the entire State. The Wilcox formation is older and generally thicker than the Carrizo and underlies it in the downdip area. Generally the Carrizo contains coarser sands

and in many areas water from the Carrizo is of better quality. The combined thickness of the two formations in this belt ranges from about 100 feet to several thousand feet, increasing in thickness generally downdip. Water occurs in the Carrizo-Wilcox under artesian conditions. It is confined by overlying beds of clay and the quality of water in the two formations becomes generally less suitable for most uses downdip. Fresh water occurs in the Carrizo at greater depths than in any formation in Texas. In Karnes County a well to a depth of 5,355 feet produces water containing 1,150 parts per million dissolved solids. The rate of downdip deterioration of quality varies with individual sands, but in general going downdip the proportion of sodium in the fresh water in the Carrizo-Wilcox becomes great enough to make water unsuitable for irrigation long before brackish water has been reached.

Recharge comes from precipitation and stream losses on the outcrop areas. In the East Texas portion of this aquifer, available recharge from streams crossing the outcrop is being rejected because the aquifer is full and the transmission capacity under natural hydraulic gradients has been met. However, in the western part of the aquifer discharge by irrigation wells may have already exceeded the rate of annual recharge.

The greatest use of water from the Carrizo-Wilcox is for irrigation in the Winter Garden area. Most of municipalities and industries throughout the area shown on the map are supplied by water from the Carrizo-Wilcox.

The Gulf Coast aquifer is composed of a complex network of lenticular sand units extending vertically through a series of geologic formations. The maximum depth of water of usable quality in the Houston area is approximately 3,000 feet and approximately 30% of the section from the surface to that depth is composed of sand. Water occurs in the Gulf Coast aquifer under both water table and artesian conditions. Artesian conditions exist where layers of clay and silt

form confining beds above fully saturated sand sections. All of the fresh ground water in the Gulf Coast sands is in "transient storage". It has been estimated that the amount of fresh water in transient storage ranges from 2,000 acre-feet per square mile in the Corpus Christi area to about 13,000 acre-feet per square mile in the Houston area (Wood, 1956, p. 1). The transmission ability of the aquifer in many areas is the principal factor which limits the development of water in the sands.

The Gulf Coast sands are recharged by water infiltrating into them in the outcrop areas. Much available recharge from streams is believed to be rejected in areas where the annual precipitation exceeds 40 inches; however, where the precipitation is less than 35 inches per year probably little or no recharge is rejected to streams (Wood, 1956, p. 1). Although natural discharge from the sands is accomplished by slow upward percolation, large quantities of water are withdrawn by wells. In 1954, about one million acre-feet was pumped for irrigation (mainly rice irrigation), industrial, and municipal uses.

The normal hydraulic gradient in the Gulf Coast aquifer is generally south and east toward the Gulf Coast. However, in some areas of concentrated development where water levels in local areas have shown large declines, the coastward gradient has been reversed and salt water from downdip areas is moving slowly toward the wells.

In summary, it is apparent that conservation and development policies applied to ground water aquifers under these widely varying conditions will have to take into account hydrologic conditions, availability of water supplies from other sources such as surface supplies, and the relative needs of the users of ground water resources.

There are, however, in the State some problems which are common to all the aquifers. Chief of these is the problem of contamination. The contamination to

fresh ground water results from the lateral and vertical encroachment of naturally saline waters and from the disposal of artificial or man-made wastes. No equitable or effective method of coping with the problem of contamination has yet been devised in Texas and yet the solution to this problem and to the many other problems associated with our ground water resources will be found in an awakening public awareness and the growth of our technical knowledge.

Austin, Texas
August 19, 1960

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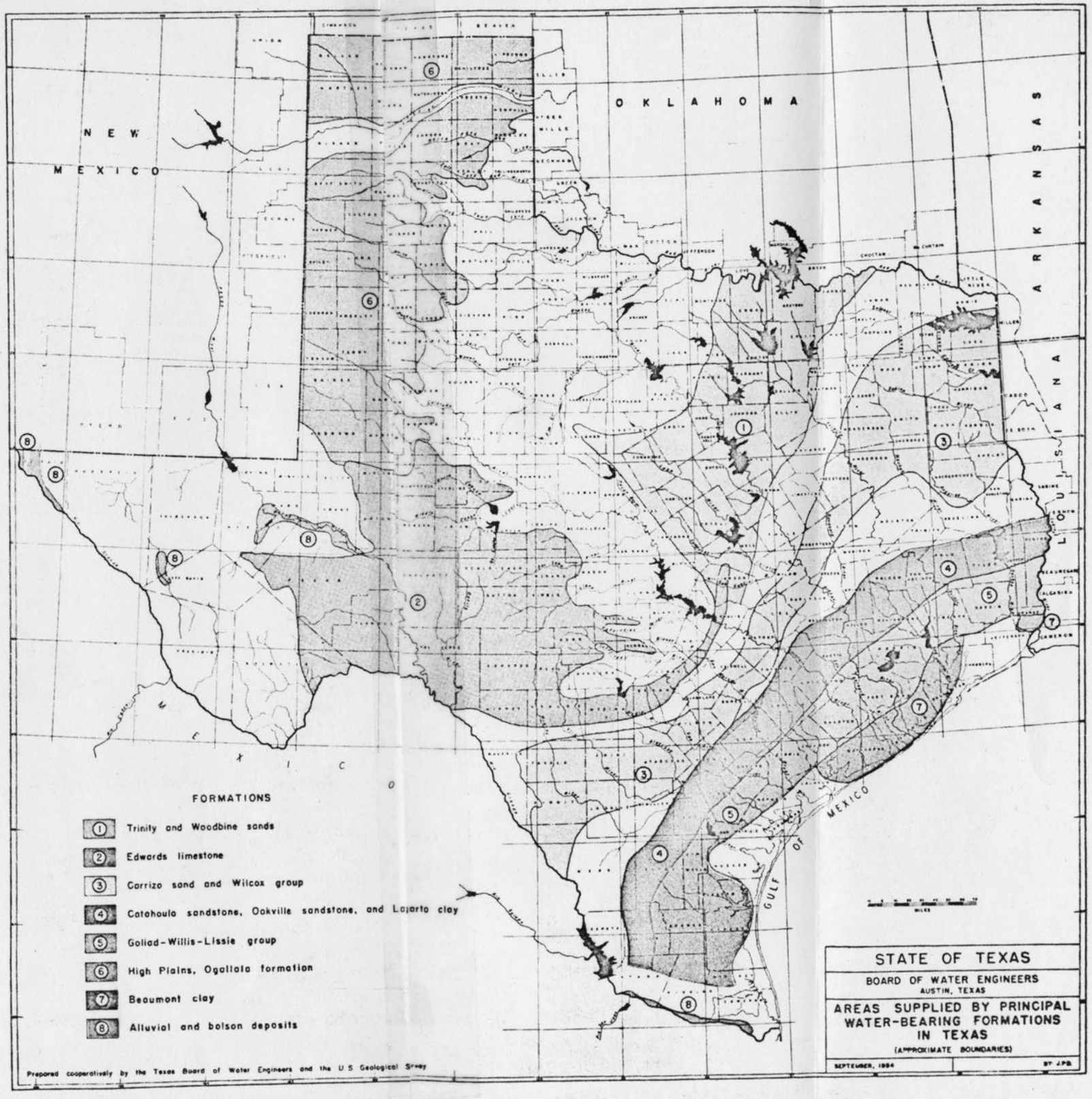

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TEXAS GROUND WATER LAW

Laws are related to the cultural and economic background of the people. The early history of Texas is "semi-unique", in that Texas was the meeting place of many people of various nationalities and cultures. During this period six flags unfurled their colors in the versatile political breeze while sovereignty over Texas changed eight times. Geographically the Isthmus of Panama divides the two great Americas; however, culturally and linguistically an imaginary separation occurs along the Rio Grande. Today more than a million Texans are Spanish-speaking. The Latin-American influence is found in geographic names, architecture, general culture and law--especially law governing water and its uses.

Grants of land and the rights appurtenant thereto were made by Spain, Mexico and the Republic of Texas. It is the settled law of Texas that in determining the rights of holders of title from prior sovereigns, the controlling laws are those in effect when the grants were made. Subsequent changes in the law after title has passed out of the sovereign do not affect rights which have already vested.

From 1840 until 1889 the Common Law of England was the measure of rights pertaining to land granted by the Republic of Texas and the State of Texas. In 1889, the 21st Legislature enacted Texas' first water laws, establishing the prior appropriation doctrine. It was entitled "An Act to encourage irrigations, and to provide for the acquisition of the right to the use of water, and for the construction and maintenance of canals, ditches, flumes, reservoirs, and wells for irrigation; and for mining, milling and stockraising in the arid districts of Texas."

Section 2 of the Act declared, "the unappropriated waters of every river or natural stream within the arid portions of the State, to be the property of the public, and may be acquired by appropriation for the uses and purposes provided." This initial act was only applicable to the surface waters of the arid portions of the State, with the humid area of the State remaining subject to either the Spanish, Mexican or English Common Law, depending on the source of land title.

The Legislature in 1893 and 1895 amended the original Act and among the additional provisions, declared to be the property of the public, "the underflow of every running or flowing river or natural stream." Ground water, at the time, apparently had little or no significance and did not merit the attention of the Legislature.

Around the turn of the century Mr. W. A. East resided on his homestead in Denison, Texas. He had constructed a well on his land which was approximately 5 feet in diameter and 33 feet deep. It was classed or termed as a "good well" and provided adequate water for domestic and household purposes. In 1901 the Houston & Texas Central Railroad Co. constructed a well on its land adjacent to Mr. East. Its well was larger in diameter than Mr. East's well, and 66 feet in depth. The Railroad Company pumped its well at the rate of 117 g.p.m. or about 25,000 gallons per day. This amount was necessary to satisfy the water requirements of its engineers and shops. Neither of the wells produced from the underflow or a subterranean stream, but rather so-called percolating water.

The heavy pumping by H. & T.C. Railroad Company ultimately dried up Mr. East's well. In 1902, East brought suit against the railroad for damages

in the amount of $206.25 growing out of the alleged destruction of the well. Little did Mr. East apprehend that the final decision in his cause of action would become a guiding light and set the rule for the Courts to follow in the years ahead relating to the ownership and use of ground water in Texas.

The case was tried before the court without a jury, and resulted in a judgment for defendant, and Mr. East appealed his suit for damages to the Court of Civil Appeals.* The Court of Civil Appeals held, in accordance with the law applicable to defined streams, that the railroad's rights to use its well was limited to a reasonable use. The Court found that: (1) the railroad's use of its well was not a reasonable use of its property as land but an artificial use; and (2) if the doctrine of reasonable use, as applied to defined streams is applied, an unreasonable use. The Court of Civil Appeals reversed the trial court's findings and held that East was entitled to damages. The Court cited and relied upon cases holding that the right of a landowner to produce percolating water is not absolute, but is qualified and limited to the amount necessary for the reasonable use of the land, as land; and that the rights of adjoining landowners are correlative.

Houston & Texas Central Railroad Co. appealed to the Supreme Court and writ of error was granted.** The Court, in what is now considered a landmark decision rejected the doctrine of correlative rights, or reasonable use. It held that since the railroad was making a legitimate use of the water, it could pump all the water it desired from its own land, and Mr. East's damages

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*East v. H. & T.C. Ry. Co., 77 S.W. 646 (Tex. Civ. App., 1903)

**Houston & T.C. Ry. Co. v. East, 98 Tex. 146, 81 S.W. 279 (1904)

were damnum absque injuria (injury without wrong). There were no allegations nor proof of either malice or waste. The Court said:

> "The mere quantity of water taken by the owner from his land has nowhere been held to affect the question. Exhaustion resulting from excavation and pumping .....has been considered in several cases to give rise to no liability."

The opinion quotes with approval the English rule announced in Acton V. Blundell, 12 Mees. & W. 324, saying:

> "So the owner of the land is the absolute owner of the soil and of percolating water, which is a part of, and not different from, the soil. No action lies against the owner for interferring with or destroying percolating or circulating water under the earth surface."

The Supreme Court reversed the judgment of the Court of Civil Appeals and affirmed that of the District Court. The Court reasoned that:

> "In the absence of express contract and a positive authorized legislation, as between proprietors of adjoining land, the law recognizes no correlative rights in respect to underground waters percolating, oozing, or filtrating through the earth; and this mainly from considerations of public policy: (1) Because the existence, origin, movement, and course of such waters, and the causes which govern and direct their movements, are so secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would, therefore, be practically impossible. (2) Because any such recognition of correlative rights would interfere, to the material detriment of the commonwealth, with drainage and agriculture, mining, the construction of highways and railroads, with sanitary regulations, building, and the general progress of improvement in works of embellishment and utility." The mere quantity of water taken by the owner from his land has nowhere been held to affect the question. Exhaustion resulting from excavating and pumping for mining purposes has been considered in several cases to give rise to no liability. So the authorities generally state that the use of the water for manufacturing, brewing, and like purposes is within the right of the owner of the soil, whatever may be its effect upon his neighbor's wells and springs.

In the intervening years since 1904 the Supreme Court has relied upon the East decision in several cases relating to ground water, and there is no doubt that the East decision has influenced the Texas law with respect to owner- of oil and gas.

As might be expected, with the increased use of ground water, the correctness of the East decision has been brought sharply into focus during the past few years. In 1955 the rule of the East case was squarely before the Supreme Court in two cases. The first of these is the Comanche Springs Case* from Pecos County. Here, it was seriously and ably contended that the rule of the East case had become obsolete and should either be modified or completely overruled. The El Paso Court of Civil Appeals refused to do so, following the East decision. The question was directly presented to the Supreme Court on application for writ of error, which was refused with the Notation, "no reversible error".

The second case is the City of Pleasanton decision.** In this case, the Supreme Court granted the application for writ of error on a point involving waste of ground water, and in the majority opinion spelled out its reasons for adhering to the English rule of ownership adopted in Texas by the East case.

Since the Texas Supreme Court has followed the absolute ownership theory of the East case and has held that the courts cannot enjoin anything but wanton and willful waste, it is clearly up to the Legislature to provide for the conservation of ground water and the prevention of waste. Once it is recognized that our ground water supply is confined in separate, relatively well defined

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* Pecos County Water Control & Improvement District v Williams, 271 S. W. 2d 503 (Tex. Civ. App., 1955, err. ref., n. r. e.).

** City of Corpus Christi v. City of Pleasanton, 154 Tex. 289, 276 S. W. 2d 798 (Sup. Ct., 1955).

reservoirs and that some reservoirs are artesian and some are not, and that each represents a separate problem, it becomes clear that regulation by reservoir or by sub-divisions thereof is the most practical method of conservation.

In 1949, prior to the decisions in both the Comanche Springs and the City of Pleasanton cases, the Legislature authorized the creation of districts for the conservation of underground water. In so doing, the Legislature made the following declaration:

> "The ownership and rights of the owner of the land..... in underground water are hereby recognized, and nothing (herein) shall be construed as depriving or divesting such owner.....of such ownership or rights, subject, however, to the rules and regulations promulgated pursuant to this section....."

The Legislature also declared that the words "underground water" mean water "percolating below the earth's surface, and do not include defined subterranean streams or the underflow of rivers".

Since conditions in various parts of Texas are dissimilar--the average rainfall varying from 10 inches near El Paso to 56 inches on the Louisiana border--and since the ground water reservoirs, the land use, and the water use vary so widely, a large measure of relatively local autonomy is indicated rather than authority vested in one statewide central agency to regulate all reservoirs by blanket rule. This local regulation approach is the one presently adopted by the Texas Legislature, though its statutes on the subject invite strengthening and improvement.

CONSTITUTION OF THE STATE OF TEXAS

Art. 16, Sec. 59. Conservation and development of natural resources; conservation and reclamation districts

(a) The conservation and development of all of the natural resources of this State, including the control, storing, preservation and distribution of its storm and flood waters, the waters of its rivers and streams, for irrigation, power and all other useful purposes, the reclamation and irrigation of its arid, semi-arid and other lands needing irrigation, the reclamation and drainage of its overflowed lands, and other lands needing drainage, the conservation and development of its forests, water and hydro-electric power, the navigation of its inland and coastal waters, and the preservation and conservation of all such natural resources of the State are each and all hereby declared public rights and duties; and the Legislature shall pass all such laws as may be appropriate thereto.

(b) There may be created within the State of Texas, or the State may be divided into, such number of conservation and reclamation districts as may be determined to be essential to the accomplishment of the purposes of this amendment to the constitution, which districts shall be governmental agencies and bodies politic and corporate with such powers of government and with the authority to exercise such rights, privileges and functions concerning the subject matter of this amendment as may be conferred by law.

(c) The Legislature shall authorize all such indebtedness as may be necessary to provide all improvements and the maintenance thereof requisite to the achievement of the purposes of this amendment, and all such indebtedness may be evidenced by bonds of such conservation and reclamation districts, to be issued under such regulations as amy (may) be prescribed by law and shall also, authorize the levy and collection within such districts of all such taxes, equitably distributed, as may be necessary for the payment of the interest and the creation of a sinking fund for the payment of such bonds; and also for the maintenance of such districts and improvements, and such indebtedness shall be a lien upon the property assessed for the payment thereof; provided the Legislature shall not authorize the issuance of any bonds or provide for any indebtedness against any reclamation district unless such proposition shall first be submitted to the qualified property tax-paying voters of such district and the proposition adopted. Added Aug. 21, 1917, proclamation Oct. 2, 1917.

CIVIL STATUTES OF THE STATE OF TEXAS

Art. 7880--3c Underground water conservation districts

Definitions

A. Unless the context of this Section 3c indicates a different meaning, the words hereinafter defined when used in this Section 3c shall have the following meaning:

(1) "Board" is the State Board of Water Engineers.

(2) "District" is an Underground Water Conservation District which includes within its purposes and plans those functions authorized by the provisions of this Section 3c.

(3) "Underground water" is water suitable for agricultural, gardening, domestic or stock raising purposes, percolating below the earth's surface, and does not include defined subterranean streams or the underflow of rivers.

(4) "Underground water reservoir" is a specific subsurface water-bearing reservoir having ascertainable boundaries, and containing underground water capable of being produced from a well at the rate of not less than one hundred and fifty thousand (150,000) gallons a day.

(5) "Subdivision of an underground water reservoir" is that reasonably definable part of an underground water reservoir within which the underground water supply will not be unreasonably affected by withdrawals of water from any other part of such reservoir, based upon known geological and hydrological conditions and relationships and upon foreseeable economic development at the time of the designation or alteration of such subdivision. When the Board of Water Engineers has ascertained the boundaries of a subdivision, pursuant to this Act, its findings on the location of such boundaries, the questions of "Reasonableness" and "Affect" in the foregoing definition, and all other questions essential to the existence of a subdivision, shall be conclusive and final unless a suit is instituted, pursuant to paragraph F hereof, within thirty (30) days from the date on which the order of such Board is entered. As amended Acts 1955, 54th Leg., P. 1239, ch. 496, Sec. 1.

(6) "Waste" shall mean:

(a) the withdrawal of underground water from an underground water reservoir at such a rate and in such amount so as to cause the intrusion therein of water not suitable for agricultural, gardening, domestic or stock raising purposes;

(b) the flowing or producing of wells from an underground water reservoir when the water produced therefrom is not used for a beneficial purpose;

(c) the escape of underground water from one underground water reservoir to any other reservoir not containing underground water, as defined in this Section 3c; and

(d) the pollution or harmful alteration of the character of the underground water within the underground water reservoir of the District by means of salt water or other deleterious matter admitted from some other stratum or strata or from the surface of the ground.

(e) Willfully causing, suffering, or permitting underground water produced for irrigation or agricultural purposes to escape into any river, creek, or other natural watercourse, depression, or lake, reservoir, drain, or into any sewer, street, highway, road, road ditch, or upon the land of any other person than the owner of such well, or upon public land. Added Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 2.

(7) "Beneficial purpose" means the use of underground water for agricultural, gardening, domestic, stock raising, municipal or mining purposes, for exploring for, producing, handling and treating of oil, gas, sulphur or other mineral, for manufacturing, industrial, commercial, recreation or pleasure purposes or any other purpose that is useful and beneficial to the user thereof.

(8) "Segregated irrigated area" shall mean an irrigated area separated from other irrigated areas by at least five (5) miles of unirrigated lands.

(9) Unconstitutional

Paragraph (9) was amended by Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 3.

Creation of districts; powers and functions

B. Districts may hereafter be created for the conservation, preservation, protection, and recharging and the prevention of waste of the underground water of an underground water reservoir or subdivision thereof, defined and designated in accordance with the provisions of Subsection C of this Section 3c. To accomplish these purposes pursuant to Section 59a, b, and c, of Article XVI of the Constitution of Texas, the administrative and procedural provisions as now or hereafter contained in Chapter 25, Acts of the Regular Session of the Thirty-ninth Legislature of the State of Texas, 1925, as amended,[1] shall apply in so far as applicable to such Districts, but such Districts shall not be organized for any purposes except those set forth in this Section 3c.

[1] Article 7880-- 1 et seq.

Such Districts shall and are hereby authorized to exercise any one or more of the following powers and functions:

(1) to formulate, promulgate and enforce rules and regulations for the purpose of conserving, preserving, protecting and recharging the underground water of the underground water reservoir or subdivision thereof;

(2) to formulate, promulgate and enforce rules and regulations to prevent the waste, as herein defined, of the underground water of the underground water reservoir or subdivision thereof;

(3) To require permits for the drilling, equipping or completion of water wells or the substantial alteration of the size of the wells or the pumps used therein, or all or any of such acts, and to issue such permits subject to the rules and regulations promulgated by the District pursuant to subparagraph (4) next below, and subject to such terms and provisions with reference to the drilling, equipping, completion or alteration thereof as may be necessary to preserve and conserve the underground water, to prevent waste, to minimize as far as practicable the drawdown of the water table or the reduction of artesian pressure, or to lessen interference between wells. No person, firm, or corporation shall hereafter begin to drill or drill a well or substantially alter the size of a well or pump used therein, within the boundaries of a District organized hereunder which well could reasonably be expected to produce in excess of one hundred thousand (100,000) gallons per day from the underground water reservoir or subdivision thereof without first having applied to the Underground Water Conservation District for and had issued a permit to do so, unless the drilling and operation of the well is otherwise exempt herein.

The District shall promptly consider and pass upon applications for permits required in the preceding Section 3. If an application shall not have been passed upon within twenty (20) days from the receipt thereof by the District, or has not been set down, within that time, for a hearing upon a day certain, the applicant may go into the District Court where the land lies and obtain a mandamus to compel the District to act upon the application or set it down for a hearing.

The hearings above provided for shall be held within thirty (30) days from the date the hearing is called, and the District shall act on such application within ten (10) days after such hearing. As amended Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 4.

(4) Either (a) to provide for the spacing of wells to be drilled for the production of water from the underground water reservoir or subdivision thereof; or, (b) to regulate the production of wells producing underground water from such source, unless such wells are otherwise exempt herein, or both (a) and (b), so as to minimize as far as practicable the drawdown of the water table or the reduction of artesian pressure; or to prevent waste.

Provided further, however, that the owner of any tract of land, his heirs, assigns and lessees who have no well capable of producing in excess of one hundred thousand (100,000) gallons per day on said tract, shall not be denied either a permit to drill a well on his land or the privilege to produce underground water from his land subject to the rules and regulations of the District. As amended Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 5.

(5) to require records to be kept and reports to be made of the drilling, equipping and completion of wells into the underground water reservoir or subdivision thereof and the taking and use of underground water therefrom; to require accurate drillers' logs to be kept of such wells and a copy thereof and of any electric logs which may be made of such wells to be filed with the District and the Board;

(6) to acquire lands for the erection of dams and for the purpose of draining lakes, draws, and depressions, and to construct dams, drain lakes, depressions, draws and creeks and to install pumps and other equipment necessary to recharge the underground water reservoir or subdivision thereof but no such District having the powers granted in this Section 3c shall engage in the sale or distribution of surface or underground water for any purpose;

(7) to cause to be made by registered professional engineers surveys of the underground water of the underground water reservoir or subdivision thereof and of the facilities for the development, production and use of such underground water, to determine the quantity thereof available for production and use and the improvements, developments and recharges needed for such underground water reservoir or subdivision thereof;

(8) to develop comprehensive plans for the most efficient use of the underground water of the underground water reservoir or subdivision thereof and for the control and prevention of waste of such underground water, which plans shall specify in such detail as may be practicable the acts, procedure, performance and avoidance which are or may be necessary to effect such plans, including specifications therefor; to carry out research projects, develop information and determine limitations, if any, which should be made on the withdrawal of underground water from the underground water reservoir or subdivision thereof; to collect and preserve information regarding the use of such underground water and the practicability of recharge of the underground water subdivision thereof; to publish such plans and information, bring them to the notice and attention of the users of such underground water within the District, and to encourage their adoption and execution;

(9) to enforce, by injunction, mandatory injunction or other appropriate remedy, in courts of competent jurisdiction, rules and regulations duly adopted and promulgated by such District; provided, that no rule or regulation shall be effective until a brief resume thereof has been published once a week for two consecutive weeks in one or more newspapers to give circulation within the District, and such rule or regulation is to be effective not less than fourteen (14) days after the date of the first publication.

(10) The drilling of any well for which a permit from the District is required and for which no permit has been obtained, or the operation of any well at a higher rate of production than the rate approved for such well, is hereby declared to be illegal, wasteful per se, and nuisance. Any person having an estate in land adjacent to or any part of which lies within one-half mile of such well may, with or without the joinder of the District, bring suit in court of competent jurisdiction to restrain or enjoin such illegal drilling or operation or both. He may also sue for and recover any damages which he may have suffered by reasen of such illegal operation and such further relief as he may be entitled to in law or in equity. In any suit for damages, the existence of such well in violation of the rules of the District, or the operation thereof in violation of the rules of the District, or both, shall be taken by the courts, to constitute prima-facie evidence of illegal or illegitimate drainage. Such suit may be brought in any county where (a) the illegal well is located, or (b) the affected land of the plaintiff, or any part thereof, is located. The cause of action and rights here created or recognized shall constitute a cumulative or additional remedy and shall not be considered to exclude, impair, or abridge any other rights, remedies, or causes of action which are or may be available to any individual or to the District. Such suits shall be advanced for trial and be determined as expeditiously as possible, and no postponement thereof or continuance, including a first motion therefor, shall be granted except for reasons deemed imperative by the court. Added Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 6.

Area included; designation of underground water reservoirs and subdivisions

C. No petition for the creation of a District to exercise the powers and functions set forth in Subsection B of this Section 3c shall be considered by a Commissioners Court or the Board, as the case may be unless the area to be included therein is coterminus with an underground water reservoir or subdivision thereof which theretofore has been defined and designated by the Board as an underground water reservoir or subdivision thereof. Such district, in conforming to a defined reservoir or subdivision, may include all or parts of a county or counties, municipal corporations or other political subdivisions, including but not limited to Water Control and Improvement Districts.

It shall be the duty of the Board from time to time and in any event upon application by petition in the manner provided in Section 10[1] of the Acts of 1925, Thirty-ninth Legislature, Chapter 25, page 88, after notice and hearing as provided for in Section 15 and Section 21[2] (as amended), Acts of 1925, Thirty-ninth Legislature, Chapter 25, to designate underground water reservoirs and subdivisions thereof and thereafter as future conditions may require and factual data justify to alter the boundaries thereof; provided, however, such alteration shall not invalidate the creation of any District theretofore created with the powers provided for in this Section 3c.

1 Article 7880--10
2 Articles 7880--15, 7880--21

Ownership of underground waters; application of laws

D. The ownership and rights of the owner of the land, his lessees and assigns, in underground water are hereby recognized, and nothing in this Section 3c shall be construed as depriving or divesting such owner, his assigns or lessees, of such ownership or rights, subject, however to the rules and regulations promulgated pursuant to this Section 3c.

It is specifically provided in this connection that:

(1) the priorities, regulations and provisions of the law relating to the use of surface waters shall in no manner apply to underground water;

(2) the provisions of Section 4a of Chapter 25, Acts of the Regular Session of the Thirty-ninth Legislature of the State of Texas, 1925, as amended by Chapter 107, Acts of the First Called Session of the Fortieth Legislature of the State of Texas, 1927[1], shall not apply in the exercise of the powers and functions conferred by this Section 3c;

(3) nothing in this Section 3c shall be construed as applying to wells drilled, under permits granted by the Railroad Commission, of Texas, for oil, gas, sulphur, brine, or any of them, for core tests, for injection of gas, salt water or other fluid, or for any other purpose;

(4) nothing in this Section 3c shall authorize or permit:

(a) The requirement of a permit for the drilling or producing of a well drilled to supply water for the drilling of any one or more wells mentioned in (3) next preceding, so long as such well and the production therefrom is being used for such purpose or purposes and not thereafter. When the well has ceased to be so used, it may thereafter be used as an ordinary water well if it meets the spacing and other rules of the District; and if used, such well shall thereafter be subject to the rules and regulations of the District. As amended Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 7.

(b) the requiring of a permit for the drilling or producing of a well drilled, completed and equipped so that it will not produce in excess of one hundred thousand (100,000) gallons of underground water per day; or

(c) the restriction of the production from any well producing underground water to an amount less than one hundred thousand (100,000) gallons of underground water per day; provided, however, the wells mentioned in (a), (b) and (c) above shall be equipped and maintained so as to conform with the rules and regulations, promulgated by any District pursuant to this Section 3c and applicable to the underground water reservoir in which such wells are completed, requiring the installation of casing,

[1] Article 7880--4a

pipe and fittings in wells so as to prevent the escape of underground water from one underground water reservoir to any other reservoir not containing underground water and so as to prevent the pollution or harmful alteration of the character of the underground water within any underground water reservoir, as herein defined.

(5) The provisions of this Act and the rules and regulations promulgated hereunder shall apply only within the area designated by the Board of Water Engineers as a reservoir or a subdivision thereof over which a District shall have been organized. They shall not apply outside of such areas. Added Acts 1955, 54th Leg., p. 1239, ch. 496, Sec. 8.

Elections

E. (1) Districts exercising the powers and functions provided for in this Section 3c shall include no segregated irrigated area unless a majority of the property taxpaying voters residing in such segregated irrigated area and voting at the election favor the inclusion of such area within the District.

(2) Districts proposing to issue bonds for carrying out one or more of the powers and functions conferred by this Section 3c shall not be required to submit their plans to and secure approval of the Board as required by Section 139 of Chapter 25, Acts of the Regular Session of the Thirty-ninth Legislature of the State of Texas, 1925.[1]

(3) The directors of all Districts created to exercise the powers and perform the functions in this Section 3c provided shall be selected according to the 'precinct method,' as such method is defined and provided for in Senate Bill 247 enacted by the Forty-sixth Legislature, Regular Session, 1939[2], and all provisions of said Senate Bill 247 relating to the election of directors by the precinct method shall be applicable to Districts created under this Section 3c; provided, however, in the creation of precincts for the election of directors of such a District, if any portion of a municipal corporation is a part of one precinct, then no portion of such municipal corporation shall be included in any other precinct; provided further however, that a municipal corporation having a population of more than two hundred thousand (200,000) persons according to the last preceding Federal Census may be included in not more than two (2) precincts.

(4) At any election for the creation of such Districts or for issuing bonds or otherwise lending the credit of the District, only the property taxpaying residents of the District who have duly and personally rendered their property for taxation and which property appears on the rendered roll and who are otherwise qualified shall be entitled to vote.

[1] Article 7880--139
[2] Article 7880--38a

Contest of validity of act or rules, regulations or orders

F. Any interested person, firm, corporation or association of persons affected by the provisions of this Section 3c or by any rules, regulations or orders made or promulgated by a District hereunder or by any act of the Board pursuant hereto and who may be dissatisfied therewith shall have the right to file a suit in a court of competent jurisdiction in any county in the State of Texas in which such District or any part thereof is located if the suit is against a District or its directors and in a court of competent jurisdiction in Travis County, Texas, if the suit is against the Board, to test the validity of this Section 3c, and such rules, regulations or orders or any of them or any act of the Board. Such suit shall be advanced for trial and be determined as expeditiously as possible, and no postponement thereof or continuance shall be granted except for reasons deemed imperative by the court. In all such trials the burden of proof shall be upon the party complaining of such law, rules, regulations or orders or act of the Board, and such law, rules, regulations or orders or act of the Board so complained of shall be deemed prima-facie valid but the trial shall be de novo, and the court shall determine independently all issues of fact and of law with respect to the validity and reasonableness of the law, rules, regulations or orders or acts of the Board complained of. The provisions of this Subsection shall be cumulative of all rights of court action by the affected parties and shall not impair or restrict their right to equitable relief.

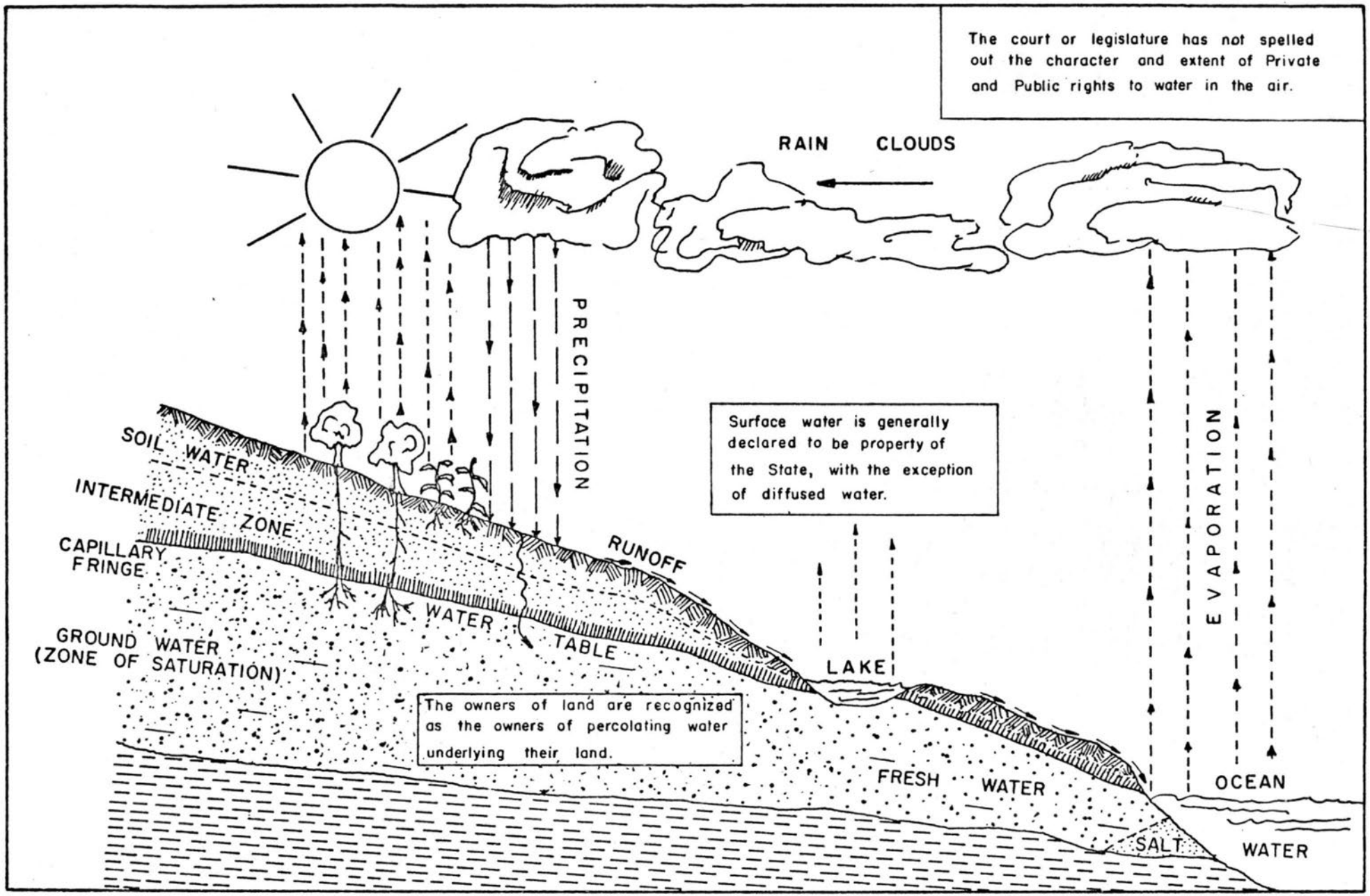
Taxes

G. No District created under this Section 3c shall have the power to levy or collect a tax for any purpose to exceed fifty cents (50¢) on the One Hundred Dollars ($100) assessed valuation on property in the District subject to taxation.

Dissolution of districts

H. Any such District may be dissolved in the manner provided by Section 10 of Chapter 280, Acts of 1929, Forty-first Legislature, Regular Session, [1] regardless of whether or not such District may have outstanding indebtedness at the time of dissolution. In the event such District shall have outstanding bonds or other indebtedness maturing beyond the current year in which such dissolution occurs, the Commissioners Court of the County in which the District is situated shall levy and cause to be collected as county taxes are assessed and collected, sufficient taxes on all taxable property within such District to pay the principal and interest on such indebtedness when due. This paragraph shall not apply to Districts composed of territory in more than one (1) county. Acts 1925, 39th Leg., P. 25, Sec. 3c, added Acts 1949, 51st Leg., p. 559, ch. 306, Sec. 1.

[1] Article 7880--10



HYDROLOGIC CYCLE

STATE BOARD OF WATER ENGINEERS
P. O. Box 2311 Capitol Station
Austin, Texas

IMPROMPTU REMARKS OF WILLIAM L. BROADHURST, CHIEF HYDROLOGIST, HIGH PLAINS WATER DISTRICT, TEXAS

Thank you, Mr. Colburn. Ladies and Gentlemen. Everyone else has had a prepared paper, and although Judge Dent said he would talk off the cuff, he did have some important text. But I didn't bring any notes and there are several reasons for that. First, had I prepared a paper in advance, I wouldn't have had the opportunity to criticise some of the statements that have been made by those who had prepared papers. Second, some of the information that I propose to present to you does not lend itself too well to a prepared report and I wanted to make a persuasive talk rather than present factual data. And third, perhaps it's because I'm just lazy and didn't like to write.

I represent the High Plains Underground Water Conservation District which was created under the laws of Texas by a vote of the people within a part of the ground-water reservoir south of the Canadian River which was discussed by Mr. McMillion. One reason for changing the program yesterday was to permit Mr. McMillion to explain the various aquifers throughout Texas--and I'm sure that you have as great a number and just as great a variation of aquifers in Colorado as we have in Texas. Another reason was to permit a discussion by Judge Dent as to the ground-water law under which we operate, and third to permit me to give you a brief discussion of the operations of one ground-water district under that law.

The Texas ground water law was passed by the legislature in 1949, and, as Judge Dent pointed out, it provides that the State Board of Water Engineers shall designate ground-water reservoirs or subdivisions of reservoirs. The Board may do that on its own motion, or it shall do so upon petition. The Board was petitioned in 1950, soon after the law was enacted, to designate a reservoir in the South Plains area. Meetings were held within the area, and in turn the Board designated all or part of 21 counties south of the Canadian River as a ground water subdivision of the Ogallala Reservoir. The law provides that the Board shall appoint the initial temporary directors consisting of five men who reside within that area. Those men then are charged with the responsibility of calling an election at which time the local qualified taxpaying voters vote for or against the confirmation of the district.

Personally, I think the local option provision is the major shortcoming of the ground-water law in Texas. The law provides that the State Board of Water Engineers shall designate an area, but then it also provides for local option vote within the area. When the vote was held in the southern High Plains, thirteen counties voted to create the district and eight counties voted not to create the district. So the district consists of thirteen counties. The other eight are part of the same reservoir and part of the same subdivision, yet they are not a part of the conservation district. I think that is a major deficiency in our law. However, in a water-table aquifer such as we have in the High Plains, this fact does not seem to be a great stumbling block in the operation of a conservation district. I think it would be a major factor in an artesian reservoir because certainly the development in one part of an artesian reservoir will have significiant effects in the surrounding area.

The High Plains Underground Water Conservation District was created by a vote of the people in 1951. The law provides that the directors, also elected by the people, may pass rules and regulations for the conservation, preservation, protection, and recharging of the ground water. And there again, as Judge Dent mentioned a while ago, our concept of conservation is perhaps a bit different from the discussion given by Mr. Harris, in which he said that you couldn't use water and conserve it at the same time. What does soil conservation mean? Can't you practice soil conservation and use that soil at the same time? Conservation of our forests. Does that mean don't use them at all? I don't think so. I think it means use them, but use them wisely. Then to us, conservation of ground water means orderly development and provident use based on the knowledge and the economic conditions of the time.

You see now I can disagree with the statement that Mr. Conover made regarding conservation. Again, conservation is philosophical. He used the expression that it meant the greatest use for the greatest length of time. I don't think time necessarily is an important factor. Let me give you an illustration. We think that it is pretty universally accepted throughout the world that there is a genuine need for the conservation of petroleum today, don't we? But just one hundred years ago, in 1860, there was no need for the conservation of petroleum, was there? The economics and use of the resource at that time did not require the conservation of petroleum. It is quite possible, I am not saying probable but quite possible, that one hundred years from today there may be no need for the conservation of petroleum. With the development of synthetic lubricants, with the development of atomic energy, and the discovery of other forms of energy that we don't even dream of today, there may be no necessity for the conservation of petroleum one hundred years from now. Therefore, I think that conservation of water means the economic use based on knowledge today. Because what we consider conservation today in one area may not be conservation tomorrow in the same area.

The Texas ground-water law is unique and perhaps it is impossible for Colorado to form districts similar to ours. I think though you can practice conservation by districts or areas even though you have a different concept of ownership of ground water; because, as Judge Dent said again, water doesn't know whether it's owned by an individual, by the state, by the community, or by a district. It doesn't pay any attention to ownership. It obeys the laws of physics. The laws of man should be in accord with the laws of physics, and, as Mr. Miller pointed out in his letter, the purpose of this meeting should be to help provide a man-made law for economic use of a resource. Again, I think that this is the point----economic use regardless of who owns the water.

Many people have severely criticised the farmer of the High Plains because they are using up the ground water. Maybe we are subject to criticism, but we know that we are using up the ground water. Yet, if you build a home and start living in it, it starts deteriorating. If you buy an automobile and start driving it, you start wearing it out. If you are a farmer, you buy a tractor and when you start using it you start to use it up. But if you get value received from the product, and that's what you bought it for--to use--we think again, if you get value received for the water, whether you use it up or not is insignificant.

I went down to Guatamala three or four years ago to work with the people down there and made a brief analysis of their water situation and how they could develop some rules for the use of the water before they get into controversy. And that country had a pretty highly developed civilization before the wheel was invented--quite a long time ago. The ruins down there, the pyramids, and other records indicate the Mayan Indians had a pretty highly developed civilization more than 2000 years ago. Yet, today they are thinking about developing and using their water resources. So again, the element time doesn't mean too much. I couldn't help but wonder, though, as I flew back over the dense jungle of Peten--no population there now, just a few Indians, many snakes, and wild animals--what the historians would be writing about the High Plains of Texas in the year 4000.

People have been asking what is the solution to our water problem in West Texas. I have said in my opinion there is no solution. The only thing is to learn to live with the problem, because even if we can desalt sea water at a nominal cost there are still problems involved. If we can bring pipe lines from the Gulf of Mexico, from the Great Lakes, or from Alaska, there are still problems involved--probably greater problems than the ones we have today. There may be solutions in certain sections of the United States--but I can't see any solution in our country. It is going to be an increased problem as time goes on. Well, the statement has been made that every time we solve one problem, two pop up to take its place. But the answer to that is if we didn't solve the one we would have three to contend with.

As Judge said, I think we have even more than just two philosophies. I think that we have as many philosophies on ground water in Texas as we have people. I talked to a group one time about the source of the water in the High Plains, and I said that I didn't know for sure where the water came from. Logically the source of water is precipitation on the plains. One fellow said, I don't agree with you--the source of water is not rainfall at all. And I said, what's your idea? He said it comes from the Gulf of Mexico. And I said, well, how do you account for the fact that the water up here is fresh water, and the water in the Gulf of Mexico is salty? He said the water is sloshing back and forth through the sand, and the salt is filtered out of it. And I said well, O.K. I can't believe that, but assume that that is right, how do you account for the fact that the water level here on the plains is 3,000 feet above the level of the Gulf of Mexico? He said well the earth is spinning on its axis and the water is thrown out here by centrifugal force. And I said, if it's thrown out here why does it stop at this particular level? He said, haven't you ever heard of gravity, that keeps it from going any further. I said maybe you have something there. If you want to believe that theory, you are just welcome to it.

Now again, I said I don't have a prepared paper. I do have several things here that I want to show you on the black board. As Judge pointed out, we are not involved in a lot of litigation. The High Plains Water District has been in operation now about nine years, and we have been in the Court House one time. One of the first things the district did was to prepare a set of rules and regulations and one of the first rules was to require permits for the drilling of wells. And down there if a well doesn't produce 100,000 gallons a day, it isn't a well. The legislature of Texas said so. It's got to produce more than 100,000 gallons a day to be a well. But any well that is designed to produce more than that is defined by the legislature as a well and a district may require permits for the drilling of those wells. Well, as I said, our district covers parts of 13 counties, and those five directors felt in order to make this a locally controlled district, they didn't want to assume the responsibility of all regulations. They wanted the people to help. So they provided for the election of five committeemen from each of the thirteen counties. The committees would not be governing bodies, but they would be sounding boards from the local areas. The directors said, to start with, we will require that people get permits to drill wells. But the county committees may determine the spacing of those wells. Some counties required wells to be 200 yards apart, others 300 yards, others 400 yards, and another half a mile. And it came to pass that a county line, an imaginary line, passed through a farm. One county required a well spacing of 880 yards and the other required a spacing of 300 yards. The land owner said there is something wrong. If I drill a well here, it may be only 300 yards from another well, but if I drill right over there it must be 880 yards. Something is wrong

with the rule and the directors agreed. They said we must establish a standard set of rules, spacing rules, throughout the district.

When we started talking about well spacing based upon economics, one attorney said don't pay any attention to economics--you stay underground. You're dealing with the underground water; after it gets to the top you have no more to do with it. I said if we're not looking at this thing from the point of economics, what is the purpose of the district?

But there is something more than economics involved and I jotted down one point that the gentleman from Kansas made yesterday which hits the nail right on the head. He was talking about southwestern Kansas, where ground water occurs in the Ogallala formation, the same formation as in Texas. Kansas has not established a rule for development yet, but he said that a rule must be understood by and acceptable to the people of the area. And that is the crux of our spacing law. I said this spacing proposition is similar to the speed limits on the highways. I think Colorado has recently taken steps that explains what I am going to say. If the people of Colorado would pass a law that no one shall exceed a speed of 30 miles an hour on any road in the state, and if they could enforce it, they would probably save a lot of lives and a lot of property. But how could they enforce it? It would take a traffic cop for almost every fellow traveling down the road. It is just impractical. On the other hand, if they should pass a law saying that the speed limit shall be 160 miles an hour, then less people would violate the law--but there would be a heck of a lot more wrecks. So what they tried to do was reach a happy medium--a compromise. They have recently increased the speed, as I understand it, on four-lane highways from 60 to 70 miles an hour as a practical matter. Our well spacing program in the High Plains of Texas is based upon this same philosophy. The rule is if you plan to drill a well and install an 8-inch pump that will produce a thousand gallons a minute, it must be 400 yards from any other existing well. Smaller capacity wells may be drilled at closer spacing. Our people knew, and I believe they still know, that if you install a thousand gallon-a-minute well every 400 yards, they are too close for economic development of the area. On the other hand, if you are in a prolific water area, and you are the man who owns 80 acres of land and there is a public road along here, the distance from the center of that road to the center of this 80 acres over here is 440 yards. Now suppose this man has a well here, and this man has a well there, but there is no well on this 80 acres. The law says that no man shall be denied the right to drill a well and produce water. Consequently, the rule permits an 8-inch well 400 yards from any other well.

But here again, there is a difference in philosophy. As was pointed out yesterday, when the State Engineer of New Mexico determines that enough wells have been drilled in a given area to deplete the supply in forty years he may stop the drilling of additional wells. Yet our philosophy is--that just because one land owner drilled his well first is no reason that his neighbor should be forever denied the right to drill a well. Again, some of the reasoning for limiting the number of wells is based on the theory that well owners need to produce for a number of years in order to justify the investment. That may be true in some areas, but it is not true in our area. Several years ago a friend of mine inherited a farm--220 acres. It was a dry land farm, and he was renting it for cash rent at $4.00 per acre per year. His gross income was $880.00 from a 220-acre farm. He came to me one day and said that his tenant had made him a proposition that if the owner would drill a well, the tenant would install the pump, furnish the motor, and the fuel, and they would share the crop. What do you think about it? I said I think that it is a good proposition. The well, casing, and pump base cost the owner $1050.00. The tenant bought a pump and automobile engine and started irrigating. The landlord got one fourth of the cotton and one third of the grain sorghum. I don't remember the exact figures--they are insignificant--but the point is that the first year the landlord, after having paid for the well and casing, made eight and one half times as much profit as he had under the cash-lease system on a dry-land farm. The tenant, after he had deducted the price of the pump, the price of the motor, and the price of the fuel, made six times more profit than he had been making under dry land. The point is this----after the first year, had the well caved in and the pump and motor gone to the bottom, the landlord made money, the tenant made money, the man who sold the pump made money, the man who sold the casing, the man who sold the motor, the fuel, there was created wealth in one year's time to more than offset all the costs of the well. Now that again has a lot to do with the philosophy of the development of ground water. I know that in many areas irrigation development cannot pay out in one year. That is true especially in the development of surface waters where you have dams, canals, and the like--it takes many years to pay off. But our people don't hold to the philosophy that it takes forty years for a man to pay for his irrigation improvements where wells are concerned.

Mr. McMillion pointed out that ground water in the High Plains is a matter of storage, and I think we will agree that when irrigation development started back in 1910, we had 100 percent of this supply. A few irrigation wells had been developed prior to World War I, but during that war the farmers could make more money dry-land farming than they could irrigating, so they quit irrigating. In fact they quit altogether during World War I and the early '20s. The drought of the '30s came along, the right-angle gear drive became perfected, turbine pumps became more efficient, and cheap automobile engines were used for power.

The pumping units became much cheaper and more practical and irrigation farming increased in popularity. During the '30s we pumped a little bit of water and used it, but in 1941, the wettest year on record throughout the High Plains, the area received heavy recharge and the water levels all over the plains came up. For all practical purposed in 1942 we still had 100 percent of the water supply in the High Plains of west Texas. By 1960, the water table had declined as a result of heavy withdrawals, and, throughout the High Plains irrigation area as a whole, we had used up about 25 percent of the supply.

We still irrigate some alfalfa in Texas. It will take roughly, I think, 48 inches of water a year to grow a field of alfalfa. And then you may make as much as 4 tons per acre. That means about 3 acre feet of pumped water, or a million gallons or roughly 8 million pounds of water to produce 8,000 pounds of hay--one pound of hay--1,000 pounds of water. The purpose of the research in our area should be to develop plants that are efficient users of water.

Half of the five million acre-feet of water pumped is used in the production of grain sorghum. We had some studies made by an economist at Texas Tech a few years ago on economic use of water, and we found at that time--1957--that if a man bought a piece of land and bought some water, the main price that he paid for the farm was for the water. When he bought a farm, he was paying about $10.00 per acre foot for the water in the ground. Based upon 1957 yields and 1957 prices for grain sorghum as a cash crop, he was selling his water at $10.13 per acre foot. Through cotton, at 1957 prices, he was selling water at $66 per acre foot.

The economist at Texas Tech. also told us that of the dollar paid by the consumer for grain sorghum products, the man who produces it receives eleven cents--of the dollar paid by the consumer, the producer receives eleven cents. I suspect it takes more water to produce a pound of grain sorghum than it does to process and market a pound of grain sorghum. Some say that we shouldn't invite industry to an area like this. I think that is wrong--we should invite industry. Lets process the products grown in this area and in turn receive greater economic returns for each gallon of water. So again, much of our work is not legislation, not taking people to the Court House, but it is providing a tool to assist the people of the area in orderly development and better economic use of their natural resources.

I left some copies of information here that we have prepared as educational material. We tried to point out in very simple terms a leaky faucet and what it means over a period of time to permit that leaky faucet to go on. Then in turn, users of large quantities of water are discussed. The material was prepared for

fifth and sixth grade kids. We hoped they would look at the pictures and then take the book home and get their fathers and mothers to read it. We think it has been pretty successful. We have prepared these brochures for insurance companies and others who have invested millions in properties in that area.

I'm not even going to get into this very much, but I do want to touch on it briefly--what we are doing as a district. This is a brief prepared back in 1954. It is called cost depletion deduction for income tax purposes in the case of underground water. You know the laws of this land are that oil and gas, mines and other natural deposits that are used up in production of income are entitled to depletion allowances. We contend the underground water in our area is a natural deposit, it has a cost, and it is being used up in the production of crops which we sell for income. We say, if the other natural deposits are entitled to depletion allowance, then ground water is entitled to depletion allowance. The purpose is not to deprive the federal government of tax dollars, but if the federal government will recognize depletion, recognize the value of water, then the individual land owner will be able to evaluate the net returns from using up part of his capital investment. In the long run, depletion allowance should encourage better water management, and, in turn, permit the land owner to make more income and pay more taxes over a long period of time.

A Plan for the Practical Management of the Water Resources in an Alluvial Valley 1/

By Edward A. Moulder 2/

The most efficient use of water in an alluvial valley often involves coordinated management of both the ground- and surface-water resources. Often, however, certain legal considerations prevent close coordination or make it difficult. In Colorado, where water rights are administered under the "appropriation doctrine," ground-water rights generally are junior to surface-water rights because the surface-water rights were acquired earlier. Although there may be enough water to satisfy both, oftentimes the occasion arises when surface water is in short supply. Because the courts recognize that use of one of the two sources may affect the other, the ground-water rights can be revoked temporarily even though by so doing the surface-water user may not benefit proportionally. Ideally, optimum development and management of ground and surface waters is best accomplished through a single organization having full control over the waters. However, the situation presently existing in some valleys in Colorado is such that, as a practical measure, two groups might effectively carry out integrated water management. The two-group organization is proposed herein as a plan whereby the surface-water user will get his fair share of the water and the ground-water user will obtain the maximum benefits from his right.

The plan calls for the organization of two groups--one representing the surface-water users, the other representing the ground-water users. Each should be led by men who are dedicated to making the plan work and who are willing to act impartially. The groups need not represent an entire drainage basin, although that too would be possible. The subdivision of the basin should be based on the hydrology of the basin, however, rather than on political boundaries.

An example may be the best way of presenting the plan. Let us assume that the effective hydrologic boundaries of an area adjacent to a particular stretch of stream have been established, and that the ground-water users are organized and have designated a board of directors. Streamflow records for this stretch of the river show that, between the upper and lower ends, the return flow (effluent seepage) ranged between certain amounts during the period of record. The two groups could establish by compromise a minimum figure or set of figures for return flow across the area that the ground-water group would be responsible for maintaining. Periodic meetings could be called to adjust the figures if additional facts made such an adjustment appear advisable. The members of the ground-water group would then decide among themselves whether deficiencies would be made up by restricting use of ground water or by supplementing the surface

2/ United States Geological Survey, Denver, Colorado

1/ Approved by the Director, U. S. Geological Survey for Presentation At The Western Resources Conference, Boulder, Colorado August 24 and 25, 1960

flow with ground water pumped from wells owned or controlled by the ground-water group. The latter possibility seems the most likely because it would be easier to manage, probably would be the most effective, and probably would be most equitable to the ground-water users. In some cases, however, it might be necessary also to restrict ground-water withdrawals if the total water supply were inadequate.

The problems of putting into effect such a plan are many, but they probably are not as formidable as the apparent alternatives. At present, the following situation is a likelihood: A surface-water user finds that during a drought period there is insufficient water to meet his rightful share. He is aware that the pumping by a nearby ground-water user may be affecting the availability of surface water. He asks the court to acknowledge his prior rights; the court may order the ground-water user to cease pumping until the surface-water supply is restored. Such an action may or may not materially benefit the surface-water user, depending upon the hydrologic factors involved. In most cases, the amount of surface water gained during the critical period would be only a small part of the ground water that would otherwise be used beneficially. The cost involved in court actions and delays would impose a penalty on both parties and might prove not to be worth the effort. In contrast to this situation, the proposed plan would offer the surface-water user immediate relief, while the damage to the ground-water user might be slight.

A brief review of some of the hydrologic functions of the water system may lead to a better understanding of the plan and associated problems. Figure 1A shows that intermittent streams generally are influent--that is, the stream recharges the underlying ground-water reservoir. The perennial stream (fig. 1B), on the other hand, generally is effluent, receiving water from the aquifer. The discussions herein pertain only to the latter situation. Before ground-water withdrawals were started, the streamward movement of water through alluvial acquifers resembled closely that shown in figure 2. Figure 3 shows that water moving toward the stream can be intercepted by pumping from a well; if, as shown in the sketch, the pumping level is below stream level, a part of the well discharge may come from the stream.

Figure 4 shows diagrammatically the principal routes that water travels in the type area under discussion. As can be seen, ground and surface waters are closely related. A part of the precipitation falling in the basin is evaporated before it can reach the stream or ground-water reservoir. A part of the water reaching the stream evaporates and a part is diverted to supply certain needs. Not all the diverted water is consumed; a part returns to the stream directly or after infiltrating to and percolating through the ground-water reservoir. The part of the precipitation that infiltrates to the ground-water reservoir may be partly consumed by evapotranspiration. A part may be pumped or discharged to the stream. Like the water diverted from the stream, the pumped water is consumed only in part;

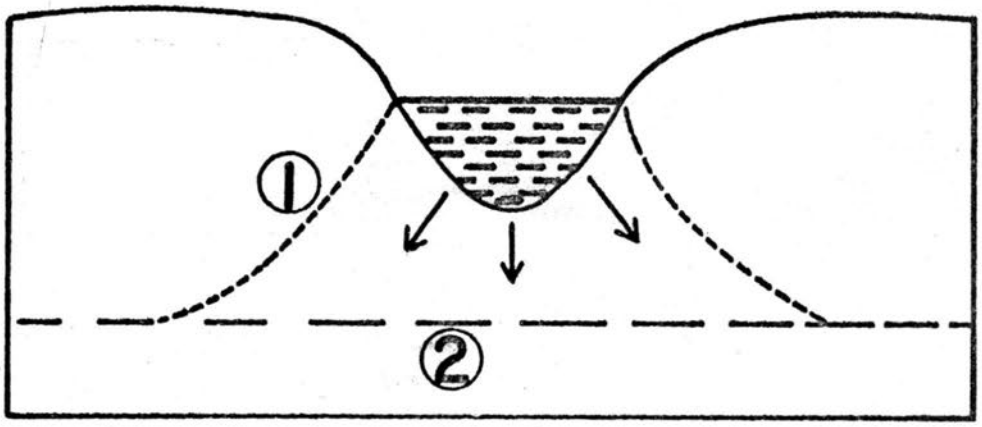
the remainder returns either to the stream or to the ground-water reservoir. That the stream and ground-water reservoir are hydraulically connected means that the stream may be either effluent (fig. 2) or influent (fig. 3), according to the slope and position of the water table.

The location of the wells with respect to the stream is important to efficient operation of the plan. Although it may be impractical to have the supply wells located strategically, the wells proposed for supplementing the surface-water supply might be so located. If the time of pumping can be estimated, the wells might be located so that their effects on the stream are not significant during the period of critical need for surface water. Proper location also might allow partial replenishment of the depleted ground-water storage by influent seepage from the stream during noncritical periods. The selection of the best locations would require a detailed study of the water-bearing properties of the ground-water reservoir. Referring to figure 4, the plan for supplementing the surface supply is as follows: During the critical period, water is pumped from the ground-water reservoir directly to the stream (see flow path indicated by dashed lines). The withdrawals come principally from ground-water storage and are partly replenished during the noncritical period by influent seepage.

A more direct method of replenishing depleted ground-water storage may be worked out jointly by the two groups. Streamflow in excess of the immediate needs of surface-water users could be diverted to the wells, recharging them artificially, or to areas where permeable surficial materials would permit water to seep from basins or furrows.

The author suggests that this plan be considered as a possible means toward better water management. If the plan should prove successful, it may encourage exploration of other water-management plans, and may preserve good personal relationships among water users. Should the plan be considered seriously, certain legal and hydrologic studies should be undertaken to determine the feasibility of the plan and the best methods for putting it into practice. Among these would be a study of existing laws (or the need for additional legislation) that would permit the organizing and proper functioning of the proposed groups of water users. Also, hydrologic studies pertaining especially to return-flow patterns and the designation of practical hydrologic boundaries of ground-water reservoirs would be needed.

(A) INTERMITTENT STREAM

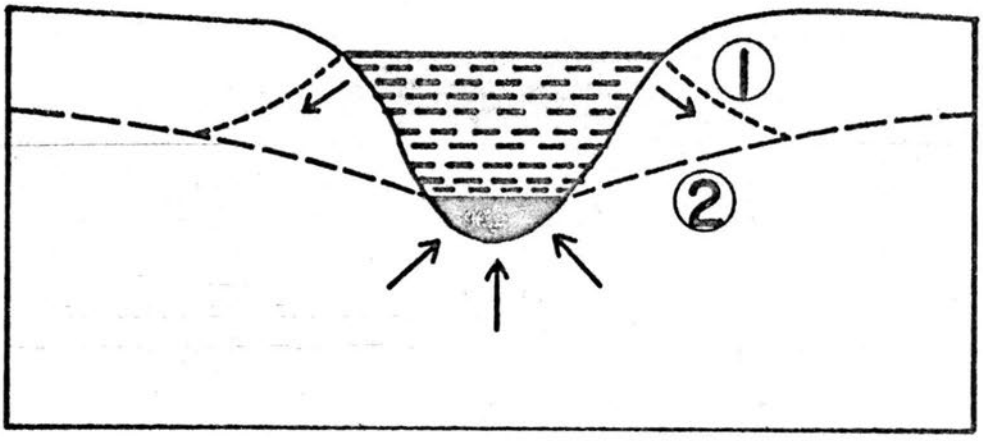


WATER TABLE

① Stream flowing

② Stream dry

(B) PERENNIAL STREAM



WATER TABLE

① Flood flow

② Normal flow

FIGURE 1

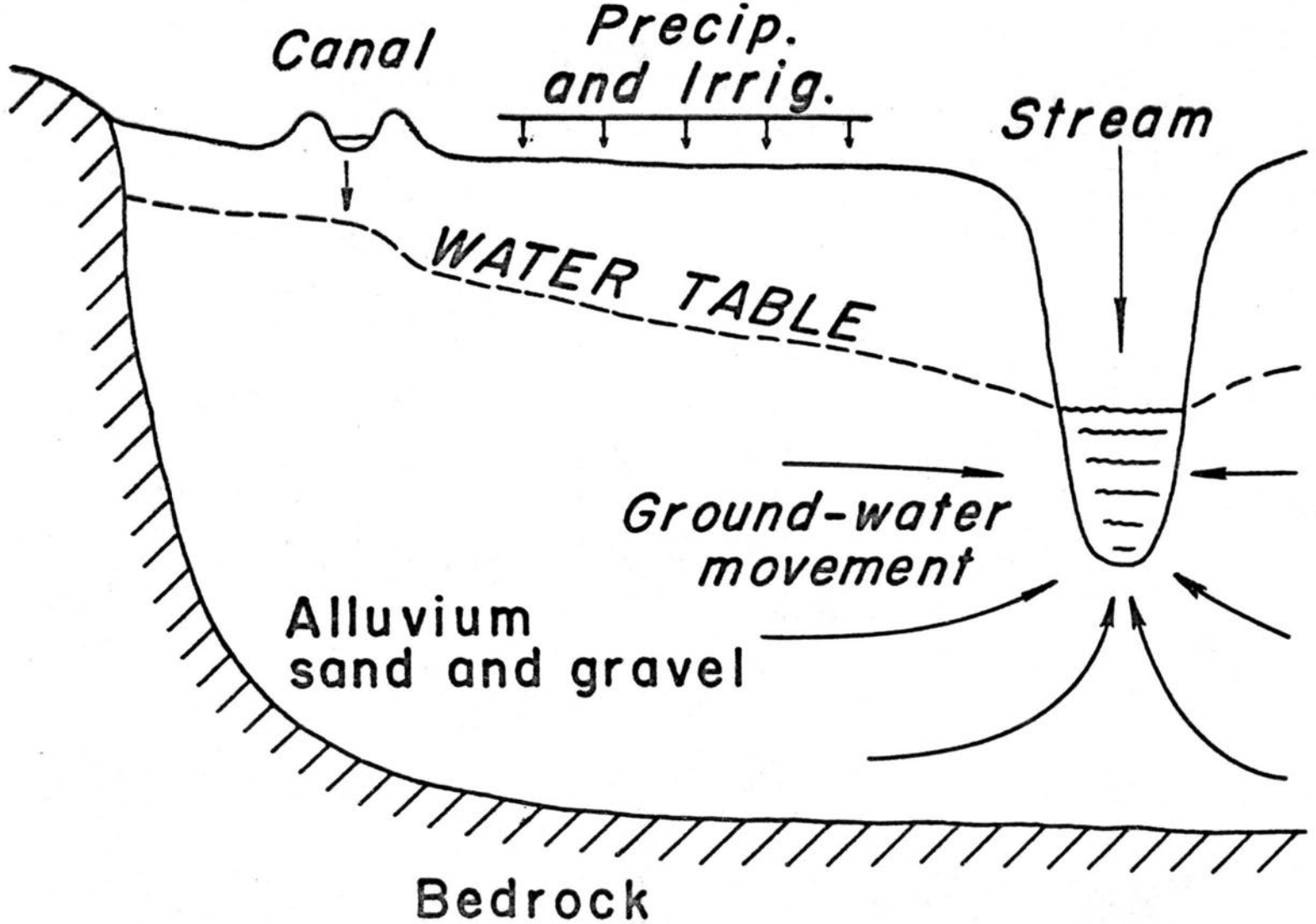

Canal
Precip.
and Irrig.
Stream
WATER TABLE
Ground-water
movement
Alluvium
sand and gravel
Bedrock

FIGURE 2

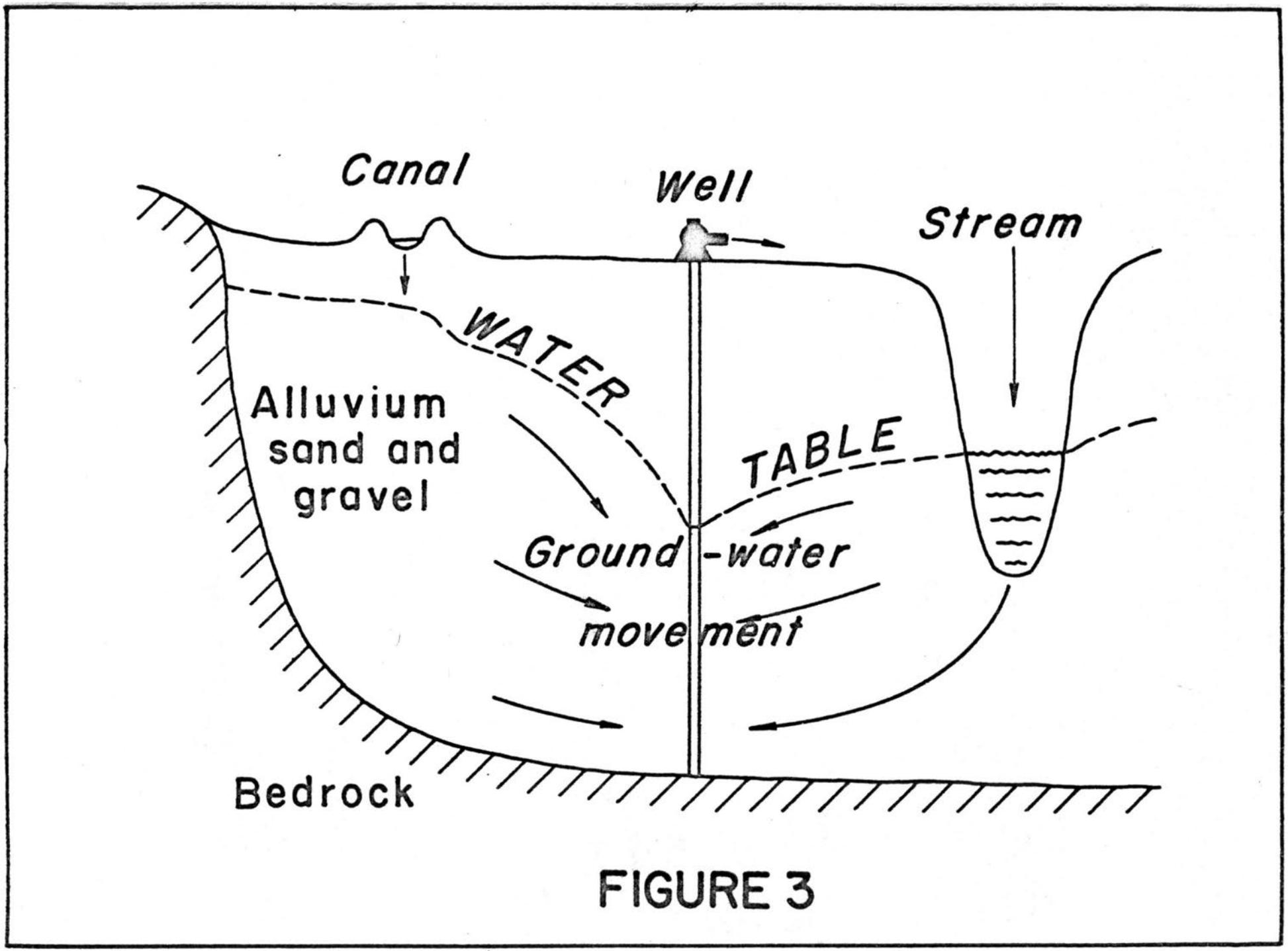

Canal
Well
Stream
WATER
TABLE
Alluvium
sand and
gravel
Ground-water
movement
Bedrock

FIGURE 3

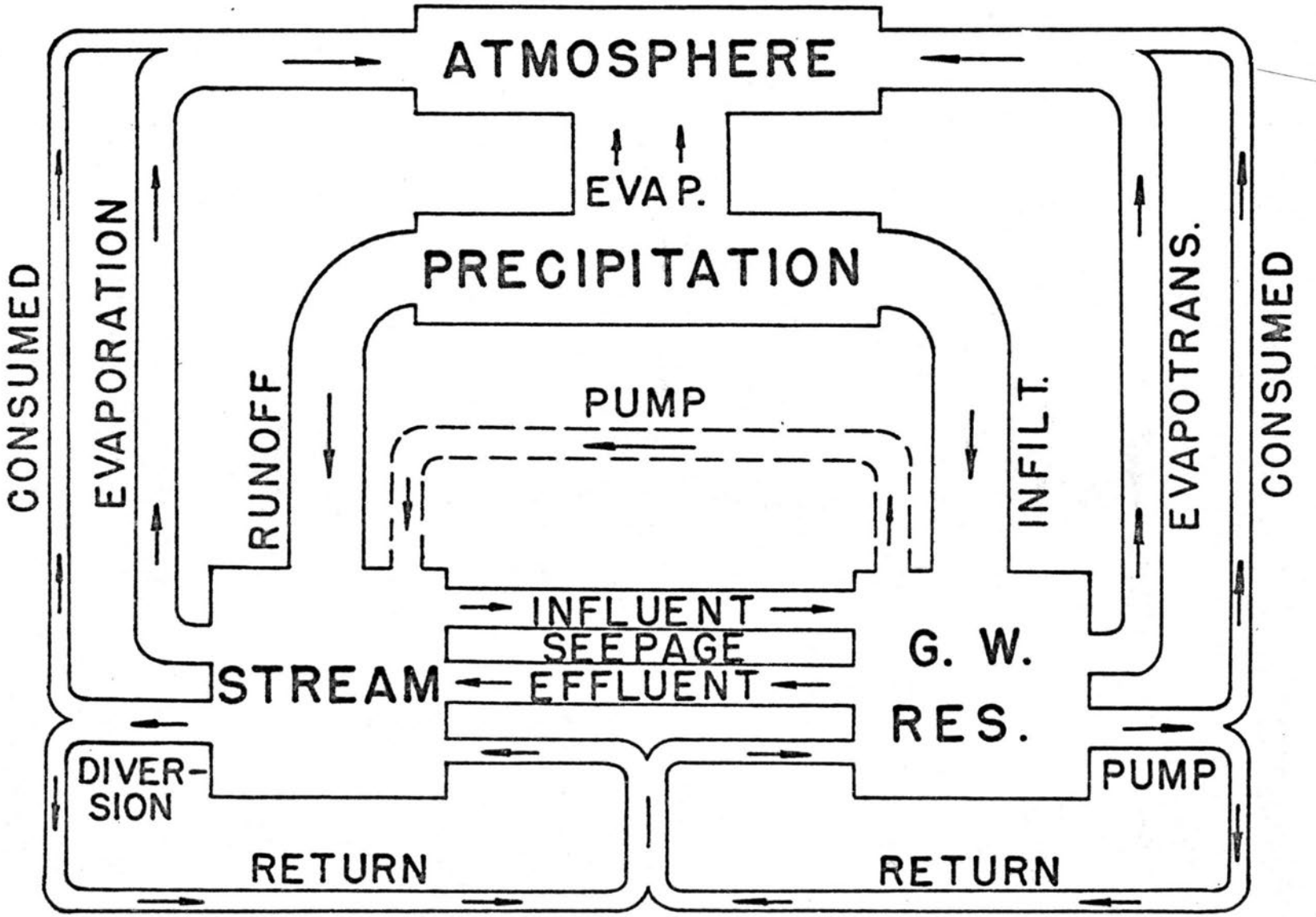

ATMOSPHERE
EVAP.
PRECIPITATION
CONSUMED
EVAPORATION
RUNOFF
PUMP
INFILT.
EVAPOTRANS.
CONSUMED
INFLUENT
SEEPAGE
G. W.
STREAM
EFFLUENT
RES.
DIVER-
SION
PUMP
RETURN
RETURN

FIGURE 4

REMARKS OF WILLIAM R. KELLY, ATTORNEY AT LAW, GREELEY, COLORADO

Ladies and gentlemen. I appreciate this opportunity to express my views. I am interested in ground water--that's why I am here. I have been on the ground water committee and on the council of the Water Section of the Colorado Bar Association for many years, and I am very glad to see that a study and report on the ground water situation in Colorado is to be made by Sam Chutkow and Dave Miller. They are men of exceptional experience and standing in their profession and in ability to deal with our situation.

Now, I only want to talk about the situation in Colorado. I have studied ground water acts of other states, and it seems to me that in the end, in spite of what they say, they come to the conclusion, even where they said ground water rights were based upon the appropriation doctrine, when they come to decide the cases, they have held that there was a landowner's right to reasonable use. Nebraska's Supreme Court has held that.[1] And in the latest Utah case, I believe decided within the past year, they held that a man had a right to reasonable use of water in his own land even though delinquent under a statute they had adopted about ten years ago,[2] which had reversed their whole hundred years of history and ruling on ground water, that, even though the court, in Utah, held that they had been wrong for a hundred years.

Now of course our situation is not the same, in Colorado, at least in the South Platte Valley, as it is in Texas, where the ground or soil conditions may be different. It is not the same as it is in New Mexico, where their constitution makes all water property of the public and subject to appropriation. There they had that critical situation that grows out of the Roswell Basin, where they had to adopt some regulation. And yet, even there, I think their system is not strictly on the appropriation basis.

Our settlement in Colorado was made largely by men who came here for the "Gold Rush" - the "'59ers". Many of them had been to California and tried the gold rush there and came back. They didn't find the gold there, but they thought they would try for it in Colorado. They brought with them the appropriation doctrine, from mining custom, that the person who diverted it first was the first in the right. But they know that they applied that to the water of natural streams. The gold miners weren't interested in digging wells for irrigation. What they were interested in was the use of water power for operating stamp mills, the reduction of the ore, or flushing gravel, or sluicing for placer mining. Those folks dug their ditches, moved on, and those old ditches passed out of existence. They were rather transitory. In our early lawmakers draft of a constitutional provision in 1876, the water which they

1. Luchsinger v. Loup River Power Dist., 140 Neb. 179, 299 NW 549.
2. Carbon Canal Co. v. San Pete Water Assn., 353 P2d 916.

said was the "property of the public" was not all the water. They said only, "water of all natural streams" is the property of the public, and subject to appropriation.

Later came the agricultural development, and gradually, the need of more water, from the water in the streams, came the putting down of wells by farmers.

This situation began away back in 1889. Never until now, recently, sixty years later, was it questioned that a man had the right to the water in his land, except in cases where that water was being taken from natural streams. Of Course, where a well was so near a natural stream that it is depleting the flow of the stream, why a man is in the same position as if he were pumping out of the stream. He would have to be governed and take his turn according to his priorities under the appropriation doctrine.

Many wells are ten or fifteen miles from the stream, and they have no evidence of substantial contribution to the stream. The water coming from rainfall, let's say 15 inches a year, and added to application of water for the irrigation is about that much, say a foot and a half a year, accumulated and formed an underground reservoir. Farmers found that by putting down wells they could bring this water up and use it, over and over again, on their crops. They had been doing it for 60 years in Weld County. There is a well case in the Colorado Supreme Court that goes back to June, 1889.3. Now, in that case, it was held that if that well was depleting the natural stream, it was subject to priorities. It never was decided whether it was diminishing the flow of the natural stream or not. That well, or its replacement, is still in operation. It is close to the bank of Lone Tree Creek. It was claimed it was depleting the stream.

When water was brought out of these bench lands from the rivers, it went down into the soil and kept building up. This ground water which had existed began to come to the surface and to cause marshes. Land went bad, in places began to deteriorate from alkali and seepage. Water began to be drawn off. In many cases it was just spreading out into the ponds and lakes, being exhausted by evaporation, largely.

Then in this recent era, beginning more rapidly with the drought era that began about 1919, there began to be quite accelerated development of wells, irrigation by wells. That water that was taken up out of the ground reservoir by wells, out of the land, is put right back into the land. It goes down again into the same land, makes use of storage in the soil to bring it to the greater use--not greater consumptive use, than is brought by using the water in reservoirs where there is great evaporation as well as a seepage.

3. McClellan v. Hurdle, 3CA 430.

Well water use on crops is an economic use. In these reservoirs in Northern Colorado, evaporation in the hot summer, like this one we have just been through, is often as much as one foot in depth per month. I think on Lake Mead, the engineers have said, that seven feet in depth evaporates in a year there. Now carriage in canals also consumes more water than does well use, at least on the average in these canals we have in Northern Colorado. Here about 30 per cent of the water taken into canals, is lost in carriage, canals only deliver about two-thirds to the farmer's headgate, of what was taken on at the stream headgate. That water seeps down into the land. By pumping it, the marsh lands are being reclaimed. That wet land, that was formerly alkali and unproductive to the farmers, now has become very productive in crops. Some of the seep streams are so being dried up.

This water has added, this water from wells, pumping, has added to the economy of the country. At least a third total additional acre feet of water is so made available to agricultural crops.

That ground water that goes onto this land, here in the South Platte Valley at least, is not all water that came of the South Platte River or South Platte River tributaries. As much as the Cache la Poudre River, which is our principal tributary to the South Platte, is introduced into this valley from extraneous sources, from the North Platte transmountain diversions at Cameron Pass, from the Laramie Poudre tunnel, from the Colorado River by the Grand River Ditch which we see as we go over Trail Ridge Road, which canal brings about 25,000 acre feet annually into South Platte Valley. And Denver introduces water into the Platte through the Moffal Tunnel from the Frazier and the Roberts Tunnel from the Blue River tributaries of Colorado. But greatest of all comes from the Colorado-Big Thompson Project out of the Colorado River, which originally was estimated at 310,000 acre feet, but in reality is going to be experienced probably as only about 80 per cent of that. That's new water. It is going into the soil and wells are pumping it up, stopping seepage and drainage, and adding greatly to the production of crops in this area.

It has resulted that, for the benefit of the whole country by recognition of it, as was the appropriation of streams accepted by custom, we have been allowing it to go on, now for over 50 years. The doctrine which by custom has been applied in Colorado for greatest public benefit as to water which is not tributary of a natural stream, is the doctrine of reasonable use, just as it is in California.

This is the doctrine of rationing which we apply to oil to which ground water by its fugacious nature is analogous.

We need regulation, to assure this reasonable use, as we do to shut one man out from draining the oil out of his neighbor's land, of course. Where the water is being diverted by pumps out

of some area so near the stream that it is depleting the stream, that water is governed by the constitution anyway. Where it is tributary to the stream, the water is subject to appropriation and to the doctrine of relative priorities. Such a doctrine for non tributary water would be against public interest in Colorado. By custom we have acquiesced in and accepted the reasonable use doctrine as to non tributary ground water.

GROUND WATER DEVELOPMENT IN NEBRASKA

BY Vincent H. Dreeszen, Assistant Director
Conservation and Survey Division, University of Nebraska

Nebraska is located geographically near the center of the United States midway between the more humid areas to the east and the more arid lands to the west. The average annual precipitation grades progressively greater eastward from less than 16 inches in western Nebraska to slightly more than 34 inches in the southeast corner of the state. Because of the variability of precipitation and the recurrence of dry periods Nebraskans have always been interested in developing supplemental water supplies for agricultural use.

Nebraska has slightly more than 5,800 miles of permanently flowing streams which are largely supported by ground water discharge. It was natural for the early drought-pressed settlers to use some of this water to irrigate their crops. History relates that one of the first diversions for irrigation in Nebraska was in 1887 by a group of immigrants from Colorado who brought the practice from their former state. In accordance with the custom prevailing in the western states they posted a notice of appropriation and so filed a notice with the county clerk. At that time it was generally recognized in Nebraska that riparian owners could make a reasonable use of the waters of a stream for beneficial purposes. In 1889, in spite of a considerable clamor from residents in the central and eastern parts of the state who feared that legislative action to protect the rights of western water users would ruin the agricultural reputation of the state, legislation was enacted. The legislation recognized and protected the rights which had been initiated and provided for the appropriation of running water. It provided for no state administration or irrigation districts. The severe drought of the early 1890's resulted in increased diversion of river water and enough state interest in irrigation that a water-rights law was passed by the legislature in 1895. The law created a state department with power to administer the waters of the state on an appropriative basis and to authorize irrigation districts; it created preference in use of water in the order of domestic, agricultural and manufacturing use, and it fixed a maximum diversion rate. This law of appropriative rights was given constitutional sanction in 1920 and remains substantially the same today.

Visions of an unlimited water supply proved unfounded in the North Platte Valley as early as the late 1890's. The problem of a sufficient flow of water to meet established irrigation requirements was increased by upstream diversion of Platte River water in Wyoming. The obvious answer was to construct reservoirs to impound waters otherwise running to waste in the non-irrigation season, in other words, a plan of management to more effectively utilize available water. Even so, the requirements of all irrigators in the Platte Valley could not be fully met and the users have had to adjust their irrigation practices accordingly.

The terrible drought of the 1930's aroused enough action and interest to begin the impounding of waters in our other rivers for irrigation use and flood control. Approximately 800,000 acres of land are now irrigated with surface water, and an additional 200,000 are furnished supplemental water.

The previous remarks may help to better understand the development of ground water supplies in Nebraska. We proudly boast that the amount of ground water in storage at readily available depths is greater than in any other state in this section of the country and we consider ground water to be one of our greatest resources. The later geologic events occurring in the state were significantly different than in the surrounding areas resulting in the deposition of greater thicknesses or permeable materials over broader areas than in the neighboring states. The amount of water stored in these relatively shallow reservoirs has been estimated to be at least 990,000,000 acre feet. Recharge conditions are ideally unique in much of Nebraska because of a generally flat terrain and the most extensive deposits of wind-blown silt (loess) and the largest area of sand hills in the country. This combination of tremendous ground water storage plus the excellent recharge conditions led many Nebraskans to believe the supply inexhaustible, the belief held by pioneer surface water users in their supply.

The ground water resources of about one-half of the state have been quite thoroughly investigated on a regional basis by test drilling as a part of the cooperative program of the Conservation and Survey Division, University of Nebraska and the Ground Water Branch, U.S. Geological Survey, The cooperative program was initiated in 1930 and since that time about 3,000 test holes, totaling about one-half million feet, have been drilled. A state-wide cooperative observation well program has been conducted since 1934. Results of both of these programs have been published separately and in more comprehensive reports by both state and federal agencies.

The expenditures by the State-Federal cooperative program have averaged slightly more than $11,000 per year for each party during the 30 year period. The cooperative agreement for this year calls for $33,500 to be contributed by each party for ground water study.

All Nebraska municipalities but two--Omaha and Chadron (and they have plans to change)---have developed their water supplies from wells. Most of the water used by industry in the state is pumped from ground water and approximately 1,750,000 acres of land are irrigated from a registered total of 23,360 wells. The principal use, by far, for ground water in the state is for irrigation. Interest in, and the development of, ground water for irrigation since the advent of modern pumping and well drilling equipment have been influenced primarily by the weather.

Approximately 750 irrigation wells were installed from the early 1900's to 1930. Most of these wells were drilled in the river valleys. The rate of installation increased greatly during the drought years of the 1930's and by 1942 an inventory showed 3,526 wells with activity spreading into the uplands. The installation rate remained about the same during the period from 1942 to 1948 partially due to the hot dry summers and continued expansion in the uplands. At the end of 1948 the total

number of wells in the state was 7,150. Only 2,000 wells were installed between 1948 and 1953 during a period of more abundant precipitation. The number of irrigation wells were more than doubled in the next 4 years with between 3 and 4 thousand wells being installed each year. The expansion was activated by precipitation deficiencies and it spread into the eastern part of the state. Since 1957 we have enjoyed above normal precipitation in most areas of the state and the irrigation well installation rate has been less than 500 wells per year.

The development of ground water in the state has taken place with essentially no legal restrictions. The only state statute relating to ground water prior to 1957 was one prohibiting the waste of artesian water and providing a penalty for offenses. The State Supreme Court, in 1932, ruled "An owner of land is entitled to appropriate subterranean water found under his land, but he cannot extricate and apply it unless there exists a reasonable and beneficial use to the land which he owns, especially if such use is injurious to others who have substantial rights in the water, and if the natural underground supply is subject to all owners, each is entitled to a reasonable proportion of the whole." The decision in effect upholds the so-called American rule of reasonable use prevalent in many of the western states.

The legislature, in 1957, created the Department of Water Resources and transferred the powers and duties of the State Engineer relating to water rights to that department and to the Director of Water Resources. In the same year the legislature established preference in the use of underground water. Domestic use was given first preference, and the use of water for agriculture was preferred over its use for manufacturing or industrial purposes. In 1957, the legislature also passed two additional laws and declared "the conservation of ground water and the beneficial use thereof are essential to the future well being of this state." These laws require, among other things, the registration of all irrigation wells with the Director of Water Resources, identify an irrigation well as one used to irrigate more than two acres, require the filing of well logs, and specify that no irrigation well shall be drilled within six hundred feet of an existing irrigation well on neighboring land.

In 1959 the legislature enacted a law to provide for the establishment of ground water conservation districts by petition. It provides for approval of the boundaries of such a district by the Director of Water Resources and the Director of the Conservation and Survey Division, University of Nebraska, and empowered the districts to tax and to take corrective measures "to ensure the proper conservation of ground water within the district" after a public hearing. Provision was made for the board of directors to compel compliance of adopted measures by action brought in district court. No petition for the formation of a ground water conservation district has been made as yet.

The present state law relating to ground water with the exception of registration and spacing of irrigation wells, preference in use of water, and waste of artesian water leaves the decision of rights to use of ground water and its control to the courts and to local ground water districts, if and when they form. The present legislation came into being after two serious droughts in recent years and after concern was felt in parts of the state that some over-development of ground water resources was taking place. The interest in ground water conservation has apparently lessened during the past three years of above-normal precipitation.

Hydrologic conditions differ considerably throughout the state: the west is semi-arid, the east sub-humid; the average annual recharge varies from less than one inch in some regions to as much as several inches in others; water levels are rising due to surface water storage and spreading in some areas, while in other areas the threat of a declining water table exists; and, ground water reservoir conditions differ greatly. The variability of these hydrologic conditions has made it difficult to establish a state policy on ground water which is acceptable to a majority of the water users.

No critical ground water shortage has developed in the state as yet. Local areas have been over-developed by cities and villages but they have generally been able to alleviate their problems by well spacing. Over-development of ground water has taken place in parts of the Platte Valley where a concentration of 200 to 300 irrigation wells per township (36 square miles) is common. Although the water table has declined only a few feet the competition for water diminishes the discharge of wells during the irrigation season. Some irrigators have adjusted irrigation practices accordingly while others have deepened their wells or drilled additional ones. A similar situation exists in the south central plains area where well concentrations vary from 20 to more than 100 wells per township. Competition for water during the season is not a serious problem in this area but water levels have lowered two to five feet below their median level. Much of the development has been in the past ten years; a prolonged dry period would result in a considerable lowering of the water table. At least one small area in western Nebraska with a high concentration of wells is apparently mining water. Limited recharge, low permeabilities of water-bearing formations, and no surface water surplus may offer like areas no alternative.

Much concern has been expressed in the state for the problem of over-irrigation. Some irrigators allow water to run to waste and some obtain only a fraction of the yield per unit of water that others do. A form of waste is the questionable practice of irrigating certain crops and some marginal lands. Other irrigation practices subject to question because of waste or poor distribution are losses of water through evapo-transpiration in open ditches and in sprinkler systems while another is the practice of fall irrigation.

The conflicts in ground water use in Nebraska are similar to those of other regions. Shallow domestic wells have gone dry and artesian supply has been diminished in some pump irrigation areas. Threats to municipal and industrial supplies exist from well irrigation but have not yet developed.

Irrigation wells pump water which otherwise might move to a stream where water rights exist. The consumptive use of both surface and ground water tend to reduce stream flow conflicting with its use for industry, sewage dilution, recreation and wild life. Consumptive use of water conflicts sharply with non-consumptive use when the supply is limited. Similarly, conflicts may develop between users of ground water where certain uses employ more people and return more dollars per unit-amount of water used. Future demand may require the state to re-evaluate the policy of the preference of agricultural use over manufacturing and industrial use.

Pump irrigation has been of great benefit to the state. It also means a lot to the owners of the 23,360 irrigation wells who, if we assume have each made an average investment of $7,500 in irrigation, have invested a total of $175,000,000. The overall economy of the state has been given a big boost and has become more stable through the use of our ground water resources. A great resource is of no benefit to anyone unless it is used. We have taken the first steps in conservation of ground water: it is being put to beneficial use; much basic data has been collected through 30 years of study; the state has recognized the need for its wise use and conservation; and we have a generally well informed public who has demonstrated its interest in conservation of resources by its actions in soil conservation work and watershed development programs.

Many of our problems in the conservation and wise use of ground water can be answered by research, the collection and evaluation of basic data, and education. A number of county or district organizations composed of pump irrigators have formed. These groups organized for the purpose of improving pumping and irrigation efficiency and are carrying on observation well measuring programs in much greater detail than we can do in the State-Federal program.

We are making real progress toward coordinating use of ground and surface water. The more stable surface irrigation projects are those where wells are pumped for supplemental water and in turn the same areas are the ones in which we have the healthiest ground water conditions. Storage from the Sutherland project supplies water to 100,000 acres below North Platte; the Tri-County project which stores water in Kingsley Reservoir near Ogallala serves about 116,000 acres in Gosper, Phelps and Kearney counties. Considerable amounts of ground water are pumped in both areas but the water levels have risen, in the case of the Tri-County area, from a few feet to as much as 100 feet. The artificial recharge has been by accident rather than design. The Mid-State Reclamation District has developed a multi-purpose plan in the Platte River Valley east of Grand Island which proposes to irrigate 146,000 acres of land and does plan to provide recharge water to approximately 200,000 acres which are now irrigated from wells. The extensive ground water reservoirs offer excellent possibilities for the storage of surplus surface water in an evaporation-free environment.

Surface water will provide water to irrigate an additional 1,528,000 acres if present Missouri Basin plans for Nebraska are carried to fulfillment. We need to utilize all our water resources, whether surface or ground water, in a plan of water management. Much basic data needs to

be collected and evaluated and problems of policy established before such a plan of water management will materialize.

The state policy on ground water and legislative control may follow that already established for surface water. Present legislation and the views expressed by water users to legislative study committees suggest, however, that the variability of climate and other hydrologic conditions in the state may initially call for somewhat differing policies and controls in various parts of the state.

REPORT TO GROUNDWATER SECTION OF WESTERN RESOURCES CONFERENCE
BOULDER, COLORADO
August 24-25, 1960
BY
VICTOR E. ZIEGLER, INVESTIGATION ENGINEER
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
BISMARCK, NORTH DAKOTA

North Dakota's groundwater program is a cooperative venture being carried on jointly by the Groundwater Branch of the U.S. Geological Survey and the State Water Commission. This program was initiated in 1945 and the work is being done with the financial cooperation of these two agencies on a 50-50 basis. The State Geologist acts as a technical advisor and assists the Commission in the general supervision of the program.

The ultimate aim of the program is to obtain an over-all knowledge of the groundwater resources in the entire state which would be adequate for effectively directing the optimum development of this resource for domestic, municipal, industrial and irrigation purposes and also for effectively programming conservation and administrative measures which may be necessary or desirable in connection with its development and practical use.

The general plan has been to conduct these groundwater studies on a large scale and the county has been selected as the logical basis since it is a fair-sized political subdivision which can participate financially to the costs of this program. In such cases the county allocates and contributes funds to the state and it in turn is used to match funds available through the U.S. Geological Survey; however, there has been, and currently is, a great need for adequate and perennial groundwater supplies for numerous communities throughout the state which are attempting to construct public water supply and sewage facilities for the first time or which are experiencing shortages under present facilities and are forced to find added supplies. Therefore, about 50% of our investigational work has been directed toward securing data on the groundwater sources that would be within the reach of these communities.

During the past fifteen years, investigations have been completed or are under study in 47 areas of our state. Reports have been completed on 27 of these areas. This comprises a total area of approximately 12,400 square miles or nearly one-sixth of the area of our state.

To date, drilling has been completed on two county-wide studies and field work is in progress in two additional counties. The rest of the areas studied vary from one to four townships in size near municipalities in need of water supplied.

Up to July 1, 1960, more than 1760 test holes had been drilled and these holes represent a total of approximately 233,000 feet of drilling. The reports of these studies are available free of charge to anyone interested in obtaining this data from any of the cooperating agencies.

The administration of our program is a joint responsibility. The U.S. Geological Survey provides the technical personnel to complete the well inventories, interpretation of drill log data, basic research on the surface geology and compiles this data into report form. The State Water Commission provides the drilling equipment and assumes the costs involved in the test drilling required in the field to

locate the subsurface geology and potential aquifers. The State Engineer, State Geologist and the District Geologist of the U.S. Geological Survey meet periodically to map out the areas in which we plan a test drilling program. This cooperative enterprise has worked very successfully and we feel that this type of program best serves our needs.

In addition to this cooperative program, the investigation division of the State Water Commission is currently starting a research project into developing some of the potential groundwater areas for irrigation. This is accomplished by drilling a production test well in a potential area to determine the optimum yield of an aquifer in an area. The resulting well also serves as a visible demonstration of the capabilities of a well as a water source making promotion of a project a more simplified task. The work is accomplished with a state owned rig capable of drilling a large diameter hole. Our current research program also presented a problem of water quality which is suitable for irrigation. As a result, research in cooperation with the North Dakota Agricultural College Experiment Station in an effort to find out the effects that various water qualities have on the different soils is being conducted. Some experiences in our state have proven that the present standards which delineate the suitability of water for irrigation are extremely conservative and we feel that if more is known about this condition many projects which now are considered unsuitable can be developed and would have no damaging effect on the soil to which the questionable water is applied.

During the Pleistocene Age, when the Master Engineer decided to make adjustments in His original construction pattern, He put into use a gigantic buldozer known as the glacial ice cap. With this dozer, a great dam known as the Max moraine was constructed. The dam shut off the Missouri River escape route into Hudson Bay and forced it to excavate a new channel to the south as we know it exists today. It is possible that the Master Engineer may have purposely left a leak in His dam and if so the potential for adequate groundwater resources for irrigation, municipal and industrial uses will be great. To date, no definite data on the quality and quantity of this potential is known. We believe that this giant bulldozer may have filled the ancient channel of the Missouri, the Yellowstone and the Little Missouri with sand, gravel and rock. If seepage occurs from these streams, it is possible that water is feeding down the original channel to the Hudson Bay. Artesian wells which are difficult to control have been encountered at shallow depths by seismograph crews working in what we believe is the original channel area. This old channel has been known for many years, but no detailed study has been made to define the shape, depth and exact location. The State Water Commission has recently been authorized to study this area and determine the potential of this source of supply. I am happy to report that this study is now underway and will cover three counties in the northwestern corner of our state. The results of this study will not be known for several years since the original channel has been completely obliterated by the ice cap and much detailed drilling will be required to determine the confines of the original river bed.

Section 61-0101, 1957 Supplement to the North Dakota Revised Code of 1943 is the law which defines the waters which belong under the jurisdiction of our state. All groundwater users, except wells that are used for domestic purposes, are required to obtain a water right in order to protect the use of this water. North Dakota recognizes the Riparian Doctrine of water use for stock watering and garden purposes. Otherwise our water laws follow the Doctrine of Prior Appropriation, similar to the other seventeen western states.

Groundwater was placed under the jurisdiction of our water laws by legislative enactment in 1955 for the purpose of controlling the amount of water pumped from our aquifers. This affords the State Water Commission with a means of protecting the riparian owners' rights and can also be used as a control to prevent the mining of groundwater. An example of this is in the southwestern area of North Dakota where the Fox Hills aquifer is depleting as the water table is constantly lowering. If there were no control, it is conceivable that uraniferous lignite developments could employ well fields for their use and thus endanger the water supply for the cities of Bowman and Hettinger, whose wells tap this aquifer. A most recent example is the case of a large oil company requesting the right to use groundwater from surface aquifers in the northwest corner of our state for injection underground to approximately 10,000 feet in the unitization of an oil field in an effort to force more oil out of a pay zone. Excessive pumping by the oil industry could ruin the supplies of several small towns and leave them without any water. This law has given the state an opportunity to protect these riparian owners. The water right was granted with the stipulation that pumping would be stopped if it were found that the water table was being lowered indicating that the aquifer tapped was being mined.

To date the problems concerning groundwater have been few. This is due to the fact that we have not as yet experienced extensive development of any groundwater aquifers for irrigation or industrial development. A tremendous interest is currently being shown by farmers in using well fields to develop sufficient irrigation areas to guarantee them a stabilized feed supply for their basic ranching operations. This is evidenced by the fact that we have investigated two small irrigation projects along the Yellowstone River and in both cases have been successful in obtaining a suitable water supply for these irrigation districts. Construction on these projects is underway and more requests for aid from adjacent areas are being received. I personally believe that we are on the brink of seeing tremendous strides made in the development of our groundwater resources. We are here today to gain valuable information from the experiences of others so we can be prepared to meet any situation that may arise on the groundwater development program.

Our current planning is to formulate and adopt a set of minimum standards for irrigation well construction and legislation giving us some control over the drillers operating in the state so we can observe their operations and protect the farmers from the "fly-by-night" operators prominently found in the drilling industry.

GROUND WATER LEGISLATION AND ADMINISTRATION IN OREGON*

By Jack E. Sceva, Ground Water Geologist

Oregon State Engineer

Since the first settlers started moving into what is now Oregon, the doctrine that the first in time is first in right has been the practice in the use of water. This doctrine was spelled out in our statutes when our surface water code was enacted in 1909. This act which has been pretty thoroughly tested in our courts, stated that "all water within the State from all sources of supply belongs to the public" and that the only way a water right could be established subsequent to the effective date of this legislation, was by making an application to the State Engineer, the approval of the application by the issuance of a permit and the beneficial use of water within the time limits set forth in the permit.

This act also provided for the adjudication of vested rights, the rights established by the beneficial use of water prior to the effective date of this act. In the adjudication, the State Engineer does most of the work, he sends the notices, files the claims, hears the exceptions and eventually prepares his findings and submits them to the court. These findings which are incorporated in a court decree become the final determination of the vested rights of the stream being adjudicated.

In 1927, Oregon passed its first ground water act. This act was very similar to the surface water act in the procedure for establishing ground water rights. This act, which was effective in only the dryer eastern part of the State, failed to provide for the adjudication of the vested ground water rights.

With the increasing use of ground water throughout the entire State, our 1955 Legislature, after a careful study by an interim committee, passed the Ground Water Act of 1955. This act, which is effective throughout the State includes the policy declaration that "Beneficial use without waste, within the capacity of the available sources, be the basis, measure and extent of the right to appropriate ground water". The appropriation and use of ground water for stock, domestic or group domestic uses in amounts less than 15,000 gallons per day, and small commercial or industrial uses were exempted from the provisions of filing for water rights.

It was realized from the experience we have had with surface water adjudications that it would be many years before some of our ground water reservoirs would be adjudicated, so our Legislature provided for the registering of the wells constructed prior to the effective date of the 1955 act. These well registrations or claims will be used as evidence for establishing priority dates and beneficial use in future adjudications.

The adjudication of the ground water reservoirs in Oregon will be considerably more than a determination of the vested rights. Our statutes require that the adjudication also include a description of the boundaries and depth of each ground water reservoir, the lowest permissible water level that will be allowed, the characteristics of the ground water supply, the

serviceable methods of withdrawal of ground water from each reservoir, and rules for controlling the use of ground water. Once an adjudication has been completed it will be a matter of regulation of withdrawal on the basis of priority and the spacing of new wells to maintain the water table at or above the lowest permissible position. In some extensive ground water reservoirs however, the regulation of withdrawals on the basis of priority of all the water rights on the ground water reservoir will not be a feasible method of maintaining the water table. It is probable that if this problem occurs, a part of the ground water reservoir would be determined as being a "critical ground water area" and ground water withdrawals within the critical area would be regulated on the basis of priority.

Once a ground water area has been determined as being "critical", the State Engineer has considerable authority to regulate and control withdrawals and prescribe corrective control provisions. To date there have been two critical ground water areas determined in Oregon on the basis of declining water levels. The corrective contral provisions ordered for these areas include the closing of the areas from further appropriation except for stock and domestic purposes, the rejection of some pending applications for new developments, and in one case the restriction of withdrawals to wells operating on a priority of 1932 or earlier. The watermasters have also been ordered to stop all unlawful appropriations and regulate withdrawals to the limit of the duty of water that is set forth in the water rights. To aid in the regulation of withdrawals and in order to obtain the quantitative data in regard to ground water withdrawals, the well owners were ordered to equip their wells with control valves and totalizing water meters. Both of the orders determining "Critical Ground Water Areas" have been appealed to the courts and are before the courts at this time.

One problem that is becoming more common in Oregon is the complaint that an irrigation well has dried up an adjacent domestic well. Many of the older domestic wells are shallow small capacity wells that penetrated only a few feet below the water table. As we are operating under the policy of maximum beneficial use within the capacity of the available supply, it is physically impossible to develop a ground water reservoir without causing some lowering of the water table. It is our belief that under Oregon's Ground Water Act that the development of ground water from near the top of a ground water reservoir is a privilege and not a right that is to be protected. The lowering of the water table only a matter of a few feet may in some places make a suction type pump inoperatave and necessitate the installation of a deep well pump. We also believe that the method of diversion is a privilege and not a right that is to be protected. The question that is often raised is "What is and what value is a ground water right?" We believe that under Oregon's Ground Water Act, the owners of water rights have the right to appropriate the public waters of the State for the purpose and to the extent given in their rights to long as appropriations are within the capacity of the available supply. The priority of a water right is the basis for protecting and regulating appropriations when they have exceeded the capacity of the reservoir. The available supply of each ground water reservoir will be determined in the adjudication by the lowest permissible water level allowed, or it may be determined in a critical ground water area determination. Until such time as these determinations have been made, the State Engineer would have no authority to stop the operation of an authorized well except to prevent waste or unlawful use. When an ample ground water supply is available a ground water right may

appear to be of little value; however, should the supply become short, the existence and priority of a water right will determine whether a well will be allowed to operate.

The problem of interference between ground water rights and prior surface water rights is not clearly set forth in our statutes. The State Engineer may reject a ground water application when it appears that the development will impair or substantially interfere with an existing surface water right. In practice, wells that are in proximity to springs or other bodies of surface water, and it is found that there is an almost immediate and substantial interference with existing rights to surface water, the wells are regulated in accordance with other appropriations along the stream.

In many places individuals with surface water rights have been making application for permits to appropriate ground water to supplement their surface water supply. In some places, especially in the Willamette River Valley of Western Oregon where most of the irrigation is by sprinklers, a number of individuals have abandoned their surface water appropriations and have turned to ground water as a source of supply. In some instances, the farm operators have found that the use of ground water was much more convenient as it eliminated the maintenance of pumping plants along the stream and long pipe lines leading from the stream to the place of use. As time goes on we expect to see many more farm operators tuen to ground water for their water supplies, especially along streams where short summer supplies have or will develop.

Beneficial use of water is an important part of a water right. The question as to what constitutes "beneficial use" and what constitutes "waste" is sometimes very difficult to determine. For example, there is an area in Southern Oregon where "hot water" or high temperature ground water is developed for heating purposes. As the water is somewhat mineralized, heat exchangers are used to withdraw the heat from the water which is then discharged to the storm sewer system. In some instances, the heat exchange units are relatively efficient, while in others a much larger quantity of water is required to obtain the same amount of heat. The efficiency of water use should be a criterion for determining what is beneficial use and what is waste. To date the efficiency of water use has not been important in the administration of our water laws; however, in areas where short supplies develop, the efficiency of water use will play a more important role in determining beneficial use.

The continued beneficial use of water is necessary to maintain a water right in Oregon. Whenever the owner of a water right fails to use the water for a period of five successive years, the right to the use shall cease and it shall be conclusively presumed to be an abandonment of the water right. This abandonment provision has raised some question as to the status of water rights on lands taken out of production under the U.S. Soil Bank program. This question will probably ultimately be decided by our courts.

Factors other than quantity of the ground water supply also come under the control of the State Engineer. Problems of ground water pollution can be grounds for creating a critical ground water area. A New problem that

is developing in the Portland metropolitan area concerns the temperature of ground water. In this area, many of the newer office buildings are being air conditioned with ground water. Restrictions and sewer rates for the disposal of waste water into the Portland sewer system has resulted in the construction of a number of injection wells for the disposal of waste water.' During the summer months when water is being used for cooling warm water is being injected into the ground. Some systems that are designed for the use of water of a certain temperature may become inefficient or inoperative when there is a marked change in the ground water temperature. Whether the temperature of ground water is a natural quality of the water that should be protected is being studied at this time.

To date, serious problems of water level decline or ground water mining have not developed in Oregon. Problems of water level decline have been confined to small areas of concentrated pumping. The development of our ground water resources is just in its beginning stages. There are less than 6,000 irrigation wells in the entire state, and a much smaller number of industrial and municipal wells. It is our belief that Oregon's Ground Water Act has the necessary control provisions and has been enacted at an early enough stage in the development of our ground water resources so as to be effective in the prevention of serious ground water problems.

* Presented at the Ground Water Section, Western Resources Conference Boulder, Colorado, August 24-25, 1960

COMMENTS ON PAPERS PRESENTED AT THE GROUND WATER SECTION OF THE WESTERN RESOURCES CONFERENCE, AUGUST 24 and 25, 1960

BY
MORTON W. BITTINGER
COLORADO STATE UNIVERSITY

It is impossible to adequately summarize the many excellent papers presented at this conference. However, a few words can be said about the major points of agreement and disagreement which have been presented during the meeting. The points of agreement are clear cut and were mentioned by many of the speakers. The physical aspects of ground water development and management in which there is general accord, include the following:

1. That legislation should recognize ground water as part of the hydrologic cycle and part of the total water supply of each area.

2. That the optimum use of the total water resources in a basin will result only when operation and management of the ground water reservoirs are coordinated with surface water use.

In other words, man-made laws must recognize and be compatible with the laws of nature. Legislation which does not recognize these facts will be difficult to administrate or will not serve the public purpose to the greatest advantage. The biggest problem for Colorado seems to be in getting a satisfactory marriage between the physical facts, which cannot be changed, and the existing legal, economic, social, and other institutional situations which resist change.

Another point brought out by many speakers is the great need for a wiser and better use of the water we withdraw from our ground water reservoirs. I believe we will all agree that we have a long way to go in this field and that it is a very important part of the proper management of our overall water resources.

Many speakers have recognized that there is no alternative but to deplete certain ground water reservoirs which have a very low recharge potential. However, the question of the proper length of life of the reservoir and the type of control needed to assure that the supply will last sufficiently long become points of dissension.

A basic question which Colorado must answer in the High Plains of the state where development is young, but depletion inevitable, is: should exploitation be allowed to progress with no control, or should this reservoir of ground water be held in reserve for future periods of greater need or national emergency? Colorado can still make this decision, whereas many other parts of the High Plains cannot. They are past the turning-back stage.

In closing, I feel that it is necessary to bring up a point which has been touched upon but not amplified to any extent. This is the need for the scientists and technical people, who must develop and set forth the plans for management of our ground water resources, to keep the public fully informed and to create confidence in their ability to do this planning wisely and scientifically. The use of ground water predates recorded history, and legends, superstitions and mysteries surround the use of ground water. Scientists must sweep away this mystery before the confidence of the average ground water user is obtained. Many of us have been guilty of not keeping the public informed of the capability of the ground water scientists to scientifically manage our ground water reservoirs.

COMMENTS ON THE GROUND WATER SECTION OF THE WESTERN RESOURCES CONFERENCE, UNIVERSITY OF COLORADO, AUGUST 25, 1960, BY ROBERT EMMET CLARK, PROFESSOR, SCHOOL OF LAW, UNIVERSITY OF NEW MEXICO, ALBUQUERQUE, NEW MEXICO

Thank you, Mr. Miller. I'm afraid that this very loyal group might be frightened a little. However, I am not going to summarize all of the laws mentioned. After the confusion you have listened to I am sure you don't want me to try. It is impossible, obviously, to try to summarize and evaluate all of these papers given in two days and try to do it in a few minutes. However, I do think there are several important things that should be said by way of emphasis. In the same way as Mr. Bittinger emphasized what has been said, I am sure that there are some other things that should be said by way of dispelling confusion, particularly about the law.

Now, I want to say, Mr. Miller, as a law professor and a person who has been involved in these problems, that I feel that this conference has been most rewarding to me as a person interested in the subject. And I say this for two reasons--one is personal and because I am a teacher. But I would like to say it for the third reason, which I think might express the feelings of others in this room. This represents, in my judgment, a very successful venture in getting persons from different areas of knowledge to talk to each other somewhat intelligently. I recognize that I may be mistaken about this when we talk about the law. This conference represents a great advance. I think that this conference proves that economists don't all sound like theologians, and that engineers and lawyers, who are more concerned with empirical facts rather than concepts, can communicate with each other. It has proved very rewarding for me, and I think some other lawyers in the room, to listen to these gentlemen from the other disciplines. I have two real regrets which I must express, Mr. Miller. I think some of the others here feel these. One is that some of these papers were not heard by the whole conference. Secondly, I am very sorry that I don't see or have not been able to find, after diligent search, any representative of the state of Montana here. The state of Montana is planning to have a conference beginning the 13th of September which is dedicated to the same purpose for which this conference was dedicated, I believe. And I am going to take all of the information that I can carry from this conference up there and make it available to the people in Montana who have a great problem and also a great opportunity because theirs is the last state in which there can be a "marriage of the different approaches," to use Mr. Bittinger's phrase. The scientific information and the technological know-how can be used and the institutional lag can be

brought up to date. Montana is the last state to have this opportunity, if I can except Colorado from this momentarily. I am mindful that the purpose of this conference was to try to educate the people of Colorado specifically, and all of us generally, and I think the emphasis here was on three things, the last of which I will discuss.

One emphasis was on the physical conditions and technological skills and opportunities. We had a number of excellent papers about these.

Second is the area of existing economic conditions and economic goals and economic and social consequences.

Third is the institutional factor that makes the use of technological information and scientific attitudes available and useful to us. Here I include, of course, the field of the law. Now I think that the thing that I got out of this whole discussion for two days dealt with this topic, if I can put it all in one sentence: Some kind of integrated or correlated management of all water supplies under some kind of system of rational public control. I would say that this was the theme of this discussion for two days. I think that Mr. Conover's statement at the outset emphasized this. It was interesting to me to observe the number of people who emphasized the law all the way through, until finally the gentleman from North Dakota thought he had prepared a paper in the wrong field, although he actually presented an excellent one on controls in North Dakota. The discussion of the legal problems is not a prerogative of lawyers. It was interesting to me to hear other people's concern about these institutional frameworks within which we must operate. I am reminded here of a story that is attributed to our State Engineer, whose assistant is here in the room. He says that it is well known among lawyers and maybe among engineers that water rights litigation has made poor lawyers out of some good engineers and some bad engineers out of excellent lawyers.

The emphasis on public control in this conference I think was stated both by Judge Dent in the area of Texas which remains unique in its property rights and by Mr. Broadhurst, the Chief Engineer for the High Plains District. They disagreed on the amount and the area of public control, but they were certainly both talking about the necessity for some kind of public control, whether self-controlled or imposed by a group in a small area.

I want to try to say a little bit about "rights" because I'm afraid of the mis-use of the term. I worried about this yesterday. Lawyers use the phrase "vested rights" the way some of you may use the phrase "national

pride." And it is not always clear what is being said. What has happened in Texas, and what has been the law in Texas, and what has happened in Kansas offer examples to compare. They present an opportunity to see very clearly, as we should, the difference in an attitude toward this phrase, this word "vested rights" in giving it an empirical reference. In Texas, a vested right in percolating ground water exists in a vacuum, so to speak. It is not measured by the amount you use. As Judge Dent told you, it is limited only by waste or by some kind of pollution or negligent use of it. Now in Texas the recognition of a need for some limitation under the police power of the state is recognized under the good legislation under which the High Plains District was organized. This legislation was permitted by the Constitution of Texas which says that resources can be taken care of in a certain way as the legislature provides. The legislature has authorized three districts. In those districts this absolute right, which can exist only theologically speaking, if I may use that phrase, can be limited in terms of what the people want in that district. Now we'll set that definition aside for a moment, and look at Kansas. The Kansas legislation says, and it was upheld by the Kansas Supreme Court, a vested right only exists in the amount you use. That means actual beneficial use or water that is put to use by a specific date. The Kansas court said, "We don't recognize any property rights in unused water." The argument that water in the ground is like uranium in the ground is fallacious, and I don't have to tell you scientists or engineers how fallacious it is. It is not the same water that's there all the time for many centuries. What I want to emphasize is that this constitutional problem is enlarged and embellished and distorted beyond the understanding of intelligent people like those attending this conference. The idea of "vested rights" does not mean some kind of a philosophical concept only. It has a specific kind of reference. That's been the stumbling block in much of this legislation.

One of the other problems of legislation, and I was glad that Mr. Kelly got to talk about it because he laid the groundwork for this criticism, and I wish that he were here to hear it, is the distinction between non-tributary and tributary ground water in Colorado. This is a two-edged sword in Colorado. I live down stream from Colorado, and we know about both edges of that sword just the same as Texas knows about New Mexico's law. Colorado is the only western state that has a legal presumption that all water not shown to be non-tributary is tributary to a stream. The other side of that sword is this: It presents a great opportunity for Colorado to integrate rationally some kind of administration of both surface and ground water. Now with respect to non-tributary waters, I am told

that until we have more hydrological data and until we have more precise knowledge which we should gain by research and by legislation that compels data collection, it is going to be very difficult to separate all these waters into different kinds. One of the glories of the appropriation system--and I'm not saying this personally--one of the utilitarian aspects of it is that it lends itself to a system of unified control in the western states. You all must know that until about twenty years ago most of the courts in the west were still talking about appropriation of surface flow and appropriation of underground streams, but they were also talking about the English landowners' rule of unlimited use with respect to percolating waters. There are only two states left in that category. One is the state of Texas, and we just talked about the modification which they themselves made since 1949, and the other state only by way of dictum in a case is the state of Montana. New Mexico--and I'm not here to brag about New Mexico--I'm simply saying that New Mexico long since arrived at the conclusion that the appropriation system, at least the vocabulary of the system, could be used to manage some kind of a unified system. Here, I think the people interested in legislation have to look to see the two choices open with respect to legislative changes. You can have loose controls to cover the whole state that aren't very good, or you can have specific controls set up in a legislative framework that covers specific areas where data is available and where knowledge of its physical conditions exist. It seems to me that this is the choice for the Colorado legislature. The doctrine of reasonable use is a wonderful phrase--it sounds reasonable --but what kind of real reference does "reasonable use" have? When it gets down to application, sometimes it refers to the fellow who gets to the ditch first. Reasonable use has to be defined in terms that can be administered by the water masters, by engineers, by people who are going to deal with the physical facts. So I would say here that any kind of good legislation has to recognize not just those institutional factors, but must have available scientific and technological data and all those other sources of information that we acquire over a period of time through study and research.

I would say that although I am not optimistic by nature, I feel that if this many people can get the benefit from two days of discussion in as many different fields of learning and understanding as have been gathered here, there is considerable hope for some kind of rational development in the field of unified control of all water resources.

Thank you very much.

South Dakota Ground Water Administration

by
J. W. Grimes, Chief Engineer
South Dakota Water Resources Commission

South Dakota has statutory law covering the development and use of ground water. Acquisition and regulation of water rights in ground water have the same basis as those for surface water, namely the appropriative principles of beneficial use as the measure of the continuing validity of the right and priority in time being the better right. Except for "domestic use" (ordinary household use, stockwatering and not to exceed one-half acre of irrigation), application for a permit to appropriate water, published intent to develop and use ground water, perfection of the permit by inspection of the constructed works and beneficial use of water, constitute the water right acquisition procedures.

Court case history predates the effective date of the statute (July 1, 1955). This history is meager but decisions rest upon the principles of the riparian doctrine in common law. During the past five years, the provisions of statutory law have been widely accepted in the State but, since the courts have not had a case by which the statutory provisions may be interpreted, acquisition of water rights and regulation of water use may be questionable.

Under provisions of statutory law, administration of water rests with a seven-member lay Commission and an executive staff. Statutory provisions and regulatory policies limit total annual water withdrawals to the average annual recharge. Technical control of withdrawn quantities is based upon characteristics of the aquifer and water remaining in place. Control data is obtained from a series of strategically located and logged observation wells. Both water levels and changes in hydraulic gradients compared to historical records constitute the basis for technical evaluation of aquifer conditions and the availability of unappropriated water. This is cross-checked against data collected from users as to the annual amounts of water used and against records furnished by well drillers under provisions of well driller licensing provisions of the ground water code. The latter check has been found to be unreliable, due primarily to negligence of the well drillers and inconsistancies of descriptive data furnished by the well drillers.

These methods of technical control seem to fit South Dakota ground water supply conditions. Physical occurance of ground water supplies in the State may be divided into three major sub-divisions: (1) Deep artesian ground waters underlying the entire area with few exceptions and (2) shallow ground waters (usually 200 feet or less in depth) which occupy glacial melt water channels in eastern South Dakota and which may or may not have artesian head and (3) alluvial ground waters

occupying the geologically recent sands and gravels of present stream valleys.

Conditions described as (2) and (3) intermingle in some cases. There is no practical interchange of waters occurring under conditions described as (1) and those under (2) and (3).

Depending upon location, from 40 to 7 separate deep artesian aquifers exist. The uppermost two have been widely tapped for rural household, stockwater, municipal and industrial water supplies. Prior to 1920, artesian heads had been reduced, ranging in amount from little to 250 feet of loss. Since 1920, new equilibrium conditions have been reached and additional losses of artesian heads have not been serious nor have they been wide-spread. During recent years, deeper horizons have been tapped, especially since the advent of the federal Great Plains Conservation program of financial assistance to ranchers for stock water supplies. Heads encountered may be 250 pounds per square inch or more at ground surface with quantities of water ranging to 250 gallons per minute from 20 inch diameter wells. These higher heads require careful drilling techniques to avoid uncontrollable well holes, the control of which is covered by general regulatory artesian well construction specifications issued by the Water Resources Commission under authorities contained in the ground water statute. The larger quantities of flow from these artesian wells result in difficulties of administration aimed at restricting the amount of water withdrawn to the amount needed. Development of the deep artesian water supplies require appropriative water rights if the water is to be used for other than "domestic purposes."

The chemical quality of the deep artesian ground waters varies widely among the separate aquifers but is universally brackish except in the near vicinity of the Black Hills in extreme western South Dakota. Total dissolved salts range from 1800-1900 parts per million in the upper aquifers to perhaps 3000 parts per million in lower horizons. Generally speaking the deeper the water source the higher the quantity of dissolved salts. In some areas, chemical constituents produce adverse physical characteristics with long-time human use and the stranger must be careful with use considering short-term effects which may or may not be harmful depending upon his physical needs at the time. Irrigation use of these deep artesian waters have been attempted but the quality makes them unfit for such use. These deep supplies have been tapped for maintenance of recreational and wildlife lakes. Because of questionable benefit and because of the adverse effects of such large withdrawals upon surronding domestic water supplies from the same source, water rights to develop these supplies for lake level maintenance purposes are usually refused.

The shallow glacial melt water channel ground waters (defined under (2) above) are usually fresh qualitatively, produce copious quantities per well and are now widely used for irrigation and other beneficial purposes. Total quantities are limited, however, and some of the areas have reached or are approaching optimum development. In these areas controls on use and development are tightly administered. As mentioned above, no decision of the Water Resources Commission under provisions of the statute have been appealed to the courts by a water user or by a water right applicant despite the statutory limitation of what may be termed a restriction of his common law rights.

Except where alluvial sands and gravels intermingle with glacial melt water channel aquifers, water supplies defined as (3) above produce small quantities of water only. Primary use is for "domestic purposes" and as such are not subject to appropriative water right acquisitions under statutory provisions. Also, the naturally limited small quantity capability produces but few administrative problems concerning wasteful diversions or methods of diversion.

In summary, the appropriative water right acquisition and regulation of ground water development and use under provisions of statutory water law is working in South Dakota. The statutory limitations have not been tested in the courts. Consequently, the success of statutory provisions and technical methods of control must be qualified until such time as they meet court case tests.

STATE OF IDAHO
DEPARTMENT OF RECLAMATION
GEO. N. CARTER, STATE RECLAMATION ENGINEER
BOISE

ROBERT E. SMYLIE
Governor

August 17, 1960

Mr. David J. Miller
c/o Ground Water Section
Western Resources Conference
Coronado Building
Greeley, Colorado

Dear Mr. Miller:

I appreciate your kind letter of July 19, 1960 regarding the program for the Ground Water Section of the Western Resources Conference and especially the invitation to participate in the conference and present a summary of Idaho's ground water legislation and experience with it.

Inasmuch as there is little to add to the letter I wrote you March 30, 1960 on this subject I fear any presentation I could make would be nothing more than a recitation of the Ground Water Statutes of Idaho, of which you have copies, and stating the fact that further than processing the many applications for permit through the statutory procedure leading to a water license, there have not been any new developments.

However they are certainly coming.

By far the greatest increase in irrigation in Idaho since 1945 has been with a ground water source of supply. As near as is known about 500,000 acres of irrigated land in Idaho now obtain a water supply from wells. Since October 1, 1959 water right applications have been filed with this department for 140,000 acres of desert lands. Not all of these will mature into licensed rights; what percentage will is problematical, but the zeal to irrigate new land from a subterranean source of water supply seems to know no bounds.

So I see looming in the future, how soon I do not know, a grand scramble to determine priorities when these ground water reservoirs are seriously over pumped. Or else Idaho will follow in the steps of California or Arizona and pump and pump until there is no water resource left for any body. The only reason this has not yet occurred is the fact that ground water supplies in Idaho are so abundant; but certainly they are not inexhaustible as so many operators believe.

By Idaho law the courts have original jurisdiction in the matter of determining water rights and their priorities, both surface and subterranean sources. The ground water statutes declare that the right to the use of ground water may be acquired only by appropriation. Such appropriation may be perfected by means of diversion and beneficial use or by the permit law. Thus far a general adjudication action seeking to fix amounts

and relative priorities and/or the safe annual pumpage of an underground supply has not been brought. Until such a suit is filed, decree entered and taken up to the Supreme Court for comfirmation or otherwise, the strength of Idaho's ground water law may be uncertain.

Intricate questions relating to ground water claims are arising all over the state. They are diverse in nature.

One angle is simple interference of one well with another. Some of these cases are settled by invoking the machinery of a local "ground water board" provided by statute. The scope of these cases is limited and settles nothing so far as the regimen of a ground water basin is involved. Other cases are settled by arbitration under the general arbitration laws of the state. Likewise the scope and finding in these cases is only local.

Then there are the large ground water basins where pumping is being done generally over many square miles or even townships all within one watershed or stream system. While well interference or basin ground water depletion may not to date have become a problem yet there is strong presumption, I believe, that ground water extraction in the upper reaches of a watershed is depleting the surface flow of the stream. Something maintains the surface flow of a stream especially in the latter part of a water year when snow melt and spring rains have ceased to flow visibly to the stream. It is invisible inflow , and taking this out with pumps robs surface rights which heretofore had a late season irrigation supply.

One other violation of sensible preservation of ground water supplies is allowing artesian wells to run to waste 6 months of the year. This happens in Idaho. There is one notable artesian basin in Idaho which has been investigated some what thoroughly by this office. Thereafter the matter of the state ordering capping of the wells was put up to the Attorney General. His interpretation of the law was:

"Section 42-1603 requires that every person coming under the provisions of Section 42-1602 shall apply to your Department for approval of any mechanical device for controlling the flow, and shall change, alter or install only such equipment as shall be approved.

Section 42-1605 makes it a misdemeanor for any person to violate any of the provisions of that chapter, in other words, the Act of 1921.

It is plainly the duty of the prosecuting attorney of a county in which such violation occurs to proceed under Section 42-1605. Whether your Department is authorized to proceed by a civil action to abate any common nuisance defined as above pointed out, is another question. I doubt very much that such authority exists, for the following reasons:

To begin with, why did the Legislature of that year use the

word "common", rather than refer such a situation to the already long existing law concerning public nuisances? While many courts have held under different facts and statutes that "common nuisance" and "public nuisance" meant the same, I have found no case which dealt with factual conditions, or a special law, such as exist here. Inasmuch as this is a criminal law, it would seem probable that it must be strictly construed. Since it nowhere even suggests civil action for abatement, I am inclined to think that to read that into the 1921 Act would probably violate the rule of construction just now stated".

And then the reluctance or dilatory action of the county attorney stymies us.

You asked for a summary of Idaho's ground water legislation together with its actual administration and experience with it. I have described in the foregoing to what extent the legislation has been administered; only the part prescribing procedure for appropriating ground water. As for experience in enforcement there has been none. Probably we should have a try at it but thus far the earmarks of a warranted case have not been apparent.

If this letter and mine of March 30, 1960 are of value in summarizing ground water legislation of the western states you are at liberty to use them.

I would appreciate receiving a copy of the summary and proceedings and can pay the registration fee of $15.00 therefor.

Other meetings and hearings set for that week preclude any attendance at the conference. My best wishes for a fruitful meeting.

Sincerely yours,

Geo. N. Carter

GEO. N. CARTER
State Reclamation Engineer

GNC:mr

GROUND WATER STATUTES

Idaho Code 42-226 to 239 Inclusive

(Chapter 200 Session Laws of 1951
and
Chapter 182 Session Laws of 1953)

42-226. GROUND WATERS ARE PUBLIC WATERS. — It is hereby declared that the traditional policy of the state of Idaho, requiring the water resources of this state to be devoted to beneficial use in reasonable amounts through appropriation, is affirmed with respect to the ground water resources of this state as said term is hereinafter defined - : and, while the doctrine of "first in time is first in right" is recognized, a reasonable exercise of this right shall not block full economic development of underground water resources, but early appropriations of underground water shall be protected in the maintenance of reasonable ground water pumping levels as may be established by the state reclamation engineer as herein provided. All ground waters in this state are declared to be the property of the state, whose duty it shall be to supervise their appropriation and allotment to those diverting the same for beneficial use. All rights to the use of ground water in this state however acquired before the effective date of this act are hereby in all respects validated and confirmed.

* * * * *

42-233a. NOTICE OF APPLICATION.—Within a period of ten days after the filing of any application for permit with the state reclamation engineer, as herein provided, the state reclamation engineer in a critical ground water area, as hereinafter defined in this section, shall issue a notice of such application stating the name of the applicant, the location of the well or wells, the amount of the flow of water proposed to be used, and the description of the premises upon which the water is proposed to be used. Such notice shall also state that all persons having an interest in the critical ground water area desiring to oppose the issuance of a permit pursuant to such application, must within a period of thirty days from the first publication of such notice file in the office of the state reclamation engineer a protest to such application. A copy of the notice shall be furnished to the applicant, who shall cause the same to be published in a newspaper published in the county where the well described in said application is proposed to be located; or if no newspaper is published in such county, then in a newspaper of general circulation in such county. Publication of said notice shall be made two times, once each week for two consecutive weeks, and proof of such publication shall be furnished by the applicant to the state reclamation engineer. "Critical ground water area" means any ground water basin, or designated part thereof, not having sufficient ground water to provide a reasonably safe supply for irrigation of cultivated lands in the basin at the then current rates of withdrawal, as may be determined, from time to time, by the State Reclamation Engineer.

In the event the application for permit is made with respect to an area that has not been designated as a critical ground water area the State Reclamation Engineer shall forthwith issue a permit in accordance with the provisions of Section 42-234 without requiring compliance with the provisions of the preceding paragraph of this section or the provisions of Section 42-233b.

OKLAHOMA'S STATEMENT
GROUND WATER SECTION
WESTERN RESOURCES CONFERENCE

Boulder, Colorado
August 24, 25, 1960

Prepared by Frank Saab, Executive Director
Oklahoma Water Resources Board

The Oklahoma Ground Water Law was adopted in 1949. This Statute, we find, is a very good one that can be readily administered if sufficient technical data is available. However, we wish to make some observations regarding some refinements in the interest of the applicant or users of ground water.

In the first place, the law provides that an applicant for use of ground water has two years in which to complete his works and put the water applied for to beneficial use in the amount or volume of water applied for. This procedure results in a priority date on the amount of water put to beneficial use within a two year period. In other words, if a man applies for 200 acre-feet of water to irrigate 100 acres of land and at the end of the two year period he has only developed and irrigated 10 acres of his land, he forfeits a priority date on the other 90 acres or 180 acre-feet of water because of the two year limitation.

We all know that most applicants going into irrigation are inexperienced in irrigated agriculture. The proper procedure would be to develop small tracts of land until the irrigator has learned some of the techniques that are so important to success. We quite frequently make the statement that "It is much better to make a 10-acre mistake than a 100-acre mistake."

The law further provides that the Board shall, upon receipt of a petition signed by one-fourth or not less than 25 land owners above a ground water basin, make a hydrographic survey and the subsequent adjudication of water rights of the basin. Again, the two-year limitation applied even after the basin has been adjudicated by the Court.

In addition, after the hydrographic survey is made and water rights have been determined, the Oklahoma Water Resources Board has the authority for the spacing of wells, but no control of spacing until after the hydrographic survey and the adjudication of water rights has been completed.

We propose to offer an amendment in the next session of the Legislature to amend that section of the Statute setting up the two-year limitation on development. We shall propose that an applicant for ground water, before or after adjudication of rights, be allowed two years in which to begin construction and development of his program and an additional three years in which to complete his project. We believe our Legislature will look with favor on such legislation.

Our greatest problem in administering our Ground Water Law is that we do not have the funds available for the basic research to determine the scope or extent of our various ground water basins throughout Oklahoma. Neither do we know the safe withdrawal of those basins, nor the recharge rate.

Listed below are some comments with reference to our estimates of ground water basins in Oklahoma which are also displayed on the attached map:

Extent of Oklahoma's Ground Water Resources

Ground Water is Oklahoma's most valuable mineral resource. The amount and value of this resource has not been determined, but, according to present information, the various ground water reservoirs of the State are estimated to contain more than 300 million acre-feet of fresh water. At a conservative figure of $10 per acre-foot, the fresh water stored beneath Oklahoma has a value exceeding 3 billion dollars. It supplies 70 percent of the irrigation water used in Oklahoma and minicipal water for more than 300 towns and cities. In fact, more than half of the people in the State rely on underground sources for drinking water and household supplies.

Ground water is available over most of Oklahoma in quantities sufficient for domestic supplies, however, in some parts of the State, the water is salty or "gyppy," and is unfit for most uses, so that household water is collected in cisterns. In some areas ground water may be of better quality than surface water, and industries and commercial users frequently develop private supplies to satisfy their own needs. Where water is used for cooling, industries may prefer ground water because it is of nearly constant temperature and quality at all times.

Figure 1 shows the location of the principal ground water reservoirs of the State. The most important aquifer consists of the sands and gravels of the High Plains (1) and contains more than 100 million acre-feet of available water. It supplies most of the water requirements of the High Plains, including water to irrigate 75,000 acres. Other important aquifers that supply irrigation water in the western part of the State are the alluvial deposits along streams (2), the Whitehorse Sandstones (3), and the gypsum beds of the Dog Creek shale and Blaine formations (11). In Central Oklahoma sandstones of the Vamoosa formation (5), Garber sandstone and Wellington formation (6), and Wichita formation (7) are important sources of water for municipal and industrial purposes. Near Ada wells in limestone of the Arbuckle group (3), produce more than 2,000 gpm for municipal use. In the northeastern part of the State cities and industries tap the Roubidoux formation with wells 1,000 feet deep. Most of the streams draining the Ozark Mountains are fed by springs issuing from limestone of the Boone formation (10). Sandstones of the Trinity group (9) in the southeastern part of the State contain large quantities of ground water that is essentially undeveloped.

Oklahoma has tremendous resources of underground water. The exact

quantity is unknown, but it is estimated to be more than 40 times the amount stored in all the reservoirs and lakes of the State, and more than 8 times the average annual flow of all the streams draining the State. If spread evenly, it would cover the State to a depth of more than 7 feet. Because some of the water is held tightly in rocks, such as silt and clay, it is not all available for man's use, but a large part may be. It is constantly being replenished from the rain and snow that fall on the State. The rate of replenishment is rapid in areas underlain by limestone and other cavernous rocks, but slow in other places. In places where rain soaks readily into the ground, the annual "ground water crop" may exceed the surface runoff. For instance, south of Enid ground water insoak is about 300 acre-feet per square mile each year, whereas stream runoff in that area is less than half as much.

Ground water reservoirs of Oklahoma supply about one-third of the water used in the State. In most places these reservoirs are not fully developed and additional facts are needed for proper development. With prudent planning and wise management, we can continue to use this valuable resource for many years without depleting it.

The Oklahoma Water Resources Board greatly appreciates this opportunity of participating in this conference.

Respectfully submitted,

Frank Raab

Wyoming's Ground Water Law and Administration

By Earl Lloyd, State Engineer

A Ground Water Law (now Sections 41-121 to 41-147, inclusive, Wyoming Statutes, 1957) was enacted by the 1957 Legislature of the State of Wyoming and it became effective on March 1, 1958. Previous to that time, a law was in effect which was enacted in 1947, the principal feature of which was the requirement for filing a statement of claim with the State Engineer on all existing water wells, except those for domestic and stock purposes, and the filing of a Well Registration on all wells completed after April 1, 1947 - such registration to be filed within 30 days after completion.

The present law requires that an application be filed and permit secured from the State Engineer before any well to divert and appropriate underground water is commenced, but excepts those for stock and domestic purposes. Such stock and domestic wells are exempted from the provisions of the statute and are given a preference right.

Other sections of the law provide for declaring an area a "critical area" and for the appointment of division and district advisory boards. Administration of the law is placed under the State Engineer and the State Board of Control, which in Wyoming is a quasi-judicial body that adjudicates rights to water and has rather wide authority in water matters.

Priority of appropriation of underground water obtained prior to April 1, 1947 dates from completion of the well. Priority obtained subsequent to April 1, 1947 and prior to March 1, 1958 shall date from the filing of registration in the State Engineer's Office, and the priority of rights subsequent to March 1, 1958 shall date from the filing of the application for permit in that office.

Reports of completion or abandonment of the well are required, under the permits, and these reports include quite complete data on those completed. Adjudication of rights is to be made by the State Board of Control.

Provision is also made for correlation of priorities of rights when different acquifers are interconnected or

when underground waters and waters of surface streams are so interconnected as to, in fact, constitute one source of supply.

Our chief difficulty in administration of the law, up to this time, has been because of the section which provides that if a well, for other purposes than stock or domestic use, interferes unreasonably with such an exempted well (which is given a preferred status) the State Engineer can order the interfering appropriation to cease or reduce withdrawals unless he shall furnish at his own expense sufficient water at the former place of use to meet the need for domestic or stock use. This problem has arisen in several areas.

COMMENTS ON COLORADO'S GROUND WATER PROBLEMS

by Geo. W. Colburn 1/

Colorado's chaotic ground water problems are the result of many different factors. In the first place no orderly program for the development of Colorado's ground water potential has been able to materialize. Each different problem has been attacked as a matter which should have been swept under the rug of indifference or poked down the rat hole of individual interest. As a consequence the problem that belongs to everyone has become nobody's problem to a great degree. Only a very few people, mostly professional water men, have attempted to approach the problem in a rational, scientific, objective manner. They are the unsung heroes, not yet fully appreciated, of the ground water field and by whom any progress, such as it may be, has been pushed forward. Their foundation laying of scientific data will be proved more and more valuable as the citizens of Colorado learn, as learn they must, of the effects of indifference, ignorance, and neglect of ground water potentials.

The present Colorado Ground Water Law resulted from some compromises by the several factions representing differing opinions. As a consequence no clear-cut opinion or doctrine has been stated. Work on it was started long before any semblence of a ground water law was placed on the statute books of the state. The first attempt that was successfully entered in the statute books was, in reality, a well driller licensing law which placed their supervision under the Colorado Water Conservation Board. This 1953 statute, set out certain requirements for licensing drillers, obtaining data on their drilling activities and providing penalties for violations. In many respects it was not a good law but in other respects it was better than the 1957 act. The 1957 act changed the administration to the Office of the State Engineer and extended the funtions by requiring registrations of existing uses, the issuance of permits for the use of ground water, the licensing of drillers, and creating a Ground Water Commission with specified duties and authority. It did not stipulate penalties, other than revocation of license, for violations of the act. It is, admittedly, quite a weak law, harrassed by the uncompromising viewpoints of various factions, and passed only as a hurried expedient. Action seems to vary inversely as the amount of snow in the hills. The bickering seems to have been between at least four main, differing ideas. First are those who want no discipline of ground water activity in any way, shape or form. Secondly are those who are so inert that any change requires a particularly strong goad to move them out of the way of those who are asking for some form of discipline or control to protect these inert from the results of their own inertia.

1/ Executive Secretary, Colorado Ground Water Commission

Then those who do desire progressive programs are again divided as to those who want a riparian or perhaps a slightly modified riparian doctrine as opposed to those who want to administer the resource on a strict time appropriation doctrine, or an approximation thereof.

Somewhere in the midst of this conflicting and disco-ordinated thinking is a solution. This solution, it seems, must be the result of at least three basic and fundamental premises: (1) A desire to reach an equitable, workable and logical method of optimum use and conservation of this, our priceless resource. (2) The ability to sit down at a conference table to discuss calmly and sincerely, the differences between the philosophies of administration; being willing to accept as sincere and honest any opinion as to the other point of view and to stand ready to compromise, for the good of the majority of the people of the State, any controversial point which can be honestly accepted. (3) And most important, the force to present the consolidated solution to the legislative bodies in a package which they can or will accept without regard to political complection or individual interest.

Some informed authorities, still idealistic, hold no brief for any philosophy of administration, believing that this is a decision which must be made in accordance with the fundamental premises listed above. However, it should be pointed out, as in many other fields, complete detailed administration cannot be made by any inflexible dictate because of the widely differing problems geologically and geographically present in Colorado. These range from the Ogallala and deep consolidated formations thru the artesian ocean of the San Luis Valley, the alluvial basins of the South Platte and Arkansas river basins to the San Juan basin where ground water is scarce, and in all the variations caused by the transitions between these various conditions. So, the law that contains the solution, must be flexible enough to encourage decisions of adminstration to the best interest of the users of ground water in accordance with the doctrine decided upon by legislative action.

There must be legislative action, otherwise this, their prerogative, will be assumed by judicial action in decrees which, although equitable in a given situation, may be non-equitable in another area, but established as precedent and can be quoted and accepted as such with considerable credence. It is understood that the legislative branch of the government is quite as jealous of its prerogatives as the judicial branch is of theirs. This, then, may be the challenge they must meet. Neither have excelled in this phase up to the present.

Those who have had the foresight to realize the changing conditions now becoming more and more apparent to all, have called this conference to request the experience of other sister states in their ground water problems. These have been brilliantly presented here by able and earnest authorities. Now, it is up to Colorado thru her officials, her legal, engineering, geological and legislative technicians to labor earnestly, honestly, diligently and compromisingly with one another to bring forth a comprehensive solution to the complex problems of how to make Colorado's Ground Water Law a living, vital, active, and positive reality and thus realize the true heritage of Colorado's "Last Water Hole".