Third Annual

WATER CONFERENCE

NEW MEXICO STATE UNIVERSITY

OF AGRICULTURE · ENGINEERING · SCIENCE

NOVEMBER 6 & 7, 1958

NEW MEXICO WATER CONFERENCE

Sponsored
by

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   2. Agricultural Extension Service
   3. School of Agriculture
   4. School of Engineering
   5. Cooperative Agent, USDA-ARS, SCS

II. Water Conference Advisory Committee

III. Water Resources Council - New York City, New York

IV. New Mexico Economic Development Commission

V. Southspring Foundation - Roswell, New Mexico

VI. Charles Lathrop Pack Forestry Foundation - Tucson, Arizona

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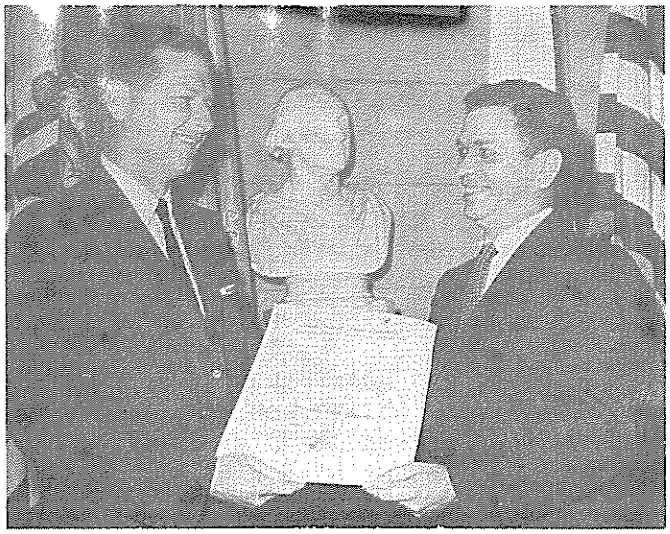
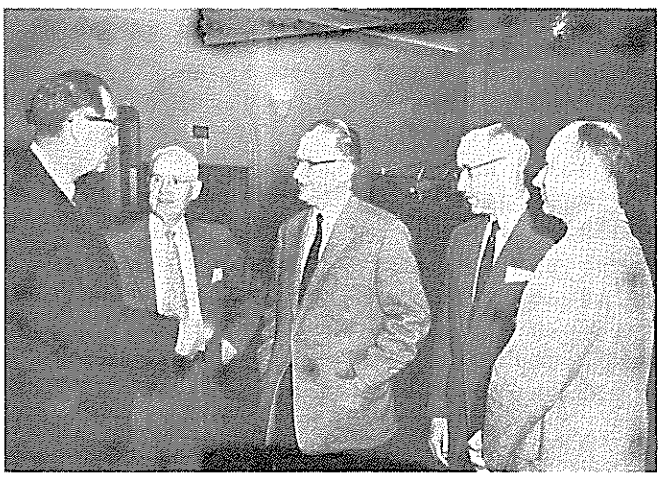


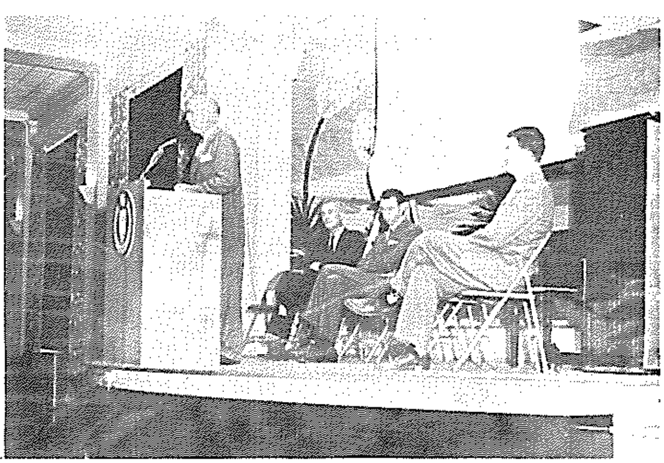
Elmer G. Bennett, right, undersecretary of the Department of the Interior, receives a scroll of appreciation for the department's work on saline water reclamation from Rogers Aston of the Southspring Foundation, Roswell, N. M.

Rogers Aston, second from left, Southspring Foundation, Roswell, N. M.; and Dr. H. R. Stucky, conference chairman, examine some of the many newspaper clippings about the conference, as Jim Cole, left, NMSU ag economist, and Albin Dearing, executive vice-president, Water Resources Council, New York, N. Y., look on.



New Mexico Senator Clinton P. Anderson, left, is welcomed by Dr. Roger B. Corbett, center, president of New Mexico State University. Left to right, Senator Anderson; John P. Murphy, Middle Rio Grande Conservancy District, Albuquerque, N. M.; Dr. Corbett; Dr. H. R. Stucky, head of NMSU's agricultural economics department and chairman of the conference; and Dr. Robert H. Black, dean and director of the college of agriculture and home economics at NMSU.

W. P. Stephens, second from left, New Mexico State University ag economist, points out a stream gauge model in one of the exhibits at the Water Conference. At the left is C. L. Forsling, Pack Foundation, Albuquerque, and at the right, David Miller, Water Resources Council, New York, N. Y.



Jack Wentworth, left, of the New Mexico Economic Development Commission, explains the functions of the organization. On the speaker's platform are, left to right, W. B. O'Donnell, dean of New Mexico State University; Ivan F. Rice, president of the Rice Engineering and Operating Co., Hobbs, N. M.; and Randall F. Montgomery, manager of the Hobbs District of the New Mexico Oil Conservation Commission.

FOREWORD

The story of water is the story of the human, agricultural and industrial development of New Mexico. The places people live, their method of making a living, the type of communities they have built were dependent on water. Water will continue to be a dominant factor in the future development of New Mexico and the Southwest.

Recognizing the vital role water plays in the economy of our state, the Annual New Mexico Water Conference was instituted in 1956 by New Mexico State University of Agriculture, Engineering and Science. The Third Annual Conference was held in November, 1958. These conferences are open to every interested person and are designed to permit and encourage a free and constructive consideration of New Mexico's water problems. Milton Hall on the State University Campus has been the site for each of the conferences.

The annual conferences are attended by leaders in agriculture, government, business and education from many areas in New Mexico. The 1958 conference attracted such leaders from several states, some as far away as New York and Washington, D. C. The bringing together of these papers and the exchange of thought during each of the three conferences has done much to focus the attention of the people of the state on the need for a definite, well coordinated program of water development and conservation with all major water user groups participating.

Beneficial use and prior appropriation have long been the guides to the use of our limited water supply in New Mexico and the West. More attention must be given to these two factors in all water deliberations. Our scarce and valuable water supplies can not be wasted. Greater emphasis is being given in the entire United States to putting water resources to beneficial use. The Water Conference offers an opportunity for various interests to express their views and for each of these groups in water development and conservation to more fully understand and appreciate the legal, economic, and other factors affecting water use.

The Conference was sponsored by New Mexico State University through the Agricultural Experiment Station, Agricultural Extension Service, College of Agriculture, College of Engineering, and Cooperative Agent, USDA-ARS, SCS, with the cooperation of the Water Conference Advisory Committee, Water Resources Council - New York City, New Mexico Economic Development Commission, South Spring Foundation - Roswell, New Mexico, and Charles Lathrop Pack Forestry Foundation - Tucson, Arizona.

The papers appearing in this publication are in the order in which they were presented. The program which follows this statement will serve as an index to the papers.

H. R. Stucky

H. R. Stucky, Head
Department of Agricultural Economics
and General Chairman of New Mexico Water Conference

NEW MEXICO WATER CONFERENCE PROGRAM

New Mexico State University of Agriculture,
Engineering, and Science

November 6 - 7, 1958

Milton Hall (Student Union Building)
New Mexico State University Campus

Theme of Conference

"NEW MEXICO WATER - PRESENT USE AND NEW SOURCES"

<u>Thursday Morning - November 6</u>

		Page Number
8:00	Registration - Milton Hall	
	General Conference Chairman - H. R. Stucky	
9:20	Invocation - Rev. Frank F. Jones First Presbyterian Church, Las Cruces	
9:25 - 9:45	<u>Orientation of Water Resources Research and Welcome Address</u>	
	Dr. Robert H. Black - - - - - - - - - - - - - - Dean and Director of Agriculture New Mexico State University	6
9:45 - 10:00	<u>Introduction of Senator Anderson</u>	
	Dr. Roger B. Corbett President New Mexico State University	
10:00 - 11:00	<u>Address - Congressional Interest in Water Resources</u>	
	Honorable Clinton P. Anderson - - - - - - - - - United States Senator from New Mexico	11
11:00 - 11:20	Recess	
11:20 - 11:50	<u>Work of Water Resources Council</u>	
	Albin Dearing - - - - - - - - - - - - - - - - - - Executive Director Water Resources Council, New York	28

ORIENTATION OF WATER RESOURCES RESEARCH AND WELCOME ADDRESS

Robert H. Black*

It is my very pleasant privilege to welcome you to the Third Annual New Mexico Water Conference program. I believe the title which is used this year "New Mexico Water - Present Use and New Sources" is a very appropriate one.

Perhaps it will be of interest to you to know how the Water Conference got started here on our campus. In the spring of 1956 the Agricultural Economics Department, during the course of its graduate and staff Seminar, called in a number of interested people to discuss the water problem. The Seminar was conducted with participating specialists from the State Engineer's Office, Bureau of Reclamation, Geological Survey, Forest Service, Interstate Streams Commission and others. It was so well received that it attracted public attention and others requested permission to attend. As a result of these requests, it was decided to hold the Seminar a second time. This session was called "The New Mexico Water Conference". Subsequently, the Dean of Agriculture and the Dean of Engineering appointed a nine man committee, representing the various departments of the two schools, to organize a regular Water Conference. Dr. H. R. Stucky, of our Agricultural Economics Department, served as Chairman of this Committee and has continued in that position since its organization. Following the first conference, it was the will of those who attended to make it an annual event. A Water Advisory Committee was selected to represent the various areas and interests of the state. The Advisory Committee met with the A & M Water Conference Committee in May to start planning for the meeting which will be held during the two days you are here. In addition, this Advisory Committee will meet again Friday morning, November 7, with the A & M Committee to start planning for the Fourth Annual Conference.

Water is of tremendous importance to the agriculture of New Mexico. Some 860,000 acres of land are irrigated in this state with 66% of it being irrigated by wells. It is estimated that approximately $55,000,000 is invested in pumping equipment and distribution facilities for the operation of the 7500 wells in New Mexico. Presently 94% of the water used in New Mexico is used by agriculture. Industry uses 1% and municipal and domestic uses total in the neighborhood of 5%. Almost twice as much ground water is used as surface water with 98% of the surface water used in agriculture. Approximately 90% of New Mexico's $100,000,000 in cash crop receipts come from irrigated farms. These returns except for acreage allotments on some of the primary crops, probably would be

*Dean and Director of Agriculture, New Mexico College of A & MA.

substantially higher. Irrigated agriculture supplies some supplemental feeds for our $100,000,000 livestock industry.

A little less than 15% of New Mexico's population lives on farms and ranches, and another 24% is classed as rural non-farm population. Some supplementary income from farming is gained by this non-farm group.

Historically, it has been said that irrigation has been practiced in New Mexico for over 800 years. New Mexico's citizens are water conscious and it speaks well that we who are interested in water are here today to pool our resources of knowledge and ideas to attain more efficiency in the use of this most vital of our gifts.

It has been suggested that I discuss the water research being conducted at New Mexico A & M.

Our Agricultural Economics Department is conducting several studies which are pertinent to New Mexico. Some of these studies are a contributing part of cooperative regional work. One project is "An Analysis of Ground Water Laws and Related Institutions as They Effect the Economy of Lea County, New Mexico". The objectives of this study are: (1.) To inventory the ground water laws and administrative and judicial decisions that apply to Lea County; (2.) To evaluate experiences with ground water laws and decisions as they effect the economy of Lea County and; (3) To estimate and evaluate the probable future effects of present ground water laws and decisions on Lea County. This study is directed toward developing economic criteria which will reinforce or modify our aid in giving direction to existing law and legal decisions affecting the allocation of ground water. This study is scheduled to be completed by 1959. A second project in Ag Economics is entitled "Economics of Pump Irrigation Farming in Lea County". This research has as its objectives: (1.) To determine the cost of pump irrigation water in the Lea County basin; (2.) To determine the production requirements, cultural practices and costs of production for various farm enterprises and; (3) To determine the most profitable combination for crop and livestock enterprise. It will be of interest to note that similar information on the cost of pumping is being prepared for Curry County. A third project is entitled, "Economics of Pump Irrigation Farming in the Estancia Valley". This study is similar to the one being carried on in Lea County and it is believed that we will have a publication in the very near future giving the information from these studies. This study will be expanded to include all pump irrigated areas in 1959. Another project in this department is a cooperative one utilizing "Resources for the Future" funds. This project is financed from a $50,000 contract between the University of New Mexico and the Resources For The Future. The University of New Mexico enlisted a project committee with membership from associate institutions and other groups in the state. Dr. Stucky, of our Agricultural Economics Department, is a member of this committee and $10,000 has been allocated to this institution to study water. Professor Bromilow of our Civil Engineering Department cooperated on the industrial section. The purpose of this joint project is to determine the value of San Juan River water for agriculture and for other uses. Among the important agricultural committees working in the Western states on water research are: The W-33 Committee which is studying the "Economics of Water Application" has just met here at State College on November 3 and 4. There are seven states cooperating in this project; The W-42 Committee studying "Economics of Ground Water Laws" met at the college on November 4 and 5. The New Mexico contributing project deals with the analysis of ground water laws and related institutions as they affect the economy in Lea County. Another committee from the Western Agricultural Economics Research Council has set up a region wide committee to expand and improve the water research in the West. This committee will be meeting in Denver on November 17, 18 and 19 of this year to coordinate findings and make plans for future research. In addition, the Great Plains Council, representing 10 low rainfall states, has a research committee that is vitally interested in water. Associate Director Curry, of the New Mexico Agricultural Experiment Station, is Chairman of a four-man sub-committee of the Great Plains Council charged with the responsibility of developing water and irrigation research projects applicable to the Great Plains Research area. Actually, Mr. Curry and his Committee have developed three such projects and a further hearing by the general Research Committee will determine when and how soon one or more of the projects, dealing particularly with water and irrigation, may be activated.

The Agricultural Research Service of the U. S. Department of Agriculture is doing some research in the upper Colorado area. The New Mexico Agricultural Experiment Station is willing to assist in every way possible with this particular research.

Our Department of Agricultural Engineering is also doing some work with water. One of their projects is, "Water Requirements of Cotton grown on Light Textured to Medium Textured Soils in Mesilla Valley". In addition, they are doing research on the water requirement of alfalfa grown on fine textured soils. The objective of this research is to determine the desirable frequencies of irrigation for cotton and alfalfa production; also, these researchers want to find the desirable range of depths of irrigation water applications, as it is related to optimum production under a limited to adequate water supply. They are investigating the affect of variable depth of irrigation applications and are attempting to determine the utility of electrical resistance blocks as a suitable method for determining the proper time of irrigation. Finally, they want to determine for row crops the relative yield from single beds as compared with double beds when furrow irrigation is used.

In 1950 the Ag Engineering Department, in cooperation with the irrigation division of the Soil Conservation Service, prepared a bulletin which was published, describing the water requirements for crops grown in all irrigated regions of New Mexico. A climatological data method was used to compute the unit consumptive use of all crops. The information in this publication represents average data for each crop. This information has been available as a temporary guide to suffice until more refined data have been determined by research. It is one of the objectives of the afore mentioned projects to determine with greater precision the water requirements considering the influence of site conditions.

It is planned that in the future our Ag Engineering Department will do some cooperative research with the staff in soil physics and soil fertility to study water requirements of crops as influenced by fertility levels and moisture levels.

Our Agronomy Department is studying practices of irrigating pastures and is making observations of various types of irrigation on crops.

In another project, studies are being made of the salt tolerance of cotton and alfalfa under New Mexico conditions and of methods of reclaiming salt-affected soils. Irrigation waters of varying chemical concentration are used to determine how the particular salts in the water affect plant growth. Movement of salt, as affected by shape of the planting bed, is being studied in glass plates that permit observation of the flow patterns of irrigation water carrying soluble salts into the bed.

In an additional project, exchangeable sodium accumulation in soils when irrigation waters of varying sodium calcium ratios are used is being investigated. Both calcareous and non-calcareous soils are included in the experiment in order to determine what factors affect the rate and magnitude of sodium absorption. Along with the soil study, alfalfa is being grown to learn how the sodium/ calcium ratio in irrgation water and in the soil solution affect the yield and chemical composition of plants.

As part of this study, a survey was made of the quality of irrigation well waters in New Mexico and a bulletin summarizing that survey has been published. The data show that there is a wide variation in water quality in the ground water basins of New Mexico but that the chemical characteristics of waters in any one basin are similar.

The Middle Rio Grande Sub-station at Los Lunas is doing some research on the irrigation and nutrition of chile. We are also doing some irrigation research at the Northeastern Sub-station at Tucumcari, where they are studying the fertilization of cotton and its relationship to irrigation.

Dr. James L. Gardner and his U.S.D.A. Associates stationed on this campus are studying, "The Hydrology of Southwestern Grassland Areas as Related to Their Net Yields of Usable Water and Sediment Production".

The main objectives of the work are to determine the interrelated influence of soils, geology, land use, watershed size, and vegetation on water yield; to get accurate field data on areal distribution of rainfall amounts intensities, and times by an adequate network of raingages; and to determine the relation of water yield to range conservation practices.

Two areas--one of 65 square miles on Upper Alamogordo Creek in New Mexico, another the 60 square mile Walnut Gulch watershed in which Tombstone, Arizona, lies--have been covered with recording raingages at approximately 1 mile x 1 mile intervals. Runoff is being measured by means of prerated measuring flumes--one thus far on Alamogordo Creek, five on the Walnut Gulch area. More of these prerated flumes will be established on both areas as time and funds permit. Inventories of the soils and vegetation have been made on the Walnut Gulch area and of the soils at Alamogordo Creek. The vegetation inventory at Alamogordo Creek is still to be made. These vegetation inventories will be repeated at intervals yet to be determined. Besides these two large areas, three small watersheds of less than one square mile each about 40 miles northwest of Albuquerque and four near Safford, Arizona, are being similarly studied.

The Department of Civil Engineering, which is headed by Professor Frank Bromilow, who is also the Associate Director of the Engineering Experiment Station, is conducting some studies of a slightly different nature. First, they are investigating the flows of the Rio Grande and the relationship of the flow to the ground water in the Mesilla Valley. This should supply some very vital information for well users. Along with this, they are making a study of the growth of Algae sewage plant effluent. They have a third study which is designed to measure Aerobic digestion in the liquid state. The research staff in Civil Engineering also is interested in the desalinization of water, but this is planned for future work, since they do not have an active project in it at the present time.

We are all deeply aware of the vital and important position that water occupies in our economy. It is necessary for irrigation, for industry, manufacturing, municipalities, rural homes, livestock, power, recreation, wildlife and many others. It is our sincere wish that this Conference will move us closer to a more complete understanding of the water problems in New Mexico and that it will set forth some guide line as to the most important areas where research is needed. Finally, we should like to repeat again that we are pleased that you have come to your Land-Grant College for this Conference. If any of us can be of any assistance to you while you are here, I am sure that we will be glad for the opportunity to help.

CONGRESSIONAL INTEREST IN WATER RESOURCES

Clinton P. Anderson*

This is a rare privilege.

At last I have the opportunity to do something I've wanted to do for many years. That is to tell the fascinating story of the historic interest of Congress in charting the development of our natural water resources.

When I received your invitation to speak here, Dr. Roger Corbett, who extended the invitation, said the topic should be "Congressional Interest in Water Resources." That was almost like suggesting that I sit down and tell my life story.

Water, like sunlight and air, is one of the basic ingredients of life. Hence, you would think there would be universal interest in water and its conservation and utilization. But I have not always found it so--due, probably, to the fact that some persons, some regions, must struggle to get enought water to drink, to use in industry, and to grow crops while others get too much water and must work to meet the constant threat of flood. There are in these United States many examples of drouth and flood. Likewise, there are divergent views as to the need to develop water resources and still more arguments on opinions as to how it should be done in those cases where agreement is possible as to need.

It is this story which we will visit about this morning--the story of the role played by Congress throughout our national history in recognizing and responding to the water needs not only of the nation but of local communities. In the process, the Congress established a vital right to provide for transportation, flood control and the generation of electricity. Each of these steps encountered fierce opposition but none so enduring as the question of constitutionality. Congress time after time has been challenged by the Executive Branch when water resources programs were proposed. Initially, almost without exception the Executive Branch raised Constitutional objections. While the objections in the end were cast aside, on more than one occasion they succeeded in delaying individual works.

So the first conclusion the historian must draw in any review of Congressional interest in water resources is that the Congress had to secure for itself the right to act in this area of the national interest.

Accordingly, my comments today will center first on the great Constitutional debate between the Congress, the Executive and the Courts. Then we will see how water-resource policy concentrated first upon navigation, then flood control, then irrigation, then power--and ultimately broadened to encompass the multiple-purpose approach which includes

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*Senator of New Mexico

insofar as possible all purposes as they are applied both to individual projects and to comprehensive river basin development.

Without the insistent jabbing of Congress, this country might never have opened the rivers and harbors to commerce, might never have harnessed the mighty rivers of the Tennessee, Colorado, Columbia and Rio Grande. The country might never have supplied electric energy and irrigation water to stupendous networks of homes, farms and factories; might never have controlled floods in the far-flung valleys of the Mississippi and Missouri; might never have written an amazing chapter in world history.

In the beginning, the abundance of water in the United States was, in itself, the greatest problem. To grow, to prosper, the infant United States had to find ways to use its rivers and harbors. So the Congress first turned its attention to the problem of developing commerce on rivers and canals and thus began the struggle with the Executive Branch which has continued unabated to the present.

It would not be possible for me to attempt here to lay out even a brief history of the numerous judicial opinions upholding the Congressional right to legislate on water resources, but in nearly every instance they have come to rest upon Article I, Section 8, of the Constitution. This section enumerates the powers of the Congress and grants to the Congress the power:

> To regulate Commerce with foreign Nations, and among the several States, and with the Indian Tribes.

With this section in mind, but without any judicial opinion to guide it, the Senate on March 2, 1807, passed a resolution directing the Secretary of the Treasury to prepare a report on the means for improving waterways as an aid to transportation.

Albert Gallatin, then Secretary of the Treasury, prepared a report magnificent in concept and historic in importance, but it was born 100 years too soon. He proposed that the United States not only improve its individual waterways, but develop entire watersheds and link them in a comprehensive national system. He declared that the United States government alone was of a size to match the task which he estimated would costs $20 million.

In general he proposed a system of great canals on the Atlantic seacoast to unite New England and the South, roads and canals to connect the Atlantic rivers and Western waters, canals between the Atlantic rivers, St. Lawrence river and the Great Lakes, and interior canals and roads. He insisted that the plan, to yield benefits worthy of the undertaking, be developed as a unit.

But the ears of the nation were not accustomed at that time either to the sound of $20 million or such vast concepts. The plan was laid aside. Nonetheless an idea had been born.

When the war of 1812 brought with it the irresistable demand for better transportation a chain of events was triggered which brought Congress face to face with the need to find ways to develop waterways.

So on December 16, 1816, John C. Calhoun introduced a resolution in the House of Representatives proposing:

> That a committee be appointed to inquire into the expediency of setting apart the bonus, and the net annual proceeds of the National Bank, as a permanent fund for internal improvement.

Calhoun declared that Congress should examine domestic affairs "of all which, internal improvement was not exceeded in importance by any." A committee was formed and it caused the introduction of a bill to build canals and finance them from Federal funds. The Congress passed the measure and sent it to President Madison who vetoed it on his last day in office, asserting it was unconstitutional.

Though he vetoed the bill, Madison said he fully recognized the great importance of canals and improved navigation. He hinted that the Constitution might be amended to give to Congress the power to enact such laws.

The waterways question did not die. As battle in Congress often do, it arose again with renewed vigor. To the 15th Congress, which brought in many new members, President Monroe recommended an amendment to the Constitution to provide for such legislation. He was countered by Henry Clay who said Congress already possessed such powers. In the debate which resulted, a special committee found several precedents to support its contention that Congress needed no further authorization to act, declaring:

> ...if the Constitutional majority of the two Houses should differ with the Executive Department, the opinion of the latter, however respectable, must yield to such an expression of their will...

The committee then reported a bill almost identical with the measure vetoed by Madison. A 10-day debate on it opened on March 6, 1818. Despite pleas by Clay and others, the bill suffered a narrow defeat--not because the Congress failed to recognize the need for waterway improvement--but because the iusse had become a struggle for supremacy between the Legislative and Executive branches.

Two years later Chief Justice Marshall broke up the argument by ruling in favor of the Congress. In the most famous of all opinions on the Commerce Clause of the Constitution, Justice Marshall said, in his decision on the appropriation of funds for a survey of Mississippi and Ohio tributaries:

> The power of Congress....comprehends navigation within the limits of every State in the Union, so far as that navigation may be, in any manner, connected with 'commerce with foreign nations, or among the several States, or with the Indian tribes...'

Thus it was not until 1824 and 1825 that Congress was able to establish the general policy of Federal improvement of rivers and harbors.

Subsequently, President Jackson agreed that the Congress had the power to appropriate money for the construction of a national system of improvements, but he though nevertheless that an amendment to the Constitution should be passed, carefully defining Congressional powers in such matters. He said he believed that the Congress had no power to make local improvements, and he vetoed several bills which, to him, seemed primarily to aid local enterprises. Jackson and Congress seldom found themselves in agreement on whether or not a proposed project was local or national in character.

President Van Buren viewed Constitutional provisions as even more restrictive than had Jackson and as a consequence internal improvement ceased to all practical purposes during Van Buren's administration. But neither Jackson nor Van Buren was able to quiet the clamor in Congress.

The debate attracted such wide attention that President Tyler in his message of 1843 recommended that appropriations for harbors be made, but that they be limited to western harbors. Congress promptly passed bills providing appropriations for both western and eastern harbors. Tyler vetoed the eastern harbor bill but accepted the western bill.

President Polk continued the war with Congress and bitterly denounced in veto messages the bills presented to him in 1846 and 1847. A river and harbor bill finally was enacted in 1854 but again encountered a veto, this time from President Pierce.

The Constitutional debate subsided in 1865 when the Supreme Court reaffirmed the power of Congress to regulate commerce and control navigable waters. The next year the Congress succeeded in getting a Presidential signature on a rivers and harbors bill and from that day forward waterway improvements fared somewhat better.

The next step in the long struggle by Congress to meet the water needs of the nation--in this case flood control--began much later in our history than did the transportation struggle. Historically, flood control has been viewed as local in character although debates in Congress even in Colonial days reflected indirectly many arguments in favor of Federal responsibility.

In 1845, John C. Calhoun suggested assigning certain public lands to the states for use in flood protection. In effect, he proposed to aid the states through gifts of land rather than money. The idea gained support following severe floods in 1849 and 1850 and as a consequence Federal aid for levee building was offered for the first time.

Congress acted first by granting under the Swamp Lands Acts of 1849 and 1850 unsold swamp and overflowed lands to Louisiana, Arkansas and other states. State legislatures were empowered to dispose of the grants and use the proceeds for drainage, reclamation and flood-control.

Following closely on the heels of these Acts came authorization for comprehensive studies of the Mississippi and appropriations by Congress for topographical and hydrological studies. Much comprehensive work was underway when the Civil War intervened. Some levees were destroyed in the military campaigns of that conflict.

Immediately after the Civil War, Congress found itself inundated with control bills, reports and recommendations. On March 27, 1867, the Senate Finance Committee reported that it was satisfied of the "constitutional power and the expediency and good policy" of granting Federal aid in the construction of levees along the lower Mississippi. The committee recommended the expenditure of $3 million to accomplish the aims of its findings.

Although through the years scores of bills had been introduced and much discussion heard, Congress was unable to pass any flood control measure of a constructive nature until 1874 when it provided for a commission of engineers to investigate and then report on a permanent plan for reclamation of the Mississippi areas subject to flooding. A flood in the spring of that year caused widespread suffering and Congress appropriated $90,000 for relief.

It is interesting to note that the right of Congress to participate in navigation improvements was so well established by this year that most flood control proposals were advanced in the name of navigation.

Unitl 1890 funds appropriated for levees were described as "for navigation improvements and incidentally for flood protection."

This concept changed gradually and by 1917 the subject of flood control was being openly approached. The result was the authorization on March 1, 1917, of $50 million for flood control on the Mississippi and Sacramento rivers.

Following this came the Flood Control Act of 1917 which introduced the principle of sharing of costs by Federal and local governments. This Act specified that for every $1 put up locally for flood protection, the Government would put up $2, providing that local interests paid right-of-way and other costs.

Flood control legislation of more recent origin is within the memory of most of us, particularly following the disastrous Mississippi floods of 1927 and 1928 which prompted Herbert Hoover, then head of a special flood relief commission, to urge that the Federal government learn its lesson and provide engineering works adequate to the flood need. He argued that the cost of construction would by no means equal flood loss in 1927 alone.

So out of the disaster came broadened flood control responsibility for Congress. The responsibility now extends into hundreds of millions of dollars annually. Omnibus "Rivers and Harbors" and "Flood Control" bills now are among the largest expenditures authorized by Congress outside national defense.

I think it should be mentioned here also that along with the expansion of U. S. flood control activities, the Congress, in the Flood Control Acts of 1936 and 1938, established a nationwide program for run-off and water flow retardation and for the control of soil erosion. This watershed protection is carried out by the Secretary of Agriculture as a corollary to the flood-control program of the Corps of Engineers. Progress on this phase of the program was slow until 1954 when the Congress enacted the Watershed Protection and Flood Prevention Act which set up a program for Federal cooperation with local organizations.

With amendments to this program, which became law in 1956, the program now is gaining momentum. A broad multiple-purpose program for conservation and development of water and related land resources in small watersheds all over the country is under way and will be completed within a few years--tribute to Congressional attention and interest in the smallest water problem of the land. The small watershed program is under way.

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There is one remaining major area of Congressional interest in water resources which will occupy the major portion of my discussion. That is the Congressional role in the reclamation and utilization of arid lands, hydro-power and recreation areas.

The history of reclamation in the United States is as old as the country itself and is conclusive evidence of the enlightenment and good judgment which guided the pioneers.

As settlers in the years following the Civil War filled up what had been called the American Desert, they discovered an important fact: unless they could irrigate, they were doomed.

So during the 30 years between 1870 and 1900, anguished demands for Federal irrigation works swelled into a sustained roar. Individuals did what they could; small companies were formed; but their engineering, their resources and their endurance were puny in comparison with the need. Men of meager means were pitted against river basins of appalling size, where the rivers they sought to harness had pitiless disregard during the Spring runoff for the ditches and headgates so painfully constructed the year before. Help--big help--had to be found or the dreams of a people--and a region--would die.

Congress, perhaps in anticipation of these outcries, passed a general law in 1866 designed to develop water resources in the West. It was the aim of this law to grant, prior to settlement, rights of way for ditches and canals on public lands to any holder of valid water rights. By 1867 several bills were introduced in Congress to encourage irrigation and reclamation of unproductive California lands. Bills soon were submitted to provide the same help for other Western states. Most of the bills constituted requests for land grants to aid in the construction of irrigation canals, similar to the grants for the construction of railroads.

On March 3, 1873, Congress passed a bill setting up a board to examine and report on a system of irrigation for the San Joaquin, Tulare and Sacramento Valleys of California. Recommendations for the system came a year later as a result.

In 1877 Congress passed the Desert Land Act which provided for reclamation of arid lands in the states of California, Oregon, Nevada and (later) Colorado; and the territories of Washington, Idaho, Montana, Utah, Wyoming, Arizona, New Mexico and (the) Dakotas. The act authorized the sale of 640 acres of land at $1.25 per acre to any person who would irrigate it within three years. The Act also specified that:

> All surplus water over and above such actual appropriation and use, together with the water of all lakes, rivers and other sources of water supply upon the public lands and not navigable, shall remain and be held free for the appropriation and use of the public for irrigation, mining and manufacturing purposes subject to existing rights.

In 1890--because 640 acres proved to be too much land for an individual to irrigate, and because the Act and other laws had given rise to land speculation which allowed one person to acquire up to 1120 acres--Congress limited all entries to a maximum of 320 acres per person.

Even though the Desert Land Act was supposed to have been "all inclusive," Congress continued to exercise leadership in the matter of Western water resources, authorizing a number of investigations which resulted in several comprehensive and detailed reports on the state of irrigation, with recommendations for Federal action. Major John Wesley Powell's "Report on the Lands of the Arid Region of the United States" appeared in 1878. Subsequently a Senate resolution led to a report by Richard J. Hinton, dated 1886, on "Irrigation in the United States." Three years later another Senate resolution authorized a seven-member

'Select Committee on Irrigation and Reclamation of Arid Lands' whose job it was to come up with the "best mode" for reclaiming the arid lands of the American West. A year later--in 1890--the committee submitted a very significant and comprehensive report on a Senate bill (S. 2401, 51st Cong. 1st session, Rpt. 928) proposing the creation, with consent of the states or territories, of a system of Natural Irrigation Districts.

The proposal was that three classes of districts be set up throughout the arid regions, to be supervised by a board of irrigation commissioners, an irrigation court, and district superintendents of irrigation, forestry and pasturage. The report had a great impact on the public and was largely responsible for educating Americans at large to the importance of irrigation. Legislation which followed in Congress found strong support in the investigations upon which the report was based.

In 1890 Congress passed a law reserving to the United States right of way for Federally-constructed ditches and canals on Western Lands to which patents were being issued. The following year the law was broadened to include rights of way to canal and ditch companies for reservoirs and canals, and authorized entrymen on public lands to associate in the construction of reclamation works.

Thus the stage was set for full-scale reclamation development of the West, and for 12 years state and local organizations attempted to proceed. Again there was the old miscalculation of the size of the job. Attempts to proceed on the state level began about 1886 and continued until passage of the National Reclamation Act in 1902. In nearly every case they fell short.

In an effort to beef up the program the Carey Act of 1894 was enacted. It authorized Federal donations to each public-land state of a maximum of one million acres of desert land to aid:

> in the reclamation of the desert lands therein, and the settlement, cultivation and sale thereof in small tracts to actual settlers...

Participating states were required to agree to cause the lands to be irrigated, reclaimed, occupied, and cultivated by actual settlers. Tracts sold by the states were limited to 160 acres for one person, and the lands were to be used only for reclamation, cultivation, and settlement. An amendment in 1896 empowered the states to provide for liens against reclaimed lands to repay reclamation costs.

Even the Carey Act was not enough.. Land could not replace cash. The states -- and particularly the newly-forged Western commonwealths-- were in no position to assume such responsibilities. There were other last-ditch efforts and legislation to encourage reclamation prior to 1902, but they are remarkable because of their ineffectiveness. Albert Gallatin's prediction was proved at last. The Government alone was competent to undertake this program. Hence the national platforms of both major political parties that year favored Federal reclamation programs for the arid lands. Said the Republican platform:

> In further pursuance of the constant policy of the Republican party to provide free homes on the public domain, we recommend adequate national legislation to reclaim the arid lands of the United States, reserving control of the distribution of water for irrigation to the respective States and Territories...

The Democrats said:

> We favor an intelligent system of improving the arid lands of the West, storing the waters for purposes of irrigation and the holding of such lands for actual settlers.

Hence, there was little surprise when bills were introduced in the 56th and 57th Congresses. Favorable reports on these early bills were soon forthcoming.

But once again, as with nearly every new undertaking proposed for the Federal government, they were challenged as unconstitutional. It was argued there could be no constitutionality in using revenues from the many to provide a benefit for the few.

In reply, supporters of Federal reclamation cited the "general welfare" and "property" clauses of the Constitution -- and said that reclamation would pay for itself. Other opposing arguments were raised, among them the allegation that agricultural overproduction would result. (Does that argument have a familiar ring today?)

Having won the skirmishes, the pro-reclamation members of Congress succeeded in passing a bill. President Roosevelt signed the Act on June 17, 1902 and a new wave of development was made possible in the West.

This law provided that revenues from the sale of public lands in the 16 states (Texas was not included in the reclamation states until 1905) be set aside to finance the construction of irrigation works -- which would be required to repay their construction costs within 10 years. This, as a revolving fund, would serve as a source of financing for further irrigation projects at the direction of the Secretary of Interior. The law restricted to 160 acres the amount of land to which each individual settler would be entitled and required settlers to comply with settlement provisions of the homestead law.

As efforts were made to carry out the Act, it became apparent that some of its provisions should be broadened if they were to be effective. Two such developments provided for the disposal of surplus electric power and for the furnishing of water supplies to towns in the vicinity of the projects.

By 1920 the repayment period had been extended and the Secretary had received authority from Congress to furnish project water under certain conditions for "purposes other than irrigation."

The Act was broadened by Congress through the years to match the growth of the West. This broadening was a clear recognition of changing needs. The Reclamation Act of 1939 extended the authority of the Secretary to make examinations and surveys in connection with existing and proposed irrigation projects and to participate in a multiple-purpose approach to reclamation. The Secretary was authorized to allocate part of the cost of projects to flood control or navigation, to consult with the Corps of Engineers and perform investigations jointly with the Secretary of War, to supply water to municipalities and specify conditions for the sale of electric power generated at reclamation projects.

The Bureau of Reclamation has, through June 30, 1957, performed work on more than one hundred projects at a cost totalling more than $2.9 billion. Congress made this possible.

The laws enacted by Congress have made it possible today to irrigate more than 7-1/2 million acres of land, which is more than one fourth of all irrigated land in the 17 Western states. In addition, reclamation projects with an installed capacity of more than 5 million kilowatts produce in these states more than 25 billion kilowatt-hours of electric energy annually.

Crops worth one billion dollars are produced each year as a result of these projects and revenues of more than $60 million come each year from the sale of hydroelectric power. Congressional interest in Federal reclamation in the West has paid off bountifully.

Yet in the face of this record, by 1946, it was being alleged that federal water resources programs were becoming so complex and expensive that many smaller projects were being unduly delayed.

To meet these objections--they were justified--a number of the members of Congress (and I was one of them) sponsored in the 84th Congress a bill which became the Small Reclamation Projects Act of 1956. This Act permits local organizations formed states under state laws to construct projects costing up to $10 million with interest-free Federal loans toward the irrigation costs of the projects not exceeding $5 million.

More than 50 local organizations filed formal notice of intent to apply for loans under the program during the first year. Actual work is now getting under way on one of the first such projects to be approved. It is located near Cameron, Texas. This is but another example of the willingness and desire of Congress to make Reclamation workable in the West.

As events have shown, the development of water resources in the West has been spurred on occasion by the potential for generation of power from falling water. As the complexity of projects grew, it became obvious that irrigation alone could not repay their costs. Thus power became the breadwinner for the projects. What began as a single-purpose concept soon contained other purposes.

So it will be fitting at this point to review briefly the development under the guiding hand of Congress of the multiple-purpose approach to Reclamation.

Congress passed the first law recognizing the possibility of multiple-purpose projects in 1879. That was an Act for planning the improvement of the Mississippi for navigation and flood control.

A number of developments followed during the succeeding 25 years which defined and secured the principle of Federal participation in hydroelectric generation in the West, even though a number of private developments were authorized in hit-or-miss fashion.

These developments and pro and con arguments culminated in 1925 in the authorization of Hoover Dam, the first large multi-purpose project. This project is so huge and its consequences so widely known that I do not propose to enumerate them. However, Hoover Dam symbolized in a package nearly all of the problems and solutions available to the water needs of the West.

There was a further step in the development of the modern concept of Reclamation. As usual, it was provided by Congress.

In 1933 Congress established the Tennessee Valley Authority and in so doing blazed the trail toward comprehensive, full-scale, multiple-purpose development of entire river basins. Again Albert Gallatin was vindicated. The TVA project--one of the reclamation wonders of the world--was the first project of this type.

But like its predecessors, it followed years of Congressional and national debate.

It hardly seems possible that the issues of constitutionality would still be heard in Congress on this subject, but Senator Norris, who led the final and successful effort to authorize TVA, again had to convince a great many persons and organizations that Congress had the authority under the Constitution to provide for this kind of project.

Having once again established its right to undertake multiple-purpose development of the water resources, the Congress moved ahead to authorize the Missouri River Basin Project, the Columbia Basin Project, and the Upper Colorado River Storage Project.

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As we come abreast of developments in recent months we find that Congress has continued to exercise leadership in formulating, adopting and pushing water resources policies vital to the growth and prosperity of the nation as a whole. Although reclamation historically has been associated with the 17 Western states, it no longer can be looked upon as a benefit solely for the West. Benefits of reclamation are increasingly attractive to other portions of the United States, and wealth created in the West by Reclamation finds its way to all parts of the country.

During the past two Congresses, legislation was enacted to authorize reclamation projects costing about $1.4 billion. Omnibus river and harbor and flood control authorizations have been approved for another $1.5 billion. Development of hydropower at Niagara by the state of New York was authorized, adding about 2 million kilowatts to the power capacity of the nation. The project will cost an estimated $600 million.

The Watershed Protection and Flood Prevention Act has been amended to broaden and expand the small watershed land and water conservation program of the Agriculture Department. Limits for construction of small flood-control projects by the Corps of Engineers have been raised to permit more of this work to go forward under emergency conditions and without attention by Congress.

During the second session of the 85th Congress, the Senate and House took action to spur activity by the Department of Interior in both old and new fields.

Senate Resolution 299, which I sponsored, was adopted expressing the sense of the Senate that the rate of construction of ready-to-go reclamation projects should be accelerated as a means of alleviating unemployment, to provide urgently needed water supplies, and to provide for a permanent strengthening of the economy of the 17 Western States and the nation as a whole. The resolution recommended construction of projects totalling $330 million this fiscal year, nearly double the President's original recommendation. The result of this resolution was a second Presidential recommendation calling for a considerable increase in the rate of construction on these projects, including Navajo Dam, a part of the Upper Colorado River Storage Project. In this way, the Senate sought to deal with familiar needs.

The 85th Congress also was looking ahead. It foresaw the day when our water resources will require more than a speed-up in the construction rate in order to meet demand.

What Congress had in mind is the fact that by 1975 the demand for fresh water in the country for all purposes will begin to exceed the total available supply. In other words, a national water shortage is on its way, and it will bring to the humid East some of the problems faced for generations by the arid West.

Two steps were taken to recognize this future situation. The first was the passage of the "Water Supply Act of 1958." The second was passage of S.J. Res. 135, to provide for full-scale demonstration of five or more selected processes for the conversion or treatment of saline and brackish waters.

The first step declares it to be the policy of the Congress to recognize the primary responsibilities of the states and local interests in developing water supplies for domestic, municipal, industrial, and other purposes, and for the Federal government to participate and cooperate with them in developing such water supplies in connection with existing and proposed Federal water resources development projects. Under the law, water may be stored in Corps of Engineers and Bureau of Reclamation projects as follows:

1) State or local interests to agree to pay cost of water supply provisions.

2) Up to 30 per cent of cost of any project may be allocated to anticipated future demands where reasonable assurances are received that repayment will be made within the life of the project.

3) Entire cost, including interest during constructions, allocated to water supply to be repaid within 50 years after project is first used for storage of water for water-supply purposes, except that payment of the cost of storage for future supplies may be deferred up to 10 years without interest.

4) Interest rate to be determined on basis of the computed average interest rate payable by the Treasury on long-term Government bonds.

With the exception of the last provision, this Act should go a long way toward adapting our multiple-purpose river development program now under way. In passing this legislation, the Congress once again had to override Presidential objections. Mr. Eisenhower, in vetoing a similar and previous measure, expressed his

> ...firm conviction that such important substantive changes affecting water resources policy and costs should be made, if at all, only after full, independent consideration not related to an omnibus authorization bill.

Personally, I object to an interest rate provision tied to the interest rate paid on long-term Government bonds. If the Glen Canyon Dam had not been started when it was, it could not have been charged interest at a rate of 2-7/8 per cent. Only a few months later the rate was 3-5/8 per cent -- enough higher to remove its ability to help finance succeeding dams. If the succeeding dams had been required to pay 3-5/8 per cent interest, they could not have paid out at all.

That is why I introduced a bill during the past Congress to peg interest to be paid on reclamation projects at a maximum of 3 per cent. As you know, interest is charged against only that portion of a project's cost which is attributable to power generation.

To me--possibly because I introduced it--the saline water resolution is of even greater long-range significance to the country than the Act I have just described. This legislation authorized $10 million for the construction and operation within a seven-year period of five or more full-scale demonstration plants for the production, from sea-water or other saline or brackish waters, of water suitable for agricultural, industrial, municipal, and other beneficial comsumptive uses. Here again, Congress was looking far ahead to tap a new water resource.

California long has coveted the waters of the Upper Colorado River Basin to supplement the share of the flow she now enjoys. California has a water problem--not of supply but of distribution. Her choices are limited. She can spend the estimated $11 billion necessary to transport the abundant waters of her northern areas to the parched southern portion, or she can rely upon a saline water conversion program. She has reached and passed the ceiling on Colorado River water.

S.J. Res. 135 was drafted in the hope that demonstration conversion processes could be established in Southern California, on the East coast, the Gulf coast, and in the Northern Great Plains and the Southwest. By the time it became law, the resolution provided for three saline water conversion plants within the United States and a minimum of two brackish-water treatment plants. The geological distribution will follow the pattern I have outlined.

Here again, it must be pointed out, the Congress was forced to act in the face of an adverse recommendation by the Executive Branch. In commenting on this legislation to the Budget Bureau, Assistant Secretary of Interior Aandahl presented an adverse recommendation. Subsequently the Budget Bureau recommended against enactment.

However, to be fair, it should be pointed out that following Senate passage of S.J. Res. 135, the Executive Branch withdrew its objections and indicated a willingness to follow the lead of the Senate. The result was final passage of the resolution by the House and signature by the President.

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There is one further water resources field in which Congress recently showed interest--the field of outdoor recreation. It requires only a moment of reflection for anyone to realize the importance of water to the recreation needs of the nation.

Fishing, boating, hunting, swimming, water-skiing, ice skating--these are but a few of the recreational demands upon our water supply are climbing rapidly. They can be met and should be met, along with all other demands.

In recognition of the impact and interplay of recreation and other demands on our water and other resources, I sponsored along with others during the 85th Congress a bill to create an Outdoor Recreation Resources Review Commission to make a three-year study and report on our total inventory of such resources.

The study will cover such things as timber, minerals, wilderness areas, bays, rivers and lakes. It will take into account the future availability of water as a recreational resource as well as pack trails into wilderness areas. In the process, the Commission may not only discover new uses for established water resources, but justify--along with other purposes--the construction of hitherto by-passed reclamation projects. Someday the multiple-purpose concept of reclamation development may be broadened to enfold recreation as a justification along with navigation, flood control, irrigation and power generation. I am happy to report that I have been appointed to serve on this Commission as a representative of the Senate and its Committee on Interior and Insular Affairs.

Now perhaps we might repeat for the record the story of Elephant Butte Dam. It was one of the first dams to be built following enactment of the Reclamation Act of 1902. I think it tells better than anything I have said so far the real story of Reclamation.

Elephant Butte Dam is a part of the Rio Grande Project which includes Elephant Butte Dam and distribution and drainage systems for the irrigation of about 178,000 acres of land in the Mesilla and Rio Grande valleys of New Mexico and Texas extending 100 miles upstream and 40 miles downstream from El Paso. Power is produced at Elephant Butte Dam and transmitted to private and cooperative utility concerns in New Mexico and the El Paso area of Texas.

The project was authorized in December 1905 and irrigation construction started the next year. Construction of the dam proper did not start until 1912 and was not completed until June of 1916. A spillway channel and dike paving were added in 1921 and construction of the power plant was begun in 1938.

First water was available under the project in 1908 and the first power in 1940. The reservoir has been full only twice--once in 1924 and again in 1942. A few more years like 1958 and it might spill again!

Caballo Dam was authorized and begun in 1936. It was completed in 1938. Together, Elephant Butte Dam and Caballo Dam have a storage capacity of more than 2.5 million acre feet. The power plant has a capacity of 24,300 kilowatts.

The original cost of Elephant Butte Dam was $6,074,800 and the power plant $1,460,000. For comparison, I asked the Bureau of Reclamation for estimates of the costs of these units at 1958 prices. I was told that Elephant Butte Dam today would cost $36,632,000--almost six times what it cost in 1912-16. The power plant would cost $4,497,000-3-1/2 times what it did in 1940.

There is a great deal more to the story. The project has lived up to the Reclamation promise of growth and wealth. There are 4860 full and part-time farms operating within the project and 178,196 acres being irrigated. Population served by the project totals 237,972 as follows: 14,108 residents on full-time farms; 6271 on part-time farms; 17,593 residents on lands in urban and suburban residential, commercial, and industrial properties, and 200,000 users of municipal water. In addition, Hudspeth County Conservation and Reclamation District No. 1 in Texas receives supplemental irrigation service for 88 full-time farm units on 18,330 irrigable acres with an estimated population of 2000.

Net investment of the United States in Rio Grande project facilities as of June 30, 1957 was $19 million.

Against this, the U. S. holds repayment contracts valued at $10.1 million, of which $7.2 million had been repaid as of June 30, 1957.

Federal tax revenues attributed to construction of the Rio Grande Project from 1940 to 1957 totalled $240.4 million and $17.3 million in 1957 alone. In other words, the Federal government got almost all of its money back in one year and through the years it has reaped a colossal profit!

But the story doesn't end even there. As of 1957, the cumulative gross crop value from lands within the Elephant Butte Irrigation District and the El Paso County Water Improvement District No. 1, both served by the project, was $862,768,821--almost enough to equal the total cost of the Upper Colorado River Storage Project! Gross crop value for the year 1957 in the two districts was $35,973,181. Gross crop value per acre for the two districts for 1957 was $261. Not only has the project been a bountiful investment for the United States--and that means for taxpayers in New England as well as California--but a lot of farmers, businessmen and industries have made money too. It is an absolute truth that the value--the returns--of such projects are too large to calculate. And if I'm not misinterpreting what I see, this project has contributed mightily through the years not only to the frustration but to the contentment of fishermen.

So I say to you, despite the differences of opinion between the Legislative and Executive Branches of our Government, the Congress always has had the courage to press ahead to determine water resources policy and encourage development programs which have and will guide the destiny of our nation for centuries.

The Congress has, from the begining, peered into the future and demanded bold action and progress unmatched on earth. The results have justified its faith.

WORK OF WATER RESOURCES COUNCIL

Albin Dearing*

Mr. Chairman, Ladies and Gentlemen:

Many of our economists report that today we stand on the threshhold of our Golden Age. They remind us that during the past one hundred years the average number of horsepower per worker has been incresed five times over, and the average out-put per man hour increased six times over. This means, for example, that today's farmer gets twice as much work done as his much harder working predecessor of 1900, while at the same time his farm yield per acre is fifty percent more than the farm of 1900, and drudgery on the farm has been almost entirely eliminated. Other technological developments have also helped us to make more efficient use of raw materials. We now get more than six times as much delivered energy by burning a ton of coal as we did in 1900. With automation today's factory has become almost automatic, from the processing of these raw materials to the machining, and even assembly operations. These electronic devices are not only faster but they are far more accurate than the human brain. In terms of production this means, for example, that a steel strip mill which only a few years ago operated at a speed of 600 feet per minute today rolls thin guage steel at the rate of a mile a minute, producing enough for five millions cans in an eight hour day. A still newer design calls for 100 miles of steel sheet, 14 feet wide, every hour! And this, if you please is but twenty-eight years since the first strip mills began to replace the hand mill.

Conveyor belts which at the outbreak of World War II sped along at 300 feet per minute, now move at more than 1,000 feet per minute. A diesel vessel on Long Island Sound, with seven man crew, sucks up oysters through a rubber hose at the rate of 1,000 bushels per hour where not long ago an individual oysterman laboriously pulled in one single rowboat load in a whole day. In communications, newsprint machines that whirred magnificently at 900 feet per minute during the Twenties today rip along at 2,500 feet per minute. Newspaper presses can produce 1,200 standard newspapers per minute which is faster than bullets come out of a Browning machine gun and exactly twice the best speed of such presses scarcely twenty years age. An electronic printer, produced by Potter Instrument Company for use with punchcard sorting systems, prints 24,000 characters a minute, or five lines of type per second. Now R.C.A. has its phenomenal Ultrafax which unifies in one process television-radio facsimile relaying and high speed motion picture photography. This machine has demonstrated the uncanny ability of transmitting and reproducing, in less than three minutes, every page of the novel "Gone with The

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Wind," at a rate of a million words per minute!

And so it goes in our magical age of automation, this fabulous realm of silicons, transistors and the feed-back principle, which runs our factories, communicates across space at the speed of light, and works out intricate mathematical problems. To multiply 6,834,872 by 1,488,639 takes a good man with a pencil and paper five minutes, but an electronic computer at the University of Toronto in 1952 could multiply 500 pairs of such numbers in two seconds! Still that wasn't fast enough, so the Atomic Energy Commission's Argonne Laboratory brought out a machine that could multiply twelve digit numbers by other twelve digit numbers 2,000 times in one second! Last week the New York Times announced the award of an Army contract to I.B.M. for a machine which will add 30,000 ten digit numbers a second.

How has all this affected us? What is it doing to our way of life?

We live better, we have more, we work less and far more effortlessly and get more done, and we earn more to buy more things than any man who ever walked the face of the earth. There, presumably, is the basis of what we call our standard of living. It does not alone represent an economic achievement. The fact is that we not only may enjoy just about whatever we may convince ourselves we need, for less work, but that we can have it in an environment of better physical health, more advanced education facilities, and a far more fully developed cultural and spiritual atmosphere designed to encourage those seeking to express themselves and their convictions in these vital areas of human endeavor. We have better painters and sculptors, finer musicians, more penetrating research in the realm of the humanities than has yet been the good fortune of any society.

Greater output in less time means more leisure. It is a widely held belief that with this decade our work-week will shorten to four and a half days from its present five, just as it has been consistently shortened from the 72-hour work week of 1850 to today's 40-hour week. Looking beyond 1960, qualified observers forecast further decreases in the amount of daily work we must do to maintain and improve our standard of living. They describe that period as our new era of leisure, pleasure and plenty. It is no utopian dream. Most Americans already have more leisure than any of their antecedents. If one isn't convinced that Americans have more leisure and intend to make the most of it one need only look at the number of pleasure craft sold each year, -not automobiles, not television sets,- everyone seems to have at least a brace of those, but boats. Last year there were more than 25,000,000 boats on our waterways, which means that one person out of every seven in the population has a boat.

Moreover, we have more retired people (ten times more in proportion to the population than we had in 1850). Our senior citizens live longer, happier lives, free of the vicissitudes of pain and want. The median age in our population which was nineteen years only a century ago is now thirty years. At the other end, in case you should be worrying lest we become a race of patriarchs, we have an unprecendented number of small fry coming up. In fact, about a quarter of the population today is under twelve years of age, and the boom in babies seems to be holding.

Now, purveyors of these sorts of statistics are too often prone to view the future in terms of demand for our collective good and services. Let's move over with the sociologists and get another perspective. There the picture is, frankly, not as pleasant. While Stuart Chase and other students of American mores may wonder how Americans will spend their leisure, concerned lest we become a nation of pleasure lovers rather than a society seeking more substantial satisfactions out of life, the people who study mankind in relation to his environment, the ecologists, think perhaps we may never have that problem. That unless we can hurdle two major obstacles we will never know any promised age of leisure, pleasure and plenty. Markets are people, normally. More good are sold because there are more people to buy them, a very familiar economic law of supply and demand. But if either end of that equilibrium is seriously overweighted the result is equally disastrous.

Today there are 2,655,000,000 people in our world, which is just double the number we had only one hundred years ago. With each passing day another 85,000 people are added to our population. In round numbers, this means that every ninety days we have enough people to populate another New York, another London, or another Tokyo. Modern medicine is still prolonging life, still decreasing death rates throughout the world, and because birth rates have not decreased proportionately, world populations mushrooms. The tombs of all the world's wars have been insignificant as measured against the increase in births, accelerated by these hygienic advances. And, as our friend Sam Ordway says, the insidious thing about population growth is that it is cumulative. At the present rate of growth we will have 3,600,000,000 world population by the end of this century. Proportionate to its population increase we no longer inhabit a world of 25,000 miles in circumference but one which has shrunk to one-fifth that size in the past three centuries, and is still shrinking. Its resource base, its productive mines, forests, soils and waters are only a fraction of what they were in 1650. Major population increases are occurring in those lands which are already unable to support their people adequately. It has been estimated that the production of two and one-half acres is needed to feed a human being, minimal requirement. Since we do not have that amount of food production in the world today a great many people starve to death. We are accustomed to thinking of population pressures in terms of India's teeming masses, or of China's hordes and their tragic floods and famines. But it is not alone there. The problem of overpopulation is found just about everywhere one looks,- whether it be Asia, Africa, or the Americas. Right on our doorstep, not four jet hours from where we sit, in the West Indies, starvation is the pitiless plight of half the population of Haiti. Cannibalism is again rampant. Perhaps worse than it has ever been. And as these pressures mount, whether it be in India where a quarter of a million people roam the streets of Calcutta, never knowing where their next meal will come from, or whether it be Haiti, China or Brazil, what will happen? We are not the kind of people who could long be preoccupied with how to spend our leisure time while our neighbors starve, even if we dared. We are proud of our contributions for the relief of mankind's pain and want. We strive tirelessly for more such discoveries. But we must realize that those scientific contributions are largely at the base of the population problem. India never knew her present dilemmas before the coming of western man; when the British colonized India there were fewer than a third the inhabitants she now has.

Another tragedy of our times is the warm hearted belief that the "have" nations of the earth can support the "have not" nations. This idea enjoyed wide currency until quite recently, largely because of efforts after World War II to find homes abroad for 5,000,000 displaced Europeans. The belief was that the population pressures could be eased in Europe and that these people would find new homes in what was described as the "food long" and "labor short" nations, countries with jobs and capable of producing more food than their own people needed. In all the Free World there were believed to be five such countries. These were Australia, New Zealand, Canada, the Argentine and the United States. In reality, reflecting the fact that total world food production today is only nine percent greater than it was twenty years ago, while population increases are twelve percent greater, three of those countries on closer inspection had to be eliminated. Agriculture in both the Argentine and Australia has been the victim of very bad planning during recent years, stemming from an obsessive popular idea that each of those countries should become great industrial centers, even at the systematic destruction of their productive agriculture. As a means of realizing this, both livestock and crop production were forced down in price or shorted of labor, and their national economy hasn't yet fully recovered. Canada, for all its capacity as a producer of minerals and forest products, rests largely on a sheath of stone, poor crop soil, and most of Canada has frosts every month of the year. New Zealand is a land of some potential, but since it is about the size of Colorado it can be of little significance as a world food supplier.

Whom does that leave as food supplier for the Free World? And how would it work? In sharper focus, the problem is no longer one of finding a home for 5,000,000 displaced Europeans. In true perspective it begins to take on the somber shadow of something far more threatening. As a means of relieving population pressures in a crowded area, experience has shown that to move people from one area to another brings only temporary relief; that within two decades the pressures are again as great. History has also shown that, however noble the wish, however commendable the design, it is almost impossible for one nation to transport food to feed another, for any period of time in any large amount. Nehru's need for grain in India in 1951 - 6,000,000 tons, - was obviously a large amount. It would have required 600 ships, of at least 500 feet in length, to carry it, with the dispatch of two such ships per day every day for an entire year. As much as another nation may wish to help, the tragic fact is that each will have to work out its own problem pretty much alone. We can, however, afford to be a little patient with Nehru if in his predicament he turns to Russia, to China, or to wherever else he can get help.

"As these pressures grow all over the world in the next decades, particularly on the continents of Africa, Asia and Latin America, the Western Democracies, themselves increasing in numbers, will be competing with each other to feed and support these super-spawning areas, to win them into their political orbits. But whether these areas accept support from the West or from Russia, or from both, the total of goods increasingly consumed and the total numbers of people born, is bound to bring about a more unfavorable ratio of population to resources than exists in the world today, says Sam Ordway. Neither will it prove beneficial to "industrialize" those so-called "backward" areas, as proposed under Point Four and some of its successors. To industrialize these areas, to attempt to raise their standard of living has so far resulted only in increasing the populations and further compounding the problem, and in the end lowering, not raising their living standard.

What is the situation here at home? We think of the great population upsurges in India, China and Africa as being problems uniquely identified with those places. Actually, the net gain is greater in the United States today, than in either India or China. Official Census Bureau estimates in 1938 were that we would have 154 million people by 1980. We have already passed that figure and the rate of gain is racing along faster than anyone dreamed. The estimates now are that we will have, at the end of this century, between two and three hundred million people, in fact we will pass the 190 million mark before 1975. To feed that 1975 population we will need 113 million more acres of crop land than we now have--which is 70 million more acres than are now envisioned in all the government's present land reclamation projects--and additionally will require that we put out present farm acreage under considerably more "forced draft" production, increases it cannot long survive. Throughout our great midwest region productivity of the soil is in a steady decline at the rate of seven-tenths of one percent per year. In fabulously fertile Iowa the decline is as high as one percent per annum. This is nothing more than the slow corrosion which in the long future will prove a weakening factor in our people and our country just as it has done in Spain, Egypt, Korea and China. "The day is still to come," says Fairfield Osborne, "when we will realize that the protection of our agricultural base is the first need of a 'national defense' program. Not military defense but the defense of values that make American life what it is. The relationship of those farm acres and our highly industrialized economy is not readily understood. An automobile plant, a chemical plant, a steel mill, a rayon spinning mill, all seem operations quite remote from the farm. But are they? Now, I know, statistics should be recited with the same reluctance with which they are apt to be heard, yet these figures so strikingly illustrate the industry-farm relationship that your anti-statistical pain (which most of you by now must already feel acutely) should be endured for just a momemt. To manufacture a million automobiles requires:

"89,000,000 pounds of cotton, the crop yield of 558,000 acres (for upholstery, for brake linings, timing gears and safety glass);

"500,000 bushels of corn, the harvest of 11,280 acres (for rubber substitute butyl alcohol, solvents);

"2,400,000 pounds of linseed oil, the yield of 17,500 acres of flax (for paints, oil, soap, glycerine);

"2,500,000 gallons of molasses, from 12,500 acres of sugar cane (for antifreeze, shockabsorber fluids and solvents);

"3,200,000 pounds of wool from 800,000 head of sheep (for upholstery, gaskets, anti-rust, floor coverings and lubricants);

"1,500,000 square feet of leather, from 30,000 head of cattle (for upholstery, hide and glues);

"20,000 hogs to supply 1,000,000 pounds of lard (for lubricants, oleic acids, and bristles for brushes);

"350,000 pounds of mohair from 87,500 goats (for pile fabric upholstery);

"2,000,000 pounds of soybean oil from the crop of 10,000 acres (for the enamels).

Thus to meet the present annual output of six million cars there is needed the produce of 3,600,000 acres, to say nothing of the very large supply of animals involved. Agriculture supplies an increasing number of other purposes than just food."

Our compelling passion for more and more production would seem to risk pushing our economy to a point where we are no longer one of the nations producing more than we need. Heretofore, we might have taken immense satisfaction in the fact that our gross national product, the total value of what we make, increases at a rate of about three percent per annum. But three percent per annum, compounded, results in doubling every twenty-five years. 1950's gross national product of $300 billions becomes $600 billions by 1975,- or could be expected to reach that figure provided we have not so undermined the resource base to prevent it. Only now are we waking up to the fact that for several basic minerals, minerals which we confidently believed were here in inexhaustible numbers, we must rely now on foreign sources. For example, in 1900, we produced from our mines fifteen percent more than we needed; today we have not only reversed that but now must depend on foreign sources for at least ten percent of our requirement. Just how fast are we decreasing that resource base? Well, here it is:

"The quantity of most metal and mineral fuels used by the United States since the first World War exceeds the total used throughout the entire world in all of history preceding 1914. That thought is difficult to absorb. That we Americans have used as much of the Earth's riches in forty years as all the people, the world over, have used in four thousand.

There is no need for me to tell this audience that as a Nation we are using water at an alarming rate. Demands of our industrial plant, the intensive farming of our croplands, the accustomed need for all the labor saving devices in the home, are costing us a great deal in the one resource we have not yet synthesized nor found a satisfactory substitute for. Not only is our population's aggregate demand many times greater but the per capita water consumption for each man, woman and child in that population is more than double what it was fifty years ago. Here is the balance sheet. From annual precipitation, rainfall and snow, this country receives an average of about 4300 billion gallons a day of which 3,000 billion gallons is lost, for use purposes, through evaporation. That leaves us, us collectively because it is not equally distributed, a 1,300 billion gallons daily average water supply. Of that we use 200 billion gallons daily to run our factories, our farms, our homes to float our ships, maintain the water table level, irrigate fields and drive hydroelectric power generators. Well you say, that's fine. If we get 1300 and use only 200 that's about 16 percent. What's all the worry? Moreover, you can add, much of the water used is not consumed. It can be used over and over so in reality we have a considerable reserve, don't we?

Here's where the trouble starts. First, the water is not evenly distributed either geographically or seasonally. Some regions get an abundance, others get little. Rainfall and snows are natural phenomena - in other words we have an environment that is largely man made intended to function as man directs 365 days a year, but it draws its essential raw material, water, from a source which may or may not synchronize its function with regularity. Moreover, there are other limiting factors. A great deal of this precipitation, once used, is dangerously polluted, or otherwise rendered unusable, particularly in the densely populated areas where the briefest dislocation can cause a tremendous amount of suffering and unhappiness in the lives of millions of people, as well as in their industrial and agricultural production.

Moreover, in the long pull, if today we are using 16 percent, by our present rate of growth we can expect before the turn of the century that we will be using all the precipitation we have. Should meanwhile we have to go to war, the water dilemma will be that much quicker upon us.

For a dismal fifteen minutes I have, factually, I believe, told you of all the barriers, all the obstacles, all the hazards imposed by nature and by man himself which stand between us and our promised destiny,- that happy era of leisure, pleasure and plenty. In reality, ladies and gentlemen, the future is not hopeless. Far from it, in fact. Provided that we are aware of these problems, and further provided that we will dedicate ourselves to human actions based on a constant revolution in human attitudes. We will not solve tomorrow's problems with yesterday's remedies.

Several months ago in Nevada an underground atomic explosion took place involving one kiloton equivalent of T.N.T. So powerful was this blast that it opened a vast chamber in solid rock, forcing the rock to separate, to open up, to form a cavern with glazed walls, where the tremendous heat, the latent energy of this explosion, now contains itself, waiting to be drawn off and used as power, whenever we care to do so. Next year we will detonate another such explosion, this one one megaton T.N.T. equivalent, and in a deep underground formation of oil shale, an area containing 50 million cubic feet of this oil bearing rock. What will happen? I am told that the shale will be pulverized to such a degree that by very ordinary separation methods not involving any milling, it will yield 25,000,000 barrels of oil, - the result of a single blast. If that is practicable and we and our Canadian neighbors can economically utilize the vast deposits of oil shale, our oil reserve again becomes sizeable. But even without it, Oil in its present state is know to lie in formations thus far inaccessible to conventional extraction methods. One such deposit under the Sprayberry range in West Texas, a formation ten miles long and a thousand feet thick, contains not millions but billions of barrels of oil. An atomic blast to fracture that deposit, to move it over where it will be accessible to drilling, would demonstrate another useful function of the atom, and would also demonstrate how broadly it will widen our resource base both in its own right as well as it the expansion of our useable reserve of other fuels.

Whether we ever use an atomic bomb again, whether we ever harness the enormous power of the atom to turn a single wheel, the great value of the fissioned atom's radio-isotopes, a sort of by-product, are already bringing us closer to that day of leisure, pleasure and plenty. These extraordinary agents of the atom are already at work in the fight against cancer, as a means of exploring new dimensions in the structure of metal, measuring to hitherto unobtainable degrees of accuracy, the thicknesses and weights of precision articles on the assembly lines, determining the proper kinds of fertilizers for particular plants, destroying pests, making it possible to produce really effective insecticides, and most important of all, in light of the enormous population pressures and shortage of food in the world, explaining what takes place in photosynthesis, the plant's method of manufacturing protein, fats and carbohydrates. In that very critical area, if we can learn how these cells are formed, who knows but what we will be at last in consonance with the greates mystery of life itself, the formation of cells. These invaluable atomic by-products, these radio-isotopes, have just begun their useful journey with us. Already, in ten brief years they have revealed the answers to hitherto insoluble mysteries in chemistry, biology, agronomy, medicine, literally the whole realm of science, including geology.

While we know and can measure our surface waters we have yet to know and measure the extent and quality of our ground water. The atom, and what we have learned from it, is helping us to do that. And having helped us, by measurement of radioactive tritium discharged from these waters underground we will know exactly from where we can dependably draw these waters. We can even determine their movement, thousands of feet underground, and measure their quality.

New Mexico has an abundance of marginal waters, underground. New Mexico has a vast supply of fossil and atomic fuels. Our population pressures, our need for more productive land, will bring these factors into equilibrium, a happy and a prosperous one, provided that this generation in New Mexico where both the atom and the rocket first proved themselves takes up the challenge boldly in the spirit that man does not live to extenuate the miseries of the past nor to accept as incurable those of the present.

INTRODUCTORY REMARKS

Rogers Aston*

ENTHUSIASM IS A DYNAMIC FORCE - ACCOMPLISHMENT IS BASED ON, AND DRAWS ITS STRENGTH FROM THIS VITAL FORCE. We must realize that the results of such a force are CORRELATED TO THE DEGREE OF KNOWLEDGE DIRECTING THIS ENTHUSIASM...ACTION BASED ON IGNORANCE can be WELL INTENTIONED, but none the less, NON-CONSTRUCTIVE or even DESTRUCTIVE...The first prerequisite of constructive action is KNOWLEDGE...KNOWLEDGE VITALIZED BY ENTHUSIASM AND DEDICATION WILL INEVITABLY RESULT IN ACCOMPLISHMENT.

The water problems of the State of New Mexico and those of our great country are vastly complex. The more one works with the facts underlying our water problems, the more keenly aware he becomes of the scope and complexity involved. GENERALITIES CAN OFFER NO REAL SOLUTION ...NO HARD AND FAST ENGINEERING FORMULA CAN GIVE THE COMPLETE AND FINAL ANSWER. There is one absolute physical law concerning water that cannot be denied...WE MUST PHYSICALLY AND ECONOMICALLY HAVE WATER IF WE ARE TO SURVIVE!! In the end result, WATER IS WORTH WHAT WE HAVE TO PAY FOR IT!!!

> Did you know that your own body is approximately 71 percent water? You can lose nearly all of your body fats and one-half of the protein from your body and survive. If you LOSE A TENTH OF THE WATER CONTENT OF YOUR BODY, YOU WILL DIE.
>
> Industrial and population growth in the state and nation are throwing vast demands on our limited water supplies. The population in the United States is expected to almost DOUBLE IN THE NEXT 42 SHORT YEARS.

THE DISTINGUISHED GENTLEMEN WHOM I SHALL BE PRIVILEGED TO INTRODUCE THIS AFTERNOON WILL GIVE YOU MUCH INFORMATION REGARDING OUR WATER PROBLEMS AND THEIR POSSIBLE SOLUTION... Before introducing them I should like to make one or two concrete suggestions.

1. New Mexico needs an INTEGRATED WATER STUDY:

   (a) The preparation of a comprehensive index of all studies and reports now on hand.

   (b) An impartial study of New Mexico water problems, including an accurate inventory of its surface and underground water resources.

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(c) An estimate of present and future water requirements.
(d) An outlining of a comprehensive and effective water conservation program.

2. The United States needs a NATIONAL WATER INVENTORY to determine integrated composite water situation. Such an inventory to be undertaken on a NON-PARTISAN BASIS, WITH FULL RECOGNITION OF THE PRINCIPLES OF INDIVIDUAL LIBERTY, PRIVATE OWNERSHIP, REGULATED FREE ENTERPRISE, SELF GOVERNMENT AND JUSTICE.

3. We must and will support all worthwhile experimentation on technical solutions to our water problem. The DISTINGUISHED SPEAKERS on this afternoon's program will discuss some promising areas of research. I should like to list a few general categories if I may:

(a) Desalinization
(b) Conservation and Evaporation Control
(c) Climate Control
(d) Redistribution and Exchange
(e) The Application of Atomic Power

4. We must UTILIZE ONE OF OUR COUNTRY'S MOST FERTILE SOURCES OF ACTION - The inquisitive, vital and capable minds of our youth. One of the most effective ways that we can insure an informed and aware youth would be through the establishment of a CHAIR OF WATER. This CHAIR OF WATER should offer instruction in the physical, historical and international field of water. It should cover the economic, legal and engineering facts concerning water. A graduate from this special field of water study should receive a special degree designating him as qualified to deal with water problems. I suggest that New Mexico set the example by the establishment of such a CHAIR OF WATER.

Great electronic computors or "Brains" have been developed in recent years that challenge the comprehension. These great scientific strides still fall short of achieving one function reserved to the human mind! THE ABILITY TO DREAM AND IMAGINE...GREAT ACCOMPLISHMENTS OF THE FUTURE DEPEND ON GREAT IMIGINATION!!! The FIELD OF IMAGINEERING IS OPEN TO US ALL!!

Let's Dream Big! It is time for POSITIVE AND CONSTRUCTIVE THINKING - TIME FOR FAITH IN THE FUTURE, BUT FAITH WITH ITS WORKING CLOTHES ON, the dynamic and positive force of IMAGINEERING.

The speakers I am privileged to introduce on behalf of the Water Resources Council are examples of such VISION based on the practical knowledge to PUT THIS VISION TO WORK...

THE WHEREWITHAL

Jack M. Campbell*

It is indeed a pleasure for me to appear before this Third Annual New Mexico Water Conference. The scope of the program to be presented at this conference is most gratifying and those who are responsible for it are indeed to be congratulated.

I have been asked to discuss with you the matter of possible methods of financing a complete study involving the present water supply, future water requirements, and possible additional sources of water in the State of New Mexico. It is impossible for me to make suggestions as to the financing of such a far-reaching program without making some preliminary remarks regarding the program itself.

It seems to me that almost the whole future of New Mexico depends upon the application of an effective water conservation program to the water we now have and to the development of additional water sources for the future, together with the reasonable allocation of admittedly limited water supplies to agricultural, domestic, and industrial uses. Where the future depends upon such an essential resource which is so limited in quantity, we have the solemn obligation at as early a date as possible, to commence a long-range planning program and, of course, to find ways by which it can be financed. New Mexico is on the threshold of tremendous growth, limited primarily by its water resources and their proper development. Time is of the essence. We cannot expect to stave off the growing expansion into this area while we consume ten years or so in commencing or completing our planning. We need to analyze the problem, determine first where do we now stand, and then, find out whither we are bound.

Before we are in a position to seek financial help from any of several sources which I shall mention, we should first determine where we now stand and what information we now have available as to our present water resources. Only when this is determined can be recognize the magnitude of the planning job, including its cost. I would therefore suggest that, through the Office of the State Engineer, we immediately undertake a collection of all studies, papers and records from the many and various sources in the State of New Mexico, including surface and underground conservancy agencies, and that these be indexed by the Office of the State Engineer and a brief compilation and a summary of these studies be made available. It would, it seems

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to me, be advisable to have this work at least well underway by the time the Legislature meets next year, so that adequate funds could be justified for the completion of the compilation and indexing. Once this central library of information is established and a determination is made of the nature and extent of the material now available, we should be in a position to determine what is then required to complete the job. When this determination is made, only then should we seek from any source, the sizeable amount of money which will be required to complete an adequate survey and plan for the future. Once this basic determination is made, I have several suggestions for your consideration as to how such a project might be financed.

FIRST: I would urge that every effort be made to finance such a study through private fund sources. It occurs to me that such a study in the State of New Mexico would indeed provide a public service of the highest degree should some of the larger private foundations see fit to participate in it. Again, it must be said that these foundations are established by and operated by business men who will need to know in detail what is now available and what we seek. I suggest that private sources be first explored, not to minimize the part that Government agencies can play in the program, but rather to eliminate political implications and to provide the energy and stamina which often seems to be present in privately financed efforts, but often wanting in Governmental efforts. It has been my observation that, in the operation of some Governmental agencies, time is not of the essence.

SECOND: If sufficient private funds are not available to finance a water survey and planning program, we must, of course, seek public funds. If it becomes necessary to do so, I am satisfied that if a present inventory is made available and a comprehensive plan for future action is presented, the New Mexico Legislature will give such a program its earnest consideration. It occurs to me that there may be at least two possibilities insofar as state funds are concerned. That part of the program which can be directly related to irrigation could perhaps be financed through the Permanent Reservoir for Irrigation Purposes Income Fund established under the various acts of Congress at the time of statehood. This fund, now totaling almost one million dollars, has accumulated from the income from 500,000 acres of land set aside under the terms of the Ferguson Act of 1898 and must be used for the development of agriculture. The extent to which these funds might be available would depend upon the program inasmuch as these funds must be used for purposes which will promote irrigation and irrigation projects, but it seems to me that perhaps a legal opinion should be obtained from the Attorney-General to determine the feasibility of using some of these funds for survey and planning purposes. The most obvious source of state funds is, of course, by appropriation and this is perhaps the most straightforward and realistic approach to the matter, but it will require a program of education based upon careful planning before Legislative assistance is sought or obtained. If the basic information is obtained, and if a plan is carefully conceived, I can think of no more justifiable appropriation of public funds than one which will finance a program of water survey and planning in our state. In my judgment, it would be an investment in the future which we could justify as a most solemn obligation to future generations.

THIRD: We should, in planning the financing of such a program, carefully explore the availability of Federal funds, either through an outright grant or on a matching fund basis, and in examining these possible sources, we should at the same time determine what, if any, conditions may be attached to the obtaining of Federal funds. So far as I am concerned, I consider this matter to be peculiarly the problem of our state and if I had my way, I would prefer that it be financed either from private sources, or entirely from state funds, but I realize that Federal funds are now an integral part of our state's financial structure and I certainly would recommend that inquiry be made as to the availability of such funds for a study of this sort. I have not made such an inquiry, but based upon my past experience, I have the feeling that somewhere in the vast operations of the Federal Government there must be some agency or agencies with funds available for this purpose.

Whatever funds we may obtain, we should in our planning, utilize all of the materials and personnel available in the state and federal agencies for the studies of this nature. The staffs of the various conservancy districts, the Office of the State Engineer, the United States Geological Survey, and others have much material and well-qualified personnel who, under proper arrangements, could assist materially in the program and thereby contribute to the financing of it.

It seems to me that the first and most essential step toward obtaining adequate financing for a planning program must be the establishment of some planning organization through which the effort may be made. As much as I am convinced that we seem to be top-heavy with Boards and Commissions of various sorts, I am convinced that, in order to properly accomplish this particular job, we should have a Water Resources Planning Board consisting of a limited number of state officials and citizen representatives with a peculiar interest and knowledge of water problems. This planning board should supervise the compilation of information presently available through the Office of the State Engineer, as the active state agency in the matter, and then should conceive an overall plan of operation which would include a realistic estimate of time and cost involved. This proposed program should be published and be available for study by private funds' sources and for Legislative consideration if necessary.

I cannot over-emphasize the urgent need for such a planning agency. We have many state agencies with an interest in this matter. The Office of the State Engineer is, of course, primarily interested in the administration of all water laws of our state. The Economic Development Commission is interested in water supply for possible future industrial development. The Oil Conservation Commission has an interest in the availability of water for secondary recovery of oil from depleted oil fields. The Office of the Commissioner of Public Lands has a legitimate interest in the availability of water under the vast areas of land held in trust for the schools and other public beneficiaries. Each of these agencies has personnel who are qualified to assist in a program. But somewhere, out of all of this diverse interest; there must come some semblance of order if we are to justify the expense necessary for an adequate water planning program.

I have no doubt in my mind but that, if such an organization can come up with a program which has determined our present position and plotted a firm course for future planning and action with regard to water resources in New Mexico, the funds will be available.

DEVELOPMENT AND UTILIZATION OF SALINE GROUND WATER RESOURCES

David W. Miller*

This afternoon I plan to discuss the role that local saline ground water resources will play when the costs of converting these waters become competitive with the costs of importing fresh water from distant sources. There has been much discussion in newspapers and magazines that any program for saline water conversion will necessarily involve the construction of very long pipelines. These pipelines would either bring the untreated salt water to inland conversion plants or would distribute fresh water from coastal conversion plants. This is a misconception that should be corrected.

In the first place, costs for building pipelines for water transmission and pumping water over distances of hundreds of miles are exhorbitant and probably always will be. Except for only a few large cities, pipelines more than a few miles in length are uneconomical. This has been shown by the fact that many towns only a few miles from the tremendous fresh-water supply of the Great Lakes suffer water shortages year after year. If it were economical to build long transmission lines for water supply all over this country, there would be little need to discuss saline water conversion because we already have enough fresh water stored in many parts of the nation to satisfy all of our demands. Thus, inland areas which now lack adequate fresh water will undoubtedly have to resort to converting local saline water supplies if the costs become reasonable.

Where, however, are saline waters to be obtained in these inland water-short regions? One logical source, whose potential value has not been fully appreciated, is the vast reserve of saline waters contained in extensive geologic formations in many parts of the country. Saline ground water, because of its abundance in so many critical areas, offers the distinct advantage of being available for conversion directly at or near points of demand.

Furthermore, energy costs in many of the conversion processes are proportional to the mineral content of the water. For this reason, increasing interest is being shown in the demineralization of "marginal" saline waters rather than sea water or brine. Our underground reservoirs contain the most important reserve of slightly saline and brackish waters and this potential resource may eventually be utilized in lieu of sea water even in coastal areas.

What is saline water? This question is a great deal more complex than it sounds, for there are many different standards and definitions

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for salinity, depending upon the contemplated use of the water. For example, the U.S. Public Health Service has established certain limits on concentrations of chemical constituents which have been widely adopted for public supplies in general. They recommend that the content of dissolved solids should not exceed 500 ppm and chloride 250 ppm in water for drinking purposes, except in areas where such water is unobtainable. Actually, however, most people cannot taste chloride unless the concentration is higher than 350 ppm. In fact, some public and rural supplies contain more than 500 ppm of chloride and 3,500 ppm of dissolved solids and have been used for many years with no apparent harmful effects to the consumers.

A completely different set of quality standards has been applied to irrigation waters. In this case, the tolerance for salinity, and sodium chloride in particular, depends upon the characteristics of the soil, the types of plants involved and many other factors including drainage and climate. Water containing less than 700 ppm of dissolved solids can be used under almost any conditions for irrigation but in certain areas and especially in the southwestern United States, water containing several thousand ppm is being applied to crops with some degree of success.

Industrial processes, on the other hand, demand water of very high quality. For example, the production of rayon requires water containing less than 100 ppm of dissolved solids. Tolerances for the chemical industry in some cases are even more severe, and in most paper-making processes, chlorides should not exceed 50 ppm and dissolved solids 200 ppm. Consequently, it is often necessary for an industrial plant to chemically purify water which by other standards is considered fresh.

Areas may be rated by the Public Health Service and other governmental agencies as having a surplus of water, and this may be perfectly true when only use for public supply is being considered. However, in view of the strict chemical tolerances imposed by certain manufacturing processes, these same areas may be regarded as deficient in water supply by industry.

Thus, the terms "fresh water" and "saline water" may take on different meanings to the farmer, the industrialist, and officials concerned with public water supply. This ambiguity must be recognized in planning regional water-supply developments, for the past, money has been spent on the construction of water supply facilities and treatment plants which have benefited only a small portion of the major users.

Usually, the term "slightly saline" designates water with a dissolved solids content of less than 3000 ppm, and brackish or moderately saline is used to designate a range of 3000 to 10,000 ppm. The average salt content of sea water is 35,000 ppm and waters are considered "saline" when the dissolved solids content falls between 10,000 and 35,000 ppm. Waters above 35,000 ppm are referred to as brines.

Waters covering the full range of salinity outlined in the categories above can be found in many of the ground-water reservoirs of the United States, and their origins can be attributed to several geologic and hydrologic factors. Many of the sediments which now make up the geologic formations of the world were originally deposited in salt-water seas. After these ancient seas had retreated, the sediments were subjected to various processes including consolidation, folding and faulting. Nevertheless, some of these formations retain the original salt water in which they were deposited. Water which has remained in sediments since their deposition is referred to as connate. Most of the sediments containing connate water are either deeply buried or else contain structural and stratigraphic traps that have confined the original water. Other sediments, which at one time were completely saturated with salt water, have only been partly flushed by fresh-water recharge from precipitation. For example, some of the sand and gravel aquifers of the Gulf coastal region have emerged above sea level only recently, geologically speaking, so that the period of exposure to fresh-water recharge has not been very great. In these aquifers, brackish and saline ground water may be found far inland from the coast at relatively shallow depths.

Many geologic periods have included epochs when salt was precipitated from evaporating waters in closed basins, forming beds of evaporites such as salt, gypsum and anlydrite. Some of the geologic formations which now crop out at land surface were formed in this manner. Also in many of the existing closed basins of the west, evaporation and transpiration by plants has tended to concentrate salts in the shallow water-bearing beds. Streams flowing over these beds dissolve the salts and if water from these streams percolates into the ground, it becomes saline ground water. Where salt beds are buried, slowly moving ground water may dissolve the salts and carry them some distance away.

The shoreline areas in most parts of the United States are underlain by natural saline ground water bodies whose occurrence and extent are due to a hydraulic balance between discharging fresh ground water and the adjoining salty surface water bodies. Generally, the saline ground water occurs in the form of wedges some of which extend inland for many miles in the deeper formations. The natural saline ground waters underlying the coastal plain from Long Island to Florida originated in this manner.

In many parts of the United States, encroachment has caused braskish and saline ground waters to move some distance inland from the shoreline. This encroachment into fresh-water aquifers has been caused by a lowering of the fresh-water head resulting from pumping, drainage, or drought. For example, heavy pumping in the coastal basins near Los Angeles, California, has lowered water levels more than 50 feet below sea level, has reversed the natural seaward direction of ground water flow, and has caused sea water to move into the ground water reservoir.

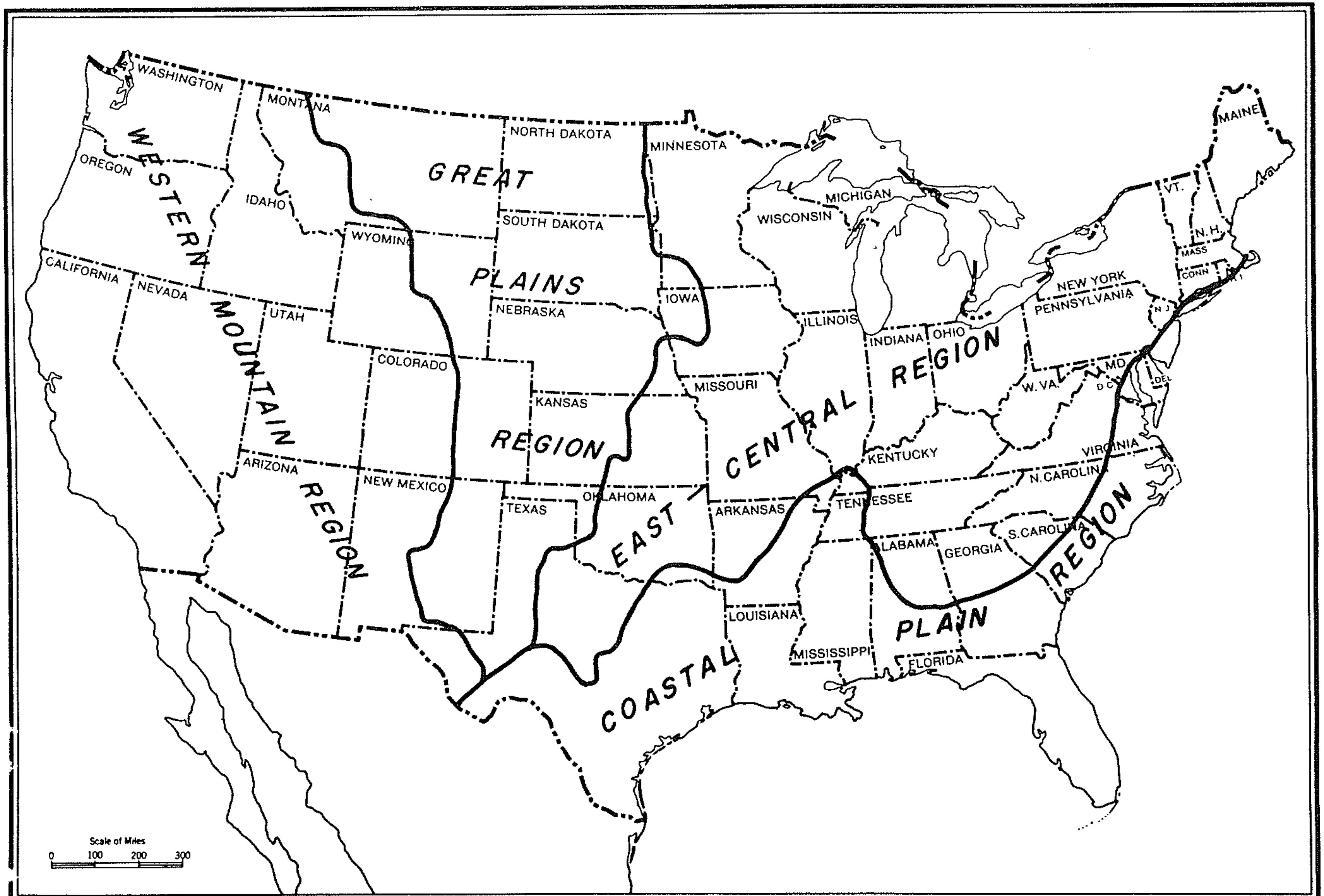
Salt-water encroachment at Miami, Florida, on the other hand has been caused mainly by the construction of drainage canals. Discharge of fresh ground water into these canals has lowered the head in the principal aquifer by removing stored fresh water. Also, during dry periods the canals have carried salty surface water from the ocean inland for several miles and have allowed this salty water to leak into the ground water formations.

Salt-water encroachment has also occurred in areas where fresh ground water bodies are directly or indirectly in contact with connate saline ground-water bodies. This type of encroachment has affected large areas in the western United States, including the San Joaquin Valley in California and parts of New Mexico and Texas. Heavy pumpage and drought conditions have caused connate water to move vertically and horizontally into fresh-water aquifers, sometimes through beds which previously had been thought to be relatively impermeable. Fresh-water heads have been lowered to such a degree in these critical areas that the problem of contamination by saline waters has become severe.

From the foregoing discussion on occurrence, we can understand why the United States has reserves of salty ground water ranging in quality from slightly saline to brine. Because my time is limited today, I will not attempt to do more than briefly summarize some of the findings of an inventory of saline waters of the United States conducted by the U.S. Geological Survey, the results of which were recently published as Water Supply Paper 1374. The major ground water regions that will be discussed are shown in figure 1. Both fresh and saline ground water resources will be outlined for each area in order to give a more complete picture of the ground water situation.

The Atlantic and Gulf Coastal Plain region has the greatest reserve of fresh ground water in the entire country, but also includes many areas of serious overdevelopment. In general, slightly to moderately saline ground water is available in large quantities from the thick and permeable sand, gravel and limestone formations in many parts of the region. A narrow belt along the coast from New England to Texas, almost the entire States of Louisiana and Florida, and large parts of Alabama, Mississippi, Arkansas and Texas have in addition to large supplies of fresh ground water, tremendous quantities of saline water at moderate depths.

In the east-central region, the principal sources of fresh water are the glacial sand and gravel deposits north of the Ohio River, and extensive sandstone and limestone formations where they occur at shallow to moderate depths. The unglaciated part and to some extent, the glaciated part of the region are areas of barely adequate ground water supply, especially in some industrial localities where existing supplies have been overdeveloped. Except in the New England States, the Blue Ridge and Piedmont provinces, and those parts of Minnesota and Wisconsin that are underlain by crystalline rocks, moderate to large quantities of saline water are available from the sedimentary rocks.



GROUND-WATER REGIONS OF THE UNITED STATES

In the absence of more suitable supplies, many towns and villages in parts of the Mississippi Valley presently are using slightly saline ground water.

In the Great Plains region fresh ground water supplies are generally deficient, except in some areas underlain by unconsolidated and semi-consolidated sands and gravels. The most extensive aquifers are the Dakota sandstone and the Ogallala formation of the southern half of the region. Both formations yield water that is highly mineralized. The Ogallala is underlain by older formations which contain saline water at moderate depths. In the Roswell artesian basin of southeastern New Mexico, limestone is the source of large quantities of water, much of which may be classified as slightly saline to brackish.

In the Western Mountain region, which occupies approximately the western third of the United States, the principal sources of fresh ground water are the lava flows of the Columbia Plateau, the valley-fill deposits of the Basin and Range and Pacific Mountain provinces, and the glacial deposits of the Pacific Northwest. The southern half of the region is an area of perennial water shortage, a condition which has been aggravated by recent increases in ground water pumpage for municipal and irrigation purposes. In many parts of the region, surface water is fully appropriated, and fresh ground water is completely developed or overdeveloped. In the Plateau province which extends from Montana to Arizona, slightly saline water is present in all the formations at moderate depths. Slightly to moderately saline ground water also occurs in many of the closed basins of New Mexico, Utah, Nevada, California, and Arizona. Ground water supplies of the Colorado Plateau are generally of good quality; however, fresh to moderately saline water is produced from several aquifers which underlie much of the region.

The significant conclusion gained from this survey is that supplies of saline ground water are available in most parts of the United States. These saline supplies have a great potential value for demineralization particularly in heavily populated and high industrialized areas where fresh-water resources have been depleted or have become contaiminated. In such places, the demand for good water already exists, so that the greater costs of saline water conversion may soon be acceptable. Therefore, we may see some of the first full scale saline-conversion plants constructed in areas where once-ample supplies of fresh water have deteriorated over the years.

In many parts of the country, saline ground water will be the only readily available source of water for conversion. Undeveloped sources of fresh water are becoming more remote and the rising cost of constructing pipelines to transport this water is approaching some of the predicted capital costs for saline-water conversion of local supplies. This is particularly true in the southwest where few untapped sources of fresh water remain. Small supplies of up to about ten mgd (million gallons per day) will especially require on-the-spot water for demineralization because of prohibitive transmission costs. Thus, local ground water supplies which up to now have been of below standard quality will become increasingly important.

Even in coastal areas with an unlimited abundance of sea water nearby and in other places where brackish or saline river waters are readily available, ground water may have distinct advantages over surface water as a source of supply for demineralization. One principal advantage is that ground water is usually free of turbidity and suspended matter, thereby reducing initial treatment costs. Also important is the fact that temperatures and chemical quality characteristics of ground water are not subject to the wide variations commonly observed in surface waters. For some demineralization processes, these stable qualities would simplify plant operation.

However, the most significant reason for considering saline ground water for conversion in many parts of the country is it's low content of dissolved solids as compared to sea water. Conversion costs in some processes are directly related to the dissolved solids content of the raw water and consequently the lower the salinity the cheaper the operation. In the ion exchange method, for example, the cost of converting water containing 3500 ppm of dissolved solids is estimated to be only about 20% of the costs of converting ocean water.

Therefore, whenever a salt-water conversion plant is to be constructed, all potential sources of water supply, both surface and ground water, should be investigated as to availability, dependability and quality. Even on small islands completely surrounded by salt water, some slightly saline and brackish ground water is usually available, often in quanities entirely adequate to satisfy the needs of a conversion plant.

This brings us to the problems involved in actually developing a ground water supply for use in the saline-water conversion plant. As is required in any new ground water development, a thorough geologic and hydrologic investigation should be made before the well facilities are designed. The purpose of such investigations is to determine the hydraulic characteristics of the water bearing formations, to provide data showing the extent and degree of interconnection of these formations, and to establish the maximum rates at which pumping can be maintained without depleting the ground water supply or lowering water levels severely. These studies become even more essential when desalinization is being considered because capital costs for a conversion plant are so much larger than those for normal water supply facilities, and economic considerations dictate that the source of water be dependable.

Aside from the usual considerations involved in developing ground water supplies, certain other specialized problems may arise in pumping brackish or saline ground water. For example, this pumping may directly affect associated fresh ground water bodies. In some areas where encroachment is occurring, the effect will be beneficial because the withdrawals of saline ground water will tend to equalize pressure differences and either retard or prevent further contamination of the fresh-water unit. However, in other areas, where the storage capacity of the saline ground water aquifer may be small and recharge possibilities limited, the pumping of saline ground water may induce fresh water to move toward the wells and thus deplete the fresh water supply. Here again, preliminary hydrologic investigations before construction of the installation and proper management after development should provide adequate warning of any such dangers.

Another problem that may arise in the pumping of brackish or saline ground water supplies is corrosion of equipment in wells. Special pumps, screens and other materials have already been designed for use in wells pumping brackish or saline ground water, but initial and replacement costs are sometimes high. However, improvements are being made and this should be less of a problem in the future.

The disposal of brine residues from conversion processes may be a problem in some areas and may significantly increase the costs of conversion. The success of many of the methods proposed for disposal such as injection into underground strata or discharge into pits and basins will depend on an adequate evaluation of local ground water conditions. Generally, the requirements for an injection system are properly constructed wells, elimination of suspended solids and chemical compatibility between the injected water and natural ground water. With regard to the recharging of brine residues into pits and basins, care must be taken to guard against contamination of local fresh ground water supplies. Because ground water can move great distances in certain types of aquifers, such as those composed of limestone or fractured shales, a thorough knowledge of water-table gradients, effects of nearby pumping, and infiltration characteristics of the surficial materials should be gained before waste pits or basins are located. In some cases, the underground migration of contaminants has affected nearby wells used for potable supplies and has resulted in serious problems.

In the past, studies of our ground water resources have, of course, stressed the availability of fresh water. However, now that we have entered the era of saline water conversion, we should be adequately prepared with regard to data on the location, quantity and quality of our saline ground water reserves. The U.S. Geological Survey has already published several reports on saline water resources. One, which I have already mentioned, is a generalized reconnaissance on the entire United States; others describe the occurrence of saline water in various states including Texas and New York. The Geological Survey is also conducting studies of a similar nature in North Dakota, New Mexico and Oklahoma. Although these general reports are invaluable, they can not provide all the data needed with regard to the development of saline water. Water supply needs are spot problems and the feasibility of converting saline water will depend upon conditions at the point of use. Therefore, studies will have to be made at individual sites with regard to water source conditions, power costs, waste disposal and the various other factors involved in saline water conversion.

Large quantities of saline ground water are already being used for industrial cooling and agricultural purposes. Thus, saline ground water resources are an important part of our national water picture. With the desperate need for new sources of potable water, and the anticipated decline in costs of desalinization, saline ground water reserves will become even more important and will play an increasing role in future programs for water supply development and management.

DESALINIZATION OF WATER

John O'Meara*

There are three principal reasons why I consider it a high privilege to participate in the Third Annual New Mexico Water Conference. First, meetings such as this, are the backbone of water resources development planning. Second, I expect to learn a great deal from your discussions, and third, desalinization, my assigned topic for this Conference, is a subject of world-wide interest and growing promise.

The challenge of providing adequate supplies of water to meet our growing demands is indeed great, but to me, this Conference is witness to the fact that you have long ago firmly resolved not to let the lack of water curtail the future expansion of your population your agriculture and your industry.

By drawing upon your inspiring heritage of water resource development, groups such as this will provide the necessary leadership to meet and answer the challenge.

One answer to that challenge is the coming realization of the ancient dream of man -- fresh water from the sea at a competitive price. Often overlooked, but just as important, and of first interest to this area -- fresh water from the vast reserves of inland brackish water.

For purposes of desalinization, the Office of Saline Water divides water into just two general categories:

Sea water containing 35-40,000 ppm (parts per million), dissolved solids, and brackish water, ranging in dissolved solids content from 1,000 up to 35,000 ppm.

Before we discuss the latest developments in the field of saline water conversion, I believe it would be of general interest to review some of the history of man's effort to freshen the salty seas.

We must realize that all of the world's people live on less than one-quarter of the globe's surface. They are dependent for life entirely on the fresh water upon and beneath the inhabitable land. Man's epic struggle to survice on this planet could be written in terms of his constant concern and need for water.

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* Special Assistant to the Secretary, United States Department of Interior.

Through the ages, natural supplies of water, fluctuating in an erratic manner, have governed the rise and fall of civilizations. Some of the most creative and cooperative ventures in the annals of human advancement were applied to the development of water resources. As a part of his quest for water, man has been trying for along time to change salt water into fresh. Probably a lot longer than most people realize.

Aristotle wrote about it. Caesar was able to obtain fresh water from the sea, and in so doing, frustrate the efforts of his enemies when he was besieged at Alexandria. Francis Bacon discussed it in his book "Sylvia Sylvarum," which was published in 1635. Thomas Jefferson conducted some successful experiments in 1791.

Actually, the distiliation of sea water to obtain fresh water is a technique almost as old as the teakettle. The first practical installations came with the advent of the steamship and its requirement of fresh water for boilers. Today, every large ocean-going vessel has its battery of evaporators.

The first large, land-based plants, those in Curacao and Aruba in the Caribbean Sea, were not built until 30 years ago. On these islands there is very limited rainfall, and the character of the land is such that it retains very little water that can be recovered from the ground by wells. The only alternate source of fresh water is by expensive tanker transport.

The plight of the Virgin Islands gives startling evidence of just how expensive it is to obtain water supplies by this method. To supplement the inadequate supplies of natural water on St. Thomas Island, the public works department has been forced to haul water by barge from the island of Puerto Rico. In 1957 they imported 33 million gallons in this manner at an average cost of $6 a thousand gallons.

During the last war, portable distilling units were developed for the armed services to purify both sea and brackish water into drinkable supplies. These stills had extremely small capacities, and their high cost of water production was of secondary importance. They served their purpose by providing a compact, versatile unit that produced an otherwise unattainable supply of fresh water.

During the early post-war years, scientists and technicians were conducting only sporatic research for a more efficient saline water conversion process than could be accomplished by the then expensive distillation process.

During this same period, from a status of barely casual interest, the increasing demand for fresh water began to occupy public interest.

Even the most amply provided parts of the Nation began to evidence concern.

With our population growing at chain-reaction speed, our industrial community expanding at an unprecedented rate and agricultural interests pressing for more irrigation - all at a time when our natural supplies of water were depressed by widespread drought, the value, perhaps eventually even the necessity, of turning the unlimited supplies of ocean water to productive use became unmistakably clear.

To stimulate the scientific search for such a process, or processes, Congress passed the Saline Water Act in 1952. The first law provided $2-million for a five year period to conduct research and technical development work. It was amended in 1955, by extending the life of the program through 1963 and raising the authorization of $10-million.

In the six short years this program has been in effect, Congress has appropriated a total of only $4,020,000, including the current fiscal year appropriation, the largest yet received - $1,170,000.

This is what has been done.

Our research embraces many fields of science, but it is limited by the fact that there are only two basic ways to obtain fresh water from salt.

1. Take the water out of the salt.

2. Take the salt out of the water.

Within these limitations, however, we have many possibilities.

Where should we begin? How can we best solve this problem? These are questions that faced the newly formed staff of the Office of Saline Water in 1952.

The authorized program was designed to encourage private research and development in this general area and to assist such private effort by means of a program of Federally financed research and development contracts where private activity alone did not seem to be making sufficient progress. Public effort both local and Federal was to be coordinated for the purpose of accelerating research and development.

One of the first policy problems to be worked out was to decide what procedures would be followed in deciding who would receive contracts and at the same time make sure than any money granted is wisely used. The problem was solved by adopting a system that had long been successfully used by the National Science Foundation.

When a research proposal is received by the Office of Saline Water, it is carefully evaluated by the staff. If it carries even the seed of a practical idea, it is submitted to several of the Office's scientific consultants - experts outside the Government - for review. On the basis of the consultants' evaluation, the Office may proceed to negotiate a research contract. Research results are later scrutinized by the Office and its consultants. A favorable report may lead to further research or pilot plant development.

To stimulate interest and to obtain the greatest practicable participation of private knowledge and skill, an active campaign was developed at the outset of the program to bring together all existing and new ideas on conversion methods for research and development, and to enlist the cooperation of engineers, scientists, and organizations in exploring these ideas and methods. A brochure, "Demineralization of Saline Waters," was compiled and distributed, outlining all known phenomena or processes that might be considered for saline water conversion.

The success of this campaign can be accurately evaluated. Over six hundred citizens have submitted ideas and proposals. Many of these suggestions have had great value, resulting in research that is developing entirely new processes.

Not all suggestions received, however, are worthwhile. One man, for example, thought it would be a good idea to tow icebergs from the Arctic to the United States, here to be melted down into fresh water. Another contract seeker built his proposal around a rocket with a nose cone constructed of palladium - a metal, he claimed, which permits only hydrogen to pass through it. Fill the nose cone with oxygen, he suggested, and shoot it into the stratosphere. Since hydrogen is the lightest known element, he reasoned it surely must be in heavy concentration at some great height. As the rocket passes through this concentrated layer of hydrogen, the hydrogen will penetrate the palladium, and when twice as much hydrogen as oxygen is in the nose cone, you will naturally have H_2O - water! Just one final Recover the nose cone.

Early experience in the program indicated the need of developing a formula for determining costs of conversion of saline waters. At the outset of the program, the cost estimates made by advocates of the various processes were analyzed. It was found that few of these estimates, if any, included all actual costs. Further, many such estimates of five or six years ago represented optimistic extension of laboratory results to future large-scale application. Thus, for example, it was estimated that projected largesize distillation plants utilizing processes then in commercial production could convert sea water to fresh water at a cost of $1.25 to $1.50 per thousand gallons of product. Overlooked by some was the fact that such large-scale operation had not been actually accomplished.

In an effort to establish an accurate basis for computing costs, the Office of Saline Water prepared and published a "Standardized Procedure for Estimating Saline Water Conversion Costs." This procedure was designed as a standard to include all factors affecting the cost of the conversion product in order to obtain a reliable figure. To compute water costs under this procedure such items as total plant investment; operating costs, including fuel and chemicals used in the process; supplies and maintenance materials; labor; amortization; taxes; interest; insurance; etc., must all be calculated and itemized.

This procedure has proved invaluable for comparing conversion costs, but its use to a certain degree, penalizes the program, because the cost of water supplied from natural sources is not generally computed so comprehensively. In other words, the Office of Saline Water is quoting actual cost of product water, whereas, in many instances, rates for water supplied from natural sources is an arbitrary figure which does not necessarily reflect total cost. It is common practice to charge off the capital investment of a water supply system against property taxes or other revenue sources. I am not sure just what per cent of the cost of natural water capital investment might be, but I do know in converting sea or brackish water to fresh, the capital investment can amount to as much as 75 per cent of the computed cost.

Even with the standardized procedure, cost computation and comparison continues to be a nagging problem. With most of the land-based distillation plants located in foreign countries, we cannot say with certainty that their published conversion costs are accurate by our standards. The flash distillation plant in Kuwait, for example, is converting fresh water from the salty Persian Gulf, for an announced price of .63 cents per thousand gallons. This cost evaluation was computed by the consulting firm of Ewbanks & Partners, London, England. We don't know if this firm considered all the cost factors listed in our standardized procedure to arrive at this figure. Other unusual circumstances affect this announced price. The plant utilizes the waste gas from the extensive oil fields in Kuwait, so fuel is supplied at no cost. Free land, low cost labor, tax and interest-free operation may also be reflected in the product price. The point is, even if the attractive published price of .63 cents per thousand gallons for this process is accurate, it could not be duplicated here.

Estimating fuel oil at $2.40 per barrel, for example, the cost of conversion for this system would jump to $1.87 per thousand gallons.

On several occasions there have been press reports of new processes for which the inventor claimed a conversion cost of only 15 or 20 cents per 1000 gallons. It is only natural that such claims should receive wide circulation, for such a conversion cost would represent a major scientific breakthrough in the state of the art.

Unfortunately, in checking these proposed processes -- and they have all been only that -- a proposal, we have found they are either based on a set of unreliable critical assumptions, or the claimed price represented only a fraction of the actual conversion cost.

Twenty years ago it cost about $5,00 to distill a thousand gallons of sea water to fresh. In line with the economic trend of the times we could properly expect today's cost to be about $10.00 per thousand gallongs, but progress achieved through research and development is bringing the cost of conversion down.

Some of the latest installations are producing fresh water from the sea for $1.75 per thousand gallons. Moreover, we believe plants may now be designed and actually operate to produce fresh water from the sea for $1.00 per thousand gallons. If our present laboratory results prove out in actual operation, we may soon be able to reduce the conversion cost to 50 or 60 cents a thousand gallons.

I have emphasized cost, because the program has only one goal -- converted water at an economic price. All the problems faced by the Office of Saline Water are either born of, or directly related to, cost factors.

While the air has been full of cost claims and counterclaims, research and development has been progressing at a remarkable rate.

Laboratory and economic study to date has narrowed the field from some twenty phenomena or processes to five broad groups: (1) distillation through artificial heat; (2) solar heat distillation; (3) separation of salt by membrane processes; (4) freezing; and (5) chemical or electrical means of separation, including solvent extraction.

Many people have wondered why we continue research in so many different processes. Why not concentrate all research on just a single system? We are exploring the broad field because, first: we do not know which process will ultimately prove to be the most economical, if indeed it has even yet been conceived; and second, it has been ascertained that the various potential processes must be tailored to suit different conditions of providing fresh water from a variety of saline sources, in different locations, for different uses and in various quantities. Some may be best adapted to supply an individual farmstead or home, others to furnishing millions of gallons per day to a city or an industry.

Improvement of conventional distillation processes, both to reduce their high investment cost by increasing the rate of heat transfer and to reduce the energy cost by diminishing the heat losses, engaged extensive study from the first.

Although there are several different types of distillation equipments and cycles, all are presently subject to the same general limitations - scale depostion and corrosion. Scale forming constituents are precipitated out of solution as evaporator temperatures rise above 160° F. The scale fouls heat transfer surfaces and impedes fluid circulation. The brine is corrosive, necessitating the use of expensive alloys.

A series of research and development studies has been in progress in the fields of heat transfer, scale prevention, and less expensive corrosion resistant materials of construction.

A distillation process using long tube vertical evaporators adapted from time-tested equipment widely used in the chemical industry is now under pilot plant test at Wrightsville Beach, North Carolina. In this cycle sea water is passed through a series of evaporators under progressively reduced pressure. The efficiency and economy of this process depends completely on scale free operation. We believe this can be accomplished through new techniques we are testing in the pilot plant operation.

Another pilot plant, also at Wrightsville Beach, North Carolina is testing a vapor compression process invented by Dr. Kenneth C. D. Hickman of Rochester, New York. This system has an evaporator consisting of a stack of eight discus-shaped copper rotors. Sea water is introduced into the inside of each rotor by stationary nozzles; there reduced pressure causes it to evaporate rapidly. The vapor is compressed and condensed on the outside of the rotors, its latent heat passes through the rotors and in turn aids the vaporization process on the inside surface.

The flash type of distillation process is now receiving increasing commercial application. In this process, warm salt water enters an evaporation chamber in which the pressure has been reduced below the boiling point of the salt water, thereby inducing a portion of liquid to vaporize or flash into steam.

Distillation by means of solar heat has the advantage of eliminating the cost of the fuel energy otherwise required. However, the diffuse nature of solar energy makes necessary the use of large areas for collection. The major problem in solar distillation is reduction of equipment costs. Research on solar stills having that objective and of increasing efficiencies has been carried out by the Office of Saline Water. Both glass and plastics membranes have found application as transarent covers for solar stills, and equipment costs are being reduced.

A comprehensive development program on solar stills through contract with Batelle Memorial Institute of Columbus, Ohio, has been initiated. Several solar stills of improved design are being installed for further testing and development at a seashore test station near Port Orange, Florida. Solar stills have attractive possibilities for areas where solar intensities are high and other conversion methods costly or impracticable.

Salt water separation by freezing has been the subject of a number of experimental researches. The use of freezing has certain inherent advantages such as a lesser tendency toward scaling and corrosion because of the low temperatures involved, and more important, the lower energy required to freeze sea water as compared to the energy required to vaporize or bring it to a boil. A direct freeze-separation process developed by the Carrier Corporation of Syracuse, New York, will soon be ready for pilot plant testing.

All the processes just discussed follow the general process formula of taking the water out of the salt. One group of researchers held to the theory that it would be more efficient to take the salt out of the water since the salt represents only 3½ per cent of raw sea water, and in some brackish water less than one-half of one per cent.

Six years ago this theory was little more than a laboratory phenomenon. Today it is a commercial reality.

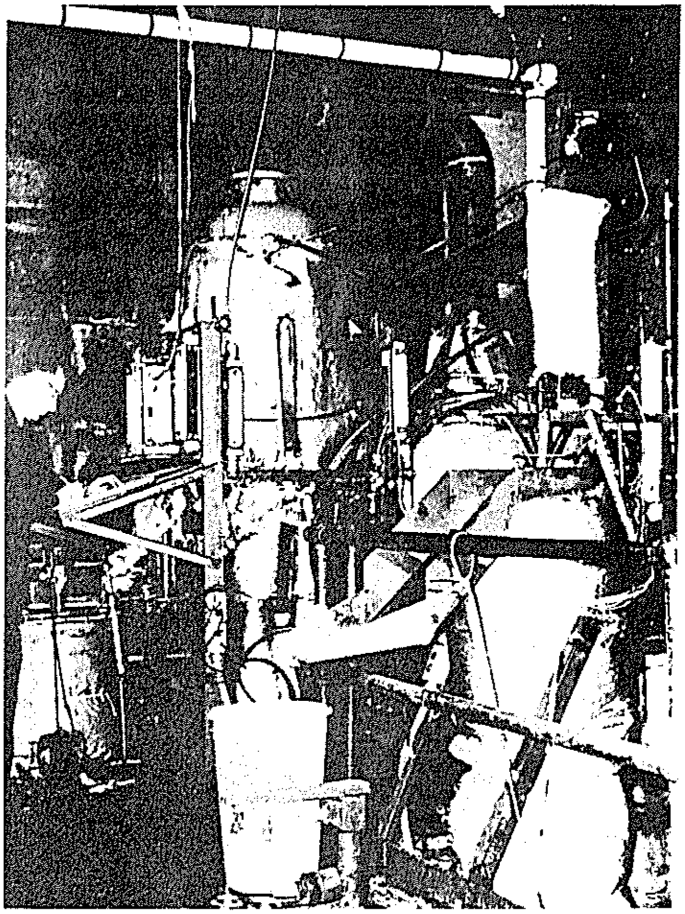
This process, known as electrodialysis, utilizes a combination of electric current and thin membranes of resin or plastic to remove the dissolved solids from the water.

An electrodialysis cell consists of a sandwich of alternating cation permeable and anion permeable membranes. Upon the application of an electric current the positively charged ions, (such as sodium) pass through the cation permeable membranes and negatively charged ions, (such as chloride) move in the opposite direction and pass through the anion permeable membranes. The water in the center chamber of each membrane sandwich is thus depleted of salt while the water passing through the intervening pairs is enriched.

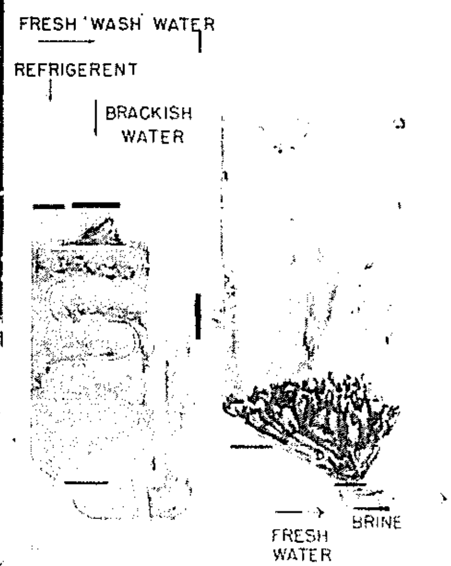
One of the limiting factors in the use of this process has been the membranes themselves. Consequently, during the past few years, considerable research has been aimed at improving the characteristics of those membranes. As a result, greatly improved ion selective membranes have been developed. This process has proved most efficient for the conversion of brackish water.

One of the most advanced electrodialysis processes is that of Ionics, Inc., of Cambridge, Massachusetts, developed through assistance of the Office of Saline Water. More than 20 Ionics production plants are in use having capacities ranging from 500 gallons per day upward, with the largest plant of 86,400 gallons per day in the Middle East at Bahrein.

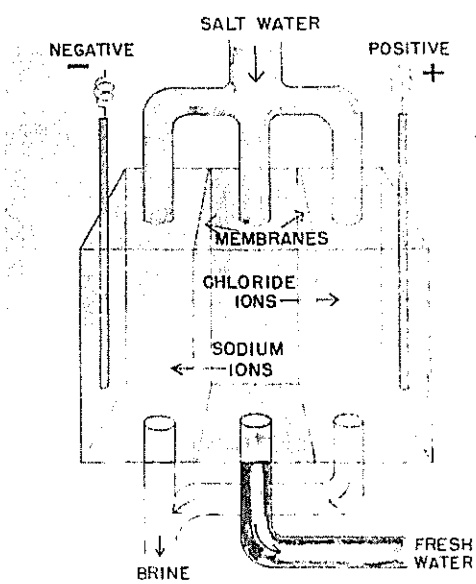
We have expanded our research program to include atomic energy. We have just recently completed a contract study of the applicability of combining nuclear reactors with saline water distillation processes.

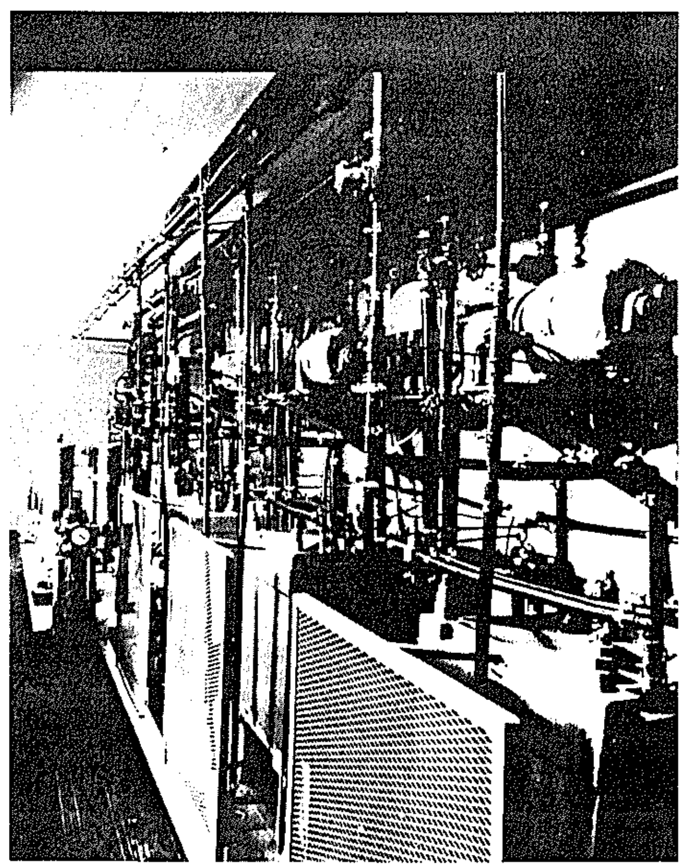


FREEZING



ELECTRIC MEMBRANE





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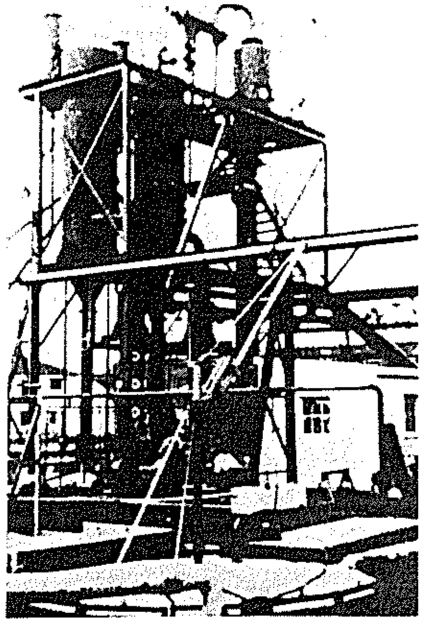

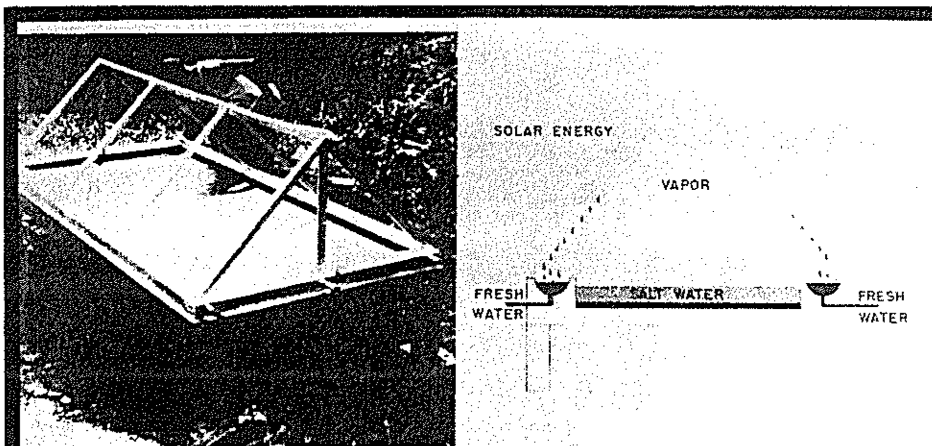

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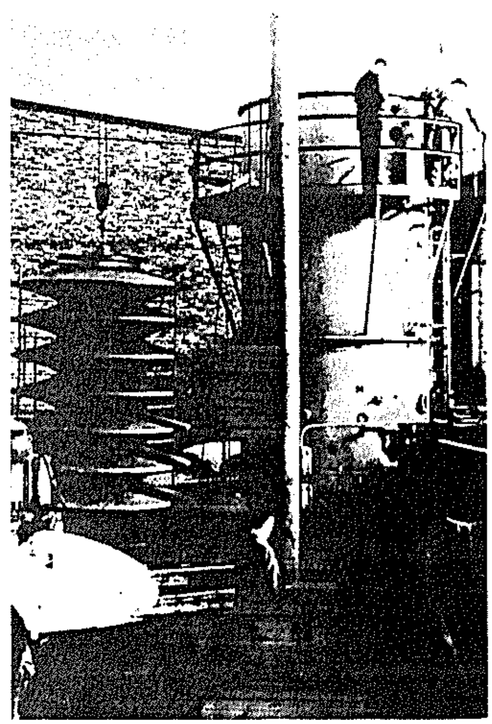

A new $98,000 contract co-sponsored by the Office of Saline Water and the State of California has already been negotiated for definitive study of a process reactor-steam plant, in order to estimate costs and establish problem areas for research and development work through pilot plant operation.

We know the conversion of sea water to fresh in great quantities will require the expenditure of a staggering amount of energy - either as thermal energy for distillation or mechanical energy for pumping. The energy requirements are so large, indeed, that it seems unlikely, at least in certain areas, that fossil fuels can supply this energy without seriously affecting the supply-demand balance.

Not only is there a great abundance of nuclear energy, it also has definite potential economic advantages in comparison with other fuels.

We will continue to vigorously pursue our research in the application of nuclear energy as a source of heat for distillation, and at the same time, explore the possibility of adapting its use to the development of other processes.

The Office of Saline Water has negotiated over sixty research and development contracts. Of these: 20 have been with universities and colleges; 30 with research organizations; 10 with industrial concerns; and 3 with government laboratories. These contracts have a value range of $1,000 to $245,000. You might be interested to learn that one of these, a $1,200 contract was with New Mexico Highlands University for a preliminary study of solar energy storage materials. A new $8,000 contract has just recently been signed with Highlands to further develop the original contract studies.

In addition to the research and development contracts, the Office of Saline Water has also entered into five cooperative agreements. One of these is with the State of California. Negotiations are underway for similar agreements with the States of Texas and Florida. Perhaps this group will provide the spark that will bring New Mexico into formal participation in the saline water conversion program. Such participation, as I will point out in a few moments, might have considerable bearing on future developments of the program.

Now, I want to dwell for a moment on the future prospects of the program and, if time permits, I will attempt to answer any questions you may have.

The future is bright.

Plans are now being completed to inaugurate a new and highly important $10-million development program authorized by the 85th Congress. This legislation was introduced by New Mexico's own Senator, Clinton P. Anderson. He was later joined in the sponsorship of this Resolution by Senators Case of South Dakota, Kuechel of California, Wiley of Wisconsin, and Johnson of Texas.

This new legislation authorizes us to design and build not less than five large demonstration plants to test some of the new processes that are being developed.

The Secretary of the Interior, Fred A. Seaton, who, I assure you, has an intense personal interest in this program, will select the first process to be tested on or before March 2, 1959, and the remaining four processes at three-month intervals thereafter.

Three of these processes will be designed to test sea water conversion. One will be located on the west coast, one on the east coast and one on the gulf coast. Two of these plants will have a designed capacity of not less than one million gallons per day.

Two plants will be built to test brackish water conversion processes. One of these plants will be located in the Northern Great Plains and the other in the arid areas of the Southwest. One of these plants will have a designed capacity of not less than two hundred and fifty thousand gallons per day.

The Department is actively seeking State and local financial assistance and cooperation in selecting sites for these plants. Six principal conditions will be considered in reaching a decision on the location, size and type of the five different processes.

These conditions are:

1. The type of process to be demonstrated.

2. Location where water is needed.

3. Availability of the raw produce - saline water.

4. Local factors affecting the plant.

5. The type and extent of local public and private financial support, including the viewpoints of the State or other cooperating agencies.

6. Demonstration value.

A prospectus outlining these six conditions has been prepared and is now available to States or other interested parties. (I have a few copies of this prospectus with me, and will distribute them on a first come--first served basis).

We expect to gain much valuable new knowledge from this program. Knowledge that will bring us much closer to the day we will be able to supply the technological information that will provide fresh water from sea and brackish sources at a competitive price for homes and industry, both here and abroad.

As we continue to make progress in the field of lower cost conversion, the tangible results of potential succes are challenging to imagine: hugh plants rising along the seacoast, capable of producing millions of gallons of fresh water a day; other plants for brackish water inland; providing life-giving liquid to great tracts of now arid wasteland--in America, North Africa, Australia, the Middle East--made to bloom and bring forth a good life and a higher standard of living for men, women, and children around the globe.

A LOOK AT NEW MEXICO'S WATER PROBLEMS

A. G. Fiedler*

I am especially happy to attend this Third Annual New Mexico Water Conference, not only because of the opportunity to represent the United States Geological Survey but also because the subject of this conference is one which interests me greatly as an individual.

This interest goes back a long way - longer than I like to be reminded of - but suffice it to say the from 1925 to 1928 my Geological Survey colleagues and I worked with the people of Chaves and Eddy Counties in a study of the problems of the Roswell artesian basin. I am informed that in the Pecos Valley, at least, the results of those studies are fairly well known, and that they seemingly have had some effect on the State's water policies. To provide the background for subsequent remarks, a brief review of some of the history of that work may be of interest.

Extensive use of the Roswell artesian basin as a source of water for irrigation farming began around the turn of the century. Soon it was recognized that this use was affecting the artesian head and that some degree of regulation was desirable. The first act of the State Legislature regarding use of water from the basin was passed in 1905, and, as conditions continued to deteriorate, a series of legislative acts were passed during the 20-year period ending in 1925. By this time it had become evident that some evaluation of the magnitude of the water resource would have to be made. The Geological Survey was called in and the investigation I mentioned earlier was undertaken. The results were published in U. S. Geological Survey Water-Supply Paper 639 and in the Biennial Reports of the State Engineer of New Mexico.

It didn't take very long to get a reasonably accurate idea of the amount of water available from the artesian basin. But what did take some time was to acquaint the people of these counties with our appraisal and to reach some reasonable conclusion as to what should be done to improve conditions in the artesian basin. As a result of a recommendation made in the preliminary report of the Survey's investigations, published in 1926, a law was passed in 1927 which declared certain waters to be public waters subject to appropriation for beneficial use. Although declared unconstitutional on technical grounds

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by the State Supreme Court in 1929, that bill, suitably modified, was the basis for the 1931 Act of the State Legislature, which has become a model for much other ground-water legislation throughout the West.

Not yet can it be stated, however, that this act has solved the ground-water problems of the Roswell artesian basin, or of the State as a whole. The impact of a great expansion in farming activities, due to high agricultural prices, and of a rapidly expanding population was too much for it. Thus, the Geological Survey's studies have not yet led the people of this State out of the apparent wilderness in which they find themselves. It merely pointed the way. There is no panacea which will solve all existing problems.. So that there may be no misunderstanding as to my position, it may be pertinent to call attention to the subject of my discussion, namely, "A Look at New Mexico's Water Problems." In the final analysis of our subject, I become simply one more worker in what has turned out to be a pretty complicated vineyard.

During the 30 years that have elapsed since the Survey's study of 1925-28, I have not been intimately in touch with all the excellent water studies that have been in progress in New Mexico, but I have followed with more than casual interest the forthright efforts of State administrators in applying scientific knowledge in the administration of water rights in the State. Despite this absence of intimate contact, I hope I may be pardoned for making some comments as to the nature of New Mexico's water problems, and I may even go so far as to indicate what might be done about some of them.

One conclusion that can be reached is that no one can consumptively use the water of a stream system, including its tributary ground water, without affecting the supply available to his neighbor.

A second conclusion is that the primary and determining characteristic of a water resource, and the one that differentiates it from other resources, is its variability.

Lest these conclusions be dismissed as being too obviously fundamental, let me say that every water problem stems from trying to ignore or to overcome one or both of them.

The Territory and State of New Mexico have dealt with water problems for more than 100 years. If these two conclusions are valid and if they have been recognized in one form or another for 100 years, why is it necessary to have meetings like this one? Why is it that today we seem to be in such an uncomfortable - shall we say - situation with respect to water use? It is not enough to say that we don't have enough water; it has been known for 100 years that New Mexico's climate is largely arid to semiarid, there being only small areas that are subhumid.

It took 100 years for our present development and demand for water to evolve. This leads me to a third conclusion - it is that our ability to cope with water-resource problems cannot exceed our understanding of them.

When water-resource development began in New Mexico the first two conclusions were quickly recognized and the conditions were equally quickly remedied. The doctrine of prior appropriation took care of the first deficiency and storage of water the second, insofar as surface-water supplies were concerned. Ground water, however, as a source of water supply, was of no particular importance - something that could be left, along with some other intangible and indeterminate problems, to the water witches and to students of supernatural phenomena. The fact that we had no knowledge about a very considerable portion of what today we call the hydrologic cycle didn't make much difference. All of which indicates what a tremendous margin for error there was in the utilization of the State's water supplies. It was not surprising, therefore, that problems of the future did not figure prominently or cause much concern during our first 50 years of development.

That is not to say, however, that there were no problems. Certainly there were. For a long time, if what we hear is true, the shotgun must have been just as important to the irrigator as his shovel. But along with measurement of water came statutory law and court decrees - with order, came organization. And, with organization, came a more complex development which used a greater proportion of the water resource. Thus by 1906 we had the ability to conceive and plan the Rio Grande project, including the tremendous Elephant Butte Dam, then forming the largest artificial reservoir in the world.

But, unnoticed and unconsidered, like the flaw in the title to the homestead in the old melodramas, were two important facts. Even after 50 years we didn't understand the hydrologic cycle fully, and we didn't realize how widely a water supply might vary.

As might be expected, an artesian basin was the first important source of ground water developed for irrigation use in New Mexico. I say "expected" because, where pumping is not needed, water is available at low cost. But the rapid changes brought about by increased water withdrawal in the Roswell area had an important effect which we don't think of today. One of the important reasons that prompted the Roswell investigation was that the farm loan banks considered the long-term availability of water so uncertain that loans for farming operations were made only on the basis of dry-land values of $10 to $15 per acre, whereas irrigated lands having a good water right were valued at $250 to $300 an acre. Other capital was available only at high rates of interest, 10 to 12 percent. So, although water might be cheaply available, the cost of developing a farm was high.

The Geological Survey's study in 1925-28 had two purposes, to delineate the magnitude of the water resource, and to establish the basis for a means of regulating the use of water in the basin. It is interesting to note that the means of regulating the use of water proved to be the extension of the doctrine of appropriation. The 1927 act declared that waters "in underground streams, channels, artesian basins, reservoirs or lakes, the boundaries of which may be reasonably ascertained by scientific investigations or surface indications" were public waters and subject to appropriation for beneficial uses under existing State laws relating to surface-water supplies. Subsequent history has shown that the magnitude of the water supply was evaluated successfully and that most of the financial difficulties were overcome.

Many technicians recognized in 1927 that there were certain deficiencies in the proposed code for the control of the use of ground water. The most important was in trying to separate ground water from surface water and, at the same time, applying to ground water the same regulations that were currently being applied to the use of surface waters. Furthermore, the law was made applicable to specific classes of ground water. Fortunately, New Mexico did not wind up with as many different kinds of ground water as some States.

Several reasons can be given as to why things were done the way they were. First, we did not possess our present-day tools for measuring and evaluating the role of ground water in the hydrologic cycle. Second, the authors of the 1927 act knew that the classes of ground water to which the law applied were cumbersome and unrealistic, and were not those endorsed by competent hydrologists. However, court decisions and water law in the West had so firmly established the pattern of classifying ground water that they believed that, in order to obtain the passage of legislation which would provide some measure of control over the withdrawal of artesian water, it was necessary to adhere to accepted legal terminology. Had the authors of the 1927 act simply stated that all ground water was public water subject to appropriation for beneficial use, it is doubtful that a law would have been enacted until many years later. From a practical standpoint, the only important critical area at the time was the Roswell artesian basin. No proposal, satisfactory to the area in question, was to be jeopardized through an inability to achieve an understanding on a statewide basis. In other words, it was hard enough for Chaves and Eddy Counties to understand what their problems were. To attempt to educate the whole State at that time would have been impossible even if the education had been restricted to ground water. Still more impossible would it have been to point out the interconnection of ground water and surface water and to gain acceptance of the concept, now coming to be recognized as inevitable, that rights to interconnected surface and ground water must be correlated.

By the early 1940's, we had made a great deal of progress in resource development. We were coming more and more to understand the basic problems involved. The Rio Grande and Pecos River Joint Investigations had done much to evaluate major surface-water supplies in the State and to appraise their uses. Ground-water development in the Pecos and Mimbres Valleys was proceeding on what appeared to be a stable basis. Interstate agreement had been reached on the use of water in the Rio Grande. Discussions leading to the adoption of a Pecos River Compact were under way. Our water supplies, bolstered by the heavy precipitation of 1941 and 1942, looked good. By the end of the war it seemed as though we were well on our way to a new level of development of the water resources of the State.

But we still had not looked critically at some of the fundamentals of water-resource development. We still had not faced the first two of the conclusions that I have set forth today. So, in the last 10 years the errors of our past have caught up with us.

Since the war New Mexico has had a tremendous increase in population. This increase has been responsible for an ever-increasing demand for water. High prices for crops, increased efficiency of pumps and motors, and efficient farming methods have led to more intensive use of our water resource. But as communities have increased in size they have turned almost without exception to ground-water sources for new supplies of water.

At the same time, New Mexico has gone through a period of sustained drought. Declining amounts of surface runoff led to installation of pumps in areas which before had been wholly dependent on supplies delivered by gravity. Thus, at a cost, we met our water demand in the face of declining supplies. How long this could have been kept up I don't know, but certainly it is fortunate that we have had above-average precipitation for the last two years.

There is a real question as to how the drought we have been through compares with the droughts of former years. Though we may all hope for more abundant rainfall in the next few years, we should not overlook the fact that droughts will return. Even though the floods that have occurred in Texas in recent months are still in mind, Dr. Vance E. Myers, a University of Texas meterologist, warned in an article in the Austin (Texas) Statesman of August 20, 1958, that droughts would return to Texas within the next 15 to 20 years. This forecast supplies emphasis to the fact that periods of plentiful precipitation will ultimately be followed by drier periods. The low runoff of the 1930's coincided with low farm prices and poor business conditions. What would the severe droughts of the past have been like if we had been trying to maintain or increase water yield in a time of declining supply? Are we, therefore, able to sustain our present demands upon our water supply without high-cost importation from areas which now are favored by a surplus of water?

The answer, as I see it, is clear. Under present conditions, no. The next question is, of course, is there anything that can be done about this situation? Here the answer is, perhaps. I am certain that we will find no panaceas, no quick and easy answers to our problem. What we must do is to really being to study water in all its forms and learn how to use it to the best advantage.

This study of the various phases of the hydrologic cycle must be undertaken so that all the forthcoming results remain in their proper perspective. We must understand why water does or does not precipitate as snow, rain, or hail, yet we must not be led, at the outset, to assume that cloud seeding or any other process is the cure to all our problems. We have to learn those conditions under which we can suppress evaporation at reasonable cost. We must study means of reducing the consumption of water by nonbeneficial vegetation. But we must also be certain that we know the difference between beneficial and nonbeneficial uses. With respect to this latter item, I can recall a period when tree planting was considered a means of modifying climate and creating more abundant water supplies. We all appreciate the beauty and value of trees and their usefulness in preventing erosion; however, it is now well understood that trees consume water as do other types of growing vegetation.

Our increasing demand on ground-water supplies has brought us into contact with water of poor quality. There is need for further study of the processes for the conversion of brackish waters to fresh water. Until we have evaluated the magnitude of our brackish-water resource and developed an efficient low-cost means of conversion, we must look elsewhere for help. In this connection it should be mentioned that the term "low-cost" in relation to processes for improving the quality of water is a relative one. A process may be considered low-cost if the yield in terms of salable product is sufficiently great to permit at least a reasonable profit. A process may be low-cost if it is used for producing an industrial product of high value. The same process may be high-cost if used to provide water of a quality suitable only for the irrigation of ordinary field crops.

Through this discussion I hope it is evident that we cannot expect any wonderful or miraculous cure for our water-supply problem. Until we realize this we are not going to get at the heart of the situation. Our chief problem is that of determining how we shall use a resource that varies in magnitude. It is entirely evident that we must know something about this resource, but, having done that, we are confronted with the crux of the problem - how do we, as water users, agree to use this resource? As Shakespeare said, "Ah, ther's the rub." Because, when we deal with people we are concerned with government operation and free enterprise, property rights and socialism, priority and state control, all of which may seem to have nothing to do with water. However, these subjects form the philosophic background of any discussion that has to do with procedures devised to administer the use of this variable resource, and they must be considered in reaching solutions.

Up to the present time our efforts have been in the direction of trying to validate a use of water which is junior in right under the doctrine of appropriation. This has been done at a constantly increasing cost. It can be shown, however, that there is a physical as well as an economic limit to this process. Under the most careful plan of development we will have periods when there will be an expansion of use of water that cannot be sustained in other years. How do we, or do we, provide the organization and means of control that will hold down the waste of water by beneficial users and the consumption, by either evaporation or transpiration, that is of no benefit to mankind?

Our chief hope, it seems to me, is for an understanding of the situation at all levels among our people which will lead to a willingness to pay the cost of learning the limitations of the water resource and of adopting the measures that will enable its full development. The cost will be both economic and social. It will involve higher taxes to support the necessary investigations, and it will require social adjustments to realize the maximum economic return from every drop of water. And, at the same time, it will require just compensation for existing water rights which are transferred to other uses. This effort, of course, presupposes a full understanding of the water situation by those technical people who deal with water in its physical form. It is here that I must make reference to my own agency, the Geological Survey, to the Weather Bureau, and to the other agencies, governmental and private, that are engaged in the study of water, and to the administrators of the laws and regulations that govern the use of this resource. These are the people who must be responsible for the details of planning the water-management program of the future.

The situation, in brief, can be well summarized by a statement which appeared in a recent report issued by the Conservation Foundation of New York. It is quite applicable to the water problems of New Mexico, as well as to the water problems of many other areas in the United States:

> "We are still developing water in shortage areas for uneconomic uses. We are blithely expanding our uses, and developing claims on water with no clear plan for its allocation. Water developments, once accomplished, are permanent commitments of capital, location, and economic prospects, as well as policy. But public policy, such as it is, has suffered a series of conflicting, antiquated or ill-thought-out and unrelated year-to-year actions...There will not be <u>more</u> water (barring some unlikely developments) in our time. There <u>is</u> water to be had, for a <u>price</u> in money, effort, and by careful thought, planning and compromise. Better use,

wise use, and full use are attainable goals. Entire water courses need development. We must guide the direction of our progress rather than drift into the future."

New Mexico, as a leader in water legislation in the West, already has a solid foundation of law on which to build the water developments of the future. She must now undertake the difficult effort of making those sound principles effective in terms of new legislation, development, and management that will safeguard her future for the next thousand years and beyond.

ACKNOWLEDGMENTS

Especial acknowledgment is made to Thomas Maddock, Jr., Hydraulic Engineer, Water Resources Division, U. S. Geological Survey, for assistance in the preparation of this paper.

GENERAL DISCUSSION

(Change to O'Meara)

Q. Are plans being made for research in California on desalinazation using atomic reactors? A. No, there has been no contract let for construction of an atomic reactor which might be used on desalinazation. The Atomic Energy Commission is checking the books now, but there are no plans. I am hoping that this will be done. But it will require a plant having a capactiy of 20 million gallons per day. We are hoping that experimental plants now in existence will yield information on this.

(Reynolds to Aston)

Q. Are comments in order from the floor? A. Yes. Comment - It appears that there are some questions on the quality as well as quantity of information on our water resources. We are concerned that many will be left with too dim a view of the information available on New Mexico water resources. We do have a revised program for preparing a comprehensive index. However, the job is not adequately financed. The inventory of water resources is being done in cooperation with the Geological Survey. A 50-50 cost-sharing proposition is the present situation. New Mexico occupies a leading position in the Southwest in this respect. Our state also leads in study and action to control phreatophytes (water-consuming weeds) to salvage existing water supplies.

The only surface water sources still not fully used in New Mexico are the San Juan River, the Canadian River below Conchas Dam, and the Gila-San Francisco Rivers...Industry can increase its available water supply simply by buying up water rights from farmers, as is permitted under New Mexico law.

(Aston to O'Meara)

Q. A community of 6,000 people in California is proposing a program to treat brackish water. Do you have any information on this? A. No, they went ahead on their own. But it will be an ionic process. They are importing water now by truck. The process will cut drinking water cost in half. This is the first city to my knowledge to do this.

(Aston to Miller)

Q. Do you have anything on this? A. It is supposed to produce 28,000 gallons per day for an average cost of $1.50 per day per capita for drinking water on an investment of $80,000.

(Aston to Panel)

The population density in the Southwest of three persons per square mile is the lowest of any temperate area. Our limiting factor is water. Do any of you have any comment?

(Answer by Dearing)

We have made population studies in Arizona. It is hard to differentiate growth factors and trend factors (movement from one part of the county to another). There is a trend of new population to the Southwest. We wonder about such items as occupation, age group, and income. Is it from the retired group or a group of young settlers? Whatever the reason -- they are coming. And even a moderate increase in the supply of water has a big effect -- especially in electronics with its relatively low demand for water. But around Tucson, Phoenix, and in New Mexico, chemical industries are limited because of their large demands for water. We do have growth in electronics.

(Comments by Wentworth)

We have been watching population increases which are comparable only to two other parts of the world. Many people may be retiring but the missile-nuclear-electronic complex has had the effect of bringing in highly desirable types of people -- physicists, chemists, and engineers. We are getting a very desirable class not willing to leave the area voluntarily.

With 94 percent of our water used for irrigation, 4 percent for industry, and 1 percent for urban consumption, a small decrease in water used for agriculture could give a great impetus to industry. Actually, a small transfer would be all that is necessary. Other than this, New Mexico has three substantial areas of surplus surface water -- the Canadian, San Juan and Gila-San Francisco rivers. Concerning an inventory -- a very substantial contribution has been made by the New Mexico College of Mines in terms of education and research. The water shortgages are only relative. On the other hand, it is serious for most industries. We have consumed only beneficially about one million acre feet out of three million. We probably do have an adequate total supply. The problem is in putting it to beneficial use.

(Aston to O'Meara)

Has anything been done with desalinization by-products? Yes, with brine (possibly a pickle factor). Seriously, we can reduce the brine down for chemicals. However, it is not economical yet. We do have problems now of brine disposal. We cannot solve the problem independent of site. Each site has its own problems. I would like to congratulate this group. Out talk must be followed by action. I congratulate you people for participating in this type of conference.

(Aston to Fiedler)

On predictions, how have predictions of disaster been avoided (such things as dropping water tables)? They are not now apparent. (Answer) The question has many aspects. I must confess that investigations of 1925-28 did not have the mathematical and hydrological tools available today. Old reports used common sense. On studies of the Roswell-Artesia Basin -- The answer was to try and get your teeth into it. First thing -- what problem is chosen. We tried to find out what was available. We reviewed old reports such as the geological survey (1905-25). We reviewed the laws of the period. We reviewed data based on reports of users to well supervisors. We had to cull out bad reports. We had to reconstruct the day-to-day evidence of what was occurring. We measured artesian quality of water. Also, we made observations on shallow ground water in the artesian basin. The solution we decided was to divert pressure from the artesian to the shallow ground water level. This is not related directly to artesian supply. All of this is rambling around the question. But in summing up: (1) Find out what we have for analysis, (2) Conduct out research in aspects of problems which are least known (i.e. brackish water, origin, migration, elimination of salt cedar). There is much to be done in fundamental research in the hydrologic cycle. From there we must formulate a plan. The plan must be made by those most qualified to make them. <u>Also we need some selling</u>. Where the public is involved, we must educate them. They must go along with the project. In utilization work, the plan must be sold to those carrying out the plan or to those that see the plan is to be carried out. We must convince people to get behind the plan (such as public-spirited citizens). The final problem is executing the plan.

(Comment by Robert Emmett Clark of New Mexico University)

The past year the Law School has received a $10,000 fund to purchase materials. The Law Faculty voted that one of the four areas in which this fund should be spent is natural resources. There is a need for understanding in this area. A large part of their decision was the recognized need for publication of these conferences. It was a unanimous vote.

(Question from floor to O'Meara)

Is there an overall federal program for control of water? (Answer) I am not able to answer that question.

(Question from floor to O'Meara)

Is there a program to study the use of waste and sewage water? (Answer) Yes, under the program of pollution control.

(Comment by Dearing)

In Los Angeles and Baltimore the effluent is being used in aluminum and steel plants (100,000 gallons per day). Some other studies indicate considerable sewage is being lost. Studies indicated water on highways and airports are being lost and airports in New York City alone could supply the water needs of 40,000 people.

The Water Research Council has been very concerned with pollution. About 50 percent of the water loss in the East is through pollution. It is a big source of damage. There are between 4,000 and 6,000 sources of pollution. The government does have a $50 million program on pollution control.

(Question from floor to Fiedler)

What percent of the total water supply is evaporated and how is it being controlled? (Answer) Suppression of evaporation is under study by several agencies in the Department of Interior, the Geological Survey with the Corps of Engineers, and local agencies. They have used monomolecular films in order to suppress evaporation. I am not too familiar with their studies, but considerable progress has been made. The answers are not yet conclusive. The suppressant is not effective on large areas because of turbulence by wind action. Progress is being made on transpiration. The U.S.D.I. and U.S.D.A. indicate substantial losses of water by transpiration. Different types of plants use different amounts and cutting down vegetation is one attempt to eliminate undesirable heavy users. Conversely, some plants are encouraged to prevent erosion. These should be plants with low water use.

(Question from floor to Aston)

My impression is that New Mexico is in a desperate water situation. Is this true? (Answer) No, because we have a lot of water which can be put into beneficial use if we can develop the proper techniques.

(Comment by Stucky)

We do have 90 million acre feet of water falling on New Mexico. We use only 4 million acre feet for municipal, industrial and irrigated agriculture. If we could cut down on the estimated 60 percent which evaporates annually, we would increase our water supply tremendously. Even a 5 percent reduction in this loss would give us over 4 million acre feet of water, or as much as we are now using.

(Comment by Reynolds)

Concerning effluent -- many cities are using it, but not local effluent. They are using the effluent from other cities. However, it occurs to me that the host institution can make a major contribution on the efficient use of water. The program is hampered by a lack of financing.

On Dr. Fiedlers comment on evaporation control -- the techniques are applicable to small reservoirs, 1 to 2 acres in size.

The stockman faces the problem of dry stock tanks in summer. If evaporation could be reduced 50 percent, and since stock use very little water, the technique is very applicable to stock tanks. The host institution could make a major contribution on design and management of stock tanks.

(Comment by Aston)

We are contemplating turning out a phamphlet which would define terms and indicate problems. No one should believe that New Mexico has used all of her ground water. We do have areas of unexplored resources. We should not project specific problems to cover all of the area.

(Comment by State Health Official)

New Mexico has only one community that does not have a sewage treatment plant. The federal government has given $2 million to the state for development of these plants. Eight million dollars has been spent in the past few years. They have made studies to determine if atomic plants are contaminating ground water. Anaconda has spent $500,000 to make sure they are not contaminating water. This indicates that they are quite concerned about contaminating water, when a private concern spends this much money

(Concluding Comment by Aston)

I suggest the group adopt a resolution to have one of the desalinization plants proposed by the government be located in New Mexico. (Vote taken and the resolution approved). I suggest we send the resolution to our congressional delegation, to various government offices, and to the office of the State Engineer.

WATER'S CHALLENGE TO OUR FUTURE

Elmer G. Bennett*

In the foyer of the Department of Commerce building in Washington, there is a big clock to which is attached a counter turning big numbers ahead at the rate of 330 per hour. The register is recording our national population which is presently increasing at that rate.

On October 16, that counter turned 175 million. Tonight, as I am speaking to you 21 days and nine hours later, it has gone up another 182,652. By 1967, according to the demographers whose business it is to keep track of population trends, the count will exceed the 200 million mark.

Within the next 20 years, according to Census Bureau projections, we will have a population of 260 million and 2010, fifty years from now, our population will have more than doubled, probably ranging around 370 million people.

That population gain will be felt by every one of our states which by that time should surely include not only Alaska but also Hawaii, and by our territories as well. If the present trends continue, the impact will be greatest in the West as it has been in the last two decades.

Since 1940, the population of the western states has increased 55 per cent--from 27 to 42 million people. This is nearly twice the national rate of increase. I am indebted to U. S. News and World Report for other growth statistics which are relevant to our discussion here tonight.

Between 1940 and today, employment in the western states has increased 108 per cent, which is nearly double the rate of population increase. Personal income is up 455 per cent, bank assets are up 379 per cent, capital spending for plant and equipment is up 930 per cent and the value of manufacturing output is up 770 per cent.

All of these rates of increase are sharply above the national average. Project these rates of increase in business statistics along with the indicated rates of population increase and it leaves one more than a little breathless about the future of the West.

But there is another rate of increase which should give pause in our optimistic outlook concerning the West's economic development. If we had a register recording the rate of water usage to correspond with the rate of population increase, it would be pushing ciphers clear out

*Undersecretary of the Department of the Interior

of the end of the four-block-long Commerce Building by now.

Back at the turn of the century when we took our baths on Saturday night in an old tin tub by the Kitchen stove, our daily per capita consumption of water was 530 gallons. There were no air conditioners, no garbage disposals, few great industrial plants, and less than a fourth as much irrigated land as we have today.

By 1930 our per capita consumption of water had climbed to 900 gallons per day. Today, we are requiring a per capita supply for all purposes, domestic, industrial, and agricultural, of 1600 gallons daily, nearly three times our average individual need a half century ago. In terms of total use the figures are more startling. We are using 280 billion gallons daily compared with 40 billion gallons in 1900.

It is a little more difficult to anticipate future per capita water requirements than to project population trends, but some forecasts have been made placing the per capita requirements as high as 2200 gallons by 1975. Our water needs are increasing at a much more rapid and remorselessly geometric rate of progression than is our population.

This is one of the great challenges facing the United States today. Even more than nationally, it is a challenge to the West. The 85 million gain we may anticipate in population during the next 20 years is more than the nation absorbed in the entire nineteenth century. During that period of westward expansion, virtually everthing west of the Appalachians was virgin territory and there was elbow room for everyone.

There is still lots of elbow room in the West but it will require foresight and imagination if it is to be made capable of supporting the vast population of the future.

Dr. Walter Prescott Webb, the eminent western historian, is quoted as saying that the West, within foreseeable times, will never be as congested with population as are some other parts of the country. I am in complete agreement with him that it will always have plenty of wide open spaces.

Many areas are simply not adaptable to carrying a concentrated population. Then there are those magnificent areas of our national parks and some forest and public land areas which must be protected and retained in as much their natural state as possible even though they are already the Mecca of vacationing millions.

But there are many other areas, rich in natural resources and potential expansion in industry, agriculture and population, that await development. They need only the pressure of an onrushing civilization, the catalyst of an increasing population, to bring to fruition the process that has been slowly evelving since the first settlers pushed their way west across the Mississippi.

I use the term, slowly, advisedly. Actually, it is amazing what has been accomplished in the western states in the last century or even the last half century when the pace has been even swifter. And always the pace has been geared to the availability and use of water.

Back in the middle of the nineteenth century, the new territory of New Mexico was probably best known for the criss-crossing of the Santa Fe trail and the Goodnight trail up the Pecos, where the cowboys herded the longhorns from the winter grass in Texas to the summer ranges in the Rockies.

Then, as now, water was one of the territory's principal problems. I am indebted to a clipping from the El Paso Times for a story concerning the investigations along the Pecos River by Captain John Polk in the 1850's.

On the instructions of the War Department, which was seeking a rail route west, Captain Polk spent several years drilling for water at various places in the Pecos River basin. He was unsuccessful, not because of the lack of artesian water, which he found repeatedly, but because of improper equipment. Wooden boring rods and casings, and soft, wrought iron pipe, were simply not up to the task.

Nevertheless, there was a portent of things to come in a report to Secretary of War Jefferson Davis in 1855. Here is what Captain Humphreys of the Topographical Engineers wrote: "If a demonstration of the practicability of constructing artesian wells at moderate cost on the interior plains and table lands can be joined by the discovery of coal beds, fertility, industry and wealth may be made to take the place of sterility and solitude over extensive areas of those arid, naked and treeless districts."

A method of construction of artesian wells at moderate cost was developed and coal beds were discovered and mined in New Mexico. While the two were not as closely related in development as Captain Humphreys had hoped, nevertheless they have both been of major significance in the growth and prosperity of this state.

I have no doubt that New Mexico will face up to the future challenge of an adequate water supply because it has always been a leader in this field. The Rio Grande and Pecos are the principal sources of surface water in the state and there were irrigation projects on both streams long before the Federal Government entered the picture.

Irrigation is reported to have flourished on the Pecos River under the Spanish land grant colonization system early in the nineteenth century and the early American settlers had extensive systems in operation in the 1850's. From these early beginnings came the Rio Grande and Carlsbad projects which were among the first undertaken by the Federal Government after passage of the Reclamation Act of 1902.

Since that time, the Federal Government has been a copartner with the people of New Mexico in development of the State's water resources and has invested approximately $90 million in Reclamation development in the state.

This cooperation is inherent in your state constitution which reserves for the United States, and I quote, "with full acquiescence of the people of this state" all of the rights and powers of the Reclamation Act of 1902.

As early as 1931, New Mexico enacted legislation declaring that ground water occurring in underground basins having boundaries that are reasonably ascertainable is public water and subject to the doctrine of prior appropriation. In 1953, this law was strengthened to declare that all underground waters of the state are public waters and that permits to appropriate are required when declared by the state engineer. Your state is far, far ahead of most of the West in this important field of ground water regulation.

I can say from personal knowledge that there has been a close and cooperative working arrangement between the Department of the Interior and the State of New Mexico in the last several years. This is due in no small part to State Engineer Reynolds and his predecessor, John Bliss, Governor Mechem, and your congressional delegation.

In 1956, as an example, the state engineer declared the entire Rio Grande basin area adjoining the river a closed ground-water basin because of the inter-relationship between surface and ground water which was affecting the river flow. His action, in effect, protects the holders of surface-water rights and permits the planning of further orderly water conservation measures along the Rio Grande.

This groundwork of close cooperation between the State and Federal Government permits high optimism in viewing New Mexico's acceptance of the challenge of the future.

The Navajo and San Juan Indian irrigation projects have been sensibly planned as the result of remarkable cooperation on the part of the state, the Navajo Tribal Council, and the Department of the Interior, represented particularly in this instance by the Bureau of Reclamation and the Bureau of Indian Affairs.

In this case the policies were established by the state, and the technical studies and services in general were made by the Federal agencies. The state, however, assumed the leadership in ironing out the conflicts between different interested groups and achieving agreement on a coordinated plan.

Navajo Dam is now under construction on the San Juan River, and I feel confident the San Juan-Chama and Navajo Indian irrigation projects will follow in the orderly process of Reclamation authorization and construction.

At the state's request, the Navajo Dam is being made large enough to assure use of all of the state's share of Colorado River water if this is found practicable and desirable. Similarly, the tunnels of the San Juan-Chama diversion, which are the limiting factor in that project, are being planned with sufficient capacity to divert 235,000 acre-feet of water annually in the event the state desires such diversion for use in the Rio Grande basin.

It is part of the state's responsibility in the development of its water resources to determine how the water is to be used. This principle is inherent in the 1902 Reclamation Act itself.

There are a number of opportunities within the state to enlarge its water supply by salvage of moisture now consumed by nonbeneficial plants along the various streams. The Middle Rio Grande Project has accomplished a major savings by channelization and the drainage of lakes and swamps.

Similar close coordination with state agencies is being maintained in the studies on the Pecos River. Here the Bureau of Reclamation and the Geological Survey of the Department of the Interior, and the Corps of Engineers are working closely with the engineering advisers to the Pecos River Commission on plans for improvement of the Pecos River Basin.

Congress only recently authorized a water savings improvement for the McMillan Reservoir on the Pecos River above Carlsbad and an initial appropriation for completion of a planning report was made this year. However, some limitations in the authorization and the fact that the Carlsbad people desire a delay in clearing the floodway may defer actual construction of these improvements for some time.

Another means of meeting the future water needs of New Mexico is by small projects. A project does not necessarily have to be large to be successful. However, conservation of water has become a tremendously complicated affair. There are very few projects like the early ones by which our grandfathers diverted a simple stream of water out of a stream or spring into a ditch.

But there is no reason why small projects cannot be developed which fit into the total basin and state-wide concept of maximum water use.

Your state has its own program being carried out by the Interstate Streams Commission, and Federal participation is possible through the Small Reclamation Projects Act of 1956. The State Commission and the Bureau of Reclamation are already conferring on the possibility of one such small project.

Two other technical developments give promise of future water savings which will be of importance in New Mexico's future. One is the purification of salty and brackish water. Your Senator Anderson and Senator Case of South Dakota have been particularly active in supporting the Department's investigations in water purification.

Desalinization processes are already very near a point where a domestic water supply can be developed economically, but we have quite a way to go yet in bringing down the costs to a point where present processes are practicable for making brackish and saline water suitable in the large amounts necessary for irrigation purposes. However, I have no doubt that that day will come.

We would have been labeled dreamers of the wildest variety a half or even a quarter century ago for some of the measures which are being taken today to develop a water supply.

The other major water conservation measure of promise is the use of the chemical, hexadecanol, for use in curtailing reservoir evaporation. This is particularly important here in the Southwest where you have long, cloudless days and large, relatively shallow reservoirs at a low elevation.

The Bureau of Reclamation and the Geological Survey are well along on investigations which, from all preliminary reports, indicate very favorable results on small reservoirs.

The results of wind action in breaking the protective chemical film on larger reservoirs are now being studied.

Thus, in summary, water's challenge to our future is premised on two principal factors--an exploding rate of population increase and an even greater rate of increase in per capita water use.

It is a national challenge but one that is particularly important to the West and to states such as New Mexico, which are enjoying the greatest rate of population increase and conversely have the greatest water supply problems.

It seems clear that there are new possibilities of water supply, new possibilities of conservation which can be developed by the same pattern of cooperative effort that has proven so successful in the past.

Planning must be on a comprehensive basis, that is, to construct and operate projects in such a manner that the greatest possible good will be realized. This means, in most cases, that they must incorporate many purposes. More often than not the water may be used over and over again.

Such multiple benefits can be realized only by close coordination. This in turn, can be accomplished only by full participation and a positive approach by all beneficiaries as well as those water users who already have firmly established rights and who may not benefit particularly from construction of additional facilities.

I emphasize a positive approach because negative thinking, a dog-in-the-manger attitude, will get us nowhere.

Water is wasting away to the ocean in many parts of the world today simply because individuals, groups, states and nations have been unable to get together on development plans.

With the needs I have mentioned looming up larger and larger every day, we no longer have time to indulge in bitter end disputes. There is an urgency to the situation that requires constant and orderly progress in all phases of water development if future generations are to be protected. We must not let them say we have failed.

ECONOMIC DEVELOPMENT COMMISSION

Jack Wentworth*

It is always delightful to return to the campus of A&M College. I am very much impressed with the operation here, the calibre of the faculty and the atmosphere of the institution. I found the program yesterday tremendously interesting. Of course, I am not qualifiied to talk about water and shall not attempt to do so. Being the only non-technical speaker on the program, perhaps I can supply a little variety.

The New Mexico Economic Development Commission is vigorously interested in all areas of the economy, and there is none to which the purposes of this conference are not fundamental. Water is the number one problem with which we are faced in developing the over-all economy of the state. One of the members of the Commission, Mr. Lloyd A. Calhoun of Hobbs, has been very active in this field, and you are all familiar with the interest of Mr. Rogers Aston of the Southspring Foundation, a member of the Commission's advisory group.

It seems to me that this conference, in assembling both experts and laymen to discuss and develop ideas of mutual value, has a substantial contribution to make. In addition to furthering the general knowledge of this subject, great benefits will be gained in public education. It is an important step toward effective action, and the Commission is happy to have a part in it.

I want primarily to discuss economic development, and to tell you something about our work in that field. The Economic Development Commission was established in 1949 and reorganized by the 1955 legislature. It is composed of ten members, one from each judicial district, appointed by the Governor, who in turn appoint the Director. The Commission is advised by a committee of thirty-three leading citizens from throughout the state.

It is the broad objective of the Commission to promote the economic welfare of New Mexico through encouragement of existing industries, new industries, the relocation to New Mexico of out-of-state firms, and development of markets. Its methods are research, planning, and action, each as dependent upon the others as are the legs of a three-legged stool. A complex variety of activities is involved. The compilation and publication of available information and data for distribution, original research, and public education programs are basic. We are developing a mailing list of businessmen and industrialists throughout the country, which now numbers over 1,500. Our national advertising program, which is continuing, has had an effective response. A new color promotional brochure has been given wide distribution, and

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a 16mm sound, color film has been seen by over 1,162,000 people on television, including nearly 133,000 in color. Promotion of New Mexico through the news media is another important activity.

Effective public education programs lead to an increasing demand for services relating to economic development, as well as for information, both from out-of-state prospects and local communities, businesses and individuals. Among these services are calls on out-of-state prospects by industrial engineers, cooperation and participation in conferences with industries and agencies in such diverse fields as uranium, banking, and Indian industrialization, and participation with other agencies in necessary projects. For example, the Commission recently joined with state and federal forestry representatives in the sponsorship of New Mexico's first sawmill clinic, and with others in the preparation of a series of much-needed maps showing the distribution of the state's resources.

In all of its activities, directly or indirectly, the Commission is engaged in competition with other states, territories, railroads and large banks, many of which have similar agencies. It must operate on an annual budget of $100,000 which is a good deal smaller than those of most surrounding states.

One of the principal concerns in economic development is the kind and quality of expansion to be encouraged. New Mexico is a young state; the possibilities for development became apparent only within the last twenty-five years or so. It is now one of the fastest growing states in the nation, with an average annual population increase of 6 per cent. The current population is estimated to be 929,900 an increase of 36 per cent since 1950. It is expected to reach one million by 1960 and one and one fourth million by 1965. The West is the only part of the country gaining more people than it is losing; for every two leaving, three come in.

The rate of economic expansion has been equally remarkable. Total employment increased by 55 per cent between 1947 and 1957, compared with only 12 per cent in the nation. In the same period, manufacturing employment increased by 133 per cent, and in May of this year there was an all-time high of 217,000 workers in non-agricultural employment. Personal income in 1957 was 12.8 per cent higher than in 1956.

One of the most favorable indications is the way in which New Mexico weathered the recent national recession. As late as June of this year unemployment in the state, compared to the national figure of 7.7 per cent, was a minimal 2.7 per cent. While the national business activity index decreased 2.4 per cent in 1957, New Mexico's increased by 10 per cent.

A principal impetus to expansion has come of course, from the mining industry. In the less than forty years since the first production of oil and gas, oil production has increased five and one half times, natural gas thirty-five times. New Mexico is now third in the nation in gas and seventh in oil production. Both industries continue to expand, and there is still further promise in the recent announcement of the establishment of the new Lucero Basin.

New Mexico is first in the nation in the mining of potash and uranium. New facilities for production of potash are projected. We have more than two thirds of the nation's known reserves of metallurgically amenable uranium ore -- more than six times the reserves of other states. By the year's end, when installations contracted for are operating, we will have fifty-one per cent of the country's total milling capacity. In the mining of perlite, beryllium, manganese, and molybdenium, New Mexico ranks second. It is fifth in copper production. With other minerals, the total value of production in 1957 was $526 million, of which oil and natural gas accounted for 65 per cent.

The increasing diversity in manufacturing is particularly promising. Since 1950, the average rate of expansion, despite some declines, has been 47 per cent, exceeding the national rate by 35 per cent. The fact that some of the most rapidly growing industries were either the smallest or non-existent in 1950 is extremely favorable. The production of chemicals is rapidly becoming a major industry, in which $46 million will be invested for construction of facilities in 1958-59 -- more than double the figure for 1957.

Electric power production has also more than doubled in New Mexico since 1949. Based on data for 1956, the total installed and projected generating capacity is now 612,000 kilowatts. The projected generating plant for the Four Corners area, to use San Juan River Water and local coal deposits, is expected to produce one and one half million kilowatts before many years.

In construction, New Mexico is second only to Arizona among Mountain States, with an increase in valuation for 1957 over the previous year of 37 per cent.

An important stimulus of the economy comes from the nuclear physics-missile-electronics complex. Sandia Corporation, which now employs about seven thousand, continues to expand. ACF Industries is also a sizeable employer of people working in the nuclear field. Holloman Air Development Center and White Sands Proving Ground, with Los Alamos, have become communities in their own rights. Around these huge installations are dozens of smaller enterprises working directly or indirectly in the nuclear, missile or electronics fields. Total federal spending in New Mexico in the fiscal year 1958 is expected to be $635 million, in 1959, $850 million.

Agriculture remains an important segment of the economy. Total sales for 1957 were about $200 million, of which livestock accounted for approximately $120 million. The crop production index this year is 117, 11 points above the record index for 1957.

In addition to present major fields of expansion, there are two areas to be considered: First, increased development of existing resources. For example, New Mexico has approximately six million acres of commercial timber stands, in which recent figures indicate that only one third of the annual growth is cut. There are excellent possibilities for expansion here, both in production and manufacturing, but many factors must be considered, not the least of which is the availability of water. The Commission is tremendously interested in this field, and has joined with other agencies in sponsoring the first sawmill clinic in the state. Another area for encouragement -- one which is steadily growing in importance and to which New Mexico can offer special advantages -- is that of research and development services.

The second field for consideration, in which anticipation is much more difficult, is the development of a demand for new products which results from advances in technology, and the growth of new uses for existing products.

In all future planning, the fundamental criterion is suitability to existing conditions, and the most important factor involved is the availability of water. As these conferences have shown, much remains to be done in the improvement of conservation practices and the perfection and application of new conservation techniques. Impressive progress is being made toward the development and use of available surface water in the construction of the Navajo Dam and related projects, the proposal for the San Juan-Chama diversion project, and plans for a dam on the Canadian River to impound unused water. Other possible programs are being investigated.

Great hope also lies in the search for an economically feasible method of salt water purification. The Interior Department's desalinization research program has already been described here. The Economic Development Commission is cooperating with state officials and congressmen in efforts to have one of the projected pilot plants located in New Mexico, and in investigation of advantages we can offer for the establishment of such a plant. Recent developments in the nuclear field, such as work on the plasma thermocouple at Los Alamos and Dr. Libby's announcement concerning the ion exchange method, are encouraging.

While recognizing the danger of over-optimism about early success in this venture, it would be foolish to ignore its potential effect. In the meantime, our progress depends upon current programs of development and conservation. Undertakings such as this conference attest the determination of New Mexicans to meet this challenge, and we look forward with confidence to the continued, sound expansion of our economy.

THE INDUSTRIAL USE OF WATER

Randall F. Montgomery*

The industrial use of water in New Mexico is more than 1% of the some 2,125,000 acre ft./yr. presently being used. A rather insignificant volume, and most of this 39 million gallons per day is being used by the potash and oil industries. We are all familiar with the role New Mexico's mineral resources has on our economy. It is not only of local importance, but of national significance. To date our minerals industry has been primarily of an extractive nature with little processing or manufacturing taking place locally. Why? Perhaps water is one factor!

The opportunity exists for the expansion of our mineral industry; however, one of the first requirements for the development and (may I emphasize)---processing---is an adequate supply of water. What water does industry need? Of course this question is difficult to answer; however, based on certain known and many estimated figures, some of the information that is to follow may be of assistance to those of you that are charged with the responsibility to see that water requirements are met, and that the water we have is put to a beneficial use.

The population of our state has been increasing steadily at a rate above the national average, and our per capita income has increased, but is still below the national average. To make any substantial expansion in our economy it must come through increased processing of our mineral products within the state. Certainly we welcome the abnormal concentration of government activities within our state--most assuredly myself, since I happen to be part of that activity---but we cannot rely on this for a solid foundation. When the "cold war" is "hot" we are growing, but what will happen in years to come? We are not an industrial state as indicated by many statistics, including:

1. Our use of industrial water is the lowest of any state in the Union.

2. Our personal income of almost 1½ billion dollars last year was concentrated in government salaries, 32% to be exact, the highest of any state in the Union.

We are not an agriculture state, for only 9% of personal income was derived from this source -- the lowest state in the Union! We are prosperous now, but we want to remain so and grow a little with time.

*Manager, Hobbs District, New Mexico Oil Conservation Commission, Hobbs, New Mexico

Certainly one limiting factor is our water. One authority estimates that the water necessary to support one low salaried agriculture employee (and 56% of our farmers make less than $2500/yr.) could support 60 industrial workers. Definitely our future does not depend on industry or the dictatorial use of water, but we can work toward improving our use of water and increasing industry. Being close to the oil industry, I have had the opportunity to observe what the wise use of this resource has meant, and I hasten to add-to the economy of New Mexico.

I mentioned earlier that the importance of the mineral industry was not only of local significance, but also national, and since the mineral industries use most of our industrial water, I wish to indicate to you the magnitude it plays.

New Mexico is one of the greatest sources of energy in the United States and rich in basic minerals. In 1957 New Mexico produced 95 million barrels of oil, placing our state as the 7th largest producer, and our production of 731 billion cubic feet of gas placed us as 3rd in gas production. If we convert gas to a common yardstick with oil by the means of BTU's we find that the energy of gas was equivalent to 122 million barrels of oil. This plus 1957's oil production gives a total of some 217 million barrels of oil. Without adding some 15¼ million barrels of raw gasoline and LPG products stripped from our gas, we were the 6th largest state in hydrocarbon energy and just short of replacing Kansas as Number 5. Upon adding our anticipated production in 1960 of 3½ million tons of uranium ore, which according to experts is equivalent to 70 million barrels of crude oil, we may have a total of 287 million barrels of oil, placing New Mexico in 5th place and close to replacing Oklahoma as Number 4.

With this energy and our 80 known commercial minerals we have the raw materials for a large industrial development. Not only do we have energy and commercial minerals in our favor, but our position, geographical and population-wise when compared to the United States as a whole, places us in a very favorable position to be more than an export state. In 1955 New Mexico had an annual refinery capacity for about 140 million gallons of gasoline; however, we consumed 336 million gallons. Refineries located in New Mexico have a capacity for 10% of our production. The remaining 90% is exported. Therefore, a large volume of petroleum products is imported after having been processed in another state. Basic hydrocarbons used by the petro-chemical plants are raw gasoline and LPG products. In 1957 15¼ million barrels of these products were exported for use and processing. It is estimated that a petro-chemical plant processing local products will yield $12 for every $1 obtained by export of crude. True, these plants use a lot of water, but let us assume that all crude oil we produced last year could have been processed. This would have been a figure in excess of 3 billion dollars.

From these examples I have indicated somewhat the loss New Mexico is suffering due to our lack of petroleum processing plants. No doubt exists in my mind that water has been a contributing factor. However, water is available, and economically so, for many plants in several areas. A little more about this later.

WATER USED BY INDUSTRY

Most basic water data was furnished by Mr. Don Akins of the State Engineer's office and obtained from a 1955 survey. Production statistics for 1955 by the various industries was obtained from recognized source material.

PRODUCT	Mgd.	GALS. WATER/UNIT OF PRODUCT
Crude Oil Refineries	1.426	60 gals/bbl crude processed
Potash	12.386	2,425 gals/ton K_2O
Electricity	6.581	1 gal/kilowatt-hour
Oil Well Drilling	1.500	50 gals/foot hole drilled
Gasoline Plants	4.875	3,703 gals/MMCFG processed
Uranium	1.432	410 gals/ton ore processed
Copper	6.000	34,000 gals/ton recoverable Cu.
Carbon Black	.400	4,000 gals/ton
	34.600	

FUTURE WATER NEEDS OF INDUSTRY

OIL WELL DRILLING

Water needs in drilling for oil and gas are expensive due to transportation problems, but not particularly significant in volume. Estimating an average of 250,000 gallons of water per well, and this a conservative figure, we used 550 million gallons of water in 1957. Assuming that drilling activity will remain at about our present rate for the next 10 years, the total water needed for drilling will be some 16,800 acre feet.

POTASH INDUSTRY

This is a major New Mexico industry which is presently using the largest volume of water. Some 12,386,000 gallons of water per day were used to recover 1955's total production of 1,864,000 tons of K_2O equivalent. Based on published reserves of 80 million tons of K_2O, and at the continued present rate of use, it will take 595,509 acre feet of water to refine known reserves. At $37/ton the value of the potash will be $2,960,000,000.

URANIUM

Our new uranium industry, with 1.432 Mgd. used in 1955 to process 3,500 tons of ore, will need 62,884 acre feet to process 50 million tons of proven reserves. With new mills under construction and those completed since 1955 it is anticipated that the 50 million tons of proven reserves will be depleted in 15 years.

GASOLINE PLANTS

With proven reserves of over 21 trillion cubic feet of natural gas it will take 29 years to deplete at our present rate of export. With gasoline plants processing all gas and using 3,703 gallons of water per one million cubic feet of gas processed it will take 239,000 acre feet of water.

OIL REFINERIES

It is more difficult to project the future needs of refineries due to obvious factors, however at our present capacity within the next 20 years, or 200 million barrels of processed crude, we will need 28,000 acre feet. This is based on the present use of 60 gallons of water per 1 barrel of oil.

GENERATION OF ELECTRICITY

Estimated present consumption of water in generating electricity is 1 gallon per kilowatt hour. In 1955 2,402 million kilowatt hours were produced in New Mexico. Projecting this same rate and water consumption 20 years hence indicates that we will need 147,440 acre feet of water. Please note that no growth is indicated.

CARBON BLACK

At the rate of 4,000 gallons of water per ton of carbon black and assuming present production of some 1 million pounds per year for the next 20 years, this processor will need 12,276 acre feet of water.

SECONDARY RECOVERY

The oil industry of New Mexico will need in the near future enough water to produce by water-flooding 500 million barrels of oil. According to estimates made by the Bureau of Mines in 1954 approximately 2.2 billion barrels of water was injected into oil-bearing strata in the secondary recovery of 110 million barrels of oil, or about 20 barrels of water per one barrel of oil. Secondary recovery experts inform me that with increased capital outlay a minimum of 10 barrels of water per barrel of oil recovered can be reached. Basing my following calculation on the minimum figure, this will take 5 billion barrels of water, or 644,579 acre feet. At the present rate of pumpage this is equivalent to more than 2 years of water used in the Lea County Water Basin for irrigation. Another comparison: Based on 50,000 acre feet per year presently being consumed by the city of Albuquerque, it is a volume large enough to last the city 10 years.

What will be the financial return for the use of such large volumes of water? Based on present day value of oil at $3.00 per barrel, the gross income will be $1,500,000,000 -- or about what the personal income of the entire state was during 1957. Again -- another comparison would be the total expected income that will be derived from all of our known uranium reserves.

To recapitulate the above information and arrive at an estimation of water needs by these major industrial water users I have projected each industry to twenty years in the future. Obviously numerous factors will affect these estimates -- to point out a few:

Increase in known reserves, increase in processing, or conversely the decrease.

INDUSTRY	ACRE FEET WATER NEEDED IN NEXT 20 YEARS	AVG. NO. ACRE FEET NEEDED ANNUALLY*	REMARKS
Oil Well Drilling	33,760	1,688	This is based on a continuation of 1957's rate. Doubtful this can be maintained.
Gasoline Plants	158,666	7,933.3	Reserves sufficient for 29 years @ present rate.
Oil Refineries	40,000	2,000	Based on continuation of present rate for 20 years, or 200 million barrels of oil.
Potash	297,754	14,887.7	Reserves sufficient for 30 to 40 years at present rate.
Uranium	75,461	3,773.05	Present proven reserves only sufficient for 15 years @ present rate of milling, but undoubtedly new discoveries will be made.

* Computed by the editor.

Carbon Black	12,277	613.85	Doubtful if present methods of processing can survive this full 20 years.
Generation Electricity	147,440	7,372	1955 rate extended to 20 years, no accounting for increase in capacity.
Secondary Recovery	644,579	32,228.95	Doubtful, but very probable that secondary recovery will be this far along.
	1,409,937	70,496.85	

Certainly this sum of 1,409,937 acre feet of water is not small, and the geographical area of use is rather limited.

As of April 30, 1958 the Lea County Water Basin had 84,450 acre feet of water unappropriated. Since the largest portion of the 1,409,937 acre feet of industrial water will come from Lea County, it is obvious that industry must begin making plans now to develop a water source.

<u>What Source?</u>

Fortunately in southeastern New Mexico relatively large volumes of water are available at certain points from oil field disposal projects. It is estimated that from the Hobbs Pool .500 Mgd. of 15,600 PPM total solid water will be available within 6 months. I venture to estimate that the cumulative water gathered by this system will reach 500 million barrels or 64,458 acre feet by the end of 1978. Other major disposal systems such as the Monument area will be collecting and disposing of some 31,000 barrels/day within the next 2 years and by 1978 will have a cumulative production of some 500 million barrels (64,458 acre feet). Other major sources for this saline to brackish water will be Denton, Caprock Devonian, and many others.

A survey made by this speaker in 1956 indicates that from 8,914 oil wells, many in widely scattered areas, that 145,772 barrels of water per day was produced. The methods of measuring oil field waters are inaccurate and at best this figure is 25% short of the actual amount produced. However, using this figure, some 6,859 acre feet of water/year is presently available. To make a guess as to the ultimate water is dangerous, but I will venture to estimate that 5 billion barrels will be produced within the next 20 years, or 644,580 acre feet. The cost to lift this 644,580 acre feet from depths of 3,000 to 12,500 feet will have already been met, as will the gathering. But, if you please, I would like to relate what this same volume of water would cost to lift from the Lea County Water Basin at a depth of 70 feet. Based on lifting cost as published by Mr. W. P. Stephens, under certain conditions water could be lifted for as low as $3.16

per acre foot. Therefore, the cost for lifting 644,580 acre feet of water would be slightly over 2 million dollars.

Certainly many industrial plants can utilize this mineralized water, and it is desirable for use in secondary recovery. However, we are presently reinjecting water that was lifted from great depths at considerable cost back into formations from 4,000 to 12,000 feet deep. Certainly no forseeable factors will enable us to relift this water. Definitely the contamination of what water we have is to be prevented, but perhaps there are other approaches to this problem. The most apparent are:

1. Demineralization and reinjection into shallow ground water. Expenseive? Yes, but perhaps not for industrial purposes.

2. Storage of brackish water in reservoirs at shallow depths. Detailed mapping outside of the Lea County Water Basin will undoubtedly reveal that such reservoirs exist.

3. A third avenue for investigation might be termed "Controlled Contamination". That is, the injection of highly mineralized water into aquifers containing relatively fresh water, but not contaminated beyond the point that makes the fresh water nonpotable.

Other sources for industrial water in Lea County include the Santa Rosa formation at depths of 800 to 1,000 feet. Limited information indicates that this is a major aquifer.

Perhaps some of the ideas presented might sound as if this author was for sin and against motherhood, but certainly suggestions such as the above rate consideration equal to the magnitude given to the recycling of sewage.

To sum up I would like to point out:

1. That our present industries need more water than is generally realized.

2. The time for obtaining a relatively cheap source of water is rapidly drawing to a close, if not already past in most areas.

3. That the time for planning the development of future industrial water resources is here.

DISPOSAL OF OIL FIELD BRINES
EFFECT ON WATER SUPPLY

Ivan M. Rice*

Ordinarily a discussion concerning salt water is started by reviewing the value of fresh water and explaining the need to preserve our water resources. Obviously your awareness of the problem explains your presence at this meeting.

A salt water engineer tries to convince the people with whom he comes in contact, that properly handling oil field waters is not only right, it is an essential conservation measure. But like a preacher, he often has trouble cornering the non-believer and the believers don't need to be told.

The oil industry is rapidly recognizing that they have a stake in conservation. Alert management realizes that prevention of pollution is a good investment rather than an expense. The final source of revenue in the oil business is the sale of products to the consuming public. They realize that the farmer whose land has been ruined cannot buy tractor fuel to raise and harvest crops, and the fisherman won't buy gasoline to fish in streams where the fish have been killed by highly mineralized water.

To many of you the term "salt water" may not have a specific meaning. Generally water containing more than 1000 ppm dissolved solids is regarded as saline. Very saline water may contain as much as 35,000 ppm total solids. Brine is water containing more than 35,000 ppm dissolved solids. Saline water containing as much as 3000 ppm dissolved solids have been used for irrigation but the continuous use of moderately saline water on the surface results in a buildup of salts in the soil, creating the same condition as high-salinity brines except that it takes more time. Since plants obtain their mositure by osmotic pressure, and the addition of salt increases the specific gravity of the water, the plants actually starve for lack of water. One of the first signs of oil field pollution is when the upper most branches of a tree in the area are observed to be turning brown during a good growing season.

The loss of vegetation due to surface disposal of salt water is a serious problem in some states, and a very obvious one. However,

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it isn't as difficult to deal with, as the invisible situation. This is the case in a large part of New Mexico. Much of eastern New Mexico is a smooth, grassy, treeless plain. Lea County, for example, is 30 miles wide and 100 miles long but doesn't have a bridge in it. There is practically no surface drainage and the rainfall is disposed of chiefly by seepage and evaporation. The climate is considered to be semi-arid with a mean annual rainfall of 12 to 15 inches. Yet it is most likely that more water reaches the ground water zone than it does in states where rainfall is twice or three inches that amount. The reason is that the surface sediments in New Mexico are too porous to retain water and cannot support much plant life. In other areas the soil is more impermeable, retains moisture for plants, but for the same reasons, results in a much larger runoff. So, as far as having a water supply is concerned, nature may have provided New Mexico with a better, purer reservoir than man can devise on the surface. Also less water may be lost by evaporation in New Mexico than in some other areas.

The principal problem then, is to prevent mineralized waters from percolating down from surface pits into the fresh water zone rendering otherwise potable water unfit for drinking, industrial or agricultural uses. People have a tendency to put out of mind anything that goes out of sight. This is a dangerous practice as far as oil field waters are concerned, because water in liquid form on the surface occurs either as a lake or stream. That is, it is either confined in an impervious depression and the surface of the water is level as in a lake, or one way or another is down hill and the water is flowing. If salt water seeps down and forms a lake, not visible to the eye, but confined to a given area, no harm will come expect to that area. However, if it enters flowing fresh water, very little diffusion or dilution will occur and unpleasant results may go on for years.

It is evident that rain water is not impounded on the surface in eastern New Mexico, so the water must be percolating downward. If there are areas where there is no fresh water to be found, it seems reasonable to assume that the rain soaked in until it reached an impervious layer and continued to flow down grade. It is also reasonable to think that salt water impounded in earthen pits would follow the same course, only it would soak in every day of the year. Since rains are fairly infrequent the end result is a slug of salt water and occasionally a slug of rain water flowing along an impervious layer to an undisclosed destination. Whether or not that destination is another fresh water basin may never be determined.

The oil field waters with which we have been concerned in eastern New Mexico vary in total solids content from 14,000 ppm to 136,000 ppm. The low total solid content water is much more abundant than the brine, but one bbl of the 136,000 ppm water can do as much damage as nearly 10 bbl of 14,000 ppm water. Ordinarily a person can detect by taste, 200 ppm slat. So one bbl of 14,000 ppm water can practically ruin 70 bbl of fresh water and one bbl of the brine can ruin 700 bbl of fresh water. Therefore the quantity of water produced is not a favorable criteria for determining the need for sub-surface disposal.

By the same token the quantity of fresh water in an area is not a good criteria for determining the need for sub-surface disposal. Any amount of potable water that is sufficient to supply the needs of the user is important. A city requires large quantities of water, a small town less and a farmer or rancher may require only a few gallons a day. If a few gallons a day is all there is available, it then becomes more valuable. Scarcity, not abundance determines the value of any natural resource.

Recognizing that improperly handled oil field waters can do much damage our first reaction is that the water is waste and has no value. This is largely true when the water reaches the surface. However, in a water drive field, it is the energy that drives the oil to the well bore. Without a water drive it is frequently necessary to inject water into the reservoir to obtain a larger portion of the oil in place. Where salt water is available, secondary recovery operations may be considered successful. However, it is extremely unwise to use potable water for water flooding because the water used can never be reclaimed. Five to ten bbl of water are required to recover one bbl of oil currently worth about $3.00. Whether or not this is a good business practice and a conservation measure is certainly open to question.

The problems of salt water disposal are many and varied. Few progressive oil companies fail to recognize the problem but they also have the same problems a family has, namely money. First they have to find the oil, then develop and produce the properties and finally market the products. It is practically impossible to formulate an economical plan for salt water disposal early in the development stages of a field because no one knows how much oil or water will be produced. Thus a temporary means of handling salt water must be employed until the magnitude of the problem can be determined and a payout assured. While many people may feel that progress is slow we must remember that our first obligation is to meet the grocery bill and no one can afford to abandon their every day tasks to take on a special project. As a result the fields have been developed and disposal work has progressed as time and money permit.

The most satisfactory solution for handling produced oil field water is to either return it to the reservoir below the oil zone and thus help to maintain the bottom hole pressure, or inject it along the edge of the field. In eastern New Mexico the water in certain fields will be injected into fairly deep salt water bearing formations.

Gathering lines will bring the water from many producing wells to each disposal well so a large area will be protected.

While many of the oil companies have shown excellent cooperation in providing subsurface disposal, the question of oil field pollution will continue to exist until a clearly defined program is established.

CONSUMPTIVE USE OF GROUND WATER BY PHREATOPHYTES AND HYDROPHYTES

Harry F. Blaney*

In many parts of the southwest the ground water supply is exceedingly limited, and the demands for water, already great, are constantly increasing through pumping for irrigation, industrial and domestic purposes. When making an inventory of the water resources of a river basin, water consumed by phreatophytes (ground-water vegetation) such as cottonwoods, salt cedar (tamarisk), willows and salt grass growing in areas of high water-table and along streams becomes of increasing importance as greater land areas are irrigated, especially during periods of drought. Through the process of transpiration, these plants discharge and waste large quantities of ground water into the atmosphere.

Consumptive use (evapotranspiration) involves problems of water supply, both surface and underground, and watershed management, as well as those of the management of, and general economics of, irrigation, and multiple-purpose projects. Data on the use of water by vegetative cover essential in planning government and private irrigation and water supply projects. The consumptive-use requirement for water has become an important factor in the arbitration of controversies regarding major stream systems, such as the Rio Grande (2) in the United States and Mexico, in which the welfare of the people of valleys, cities, states and even nations is involved.

Research studies show that the rates of consumptive use (evapotranspiration) by phreatophytes and hydrophytes are much greater than the use of water by most irrigated crops. This paper describes and presents the results of studies and measurements of the use of ground water by phreatophytes and hydrophytes in arid and semi-arid areas of the United States, and describes a method of determining rates of water consumption in areas where no measurements except climatological data are available.

Introduction

Adaption of plants to natural conditions has distributed vegetation in more or less dominant communities throughout the world. These may be classified as: (a) Xerophytes, plants that have adapted themselves to deficient and irregular water supplies; (b) Mesophytes grow in habitats that usually have neither excess nor deficiency of water;

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(c) Hydrophytes live wholly or partly submerged in water or with roots in saturated soil that is intermittently submerged; and (d) Phreatophytes, plants that habitually grow where they can send their roots down to the water table or the capillary fringe immediately overlying the water table.

The term "phreatophyte" was first used by the late Dr. C. E. Meinzer in the early twenties (9). The word is derived from two Greek words meaning well plant. In proposing this name, Meinzer indicated that it would overlap some of the other groups such as hydrophytes.

The term "consumptive use" has been used for some 50 years by irrigation engineers in the United States. It is considered synonymous with the term "evapotranspiration" and is defined as the quantity of water evaporated and transpired from an area. It may be expressed as a rate, depth in inches or depth in feet (ac. ft. per Ac.).

In determining the available water supply of a river drainage basin for irrigation and other purposes, ground water consumed by phreatophytes such as tamarisk (salt cedar); cottonwoods, willows, and salt grass and by hydrophytes such as tules, bull-rushes and sedges, should be given careful consideration before new multiple-purpose projects are authorized. The value of data on consumptive use by these plants is recognized by administrators and engineers in regions where water rights are in dispute, or where internation and interstate water supply and water use are not in balance (2, 4).

The moisture requirements of water-loving native (natural) vegetation are usually satisfied before water becomes available for irrigation and other purposes. Measurements of evapotranspiration indicate that water-loving native vegetation uses from 50 to 100 percent more water than most crop plants. Tules and salt cedar growing in irrigation canals and drainage ditches and on their banks are exposed in narrow strips to sun and wind so that their consumption of water is unusually high (1, 15). The United States Geological Survey (12) has estimated that the total area of phreatophytes is over 15 million acres in the 17 western states, and that the total use of water by these plants is about 25 million acre-feet annually. With the exception of salt cedar, most of the phreatophytes growing in Western United States are indigenous to this country. Salt cedar was introduced into the United States from Mediterranean region about 1900. These include some 15 varieties which are spreading rapidly.

This paper presents data on measured consumptive use of water by phreatophytes and hydrophytes and describes a method of determining rates of water consumption in areas where no measurements except climatological data are available.

Conditions Affecting Water Use

Many factors operate singly or in combination to influence, the amount of water consumed by plants. The effects of these factors are not necessarily constant but may fluctuate from year to year as well as from place to place. The effect of sunshine and heat in stimulating transpiration was studied as early as 1691 by European investigators. Measurements of transpiration of various kinds of plants indicate a close correlation between transpiration, evaporation, temperature, solar radiation and humidity.

The three primary factors that affect the annual rate of water by phreatophytes are: (a) depth of water table, (b) climatic conditions and (c) density of plant growth. Usually, the shallower the water table, the higher the rate of use. For some species, the depth to ground water is the controlling factor on their occurrence and growth. For instance, salt grass commonly grows only where the depth of the water does not exceed 7 feet, while mesquite is a deep-rooted plant that has been known to send its roots 50 feet or more in search of water (15). In soils of fine texture, the height of the capillary fringe is greater than in soils of coarse texture. Thus in coarse sandy soil the capillary fringe may not extend more than one foot above the water table, while in a clay soil it may supply moisture to 7 or more feet above the water table for plant growth. Measurements by the writer indicate that most of ground-water discharge by phreatophytes occurs in areas where the depth to water is less than 15 feet. Climatic conditions control the occurrence and growth of some species, whereas others are relatively unaffected by climate. The effect of climate on the growth and occurrence of salt cedar is very noticeable. The use of water by phreatophytes is influenced by temperature, daytime hours, length of growing season, precipitation and humidity. The effect of density of growth on use of water by salt cedar, cottonwood and willows was demonstrated in the course of intensive studies in Safford Valley, Arizona, in 1943-44 (8). It was found that the water use varied directly with the volume density.

Use of Water Measurements

Evapotranspiration losses by phreatophytes and hydrophytes growing in areas on high-water table have been measured by means of tanks, lysimeters, inflow-outflow, ground-water fluctuations and other methods by Federal and State agencies (1, 2, 8). At various times during the past 30 years the writer has measured rates of consumptive use in California, Colorado, New Mexico and Texas (1, 2, 4). The results of some of these measurements and those made by other investigators are shown in Tables 1 and 2.

Table 1-Examples of measured monthly consumptive use of water by natural vegetation growing in lysimeters with high-water table in Western United States (Compiled by Harry F. Blaney)

Location	Type of vegetation	Consumptive Use of Water, inches Apr	May	June	July	Aug	Sept	Oct	Authority
CALIFORNIA									
Bonsall	Cottonwood b/	5.2	8.5	7.5	9.6	9.4	7.2	-	Muckel and
"	" a/	7.0	10.5	11.9	16.5	14.2	9.8	-	Blaney
" c/	Tules	4.6	7.1	7.5	8.6	7.4	5.7	4.7	Ditto
Victorville d/	"	7.5	11.6	12.2	14.6	12.0	10.6	5.7	"
Santa Ana	Saltgrass b/	3.6	3.7	5.8	7.6	6.1	4.5	3.0	Blaney and
" "	" e/	.7	.7	1.3	2.7	3.1	1.8	1.7	Young
" "	Willows	2.3	3.5	3.8	4.2	4.8	4.2	2.9	Ditto
" "	Wire rush f/	7.8	8.6	10.3	13.7	12.7	10.7	8.2	"
San Bernadino	Bermuda grass a/	2.0	2.1	4.5	5.4	3.9	3.1	.9	"
" "	" " g/	2.7	2.7	5.4	6.4	5.3	3.4	1.3	"
" "	Tules	5.4	4.6	6.0	6.8	5.8	5.1	4.9	"
COLORADO									
Alamosa	Tules	-	-	11.4	11.6	8.3	4.1	2.0	Blaney
"	Meadow Grass	-	-	6.5	8.3	7.8	5.8	1.2	"
Garnett	Saltgrass e/	1.7	3.0	6.2	6.7	5.9	3.5	1.6	"
NEW MEXICO									
Albuquerque	Tules	5.2	5.3	10.7	13.1	10.7	7.8	2.8	Elder
"	Saltgrass g/	.1	.6	2.8	3.5	4.2	3.4	1.2	"
Isleta	" i/	.6	4.8	5.5	6.1	5.6	3.8	.8	Blaney
"	Sedge j/	6.5	10.5	12.4	16.2	11.7	7.5	5.6	"
"	Willows k/	2.3	3.5	4.2	6.1	5.6	3.8	1.8	"
Mesilla	Saltgrass l/	2.0	2.1	3.8	9.2	7.9	6.1	4.1	"
Carlsbad	Saltgrass g/	3.2	4.7	7.2	11.8	9.2	7.6	4.3	"
"	Sacaton g/	4.5	6.4	5.8	8.1	7.1	6.1	3.5	"
"	Saltcedar g/	-	-	3.3	4.8	8.4	8.6	6.8	"
"	Saltcedar b/	-	-	1.9	4.3	8.2	6.1	6.1	"
"	Sacaton b/	3.1	2.7	6.6	6.7	7.8	5.7	3.8	"

a/ Water table 36 ins. b/ Water-table 48 ins. c/ Coastal area
d/ Mojave Desert e/ Water-table 12 ins. f/ Isolated tank
g/ Water-table 24 ins. h/ At Los Griego Station i/ Isleta Station
j/ Growing in water k/ Water-table 9 to 18 ins. l/ Water-table 14 ins.

Table 2—Examples of annual or seasonal consumptive use of ground water by phreatophytes and hydrophytes as measured by tanks or lysimeters in Western United States.

Locality	Type	Period	Depth to water table inches	Consumptive Use: Inches	Consumptive Use: Centimeters	Authority
ARIZONA						
Safford	Salt cedars*	Sept. 1943-Oct. 1944	--	86.4	219	(8)
Safford	Cottonwoods*	Sept. 1943-Oct. 1944	--	72.0	183	(8)
Safford	Baccharis*	Sept. 1943-Oct. 1944	--	56.4	143	(8)
Safford	Mesquites*	Sept. 1943-Oct. 1944	--	39.6	101	(8)
CALIFORNIA						
Santa Ana	Salt grass	May 1929-April 1932**	12	42.7	108	(1)
Santa Ana	Salt grass	May 1929-April 1932**	24	35.3	90	(1)
Santa Ana	Salt grass	May 1929-April 1932**	36	23.8	60	(1)
Santa Ana	Salt grass	May 1929-April 1932**	48	13.4	34	(1)
Santa Ana	Wire rush	Aug 1930-July 1931	24	78.9	200	(1)
Victorville	Tules	Jan 1931-Dec 1932	0	78.4	199	(1)
San Luis Rey	Tules	Jan 1940-Dec 1943	0	58.9	150	(10)
San Luis Rey	Cottonwoods*	April 1941-Mar 1943**	48	62.5	159	(10)
San Luis Rey	Cottonwoods*	April 1939-Mar 1941**	36	91.5	232	(10)
COLORADO						
San Luis Valley	Meadow grass	June-Nov 1936	0	36.3	92	(2)
San Luis Valley	Tules	June-Nov 1936	0	38.8	99	(2)
Ft. Collins	Sedge grass	May-Oct 1930	18	53.6	136	(15)
Ft. Collins	Rushes	July-Oct 1930	--	52.6	134	(15)
NEW MEXICO						
Los Griegos	Salt grass	Oct. 1927-Sept. 1928	26	22.7	58	(2)
Isleta	Sedge grass	June 1936-May 1937	3	76.9	195	(2)
State College	Cattails	July-Dec. 1936	30	44.2	112	(2)
State College	Salt grass	July-Dec. 1936	14		74	(2)
Carlsbad	Tamarisk	Jan.-Dec. 1940	36	57.3	146	(4)
Carlsbad	Sacaton	Jan.-Dec. 1940	24	48.1	122	(4)
Carlsbad	Sacaton	Jan.-Dec. 1940	48	41.4	105	(4)

*100 percent volume density. **Average yearly for period of record.

Relation of Consumptive Use to Evaporation

Meteorological conditions influencing evaporation from water surfaces likewise affect evaporation from soils and transpiration from vegetation. Both evaporation and transpiration freely respond to changes in termperature, wind movement and humidity so that evaporation from water may, under certain conditions, be used as an index of evaportranspiration losses for areas in which there is ample water to take care of evaporation and transpiration.

Studies which the author has made of water utilization in Rio Grande, Pecos River, and Colorado River basins, indicate that observed evaporation data from U. S. Weather Bureau pans may be used as a means of estimating evaportranspiration by water-loving vegetation when the relation of the two values is known for a particular area. This was accomplished in the Pecos River Joint Investigations (4) as illustrated in Table 3.

Table 3--Average computed rates of annual evapotranspiration by phreatophytes based on pan evaporation and climatic factors, Pecos River Basin, New Mexico and Texas

Location	Saltcedar along river	Computed evaportranspiration, inches		
		Saltcedar average	Brush areas away from river	Grass and weeds away from river
New Mexico				
Las Vegas	51.6	43.2	34.8	21.6
Fort Sumner	64.8	51.6	43.2	27.6
Roswell	67.4	56.4	45.6	28.8
Carlsbad	72.0	60.0	48.0	30.0
Texas				
Barstow	71.8	58.8	46.8	30.0
Balmorhea	72.0	60.0	48.0	30.0
Fort Stockton	72.0	60.0	48.0	30.0

The results of investigations in California, New Mexico and other areas indicate the observed evaporation data may be used as a means of estimating evapo-transpiration by phreatophytes and hydrophytes having access to an ample water supply when the relation of the two is known for a particular area (1, 2). As an example, for two locations in California, for tules growing in large tanks within the confines of a swamp area, the consumptive use, with reference to evaporation from a nearby exposed Weather Bureau pan, was 95 percent under desert and cold winter conditions at Victorville, and 94 percent under mild summer and winter climate near the Pacific coast at San Luis Rey (1, 2, 10). Some of the results of these investigations are shown in Table 4.

Table 4--Comparison of annual evapotranspiration by natural vegetation growing with water table at different depths to evaporation from a Weather Bureau pan, San Luis Rey Basin and Victorville, California.

Classification	San Luis Rey, Calif. Depth of water table	Annual water consumption	Ratio water use to evaporation	Victorville, Calif. Depth of water table	Annual water consumption	Ratio water use to evaporation
	Ft.	In.		Ft.	In.	
Pan evaporation	0.0	60.8	1.00	0.00	82.5	1.00
Tules	0.0	57.5	0.94	0.00	78.5	.95
Cottonwoods	3.0	92.7	1.52	--	--	--
Cottonwoods	4.0	62.3	1.02	--	--	--
Brush-grass	4.7	45.4	.75	--	--	--
Grass	12.0	14.0	.23	--	--	--

Determining Consumptive Use From Climatological Data

Actual measurements of consumptive use under each of the physical and climatical conditions of any large area are expensive and time consuming (3). Therefore, some rapid method of transferring the results of careful measurements, made in several areas, to other areas of similar conditions is needed.

From long-period records of evaporation, temperature and humidity in New Mexico and Texas, together with consumptive-use measurements at Carlsbad, New Mexico, empirical formulas were developed by Blaney and Morin for computing evaporation and consumptive use when temperature and humidity data are available (5). Consideration of these results and the factors involved is shown in the expression:

$$u = ktp\ (114-h) = kc = \text{monthly consumptive use}$$

in which "u" is the monthly consumptive (or evaporation) in feet; "k" is the monthly empirical coefficient; "t" is the mean monthly temperature, °F; "p" is the monthly percentage of daytime hours of the year; "h" is the average monthly humidity; and "c = tp (114 - h)" is the monthly use index (climatic factor). The formula for annual consumptive use is:

$$U = K_aC = k_wc_w + k_sc_s$$

in which "K_a" is the empirical coefficient for the entire year; "C" is the use index for the entire year; "k_w" is the empirical coefficient for winter period; "k_s" is the empirical coefficient for growing season or frost-free period; "c_w" is the use index for winter season; and "c_s" is the use index for growing season or frost-free period. The values of "k_w" and "k_s" were computed from observed values of evapotranspiration, temperature and humidity by the relation $k = u/c$.

Computed coefficients for winter and summer water consumption based on evapotranspiration, evaporation, temperature and humidity measurements in New Mexico are shown in Table 5.

Table 5--Coefficients for computing water consumption from climatological data.

Type of vegetation or land use	Depth of water table (feet)	Empirical coefficients k_w	k_s
Sacaton	4	0.0044	0.0139
Sacaton	2	0.0063	0.0154
Salt cedar (tamarisk)	2	0.0075	0.0216
Alfalfa	5	--	0.0174
Tules	0	--	0.0240
Evaporation, bare soil	2	0.0063	0.0083
Evaporation, water surface	0	--	0.0174

Table 6 illustrates computations of rates of use by phreatophytes along the Pecos River, New Mexico and Texas.

Table 6--Computed normal annual rates of consumptive use by groundwater vegetation grpwing along the Pecos River in New Mexico and Texas.

Station and frost-free period	Use index c_s	c_w	Annual consumptive use (U): Salt cedar (Tamarisk) Along river: Maximum 2/	Average 3/	Salt grass (Sacaton) Adjacent to river: Moist areas 4/
NEW MEXICO			Feet	Feet	Feet
Las Vegas					
May 6-Oct 9	1911	1478	4.5	3.8	3.1
Ft.Sumner					
Apr 11-Oct 18	2434	1197	5.3	4.5	3.6
Roswell					
Apr 7-Oct 31	2641	1071	5.7	4.8	3.9
Carlsbad					
Mar 28-Nov 3	2795	1058	6.0	5.0	4.0

Table 6 Continued

Station and frost-free period	Use Index c_s	c_w	Annual consumptive use (U) Salt cedar (Tamarisk) Along river Maximum 2/	Average 3/	Salt grass (Sacaton) Adjacent to river Moist areas 4/
TEXAS			Feet	Feet	Feet
Grandfalls					
Mar 28 - Nov 1	3120	1195	6.5	5.6	4.5
Balmorhea					
Mar 29 - Nov 15	2765	936	5.8	4.9	4.0
Ft. Stockton					
Mar 31 - Nov 12	2836	1018	6.0	5.0	4.1

1/ Computed from formula $U = u_s + u_w - k_s c_s + k_w c_w$ = consumptive use in feet. Based measured data at Carlsbad, New Mexico.

2/ $k_s = 0.0019$ and $k_w = 0.0006$ Water table at 2 feet.

3/ $k_s = 0.0016$ and $k_w = 0.0005$ Average water-table

4/ $k_s = 0.0013$ and $k_w = 0.0004$ Water table at 4 feet.

Eradication and Control

The development of methods to eliminate and to control phreatophytic growth along stream channels, irrigation canals and in reservoirs to conserve water is one of the most perplexing problems to be solved in Western states. This is particularly true of salt cedar (Tamarisk). Large quantities of water are lost each year in river basins by use of water by these noxious plants such as salt cedar, cottonwood and willow. The rates of evaportranspiration by phreatophytes have been measured in some areas as indicated in Tables 1 and 2. In a few areas cottonwoods and willows have been eradicated by clearing the growth and by lowering the water table, and about 50 percent of the ground water has been salvaged for use of irrigated crops. However, effective eradication of salt cedar has not been very satisfactory, and more research is needed before this problem can be solved.

The growth of salt cedar in New Mexico for many years was confined largely to the lower valleys of the Pecos River and the Rio Grande, with heavy infestations in the delta areas of McMillan and Elephant Reservoirs. However, in recent years it has spread into the San Juan, Canadian and Gila River Basins. Also, salt cedar is spreading rapidly in the Upper Colorado River Basin. The State Engineer of New Mexico in cooperation with the U. S. Bureau of Reclamation has been studying this problem since 1947. A report (14) by Thompson in 1957 describes the occurrence and spread of phreatophytes over 440,000 acres in New Mexico.

After analyzing the available data in New Mexico and other states, Thompson came to the following conclusions:

"Evidence available at this time indicates that salt cedar is rapidly becoming the predominant nonbeneficial vegetation in the lower river valleys of the Southwest where high water table and climatic conditions are ideal for its growth. It is further evident that this plant is becoming established in the higher tributaries and is invading some of the stream systems of the Northwest. It is therefore believed that, due to its extremely high water consumption and the fact that it constitutes one of the major operation and maintenance problems on irrigation and flood control projects throughout the western states, Congressional legislation should be enacted and funds appropriated for a Federal program. It is further concluded that:

"1. At present channelization is the most effective means of salvaging water in the river channels and reservoir delta areas in the heavily silt-laden river basins of the West.

2. Significant amounts of water may be salvaged by the eradication of salt cedar and other phreatophytes.

3. A method of eradicating salt cedar must be found which is more effective and economical than those currently in use.

4. Finding a commercial use for salt cedar would afford a quick method of control.

5. Additional and more conclusive studies should be carried on to determine the consumptive use of phreatophytes.

6. The volume-density method of vegetative surveys should be adopted as a standard by all state and Federal agencies."

Many experiments on test plots have and are now being conducted in Arizona by Arle (11) of the Agricultural Research Service and Bowser of the U. S. Bureau of Reclamation. These studies have been made in the Gila River channel near Yma and in a tract in the Gila River flood plain southwest of Phoenix, Arizona.

After reviewing about 10 years work in Arizona and New Mexico, Arle reported (11) that:

"Although the considerable number of experiments and trials have not resulted in an entirely economical and practical method of killing saltcedar, valuable information on its control has been developed. This information may be summarized as follows:

"1. Saltcedar is more difficult to kill on flood plains than along irrigation channels and streams.

"2. Single spray operations have never given satisfactory total plant kill of adult saltcedar and only rarely have two repeated treatments eliminated 80 percent or more of the plants.

"3. Periodic spraying of infested areas with 2, 4-D and 2, 4, 5-T will defoliate saltcedar and in this manner reduce transpiration losses.

"4. Applications of 2, 4-D and related materials appear more effective on young regrowth following mechanical destruction than on adult saltcedars.

"5. Application rates of less than 2 pounds per acre have generally given poor results.

"6. Low-volatile esters of 2, 4-D or combinations of 2, 4-D and 2, 4, 5-T have been consistently more effective than amine or sodium salts of 2, 4-D.

"7. Dormant applications of 2, 4-D and 2, 4, 5-T esters have shown promise in the control of saltcedar.

"8. Mechanical means, although expensive, are useful in the eradication of saltcedar, especially in areas near cotton or other crops susceptible to 2, 4-D.

"9. Mechanical control must be exercised at least yearly to eliminate regrowth from root sprouts and seedlings.

"10. Saltcedar is more difficult to kill with 2, 4-D and related materials than most willows, cottonwood, and other woody phreatophytes.

"11. Mechanical clearing followed by spraying of young regrowth with 2, 4-D or a mixture of 2, 4-D and 2, 4, 5-T at 2.5 pounds or more per acre repeated as necessary once or twice a year appears to be the most effective and practical method now known for controlling saltcedar."

The Corps of Engineers, U. S. A., reported (11):

"Estimates of phreatophyte infestation and water consumption in New Mexico showed that 441,000 acres occupied by phreatophytes wasted nearly 900,000 acre-feet of water a year. Nevada's phreatophyte infestation is placed at 2,801,000 acres, and the annual water loss at 1,500,000 acre-feet."

A recent report by the Bureau of Reclamation to the U. S. Army, Corps of Engineers, on the proposed clearing of 13,840 acres of predominantly saltcedar growth in the Safford Valley of the Gila River estimates the consumptive use is 47,840 acre-feet before clearing and 13,840 acre-feet after clearing. The salvage would be 34,000 acre-feet of which 19,800 acre-feet could be diverted to irrigate farms and put to beneficial use.

In 1943, Blaney estimated that if 5,000 acres of Gila River bottom land above San Carlos Reservoir in Arizona were cleared of saltcedar, cottonwoods and other phreatophytes, about 50 percent of the water used by this vegetation, amounting to 15,000 acre-feet per year, could be salvaged for use in producing copper during World War II.

A five-year study by Muckel and Blaney (10) in the San Luis Rey Basin in San Diego county, California, indicated that 52 percent or 9,280 acre feet could be salvaged from 6,390 acres of cottonwoods, willows and brush if the land was cleared and the water-table was lowered rapidly below the root zone. This was eventually done and the river bottom planted to alfalfa and vegetables.

A two year (1945-46) study by Muckel and Blaney of water losses in the Santa Ana River Canyon, California, for five miles below Prado Dam, indicated that 1,407 acre-feet of water could be salvaged (47 percent) if the 1,071 acres of cottonwood and willow were converted to sparse growths, by piping the water from the dam to intakes of two mutual water companies. These companies supply water for irrigation of orange trees.

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GROUND WATER RECHARGE THROUGH IRRIGATION WELLS

H. S. Raymond*

The Maricopa County Municipal Water Conservation District Number One - more commonly known as the Beardsley Project - has recently completed some experiments in ground water recharge by gravity injection into an irrigation well. The experiments were conducted to gain information which would indicate the feasibility of using this method of ground-water recharge as a means of recovering runoff for beneficial use. The whole effort was motivated by the acute shortage of surface water and ground water that is at the present so severe as to cause almost one-fourth of the lands in our project to lie fallow. Of course, before the recharging could be tried, certain physical conditions had to exist. First there had to be a source of water sufficient in quantity to justify its use for recharging; secondly, there had to be a means of collecting the water; and, thirdly, a practical way of injecting the water into the aquifers was essential. These conditions do exist on the project, just a few miles west of Beardsley, Headquarters of the District.

The District comprises about 35,000 acres and lies between the White Tank Mountains a few miles to its west and the Agua Fria River a few miles to the east in western Maricopa County, Arizona. The District was organized in 1925. By 1927, construction of Carl Pleasant Dam, on the Agua Fria River some twenty miles north and east of Beardsley, was completed as were the main canal and the distribution system. A drought period about that time resulted in a shortage of run-off into Lake Pleasant. It was impossible to farm enough acres in the district to produce sufficient revenue to pay its annual debt service requirement.

After refinancing through the R.F.C., the District drilled forty-three irrigation wells of about 500' in depth in 1939 and 1940. Most of the wells in the area are of relatively small yield; however, by supplementing the gravity supply with pump water the District was able to produce enough water for some very good crops. The drought continued, and in order to increase its water supplies the District in 1946 drilled an additional seventeen wells, making sixty in all. The water, although not abundant and comparatively expensive, was of high quality. High yields were made in vegetables, cotton and other crops.

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The quality of water and the favorable crop yields influenced farmers in the District and the lands adjacent to it on the south and east to drill additional private irrigation wells at about that time. As a result the overdraft on the ground water in the District has increased the average pumping lift from 243 feet in 1939 to 443 feet in 1958. The annual increase in lift ranges from ten to twenty feet depending upon the location of the well. Almost two-hundred feet of the ground water reservoir or aquifers has been dewatered. We estimate that the depletion under the District amounts to about 1,000,000 acre feet. With gravity water supplies from Lake Pleasant continuing to be very inadequate, it is easy to see why we are seeking additional sources of water.

Now, characteristic of this part of the southwest, rains of sufficient intensities occur as to cause flash floods of damaging proportions. The Beardsley Project's irrigation facilities, county roads, farm lands, and dwellings were severely damaged on the average of three times a year from flash floods caused by cloudbursts on the White Tank Mountains and on the 220 square miles of desert range land lying north of the project. In August of 1951, one storm originating in this watershed did $3,000,000 worth of direct damage to irrigation facilities, roads, crops, land, military installations, and towns. It is estimated that 18,600 acre feet crossed the district during that flood. A successful effort was made by the District and other local interests in establishing a flood-control project. In 1954, two earth-fill detention dams were constructed near the foot of the White Tank Mountains. Costs were shared equally by the Soil Conservation Service and local interests. These dams are gated and the flood waters are bled into canals and laterals at a controlled rate immediately following a storm. They have a combined capacity of 4,000 acre-feet.

In 1956 the Corps of Engineers, with local interests participating, constructed a large earth-fill detention dam to control the flood waters from the northern end of the White Tanks and the 220-square-mile watershed of Trilby Wash. This structure is ungated and has a gross capacity of 30,500 acre-feet. On September 12 of this year a storm on this watershed resulted in about 4,000 acre-feet of run-off. Unfortunately, because of the ungated outlet most of this water was lost and not put to beneficial use. It flowed from the detention reservoir thru a six-mile outlet channel to a wash that is tributary to the Agua Fria River. The dam functioned perfectly as flood-control structure. The flood crest was subdued and the water leaving the dam was a controlled flow that caused no damage. However, most of the water leaving the dam was or will be lost by evapotranspiration in the shallow sands of the wash and the river bed. We were successful, however, in placing a small temporary plug in the mouth of the outlet works during the discharge period on September 13th and retained enough water to use in a recharge experiment on September 19th.

As stated before, the need for water prompted us to try this recharging experiment. We had a source of water - the water from the flash floods in the White Tanks, and from the Trilby Wash drainage area. The detention dams collected the water and there were irrigation wells nearby into which we could inject the water. The District wells are located along the main canal, or along the laterals and sublaterals. Flood water can be routed from the flood-control dams to the canal and to all laterals and sub-laterals in the project and can be injected into the underground thru all 60 of the irrigation wells. Most privately owned wells are located so that they, too, can be used for recharging.

Mr. Thornton Jones, Water Commissioner of the Superior Court, Maricopa County, a man with keen interest and broad knowledge of water conditions in Arizona and the Southwest, and Mr. Sol Resnick, hydrologist and head of the Institute of Water Utilization at the University of Arizona, were instrumental in getting the District to try recharging through an irrigation well. On hand to help in collecting data was Mr. Kenneth J. De Cook, Research Associate, Institute of Water Utilization. Mr. De Cook has prepared a preliminary report, subject to revision, on the results of the experiments.

In all, three tests have been made. Water in all three tests was pumped from the lateral adjacent to the main canal by a gasoline - powered centrifugal pump that discharged into the well casing. The submersible irrigation pump was left in the well during the tests. The centrifugal pump delivered water to the well at a rate of about 1400 G.P.M. During the first and second tests water released from Lake Pleasant and conveyed by the main canal to the project was used. In the third test, flood water caught behind the detention dam was used. During the first test four wells within a mile radius were used as observation wells.

Mr. De Cook states in the conclusion of his Preliminary Report as follows:

1. The three recharge tests on well 3-26 demonstrated the ability of the well to receive water at a constant and fairly high rate for periods of 48 hours or less. The specific intake of the well dropped rapidly each time recharge was started, but became relatively stable after 3 to 4 hours and dropped very slowly for the remainder of each test period. In both the first and third tests, the value of specific intake was 7.8 (gallons per minute per foot of head) after 24 hours of recharge.

2. The suspended -silt and dissolved-salts content of the canal water and flood water did not appear to decrease appreciably the intake capacity of the well during the tests. The possible effects of these factors under continual recharge are not known; it has been shown in other areas, however, that periodic pumping is a feasible method of clearing wells of silt for further recharge. During long-term tests, microbial clogging may also occur, necessitating occasional chlorination.

3. Both the drillers' logs of the wells and the calculated coefficients of storage indicate the presence of a large amount of clay or other relatively impermeable material in the ground-water reservoir. The transmissibility coefficients computed from data from all the wells, however, indicate that some of the strata of coarser sand or gravel have very high permeability.

4. As recharge water becomes available, recharge may be continued on an experimental basis, accompanied by measurements and observations similar to those described above. Longer recharge periods are needed on well 3-26 and other wells in the vicinity, to provide additional information on the following:

   (1) The long-range effects of the physical, chemical and microbial quality of the recharge water, and possible treatments;
   (2) The intake capacities of other wells in the area, and
   (3) The gross hydraulic characteristics and storage capacity of the ground-water reservoir, which can be more soundly evaluated as more data are collected.

Now, the District believes that it can very easily and inexpensively construct a conduit from the lateral to the well. Recharge water can then flow by gravity and need not be pumped as we have done in the experiments. We have not determined how much water we can recover from floods and inject into the ground-water reservoirs, but whatever it may ultimately be it will be worth many times the effort and expense of capturing it. We know it will not be enough to solve our water shortage problem, but along with other conservation measures it will be a great contribution toward that end.

Some Techniques Used in the Appraisal of Ground-Water Resources*

W. E. Hale**

The United States Geological Survey throught its Ground Water Branch engages in several types of ground-water studies, ranging from rapid appraisal of small areas to detailed quantitative study of an entire ground-water basin and including investigation of basic principles of ground-water occurrence and movement. The scope of a study may range from information as to the expected yeild of a single well at a particular site to a determination of the availability of water and the probable response of an entire aquifer to the development of water for a large industry or irrigation project.

The ground-water hydrologist has a large number of investigative tools at his disposal, and he may need to use a great many of them even in the study of a small area. Many of the techniques are simple, for a technique does not have to be complicated to be useful. Some of the methods are complicated, however, for in detail the movement and the availability of ground water and the changes in water level caused by development of an aquifer are complex. In this brief period, I can touch on only a few of the methods used in our work and comment on their effectiveness. In particular, I shall discuss in some detail the methods used for determining the hydraulic characteristics of an aquifer, the coefficients of transmissibility and storage, and utilizing them in ground-water appraisals.

The availability and movement of ground water are related primarily to the hydraulic properties of the rocks, to the position of these rocks in the hydrologic system, and to climate. The rocks form the framework through which the water moves and in which the water is stored; commonly the water is in what can be called transient storage. The more accurately the picture of the ground-water conditions is to be drawn the more important are the details of the geology. Hence, knowledge of the geology is essential to all our studies, along with information on wells and springs, streamflow, and chemical quality of the water.

During the initial phases of our investigations, particularly that phase involving collection of well data, we have depended and

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will continue to depend on the cooperation of well owners and well contractors--the individual well owner primarily. Each well is a probe into, and potentially adds to our knowledge of, a particular aquifer, and commonly, enough wells exist in a given area to obviate the need for special test holes. Data obtained include the depth of each well, depth to water, yield of the well as related to drawdown of the water level, a log of the geologic material at the well, temperature of the water, and chemical quality of water samples. Thus, a great many of you participate in the collection of a part of the basic data needed.

These basic data are then assembled and studied and may be used to prepare a report describing the water-bearing beds in an area, the yield that can be expected from additional wells tapping a specific aquifer, and the quality of the water that the wells will produce. A report of this nature is qualitative, in that it describes only the general ground-water features.

A qualitative report will provide a part of the background needed, or a starting point, for more intensive quantitative studies. the objective of a quantitative study usually is an answer to the question of how much water is available, or how a system will respond to a certain development, the response to be measured in terms of changes in water levels or in the flow of a stream. Such studies require the collection of additional data.

Some of the factors needed are the characteristics not only of the aquifers but also of the poorly productive beds, changes in water level with time, the amount of water used, and the base flow of streams within the area.

The hydraulic characteristics of an aquifer are defined essentially by two properties: (1) the ease with which water will move through the aquifer (measured by its coefficient of transmissibility), and (2) the amount of water taken into or released from storage in an aquifer in relation to changes in head (measured by its coefficient of storage). These characteristics of an aquifer determine to a great extent the rate at which water levels will decline when a well is pumped and, hence, the effect that pumping will have on the water-bearing formation. Data on transmissibility are needed also to determine the rate of flow of ground water. The ability of the aquifer to store water enters into the computations of the amount of water available.

One of the techniques for determining coefficients of transmissibility and storage makes use of laboratory tests of the various rock types in a particular aquifer system. Undisturbed samples of the rock are the most desirable, for obvious reasons, but disturbed samples may be usable where a rather uniform silt, sand, or gravel is involved.

The actual coefficient of transmissibility is not determined directly by this method but rather the coefficient of permeability, which is a hydraulic characteristic of a unit cross section of the material. The coefficient of transmissibility of an aquifer is the sum of the individual unit coefficients of permeability--that is, the average coefficient of permeability multiplied by the thickness of the aquifer. The standard, or laboratory, coefficient of permeability is determined by observing the rate of movement of water through the sample under a known head at a standard temperature. The field coefficient is the same except that it is measured at the prevailing water temperature in the field. It is the field coefficient that is multiplied by the thickness to obtain the transmissibility, which is a field coefficient.

The coefficient of permeability should be determined not only in two directions in the plane of the bedding but also at right angles to the bedding. The specific yield, which under water-table conditions is approximately equal to the coefficient of storage, is determined by draining or wetting the sample, according to the initial state of the sample. The coefficient of storage may approach the porosity of the sample, particularly in coarse-grained material.

The coefficient of permeability can be expressed in a number of ways. The units commonly used in ground-water work are the gallon, the foot, and the day. The coefficient of permeability is expressed as the number of gallons of water a day that would move through a 1-square-foot section of the material under a unit hydraulic gradient, at 60°F (laboratory coefficient) or field temperature (field coefficient). The coefficient of storage is a ratio of the water yielded from or taken into, storage per unit surface area of the aquifer per foot of change in head.

The laboratory method of obtaining the coefficients of permeability and storage has some disadvantages over other methods and is not applicable in some cases. For one thing, a sample represents only a very small part of an aquifer, and hence a large number of samples from different parts of the aquifer are required if even approximately representative coefficients of permeability and storage are to be obtained. The transmissibility of a formation may differ from the permeability of the constituent rocks. In other words, a formation containing open joints and caverns certainly will have a greater coefficient of transmissibility than would be indicated by averaging permeability determinations of a number of small samples not containing such openings. This is particularly true of formations composed of limestone and gypsum. Another disadvantage is that the samples commonly must be collected from the outcrop areas, and the hydraulic charactersitcs of these weathered rocks may differ considerably from these of rocks at depth in the zone of saturation. Further, the coefficient of storage of an aquifer under artesian conditions differs markedly from the specific yield determined by the laboratory method cited above, for under artesian conditions the coefficient represents mostly water squeezed out by compression of the aquifer rather than water drained out of the pores.

Nevertheless, this laboratory technique is useful in determining the characteristics of that part of an aquifer composed of unconsolidated sediments and, to some extent, of consolidated rocks that lack large open joints or caverns.

A method used to obtain a larger and a more representative "sample" of the aquifer is by the aquifer test in the field. Some years ago Theis (1935) developed the relation between the rate of decline of water levels in the vicinity of a well and the rate of pumping of that well. Under certain conditions a carefully conducted test will provide data from which the coefficients of transmissibility and storage can be computed. Since Theis' original work, he and others have developed methods whereby certain modifying and complicating factors, such as imperable boundaries created by geologic structure or topography and effects on the aquifer caused by nearby streams or leaky artesian systems, also can be taken into consideration in aquifer testing. Although the method of making field tests is a powerful tool in determining aquifer characteristics, the range of conditions under which it can be used is small compared to the range of conditions in our realm of interest. Thus, aquifer testing is not always applicable, and judgment is required in applying the results.

In some areas a useful method of measuring the coefficient of transmissibility of an aquifer is to relate the gradient of the water table or piezometric surface of the aquifer to the discharge from it. In New Mexico the use of such a method is complicated by modifications of streamflow caused by growths of phreatophytes along the valleys. The use of water by such plants diminishes the base flow that otherwise would be contributed by discharge from the aquifer. Other complications result from actual diversions and use of water from the streams. If such modifying factors can be estimated, however, this method can be used to advantage in estimating the transmissibility of an aquifer.

The coefficient of storage often can be determined by observing long-term declines in water levels and relating the volume of aquifer unwatered to the net amount of water pumped. This method offers particular promise in areas where the use of water is remote from areas of discharge or recharge. Such places include some closed basins, such as the Estancia Valley, the Tularosa basin, and areas in the southwestern part of the State, such as the Animas, Playas, and Deming basins.

The methods mentioned so far give the coefficients of transmissibility and storage at selected points or the average coefficients of transmissibility and storage over somewhat larger areas. To obtain values of these coefficients in detail over an entire system, values must be estimated for those areas for which aquifer-test data are not available. This usually requires detailed examination of well samples, electric logs, and the like, and correlating the information thus obtained with conditions at the site of the spot determinations of permeability and storage coefficients.

With information on the coefficients of transmissibility and storage, the effects of existing or proposed developments on that system can then be analyzed.

If the wells are few, the discharge rate of individual wells can be determined by obtaining from the operator an estimate of the duration of pumping during a year, or by measuring the fuel or electric power used and correlating this measurement with the overall efficiency of the pumping plant.

In large irrigated areas, measurement of the discharge of all the wells becomes impractical. Here sampling methods are used. One method used in the Roswell basin, where most of the ground water is pumped by electrically driven pumps, is to correlate the power consumed, the efficiency of the pumping plant, and the amount of water pumped by selected wells. Then by means of average pump efficiency, depth to water, and total power consumed in the area, the amount of water pumped is computed.

Still other methods involve determining the amounts of water applied to sample tracts of land and extending this rate of use to the total acreage irrigated.

These values for pumpage, however, are gross diversions, whereas the actual diversion from the system is the consumptive use. The gross pumpage therefore needs to be corrected by the amount of water, if any, that returns to the system by seepage from canals or irrigated fields.

If all the necessary data are now at hand, it may be desirable to estimate the decline in water levels throughout a certain area after 20 years of pumping under a certain assumed pattern of development and use of the water. One method used in New Mexico is to determine the cumulative effect that pumping of each well in the area will have at selected points. This is done by use of a map on which all the wells are located and by use of a special drawdown scale. The scale is laid out in this case to show the decline in water levels that will have occurred at various distances from the pumped well at the end of 20 years, with a certain pumping rate and the assumed aquifer characteristics. The drawdown caused by a particular well is usually determined at section corners, inasmuch as these form a convenient grid in most of the areas. The drawdown indicated at these section corners is multiplied by the factor needed to adjust the scale pumping rate to the actual pumping rate at the well. The number of section corners at which the drawdown is determined for any one well depends on the distance at which a discernible drawdown can be expected to occur. The drawdown effect caused by each pumped well is listed at each section corner and then added to give the total drawdown at each corner. A contour map of the declines at the various section corners can be drawn to show the cone of depression that would have resulted under the pattern of development. Such techniques are applicable particularly in areas where the principal draft on the aquifer is pumpage from ground-water storage, such as in most of the High Plains and in some of the topographically closed and hydrologically nearly closed basins in the southwestern part of the State. In addition, the effects of boundaries, such as the impermeable boundaries formed by granitic mountain blocks and the boundary formed by a river are taken into account.

Relaxation methods offer an approach to problems involving steady-state conditions. This does not mean that the hydrologist relaxes in an easy chair and waits for the answer, although some time devoted in this manner to such problems might be fruitful. Rather, the relaxation technique is one of relaxing control at one point and making adjustments at surrounding points until an entire system, in this instance a hydraulic system, is brought into balance. This technique is rather laborious but does permit the solution of some flow problems. An extension of this method, known as Schmidt's method, permits the solution of nonsteady-state problems such as the effects of pumping on an aquifer.

A less laborious technique for some steady-state problems involves the use of an analog plotter. A sheet of electrically conductive paper is trimmed to fit the boundaries of an aquifer or to represent a part of the aquifer. A pattern of holes can be punched in the paper to change its resistance so as to represent changes in transmissibility, or blocks can be cut out to represent impermeable areas as volcanic plugs or dikes. A flow net can then be determined by passing current through the system and plotting the lines of equal potential (equivalent to the hydraulic potential) by means of a probe connected through a voltmeter to the power source. Lines drawn perpendicular to the equipotential lines define the flow net.

Another method that shows promise involves the construction of an electrical model representing the aquifer under study. A network of resistors to represent the transmissibility or permeability of the aquifer and condensers to represent storage are constructed in such a way as to simulate the geometry of the aquifer. An electrical circuit then will represent the flow of water from recharge to discharge areas. By means of additional leads the well sites can be put into the model and by regulation of the power supply the pumping effects can be simulated. If a probe is placed at a particular spot, the oscilloscope shows the change in water level with time in the form of a hydrograph. This particular hydrograph can be traced or photographed and the process duplicated at a sufficient number of points on the model to obtain a complete picture of the decline in water levels at any time at any place in the system. The hydrographs are realistic to the extent that the data on the hydraulic characteristics of the aquifers and other basic data supplied for the analysis, are correct.

Another phase of the Survey's studies that has received increased attention in recent years is the actual movement of ground water under various conditions. This increased interest has developed as the result of disposal or contemplated disposal of wastes, particularly radioactive wastes, into ground-water reservoirs. Various tracers have been considered for use in tagging water so that it may be identified elsewhere in the system. Many substances are unsuitable as tracers of ground water because they either change the character of the water appreciably or are adsorbed by the rocks through which the water passes. In fact, the difficulty with even ideal tracers is that ground water moves so slowly that either the area to be studied must be small or else a large number of injection points are needed.

One of the more promising tracers is tritium. Tritium is radioactive hydrogen which has a half life of 12½ years. This means that half the original tritium induced into a system will have decayed in 12½ years. Tritium is a good tracer in that it is a part of the water itself and appears to be only slightly adsorbed as it moves through the water-bearing formations. Techniques have been developed to determine the presence of very slight amounts of tritium, and thus a tritium "spike" need not be large to take a large amount of water.

Libby (1953) and others have suggested that the tritium content of natural waters might be useful as a tracer and as an aid in solving some water problems. In addition to its use for determining where the water will migrate, the tracer will indicate the rate of movement of the water, which together with determinations of the porosity and the head from one place in an aquifer to another, may give values of permeability; all these will then be useful in quantitative studies.

Natural tritium is produced in the atmosphere and comes to the earth with rains. Tritium is produced also by hydrogen bombs, and since 1954 the tritium content of the atmosphere and of the rains has been increased briefly after each detonation, to amounts higher by several orders of magnitude. The Research and Development Division of the New Mexico Institute of Mining and Technology was one of the first to construct equipment for tritium analysis and to explore the possibilities of using tritium as a tool in ground-water studies. The results of the initial work of Dr. Haro von Buttlar (1958) of the Institute on this subject appeared recently in the Transactions of the American Geophysical Union. The Geological Survey now has a laboratory in operation for the determination of tritium and is working on the possible uses of tritium as an aid in water-resources studies.

A few of the techniques at our disposal for use in the various phases of ground-water studies have been touched upon. Many of the techniques used in the compilation of qualitative reports are tried and true, and they will continue to be the backbone of our stock of tools. Some of the more recently developed techniques for solving quantitative problems, powerful though they are, can yield results no more accurate than the basic data supplied, and considerable effort will be required to obtain and refine the basic data, especially those involving determination or estimation of aquifer characteristics. These techniques may prove to be inadequate to handle some of the problems that may develop. More adequate techniques surely will come into being, however, as we continue our appraisal of water resources.

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PUBLIC INTEREST IN WATER RESOURCE PLANNING

Albin Dearing*

What Are The Facts About Our Water Needs?

"These needs should be met without further dilly-dallying or delay. ...The time for playing with our waterways is past. The country demands results." Theodore Roosevelt, 8 December, 1908.

1. The American people are using water at a greater consumptive rate than any other people in history.

2. With its population increasing faster than that of any other nation on earth, by 1975 it is estimated that 227,000,000 Americans will require 50% more water than today's demands.

3. Urban expansion has so rapidly reduced watersheds that we suffer more frequent and more costly drouths and floods than ever before.

4. Increased pollution is daily reducing the amount of water available for multiple use.

5. Of all our natural renewable resources, the one most essential to survival, water, has been least emphasized for research or development in terms of public or private expenditures.

For half a century the need for a program of comprehensive water resource development has been widely proclaimed in the United States. Attempts to evolve one have not progressed either because supporters of a course of action were too strongly influenced in favor of a particular water use, or because of fundamental differences concerning the administration of such programs.

Today, with ever increasing demands being made on an ever decreasing supply, specialized needs for water use are being subordinated to the common need for water itself. Those who championed prior rights of water for farming, for manufacturing, for the home, for power, for commercial fishing, for navigation, for recreation, or for wildlife preservation are coming to the realization that water, all water, must be conserved if these several functions are to survive. How to cook the rabbit has become less the problem than how to catch him.

Who Is The Water Resouces Council?

"As our people are alerted to their responsibility in this vital area, I am sure the national health and economy can be strengthened. Congratulations to the Water Resources Council and best wishes for the success of

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their important work." Dwight D. Eisenhower, 10 May, 1957.

It was perhaps logical that the technicians in the water industries, the 17,000 engineers comprising the American Water Works Association, should first sense the need for arousing the public to the realities of our water situation. It was no less logical that they would ask help from the manufacturers of equipment used to pump, purify, impound, meter, carry and contain water,—the Water and Sewage Works Manufacturers Association. After several years study this latter group agreed to underwrite the cost of an exploratory campaign which would seek to combine the several efforts of all organizations having as their objective a plentiful, good, clean, dependable water supply. In 1955 a program of research was begun which one year later brought into reality the Water Resources Council. Its first meeting was held at historic Anderson House in Washington with representatives of twelve of its present twenty-three organizations present. The Council is a non profit cooperative organization with each supporting group entitled to be represented by one voting trustee. It elects its own officers and proposes to budget its costs so that every member organization, whether directly or indirectly in the water development field, civic or eleemosynary, in character, has a share in its expense. It actively seeks support from foundations to extend the usefulness of its program.

What Is Its Program

"Since 1953 the Federal government has spent upwards of a billion dollars for flood and drouth relief. Additionally, the states, the insurance companies, and many municipalities and relief agencies have been called upon to reproduce this sum several times over. And still the American people suffer ravages of drouths and floods, with attendant human suffering and loss of life—immeasurable in terms of dollars and cents. Indeed, the American people are paying for, but not getting, a program of water resource development." Representative John A. Blatnik, conservationist, author of the Federal Pollution Control Act.

The Council has adopted an immediate, an intermediate and a long range program, timed in consonance with the development of present versus long ranged water resource projects. It seeks to:

1. Stretch the available water supply pollution abatement, more efficient use of water in agriculture, manufacturing, and the home.

2. Insure the present supply by intensified watershed development.

3. Stabilize the future supply by locating and classifying ground water aquifers and providing means to recharge them, and

4. Developing an economical power source which will make possible the conversion and distribution of saline waters.

5. Establish and maintain an objective information program designed to create an adequate public awareness of our water needs.

Generally, the Council subscribes to the belief that all natural resources are interdependent, that their proper development should be both pragmatic and flexible, with full appreciation for economic and ecological factors involved in obtaining better substantive relationships between man, his forests, minerals, soils and water. It also subscribes to the belief that water resource development is best accomplished by comprehensive planning at the river basin level that too many controls are onerous and self defeating, and that voluntary compliance with regulatory measures is less costly and more effective and will result once the public has been made properly aware of the need.

Stretching the Available Supply. The Voluntary Clean Streams Program

"For many decades the American people believed that water—like matter in general—was indestructible regardless of what was done with it. But we are beginning to learn that when pollution of our rivers, streams, and lakes renders the water in them unfit for use, that water has been destroyed for all practical purposes." "America's Needs and Resources."

Convinced that pollution abatement was the surest way to reclaim billions of gallons of water, while at the same time rehabilitating health, real estate, wildlife, property and recreational values, the Council launched its Clean Streams program through exploratory efforts in three states, which recently has been expanded to include every state. Working with the governors, the Council has proposed establishing a counterpart organization in each state, and volunteered the cooperation of its member organizations, themselves having state components, to launch a program for water conservation. Its Clean Streams program differs in some respects from other such programs for pollution abatement, principally in emphasizing the appeal for clean streams as a means to conserve water, an essential need for manufacturers, muncipalities and farmer alike. It proposes an incentive award system whereby municipalities and manufacturers volunteering to maintain the state's pollution controls for their particular waterway would be cited by the governor and given an award, a roadside marker, attesting the high degree of community responsbility. By this voluntary means, pollution controls and the need for them would come into fuller public view, and what has not been too easily accomplished by the state or municipality's regulatory agency might quickly come to pass. No enlightened community or manufacturer takes pride in an existence besides a polluted waterway, but for want of funds or initiative, many industries and municipalities persist in despoiling the waterway for their downstream neighbors, and thus hasten their own decline, and the region around them, by wantonly destroying the water supply. Several states are exploring means to adopt this program. By the end of 1958 it's hoped that all will have.

Stretching the Available Supply. More Efficient Water Use—in Manufacturing, Agriculture and in the Home.

Industry is the largest water consumer. Of the 80 plus billion gallons of water used daily, fully 65 billion is taken by manufacturing. Nearly 45 per-cent of this is used for condensing or steam generation of electric energy.

Only limited measures have been advocated by manufacturing groups to encourage more widespread use of recirculating systems and cooling towers. This segment of water conservation will make the most rapid strides as quickly as manufacturers realize its importance for their own stability in place. The Water Resources Council seeks the cooperation of the National Association of Manufacturers in an undertaking to continue the research done in this important field by the Conservation Foundation in 1950. In any tight water situation, should use priorities have to be established, human subsistence, the water required by the municipal water systems, will doubtless get top priority. Those for the production of food, the farmers, will come next and in manufacturing last. It thus behooves industry to make the most intelligent effort it can to insure that every ton of water it draws gives maximum use before being discarded.

Farmers, like their city cousins, have felt the water shortage, in many eastern areas far more acutely than ever before. With this shortage has come increased irrigation practices, virtually unknown in the Southeast as recently as fifteen years ago. Thus far the Council has not developed an opportunity to work with any particular agricultural group. It seeks this opportunity for 1958 and proposes the joint establishment of a program to encourage wider use of farm ponds instead of wholesale stream diversion for irrigation where practicable, pollution controls, destruction of wild water consuming vegetation, and advancement of the Department of Agriculture's other useful programs for cutting down destructive runoff.

For our homes today only 6,700 of our municipal sewer systems have treatment plants and the capacity of more than 2,500 of these is inadequate. Besides the greater need for municipal sewage treatment plants there is further need for expansion of the degree of treatment, in some communities, that the waste effluent may be profitably reused for manufacturing or irrigation. While this proposal has already resulted in two major sewage-to-manufacturing projects, in Baltimore and Los Angeles, opportunities for others are believed to be numerous, and may well be the answer in many water sparse manufacturing centers. Via one of its founding groups, the American Water Works Association, the Council seeks actively to: (1) educate the individual water user to his community's water needs, and (2) stimulate local appreciation of what can result in terms of prosperity for the community by protecting its consumptive, industrial and recreational water supply through plant modernization and improvements. In the home, also, opportunity is present for educational processes in water conservation. Where the water supply is metered it is relatively less difficult to make the user understand water economy. Such, however, is not the case in many cities; in others, most apartment dwellers seldom see a water bill. To manufacturers of fixtures the Council proposes that "Waste Not—Want Not" be inscribed on every pair of faucets.

Watershed Development. Planning for Tomorrow

"The superior financial resources of the Federal Government and its pre-emption of many fields of taxation have placed it in a better position than the states are to make the large capital investments that are required for water development." Dr. Reuben G. Gustavson, President of Resources for the Future, Inc.

Much of the forest land that is important in watershed protection is in farm ownership dispersed among more than three million farmers. Apart from timber production, watershed protection is the paramount service rendered to our national economy by our forest lands, there being about 470 million acres of them having value in this respect. By slowing the rain and melting snows, trees and their litter help greatly to maintain the underground reservoirs that are so important for supply water for domestic, industrial and agricultural purposes. These forests also insure surface water supplies because regulating runoff on the land they help control the flow of rivers.

Watershed protection services offered by our forests, however, are below par in all parts of the country. Virtually one-third of the original forest lands has been forever lost, and those remaining are not as effective as they might be for watershed purposes as the result of poor timber cutting practices, and failure to prevent or control forest fires and insects and disease. Twenty per-cent of the forest lands, in the western and northern states, has been damaged by overgrazing. The U. S. Forest Service estimates that there are 44 million acres that should be planted to trees.

The Council proposes a program which will enlist the help of the National Grange, the Four H Clubs, Future Farmers of America in support of the Forest Service, with emphasis on tree planting for water conservation. Because of its strong backing by conservation groups, multi purposed forest planting for wildlife protection, soil preservation as well as for watershed development could be popularly advanced among farmers. There are more than 1,000 watershed associations working to develop these requirements. It is estimated that 15 million dollars per year for the next 50 years would be needed to bring about an adequate watershed.

Stabilizing the Future. Ground Water Recharge

"Just as we are conscious of the important historic truth that civilizations rise and fall according to their ability to satisfy the need for water, so do we recognize that the vigor of our economy and the general welfare...depend upon the outcome of our efforts to deal with this problem." Governor Robert B. Meyner, 14 May, 1957.

No long term need confronts the national economy more important than that for knowing where our ground water is, how much there is, what its quality is, and how it may be recharged for future use. With few exceptions statistics on ground water are inadequate. While surface waters may be measured, underground waters are wild in the sense that they move about in interconnected systems of aquifiers. These will require detailed studies, but such must be expedited if the national economy is to be strengthened by full use of this source. Flood diversion to underground aquifiers via recharge wells conceivably could provide an almost inexhaustible reserve for at least two thirds of the U. S. land area where underground water is believed to exist.

The Council will seek to have legislation introduced in the next session of Congress which will provide the funds necessary to make this survey. Geological surveyors of the Department of the Interior estimate that a conclusive study will take ten years, but that recharge systems could be immediately constructed once the basic data for a region is at hand. Several states have already undertaken such studies independently, and many have developed means for storing ground water.

Conversion and Distribution of Saline Water. Needed, Cheap Power

With every conservation measure available operating at maximum efficiency there is reason to believe that the industrial output of the United States could be twenty per-cent greater if new water sources were tapped to irrigate and industrialize much of the arid West. The Atomic Energy Commission's Office of Saline Water has a project underway in cooperation with the University of Washington to desalinize and deliver water from the sea. So far, however, electrical power or heat from nuclear energy has not become competitive in costs with that of other energy sources. It may well be, that the government in partnership with industry could underwrite such energy development on a scale sufficiently large to reduce the unit costs and make feasible this much needed development. There are several economical methods available for separating salt from water; the cost of pumping the saline free water remains the primary obstacle.

Creating a Public Awareness

In the area of public information, the Council seeks to get the water story across via (a) its own publications, (b) cooperative advertising and editorial help of its member organizations and (c) through the cooperative advertising campaigns of the Advertising Council.

Water lines, its own publication now appears quarterly, is brief in both format and content, and intended for distribution with the mailing of water bills by municipal and private water companies. Through this type distribution it is expected that millions of readers will be reached at least four times each year, with informative, pertinent news reporting of their country's water problems, their community's needs, and what must be done for each. The Council's publicity appears in news columns from time to time as its particular projects are advanced, and the publication of its member organizations have carried its program to their loyal readerships. Additionally, the Council collaborates with national magazines having a particular interest in certain phases of water resource development.

RESEARCH CONTRIBUTIONS TO WATER RESOURCES DEVELOPMENT

Owen L. Brough*

Research is the process of evaluating the outcomes of alternative procedures or actions. It implies that some optimum, or ideal is an objective. In water resources development, the objective may be the total satisfaction of society, or a maximization of monetary gain to the individual. Therefore, we are concerned both with the general public and the individual, the different objectives of the individual and society may not be consistent and result in conflicts of interest and of action.

In my discussion I am making several underlying assumptions. They are: (1) That the demand for water is increasing rapidly and will continue to increase; (2) the supply of usable water is not increasing at the same rate as the demand; and (3) the cost of developing additional usable water will increase. Thus, demand, supply, cost and efficiency in water use are important.

These assumptions lead us to the problems which require research for their solution. My immediate concern as an agricultural economist is the economic implications of these problems, and therefore, I will talk about economic research.

I will discuss these problems under three general headings: (1) Problems associated with increased demand for water, (2) problems associated with the development of increased supply of usable water, and (3) problems of conservation and use of water. These three types of problems are not independent of each other and the study of one necessitates some evaluation of the other.

Economic Problems Associated with the Demand for Water

Research and investigations are needed to estimate future water needs. Demand for water results from our needs for such things as: (1) food and fiber, (2) industrial or manufactured products, (3) recreation, etc.

We need research to test alternative criteria and methods of allocating water among uses and users. The uses are usually multiple in nature and form a complex problem of allocation. The problem is complicated even more because the source areas of the water supply are usually a complex of private and public ownership patterns. Furthermore, some uses are competitive and other complementary. Competition

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for water arises between two or more public uses, between the public and the private uses and between private individuals or firms. Examples of the uses are: (1) domestic, (2) industrial, (3) irrigation, (4) power, (5) recreation, etc.

We need research to determine and test improved alternative methods of measuring benefits from, or putting values on water development and use including: (1) Direct and indirect benefits, and (2) the calculation of present values on future products from water use. Public and private decisions can be more accurately made if our methods of evaluating these benefits can be improved.

Economic Problems Associated with the Development of an Increased Supply of Water

We need a more complete survey of the potential water supplies. This is not economic research as such but is basic to economic research.

The questions of <u>how</u>, <u>when</u> and <u>who</u> should develop water resources needs further study. There are, of course, several alternative ways to develop water resources and we need to know which alternative will result in the most efficient development of water. Many questions need answering. Examples are: (1) Should public agencies do the developing, if so at what level of government? and (2) What part should the individual play in water resources development?

Research is needed to evaluate alternative organizational arrangements that will lead to efficient water development. The alternatives may include: (1) More local participation in planning and development, or (2) ways for local groups to participate in cost sharing.

Alternative methods of cost sharing need to be evaluated. The following questions need answering: (1) If benefits can be determined, should cost be assessed on this basis? or (2) Should costs be assessed on the basis of ability to pay? and (3) What other methods of cost sharing will lead to most efficient development of water?

There are many legal problems associated with increased supply of water. Our legal structure has an effect on who develops water and the rate of development. In most states of the West, we need to take a good look at the legal structure governing water development and use. Much has been theorized on the two major categories discussed above. We need more theoretical discussion but also we need some imperial testing of these theories.

Economic Problems of Conservation and Use of Water

This type of problem is more or less associated with the individual. In the agricultural section of our economy, the problem is primarily concerned with the efficient conveyance, application and removal of water.

More specific examples are: (1) The economic evaluation of new and improved methods of water conveyance, (2) the economic evaluation of methods of water application for different climatic and physical land situations, and (3) the economic evaluation of different methods of water removal or drainage.

Many of our action agencies have been recommending methods of water use and management without the economic evaluation of costs versus returns. Many new water conveyance and application techniques need to be tested. Much work is needed in this problem area in the form of economic evaluation of the different techniques.

Economic Research of the Land Grant Colleges

In 1950 a regional committee of agricultural economists was set up to discuss problems and develop research projects in the area of water resources use and development that could be financed by federal money appropriated for regional research. As a result, several regional research projects have been initiated. They are: (1) Economics of Alternative Methods of Water Application, and (2) Economics of Alternative Legal Arrangements in Ground Water Development.

Three more research projects are being considered for regional activation, they are: (1) Economics of Reorganization and Rehabilitation of Irrigation Projects, (2) Economics of Small Watershed Development, and (3) Economics of On-Farm Use of Irrigation Water. In addition, individual states in the West have initiated research in many of these and other problem areas.

Several other research groups in the West have been interested in water development problems. In recent years, groups of economists, sociologists, political scientists, and engineers have held regional conferences to specifically discuss water problems. To me this indicates a growing interest and consciousness of these various groups in water development.

Conclusions

In summary I would like to make the following points:

1. We can truly say that research workers are aware of the water development and use problems.

2. Trained personnel are presently doing research on these problems but not enough is being done.

3. Research can lead to a more systematic and economical development, use and conservation of our water resources.

PLANNING AS A MEANS OF AVOIDING CONFLICTS IN WATER USE

Irving F. Davis, Jr.*

The title of my paper implies that water is important, that people want it and need it, that we want more than we have, that we want what others claim, and that conflicts result. I shall assume that there is a strong demand for water and spend my time talking about the supply. Since ground water is of major importance in this area of the West, I would like to confirm my remarks to the ground water supply.

Conflicts in Ground Water Use

One of our better known land economists has said that "Water resource planning frequently involves more complications than any other type of land resource planning and more complications than arise in the planning of private farm and business operations." **

I will discuss two important reasons for conflicts in water use and then discuss methods of remedying these conflicts. The two reasons may be attributed to the peculiar nature of ground water and misunderstanding among users of ground water.

Nature of ground water

There are two natures of ground water that contribute to conflicts in water use. They are the commonality and exhausting features.

1. Commonality of ground water. In this respect ground water is like air, we can't distinguish what is our air from that of our neighbor. Its supply is common to all who use it. It can be polluted, as the smog of Los Angeles, or it can be scarce, as coal miners tell us. If we cannot distinguish our share, then how can our rights to it be established? We can pump it into a bottle and take title to it. This might be likened to the air rights upon which the Prudential Building in Chicago is built. Or it may be like the airlanes used by airplanes.

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**Raleigh Barlowe, Michigan State University, "Planning for Water Resource Developments," paper presented at Law Economics Institute, University of Illinois, July 31, 1958.

Underground water is a free good until diverted. The expense of putting it to use makes that portion an economic good. But, the water not used now may be needed tomorrow or this season or next. How can we be assured of our share? How can we be secure in our right to its use? How can we protect our capital investment in diversion structures? For the answer we look to the law of equity. When the ground water resource in its natural state is free, when it is common to several overlying owners, then it must be shared on an agreed, traditional, customary, expedient basis. We call this a water doctrine, which becomes basic to water law.

2. Exhausting nature of ground water. In this respect, ground water is like a forest. It can be depleted all at once or it can be used so as to provide sustained yield. If we mine it, then the total supply is treated as in oil or coal mining and the mineral is depleted. If we use it so as to sustain the yield, our pumping must be limited to the amount of recharge through seepage. Which shall we do? The answer depends upon economics and the law.

   If the law does not protect your investment from continued over-development and mining of a ground water basin, then economics would say to get all you can while you can and get the highest profit possible this year from its use. But, if the law protects you from such action, then economics says to use the water so as to get the most proftis possible over the years. This second approach may not give you as much profit this year as the first approach, but then your farm may be worth a lot more today based on the longer period of profitable water use. The greater advantage of the second choice is that everybody benefits and not just the farmer who get the "mostest" in the "fastest" time.

   Commonality present a legal problem. The exhausting nature of ground water presents an economic problem. They are not unrelated. Legal arrangements have adjusted to economic realities but there is a time lag so that man-made laws do not always accord with economic principles. Economic change calls for flexibility in water rights.

Misunderstanding in Use of Ground Water

Conflicts stem from misunderstanding and disagreements in ground water use. These conflicts are between uses and users, farmers and non-farmers, between watersheds, and even states. Why do they exist?

Our customs in water use have evolved from a period of abundant supplies and sparce population. This setting has changed. The question "who shall have the water?" calls for different answers. When first asked the answer was: whoever develops it. Later, the answer was: whoever has a legal right to develop it. Today the answer must be: whoever has a legal right to develop it and can do so economically.

Misunderstanding has stemmed from lack of information about ground water. Farmers and legislators alike are laboring under a number of misconceptions about ground water. They hold no clear picture about what happens underground. Legal information is lacking. Court cases are buried in District court files. Conflicting decisions have been handed down, often based on faulty hydrologic and geologic information.

Planning in Ground Water Use

About 2-1/2 years ago the Land-Grant College of the West began research on the economics of laws affecting ground water use.* Five western states have engaged in that study and results already are beginning to show. One of the first discoveries was the dearth of pertinent information available on the physical and legal aspects of ground water use. How could economists evaluate the economic implications of legal rights to water use when there was no clear understanding about the water supply or rights to it?

As a result of this dilemma an informational and educational approach was adopted in the research efforts.

In 2-1/2 years of study, the 5 states of New Mexico, Colorado, Utah, Montana and Oregon, have contributed 3 master of science thesis, 1 Ph.D thesis, 4 published articles and 12 reports in preparation for publication, all as a part of this research effort in the economics of ground water use.

Time does not permit a review of each report. A few of the findings are outstanding. This New Mexico Water Conference was started in 1956 to provide a forum for information in water use, water law and economic implications. By means of detailed statistical analysis New Mexico economists have developed annual recharge estimates that may have considerable influences on water use in Lea County, New Mexico. Utah's pump drainage studies indicate that it is possible to increase production by more than 50 percent in the Logan-Hyde and Park-Benson areas of Cache County Utah. Oregon's study has helped clarify vague legal concepts embodied in ground water law and has provided a method of economically allocating a limited water supply.

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*Western Regional Project (W-42) entitled? "Economic Analysis of Laws and Related Institutions Affecting Ground Water Use in the Western States."

Montana's research in ground water is laying the groundwork for drafting a comprehensive ground water code in that state. In Colorado 6 television programs have been presented on the subject of water. In 1957 Colorado passed its first ground water law. Legislators instrumental in drafting the bill were sent preliminary findings of ground water research.

Already accomplishments of research in ground water problems are proving of benefit to legislators and administrators and we hope to farmers in dealing with ground water resources. As for planning to avoid conflicts we feel that a conflict may be identified in economic terms before it arises in law as a controversy. We predict more complications, controversies and conflicts in the future use of ground water. Planning, based on the findings of research, is a solution. I recommend for your consideration.

COMMENTS ON DEVELOPMENT OF GROUND-WATER RESOURCES, CURRENT INVESTIGATIONS, AND PLANS FOR FUTURE STUDIES IN NEW MEXICO*

W. E. Hale**

Withdrawal of water from ground-water reservoirs in New Mexico seemingly has stabilized since about 1955. In 1955 the volume of water pumped from ground-water sources was estimated to be about 1,500,000 acre-feet. Of this amount approximately 1,300,000 acre-feet, or 87 percent, was pumped for irrigation. In 1956 and 1957 it is estimated that about the same volumes of water were pumped for irrigation. Municipal and industrial uses probably have increased in the past few years, but the amounts of ground water pumped for these purposes have not been tabulated since 1955. Judging from the amount of water pumped by the city of Albuquerque, the increase may be about 10 percent. In 1955 Albuquerque pumped about 26,000 acre-feet, in 1956 about 30,000 acre-feet, and in 1957 about 28,000 acre-feet.

Greater precipitation in 1957 than in 1955 or 1956 tended to diminish the need for irrigation water and also some uses of municipal water. A reduction in cotton allotments reduced the use of water for cotton, but additional water was used on the remainder of the acreage for other crops. Some additional land has been put under irrigation. These and other factors apparently offset each other to the extent that about the same quantity of water was needed in 1955, 1956, and 1957, as mentioned.

The volume of ground water pumped in the State, large though it is, has no real significance unless the pumpage in each area is compared with the total amount of water available there. Much of the land in the State favorable for irrigation from ground-water supplies appears to have been developed at this time. Intensive studies have been and are being made in these areas by the Geological Survey in cooperation with various State agencies to learn more precisely the amount of water available or the changes in water levels that have resulted or are likely to result during development. Several large areas about which we know little at present, in the west-central, northwestern, and northeastern parts of the State, may contain ground water in sufficient quantities for irrigation. In general, however, on the basis of the general geology, it seems that the amount of fresh water in these areas is not as great as in those areas where ground water already is being utilized for irrigation.

Plans for further ground-water studies in New Mexico by the Geological Survey in cooperation with various State and local agencies include investigations in those areas where little is known of the ground-water resources and a continuing appraisal in those areas where ground water presently is being utilized in large amounts.

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* Publication authorized by the Director, U. S. Geological Survey.
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Investigations of general ground-water resources on a county or part-county basis have been under way since 1948 in cooperation with the New Mexico Bureau of Mines and Mineral Resources, a division of New Mexico Institute of Mining and Technology, and the State Engineer Office. These studies have resulted in the publication of several basic areal reports on parts or all of several counties. Currently, basic reports are being prepared on Quay County and parts of Lea and Valencia Counties. It is anticipated that under this program a study of northern San Juan County will be started in the near future. It is planned, of course, to study the remaining counties of the State in this manner as funds permit, but it will require several years to complete such studies at the present level of activity.

The cooperative program with the State Engineer involves both the general county studies and detailed appraisal of the ground-water resources in those areas of the State where ground water has been developed intensively or where such development is related to surface-water supplies, such as in the Pecos and Rio Grande valleys. The purpose of the detailed studies is to determine the hydraulic characteristics of the water-bearing beds, the effects of pumping as reflected in changes in water levels, and the amount of water in storage. When these facts are known, the effects of continued or additional development on the ground-water supply or related surface-water supplies can be computed. Studies currently are under way in parts of the High Plains, the Pecos valley southward from the vicinity of Roswell, the Albuquerque area in the Rio Grande valley, the Gallup area in McKinley County, Grant County, Guadalupe county, and topographically closed or nearly closed basins such as Estancia and Tularosa Valleys and basins in the southwestern part of the State. General plans include beginning intensive studies in the near future of a major part of the Rio Grande Valley.

Other cooperative programs now in progress include those with the Pecos River Commission, the Pecos Valley Artesian Conservancy District, and the Jicarilla Indian Tribe. Studies for the Pecos River Commission involve consumptive use of water by phreatophytes, quality-of-water problems, and accountability of water in the Pecos Valley southward from the vicinity of Lake McMillan. The program with the Pecos Valley Artesian Conservancy District includes a study of the saline-water area in the vicinity of Roswell and an investigation of the recharge area of the Roswell basin. A program of observing fluctuations or trends in quality of ground water in the Roswell basin near the Pecos River also has been started. The program with the Jicarilla Indian Tribe involves a general appraisal of ground-water resources in the southern part of the reservation in Rio Arriba and Sandoval Counties, particularly in regard to the potential for irrigation supplies.

Some of the State agencies such as the New Mexico Bureau of Mines and Mineral Resources and the State Engineer Office also carry on ground-water studies independently of their cooperative programs with the Geological Survey.

In summary, investigations of the ground-water resources already under way in the State and plans for additional studies are substantial. The magnitude of the effort reflects the State's commendable interest and concern for its water resources.

MEETING AGRICULTURE'S WATER REQUIREMENTS

Harry F. Blaney*

Since 1940 several developments have made us realize that immediate steps must be taken to improve the utilization and increase the conservation of water for agriculture. These events are attributed to World War II, droughts, increases in population, industry, irrigated land and pollution of streams and lakes.

Our population and need for water for irrigation and other purposes has increase above normal expectations. The 1955 Agriculture Year Book indicated that the greatest single use of fresh water in the United States was for irrigation, or about half of the fresh water we use annually. However, the use of water by cities for domestic and industrial purposes is increasing rapidly and in some areas is competing more and more with water required to meet the present needs and expansion of irrigated agriculture.

According to the census reports in 1939, there were about 17,243,400 acres in irrigated farms in the 17 Western States. By 1949 the acreage had risen to 24,270,600 acres. The increase in irrigated lands in the 31 Eastern states doubled during the same period. In 1958 it is estimated that the total irrigated area in the United States is over 30 million acres, of which about 28 million is in the 17 Western states.

Since water is the limiting factor in the expansion of agricultural areas of the West, the determination of irrigation requirements of various crops and conservation of existing water supplies are of greatest importance in the economy of this area. Considerably more land with soils suitable for irrigation is available for development than there is water with which to irrigate it. Careful use of irrigation seldom exist where water is plentiful, but where it is scarce, conserving methods are the rule; wasteful practices are avoided, and water is carefully applied. The most economical use of water generally prevails where there is a diminishing supply and the cost is high. Under these conditions economy in irrigation methods, involving a better understanding of the water requirements of agricultural plants, will benefit all irrigated areas.

The design and construction of irrigation systems usually involve consideration of either of two sets of conditions. In one the area to be irrigated has been determined and the water supply is ample; in the other the known water supply is limited, while the area which

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may be irrigated is restricted only by the available water. In both cases the total quantity of water to be considered by the engineer is the irrigation requirements of the crops combined with transmission and other losses in canals.

Although a knowledge of consumptive use is important in the case of a large irrigation project, and especially a river system as a whole, it may not be as important to the individual farm as the efficiency with which the water is distributed and applied, especially on a long shoestring project. Irrigation authorities have estimated that in some areas less than one-fourth of the water diverted from the source actually becomes available for use by the plant.

Conservation of present water supply by improved irrigation practices and reduction of conveyance losses in canals and farm laterals would provide one of the largest possibilities for expanding irrigated agriculture in many areas of the West. Methods of reducing these losses is being studied by our Western Soil and Water Management Research Branch.

Another great source of water supply is the salvage of water now wasted by phreatophytes. It has been estimated that the annual evaporation and transpiration losses along water courses in the 17 western states amounts to more than 25,000,000 acre-feet or about twice the average annual flow of the Colorado River. However, it is doubtful, if it is practical, to salvage more than 50 percent of this loss. This, if feasible, would be enough water to irrigate some 4,000,000 acres of agricultural lands in these states.

Thus a large increase in the proportionate use of developed water supplies can well be made available for agriculture through conservation and reuse. The present supplies can be extended through:

1. Adoption of laws for controlling the conservation and distribution of surface and ground-water supplies for beneficial use.

2. Improved planning of river basin developments to store water now lost by flow into the ocean and reduce other wastes.

3. Reclamation of sewage and other waste water.

4. More efficient reuse of industrial waters.

5. Better land-use practices to conserve precipitation.

6. Increasing irrigation efficiencies on farms and projects.

7. Increased use of ground water.

Some of the new sources of water being investigated by Federal and State agencies include:

1. Reduction of evaporation loss from lakes and reservoirs.

2. Reduction of losses through evapotranspiration by natural vegetation.

3. Desalting sea water and saline ground water.

4. Cloud seeding to control precipitation.

5. Recharging ground water basins during wet periods to supply water during droughts.

6. Increased use of ground waters by pumping.

Sound development of further irrigation will require not only finding new water supplies but the better management and more efficient use of existing supplies. Thus continued and additional research studies by the Soil and Water Conservation Research Division of the United States Agriculture Research Service and the State Agricultural Experiment Stations are needed to solve the water-supply problems of the nation which will become more serious for years to come.

THE FARMER'S INTEREST IN WATER RESOURCE PLANNING

W. H. Gary*

When we were asked to talk on a farmer's interest in water resource research, we accepted because we thought the subject would not be too hard to discuss. However, as we began to look for information from different sources and to evaluate the proposition, it seemed to become more and more axiomatic as to be comparable to the proposition that two and two make four.

Water in New Mexico is in an opposed category from food and fiber. Not too many years ago men's winter apparel was generally wool and summer wear in society was white linen. No doubt many of you remember your mother rendered her own lard and churned her own butter. Today any number of substitutes are available for the then limited number of fibers and vegetable fats to a large degree, more replaced animal fats. Not so with water. Without it, you do not sustain either animal or vegetable life, either withers and dies.

Water in the state of New Mexico is one of our most limited resources, consequently, if the economy of the state is to expand and grow it behooves every segment of society to be water conscious and employ such practices as will be most beneficial for the people of the state. Of all segments of society agriculture is most vitally affected. The state has already recognized that the sustenance of human life has a priority in the use of water over agriculture in that it has given municipal needs the right of condemnation over agriculture.

The state of New Mexico operating upon the general theory that all water is property of the state and an individual, or group of individuals, establish there right to its use by prior, continuous, and beneficial use is naturally thereby comparable to the quotation in the scriptures, "The Lord giveth and the Lord taketh away." We hear much these days of old existing water rights, but it would seem a fair assumption that in the event of necessity, in order to continue the development of the state's economy, the state would in all probability revise the then existing rights for the benefit of its population along fair and equitable methods. If that day should come, then agriculture will suffer, for it certainly cannot go into the open market and compete financially for the use of water.

It is not my intention to be an alarmist, but my experience as a menber of the Interstate Streams Commission for a period of some eight

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years have shown that with the exception of some 200,000 acre feet of water a year in the Canadian River Basin and as soon as the San Juan Basin is developed, all of the surface water of the state is in effect over appropriated today. These appropriations have been made more or less on a fifty year average of availability of water in the several basins. Yet the precipitation and flow in these areas is so erratic that frequently we are faced with a period of years of subnormal water supply. Certainly no one would advocate limiting the use of water to that available in drought years and let the abnormal runs go on down the streams. Because of this condition of erraticflows, problems are created and it is these problems we have to resolve to the extent possible.

There are no doubt many approaches to the problem, some that appeal to me are:

1. Through research locate and develop within the realm of feasibility all the underground basins within the state. A few years back it, at least, was not common knowledge that there were underground basins in Lea and Hidalgo counties. How many more are available through searching and drilling wells?

2. Make a more effective use of the water being diverted. Records show that in practically every irrigation project from forty to fifty percent of the water diverted is consumed by seepage. Does this seepage return to the stream in sufficient volume and at such a rate as to become available for use by others or is it in effect lost and wasted? Naturally every project will have its own peculiar circumstances which no doubt will require different procedures to reclaim the wasted water to the maximum extent.

3. An investigation in a limited way is under progress now to determine the feasibility of underground storage of water in abnormal rainfall years to conserve it for future use when needed. What the result will be, is anybody's guess, yet if it can be done with justifiable volume and with reasonable expense it will mean much for the economy of the state. No doubt there are numerous other solutions to the problem that will be developed as the necessity arises, so may I close by saying that a farmer who is not interested in water research is displaying his ignorance of the subject, his lack of information, or else he is a person operating on the theory of "Let the Lord provide" and if some one has to take the Lord's place that is perfectly alright with him. Yet in my book the Lord helps him who helps himself, not to the disadvantage and deprivation of others, but in those things that help him and at the same time helps his friends and neighbors.

RESOLUTION PRESENTED BY E. G. MINTON, LOVINGTON
AT THE THIRD ANNUAL NEW MEXICO WATER CONFERENCE,
NEW MEXICO STATE UNIVERSITY, NOVEMBER 7, 1958

WHEREAS, The Federal Government is embarked on a vital program of vast significance to provide fresh water from the sea and from underground deposits of marginal brackish water in the Great Plains States, and

WHEREAS, The Federal Government has announced its intention to build several plants to demonstrate the feasibility of such desalinization processes, two of such plants to be constructed in the Great Plains States, and

WHEREAS, the impact of this program will be felt on the lives of millions of people not only in the waterless West but in the East, in Europe, in Asia, in Africa, in Latin America and in Australia, where growing needs for water are rapidly outstripping all available fresh water supplies, and

WHEREAS, the State of New Mexico is known to have nearly a billion acre feet of brackish water regularly flowing through a system of underground aquifers, enough reclaimable water to bring this region into an era of expanded prosperity for the benefit of all the people, and

WHEREAS, New Mexico with its healthful, invigorating climate, its matchless natural beauty, its abundance of oil, natural gas, coal and atomic fuels, could comfortably support several times its present population, vast industrial payrolls, and thousands of profitable farms and ranches, had it more useable water, thus enabling it to relieve the mounting population pressure of other sections, and

WHEREAS, legislation providing for the construction of these new water desalinization plants was originated and sponsored by New Mexico's own illustrious Senator Clinton Anderson, a distinguished lawmaker with courage and vision of whom all New Mexico is proud, and

WHEREAS, the administration of this program has been the responsibility of the Department of Interior through its resourceful Office of Saline Waters, competently aided by the Atomic Energy Commission, and

WHEREAS, New Mexico State University of Agriculture, Engineering, and Science, the Water Resources Council, Inc., the New Mexico Economic Development Commission, the Southspring Foundation, the Charles Lathrop Pack Foundation have all labored diligently to bring about this Conference which has been attended by more than three hundred businessmen, technicians, educators, ranchers farmers, and government leaders from all the Great Plains Region, from Washington, from New York, and from abroad, focusing worldwide attention on the seriousness of the water problem, and what, in part, this nation expects to do about it.

NOW THEREFORE BE IT RESOLVED, that the Honorable Fred A. Seaton, the Secretary of the Interior, an estimable public servant who discharges his heavy responsibility with diligence, devotion, and rare competence, that Clinton P. Anderson, who fathered this good law, and the several groups responsible for bringing about this useful assembly be each voted the unanimous Commendation of this Conference, and

BE IT FURTHER RESOLVED, that a Standing Committee be appointed. That Rogers Aston of Roswell, who is a member of the New Mexico State University Water Advisory Committee, Vice President of the Southspring Foundation, Vice Chairman of the Water Resources Council, Inc., be Chairman of this Committee. This Committee to wait personally upon Senator Anderson and Secretary Seaton and to present them with a copy of this Resolution and such Standing Committee to work with the State Engineer and others technically competent to draft plans necessary to make it feasible, with all dispatch, to procure the sites and to meet other such requirements necessary for the construction of one of the water reclamation plants in New Mexico, and such Committee to report at the next Conference, or sooner, as it sees fit, and

BE IT FURTHER RESOLVED, that a copy of this Resolution be presented to Governor Mechem, whose Economic Development Commission has already taken some initiative in this matter, to Congressman Montoya, who has followed its development with keenest interest, to Governor Elect John Burroughs, to Members of the Congressional Delegation, to the State Engineer, to Members of the State Legislature, to the President of New Mexico State University, the heads of Southspring Foundation, the Water Resources Council, Inc., and the Charles Lathrop Pack Foundation, and to the Press.

Voted at the Third Annual Water Conference, State College, New Mexico, November 7, 1958.

Signed/ H. R. Stucky

H. R. Stucky, Ph D.
Chairman, New Mexico Water Conference
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