WATER RESOURCES RESEARCH INSTITUTE

NEW MEXICO STATE UNIVERSITY

PROCEEDINGS

FIFTEENTH
MARCH 12–13–1970

ANNUAL WATER CONFERENCE

THEME :

Water——
There Is No Substitute

Las Cruces, New Mexico

NEW MEXICO WATER CONFERENCE

Sponsored By

NEW MEXICO STATE UNIVERSITY DIVISIONS

of

Agricultural Experiment Station
Agricultural Extension Service
College of Agriculture

College of Engineering
Engineering Experiment Station
Cooperative Agent, USDA-ARS-SCS

Water Resources Research Institute

and the

WATER CONFERENCE ADVISORY COMMITTEE

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Dr. James Kirby	- Assistant Director, Extension Service
Dr. Boyce C. Williams	- Agronomy - Soils
Dr. W. P. Stephens	- Assistant Director Agricultural Experiment Station
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Jesse V. Lunsford	- Civil Engineering
James P. Penwarden	- Information Services
Eldon G. Hanson	- Agricultural Engineering
O. F. Baca	- Assistant County Agent Leader Extension Service
Gene O. Ott	- Farm & Business Management Specialist Extension Service
Dr. James R. Gray	- Agricultural Economics
Dr. H. R. Stucky	- Water Resources Research Institute Chairman

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Albuquerque, New Mexico

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Las Cruces, New Mexico

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U. S. Geological Survey
Albuquerque, New Mexico

Carrol Hunton
Farmers Home Administration
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New Mexico Electric Service Company
Hobbs, New Mexico

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Forest Service, USDA
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Hoyt Pattison
Representative, Curry County
Clovis, New Mexico

Ralph Charles
Middle Rio Grande Flood Control
Association
Albuquerque, New Mexico

P R O C E E D I N G S

F I F T E E N T H   A N N U A L   W A T E R   C O N F E R E N C E

March 12 - 13, 1970

THEME - WATER - THERE IS NO SUBSTITUTE

WATER RESOURCES RESEARCH INSTITUTE

NEW MEXICO STATE UNIVERSITY

STATE OF NEW MEXICO
EXECUTIVE OFFICE
SANTA FE, NEW MEXICO

PROCLAMATION

WHEREAS, THE FUTURE SOCIAL, ECONOMIC AND CULTURAL GROWTH AND DEVELOPMENT OF THE STATE OF NEW MEXICO DEPEND UPON A CONTINUING ABUNDANT SUPPLY OF WATER OF GOOD QUALITY; AND

WHEREAS, TO ASSURE MAXIMUM CONSERVATION THE WATER RESOURCES OF NEW MEXICO MUST ONLY BE USED IN THE MOST EFFICIENT AND ECONOMIC MANNER; AND

WHEREAS, FUTURE WATER REQUIREMENTS OF THE STATE MUST BE SUPPLEMENTED THROUGH RESEARCH AND DEVELOPMENT OF LARGE SCALE IMPORTATION PROJECTS, RETREATMENT AND REUSE OF WATER, DESALINIZATION, WEATHER MODIFICATION, AND ALL OTHER FEASIBLE MEANS; AND

WHEREAS, THE FIFTEENTH ANNUAL STATEWIDE NEW MEXICO WATER CONFERENCE IS BEING HELD TO DISCUSS THE VARIOUS ASPECTS OF OUR VITAL WATER RESOURCES PROBLEMS; AND

WHEREAS, TO ACCORD OFFICIAL RECOGNITION TO THE IMPORTANCE OF WATER TO THE WELFARE OF ALL OF THE PEOPLE OF NEW MEXICO;

NOW, THEREFORE, I, DAVID F. CARGO, GOVERNOR OF THE STATE OF NEW MEXICO, BY VIRTUE OF THE AUTHORITY IN ME VESTED, DO HEREBY PROCLAIM THE WEEK OF MARCH 8-14, 1970, AS

WATER FOR NEW MEXICO WEEK

AND URGE ALL CITIZENS TO PAY SPECIAL ATTENTION THAT WEEK TO THE IMPORTANCE OF OUR PRESENT AND FUTURE WATER SUPPLIES AND NEEDS.

ATTEST:

Ernestine D. Evans
SECRETARY OF STATE

DONE AT THE EXECUTIVE OFFICE
THIS 28TH DAY OF JANUARY, 1970
WITNESS MY HAND AND THE GREAT
SEAL OF THE STATE OF NEW MEXICO

David F. Cargo
GOVERNOR

GOVERNOR CARGO'S PROCLAMATION naming the Week of March 8 to 14
As WATER FOR NEW MEXICO WEEK did much to emphasize
the Importance of water to the welfare of the people of the State

FOREWARD

The Water Conference Advisory Committee and the University Committee will miss President Roger Corbett, both as President of New Mexico State University and his presence for at least a part of each and every one of the fifteen conferences, and his participation in many of the conference committee meetings. A plaque was presented to Dr. Corbett by the Fifteenth Annual Conference in appreciation for his many contributions.

The Fifteenth Annual New Mexico Water Conference is now history and the planning for the Sixteenth is well underway.

There has been a great change in the public awareness of the total water problem, both in New Mexico and in the Nation, during the years spanned by these annual conferences - 1955 through 1970.

The Congress of the United States has passed a series of important bills to assist in education, research, demonstration, development and conservation and use, in the broad fields of supply and quality of our national water resources. Several state legislatures have also taken numerous important steps to help implement state, county, city and rural community programs.

Most of these programs have been started since 1965 and are beginning to bear the first fruits expected from them. During the period 1970 to 1980, further great changes in public awareness are expected. The social and political problems will be brought foreward as the environmental and ecological emphasis is applied, along with the traditional engineering and economic planning and development. The social phases will more and more become a part of the early planning rather than reactions, in some cases emotional and/or violent, when the public becomes aware of the developing or developed plans.

The state-wide Water Conference Advisory Committee and the University Committee have recommended that a major section of the Sixteenth Annual Conference be devoted to student papers in several disciplinary areas and from several universities in the Southwest. This should be a stimulating program.

This Proceedings issue brings together a wealth of information and viewpoints on the water program in New Mexico and the Nation, thanks to the several speakers.

Part of the funds required for the publication of this proceedings issue were provided by the United States Department of Interior, Office of Water Resources Research as authorized under the Water Resources Research Act of 1964, P. L. 88-379.

The program which follows will serve as an index to the papers.

H. R. Stucky

H. R. Stucky, Chairman
Water Conference Committee

ROGER B. CORBETT
PRESIDENT

Dr. Roger B. Corbett, who has been President of New Mexico State University since 1955 will retire in August 1970. He was given a plaque by the Fifteenth Annual Water Conference in recognition of his sincere concern regarding the water problems of New Mexico and the Southwest and for his strong support of each of the Annual New Mexico Water Conferences.

STATEWIDE WATER CONFERENCE ADVISORY COMMITTEE MEMBERS


S. E. Reynolds
State Engineer


E. O. Moore
Farmer and PCA


Fred Thompson
State Department
of Game & Fish


Lloyd Calhoun
New Mexico Electric
Company


Rogers Aston
South Spring
Foundation


Ralph Charles
Middle Rio Grande
Conservancy District

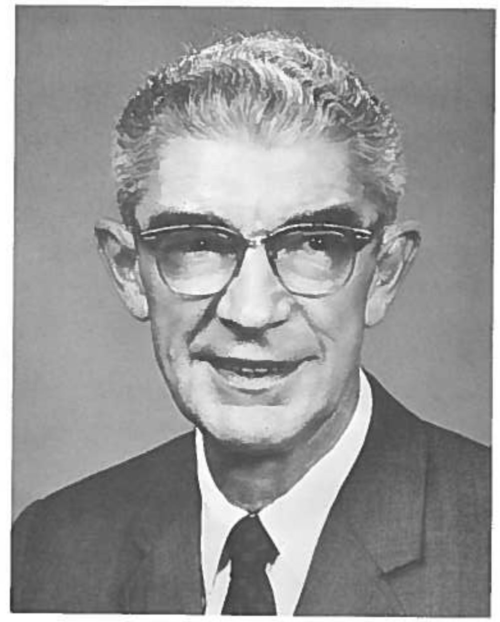

William E. Hale
U.S. Geological
Survey


Mrs. L. L. Lyon
League of Women
Voters

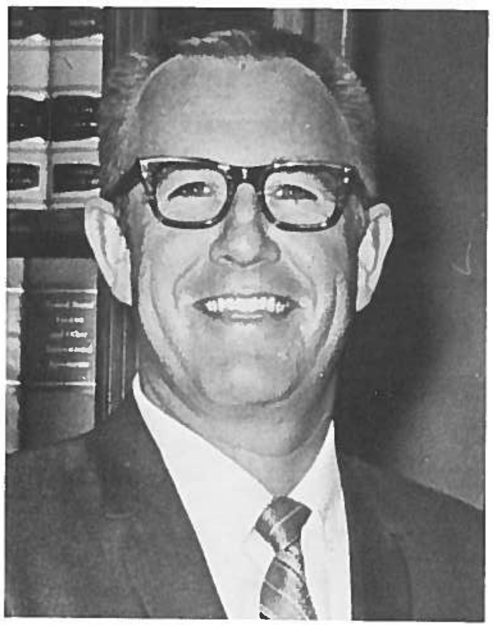

Willis Ellis
Law School
UNM


Rowland Fife
Bureau of
Reclamation

These New Mexicans, together with the others on the Advisory Committee listed on the inside front cover meet twice each year to assist in developing the conference program. Those in the top row have served for 14 conferences and those in the bottom row for 5 to 10 yeara. Much credit is due to this committee for the many solid and forward looking contributions to the success of each of the annual water conferences.



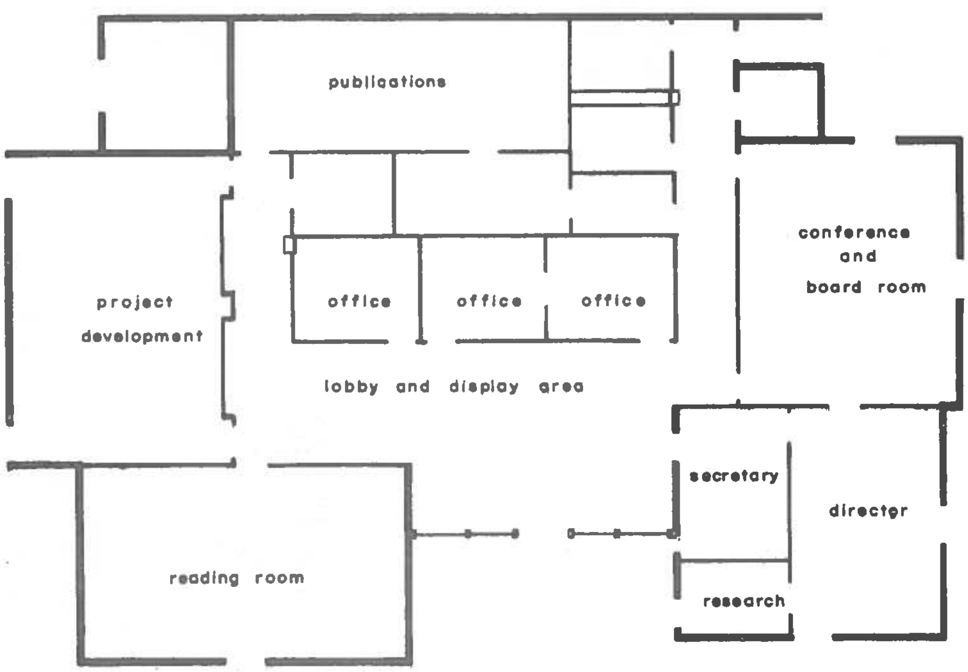
Garland Hershey, Director, Office of Water Resources Research, U. S. Department of Interior



Congressman Ed Foreman Who discussed National Water Legislation as it Affects New Mexico

John (Pat) O'Meara
Office of Saline Water
Washington, D. C.

Home of the New Mexico State Water Resources Research Institute on the New Mexico State University Campus. Construction was authorized in 1968 and completed in March 1970. By action of the Board of Regents in the May 1970 meeting, this building was named "STUCKY HALL".



Floor Plan - Scale 1/16" = 1'0"

R E S O L U T I O N

WHEREAS, the Annual New Mexico Water Conference has contributed greatly to information regarding the importance of water to the State of New Mexico, and

WHEREAS, the papers and addresses comprising each of fourteen Annual Water Conferences have been made available through the Proceedings covering each Conference and published following such Conference, and

WHEREAS, the technical papers, addresses, and panel discussions recorded in the annual Proceedings are of great value to both technical and lay people working in the area of water problems, and

WHEREAS, the success of such a demanding program with a high degree of technical quality year after year is dependent in large part on leadership, and

WHEREAS, Dr. H. R. Stucky has served each Annual New Mexico Water Conference with unselfish devotion and tireless effort, offering the rare qualities of leadership that insure success,

NOW, THEREFORE, BE IT RESOLVED that the members of the Fifteenth Annual New Mexico Water Conference respectfully suggest and recommend to the Board of Regents of New Mexico State University that the Water Resources Research Institute building on the campus of New Mexico State University be named Stucky Hall in honor of Dr. H. R. Stucky.

This resolution acted upon and approved by the membership of the Fifteenth Annual New Mexico Water Conference in session on March 12, 1970.

Harry James, Roswell; John Wright, Santa Fe; Max Linn, Albuquerque (L to R) discuss the Ecology and Water Pollution Problems

Frank Titus (C), New Mexico Institute of Mining and Technology, Chairman, enjoying pleasantries with Wm. A. Dick-Peddie (L), Biologist and Gene O. Ott (R) Extension Farm Management Specialist both NMSU before the start of the afternoon session

NMSU Academic Vice-President Donald C. Roush, who presided as Chairman visiting with Ancil Jones, Water Pollution Control Administration (C) and Colonel Whitsett, U. S. Army Engineers, during the break at the first session of the conference.

Associate Extension Service Director James Kirby (L) looking over a Water Resources publication with Carl Bronn, Director, National Water Resources Association, who was the luncheon program speaker

Arden Baltensperger, Head, NMSU Agronomy Department, who served as Chairman, third session of the conference

Ancil A. Jones, Engineer outlined Water Pollution Control Administration Program in New Mexico and the Southwest

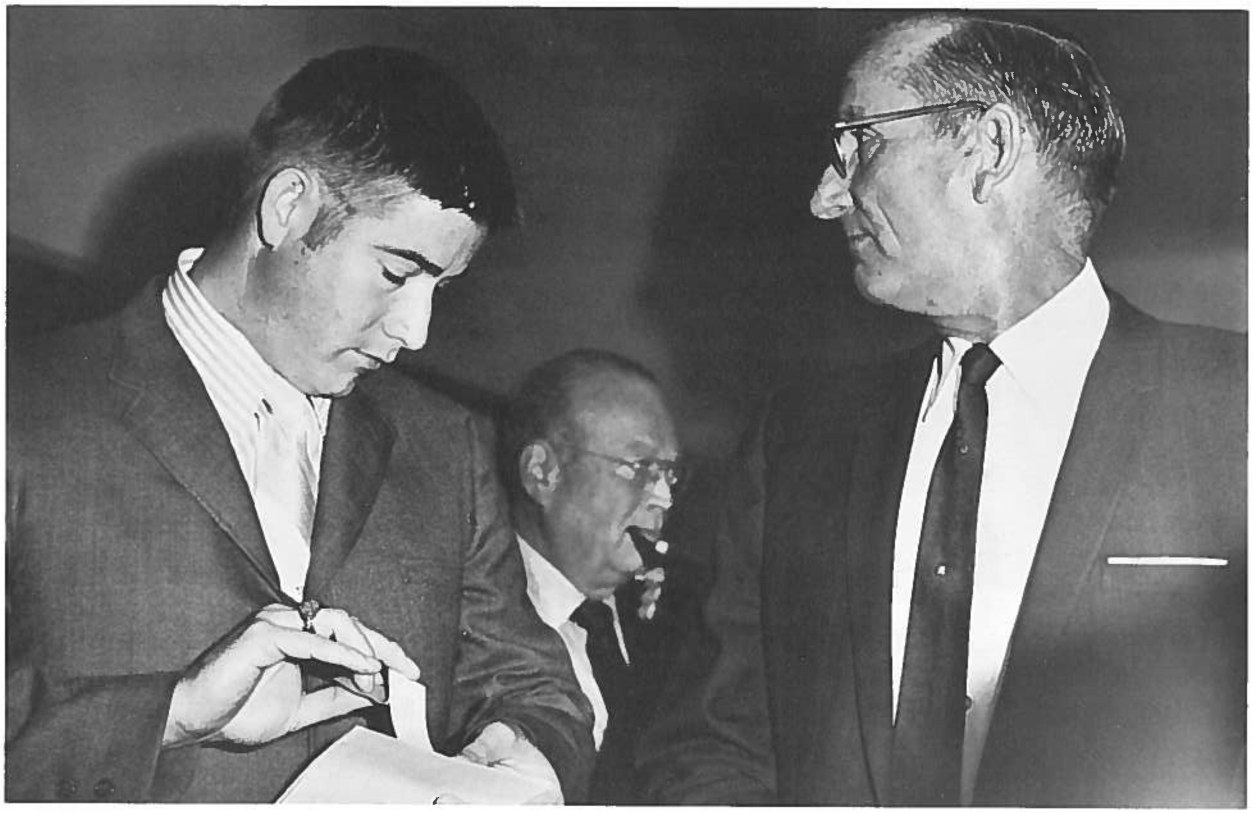
Harlan Flint, Attorney, State Engineer Office (L) and Robert Lansford (R) Agricultural Economist, NMSU discussing San Juan and Pecos Water questions

Carl Slingerland, Engineer
Interstate Stream Commission
talked on the State Water Plan
being developed by the Commission and
the U. S. Bureau of Reclamation

George R. Dawson, Agricultural
Economist discussed the subject
Social and Economic Considerations
in State Planning

Irrigability Classification of New Mexico
Lands was the subject of the paper by
J. U. Anderson, Agronomist, NMSU

John S. McLean, Geologist
U. S. Geological Survey, Albuquerque
outlined the cooperative Saline
Water Study now in progress in
the Tularosa Reserve Basin



William B. Hathaway, Bureau of Reclamation, El Paso (L); William E. Hale, USGS, Albuquerque; and Robert Hathaway, Project Superintendent, Arch Hurley Conservancy District Tucumcari, New Mexico

H. E. Dregne, Agronomist, Tech Tech, Lubbock with M. L. Wilson, Association Director, New Mexico Agricultural Experiment Station

Mrs. Max Linn, Albuquerque, who attended the conference with her two daughters and her husband, one of the speakers

FIFTEENTH ANNUAL NEW MEXICO WATER CONFERENCE

March 12 - 13, 1970

THEME OF THE CONFERENCE - WATER - THERE IS NO SUBSTITUTE

FUTURE WATER SUPPLIES THROUGH DESALTING

J. W. "Pat" O'Meara[1]

This is the third time it has been my privilege and pleasure to address the New Mexico Water Conference. I am glad that Dr. Stucky keeps asking me back, because it means to me that he believes that desalted water is destined to play a role in providing the water New Mexico will use in the future.

When we talk about water supplies for the future, we are prone to project to the year 1980, the year 2000 or 2020. Now I know that those projections sound like some remote point in time, far removed from March 1970. But let me remind you that the year 1980 is only 10 years hence and the turn of the century is only thirty years away. In terms of water supply development, those are precious few years. To me they represent a demanding deadline.

It took from the beginning of time to about the year 1800 for the world's population to reach 1 billion, but just 130 years more to reach 2 billion and only 30 years -- until 1960 to reach 3 billion. In less than 15 years there will be 4 billion people, and every single person will be doing his full share to contribute to the pollution of our air and water. Every person will require food, fiber, minerals, and metals and to obtain each of these he will need water. He will need water to drink, to wash, for health, for irrigation, for agriculture, for industry, for recreation, etc. And each drop of water he uses and does not consumptively use -- he pollutes.

In our successful quest for more and more water, we were so determined to provide the quantity demands for water, we either ignored or overlooked the fact that each time man uses water he degrades its quality. We had to pollute Lake Erie to a point where it may never recover, we had to degrade the Mississippi River, the Father of Waters, to the point where it now is known as the Colon of America, and to increase the salinity of the Lower Colorado to a degree that it nearly is unusable before we really recognize what we were doing.

When I was in high school and I studied how the timber barons raped and pillaged, for personal profit, the vast forests of the West, I simply couldn't understand how the public could stand idly by and let our natural resources be so ravaged.

But after I see what has happened to our water resources during my lifetime, I am beginning to understand.

Call it public apathy, or perhaps a failure to understand our ecology. For whatever reason, it seems we have to make a whopper of a mistake before we recognize the error of our ways.

1/ Office of Saline Water, U. S. Department of the Interior

Fortunately, timber is a renewable resource, and we have learned how to reforrest our land and manage our timber harvest on a sensible basis that is in harmony with nature.

Fortunately too, water also is a renewable resource, but we still have much to learn about its conservation and wise use. We are learning, and perhaps fast enough to solve the water problem, just as we learned how to manage our timber resources. There is an awakening public consciousness concerning the water problem, and this is an essential development if we are to marshall our efforts and assign the necessary priorities to solve the problem.

Earlier this year, eighty-two Representatives to the Congress of the United States joined in a call for an "Environmental Decade." Recommending that the 1970's be designated as the Environmental Decade, they suggested it would be a proper time for all Americans to make the following resolution:

> "I pledge that I shall work to identify and overcome all that degrades our earth, our skies, our water, and the living things therein, so that the end of the Environmental Decade of the 1970's may see our environment immeasurable better than at the beginning."

I would suggest, Dr. Stucky, that resolution as an appropriate theme for the New Mexico Water Conference during this decade.

Turning now to the saline water conversion program, I should like to report briefly of technological developments and how they relate to the all important aspect of our program--the cost of producing fresh water from saline waters.

In the current fiscal year the Office of Saline Water is operating with an appropriation of $25 million. Of considerable interest to the New Mexico Water Conference, I believe, is a considerable shift of program emphasis to the development of the promising reverse osmosis process.

In 1955, the OSW awarded a research contract to the University of Florida to study the possibility of reversing the osmotic flow. As you know, in nature, a less dense liquid flows through a natural membrane and becomes a more dense liquid. This, for example is how water in the soil is absorbed by the roots of a plant system and is transported up through the plant eventually to become a rather dense sap at the top of a tree or any other plant. The idea was to reverse this flow through a man-made membrane, and by reversing the flow, reduce the density of the liquid, or for our purposes, from a saline solution to fresh water.

After testing literally hundreds of synthetic membranes, the research team found a relatively simple cellulose acetate membrane through which they were able to reverse the flow by applying pressure to the saline solution. Although they measured the fresh water flow through this membrane in microliters per day, it was a significant breakthrough. Once scientists and engineers knew that the osmotic flow actually could be reversed, they began to develop theories concerning the interaction of the membrane and the dissolved salts. With these theories they cast new membranes, and gradually the flux, or the flow rate, of the membranes was increased. Other parallel developments also were necessary. Since the membrane is very thin, it required a supporting mechanism to withstand the pressures that had to be applied to overcome the natural osmotic pressure. The pressure that has to be applied is directly related to the salinity of the water to be treated. For sea water, the pressure is about 1500 pounds per square inch, but for most brackish waters the pressure requirements drop to about 600 psi. If the backing plate is too dense, it retards the flow of the water. If it is too porous, the membrane can rupture through the pores.

The flux rate of the membranes is being improved and the backing plate problem is being solved. Today, reverse osmosis membranes are available commercially with a flux rate for brackish water of 20 gallons per square foot per day and a life of about three years. But even more exciting is the fact that in the laboratory we now have experimental membranes with which we have achieved a flux rate of 97 gallons per day and a salt rejection rate of 97 percent. While the 97-97 membrane represents a giant stride forward, we do not see it as the ultimate membrane by any means. Is it any wonder then that we call the reverse osmosis process a promising new process and that we are shifting program emphasis to accelerate its development.

While research and engineering development of the reverse osmosis process continues, our research division is working on a new type of membrane that is so different from the present membranes that it offers the potential of developing into an entirely new process. As I mentioned, in reverse osmosis, we push water through the membrane and the salts are left behind. This new membrane allows the salt to pass through the membrane and the fresh water is left behind. Now when we consider that seawater is 3½% salt and most brackish waters are in the range of .5% salt, it is rather obvious that it would be better to remove the salt than to remove the water. No one can predict at this time if our work in this direction will be successful or not, but we have moved far enough in the laboratory to refer to the process as piezodialysis or pressure-dialysis.

Another brackish water desalting process that has already found considerable commercial application is electrodialysis. The electrodialysis process utilizes a combination of anion and cation permeable membranes and an electric current to remove the dissolved solids. The first brackish water desalting plant in the United States was erected in 1959 at Coalinga, California. Utilized to desalt local well water of about 2000 ppm. the plant produced 45,000 gallons of fresh water per day at a cost of about $1.45 per 1000 gallons. Now this may be considered by most people to be high cost water, but it was a bargain for the residents of Coalinga who up to that time had been obtaining their fresh water from railway tank cars at a cost of $7.25 per 1000 gallons.

In 1962, a 650,000 gpd electrodialysis plant at Buckeye, Arizona, reduced the cost of desalting brackish water to about 65¢ per 1000 gallons, and last year a new 1.2 million gpd electrodialysis plant went on stream at

Siesta Key, Florida. This latest plant is reporting fresh water costs of 35¢ per 1000 gallons.

At Roswell, New Mexico, we are completing the construction of a brackish water test facility. The new facility has been built on a 10-acre site adjacent to the 1-million gpd demonstration plant that was dedicated in 1963 as a part of the program of the 8th New Mexico Water Conference.

A major part of our brackish water engineering development program will be conducted at Roswell. Ten types of brackish water, ranging from low to high salinity and hardness will be used for testing purposes at the new center. These test waters will be produced with chemical additions to the City of Roswell water or by blending of city water with that available from on-site wells.

The Roswell test facility has been constructed at a cost of $1.1 million, and our fiscal year 1971 expenditures at the site are programmed at just over $1 million.

In the development of distillation processes, which is the major method for desalting sea water, OSW has requested an authorization and appropriation from the Congress to construct a VTE/MSF module. The VTE is the vertical tube evaporator distillation system developed by OSW at Freeport, Texas. The MSF is the multi-stage flash distillation process on which we have conducted extensive tests at San Diego, California. A module is a slice, or a portion of a full size plant.

Our studies have indicated that a combination of these two processes would provide a more efficient system. We will ask major desalting equipment manufacturers to provide a design of a 200 million gpd desalting plant and recommend the basic unit size of the equipment required to produce that amount of water. That is, if technology dictates that we construct eight 25 million gpd units to produce 200 million gpd, we will then proceed with the detailed design of 25 million gpd units, and then construct a sufficient portion of such a plant to obtain reliable engineering and cost data. At the present time we estimate the fresh water production of the module will be about 3.5 million gpd.

The combination of the VTE and the MSF processes offers the potential of reducing capital investment by 30% and water costs by 15% or more.

The first major desalting plants constructed by the OSW produced fresh water from sea water in the range of $1-$1.25 per 1000 gallons. A 2.6 million gpd plant at Key West, Florida, is reporting desalting costs of about 85¢ per 1000 gallons, and a new 7.5 million gpd plant at Tijuana is expected to produce fresh water from sea water for about 65¢ per 1000 gallons.

Under the provisions of a cooperative agreement between the U. S. - Mexico and the International Atomic Energy Commission, the Office of Saline

Water participated in a preliminary assessment of the technical and economic practicability of a dual-purpose nuclear power plant designed to produce fresh water and electricity for the general area of the northern part of the Gulf of California.

In considering the total water needs of a vast water starved region for the first time, the study team selected desalting plants of one-billion gallons-per-day and 2,000 megawatts of electricity as the basic unit size to provide the fresh water "rivers" that would flow from the Salty Gulf of California. A series of such plants would be required to meet the projected deficit of 4.5 billion gallons per day in 1995. Capital costs for the initial plants were estimated to be in the range of $850 million to $1.2 billion depending on the site, water conveyance routing, and interest rate assumed. Product water costs, as estimated in the study report, delivered to a major distribution center ranged from 16¢ to 40¢ per 1000 gallons.

I want to re-emphasize, that this was just a preliminary assessment. There is no plan at the present time even to proceed with a detailed engineering feasibility study, much less, any plans for construction.

The study is important, however, in pointing out the direction that desalting may take in the future, and it serves to guide some of our planning as we work toward the development of multimillion gpd desalting plants. We have a long way to go before we are able to tackle a project of the magnitude of the U.S.-Mexico study.

It is clear, however, that desalting technology is developing at a pace where its potential for long-term water system planning cannot be ignored. Furthermore, within the likely time frame of need for major new water supplies, the necessary desalting technology, along with major heat supply sources, including nuclear power, can be reasonably expected to be in hand.

VALUE OF WATER RESEARCH TO STATE AND NATION

H. Garland Hershey[1]/

First, let me say that this Fifteenth Annual Conference and the attractive and commodious new building soon to be occupied by the Water Resources Research Institute are ample testimony to the value that New Mexico places on water research. Those responsible, particularly Dr. Ralph Stucky, deserve recognition and congratulations for their leadership in advancing the cause of water research. I am delighted to be here on this occasion. Attendance at this conference, moreover, has special meaning to me because this is my first visit to a State Water Resources Research Institute since my appointment as director, Office of Water Resources Research (OWRR).

The value of water research rarely has instant visibility. It's like debating the worth of an idea, or a new concept, or a new but untried method, technique or innovation. Some people resist change because the present way has already worked, or for other reasons these people are not receptive to innovation. One may not feel a need for new ideas because he hasn't yet used all of the old ones. There is the story about the Georgia farmer who was invited by a county agent to attend a meeting on how to farm better. The farmer declined the invitation, saying, "He guessed there really wasn't any point in his coming because he wasn't doing as good as he knew how already."

From the viewpoint of the budget examiner and others who must take a hard look on justification of funds for scientific studies, a measure of the value of water research, or any kind of research for that matter, is the time lag in application of results. We know that the time lapse between useful research findings and their adoption is seldom predictable. It may be measured in years or hundreds of years. Leonardo daVinci whose life span extended from 1452 to 1519, developed basic principles of aerodynamics and engineering processes that were not put to use until long after his death. His research on open channel hydraulics was ignored for more than 250 years and some engineers today still don't know how to apply his teachings in practice. DaVinci, a man of many parts - painter, musician, engineer, geologist - worked on projects for river diversions and developed a canal system with locks that are still in operation in Milan. Some research on the other hand, salk's vaccine is an example, finds acceptance within a relatively short period, three or four years or less.

A study by the Illinois Institute of Technology under a grant from the National Science Foundation found that basic research was highly significant in five recent technological innovations of wide value and diverse application. For each innovation, experts traced the critical results,

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1/ Director, Office of Water Resources Research, Department of the Interior

reports, and experimental tests, backward in time to the innovation's origin in fundamental research. Each critical result, report, or test was termed a "key event" and was classified as due to nonmission research, mission-oriented research, or development and application. These key events were traced as far back as the 1850's. Of the 341 key events documented, the Illinois group identified about 70 percent that were nonmission research, 20 percent that were mission-oriented, and 10 percent development and application. An example of one technical innovation from their study was magnetic ferrites, which are substances used in computer memories and similar equipment. Traced backwards, the development of hard ferrites in the late 1950's at the Phillips Research Laboratories in Holland was preceded by two mission-oriented research inputs at Phillips in the early 1950's. In turn, these efforts were preceded by a sequence of nine non-mission events in crystal chemistry. These included Pauling's bond theory of crystals in 1929, Bragg's work on X-ray diffraction in crystals between 1914 and 1920, and Roentgen's discovery of X-rays in 1895. The trace further revealed communication between disciplines and complicated interconnections involving contributions in addition to those of crystal chemistry. These additional contributions of nonmission research, mission-oriented research, and development and application to the history of magnetic ferrites came from the fields of telecommunication, ceramic materials, and magnetic theory. In their overall study, the Illinois team found that about 90 percent of the basic research behind an innovation had been accomplished a decade before development of the innovation. These findings by the Illinois Institute of Technology highlight the latent utilization of the results of much research, whether problem or non-problem oriented.

In the above connection there is much concern today in the scientific community as well as in OWRR about transfer of research results. The question is, "How can we improve the communication between the scientist in the university and the practitioner faced with real-life water problems?" Obviously, water research will not have much value if the potential user is unaware of research recommendations and conclusions that may have direct bearing on his own experience and which may have practical application to a water problem demanding action. Because of this concern about technology transfer and the application gap, the Office of Water Resources Research retained the consulting firm of Leeds, Hill and Jewett, Inc., to submit a plan for a comprehensive water resources research information system. The consultants examined the nature and effectiveness of present procedure used by OWRR and the 51 State Water Resources Research Institutes to obtain information on problems requiring research and to disseminate results of research projects. Some 26 recommendations, a number of which have already been acted upon, appear in the final report. One recommendation still under examination calls for the adoption by OWRR and the State Institutes of a two-level water resources information exchange system. In this plan, OWRR would assume responsibility for national and regional dissemination of research results from State Institutes and Title II contractors and for obtaining information on national water problems needing research. The State Institutes would be responsible for exchange of water resources research information at the State and local level.

One should not forget that in the dissemination of information, conciseness and clarity of the language used in communication have great importance. Value judgments or estimates on completed water research are based initially on the published report and later confirmed or revised after field evaluation and demonstration and other considerations, including economic feasibility. Many reports, unfortunately, are too long and rambling and too difficult to read. One research hydrologist writes for another research hydrologist. The Congressman who might want to pick up a research report to comment on the good things going on in his State finds little to talk about. Similarly, consultants, planning officials, professional engineers in private practice, action agencies and others must sift through pages of verbose text to uncover the significance of the results in practical terms. A short time ago, one of the Washington newspapers published a complaint by a member of Congress on the length of government reports. He recalled that the Lord's Prayer has only 56 words; Lincoln's Gettysburg Address, 266 words; the Ten Commandments, 297 words; and the Declaration of Independence, 300 words. But a recent government order covering the pricing of cabbages was 26,911 words long!

My foregoing remarks have been of a general nature as to the value of water research. I now would like to identify some of the more pressing water problems, State and nationwide, and offer a few examples of potential or actual contributions from OWRR-sponsored water research in confronting these problems.

A major problem in New Mexico, as you all know, is finding new sources of water supply to supplement entitlements from interstate compacts and the Supreme Court decree on the Colorado River. About two-thirds of the irrigated agricultural land in New Mexico depends wholly or partly upon ground water. In 1965, according to the Geological Survey, the irrigation use of ground water in the State was estimated as 1.4 million acre-feet, most of which was mined. That is, well supplies are depleted in many places where average annual discharge exceeds average annual recharge with resultant decline in ground water levels. Total water withdrawn - surface and ground water - in 1965 for irrigation approximated 3.1 million acre-feet which include about 410,000 acre-feet conveyance loss. A second principal problem in addition to ground water mining is nonbeneficial use of water by evapotranspiration, especially along the Pecos and San Juan Rivers and the Middle Rio Grande. The total nonbeneficial use in the State has been estimated at 1.16 million acre-feet per year, including 330,000 acre-feet lost by direct evaporation from reservoirs. Sedimentation of channels and reservoirs and erosion of crop and grazing lands are other problems.

The State Planning Office, I understand, has assigned the responsibility for planning of the water and related land resource aspects of the overall resource plan to the Interstate Stream Commission and to the State

Engineer. In development of a total State water plan, research carried on by the New Mexico Water Resources Research Institute should prove to be of considerable value. The recently undertaken comprehensive resources analysis of the Pecos River basin by an interdisciplinary-interuniversity team from seven academic departments at three universities has developed basic concepts which should contribute materially to the State plan. A similar study in the Rio Grande basin involving New Mexico State University, the University of New Mexico, and the New Mexico Institute of Mining and Technology is scheduled for completion June 1970. A completed study under the OWRR allotment program has demonstrated that by means of subsurface irrigation, cotton yields can be increased by about 25 percent with reduction at the same time of about 20 percent in consumptive water use. Research under an OWRR Title II grant involving water requirements for salinity control in unsaturated soils suggests that amounts of leaching water recommended for salinity control can be revised downward, resulting in a potential saving of water in a water short area. These are only some of the kinds of studies the Water Resources Research Institute is conducting in behalf of the State.

Nationwide, water problems are numerous - concern about the quality of the environment; urban water resources management; waste treatment and disposal; conserving ecological values in water resources planning; control of heated water discharges; conservation of the estuarial water resource; water supply; water law and institutions; and the list could go on. For fiscal year 1971 which will begin July 1, 1970, OWRR identified certain major subject fields as meriting priority consideration in the selection of research proposals under the Title II provision of the Water Resources Research Act of 1964. For the benefit of those in the audience not familiar with the Title II program this authorizes financial support to any individual, foundation, university, consultant, watershed or irrigation district, State or local government agency, or private firm qualified to conduct water resources research. Funds are limited and competition for support is keen. Unlike the Title I program authorizing financial support only to State Water Resources Research Institutes and the universities participating in the program, the Title II provision of the Act is non-restrictive. Seven priority areas were established as follows:

1. Analysis of Planning, Managerial, Financial, Operating and Regulatory Policies of Water Resources Institutions.
2. Water Resources Policy and Political Institutions.
3. Hydrologic Systems Analysis.
4. Urban-Metropolitan Water Resources Problems.
5. Environmental Considerations in Water Resources Planning and Management.
6. Evaluation of Economic Importance of Various Uses of Water, Cost Allocation, Cost Sharing, Pricing and Repayment.
7. Evaluation of Social Objectives in Water Policy.

Some examples of research (both Title I and II) on nation-wide water problems will be of interest. A project by the American Society of Civil Engineers covered in the first year's report the following subjects:

1. Prefeasibility studies to determine possible effectiveness, cost and time requirements for: (a) a comprehensive systems engineering analysis of all aspects of urban water (two studies); (b) a general economic analysis of cost and pricing parameters of cost and pricing parameters of all aspects of urban water (two studies).

2. A state-of-the-art study of mathematical models and related simulation methods potentially usable for analyzing urban rainfall-quality processes.

3. Requirements for assessment of drainage damage and alternatives to direct storm water runoff control, such as utilization of recharge basins or other storage schemes.

4. Discussion of political, economic, legal and social problems related to urban water management.

Cornell University has commenced work on a study entitled "Metropolitan Water Resources Systems Analysis." Investigations pertain to application of systems methodology of preliminary planning, staging, design and operation of metropolitan water resources projects under hydrological, economic and political uncertainty. Mathematical planning models will be structured for defining and evaluating preliminary alternative designs and policies for municipal and regional water resources systems such as supply, distribution and treatment works, urban runoff collection, storage and treatment facilities. Also, to be investigated are methods for predicting the effect of alternative pricing policies on design, capacity, and operation of water supply systems. Methods will be developed for use as tools by municipal planners to aid in establishment of rational prices or rates for various types of water use.

At Illinois work has been completed on a mathematical model to relate hydraulic parameters, such as velocity, width, depth, and cross-sectional area to drainage area and flow frequency of a stream. Because of encouraging initial results in development of hydraulic geometry equations useful in the planning of projects for control or development of rivers, this study is being expanded nationwide to include streams representing a wide variety of physiographic and hydraulic conditions.

Further insight to the diversified water research underway or recently completed is apparent from such project titles as these: Evaluating Urban Core Usage of Waterways and Shorelines; Computer Simulation of Euthrophication; Factorial Analysis of Price-demand and Demand-cost Functions for Municipal Water Systems; Evaluation of the Decision Process in Water Resources Planning; Socio-economic Study of Multiple Use Water Supply Reservoirs; Systems Analysis of the Great Lakes; and Case Study of Remedial Flood Management in an Urban Area.

The Secretary of the Interior is convening a National Conference on Urban Water Research next week in Atlanta. This will be a closed work session of about 60 experts in urban water studies and practice who will review and discuss a planned program of metropolitan water resources research. OWRR, I might add, has been designated the lead government agency in urban water research by the Federal Council for Science and Technology. The significance of urban water resources management becomes apparent in view of the fact that three-fourths of the population of the United States now live and work in urban areas. Five working committees will consider these aspects: (1) water resources planning and management policies; (2) economic-financial functions; (3) urban hydrology, storm drainage, flood plain management; (4) socio-political-legal considerations in urban water resources; and (5) general research plan.

The question sometimes arises as to the value of regional research projects involving two or more institutes and the position of OWRR in this activity.

The Office of Water Resources Research strongly encourages State water research institutes or centers to approach regional water problems on a cooperative basis and to pool their talents and resources. Authority to develop regional programs and objectives appears in Section 103 of Public Law 88-379 (Water Resources Research Act of 1964) which reads: "The institutes are hereby authorized and encouraged to plan and conduct programs financed under this Act in cooperation with each other and with other agencies and individuals as may contribute to the solution of the water problem involved, and moneys appropriated pursuant to this Act shall be available for paying the necessary expenses of planning, coordinating, and conducting such cooperative research."

Few projects have involved collaboration of two or more State institutes. Interest by the institutes in the identification, assessment, and solution of regional water problems is, however, increasing. Assessment of regional problems and exploration of meaningful water research coordination are being made primarily through regional conferences. Some examples of regional efforts to coordinate research are briefly described.

The New England Council of Water Centers Directors is composed of the Directors of the Water Resources Research Institutes or centers in Maine, Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island. Its general purpose is to identify and share work on water resources research needs of common interests. The Council has received a charter from the New England Governors' Conference and enjoys close working relationships with the New England River Basins Commission of which the Council chairman is an ex-officio member. Recent activity has included regional conferences on water rights law and water resources planning and recommendations to the New England Regional Commission for a regional legislative program.

The Northeast Association of Water Resources Research Institute Directors is a thirteen State organization established to evaluate research needs and to exchange information on regional water problems and individual research programs. Membership stems from the following States: West

Virginia, Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Rhode Island, Vermont, New Hampshire, and Maine. Topics covered in recent meetings dealt with opportunities for water supply augmentation in the Northeast and with institute-State agencies relationships.

In the Midwest, research interest in regional water problems such as agricultural pollution resulted in organization of a group known as the Midcontinent Water Research Directors. Conferences have been held on evapotranspiration and on the theme, "Agriculture and Water Quality."

Discussions have taken place among the Water Institute Directors of 11 states in the far West on cooperative research for meeting future regional water needs. The general objective would be to explore and evaluate the input-output methods as an effective tool for weighing alternative water resources management policy and program decisions within a regional context. States participating in these discussions are Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

In closing, I want to compliment the New Mexico Water Resources Research Institute on its excellent record of accomplishment. Dr. Stucky and his associates have developed a fine working relationship with other universities within New Mexico, with cooperating State and Federal agencies, with advisory groups including ranchers, farmers and businessmen concerned with State water problems, and certainly with OWRR.

We, in Washington, are very pleased that Dr. Stucky is Director of the New Mexico Institute.

WATER RESOURCES DEVELOPMENT BY CORPS OF ENGINEERS

Colonel Menon W. Whitsett[1]

By way of introduction to my remarks, I want to compliment Dr. Stucky and the others responsible for this series of annual conferences on water resources development in New Mexico. This State and most of the Southwest have an ever growing need for water resources development. This need can only be met through public awareness of water problems. Meetings such as this stimulate such awareness and, to the extent that awareness stimulates action, they return benefits to the State and the area.

Dr. Stucky has suggested that this presentation be on the topic, "Current Approach to Water Resources Development by the Corps of Engineers," with particular emphasis on water resources development planning peculiar to the Southwest and New Mexico. Following his suggestion, I shall review briefly past and present activities of the Corps of Engineers in New Mexico, then attempt to relate these to regional and national trends in water resources development.

Basically, we in the Corps of Engineers consider our role to be one of partnership with the States and local governments and the various federal agencies concerned in this field of water resources development. Functionally, we play several roles. We are here to help in planning, and, where appropriate, to construct facilities to meet water needs of the Southwest. In a growing number of instances our function is helping cities, at their request, to determine the best means for regulating and managing known flood areas within their borders without having to resort to building large preventive structures.

The Corps of Engineers' program of water resources development in New Mexico began over 30 years ago. For most of this time the principal interest in water has had to do with floods, particularly along the Rio Grande and in some communities where water rushing out of the mountains through arroyos has created devastating flood damage. The Corps' first dam and reservoir in New Mexico was Conchas, near Tucumcari, which was completed in 1938. Incidentally, Conchas also was the first project in the Southwest and one of the first in the Nation to be built by the Corps. Since that time we have built Jemez Canyon, two rivers at Roswell, and Abiquiu Dam in New Mexico. We have also constructed a local flood control project at Socorro, and jointly with the Bureau of Reclamation, the Rio Grande floodway below Albuquerque.

Our Albuquerque District now has three projects under construction in the Rio Grande Basin, which will benefit the area appreciably: Cochiti Dam and Reservoir, Galisteo Dam and Reservoir, and the Albuquerque Diversion Channels. The Galisteo Project, located on Galisteo Creek about 12 miles upstream from its confluence with the Rio Grande, is 90 percent

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complete. It is scheduled for completion by the end of June this year, except for installation of some operational equipment. Cochiti Dam, located near the Cochiti Indian Village on the main stem of the Rio Grande, is now 22 percent complete and scheduled for completion in 1975.

The Albuquerque Diversion Channels Project consists of two channels located on high ground East of and parallel to the Rio Grande Valley. The North Channel, which is now complete, extends about 10 miles from Campus Wash to the vicinity of Alameda and will intercept discharges from the numerous arroyos North of U. S. Highway 66. The South Channel, which is under construction, begins about one-half mile South of Highway 66, extends South for about six miles to Tijeras Canyon and thence to the Rio Grande.

Congress has authorized new flood control projects on the Rio Grande here at Las Cruces and at El Paso. The Las Cruces Project, which was authorized by Congress in 1962, would include construction of two dams. The Las Cruces Dam would be constructed East of the city to impound waters from Las Cruces and Alameda Arroyos and from the streams that drain the area between these two arroyos. Campus Dam would be constructed on Campus Arroyo East of the university. Initiation of construction is awaiting fulfillment of the requirements of local cooperation as required by public law.

The El Paso Project is included as a new construction start in the Fiscal year 1971 budget, now before Congress. We hope to have it under construction by the end of this year. El Paso is vulnerable to flooding from the tributary arroyos on the Eastern, Southern and Western slopes of the adjacent Franklin Mountains. The plan of improvement consists of a single-purpose flood control system of detention dams, diversion dikes and channels to collect and regulate arroyo runoff into the Rio Grande.

In the Pecos River Basin the district is now concerned with projects at Carlsbad, the Los Esteros Dam and Reservoir near Santa Rosa, studies in the Rio Felix and the Rio Hondo, above Roswell, and a study of the Pecos above Santa Rosa.

Congress authorized a flood control project at Carlsbad in 1958. However, the city of Carlsbad, which was the local sponsor of the project, was unable to meet the cooperation requirements for its construction, so work on the project was suspended. After the disastrous Carlsbad flood of 1966, Congress extended the authorization of the project. The Senate has now requested a review study, which is under way in our Albuquerque District. The study is looking at possible dam sites on the Pecos, as well as on tributaries above Carlsbad, and the needs for channel rectification.

The Los Esteros Dam and Reservoir is included as a new construction start in the Fiscal year 1971 budget. This project is deserving of special mention in this presentation, because it represents in a demonstrable way some of the cooperation that I mentioned earlier as an essential to water resources development. Before going into detail, let me preface some comments about Los Esteros with a little history.

In the early days of the Corps of Engineers' participation in water resources development, the basic purposes for which we built projects were flood control and navigation. Sometimes we were allowed to include water supply in a project, but this was through special dispensation of Congress. The Water Supply Act of 1958 opened the door for including water supply for municipalities and industries, as well as irrigation, hydro-electric power, water quality control, recreation and other related purposes, in all of our reservoir projects where local interests agree to pay for the cost of those improvements. It has been difficult to include these purposes in projects in New Mexico for several reasons. These have included such draw-backs as the inability for local governmental entities to provide the necessary elements of local cooperation, the water rights of downstream users, and the shortage of avail-dam sites where water could be stored without excessive evaporation.

The Los Esteros-Alamogordo Project represents a breakthrough of some of these bars to water conservation, largely through the cooperation of the State of New Mexico, the Pecos River Compact, the Carlsbad Irrigation District, the Bureau of Reclamation, the U. S. Fish and Wildlife Service, the U. S. Department of Agriculture and the Corps of Engineers.

The project provides for construction of a dam at the Los Esteros Site on the Pecos River about seven miles upstream from Santa Rosa and for modification of the existing Alamogordo Reservoir of the Bureau of Reclamation downstream from Santa Rosa. Irrigation storage in the Alamogordo Reservoir will be transferred to the Los Esteros Reservoir, and the two will be integrally operated under the terms of the Pecos River Compact for flood control and irrigation. Thus, Los Esteros will have a permanent pool for conservation and recreation purposes.

Another new development in New Mexico water is reflected in a study of a major segment of the Rio Grande that is included in the President's budget for Fiscal year 1971. This should be of interest to all of us here today. As you know, in recent years Congress and the Federal agencies have taken a step beyond the multiple-purpose single project concept and enlarged our thinking to cover entire river basins or segments of river basins in plans for development. Such an approach permits much better utilization of our available water resources than the piecemeal type of development where we build a single project to meet specific local needs. By resolution of the Senate Committee on Public Works, we have been authorized to conduct a comprehensive study of the Rio Grande Basin from El Paso to its source in Colorado. The study will include the urgent need for flood control and major drainage on the Rio Grande in New Mexico and Colorado. But it will also include investigation of needs for irrigation, municipal and industrial water supply, water quality control, recreation, fish and wildlife conservation and related features. Improvement such as reservoirs, diversion channels, levees, channel rectification works, and non-structural alternates will be considered.

The basin-wide approach on the Rio Grande will search out the most desirable means for conserving the water resources of the area for all practical uses. One day we may be able to solve some of the water problems of this area through diversions from other basins. Meanwhile, we must make a successful effort to intelligently conserve and use the waters that are available. This would be the aim of a well-grounded basin-wide plan.

As a next step in progression beyond the basin-wide approach, we and the other agencies concerned with water resources development are now looking seriously at possible regional approaches. Many large-scale schemes, or proposals, have been advanced for moving water from areas of plenty on the North American continent to the Southwest. Most of the proposals advanced thus far have been largely conversational one possibility, which may or may not ever become reality, has at least reached the study stage. This is the possibility for diversion from the Mississippi River Westward. The success of any major diversion of the scope that must be considered hinges on three principal factors: (1) the likelihood of a future surplus water in the "giving" basin: (2) The willingness of people in the "have" area to provide water for the "have not" area; and (3) The possibility of conveying the water at acceptable cost. As the Chief of Army Engineers, Lieutenant-General Frederick J. Clarke, recently said, "It is very likely that the success of any diversion from the Mississippi River system will depend upon finding ways in which the Mississippi River people, as well as you in the Southwest, can benefit from the diversion." Aside from the problems of conveyance at reasonable cost, there are power problems, environment problems, political problems and a host of others that must be overcome.

There are presently three studies under way aimed at determining whether such a project can be devised. One is a very broad and broadly based study in which seven federal agencies and seven states are participating under the chairmanship of the Mississippi River Commission. This is a comprehensive, framework-type study of the lower Mississippi region, carried out under the Water Resources Planning Act. It is aimed at determining the unsatisfied water needs of the lower Mississippi Basin for all purposes up to the year 2020, and at developing a general program for satisfying those needs. Present schedules call for its completion by the Summer of 1973.

A second study is similar but different. It is the West Texas and Eastern New Mexico import study being carried out by the Mississippi River Commission and the Bureau of Reclamation. It too looks ahead to water needs in the year 2020, and it too is scheduled to be completed in mid-1973. The difference is that the comprehensive study aims at forming plans geared to the probable future development and need in the lower Mississippi area; whereas the import study is based on determining the remotest contingencies of possible development in that area, as a prelude to determining whether an exportable surplus exists.

The import study must necessarily be thorough and exhaustive in its search for the effects of a trans-basin diversion upon the lower Mississippi Basin itself. It must project economic needs, future municipal and industrial needs, irrigation needs, water requirements to satisfy recreational needs, look into the direct and indirect effects of a diversion upon fish and wildlife, among other requirements. In today's climate of deep concern for the natural environment and ecology, these aspects are being scrutinized very closely. Most of the aspects I have mentioned have been contracted to research institutes or other governmental agencies for study. The Corps of Engineers, among other things, is looking at the possibilities for storage reservoirs to augment low flows on the lower Mississippi River.

We expect that around the beginning of next year the study will have advanced far enough for a preliminary, reconnaisance-type report on the first phase to be issued. About a year after that, it is hoped that the ground work will be sufficiently along to permit having some proposals before the public for public scrutiny and comment. Public hearings will be held in the Mississippi Valley probably starting in 1972. Following that, the record will move through regular channels to Congress, which will then determine whether the Federal government will participate further in the import proposal.

Another study is being done by our Fort Worth District, which is working with the State of Texas to analyze the Texas water plan in terms of possible Federal participation. This plan lays considerable emphasis upon the possibility of importing water to the high plains area from the Mississippi Basin. Here, again, we are studying the feasibility, appropriateness, direction and extent of Federal participating in conveyance and storage works, and the extent and nature of Federal cost sharing.

Nobody can anticipate the results of these studies. However, there is significance to the fact that the studies are being made. As long as people are working toward a particular goal, there can be hope that the goal will be reached.

The same principle is true with respect to all phases of your water resources development in New Mexico. As long as there is dialogue such as you have in conferences such as this, there is the possibility that feasible solutions will grow from them.

In closing I want to assure you of the continuing desire of the Corps of Engineers to work with State and local interests and the other agencies of the Federal government in the interest of developing our water resources. It has been a pleasure to participate in this meeting today.

WATER POLLUTION CONTROL PROGRAM IN THE SOUTHWEST

Ancil A. Jones[1]

I am delighted to be here with you to participate in what promises to be an important annual conference. The quest for improved water quality is now recognized as one of the most urgent challenges of our time.

Water is probably the most essential single requirement for life besides oxygen. Few fully realize how priceless water is and the critical role it plays in the development of a nation's economy. In the Southwest, in particular, the growth--and in certain cases the economic survival--of some areas will be determined largely by the quantity of clean water available to the people who wish to live in those areas.

The President has expressed his concern in these words: "In order to maintain a high quality for our environment and conserve natural resources, the Federal government must provide strong leadership to coordinate an integrated program which will include all levels of government, private industry and individuals throughout the country." The President's determination to provide this strong leadership is evidenced by his appointment of Mr. Russell E. Train as chairman of the newly created Council on Environmental Quality.

Ample supplies of good quality water are essential for people, agriculture, and industry. Modern technology has developed an insatiable demand for fresh water, but it has failed to find an effective means for providing sufficient quantities of quality water at low cost.

The Water Resources Council estimates that America's use of water will increase from the present 360 billion gallons per day to some 800 billion gallons per day in the year 2000 and to more than 1,300 billion gallons per day in the year 2020.

The gravity of the water resources problem varies substantially from region to region and in the Southwest, particularly, could become critical and threaten economic stagnation. Habitual indifference to water pollution is giving way to public concern.

Adverse Effects of Pollution

Water pollution adversely affects our use of water. It increases the cost of making water usable for domestic, agricultural, and industrial purposes. Pollution restricts certain water related activities such as water contact recreation, natural beauty, and fish and wild life propagation. It creates public health hazards by providing an environment for disease-producing organisms. It produces toxic substances, some with

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long-term effects of sublethal concentrations.

I have been asked to discuss the water pollution control program in the Southwest. This is an excellent conference for such a discussion and I would hope that we share the same goal: to enhance the quality of our water resources through effective environmental management.

To achieve our goal we must first recognize and identify the sources of pollution. Abuse of land and water have generated pollutants that have created harmful effects and turned appealing areas into ghettos of ugliness and decay. A "municipal-industrial-agricultural" complex confronts this region with different kinds of pollution.

Domestic or Municipal Wastes

Domestic or municipal wastes contain decomposing organic materials that reduce the oxygen content of water and cause serious impact on aquatic life. Infectious agents spread water-borne diseases. Rapidly growing suburbs frequently place an excessive burden on waste treatment facilities and thus hasten the degradation of the receiving stream. Improper operation and maintenance of existing facilities can also be sources of pollution.

Industrial Wastes

Industrial wastes are a major contributor to the deterioration of the quality of our water resources. Research has shown, however, that all wastes in some point in history and in some ecosystem have a use. Time, needs, and technology then can determine the scope of the industrial waste problem. Last year's paper mill wastes might be tomorrow's binder for road materials. Industrial wastes, like municipal wastes, can contain decomposing organic materials that remove oxygen from the receiving waters.

Industrial wastes may contain solids that discolor and create turbidity or oils and heavy metals that are toxic to aquatic life. Hot wastes may increase environmental temperatures higher than aquatic life can tolerate. They can impart tastes and odors in water supplies or can stimulate growth of algae just as in the case of municipal wastes. Chemical residues, petrochemicals, salts, acids, silts, sludges, and radioactive substances are characteristic industrial wastes.

Agricultural Wastes

Agricultural wastes are by no means exempt from the war on pollution. These wastes have organic substances that decompose and remove oxygen from the receiving water. These wastes include animal wastes (feed lots), irrigation return flows, fertilizer, pesticides and herbicides, and wastes from canneries and dairies related to agricultural production.

Literally tons of chemical fertilizers are now applied and further use is projected. The principal nutrients supplied are potassium, nitrogen, and phosphorus. An overabundance of these nutrients, particularly nitrogen, in surface waters can contribute to excessive growth of algae and other aquatic plants which adversely affect water quality for fish, municipal water supply, and recreational purposes. Nitrogen in its nitrate form can enter groundwater and surface water. Phosphorus and potassium are transported on eroded soil particles and are deposited with sediments in streams and reservoirs.

All streams contain dissolved inorganic salts and minerals to some degree. When water is diverted for irrigation, the dissolved salts are concentrated by evapotranspiration and either accumulate in the soil or re-enter the stream in concentrated form in the return flow. This will increase the salt concentration in the stream with each use of its water for irrigation. In the arid regions of our nation, such as the Southwest and New Mexico, this problem is most important.

Sediment, from the standpoint of quantity, is the greatest contributor to pollution resulting from land erosion. Sediment pollution is expressed in the impairment of water quality and the damage caused during deposition. Harmful effects are many -- some chemical, some physical, and some biological. Sediment is not only related to erosion from agricultural lands, but is also produced as we construct our highways, buildings and from urbanization.

Pesticides and herbicides in the environment become pollutants when they, their metabolites, or degradation products remain after the desired purpose has been achieved or if these agents reach other parts of the environment other than the intended targets. Pollution from pesticides depends upon their persistence and final disposition. Persistent pesticides that accumulate in a part of our environment, such as in soil, in air, in water, or in animal tissue, are of particular concern. Some lower forms in the aquatic food chain accumulate pesticides and are in turn consumed by fish, which then retain the pesticides in their flesh. When the fish are eaten, the concentration cycle is continued. Man consumes both birds and fish and thus consumes substances in quantities which are dangerous to his health.

Knowledge of the extent and significance of pesticides in the ecosystem is fragmentary, and intensive cooperative studies will be required in order that we may be able to plan more effectively the measures needed for alleviating problems of this nature.

<u>Pollution Control Program - Public Law 660</u>

All states have water quality programs designed to enhance the quality of water resources. Through careful planning and conservation of our water resources -- we will be able to meet our water needs. The Federal Water Pollution Control Act sets up a program to accomplish this end, and Congress has made available the tools necessary to effectively manage and protect our water resources.

From the beginning, the emphasis of the Federal Program has been action to control pollution at the local level -- that is through the States and communities. The Act clearly establishes the primary responsibility for water quality control as belonging to the States. The Federal role is one of leadership and assistance and is carried out through the Federal Water Pollution Control Administration in a wide range of water quality improvement activities administered through nine regions. We are in the South Central Region. (The attachment shows the regions of the Federal Water Pollution Control Administration and locations of the regional offices.)

The Water Quality Act of 1965 provided for establishment, by the States, of Standards of Quality covering all interstate and coastal waters.

In setting the Standards, the States determined the uses to be made of specific waters, the measurable parameters affecting the quality, and the levels necessary to make desired uses possible. In addition, the States were required to submit plans for implementing the quality levels within a specific period of time.

Once approved by the Secretary of the Interior, the Standards become both State and Federal Standards, creating a State-Federal partnership for clean water.

The importance of these Standards is that they draw lines that let everyone know what is meant by clean water. Plans of implementation tell each user what must be done to maintain or attain the desired level of quality.

The Standards are the blueprint of water quality. The other portions of the Federal Program are designed to support and sustain that water quality.

The Water Quality Act of 1965 asserts broad jurisdiction for the application of Federal regulatory authority in water pollution control. Section 10 of the Act authorizes enforcement measures to abate pollution of interstate or navigable waters which endangers the health or welfare of persons in the receiving State. The jurisdiction over interstate or navigable waters is derived from the commerce clause of the U. S. Constitution, which authorizes Congress to regulate interstate and foreign commerce.

The assertion of Federal enforcement jurisdiction is qualified initially to stipulate that State and interstate action to abate pollution shall be encouraged and is not as a rule displaced by Federal action. The conditions under which Federal enforcement authority is invoked and the procedures under which it is applied thereafter conform to this stipulation of primary responsibility. Such enforcement actions can be initiated upon State request or under Federal authority, governed by the nature and effect of the pollution.

Research, development, and demonstration programs are aimed at finding better methods to reduce municipal, agricultural, and industrial wastes, wastewater renovation, and newly emerging problems of thermal pollution as well as the development of scientific information to permit better definition of water quality requirements for all uses. Grants are awarded to assist in supporting basic and applied research aimed at the discovery and development of new information and technology in the chemical, physical, biological and engineering fields.

Technical support is available to other Federal agencies, States, local communities, industries, and others in the solution of specific water pollution control problems. The Technical Services Program is the fact-finding resource of FWPCA in this region and is located at the Robert S. Kerr Water Research Center, Ada, Oklahoma.

Grants are provided for the improvement of State and interstate agency water pollution control programs, including the training of public agency personnel.

Planning grants are made to planning agencies for the development of comprehensive basin plans for water quality management, and participation in water resources planning activities of Federal and non-Federal agencies.

Water quality monitoring and pollution surveillance is achieved in co-operation with the Geological Survey. An adequate surveillance system is essential to determine compliance with established water quality standards.

Training grants and other activities are available to increase the numbers of trained personnel in the state water pollution control program, both professional and sub-professional, including treatment facility operators.

A cooperative program is provided to assist other Federal agencies in preventing pollution from their activities in response to Executive Order 11507 dated January 4, 1970, which directs the Federal Government to take a leadership role in water pollution control. This order stresses compliance with the approved water quality standards.

Financial assistance is provided to municipalities and State agencies for the construction of wastewater treatment facilities from 30 to 55 percent of the eligible project cost under certain conditions of the law. This is the largest grant program in FWPCA.

Where all projects receive 30 percent of State funds, the Federal grant can be 40 percent. In cases where the project discharges into waters where the State has established enforceable water quality standards, the Federal grant can be 50 percent, providing the State funds to all such projects is 25 percent. Under certain conditions of area wide or metropolitan planning, the Federal grant may be increased an additional 10 percent.

LEGEND

- South Central Region
- Reservoir completed or under construction
- Reservoir authorized
- Aqueduct or Canal
- Water Pollution Surveillance Station

NOTE:
The Construction Grants Region comprises Arkansas, Louisiana, New Mexico, Oklahoma and Texas.

SOUTH CENTRAL REGION

CONSTRUCTION GRANTS PROGRAM

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

SOUTH CENTRAL REGION OCT. 17, 1966 DALLAS, TEXAS

Each State is entitled to its authorized share of the funds appropriated for construction grants each fiscal year. Each municipality -- from the major metropolis to the smallest town or district -- may establish its eligibility for and receive grants assistance.

You might be interested in the effect of the program in New Mexico since the beginning (1956) through the end of February 1970. Out of a total of 119 projects, 62 treatment facilities were built or expanded by 75 projects for the following costs and grants.

Total Cost	Eligible Cost for Grant Participation	Grant Amount
$41,913,411.00	$41,155,443.00	$12,856,632.00

Note: Seven of the above projects were supplemented with funds from the Economic Development Administration in the amount of $752,720.00.

The first fiscal year appropriation was $50 million for the entire country as contrasted to the current fiscal year appropriation of $800 million. Over $154 million in Federal funds have assisted in building treatment facilities. These funds have helped build 1390 projects costing over $510 million in this region alone. The huge sums are necessary to catch up with the backlog, to expand and modernize existing facilities, to replace obsolete facilities, and to keep up with the population growth.

During fiscal year 1970, $79,148,700 will be available for construction grants in the South Central Region. Of this amount, $4,958,900 will be available for projects in New Mexico. This is a significant increase over the figure for fiscal year 1969, which was $1,872,900.

A Major Problem

From the beginning, the emphasis of the Federal program has been on action to control pollution at the local level-- that is through the States and communities.

Many local governments and the general public are not aware of the importance of efficient operation and proper maintenance of wastewater treatment facilities. As yet, it has not been accepted as a necessary operational function and, therefore, is not supported with adequate budgets and trained manpower. Salaries of waste treatment facility operators are lower than comparable water treatment plant employees, with little or no incentive for career development.

Three States in our region (Arkansas, Louisiana and New Mexico) do not have mandatory certification or licensing for operators. The other two States (Texas and Oklahoma) have mandatory certification but need to be improved and reinforced.

Adequately trained local manpower resources must go hand in hand with construction of treatment facilities.

Progress in the implementation of water quality standards is directly keyed to the assurance of achieving the highest possible level of treatment efficiency.

Design criteria, basic treatment works design, and plant operation and maintenance are the essential fundamental elements through which adequate treatment of wastes are achieved to provide the effluents to maintain water quality standards.

The construction grants program has brought to many communities, for the first time, the responsibility of operating and maintaining a wastewater treatment facility, a responsibility which does belong to the municipality or owner of the facility. Experience has demonstrated the need for improved operation and maintenance.

In March 1969, the FWPCA published the "Report on Operation and Maintenance of Municipal Waste Treatment Plants." This report summarized and analyzed the findings of 1,500 inspections conducted during the period July 1, 1962, through December 31, 1964.

Principal problems reported of the facilities inspected were: (1) operational, mechanical, and structural difficulties at about 40 percent of plants inspected, (2) odor complaints at about 19 percent, and (3) facilities being bypassed by untreated sewage at about 38 percent.

Approximately 970 facilities were inspected and more than 30 percent failed to maintain operating and/or laboratory records; and less than 10 percent of the approximately 530 stabilization ponds inspected maintained records.

Five chronic problems that create operation and maintenance difficulties are: (1) insufficient or unqualified operators, (2) inadequate control over industrial wastes, (3) design and equipment deficiencies, (4) inadequate laboratory control, and (5) inadequate records.

Some municipalities do not recognize either the importance of waste treatment or the complexity of operation. Three fundamentals required for sound and acceptable operating techniques for any treatment facility are: (1) personnel, (2) laboratory control, and (3) records.

Waste treatment facilities are expensive and complex and must be properly designed, constructed, operated and maintained by qualified personnel to provide satisfactory effluents to sustain water quality standards and to protect the public health, as well as the investment of local, State, and Federal funds -- all of which are public.

The President's message to Congress on the environment made three salient points directly affecting operation and maintenance. These are: (1) that it should be required that treatment plants be built to prescribed design, operation and maintenance standards, and be operated only by certified operators, (2) that municipalities impose users fees on industrial users sufficient to meet costs of treating industrial wastes, and (3) that Federal-State water quality standards should be extended to include precise effluent standards for all industrial and municipal sources.

To assist communities with new or existing treatment facilities towards a better understanding and discharge of their responsibilities, a minimum framework of control procedures has been developed through an operation and maintenance manual. The use of this manual is now a requirement to qualify for a Federal grant to construct a wastewater treatment facility.

Assistant Secretary of the Interior for Water Quality Research, Carl L. Klein, recognized the key to effective environmental management when he said, "A good principle in water quality management is that cleanup begins at home --- at the source, not in the waterway...whether home is the farm, the factory, the village, or the giant city. We've got to get at the problem where it starts and festers."

The Student Council on Pollution and Environment

The Secretary of the Interior, Walter J. Hickel, has said, "We want to tap the enthusiasm, vigor, and fresh ideas of our country's high school and college youth in this battle to protect and preserve our precious and irreplaceable water resources. The action we take today, or fail to take today, will determine the kind of world the younger generation will have to face just a few years from now. It is these young people who will have to live with the decisions we make, so they should have a chance to help make them."

To help the high school and college students in the country to organize and direct their efforts toward cleaning up the water, the FWPCA established the Student Council on Pollution and Environment (SCOPE).

SCOPE will provide the framework around which all the country's youth can direct their energies and ideas toward restoring our streams, lakes and estauries.

Mr. Ted Asbury, a senior civil engineering student here at New Mexico State University in Las Cruces, is the South Central Region's delegate to the National SCOPE. The first National SCOPE meeting was held on February 20, 1970. I want to say it is a real pleasure to work with Ted.

Conclusion

Responsibility for water pollution control belongs primarily to the States. Responsibility for proper and efficient operation and maintenance of the waste treatment facility rests with the owner or municipality. The Federal role is one of leadership and assistance.

Acknowledging the necessity for Federal leadership, the Secretary of the Interior had these words to say before the Senate Subcommittee on Air and Water Pollution, "We must establish proper guidelines so that each entity will know its responsibilities. Industry must know what is expected of it, as must the municipalities, the States and the regional and interstate groups. We must develop the technical capability that is needed. We must have training programs. There is much that needs to be done."

You and I, in the final analysis, are the major polluters simply by enjoying the wonderful quantity and variety of production pouring from our mills, farms, and factories while at the same time refusing to heed the insistent call for effective environmental management. You, groups like you, and the youth of this nation, hold the key to whether we grow and prosper or whether we just grow, like a cancer, and destroy the beauty of nature, life, and the possibility of life itself.

As for us in FWPCA, Commissioner Dominick's remarks before the Federal Water Quality Association set our course with these words, "We certainly do not claim to have immediate answers for all the problems that confront FWPCA, but I want to assure you as earnestly as I can that we will not be faulted by lassitude for a lack of desire, energy or action."

Your presence this morning expresses your interest and desire to do the best possible job. I will close with this challenge: "Water tests our sense of responsibility first to God -- then to man. It asks for care, requires our self-discipline, and responds to management."

NEED FOR EFFLUENT STANDARDS

John R. Wright[1]/

The administration of New Mexico's Water Quality Act is assigned to the Water Quality Control Commission. The Water Quality Act, Chapter 190, Laws of 1967, establishes the method of administering water quality in the State of New Mexico. The law provides for the adoption of water quality standards as a guide to water quality.

The Commission has adopted Water Quality Standards in accordance with the New Mexico Water Quality Act and in compliance with the Federal Water Pollution Control Act. A Federal requirement in the adoption of Water Quality Standards is the inclusion in the Standards package of a plan of implementation. New Mexico's Water Quality Standards and Implementation and Enforcement Plan have been completed and approved as Federal standards by the Secretary of the Interior. The Implementation and Enforcement Plan establishes the method of controlling water quality in the stream by the establishment of effluent quality requirements which will in effect maintain the stream quality within the limits of parameters as established by the standards.

These effluent quality requirements or effluent standards are established by the adoption of regulations. To put this in simple terms, effluent regulations are adopted by the Water Quality Control Commission in order to maintain stream quality within the standards and to prevent or abate pollution. Effluent regulations are needed because stream standards are not enforceable against an individual. Effluent regulations establish specific parameter limits which must be maintained in order for an individual to discharge waste water.

To date, the Water Quality Control Commission has adopted two regulations which deal specifically with waste disposal. They are Regulations 3 and 4. Regulation 3 prohibits disposal of refuse in a watercourse or where the refuse could be washed into a watercourse (by leaching or otherwise).

This regulation (when enforced) in effect protects the water against pollution from solid wastes.

Regulation 4 establishes effluent quality of water discharged to a watercourse. There are three parameter limitations established by Regulation 4. They are BOD at 30 mg/l, COD at 50 mg/l and settleable Solids at 0.5 ml/l. These three parameter requirements, at the limit set, control nuisance conditions. The first, BOD controls organic material that can be biologically degraded to cause an oxygen depletion and/or septic conditions. The second, COD controls organic materials such as cellulose which is not biologically degradable but does add an organic load to the stream. In all probability, COD could be increased from 50 mg/l to 100 mg/l without creating a problem in most streams.

The third parameter, Settleable Solids makes mandatory that practically all waste waters receive sedimentation treatment. Generally speaking, plain sedimentation (that is without chemical coagulation) is sufficient treatment to allow for meeting the Settleable Solids Requirement.

The existing Regulation 4 is in need of amendment. The present form was a first draft and is applicable statewide. It is not stringent enough to protect mountain streams and should be tailored to certain stretches of streams and dry areas with no flowing water.

Other parameters included in the standards that should be covered by effluent regulations are pH, oil and grease, temperature, fecal coliform, floating solids, turbidity, toxic substances, odor, color and dissolved ionic constituents.

The Governor's Policy Board and Technical Advisory Committee on Air and Water Pollution Control recommended in their message to the Governor that effluent regulations be considered for color, turbidity, salinity and temperature. You may note that color was the first consideration. The reason for a color regulation is the control of paper mill effluents. The Governor's Advisory Board was meeting during the time Parsons & Whittemore were considering location of a paper mill in the Middle Rio Grande Valley. Color is nevertheless a significant water contaminant in numerous industrial wastes and if New Mexico is to control pollution from the pending industrial development being pursued by numerous agencies, she must prepare sufficient effluent regulations to cover possible contaminants. Before an effluent regulation for color can be considered, background information on present color levels in New Mexico streams and waste water discharges must be obtained. At the present time, absolutely no color data in quantitive terms is available to the Commission on New Mexico's waters.

A turbidity regulation is needed to protect high quality waters from reduction of light penetration. The reduction of light causes a decrease in photosynthesis with a noncomitant decrease in stream biota. Again, there is no background data on turbidity available to the Commission. The U. S. Geological Survey has just initiated color and turbidity determinations on samples collected at water quality monitoring stations operated under a cooperative arrangement with the Interstate Stream Commission, a constituent agency of the Water Quality Control Commission. The Health & Social Services Department now makes quantative measurements of color & turbidity on samples of waste water discharges collected throughout the state.

Our stream standards spell out specific temperature requirements specifically for the purpose of protecting warm and cold water fisheries. The standards cover streams in sufficient detail to protect both natural and developed fishery. Effluent regulations to control temperature need to be developed in specific relation to the standards to control degradation of the state's Fishery potentials. Temperature data is available to the Commission in sufficient detail to allow for adoption of a temperature regulation, and the Commission has a proposed regulation under consideration at the present time.

Effluent regulations to control pH should be adopted by the Commission in order to protect the state's water from harmful fluctuation in pH.

The parameters of oils and grease and floating solids have not been given serious consideration to date. The Health & Social Services Department, in cooperation with the Federal Water Pollution Control Administration, is presently engaged in an industrial Waste Survey in an attempt to inventory the extent and character of New Mexico's industrial wastes. Pending the outcome of the initial inventory, additional waste water characterization may be undertaken by the Oil Conservation Commission to determine the need for effluent regulations to control oils and greases.

A fecal coliform parameter regulation is needed to protect the bacteriologic quality of our surface waters. The most stringent requirement is to protect recreation waters for body contact sports.

The fishing waters must be protected to a high degree of purity, and all other waters should be protected to prevent nuisance conditions and protect the public health. The main contributor to surface water fecal coliform contamination is municipal waste water effluents. A chlorination requirement or effluent regulation, stipulating fecal coliform levels to be maintained, will effectively control municipal waste discharges. An additional source of fecal coliform contamination, the cattle feeding industry, will require different regulations for control.

The present push for additional cattle feeding industry in the state will increase the water pollution potential, both from fecal coliform and organic contaminants.

An effluent regulation to control toxic substances will be difficult to develop, but the need is obvious to protect human health as well as fish and wildlife. The multitude of toxic elements and the continued development of pesticides and herbicides, along with the complexity in measurement of minute quantities of the materials in water adds to the problem. The control of toxic substances in effluents, however, must be developed if the state is to have a comprehensive water quality control program. The only feasible method that I can see, of control of toxic substances, is to develop a regulation which establishes a percentage of the TLM of specific species of biota, fish and mammals when exposed to waste waters. The problem will require extensive investigation before a regulation can be proposed. With the Game and Fish Dept, and the Health & Social Services Departments' present resources, it will probably take a catastrophe before the potential hazard will be properly investigated and even longer before control measures can be adopted.

Odor is possibly the least significant parameter covered in the Water Quality Standards but will be very difficult to control by effluent regulations because of the elusiveness and unquantitative nature of the parameter. To date, no effort has been directed toward the control of odors. One additional parameter not previously mentioned is radionuclides. The Water Quality

Control Commission has, to date, left the control of radioactive substances up to the Atomic Energy Commission. The Health & Social Services Department is presently preparing a report for the Water Quality Control Commission which will outline present controls in effect by Health & Social Services and Atomic Energy Commission as well as recommendations for additional controls to adequately protect the state's water resources.

I have left the subject of dissolved ionic constituents as the last parameter for discussion because it is the most difficult to cover. The consideration of property rights of individuals as protected by water rights developed under present New Mexico water law and Interstate Compacts is integrally involved in any proposal for the control of dissolved ionic constitutents. For this very reason, Water Quality Standards have not yet been fully developed for New Mexico streams and until Water Quality Standards can be developed, it is virtually impossible to reasonably consider development of effluent regulations to cover dissolved solids. The need for effluent regulations to control dissolved solids will be directly proportional to the need for water resources and higher use demands which are both directly related to population increase. The development of Water Quality Standards for dissolved solids is dependent upon ultimate development of the State's limited water resources, and is the most significant parameter considered from the standpoint of the economic position of the State. Until the value of the water resource exceeds the cost of desalinization, effluent regulations to cover dissolved ionic constituents will be nearly impossible to perfect.

The control of salinity in the interim will be through the competitive uses of water available under present water rights allocation and the control of individual situations which unreasonably increase salinity.

The needs for additional effluent regulations are great, and the resources are limited. For this reason, the most significant parameters must be considered first and a priority of need must be established. Those regulations that control, from a practical standpoint, multiple parameters will be most beneficial to water quality control. You can rest assured that the Water Quality Control Commission is developing data which will eventually permit the proper development of additional effluent regulations and that during the next several years, we will see the development of additional effluent regulations as well as modification of present and future regulations.

THE SOCIAL BENEFITS OF NATURAL RESOURCES DEVELOPMENT

Carl Bronn[1]

Our hosts suggested that I discuss "The Social Benefits of Natural Resources Development."

"Social" Benefits Mean What?

A luncheon is no place for definitions. But to focus on this intangible subject, we need ask: "What are 'social benefits'?" Some resource analysts duck the question by saying: "To hell with social benefits! Confine yourself to the economic benefits of water programs; they develop the social benefits."

Do you feel that social benefits exist only through a stream of dollars? If so you have company--Dollars are the only measure of benefits in the benefit-to-cost ratio. So, I could stop this talk with.."Social benefits are to be ignored."

However, the Congress and the Administration thought differently; they did not buy "dollars only." Their Water Resources Planning Act goes beyond economics, it says: ...plans...shall be reviewed for contributions.... in obtaining the Nation's economic and social goals."* Contributions toward social goals are therefore benefits..the Act does not discriminate between economic and social. Since we have got social benefits into our act -- water development -- let's look at social goals.

Social Goals -- Results We Want!

Jobs, for example -- In the late 1940's the Nation said: in a law -- we want "conditions to create jobs" for everybody willing to work! Therefore, water projects which create conditions which create jobs - (for people who need them) - contribute to a legally stated National goal. Under the Planning Act, such contributions--jobs and job-training -- from water projects are a value to be reviewed!

Even so, some economists ignore jobs created by water development. They argue: the stimulative effects of water projects are indistinguishable from those of any other employment of resources.**

That is, no matter how Uncle Sam spends his dough, the jobs created and other stimulative effects will be the same..so don't consider them! As presented, that means: $80 millions to build a multi-purpose dam on the Potomac River should have the same "stimulative effects" as an $80

*The term "goals" is used interchangeably with objectives, in this paper, rather than in the Budget sense that objectives are directed towards goals.
**Report on North Dakota Wetlands, 1969, by Stanford Research Institute.

1/ Executive Director, National Water Resources Association, Washington, D. C.

million civic center! Do you believe it? How many plants will be erected, how many new products transported, as secondary effects from romping down-town to see Bolshoi Ballet or burlesque at a new civic center?

Social Goals, Besides Jobs and Business

For other social goals, how about water projects which:...save lives -- community as well as individual -- by controlling floods? ...catalyze community plans into actions by providing the essential: assured water supply, during months of low run-off, during years of drouth, for all purposes! ...raise the quality of rivers by providing the water NECESSARY to mix with effluent discharged from modern treatment plant.

Maybe, you don't believe that effluent from modern treatment plant needs an assured water supply either (a) to move effluent to the next guy, or (b) to raise the quality higher than practicable by modern treatment?

If you have not accepted that storage is part of water quality in most river basins, please read carefully the facts on both sides of a paper available here at the podium. It is the paper with a graph, or chart on one side -- the side to be read first.

Would you go for using water development as a base for creating new towns-- as on the shores of Lake Havasu -- to spread out the population? A new Lake? ...How about -- as a social goal -- stabilizing river banks to avoid the streams's cutting new channels -- as nature likes to do?

Besides direct effects on society, such actions and others depend upon water resources can entice people away from centers where man has stifled nature's regenerative powers; water developments do lure people to areas where Nature can work with man for a better environment!

Social Goals Stymied

Even if you don't accept all those social goals in terms other than dollars, let us at least assume you agree that the nation pursues conditions to create employment, to provide good communities, to use land well, to care for water resources.

So also the Nation should avoid conditions which work against such pursuits. Therefore, pursuit and avoidance are twins in planning and construction projects for water care. Evaluation of projects should consider the effect of either providing stimulus or avoiding constraint!

Sometimes community plans--sponsored by Federal social programs --- cannot lead to effective actions because of water resource problems. A broad range of Federal-State programs are constrained just because approved water projects are not built! Removal of that constraint becomes the over-riding social and economic goal of the community!

Quality as a Social Goal

Quality of water -- a Social Goal -- was the Big Issue in water care during 1969. It was a band-wagon issue, laid on with lots of emotion and little balance. The thrust appeared to be at Water Quality in rivers and lakes--but actually the thrust was at quality of municipal sewage effluent, under techniques on the drawing boards, with the plant operating skills to be on hand. Municipal waste treatment will not of itself, make polluted rivers and lakes fit to swim in!*

Quality for man, versus Quality of nature

What sacrifices in daily living will campaigners make for the qualities of water, or the environment, for which they exert pressures?

Last summer, householders campaigning for bringing to life rivers and lakes were helping to kill rivers and lakes by buying high-cleansing detergents (replacing high-foaming detergents). Such detergents are high in phosphates -- as high as 43% -- which contribute to the algal blooms which lead to "dead" lakes, dead rivers, and dead fish. And most waste treatment plants to be built by the $1 billion sought will NOT remove the phosphates which householders are dumping into the systems.

..Moreover, at a conference on Great Lakes pollution, a marketing authority stated his conclusion - after study - that ladies are going to buy the product which gets clothes cleanest, whether or not it contributes to algal bloom! This is a nice lesson in real action -- spelled without an "X" -- as contrasted with ideas about social preferences. Clean clothes do come before clean water.

Another example of quality for man versus nature's quality: At a public hearing on Air Pollution, an advocate advised that no one in California be allowed to drive an auto of more than 60 HP and 2500 pounds. Asked about his own car, he said "Oh, I drive a 1969 Buick Wildcat!"

We find that in billions of choices millions of people aspire to more products of, or from, natural resources. Among these people are many "reservationists" who are against further use of resources, except that by their aspirations they are resource developers, de facto! For a better tomorrow, people seek products from natural resources -- their private roads to Quality are paved with quantities!

*"The combining of primary, secondary and tertiary treatment in total represents one of the most modern concepts in sewage treatment. Nevertheless, after completion of the process the effluent would still essentially be sewage and as such would be unsuitable for human consumption without additional treatment. This is primarily due to bacteria and virus contamination and the presence of undesirable inorganics such as chlorides and heavy metals. With suitable dilution it will not have a detrimental effect on the receiving stream." 1969 report by Stevens, Thompson & Runyan, Inc., to Washington County, Oregon

Balance

Last Fall the Public demanded -- in the environment of a fight for a sound dollar, and with many communities constrained by lack of water -- that the Senate provide $550 millions more then the House for waste treatment plant. But the House had reported that its Bill would have provided all the funds that more than half the States were prepared to spend in FY 1970 ... it was a balanced proposal.

Had the Public wanted to spend still more for Clean Water, they could have had better balance by funding delayed water development! The House report just mentioned said about water development projects:

> ...One hundred and thirty-nine projects under construction have been delayed and stretched out!
>
> ...On just 23 of those projects, delays will result in estimated cost increases of $162 millions. Estimated losses in revenue would enlarge the total loss of $280 millions!

That is only dollar loss -- the total harm reached deeply into social progress. In fact, that harm was so extensive the House used nearly two thousand pages of fine print to report it.

As one example of water quality -- and other social objectives -- stymied for lack of water, I offer you a fact sheet about one water project that not get development dollars, even as the Public pushed upward the funds for waste treatment. It shows how balance -- Quality and Quantity -- is important.

Quality of water may depend on Quantity

Were Clean Water to be of Higher priority than adequate water (silly, isn't it!), our means for Clean Water should at least be consistent. To direct Federal funds for water quality primarily to waste treatment plant -- while shorting water storage projects eligible in the same appropriation bill -- is inconsistent, and sometimes futile, because: ...in most river basins of the United States*, "water is needed for mixing with the discharge of effluent from waste treatment plants. Water that carries human and organic wastes undergoes chemical change, even if complete sewage treatment is rendered... Since under present technology additional regulation of flow for all purposes is achieved mainly by surface storage, the BASIC NATIONAL WATER RESOURCES PROGRAM BECOMES, IN EFFECT, A PROGRAM OF RESERVOIRS AND WASTE TREATMENT PLANTS."

Environmental Quality

Our double cue for care of water -- quantity and quality--may also apply to care of MAN's environment.

* Report of Resources for the Future to the Senate Select Committee on Water Resources - 1960

About the environment, men advocate a new search for balance in this world, our home. Some seek balance by restricting man's actions these ways:

> reserving vast natural resource areas, where only nature can devastate.
>
> Constraining man's appetite for things, so that each man will use less of the products of earth, air, and water.
>
> Slowing man's reproduction of himself, so fewer numbers will strive for use of natural resources.

I take no issue with the proposals--they would enhance some aspects of the quality of nature's environment. But in man's environment, quality is not the same for everybody. For instance: the low man on the consumers' totem pole may see environment like this: He is real tired of his rented, ramshackle shelter; of a shortage of johns; of enjoying neither automatic heat, nor hot water, nor air conditioning. He would like steak, once in a while, and a Buick Wildcat new, rather than a few knocks away from the wrecking yard...For him and others who "have less", quality of environment is in large part quantities of things -- tangibles called consumer goods.

But goods do impact on nature, and in a double-dealing way. First, for acquisition of materials, manufacture, and delivery. Second, in removal and disposal. Thus --- economic goals of some people do clash with social goals of others.

The quantities demanded by consumers comprising the "have-less"population, will -- if supplied -- enlarged the quality problems for the "stop the world" advocate. Elements of society are in conflict...and balance is not being sought.

As more resources are locked up or used to raise quality in nature's environment, the effect on things sought by people needs careful consideration.

In this, let us be careful that a large segment of our people do not sacrifice prospective "goodies" for degrees of restoration -- (and reservation) -- beyond the general ability to enjoy, or even to perceive. Let us look for balance among programs to develop and those to correct.

Let us devise means to use better the recuperative powers of nature, and also the vast lands from which people are moving. And let us recall that achieving "concepts" of quality in nature is but part of the National goal for enhancing the general welfare -- for still more people!

- Appendix I -

Words complemented by a case study gain more significance, and stay longer with us. Therefore -- as an appendix -- I offer these data about a project for water care. The date do not come from "dam-building" agencies. They are from County officials elected to safeguard their citizens' welfare, and from consultants.

CONDITIONS

The project lies in northwestern United States; annual rainfall averages fifty inches. But:

...only 3% of the run-off occurs during the growing season.

...a river which floods houses and barns hip-deep can be carried, at low flow, in a six-inch pipe.

...the river valley is not densely settled...nearly half the County is in farms (458 thousand acres; 137 thousand people).

...Dairy and other agricultural products are supplied to the city of Portland.

...the potential of ground water is minor. Exploration and study indicate plans should not be based on ground water.

PROBLEMS

...the disposal of treated sewage -- and also water supply for new businesses and population growth -- are serious problems because of low river flow in summer.

...the obvious measure of storing surface water formed the basis of agreement thatthe best all-around plan hinges on Federal-State multi-purpose dams. But restraints have held back progress and;

...long delays are stopping economic growth, wasting human and natural resources, and antagonizing a critical health problem!

Social and Economic Impacts

...There were 12 food-processing plants in the area in the 1940's. Now there are five.

...an agri-business firm proposing to encourage orchards and to build processing plants withdrew after finding -- thru expensive drilling and otherwise -- no adequate water supply.

...a new secondary seqage treatment plant is prohibited from operating because the river cannot take further treatment wastes.

Few Job Opportunities in the Area

...The project will provide new opportunities for employment at home so our youth will not be forced to migrate to our already crowded urban centers.

...Our high schools graduated 2,500 youth last year. Over 1,100 were thrown into the job market. Over two-thirds by survey would have preferred jobs at home, yet a high percentage had to leave for metropolitan areas to seek jobs.

Reduce Unemployment --Provide Training Opportunity

...New industries are needed to help provide equal job opportunities for our migrant population so they may become permanent members of our communities. They are rapidly being forced out of agriculture because of mechanization. A social minority of Mexican-Americans are now seeking to make this area their home.

- Appendix I -

SOCIAL AND ECONOMIC OBJECTIVES

The project provides for municipal and industrial water supplies for five towns and communities located within the watershed.

With the project in operation, production from the area will be an aid in supporting the value of the dollar because it is located near a modern port facility with the opportunity for export to Japan and other countries whose economy is rising.

The project would:

....Store winter excess run-off
....Aid in controlling floods.
....Provide water for municipalities and industry
....Provide water for a year-round live stream.
....Provide water for irrigation
....Will be the basis of a new water-based recreational area.
....Create a climate that will generate new jobs
....Reverse the degeneration of our environment
....Strengthen the economy
....Create a more liveable area
....Permit the use of waste-treatment plant now prohibited from discharging effluent.

CONCLUSIONS

Local people have made great efforts and strides towards solving local problems. The solutions to problems of environment require big efforts beyond the financial abilities of a community.

The project is an opportunity for our Federal Government to demonstrate that they are, in fact, able to be revelant to today's problems...it is also an opportunity for developing a showcase of Federal-local action in solving a common problem.

Prepared as an Appendix to "The Social Benefits of Natural Resources Development"; Speech delivered to the New Mexico Water Conference, University of New Mexico March 12, 1970

LOWER MISSISSIPPI RIVER REGION

FLOW-STORAGE RELATIONSHIP

based on this fact:

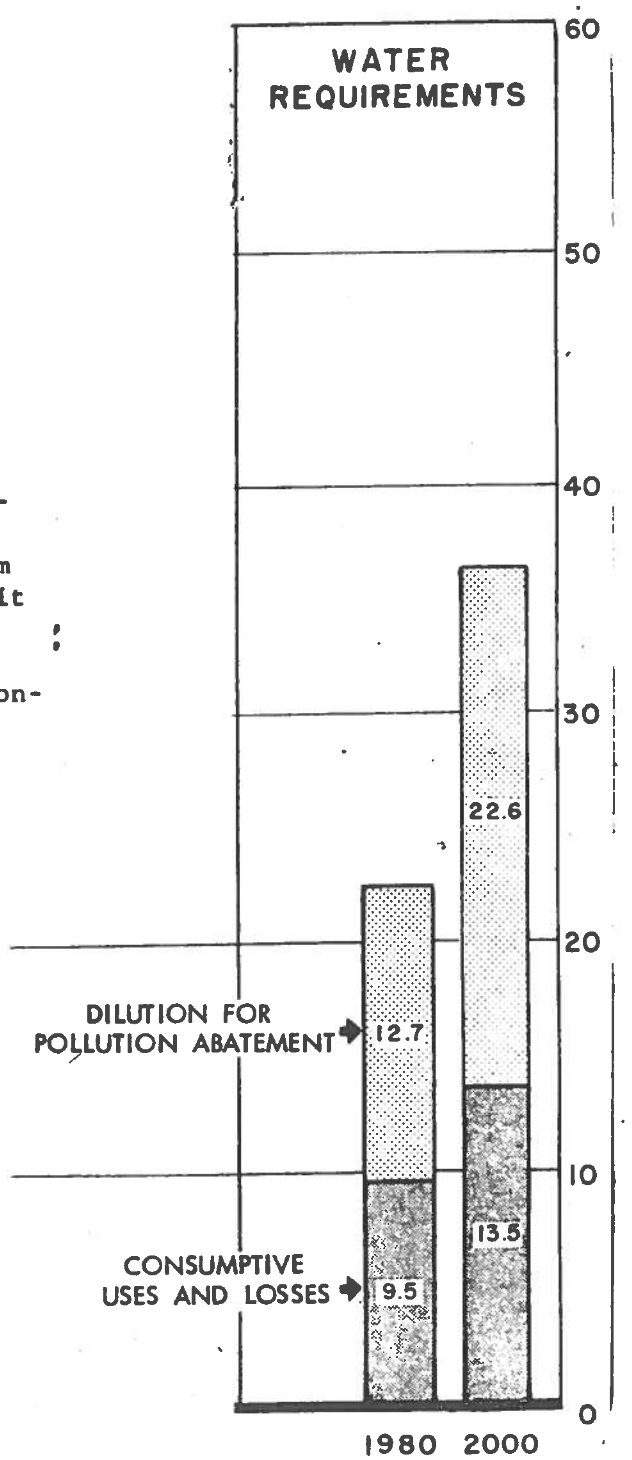
*

"..water is needed for mixing with the discharge of effluent from waste treatment plants. Water that carries human and organic wastes undergoes chemical change even if complete sewage treatment is rendered.

"Under present technology of waste treatment, unless the treated sewage effluent can be mixed with water of higher quality, stream quality will deteriorate to the point where it will be incapable of maintaining desirable aquatic life, will be inferior for domestic supply and may detrimentally influence environmental conditions.

**"Several characteristics of our model should be noted at this point. First, by relating surface flow to level of waste treatment, both of these become intrinsic elements of a "water resource program".

"Since under present technology additional regulation of flow for all purposes is achieved mainly by surface storage, the BASIC NATIONAL WATER RESOURCES PROGRAM BECOMES, IN EFFECT, A PROGRAM OF RESERVOIRS AND WASTE-TREATMENT PLANTS."



Data prepared under direction of Resources for the Future, for the Senate Select Committee on National Water Resources; 1960.

Quality vs. Quantity Relationships

from

TUALATIN BASIN WATER AND SEWERAGE MASTER PLAN

by

Stevens, Thompson & Runyan, Inc.

Stream Waste Assimilation Capacity

"Every stream has physical and ecological characteristics which enable it to absorb pollutional impacts without lasting water quality degradation. These characteristics comprise the assimilative mechanism of a stream. A finite amount of waste material may be assimilated without overloading the assimilative mechanism. This amount of waste, different for each type of waste material, is the assimilative capacity of the stream.

Algae

"Algal blooms and the resulting conditions are one of the major water quality problems in the lower Tualatin River...As far upstream as river mile 45, sufficient levels of phosphate are always available to cause significant growth. Although there are marked increases in phosphate are always available to cause significant growth. Although there are marked increases in phosphate levels at major waste loading points, sufficient phosphorus for algal growth is already present from upstream contributions. It is doubtful that primary emphasis on removal of phosphate from municipal and industrial waste effluents would effectively control algal growth.

Degree of Treatment Selection

"The combining of primary, secondary and tertiary treatment in total represents one of the most modern concepts in sewage treatment. Nevertheless, after completion of the process the effluent would still essentially be sewage and as such would be unsuitable for human consumption without additional treatment. This is primarily due to bacteris and virus contamination and the presence of undesirable inorganics such as chlorides and heavy metals. With suitable dilution it will not have a detrimental effect on the receiving stream.

"With regard to the need for nutrient removal the following Oregon State Sanitary Authority staff memorandum dated September 27, 1968, is quoted as follows:

'It is the opinion of the staff that no more 'tertiary' treatment plants should be approved for construction until such time as the Tualatin plant is in operation and its capabilities can be evaluated. Furthermore, the need for nutrient removal requires more evaluation before this degree of treatment is required. Nutrient removal from sewage effluents may have no noticeable effects on water quality in the Tualatin Basin due to the contributions of nutrient from land drainage and irrigation return water."

ALBUQUERQUE'S PLANNING FOR THE USE OF SAN JUAN WATER

J. Warner Little[1]

As I was coming over to the meeting, I stopped for a cup of coffee. I sat down next to a little old lady and we struck up a conversation. We were talking about what a fine school New Mexico State is. She seemed very much impressed by the fact that the school is working on a project connected with the space effort. As a result of the overpopulation scare, some people have suggested that we send man to other planets. But, man has to eat where-ever he is and here at New Mexico State, they're breeding cattle especially for outer space. This little old lady is looking forward, she said, to the first space shot of this herd of dairy cattle, especially bred right here in Las Cruces. "Really?", I said. "Oh yes," she said. "It's just wonderful. It will be the 'herd shot' around the world." There's only one guy I know who can tell worse jokes than that, and luckily, he's not here.

The City Commission of Albuquerque has a problem which I'm going to talk to you about today. The City of Albuquerque, back a few years ago, contracted with the Department of the Interior for a 45,800 acre feet of the San Juan-Chama Diversion water. The City Commission began to realize that 1971, the completion date of the project, is drawing close and the city will be getting this water if it can be put to beneficial use. Also, the time for paying for it is close at hand. Well, the city fathers asked, "How are we going to pay for it? What are we going to do with this water?" And the more they looked at the problem, the more complex it became to them- so they solved it in a very unusual and unique manner - they appointed a committee. Someone heard that I'd talked to Steve Reynolds a couple of times, so they assumed that I knew all about water, and put me on this committee.

When the committee first got together, we learned there were many astute people on it, but we knew very little about water and especially about the San Juan-Chama Project. It has taken us about 3 months to reach an understanding of the situation and it's been very difficult for us as laymen to do.

Albuquerque will be allowed to take 17,700 acre feet of water, beginning the first year after completion of the project. By not taking more than that figure the first 10 years, the city receives the privilege of not paying interest on the balance of the 45,800 acre feet of water. This reduces the payment schedule considerably, interest is deferred, and the first year's payment works out to only $300,000. Well, the city doesn't have enough money on hand to pay its portion - so they were hopeful that our community would come up with some way to have this water, pay for it, and put it to some use where we might derive a little revenue.

1/ Member of the Water Resources Advisory Committee of the City of Albuquerque

After looking at the city's required payment schedule, one person asked, "You mean it's going to cost this much money? Where's it coming from?" Well, it's going to have to come from increases in water bills apparently. "You mean we're going to have to raise everyone's water bill, and we can't even use this water, or we won't even need this water for industrial and municipal purposes until the year 2000 approximately? And, in the meantime, for 30 years, we're going to have to charge the people for it?" And we were told - "It looks that way." So, we went into the contract and learned that the project was built in reliance upon the word of Albuquerque that they would pay for about half the cost of the project. We learned that having this water assures the growth of our city, in fact it is even stimulating our growth we think, because we have it, and certain industries will hear about it and seek us out. Thus, we have a competitive advantage over our sister cities in Southern Arizona who are running short of water.

In the meantime, the committee had to find a way to pay for this water and play with it, putting it to good use. Otherwise, it would not be diverted, but would flow on to California, while we paid for it anyway. We learned that we couldn't commit all of it to recreation, because we're going to eventually need it to drink. But we felt we could commit some of it to recreation and then hopefully, in the interim between now and the time we're going to need it for municipal purposes, acquire additional Rio Grande water rights, so that the recreation projects will not have to be abandoned.

We agreed that having the new water was indeed good, and we soon learned that the Bureau of Reclamation was not going to amend the contract and give Albuquerque 100 years to pay, instead of 50 years, or reduce the payments when they had several other users on the drainage who would take the water on the same basis, or even on less favorable terms than Albuquerque took it. Also, it was learned that initially, the increase in water bills per city residence would be something like 43¢ a month. In the later stages, when our payment gets to be as high as $1,400,000 per year, allowing for projected population increases, it would be 93¢ monthly. So, it isn't something that is impossible to pay for.

There are several things suggested that we do with this water. The first one was that we make recreational lakes within the city limits, perhaps within the confines of the levee system of the Rio Grande. It would be nice, but I know some of you are thinking like we did, and soon found out, that it is very difficult, expensive, and the silt problem could be immense.

Then there was an idea which we haven't fully explored concerning the development of the conservancy ditches, perhaps widening them, making some ponds in certain places after we have acquired the necessary land.

There was the suggestion that dams be constructed in Tijeras Arroyo, a tributary of the Rio Grande, and some of the other mountain arroyos. That was pretty much shot down because of the cost, because of the seepage, and so many other difficulties.

We've had people suggest that we get a fish hatchery. In exploring that, I found that we had land we could donate, and we could donate the water, but apparently no agency wants to build a fish hatchery. They are too costly to operate.

Another possibility is a scenic waterfowl refuge somewhere in or near the city. This wouldn't require much water, but it would require considerable land. This is still a possibility.

The most feasible project for doing immediately appears to be the Jemez Project. It's a Corps of Engineer flood control dam on the Jemez River about 20 miles North of Albuquerque. It would give our part of the state something that most of the state lacks, and that's water recreation close to the people.

The problems you run into in these things are amazing. There is a real nice yellow book. It cost the state I think, something close to $50,000, and we wonder whether this Jemez Project was feasible. Well, we looked in that book and it said that it definitely was feasible! And that's when we really began to worry, and with good reason.

We found that impounding water behind Jemez Dam isn't as easy as we might have thought. Of course, if we do any development at Jemez, we would expect to charge fees. The Corps of Engineers, it turns out, is somewhat reluctant to have user fees charged. Recently, before a congressional hearing, the Commanding General of the Corps said it was alright to charge fees. He was explaining the Corps' regulation that states that no fees could be charged at Corps projects. So, there is little confusion within the Corps on fees, but I think we can surmount that.

Another problem is that at Jemez Dam, there's just one release gate. Should it break, or jam open, we could lose all of our water.

Our hope is for a 1000 surface acre reservoir. But, then we began to wonder. The Jemez River sometimes gets to be just a trickle, and what would happen to our 1000 surface acres if we had a low run-off year? It would get pretty small. So, we have found that we're going to have to impound slightly more water over and above the 1000 surface acres to assure a continuous pool of 1000 acres, even in mid-summer and in dry years.

Another problem is that we can only use the silt basin of a reservoir such as this, and there's only 40 some thousand acre feet of useable silt area available. Our 20,000 acre feet of water would only occupy about half of that initially, and there's still plenty of room for flood control.

We also have to consider the project life. How long before this silt basin fills up? The Jemez silt basin was designed to last 50 years and the dam is already 16 years old. This limits the amount of capital improvement we can do there for parks, golf course, picnic tables, motel, restaurant, and the like. We can't tie up too much money there because we have to amortize the investment over the remaining life of the project, and we want to keep the charges to the general public, the users, as reasonable as possible.

Then we had the suggestion that this be a city project - that the city do it and take pride in it. The city planning people came up with a study of an estimate of cost. They got $ 800,000 worth in just little things - restrooms, picnic tables, parking areas, a boat ramp, a concession building, etc. Out of the $800,000, one little item struck me as strange. It was a $100,000 item called contingency. It indicated that perhaps we didn't quite know what we were doing exactly and weren't too precise in our estimates. These are some of the problems that we are running in to on Jemez.

We've had a proposal that the city sell water for a recreation pool at Abiquiu Reservoir. The proposal was that the Game & Fish Department buy water from the city and charge admissions fees. The projected man days of use is such that the revenue would be sufficient to pay for the capital improvements required, the maintenance, administration, and also there would be enough money to pay Albuquerque $5 an acre foot for the water used there and there would be enough money to establish a sinking fund with which to acquire Rio Grande Water rights so that the project would not have to be abandoned when the City of Albuquerque needed the San Juan water.

The Game and Fish Department, because of their poor experiences with user fees, turned thumbs down on the proposal. We are hopeful that the State Parks and Recreation Department will get the money to carry on the project.

The Abiquiu Reservoir would consume only about 4,000 acre feet per year of our water, and about another 4,000 acre feet would evaporate at Jemez. Remember, we have 17,700 acre feet the first 10 years and 45,800 thereafter to try to use. So, it's rather difficult. Even with two large existing dams, all we can use is about 8,000 feet per year.

So, it appears at this time that we're still very early in the planning stages and I apologize to you for not being able to tell you more of what we're doing. We've just been working on this thing a short time. However, it appears that Albuquerque is going to have a lot of excess water in the next few years and if Albuquerque does not find a use for it, it's going to flow on down the Colorado.

You gentlemen perhaps may keep in mind that Albuquerque has this water, and until Albuquerque needs it for its own use, it's probably for sale, cheap. We're paying $31 per acre foot and we'd be very happy, it appears at this point, to take $5 for it at Abiquiu.

Our committee has learned that these things are very complex. We, on the committee, have had a terrible time just trying to learn the jargon and to understand what's happening to us. If this thing gets any more confusing or complex, I think we're going to take a lesson from our City Commission and appoint a special committee to help us get the problem solved.

THE SAN JUAN-CHAMA PROJECT: FOUNDATION FOR ADMINISTRATION

F. Harlan Flint[1]/

In the preparation of this paper, I am taking the usual license of a speaker to adjust the title assigned him so that it meets his own preconceptions of what the audience should hear. My original assignment, and the topic as it appears in your program, indicate that I will discuss accounting procedures under the San Juan-Chama Project. When Dr. Stucky first approached me with that topic, I advised him that I was not competent to speak on the technical aspects of water accounting under the San Juan-Chama Project. He assured me that I should not be concerned with that disability. In fact, he said, "If lawyers were restricted to speaking on topics within their fields of competence, they would never have an opportunity to appear on the programs of the New Mexico Water Conference." With that sobering knowledge engraved on my mind, I determined at least to mitigate my risks by broadening the subject given me to include a consideration of the nature of the San Juan-Chama legislation, a brief discussion of the project itself, and a general consideration of the problems of administering imported water in the framework of a reclamation project on an interstate stream subject to the diverse claims of many people within three states and two countries.

While many of you are more familiar with the project and its origin than I am, I will risk boring you with a brief resume of the legislation under which it was authorized. The San Juan-Chama Project had been the dream of many New Mexicans for decades before its authorization by Public Law 87-483, which became law on June 13, 1962. It was authorized as a participating project in the Upper Colorado River Storage Project, and will make possible an average annual diversion of 110,000 acre-feet of water from the upper tributaries of the San Juan River in the Upper Colorado River Basin. The waters will be collected from these tributary stream systems in the State of Colorado, and carried through tunnels penetrating the Continental Divide into a reservoir on Willow Creek, a tributary of the Rio Chama in New Mexico.

The imported waters will be used to serve the City of Albuquerque with municipal water, to provide supplemental water for irrigation of lands in the Middle Rio Grande Conservancy District, and to replace depletions in the Rio Grande Basin caused by projects for irrigation and other purposes on several tributaries of the Rio Grande in New Mexico. Depending upon the ultimate determination of feasibility and the desire of the local people to participate in these tributary units, some of the waters may ultimately be used for projects other than the four tributary units specifically authorized by the legislation.

Before discussing the problems of handling water imported into the Rio Grande Basin, brief consideration should be given to the legal and

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1/ Special Assistant Attorney General, State Engineer Office, State Capitol, Santa Fe, New Mexico

institutional basis of water law and adminstration in New Mexico. Our water law is based on the doctrine of prior appropriation. The New Mexico Constitution provides that beneficial use is the basis, the measure and the limit of the right to the use of public waters, and that priority in time of appropriation gives the better right. All of the groundwaters and surface waters of the State belong to the public and are subject to appropriation for beneficial use in accordance with law under the general supervision of the State Engineer. The basic law applies both to surface waters of the Rio Grande and to underground waters in the Basin. Our courts have ruled that the State Engineer has the authority and the duty to recognize the relationship of surface and underground waters in his administration of the law, and he is required to protect the rights of both surface and underground water users.

In addition to the water law embedded in the New Mexico Consititution and statutes, an important part of the law of the river is also found in the Rio Grande Compact of 1938. This interstate compact, entered into between the states of Colorado, New Mexico and Texas, divides the water of the Rio Grande among the three states. Thus, under the law of the river, the State of New Mexico has the dual obligation to supervise the distribution of the waters of the Rio Grande among the rightful owners of water rights within the State and to secure performance of the State's obligation to its downstream neighbors under the Rio Grande Compact. This is a complex and difficult task even when dealing only with the native waters of the Rio Grande. The question posed by my assigned topic is, how can we administer the native waters together with the imported waters of the San Juan-Chama Project when those waters are commingled? I will attempt to respond to that question later, but first let us take a closer look at the project itself, and the key provisions of the authorizing legislation.

As indicated above, the San Juan-Chama Project was authorized in 1962. However, its construction was contemplated by the Colorado River Storage Project Act of 1956 (P.L. 485). The latter law contained several provisions governing the construction and operation of the project. It provided that project storage for control and regulation of water imported from the San Juan River should be limited to a single off-stream dam and reservoir on a tributary of the Rio Chama. The Project Act also specified that this reservoir could be used only for control and regulation of the water imported, and that no power facilities could be constructed. Further, the 1956 act specified that the project must "be operated at all times by the Bureau of Reclamation of the Department of the Interior in strict compliance with the Rio Grande Compact . . . ."

The diversion and conveyance facilities of the project are virtually complete, the Heron Reservoir, the off-stream storage facility on a tributary of the Rio Chama, is scheduled for completion in fiscal year 1971.

The Bureau of Reclamation's definite plan report on the project contemplates that the yield from Heron Reservoir will be allocated as follows:

City of Albuquerque	48,200 acre-feet
Cochiti Reservoir	5,000 acre-feet
Middle Rio Grande Conservancy District	20,900 acre-feet
Tributary units	27,700 acre-feet

The 5,000 acre-feet assigned to Cochiti Reservoir is for recreation and fish and wildlife purposes, as authorized by Public Law 88-293.

There were four tributary units authorized by the legislation. The Cerro Unit is adjacent to the Red River, some 27 miles North of Taos. It originally called for the construction of a reservoir on the Red River. The reservoir site has since been found to be geologically infeasible, and the Bureau of Reclamation is studying the possibility of alternative means of constructing a feasible Cerro Unit. The second tributary project is the Taos Unit. It originally contemplated the use of two reservoirs, one of which has since been found to be physically infeasible. Again, the Bureau of Reclamation is evaluating the potential for redesign of the project by use of groundwater in a portion of the project area. The Indian Camp Dam element is still a feature of the Taos Unit.

The third tributary project is the Llano Unit, which would be constructed along the east side of the Rio Grande above its confluence with the Rio Chama. The Pojoaque Unit, about 16 miles north of the City of Santa Fe, would involve as its principal storage feature the Nambe Falls Dam on Nambe Creek, a tributary of the Rio Grande. It is anticipated that portions of the water allocated to the authorized tributary units will be released and made available for other units or purposes. The Bureau of Reclamation and the New Mexico Interstate Stream Commission are evaluating other potential irrigation, municipal, industrial and recreational customers who might use the water so released.

It will be noted that none of the authorized tributary units could physically receive and use waters released from Heron Reservoir. All the contemplated units would operate under the principle of exchange - that is, they would use additional native waters of the Rio Grande, the imported waters being released from Heron Reservoir to offset the effects on the stream.

From our brief discussion of the law of the river, it should be apparent that existing water users in New Mexico, and below New Mexico on the Rio Grande, are entitled to be protected against any new use of the native waters of the Rio Grande which would be to their detriment. Therefore, it is important that, as waters imported from the San Juan River are released from Heron Reservoir, they be delivered downstream in amounts sufficient to offset the effects of the new uses caused by tributary units. It is also important that, as these imported waters are released, they be withheld from those who have no rights therein, but do have physical access to the waters of the Rio Chama and the Rio Grande. The Bureau of Reclamation and the State must have the power to insure that water is delivered to the rightful owners thereof in the Middle Rio Grande Conservancy District, the City of Albuquerque, and the downstream users in New Mexico and Texas. If the existing rights in the native waters and the new rights in the tributary units are to be fully protected, it is also necessary that means be devised to quantify and account the incremental losses of water resulting from its storage and transportation through the system to the ultimate user. It is to these problems of administration and accounting that we now turn.

The San Juan-Chama Project represents one of the first major inter-basin transfers of water in New Mexico. In a physical sense, it also consitutes an interstate transfer of water, although the water imported is within New Mexico's allocation under the Upper Colorado River Basin Compact. The legal and institutional mechanisms employed by New Mexico in preparation for this importation project should serve as a model for any future large-scale water-importation schemes in which the State may participate.

The first fundamental prerequisite of administering the combined native and imported waters is the ability of the State to regulate and control the use of native waters of the Rio Grande system. Under our general law, the New Mexico State Engineer has general jurisdiction over the diversion and use of surface waters of the Rio Grande. The related groundwaters of the system were also brought within his jurisdiction by the declaration of the Rio Grande Underground Water Basin in 1956, pursuant to State law.

Even though the State Engineer's jurisdiction has attached to both surface and related underground waters, it would not be possible to administer those waters if existing water rights were not defined. The second prerequisite to successful administration is the binding, legal definition of existing water rights. In order to be in a position to identify and quantify existing water rights, the State Engineer has initiated a series of general water-rights adjudication suits under the authority of the New Mexico statutes.

A water-rights adjudication suit is a proceeding, usually initiated by the State Engineer, in which are joined all of the claimants of water rights within a stream system. In these massive lawsuits, sometimes involving several thousand parties, the Court defines all aspects of the water rights within the system. In the language of the statute (Section 75-4-8), the decree in such a case must declare, as to the water right adjudged each party, "...the priority, amount, purpose, periods and place of use, and as to water use for irrigation, except as otherwise provided in this article, the specific tract of land to which it shall be appurtenant, together with such other conditions as may be necessary to define the right and its priority."

These water-rights adjudication suits have many of the attributes of giant quiet-title suits with respect to water rights.

One of the first adjudication suits initiated was that on the Rio Chama between Abiquiu Dam and the confluence of the Rio Chama with the Rio Grande. This litigation is almost 100% complete with respect to the individual water rights therein. Similar law-suits are under way, or about to be under way, on each of the tributaries for which tributary units are authorized. Upon the completion of these omnibus water-rights suits, the State Engineer will be in a position to limit all water users to the use of water to which they are entitled under their existing rights or under contracts with the Secretary of the Interior for water under the San Juan-Chama Project.

With administrative jurisdiction over both surface and underground waters, and with the completion of the adjudication suits defining the nature and extent of water rights, the State will be in a position to meet two of the prerequisites for management of the commingled native and imported waters. The third strand in the fabric of administration is the accounting procedure itself - that is, the statutory or administrative method for off-setting project depletions with releases and deliveries of water from Heron Reservoir. For these procedures, we must look again to the basic legislation and to actions taken to implement it by the Bureau of Reclamation and the affected states since the adoption of the legislation.

Section 8 of the San Juan-Chama Act outlines operating conditions to be met. It requires that details of project operation essential to accounting for San Juan and Rio Grande flows shall be developed through the joint efforts of the Rio Grande Compact Commission, the Upper Colorado River Commission, the appropriate agencies of the United States and of the states of Colorado, New Mexico and Texas, and the various project entities. The same section of the act requires that Texas and New Mexico agree on a system of gaging devices and measurements "to determine the present effects of tributary irrigation, as well as present river channel losses." Pursuant to the last-mentioned provision, the states of Texas and New Mexico, through their Rio Grande Compact commissioners entered into a "Memorandum of Agreement" dated November 7, 1962, wherein they agreed upon all of the measuring stations to be maintained for the purposes of the San Juan-Chama Project Act. The act also requires that all works of the project shall be constructed so as to permit physical compliance with all provisions of the Rio Grande Compact.

A report was prepared by the Bureau of Reclamation entitled "Accounting of Water-San Juan-Chama Project, Colorado-New Mexico", February 1963. This report represents a preliminary statement of the techniques to be applied in the accounting of the waters of the Rio Grande and the San Juan involved in the subject project. In summary, the report indicates that the future flow at the Compact gaging station at Otowi Bridge will be kept equal to the Rio Grande flows prior to project operation, plus the additional San Juan-Chama water conveyed past that point for use by the City of Albuquerque and the Middle Rio Grande Conservancy District under their contracts with the Secretary of the Interior. Diversions of water from the Colorado River system will be so restricted as to assure compliance with the Upper Colorado River Compact, and the provisions of the San Juan-Chama Project authorization. The imported waters of the San Juan River system will bear the incremental losses resulting from storage and transportation of those imported waters, thus holding harmless the downstream water users in New Mexico and Texas.

As the project construction moves toward completion, and as the plans for tributary units and other uses under the project are advanced, it will be continually necessary to update the criteria for administration and accounting of water. This process is recognized by the Bureau of Reclamation in the aforementioned report of February 1963, wherein it is stated as follows: "The details of the accounting of water described herein must be subject to adjustments that may be indicated by changing conditions, changes in project plans and operations, and additional and improved engineering knowledge and data. When such adjustments may be indicated to be appropriate, the Bureau of Reclamation will consult with the States of Colorado, New Mexico, and Texas and the project entities before implementing adjustments."

While the details of accounting will change from time to time, it is our view that New Mexico has provided a solid foundation for administration by means of its law and the institutions arising out of that law, and by the process of water-rights adjudication. The existence of these laws and this system of administration provide assurance that there will be continued and improved opportunity for the development of our water resources. Further, this development will be accomplished with full protection of existing water-right owners within the State of New Mexico, with full recognition of our solemn obligations under the Rio Grande Compact, and with security for the investment of the United States in this project.

EFFECTS OF WATER MANAGEMENT ON THE ECOLOGY OF THE AREA

William A. Dick-Peddie[1]

Water is a continuous, unbroken entity existing in various forms and places and connected by groundwater to surface water, by running water to ocean water, or by the interface of surface water to water vapor. Consequently, there is a "net" or matrix of water under, on, or above the earth's surface with no loss or gain in the total amount.

Variations in composition, location, and inclination of the earth's surfaces result in differential degrees and rates of insolation, conduction, reflection, and re-radiation of solar energy over our planet. These energy differentials are further amplified by the earth's diurnal "spin" and annual "wobble". The interactions of water, solar energy, varied surfaces and the earth's "spin" and "wobble" result in the formation of climates and macro-habitats. Macro-habitats apply to such units as oceans, lakes, mountain masses, and continental plains.

Consequently, where water is, what form it is in, and what is happening to it is highly variable from place to place and time to time.

Climates and macro-habitats are then energy systems. They are often of such great proportions and the energy exchanges are so regular that the systems appear to be static and permanent. In fact the relative stability of these systems has persisted long enough to have allowed the evolution of complex aggregations of living organisms - communities which "fit" into and are an intregal part of each system. Often the degree of specificity and delicacy of the "fit" is such that even a slight perturbation of a single component (biotic or abiotic) will induce gyrations in the rates and directions of energy flow to such a degree that the system will lose its stability.

The study of the nature of these "community fits" in "energy systems" is called Ecology. From this it is obvious that an ecologist is occupationally an integrator and synthesizer. It is equally obvious that he is doomed to failure!!

I would like to suggest to you today that the Ecologists' point of view is the important feature rather than the degree of his success. In fact, perhaps there really is no discipline of "ecology" at all. An Ecologist may have to deal with physiology, morphology, taxonomy, soils, meteorology, history, sociology, and economics.

Today's technology is such that even the huge "climatic" and "macro-habitat" systems could be altered to such an extent that we might consider them destroyed. This technology combined with the geometric increase of our species' mass, make it highly probable that some of these

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1/ Head, Biology Department, New Mexico State University

systems will be unintentionally destroyed!

Men have long been aware of their modification, disruption, and destruction of sub-systems. Often these sub-system manipulations have been of great benefit to man, i.e. agriculture, industry, etc. Sometimes not beneficial such as species extinction, soil losses, pollution, etc. However, as man's ability to increase the speed and degree of system modifications continues, there is evidence that uncontrolled energy flow gyrations may be initiated. This could be dangerous!!

Let's look at some indicators of extensive manipulations.

1. Miami's seasonal temperature ranges used to be similar to those of the Keys - moderate, due to the buffering effect of water which gains and looses heat slowly as compared with land. The summer and winter temperature extremes of Miami in the past few years appear to far exceed those of the Keys. The extensive drainage of Southern Florida may well have actually brought about a climate shift for Miami.

2. The "foggy, foggy London" of Sherlock Holmes appears now to have been largely caused by soft coal consumption commensurate with the industrial revolution in England. The smoke tended to reduce insulation and add particulate matter. Both conditions modified the conditions just enough to initiate fog which led to more fog. Recently, London weather has so improved that birds not seen in many years are again nesting in the city!

3. Up until the 1920's major Midwestern rivers only flooded periodically. The Spring thaw filled Pleistocene created sloughs, marshes and potholes. Also the flood-plains of the smaller meandering rivers were filled in the Spring. This local filling and flooding allowed ample time for groundwater recharge and slowed the speed of run-off into the major rivers.

4. With the extensive drainage programs initiated in the 1920's and 30's to increase farm acreages for high cash crops (which quickly became surplus) a rain drop on the land was in a river in a matter of hours, moving at rates making the transport of soil particles easy. Consequently, bad floods now occur annually on most major river systems, delta build-ups of midwestern soils is of concern, water tables are unstable, and the Mississippi migratory water-fowl fly-way has become virtually limited to the Missouri and Mississippi Rivers.

We try to repair mistakes with other vast manipulations and need go no further into that "Dam" business. These are just a few examples of extensive man-made changes which hint of-things-to-come if we are not thoughtful.

The attempt to anticipate the possibility of distant (either in space or time) gyrations in the system caused by a local manipulation, exemplifies the ecological point of view. This long-range, synthetic, or "over-view" approach becomes increasingly difficult due to the very technological advances which make it necessary. Our knowledge explosion demands narrow specialization. Consider the name of this conference.

We can no longer necessarily assume that it is desirable to induce more precipitation, increase or decrease water run-off, reduce water transpiration, transport water for irrigation, develop water for industry, develop water for recreation, etc. Not only do many of these activities conflict directly but they most certainly could modify systems in complicated and remote ways. Actually conferences such as this, function to prevent such conflicts at least as far as water use is concerned.

Often at this point there is a tendency to reduce all problems to one of "economics". It is always important to know how the term is being used. Does it take into account new or changing value systems? With this in mind let's look at New Mexico.

Should we increase areas under irrigation for crops which have support prices?

Is the complete removal of vegetation along water courses to reduce transpiration losses the best approach in the long run if another type of vegetation such as cottonwood trees might lower water losses and at the same time provide much needed park and recreational areas?

Do we know that even if "rain making" should be successful that we want it? What if it should change the environment to such an extent that new kinds of plant communities might come into being which are highly undesirable for our present economy or value system?

Even if the economic factors were to be satisfied by some environmental manipulation, how about our ability to reverse or redirect the changes caused by this manipulation?

I suggest that there are virtually no operational generalizations which can be made about managing our environment. We really have not even defined the problems, let alone anticipated the long term results of manipulations or the consequences of a future change in our value system. Let's manipulate sparingly and cautiously. We should never make decisions concerning the modification of our environment based upon single or short term motivations.

We are all drawn toward conferences such as this where we can announce our achievements and explain our problems to understanding and sympathetic ears. We also learn a lot and have our enthusiasm renewed.

However, there is probably no system component whose management demands an ecological viewpoint more than does water. Intelligent management of this resource can never be accomplished outside of the context of a complete system. This means that "water people" must increasingly operate in "non-water people" environments. We can no longer afford the luxury of working entirely within the limited horizons suggested by such terms as watershed management, water pollution, sanitation, meteorology or hydrology.

This observation is possibly more obvious to "water people" than to many of the environmental scientists. This is indicated by the planning and interlocking nature of most of the papers at this conference, but the plight of our environment indicates that we are all still too preoccupied with our individual specialities.

Let's hope that some day soon we are able to title a talk "Water Management is Ecological", rather than, "Effects of Water Management on the Ecology of the Area".

WATER PLANNING FOR EQUILIBRIUM

Max Linn[1]/

As far as historians can tell there has been no golden age in which man and the land got along well together. This is certainly true in arid lands. The late British geographer Dudley Stamp believed that "so long as equilibrium is maintained, efforts to use arid lands may well prove highly successful. But equilibrium is very easily upset by any one of a large number of factors, and success is at once turned to failure on a large scale. The introduction of irrigation does not alter this concept of equilibrium; it merely changes the emphasis..."

I would make only one addition. The introduction of science and technology to man's use of arid regions does not alter the concept of equilibrium either. Again it merely changes the emphasis. As one observer put it, "Our ecology has been in a state of disequilibrium for several decades". Furthermore, ecological instability is increasing at such an accelerated rate that disasters are inevitable if the trend continues.

I cannot think of a better example of disequilibrium in ecology than the arid regions of the American Southwest. But why do we have this disequilibrium? And what shall we do to avoid disaster and to bring the system back to equilibrium?

Because I am not an expert on water resources, I must be cautious about offering answers. But the layman is certainly not precluded from asking questions, and he should. Let's start by looking at the relationship between water and development in the Southwest.

It is ironic that the very lack of rainfall in the Southwest which is responsible for the water shortage is also one of the main reasons why we have had such a tremendous development here. People come because of the dry climate and the great abundance of sunshine and open space. Industry comes for the same reason. And the long growing season and the predictable weather make the area extremely attractive to agriculture.

Obviously this three-way development has increased tremendously both the need for water and the competition for it. At the same time it has degraded the quality and decreased the quantity of the water that is available. People need water to drink and wash in and to carry away their waste products. They also want it for gardening and for recreation, perhaps to improve the natural environments with green belts, ponds, and lagoons.

On the other hand, commercial growers also need water, lots of it, often more than would be available even without other users. Thus agricultural

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interests come to look upon the use of water to maintain a green belt or a bosque as uneconomic or nonbeneficial. Shade trees, shrubs, and grasses which provide areas for picnicking, hiking, and camping and provide bird and game habitats come to be called phreatophytes--and phreatophytes, almost by definition, should be eradicated so that there can be more water for beneficial uses for irrigating crops.

So here we have the makings of a Greek tragedy. The irresistible forces of population growth, industrial development, and above all agriculture, all of which require water, are coming up against the immovable object which is the limitation of water resources--that very limitation which produced the appealing environment in the first place. And of course, whatever man does in arid regions affects his water supply and his water quality and shapes the land and changes the very climate that makes the area desirable.

This inter-relationship of man and water in the arid regions goes back through all of man's history and extends all over the globe.

Historical Perspective on Man and Water

Let's look at a bit of history. And in this instance I'm not citing history for the sake of custom--like telling stories that, though written into the text, begin "That reminds me..." The history of water usage more often misusage--has a profound warning for us; perhaps we can see it in time.

Both eastern and western civilizations began in arid lands, and in most cases decline was associated with misuse. The classical Greek civilization, for example, was built on misuse of the land. Here, slightly abbreviated, is what Plato had to say in Critias:

> At this period, Attica was still intact. Her mountains were lofty, soil clad hills. Her so-called shingle plains of the present day were full of rich soil and her mountains were heavy of forest. There are mountains in Attica which can now support nothing but bees. The country once produced boundless pasture for cattle. The annual supply of rainfall was not lost as it is at present, through being allowed to flow over the denuded surface into the sea, but was received by the country in all its abundance into a bosom where she stored it in her impervious potters urn, and so was able to discharge the drainage of the heights in the form of springs and rivers in abundant volume and over a wide territorial distribution.

That report of land destruction is 2500 years old. Today less than 5% of Greece remains in forest, and almost all topsoil is gone.

In Anatolia, now part of Turkey, 70% of the region was in forest in historical times. It has now been reduced to 13%. According to one geographer, "The bald mountains and foothills of the Mediterranean litoral, the Anatolian Plateau and Iran stand as stark witnesses of millennia of uncontrolled utilization, and there is still little sign that the lessons of history have been read and understood or that the opposite trend in land use has yet arisen."

In India, the same story. Uncontrolled utilization; little or no concern for environmental factors; and then ultimate destruction of the land.

In Mesoptamia the downfall of Babylon has been attributed to the loss of soil fertility because of salinization caused by improper irrigation and drainage.

In Western Egypt many of the oases once covered much larger areas than they do today. There is direct evidence that they shrunk because the Romans dug wells that depleted the artesian aquifers faster than they could be replenished.

In other areas, such as the Nile Valley where man has lived successfully with dry conditions and water for thousands of years, just recently he has begun to create new kinds of problems by using new technologies. On the Nile, dams have been built to increase the efficiency of irrigation and extend it over larger areas. But this very process has taken away the age old means of fertilizing the land, letting the silt carried down river from Ethiopia extend over the land. Today only clear water is let onto the fields, and artificial fertilizers must take the place of the annual layer of silt. At the same time the new method which keeps water in the irrigation ditches all year round also allows a parasitic snail to live all year around in the ditches. Today in some Nile Villages up to 95% of the people are infected by schistosomiasis, a devastating liver and intestinal disease carried by this snail. There is no remedy in sight so long as this method of irrigation continues.

But we do not need to go as far afield as Asia and Africa to see the effects of land misuse and water misuse. Right here in the Rio Grande watershed we have a fine example of how men have turned a green valley into a wasteland.

The valley of the Rio Puerco from Cabezon South is today a wasteland with a usually dry river channel cut as much as 50 to 75 feet below the surface of the surrounding land. But it was not always so. According to historic records and field investigations, the valley was once filled with lush grasses and the river ran close to the surface so that there was plenty of water for cultivation.

In this valley a half dozen settlements were established whose economy was based on cattle, sheep, and agriculture. But in all cases the settlers took more than the land could give. In one place 10,000 head of cattle were put in a narrow valley to eat shoulder-high grass. Farmers built small dams and dug diversion channels for irrigation and then the problems started. A season or two of unusually heavy rains produced flooding and then disastrous erosion. The river began cutting a deeper channel. Sometimes it went down as much as 10 feet in 1 year. Eventually the water was running so far below the surface of the surrounding land that irrigation was impractical. With cover gone and the irrigation water gone, the whole area was gradually abandoned.

The San Simon River, a tributary of the Gila in Eastern Arizona is a further example. In 1870 the San Simon Valley apparently was a picture of pristine beauty. The floor was flat and unbroken. Large areas were covered with grass thick enough and tall enough to be harvested for hay. In the 1880's 50,000 head of cattle were brought into the valley. By 1905 grazing combined with a critical 10 year drought extending from 1895 to 1904 had eliminated the protective grass covering the valley floor, leaving it ripe for gullying.

According to a U. S. Geological Survey report, today's picture of the valley is one of devastation; except in the short uncut reaches, the former grassy tracts are now barren flats, some completely devoid of vegetation, others supporting only an occasional stunted bush or clump of grass. In places along each side of the channel, belts up to 700 feet in width and several miles in length have been stripped of top soil to depths of 3 feet or more. Some of these remain flat and others have deteriorated into miniature badlands with relief of 2 to 6 feet. Under these conditions the potential silt contribution to the Gila River from the San Simon Valley is enormous, being limited only by the amount of water available for transportation.

There are many more examples. Civilizations that have gone down the drain, so to speak, cultures that have disappeared because man did not know how to get along with the land and the water. And all signs indicate that patterns are continuing, as if the thousands of years of experience in using arid lands and water had never occurred.

Modern Interactions of Man, Land and Water

The history of modern urban water projects in the West probably begins in San Francisco in 1900. By that time the city had grown sufficiently to outrun its water supply and engineers started looking for new sources. The result was the Hetch Hetchy Dam on the Tuolumne River in Yosemite National Park. (It flooded a canyon comparable in beauty and grandeur to Yosemite Valley itself).

The action began in San Francisco but it ended in Los Angeles. The population boom and the agricultural boom in Southern California have consistently required more and more water. And because Southern Californians have the votes, the state has undertaken massive water transport schemes to bring water from the North to the South. In fact, water utilization in the state today is almost total, and there is no major stream running unhindered to the Pacific Ocean.

Central Arizona presents a similar problem. If my figures are correct, in 1965 Arizona was pumping almost 5 billion gallons each day. Much of this water was and still is being used for agriculture which has boomed in the state since World War II. The amount of ground water taken out is far beyond the amount being replenished by the scant rainfall in the state. The result of course is that water is the number one concern of people responsible for Arizona resources. One writer put it this way. "If Arizona goes forward it must travel on water. That is why nearly every time a drop of water falls in Arizona, state and federal agencies examine it, name it, claim it, dam it, or fight over it."

The Arizona water shortage brings up several problems. First of all, the question of water waste. Large quantities of water are used to irrigate low cash value forage crops or crops that can be produced in areas having abundant water. A second problem in overdrawing ground water is the permanent compaction of water bearing layers which reduces their carrying capacity forever. Attempts at recharging a compacted water layer will not restore this capacity. The next step is land settling. Outside Phoenix there are reported to be great cracks in the desert where aquifers have collapsed. The San Joaquin Valley in California settled 25 feet because of underground compaction. The Santa Clara Valley settled 11 feet and was then flooded by the San Francisco Bay salt water. Las Vegas, Nevada also has compaction problems.

A third problem is climate. Irrigation has changed the Phoenix area from a dry desert area into a moist almost subtropical area. Today evaporative coolers no longer work in Phoenix. And again as with the Southern California boom there is no end in sight to the development of central Arizona--except the availability of water.

For some, one solution to the over use of water in Arizona is more people. It takes more water by a factor of 4 or 5 to irrigate an acre of crop land than it does to service one populated acre in Phoenix or Tucson.

Projects to Benefit the Arid West

Spurred by the ever-increasing ground water deficit in Western Texas, New Mexico, Arizona, and Southern California, regional water developers have come up with some grandiose plans for interbasin water transportation. These plans could radically affect the ecology of the whole continent. Their scope boggles the mind.

First let's look at the Texas water plan. On December 17, 1968, the Texas Water Development Board unveiled what is described as the biggest water development proposal ever seriously considered in the United States: a 10 billion dollar plan to provide Texas and Eastern New Mexico with all the water needed over the next 50 years. It involved the construction of 68 reservoirs to store all water available from Texas streams; diversion to Texas of 13 million acre feet annually of water from the lower Mississippi River; and construction of two canals to carry in Mississippi water and the stored reservoir water from east Texas to the south and the arid west and to the New Mexico border.

By the time the plan came to a vote last August 5th, the claims and counterclaims of experts on both sides of the question had created considerable doubt in the minds of the voters that anybody really knew the total cost of such a plan either in dollars or in its effect upon the environment. Opponents said that by inundating an area larger than the state of Connecticut, invaluable agriculture land, wild life habitats, and recreational and scenic areas would be destroyed. They contended further that the restriction on river flow into the Gulf of Mexico would ruin the coastal base. A University of Texas professor also contended that the plan could change the weather and prevent moisture from the Gulf from reaching through West Texas. He maintained that existing irrigation had already upset the ecology of the high plains and providing more water would upset it more. The proponents either denied the claims or said the advantages to the economy of the state of having these vast new quantities of water could overcome any of foreseen disadvantages.

On August 5th the voters of Texas rejected the plan. The present status of the project or modifications of it are not clear.

When Hurley Campbell, an outdoor writer in the Baton Rouge Advocate, learned of the Texas water plan, he tried to deal with its effect on Louisiana in specific ways. But finally the potential impact overwhelmed him. The plan, he wrote, "would destroy life in Louisiana as we have known it." If that could be the effect of the Texas water plan on Louisiana, what could be the effect of NAWAPA, the 100 billion dollar North American Power and Water Alliance Plan proposed 5 years ago to bring Arctic and Canadian water to the western and midwestern portions of the United States and even as far south as Mexico? The plan calls for collecting water from major rivers in Alaska, the Yukon territory and British Columbia, and redistributing it via canals, mountain tunnels and existing streams.

The proposed benefits are considerable from an economic standpoint. The United States, for example, would receive 78 million acre feet of water annually and 38 million kilowatts of power for sale. It would increase irrigable land in the United States by some 40 million acres. It would stabilize and control the level of the Great Lakes and increase power production on the Niagara hydro-electric complex. Everything else about the plan is also stupendous, including the keystone, a 500-mile long reservoir in the magnificent gorge called the Rocky Mountain Trench, extending from British Columbia through Alberta to Flat Head Lake, Montana.

Even the critics agree that this 100 billion dollar plan is large and imaginative but it is so, according to University of California geographer, D. B. Luten, only within engineering limits.

The plan would destroy a great deal of the low-altitude wild lands of Alaska and Canada and a large fraction of the vestiges of such wild lands in the western states. Says Dr. Luten, "No one thus far has undertaken to compare our need for these wild lands centuries hence with our need for water and no one on earth is either competent or in a position to do so objectively."

By comparison with the Northern American Water and Power Alliance, the Central Arizona project is a relatively small operation, costing perhaps a billion dollars. But Arizona politicians and economists consider the project absolutely essential to the continued growth of the State.

A good many questions should be asked about the CAP. What is the true cost of the water going to be? Fifty-five dollars an acre foot has been mentioned. Clearly no farmer could afford anything like that amount and there is no intention that he should have to pay it. That means yet another form of farm subsidy, and who is going to pay? And who gets the benefit of the subsidy? Most of the demand, roughly half, is for the irrigation of low-value forage crops which could be grown more economically elsewhere. The remaining agricultural need is for high value crops like lettuce and citrus fruits better suited to the area. The first irony is that most farmers raising forage came into the area during and after World War II and have not even the justification of long established claim to the water. The second irony is that without them, the Phoenix-Tucson area has enough water from already developed sources so that ground water, it has been estimated, would not be depleted for at least 160 years.

But there is really a much more basic question to be asked. What would happen if there were no Central Arizona project? What would happen if there were no plan to bring 2 million acre feet of water from the Colorado to irrigation projects in Central Arizona?

To digress for a moment, similar questions might be raised about the relatively minor New Mexico part of the Central Arizona project--the proposed dam on the Gila River at the Hooker site. Proponents of the dam allege that opposition is based on the fact that water would be backed into the Gila wilderness area. And it is implied that such opposition is unreasonable because the proposed dam would create a lake that would cover only 480 acres of the wilderness or about one-tenth of 1% of the total Gila wilderness area. This is an over simplification of the position against the Hooker Dam.

Conservationists also raise other questions about the dam--about the uses of the water, about the possibilities of getting underground water and about the projected life of the dam and the tremendous loss of water through evaporation. In fact, once all the objections have been raised, it seems apparent that the only justification for Hooker Dam is that it would be possible to construct it with Federal funds as a part of a political deal with Arizona to approve the Central Arizona project. And the fact that it <u>could</u> be constructed in no way indicates that it <u>should</u> be constructed.

Back to the main issue. As we have seen, the major use of water in Arizona, up to 90% of the total, is agriculture. Some economists have said that if realistic prices were charged for the irrigation water used by agriculture, much of the Southwest water shortage, particularly that in Arizona, would vanish. Not only would uneconomic uses of the water in agriculture stop, but a tremendous amount of waste would also stop. At the same time there might be a shift in the use of water from agriculture to urban uses.

But before we go any further into the subject of what should be done versus what could be done let's look briefly at some other proposed water projects, in this case hydroelectric projects.

Major Hydroelectric Projects

The largest single hydroelectric project now being considered is on the Yukon River at Rampart Canyon. The purpose of the project is to give the economy of Alaska an economic boost by providing a large amount of low cost electric power which would supposedly attract electro-processing industries -- mainly aluminum producers. But an intensive feasibility study by the University of Michigan School of Natural Resources indicates Rampart would have negligible affect upon the economy and would give Alaska 700% oversupply of electricity 1,000 miles from the nearest customer. Said one writer: "The 50% increase predicted by proponents as resulting from the Rampart Canyon Dam is nothing but sheer exuberance."

On the other hand the reactions of fishermen, wild life conservationists, and lumbermen to the project have been anything but exuberant. The average annual catch of salmon on the Yukon River by both commercial and subsistence fisheries approximates 800,000 fish. Construction of the dam would reduce this catch by one-quarter to one-half and the loss would be more than economic. To the Eskimos and Indians living along the river the annual fish camp and the drying of the salmon in racks is perhaps the only time now when he is free from unemployment worries and other benefits of white man's civilization. The advantages of this condition to these people cannot be measured in economic terms.

Another problem would be the loss of water fowl. The fish and wildlife service estimates over a half-million migratory ducks normally breed on the Yukon Flats above Rampart Canyon, and the average fowl population of adults and young is estimated at about a million and a half birds. Rampart Dam would destroy 2.4 million acres of high density breeding habitats and 4.5 million acres of lower density habitat in one stroke.

The Rampart project would also mean a great loss of mammals and forests. But above and beyond the loss is of course the question of whether there is a need for the power and whether it will be competitive, with nuclear power in the future. And similar questions are being raised regarding other proposed hydroelectric projects. A project in Manitoba, Canada, to raise the level of Southern Indian Lake 32 feet would produce 6,000 megawatts of electricity and cost a billion dollars. It would also submerge timber stands producing 10 million dollars a year and destroy a million dollar annual fishing industry, two Indian villages of 650 people, a major nesting ground of the Canada goose, whitefish spawning grounds, and hundreds of miles of streams, small lakes, and rivers which are the major vacation and recreation areas in the province. The project has been called "Manitoba Madness" by the British magazine New Scientist.

And construction of the Glen Canyon Dam, which won a 1964 award for civil engineering achievement, has also had its share of controversies. This hydroelectric project, which provides power for the California grid, has destroyed an area of great scenic value. Conservation groups are especially bitter about the dam because even those who designed it admit that it will be silted up and unusable in only a few short decades, while the canyon, which took the Colorado River millions of years to create, will never be recovered. Others have complained that Lake Powell is especially wasteful because of the great loss of precious Colorado River water through seepage and evaporation. And despite their sad history, the dam builders would have built two more dams in the Grand Canyon.

And of course what is happening in North America in terms of hydroelectric and irrigation projects, is also happening in other parts of the world - perhaps even on a larger scale. The Georgraphical Review of January this year suggests that more than a million Africans are affected by recent man-made lakes. In this poor area of the world the suffering caused by dam construction is perhaps difficult for us to conceive, but one point is everywhere the same. When man builds a dam he modifies nature and human society in many more ways than he usually understands.

We Need a New Philosophy of Water Use

I have gone beyond the problems directly related to water use in arid regions and have taken up the problems of water projects in all kinds of regions among all kinds of people. My purpose has been to indicate in some small way that the approach we take to water here is not an isolated one but it is part of an overall approach that man has taken to water and indeed all resources on this planet ever since he had a recorded history and long before. Man has always acted upon the assumption that he has in infinite resource base: if it's there, use it; when it's gone, move on.

For the most part I have been raising questions, at least implied questions, not proposing solutions. Now let me put forward a few suggestions of things we might do, or perhaps must do if we are to find a better relationship with water and with all natural resources on this planet. For one thing, perhaps we ought to re-examine the functions of irrigation. There appears to be growing evidence that it is fundamentally wrong. Even more important, I would like to raise questions about the concept of water and growth. For example, what makes population growth in arid lands so sacred? Is it not true that projections of population growth are likely to be self-fulfilling prophesies? What would happen if water is just not provided?

Two years ago a panel of resource experts for the American Association for the Advancement of Science examined the future of the arid west and concluded that it would continue to grow, water shortage or no, but that the growth in this part of the United States would be concentrated in comparatively few cities. In other words it would be mainly urban growth. Now our population is already 80% urban compared to 65% for the rest of the United States. And what has happened, in many cases, is that the urban areas such as Phoenix and Albuquerque and Denver and the vast urban complexes of southern California have to some extent grown at the expense of land and water used by irrigation farmers.

To some, urbanization seems to be a solution to the water problem. It takes more water to irrigate an acre of land for agriculture than it does to provide service both for drinking and waste disposal per urbanized acre.

On the other hand, some resource experts have questioned whether unlimited urban growth is desirable in land as dry as the southwest. According to Homer Ashland of the University of California at Riverside, the debris made by megalopolis is much harder to dispose of in arid regions. Air pollution tends to be worse because there is little rainfall to clear the atmosphere. Water pollution is harder to handle because there is little flow in rivers to dilute it. Thus urban growth in the southwest can very well destroy those values that attract people to come to the area in the first place. A typical example of course is Los Angeles, which once boasted the best climate in the United States.

And so we come to a new approach--water planning for equilibrium. Geographer Stamp has said that in arid regions the balance between man and his activities on the one hand and the environment on the other is extremely delicate. If this is true--and I believe it is--it will certainly not be easy for us to achieve an optimum use of resources indefinitely from an ecological and economic standpoint. And yet even though it is difficult this must be our aim. We can accept only those plans that provide for indefinite use of resources for the continuing benefit of man and nature.

If indefinite use seems hard for us, let us consider the alternative that history has presented. The arid lands more than any other parts of the earth seem to have favored the highest developments of mankind in practical achievement and standards of living and wealth, material and cultural, and yet in so many cases destruction of these civilizations has been complete, far more so than in the mid-latitudes where slower developments have led to more lasting results. Imbalance in the arid lands is nothing short of disastrous because there is much less latitude of action than under other conditions--in areas that are more forgiving of man's errors. Perhaps we can go further in developing water resources for the arid lands of the southwest, but not much further without endangering the quality of the environment, without destroying diversity, upsetting ecology in major areas, and actually wasting water. Therefore, perhaps we should begin to question more seriously than ever both the need for and the desirability of our major water projects - and even all the small water projects which affect the environment. We can no longer rely solely on economic or technical or engineering feasibility in deciding whether we ought to undertake a project. Perhaps instead of trying to do all we can to develop and increase resources in the Southwest we, ought to see how much we can avoid doing. In the words of Nobel Prize physicist Murray Gell-Mann, our major goal might well be to record "land marks of technological renunciation" as we move toward a meaningful harmony with the environment.

And above all, in planning for equilibrium we have to get rid of the numbers game in money and people. We have to aim for quality rather than quantity.

Consider one more point. Water is a part of the natural system upon which all life on this planet depends. No other planet in our solar system has water. Let us plan and think and act accordingly. And let us learn from history.

IRRIGATION WATER REQUIREMENTS FOR CROP PRODUCTION IN THE ROSWELL ARTESIAN BASIN

Robert R. Lansford[1]/

In 1956 the State Engineer and Pecos Valley Artesian Conservancy District jointly filed a suit to obtain a judicial determination of water rights, both artesian and shallow aquifers, in the Roswell Artesian Basin. The court on January 10, 1966 filed a partial final judgment and decree which further defined water rights in the Roswell Artesian Basin. The duty of water for irrigated agriculture was established at three acre-feet per acre per annum, only to be exceeded in any one year provided that the total amount diverted during any period of five consecutive years shall not exceed five times the annual duty of water.

A study was initiated in the Spring of 1966 at the request of the Pecos Valley Artesian Conservancy District through the New Mexico Water Resources Research Institute to assemble and analyze existing cropping patterns, water use, water quality, soil quality, crop yields, and income effects from the above-mentioned factors for the Roswell Artesian Basin in Southeastern New Mexico. This paper is concerned with the economic or income aspects of the problem.

The data for the economic analysis was derived from information obtained on 12 case study farms for the calendar years 1966, 1967 and 1968.

Linear programming was chosen as an analytical tool for the economic analysis. For the purpose of this study linear programming was used as a budgeting tool (it is a fast method for budgeting many alternative crop combinations). The primary purpose of the economic analysis was to determine the effect of different quantities of irrigation water on net farm returns.

Three linear programming models were developed from data derived from the 12 case study farms (models A, B, and C) and three for an analysis of the entire Roswell Artesian Basin (Models D, E, and F).

Case Farms

Model A

Designed to provide short-term optimal solutions with present crop enterprises based on 12 case farms, using less than three acre-feet of irrigation water. This was achieved by including only the necessary constraints which were: 1) land (size of farm)--a maximum of 209.88 acres; 2) irrigation water--a maximum depending on specified diversion level; 3) cotton allotment--a maximum of 84.34 acres.

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Model B

Designed to analyze the effect of a 5 percent increase in farm irrigation efficiency, using the same case farm data and constraints as in Model A.

Model C

Designed to meet the requirements of the government upland cotton program for the 12 case farms with about one-third of the water-right acres devoted to a soil conserving crop such as alfalfa. The constaints for Model C were the same as for Model A except for an additional constraint on a minimum alfalfa acreage of 67.64 acres. This was necessary to ensure an adequate alfalfa acreage at low diversion levels of irrigation water.

Roswell Artesian Basin

Model D

Designed to provide a short-term optimal solution with present farm enterprises, using less than three acre-feet of irrigation water per acre. Similar to Model A, but based on the entire Roswell Artesian Basin. The constrains were: 1) land--a maximum of 133,840 acres (water-right acres for the basin); 2) cotton allotment--a maximum of 37,800 acres; 3) irrigation water--a maximum depending on specified diversion level.

Model E

Designed to meet the requirements of the government upland cotton program for the basin with 52,940 acres or more of alfalfa, or about 40 percent of the total water-right acres in the basin. (Similar to Model C but applied to the entire basin).

Model F

Designed to analyze the effect of changing amounts of water diverted to a cropping pattern that closely represents the cropping pattern found in the basin in 1967. The model contained the same provisions as Model E but restricted the production of grain sorghum, forage crops, pecans, and castor beans, and required the production of small grains on a minimum of 7,000 acres. Acreages of alfalfa and small grains, approximately those of the present acreage in the basin, were used as the minimum.

The quantities of irrigation water considered in Models A, B, and C were 2.50 through 4.00 acre-feet per water-right acre, on one-quarter acre-foot intervals. The quantities considered in Models D, E, and F were 2.25 through 4.50 acre-feet per water-right acre, on one-quarter acre-foot intervals.

Cotton

Three cotton diversion plans were included in the linear programming models. These plans were designated as cotton 65, cotton 80, and cotton 95. Each acre of cotton 65 included 65 percent of the acre planted to cotton and 35 percent diverted under the government cotton program; cotton 80 included 80 percent of the acre planted to cotton and 20 percent diverted; and cotton 95 included 95 percent of each acre planted to cotton and 5 percent diverted. The water diversion and net return coefficients varied with each of the three cotton enterprises because of the different percentages of each acre planted to cotton in the three enterprises. The average irrigation water coefficients for the three cotton enterprises are presented in table 2.

Alfalfa

Four variations of alfalfa enterprises were included in the linear programming models as follows:

Alfalfa A was developed from data derived from the case farms for the production of alfalfa hay, with 4.67 acre-feet diverted, basically applied in one irrigation per cutting plus one winter irrigation and an average yield of 5.5 tons per acre.

Alfalfa B was developed from data derived from the case farms for the production of alfalfa seed and/or pasture.

Alfalfa C had a more intensive application of water than alfalfa A, using 5.33 acre-feet or irrigation water application in two 4-inch irrigations between cuttings plus two winter irrigations, with an average yield of 7.3 tons per acre.

Alfalfa D enterprise had a more intensive application of water than either alfalfa A or C, using 6.00 acre-feet of irrigation water applied in two 5-inch irrigations between cuttings plus two winter irrigations, with an average yield of 8.5 tons per acre.

The yields for crops used in the models were derived from yield data on the 12 case study farms. Prices received for commodities are reported in table 1.

The average irrigation water coefficients for the crop enterprises included in the linear programming models are presented in table 2.

Table 1. Product prices and yields, linear programming models A, B, C, D, E, and F, Roswell Artesian Basin, New Mexico.

Crop	Units	Average Yield per Acre	Average Price (dollars)
Cotton [1]			
Lint	lb	730	0.30
Seed	ton	0.6	72.00
Price support [2]	lb	750	0.1106
Diversion [2]	lb	750	0.1070
Alfalfa hay [1]	ton	5.5	25.00
Grain sorghum [1]	cwt	55.0	1.80
Forage crops [1]	ton	19.0	7.20
Small grains [1]			
Hay	ton	3.5	20.00
Grain	bu	50.0	1.00
Pasture [3]	a.u.m.	9.0	2.70
Fruits and vegetables [3]		-- [4]	-- [5]
Miscellaneous			
Castor beans [3]	lb	2,800.0	0.06

[1] Average of 12 case farms.
[2] Projected yield.
[3] From secondary data.
[4] Lettuce, 450 cartons; onions, 500 bags.
[5] Lettuce, $1.70 per carton; onions, $1.75 per bag.

Table 2. Coefficients for crop enterprises, linear programming models, Roswell Artesian Basin, New Mexico.

Crop Enterprise	Average Irrigation Water Diversion per Acre: Models A, C, D, E, F (acre-feet)	Model B (acre-feet)
Cotton (65) [1]	1.81	1.72
Cotton (80) [2]	2.23	2.12
Cotton (95) [3]	2.65	2.52
Alfalfa (A) [4]	4.67	4.44
Alfalfa (B) [5]	3.53	3.35
Alfalfa (C) [6]	5.33	5.06
Alfalfa (D) [7]	6.00	5.70
Grain sorghum	2.25	2.14
Forage crops:		
Forage sorghum	1.47	1.40
Corn silage	1.79	1.70
Small grains:		
Oats	2.17	2.06
Barley	1.50	1.42
Rye	0.45	0.43
Pasture [8]	4.00	3.80
Pecans [8]	6.01	5.71
Fruits and vegetables [8]	3.25	0.00
Miscellaneous:		
Castor beans	2.33	2.21

[1] 65 percent cotton, 35 percent diverted.
[2] 80 percent cotton, 20 percent diverted.
[3] 95 percent cotton, 5 percent diverted.
[4] One irrigation between cuttings.
[5] Alfalfa for seed or pasture.
[6] Two 4-inch irrigations between cuttings.
[7] Two 5-inch irrigations between cuttings.
[8] Not included in models A, B, and C.

RESULTS

Linear Programming Solutions -- Case Farms

Following are results of linear programming solutions for models A, B, and C. A typical farm budget was developed to compare with results of linear programming to determine the economic effect of restricting the diversion of irrigation water at seven different levels. The composition of the average net farm return was 91.35 per water-right acre.

Cotton

In models A and B cotton would be produced on 38.2 percent of the cropland at all levels of irrigation water diversions. In model C cotton would be produced on 32.2 percent of the cropland at 2.50 acre-feet diversion level and then on 38.2 at the 3.00 acre-feet level and above (figure 1)

Alfalfa

In models A and B, Alfalfa D would be produced on about 10 percent of the cropland at 2.50 acre-feet per acre diversion level and increase in almost a linear relationship to over 40% at 4.00 acre-feet per acre. In model C, by forcing in approximately 30% of the farm in alfalfa at the lower diversion levels, a mixture of alfalfa A, B, C, and D would be produced but at higher diversion levels all alfalfa D would be produced.

Other Crops

In models A and B over 45 percent of the cropland would be planted in grain sorghum, forage sorghum and castor beans at the lower irrigation water diversion levels but would decrease in almost a linear relationship to about 15 percent of the cropland at the 4.00 acre-feet per acre diversion level. This was a result of alfalfa substituting for other crops and fallow land as more irrigation water becomes available.

In model C the opposite relationship exists. Other crops comprise about 6 percent of the cropland at the 2.50 acre-feet per acre diversion level but increase to over 20 percent at the 3.5 acre-feet diversion level and then decreases to about 15 percent of the cropland at the 4.0 acre-feet diversion level.

Fallow Land

In models A and B fallow land constitutes about three percent of the cropland at the 2.5 acre-feet diversion level and decreases to about one percent beyond the 2.50 acre-feet diversion level. In model C, however, fallow land comprises about 22 percent of the cropland at the 2.50 acre-feet diversion level and decreases to about one percent at the 4.0 acre-feet diversion level. The primary reason for the high fallow acreage at the lower irrigation water diversion levels was the requirement of about 30% of the cropland be in the production of alfalfa. As the irrigation water diversion level was increased this requirement became

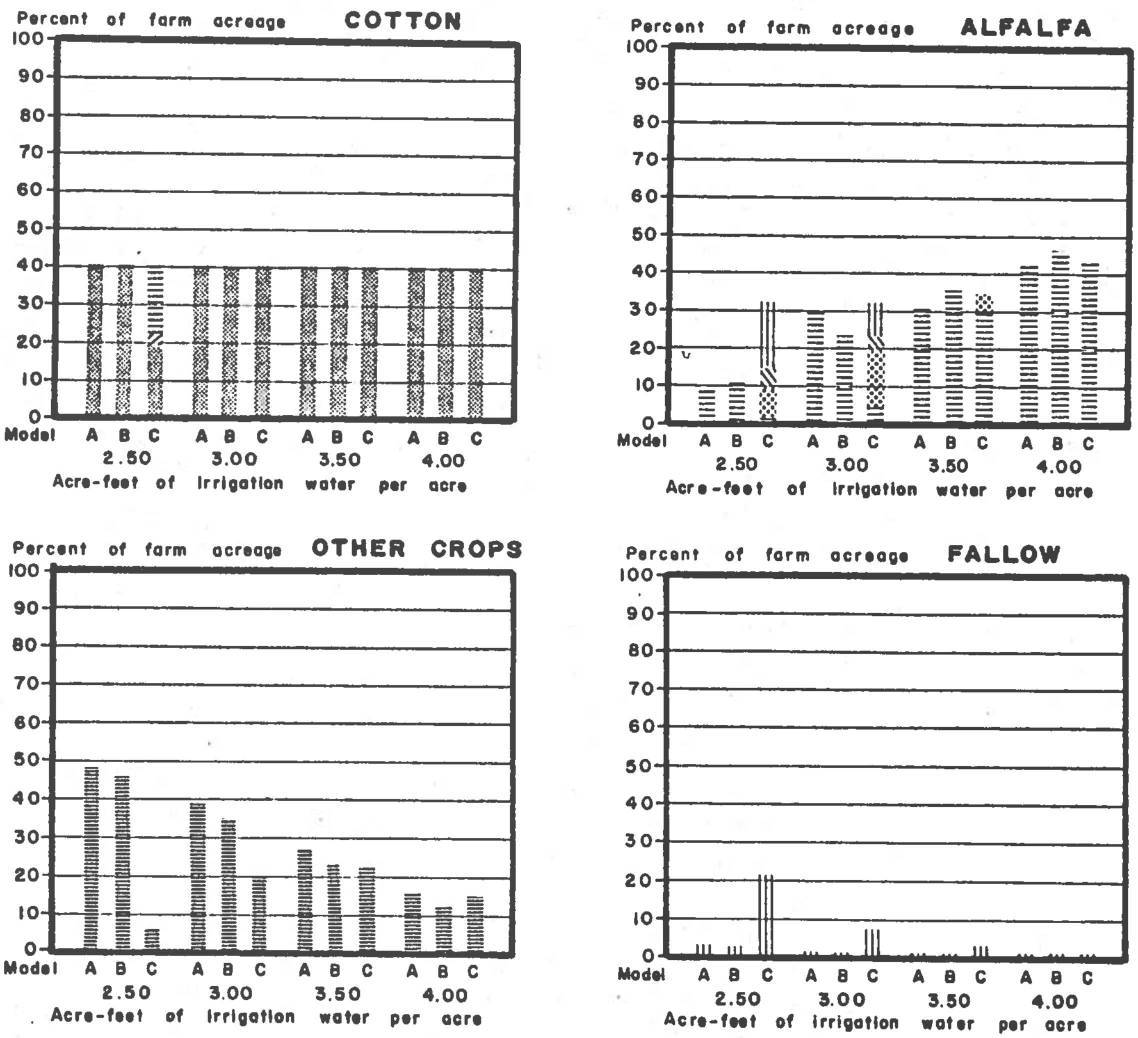

Figure 1. Percent of farm acreage devoted to cotton, alfalfa, other crops and fallow for models A, B, and C, at different irrigation water diversions, Roswell Artesian Basin, New Mexico.

easier to be satisfied. At 4.0 acre-feet per water acre Models A and C had the same cropping pattern.

The results obtained from linear programming Models A, B, and C are graphically summarized in figure 2 which shows the effect of seven quantities of irrigation water on net farm returns. In Models A and B, as irrigation water is increased from 524.70 to 629.64 acre-feet (2.50 to 3.00 acre-feet per water-right acre), net farm return increases at almost a constant rate. From 629.64 to 839.52 acre-feet (3.00 to 4.00 acre-feet per water-right acre) the rate of increase is at a lower constant rate for Models A and B.

In Model C, as irrigation water is increased from 524.70 to 629.64 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net farm return increases at almost a constant rate. From 629.64 to 734.58 acre-feet (3.00 to 3.50 acre-feet per water-right acre) the net farm return increases at a lower rate, and from 723.58 to 839.52 acre-feet (3.50 to 4.00 acre-feet per water-right acre) the net farm return increases at a still lower rate.

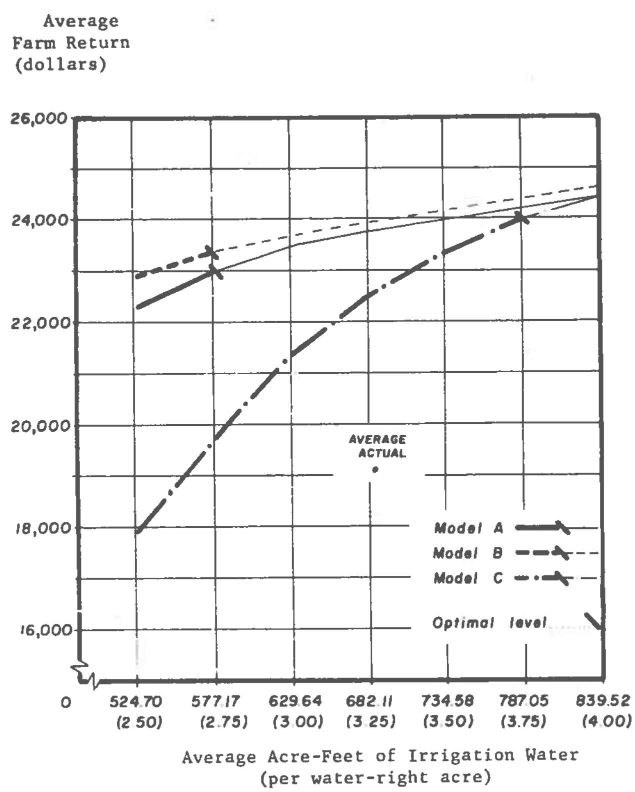

Figure 2. Average farm return and optimal point for operation for seven quantities of irrigation water of 12 case farms, models A, B, and C, Roswell Artesian Basin, New Mexico, 1967.

A comparison of the whole farm budget (3.27 acre-feet per water-right acre) with the optimal cropping programs at the 3.00 acre-feet level in each of models A, B, and C. reflects increased net returns per water-right acre under the optimal cropping programs as follows: Model A, 22.7 percent ($20.78); Model B, 23.8 percent ($21.74); and Model C, 12.0 percent ($10.95). These increased net returns were generated with larger percentages of the water-right acres planted to cotton, increased acreage of such crops as grain sorghum, castor beans, or forage sorghum and decreased acreages of alfalfa, corn silage and small grains.

Optimal Quantity of Irrigation Water - Case Farms

The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water, which was $7.68. These optimal levels are shown for Models A, B, and C in Figure 2.

The average shadow prices for Model A at the 577.17 and 629.64 acre-feet diversion levels (2.75 acre-feet and 3.00 acre-feet per water-right acre) were $8.58 and $4.80, respectively. Somewhere between these two diversion levels the shadow price for an additional acre-foot of irrigation water for the whole farm is equal to $7.68, which is the profit-maximizing point with respect to irrigation water, and likewise for Model B, at the 577.17 and 629.64 acre-feet diversion levels the average shadow prices were $9.02 and $5.06, respectively. Somewhere between these two diversion levels the shadow price for an additional acre-foot of irrigation water for the whole farm is equal to $7.68 which is the profit-maximizing point with respect to irrigation water.

In Model C the average optimal quantity of irrigation water was between 787.05 and 839.52 acre-feet (3.75 and 4.00 acre-feet per water-right acre). The average shadow prices for Model C at the 787.05 and 839.52 acre-feet diversion level were $11.54 and $4.13, respectively. Somewhere between these two diversion levels the shadow price for an additional acre-foot of irrigation water for the whole farm is equal to $7.68, which is the profit-maximizing point with respect to irrigation water.

The primary reason for the higher optimal irrigation water diversion level for Model C was the requirement that about one-third of the water-right acres be in alfalfa. This forced cropland to be left fallow at the lower levels of diversion. Fallow acreage accounted for about 22 percent of the water-right acres at the 2.50 acre-feet diversion level, 13 percent at the 2.75 acre-feet level, 8 percent at the 3.00 acre-feet level, 6 percent at the 3.25 acre-feet level, and 3 percent at the 3.50 acre-feet level.

Linear Programming Solutions -- Roswell Artesian Basin

Following are results of linear programming solutions for Models D, E, and F. A typical basin budget was developed to compare with results of linear programming solutions to determine the economic effect of restricting the diversion of irrigation water at 10 different levels. The composition of the average net basin return of $73.90 per water-right acre is shown in figure 4. The 1967 estimated net farm return to land and management for Roswell Artesian Basin was approximately $9.9 million.

Cotton

In all three models D, E, and F cotton would be produced on the maximum acreage allowed under government cotton program or about 28 percent of the cropland (figure 3).

Alfalfa

In model D alfalfa would be produced on about 2 percent of the cropland at 2.5 acre-feet per acre and would increase in almost linear relationship to 43 percent at 4.0 acre-feet per acre, then increase slightly to about 56 percent at the 4.5 diversion level (figure 3).

In models E and F at the 2.50 acre-feet acre diversion level seed alfalfa would be produced on 39.5 percent of the cropland. As more irrigation becomes available Alfalfa D was substituted for seed alfalfa. At the 4.0 acre-feet per acre diversion level model E has the same cropping program as model D but alfalfa in model F is produced on a slightly higher percentage of the cropland.

Other Crops

In Model D almost 70 percent of the cropland would be in the production of grain sorghum, forage sorghum, or castor beans at the 2.50 acre-feet per acre irrigation water diversion level but would decrease in almost a linear relationship to 15 percent of the cropland at the 4.5 acre-feet diversion level (figure 3). The decrease in acreage was a result of alfalfa substituting for these other crops. In model E other crops varied from 15 percent at the 4.5 acre-feet diversion level to 32 percent at the 3.0 and 3.5 acre-feet diversion levels. In model F other crops varied from 13 percent at the 4.5 acre-feet diversion level to 22 percent at the 3.0 and 3.5 acre-feet diversion levels.

Fallow Land

In model D there would be no fallow land at any of the 10 diversion levels. However, in models E and F by forcing 40 percent of the cropland into the production of alfalfa about 10 percent of the cropland below the 4.0 acre-feet diversion level would be fallowed.

The results obtained from linear programming models D, E, and F are graphically summarized in figure 4 which indicates the effect of 10 quantities of irrigation water on the per-acre net farm returns to the Roswell Artesian Basin.

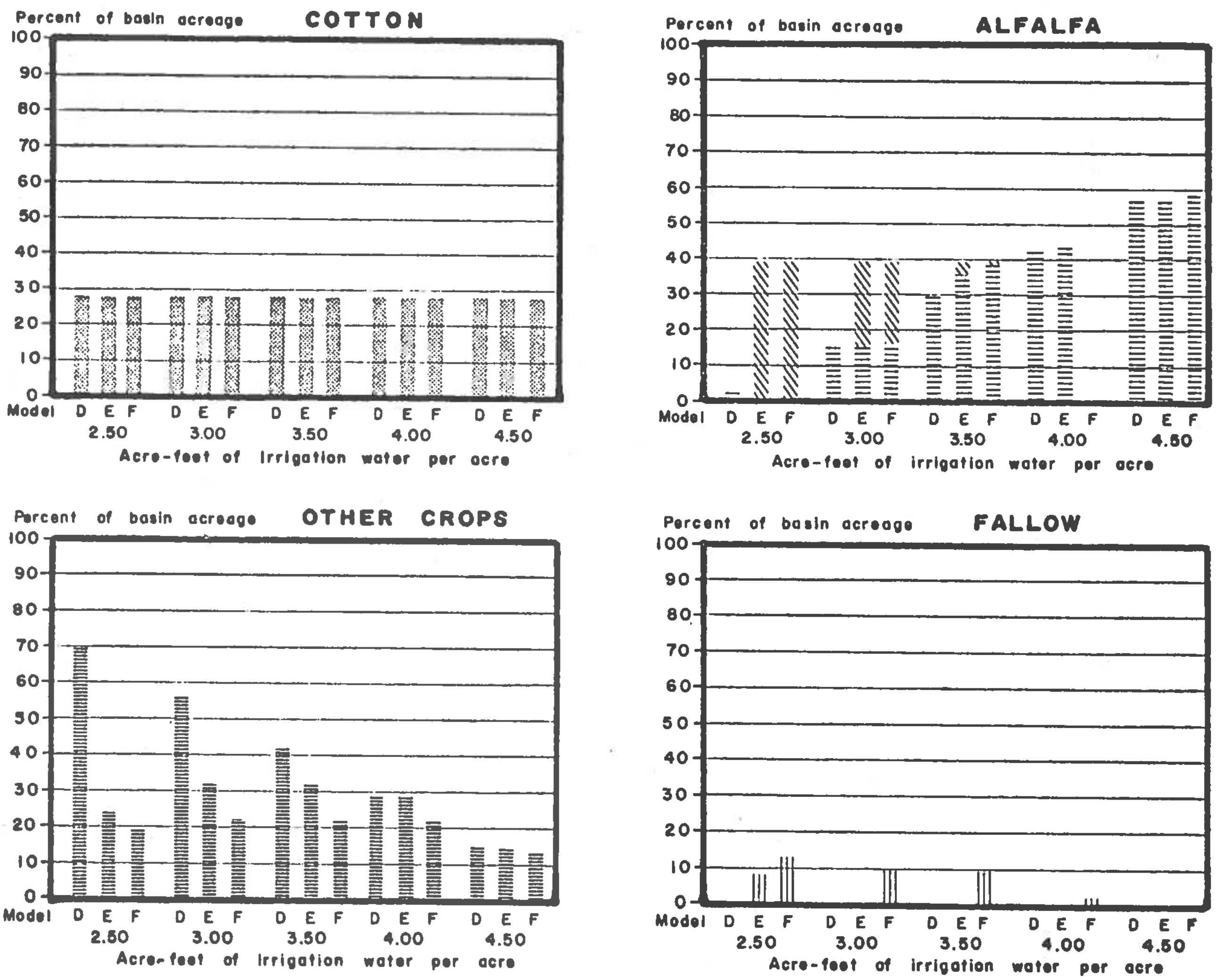

Figure 3. Percent of basin acreage devoted to cotton, alfalfa, other crops, and fallow for models D, E, and F, at different irrigation water diversions, Roswell Artesian Basin, New Mexico.

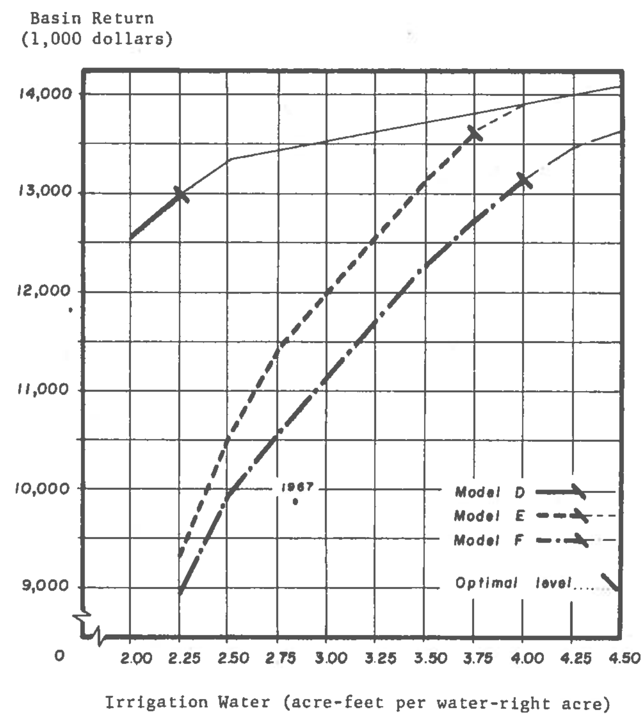

Figure 4. Basin return and optimal point for operation for eleven quantities of irrigation water, models D, E, and F, Roswell Artesian Basin, New Mexico, 1967.

In Model D as irrigation water is increased from 2.25 acre-feet to 2.50 acre-feet per water-right acre, net farm return per acre increases at a constant rate. From 2.50 acre-feet to 4.50 acre-feet per water-right acre net farm return per acre increases at a lower constant rate.

In model E as irrigation water is increased from 2.25 to 2.75 acre-feet per water-right acre, net farm return per acre increases at a decreasing rate, between 2.75 and 3.75 acre-feet it increases at a constant rate, and from 3.75 to 4.50 acre-feet per water-right acre it increases at a decreasing rate.

In model F as irrigation water is increased from 2.25 to 2.50 acre-feet per water-right acre the net return per acre increases at a constant rate, from 2.50 to 3.50 acre-feet it increases at a lower constant rate, and from 3.50 to 4.50 acre-feet it increases at a decreasing rate.

Solutions for linear programming models D, E, and F were also computed at 2.85 acre-feet per water-right acre in order to have a direct comparison with the estimated cropping patterns and net returns for the basin in 1967.

A comparison of the basin budget (2.85 acre-feet per water-right acre) with optimal cropping programs at the 2.85 acre-feet level in each of models D, E and F reflects increased net returns per water-right acre as follows: Model D, 36.3 percent ($26.79); Model E, 17.8 percent ($13.14); and Model F, 15.4 percent ($6.81). These increased net returns were generated primarily by an increase in planted cotton acreage and decreases in fallow land.

<u>Optimal Quantity of Irrigation Water -- Roswell Artesian Basin</u>

The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water, which was $7.68. These optimal levels are shown for models D, E, and F in figure 4.

Average shadow prices for Model D at diversion levels of 301,140 and 334,600 acre-feet (2.25 acre-feet and 2.50 acre-feet per water-right acre) were $13.60 and $2.80, respectively. Somewhere between these two diversion levels the shadow price for an additional acre-foot of irrigation water for the whole basin is equal to $7.68, which is the profit-maximizing point with respect to irrigation water.

The average shadow prices for model E at the 501,900 and 535,360 acre-feet diversion levels (3.75 acre-feet and 4.00 acre-feet per water-right acre) were $13.60 and $2.80 respectively. Somewhere between these two diversion levels the shadow price for an additional acre-foot of irrigation water for the whole basin is equal to $7.68, which is the profit-maximizing point with respect to irrigation water.

In Model F the average optimal quantity of irrigation water was between 535,360 and 568,820 acre-feet (4.00 and 4.25 acre-feet per water-right acre). The average shadow prices for model F at the 535,360 and 568,820 acre-feet diversion levels were $12.66 and $7.13, respectively. Somewhere between these two diversion levels the shadow price for an additional acre-foot of irrigation water for the whole basin is equal to $7.68, which is the profit-maximizing point with respect to irrigation water.

The primary reason for the higher optimal irrigation water diversion level for model E was the constraint that about 40 percent of the water-right acres be in alfalfa. This forced cropland to be left fallow at the lower levels of diversion. Fallow acreage accounted for about 25 percent of the water-right acres at the 2.25 acre-feet diversion level and about 8 percent at the 2.50 acre-feet level.

In model F the optimal irrigation water diversion level was higher mainly because of the constraint that about 40 percent of the water-right acres be in alfalfa, about 5 percent in small grains, and only about 4 percent in grain sorghum, 9 percent in forage crops and about 4 percent in miscellaneous (castor beans) crops. This forced cropland to be left fallow at all except the 4.25 and 4.50 acre-feet diversion levels. Fallow acreage accounted for about 25 percent of the water-right acres at the 2.25 acre-feet diversion level, 13 percent at the 2.50 acre-feet level, 10 percent at the 2.75, 3.00, 3.25, and 3.50 acre-feet levels, 6 percent at the 3.75 acre-feet level, and 2 percent at the 4.00 acre-feet level.

The primary differences between the calculated net farm returns for both the case study farms and Roswell Artesian Basin and the optimal solutions generated by the linear programming models were the result of differences in the cropping programs.

ADJUSTMENTS IN CROPPING PATTERNS AS A MEANS OF SAVING WATER

Gene O. Ott[1]

"Water - There is no Substitute" is the theme of this year's Water Conference. True, we cannot substitute crude oil, blow sand or any other substance to meet the physical requirements of crops for water. However, water is not a particularly unique resource, and economic substitution is possible. Certain substitutions can be made for water when it becomes scarce or costly. The same management techniques that are used in allocating other scarce resources can be used to allocate water. When labor costs increased drastically following World War II, cotton farmers substituted capital in the form of mechanical cotton pickers for the increasingly costly labor resource. In water management, capital has been substituted for water by investment in concrete lined irrigation ditches, underground pipes and sprinkler systems. Labor has been substituted for water by hiring more and better irrigators. In effect, land is substituted for water when irrigable land is dried up so that scarce water can be utilized on the remaining acres. An additional strategy used by farmers when water is limited or costly is through adjustments in the crops they produce, and the amount of water they apply to these crops.

The irrigated crop farmer is faced with the problem of how to utilize his entire bundle of resources, which includes water, in a cropping pattern which will maximize his farm's net return. Basically the economic planner is faced with much the same problem in his attempt to plot the development of an area or basin. However, it is possible for an area planner's optimum solution to differ from the cropping pattern which would result from aggregating the individual producer's best alternatives. This is possible because the areas resources are not evenly distributed between farm units, and the time period for optimization may be somewhat shorter than that used for the area approach.

Determining the most profitable cropping pattern can become quite difficult when there are many different crops under consideration, with a variety of water management practices, coupled with different levels of production and price. This complexity is increased when limits are placed on the resources available and restrictions such as governmental acreage controls, must be considered. Because of this complexity, techniques such as linear programming prove most useful in studying the many different alternatives. The use of linear programming in the Water Resources Research Institute study of the Roswell-Artesia Basin is an excellent example of how this tool can be used in the determination of the effects of different cropping patterns.

This same linear programming technique has merit as a management tool for individual farm units.

1/ Farm Management Specialist, New Mexico State University, Extension Service

Certainly, linear programming techniques of resource allocation is not without its weaknesses. When input-output coefficients are inaccurate, optimum solutions may be grossly in error. Poorly defined restrictions and imprecise levels of available resources may establish unrealistic perimeters. In addition, the program itself may not be constructed to adequately test all of the feasible alternatives. Usually the linear manipulation of the program does not consider the effects of economies or dis-economies of scale. Often the indivisibility of inputs or outputs can also contribute to unrealistic solutions. Other valid criticisms can be made of some linear programming techniques.

In my estimation, the linear programming techniques used in the study of Irrigation Water Requirements for Crop Production, Roswell-Artesian Basin[1], illustrates the effective use of economic models in determining the probable results of different cropping pattern strategies.

In this study, three different linear programming models were used with seven varying quantities of irrigation water, to determine optimum cropping patterns for 12 case study farms. Basically, Model A assumed no increase in irrigation efficiency, and a cropping program typical to that actually being followed on the case study farms in 1967. Model B did not contain provisions for a crop rotation program but did assume a 5% increase in irrigation efficiency. Model C provided for a crop rotation program which would include a minimum of one-third of each farm in producing alfalfa. In the three models, restrictions on irrigation water per acre were tested at levels of 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00 acre-feet per acre. An average of 3.27 acre-feet of water per water-right acre was actually diverted on the 12 case study farms in 1967.

Of the 21 linear program solutions calculated, only one, Model C with a 2.50 acre feet restriction, produced a lower net return than the actual average of the 12 case study farms. The average net return per acre would have decreased 6.4% or $5.86 per acre at the 2.50 acre-feet level under Model C. A major contribution to the higher net returns shown in the model solutions was caused by the increase in planted cotton acreage from 80% to 95% of the cotton allotment. 1967 cotton returns were apparently higher than most area cotton farmers expected. Generally speaking, alfalfa acreages were reduced and grain sorghum and castor bean acreage increased as the available water was reduced. Fallow acreage did not increase significantly except in Model C when water was reduced below the 3.50 acre-feet level.

Linear programming models can be used by farm managers to determine the most profitable cropping patterns for their farm. I suggest that basin models be refined and updated to assist in the determination of optimum development of an area. I further suggest that linear programming techniques be investigated as a management tool for individual farm units.

Refinements need include: models which determine the effect on cropping patterns of commodity price, varying yields, cost of water. At what price per ton would alfalfa replacd grain sorghum in the cropping pattern? At what level of production would grain sorghum drop out of the program? What would be the value of the addition of one acre foot of irrigation water to the farm?

Valid solutions will be possible only if farmers can accurately determine present input-output information for their farms, and if they can delineate the effective perimeters of their production resources.

It will also be necessary for them to be open minded in their consideration of potentially feasible alternatives. To be an effective management tool, the model must be able to simulate future conditions, situations, and their probable effect upon income.

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[1] Irrigation Water Requirements for Crop production, Roswell-Artesian Basin, November 1969, New Mexico State University, Robert R. Lansford, Carl E. Barnes, Bobby J. Creel, Eldon G. Hanson, Harold E. Dregne, Evan Carroon, H. R. Stucky

OBJECTIVES OF A CURRENT STUDY OF SALINE GROUND WATER IN THE TULAROSA BASIN, NEW MEXICO

J. S. McLean[1]

The Tularosa Basin, a north-trending valley in south-central New Mexico, covers an area of 6,500 square miles and comprises about 5 percent of the Rio Grande drainage basin in the United States. The communities of Alamogordo, Tularosa, and Carrizozo with a total population of about 28,000 are in the basin, as are Holloman Air Force Base, White Sands National Monument, and part of White Sands Missile Range and Fort Bliss Military Reservation (fig. 1).

Average monthly temperatures in the central part of the basin range from 40°F in January to 79°F in July. Average rainfall ranges from about 8 inches in the central part of the basin to about 25 inches on the high mountain slopes.

The Tularosa Basin is bounded on the west by the Organ and San Andres Mountains, the Sierra Oscura, and Chupadera Mesa; on the east by the Hueco and Sacramento Mountains, Tucson Mountain, Gallinas Peak, and the Sierra Blanca; on the north by a high topographic divide; and on the south by a low, almost imperceptible topographic divide separating the Tularosa Basin from the Hueco Bolson in Texas (fig. 2).

The Tularosa Basin is a structural trough, or graben, initiated in mid-Tertiary time in rocks ranging in age from Precambrian through early Tertiary (fig. 3). The trough has filled with alluvial detritus, some of which was ultimately deposited in lakes of mid-tertiary to Holocene in age. This alluvial fill, more than 6,000 feet thick in the south-central part, is the most important aquifer in the basin.

Fresh ground-water supplies in the Tularosa Basin are limited and will be insufficient for future needs if withdrawals continue at present rates or increase. Less than 2/10 of 1 percent of the alluvial fill in the basin is saturated with fresh water which is present in alluvial fan materials in the margins of the basin. The rest of the saturated alluvium contains saline water, with a dissolved-solids content as high as 112 grams per liter.

The large volumes of saline ground water present in the alluvial deposits in most of the basin are a potential source of water for desalting.

A study of the saline-water resources of the Tularosa Basin was begun in July 1968 by the U. S. Geological Survey in cooperation with the New Mexico State Engineer and the Office of Saline Water, Department of the Interior. This study is part of a joint effort by State and Federal agencies to prepare an analysis of the saline-water resources of the basin and an estimate of their potential for economic development. The economic

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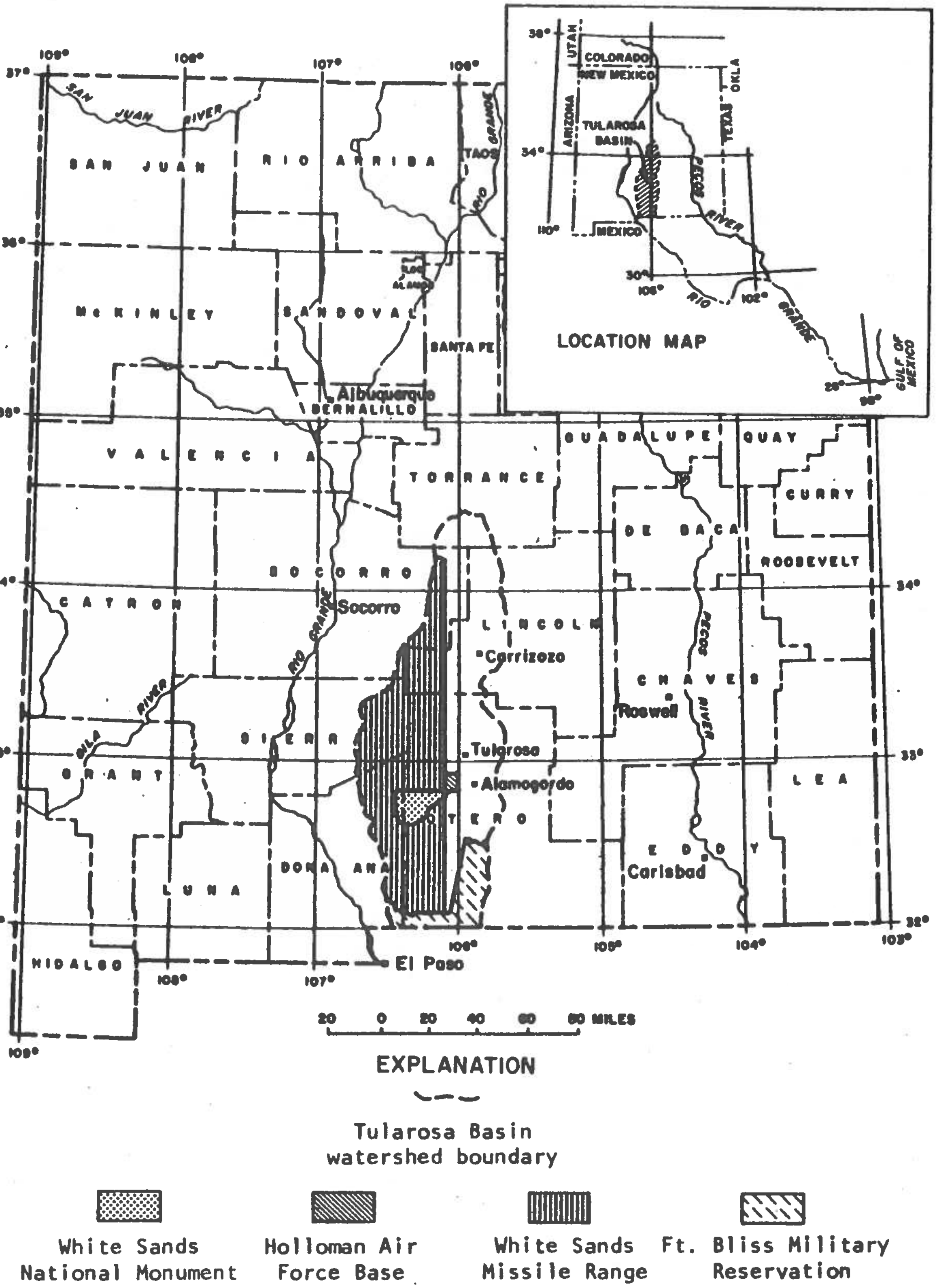

Figure 1.--Index map.

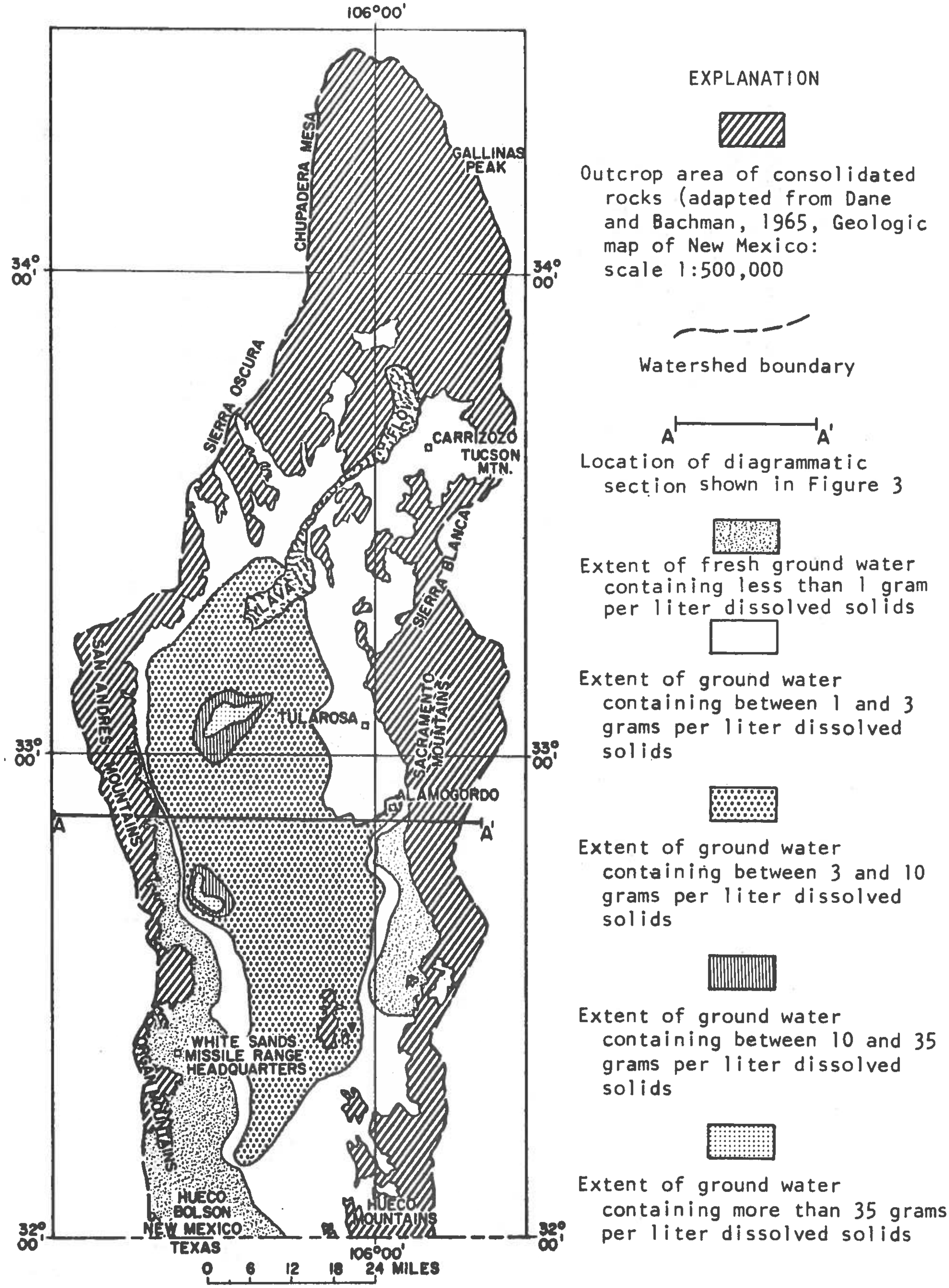

Figure 2.--Map of the Tularosa Basin, New Mexico showing the outcrop area of consolidated rocks and the extent of water-quality zones encountered immediately below the water table.

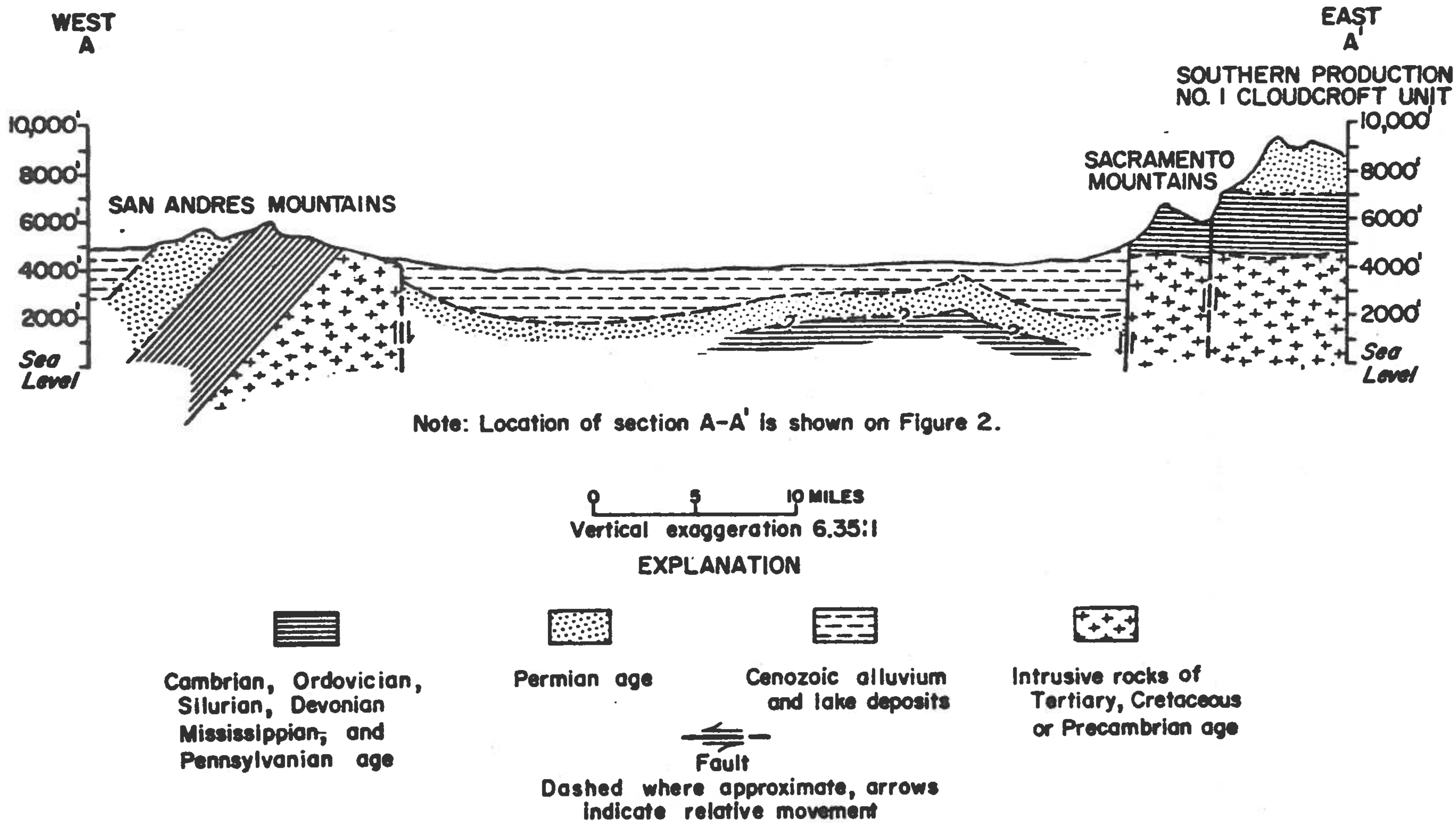

Figure 3.--Section A-A' showing geologic divisions west to east through the Tularosa Basin

analysis of the development and use of the saline water resources is being conducted by the New Mexico Water Resources Research Institute under the direction of H. R. Stucky, in cooperation with the Office of Saline Water and the Office of Water Resources Research.

Other current studies which will contribute to the knowledge of the water resources in the Tularosa Basin are: a study of Lake Lucero, a large playa or "dry lake" in the center of the basin, by W. K. Summers of the New Mexico Institute of Mining and Technology; a pilot study of the saline ground water resources of the Rio Grande Basin by T. E. Kelly, B. N. Meyers, and L. A. Hershey of the U. S. Geological Survey in cooperation with the Office of Saline Water; and a study of the fresh-water resources of the eastern margin of the Tularosa Basin by S. Garza and J. S. McLean of the U. S. Geological Survey in cooperation with the New Mexico State Engineer.

The objectives of this study of the saline-water resources of the Tularosa Basin were to delineate the extent and volume of saline-water zones of specified ranges in concentration; to determine the yields of present wells; and to estimate the potential yields of future wells completed in the saline-water zones. For this study, fresh water was defined as water containing less than 1 gram per liter of dissolved solids. Water containing between 1 and 35 grams per liter was divided into the following ranges: 1 to 3; 3 to 10; and 10 to 35 grams per liter.

The range of water quality most commonly encountered immediately below the water table is shown in figure 2. Two fresh-water lenses occur in the alluvial fill adjacent to the mountains on the east and west sides of the southern part of the basin. The water in the alluvial fill increases in salinity with depth below these fresh-water lenses. Salinity also increases toward the center of the basin where water three times as saline as sea water has been found. The fresh-water lens on the east side of the basin, which contains about 3 million acre-feet of water, is being developed as a potable water source for Holloman Air Force Base, White Sands National Monument, the city of Alamogordo, and ranches in the area. The fresh-water lens on the west side of the basin contains about 7 million acre-feet of water and is used as a potable water source for White Sands Missile Range Headquarters.

Ground water containing 1 to 3 grams per liter of dissolved solids is used for municipal, domestic, stock, and irrigation supply in the Alamogordo, Tularosa, and Carrizozo areas. Unconsolidated alluvial deposits in the Tularosa Basin may contain about 30 million acre-feet of water in which the dissolved solids range from 1 to 3 grams per liter.

Ground water containing 3 to 10 grams per liter of dissolved solids is little used: only a few stock wells withdraw water from this zone.

Ground water containing 10 to 35 grams per liter of dissolved solids is unused in the basin.

Ground water containing more than 35 grams of dissolved solids per liter (about the salinity of sea water) is unused, but may be present in over 90 percent of the alluvial fill in the basin.

Wells in the basin yield from a few gallons per minute to 1,400 gallons per minute. Transmissivities range from about 100 to 47,000 ft^2/day (squared feet per day; cubic feet per day flow through a section 1 foot wide and the full thickness of the aquifer under a hydraulic gradient of 100 percent).

Maps showing the distribution, extent and thickness, and yield of wells in these saline-water zones, will be presented in the final report "Saline Ground-Water Resources of the Tularosa Basin, New Mexico", to be published in an Office of Saline Water Report. Detailed maps of the Alamogordo, Tularosa, Carrizozo and western margin of the basin areas will also be presented in that report.

NEW MEXICO STATE WATER PLAN

Carl Slingerland[1]/

New Mexico being a semi-arid area the water and related land resources development has occurred along the stream systems and in areas of substantial ground water supplies. The state is rapidly changing from a rural to an urban environment. A little more than 90 percent of the water used in New Mexico is for the irrigation of about 1 million acres of crop land and over one-half of this supply is from ground water -- most of which is being "mined". Presently most of the urban and industrial needs are also being met from ground water sources. Some areas in the state where ground water mining is occurring will in the near future require a supplemental source of water to maintain present uses. New Mexico's use of surface water from all major stream systems of the state is controlled by Interstate Water Compacts or Federal Court decrees and our allocation from these systems has already been applied to beneficial use or will be absorbed by beneficial uses expected to arise in the near future. Therefore, projected requirements will need to be met by transfer from present uses or by new sources.

Because of the limited supplies available, and the need to determine how anticipated uses might be met, a State Water Plan has been undertaken.

A series of events over the past 10 years or so have led to the initiation of such a plan. A brief review of these events should help in understanding what the plan will include and how it is being accomplished.

In 1959 the State Legislature created a State Planning Office and directed that it function as the Governor's Staff Agency in the planning for long-range, comprehensive, balanced development of the State's water resources, in the orderly expansion of public facilities, and in other planning matters. In 1961 the Planning Act was amended with the specific reference to water resources being deleted and the area of concern broadened.

In 1961 Amendment provided that the Planning Office "shall function as the Governor's staff agency in planning for the long-range comprehensive, balanced development of the State's natural, economic and human resources and public facilities". The State Planning Office, under the 1959 Act and 1961 Amendment, is preparing a comprehensive resource plan for the State and they have given the Interstate Stream Commission and the State Engineer Office the responsibility of planning the water and related land resource aspects.

1/ Engineer, Interstate Stream Commission

In 1965 Congress passed Public Law 89-80 known as the Water Resources Planning Act. Title III of the act authorizes Federal grants to the states to assist them in developing and participating in the development of comprehensive water and related land resource plans. In May of 1966 the Governor designated the Interstate Stream Commission as the "state agency" to administer New Mexico program under Title III of that act. The Commission is directing the comprehensive water planning being done under Title III independently of the State Planning Office but in careful coordination with the other comprehensive resource planning activities of that office.

In fiscal year 1967, Federal funds were appropriated to the Bureau of Reclamation for studies to bring up-to-date the information on water supplies and uses and to develop measures to insure maximum conservation and optimum use of the limited supplies of the Rio Grande and Pecos River Basins in New Mexico. Discussions between the State and Bureau of Reclamation prompted the state to request that in order to achieve the greatest benefits to both Federal and State interests, that these studies be combined and reoriented toward a statewide approach to water resource development.

The State request resulted in the New Mexico Basins Project (State Water Plan) being budgeted by the Bureau of Reclamation, who has the primary responsibility for preparing the study and publishing the report. Close coordination is being maintained with the Interstate Stream Commission, the State Engineer, and other State and Federal agencies to assure that all basic data and the results of previous and ongoing studies are available for consideration in formulating a comprehensive statewide water plan.

The objective of the study is to develop a long-range statewide water plan which we visualize can be done in four steps.

The first step is to inventory the natural resources of the state and determine the current state of development and use of those resources. The State Engineer Office and the Interstate Stream Commission have completed an inventory of the water resources of New Mexico and their current uses. The other resources have been or are being inventoried by the appropriate agency.

The second step includes the development of projections of the distribution of population and economic activities for the State. The report will develop plans to meet the requirements of two projections. One prepared by the Bureau of Business Research of the University of New Mexico for the State Planning Office and the second prepared by the U. S. Office of Business Economics and the Economic Research Service, commonly known as OBERS, which was developed for use in the ongoing nationwide comprehensive water and related land studies which are being conducted under the direction of the Water Resources Council.

Both of these projections include estimates of population and economic activity for the 1980, 2000 and 2020 time frames. The plan will include measures to meet the water requirements for these points in the future.

The third step, involving water and related land resources, will be to determine the manner in which water requirements for the projected population and economic activity might be met with supplies available to the State under the existing interstate agreements and court decrees. This portion of the program will include: 1) Study of alternatives for the use of water remaining available from the San Juan River by contract with the Secretary of the Interior; 2) Study of alternatives for the use of water potentially available from the Gila River by exchange through the authorized Central Arizona Project; 3) Study of alternatives for the use of water available from Ute Dam and Reservoir and other works on Canadian River by contract with the New Mexico Interstate Stream Commission; 4) Study of ways and means of reducing consumptive use of water by uneconomic plants, reservoir evaporation and through improved irrigation practices; 5) Study of the potential for meeting water requirements arising from the anticipated urbanization and industrialization of the state's economy by the redistribution of water among types of use within the framework of New Mexico law; and 6) Reconnaissance grade studies of storage and transmission facilities needed to serve the projected distributions of population and economic activity.

The fourth and last step will be to determine the prospects for importation of water, weather modification, and possible desalting of saline waters to maintain our present uses and to furnish projected requirements that cannot be met with presently available supplies.

The Federal agencies and the State have studies of varying intensity underway on portions of the third and fourth phases of the program. The Bureau of Reclamation, Corps of Engineers, and Mississippi River Commission are studying the possibilities of importing waters from the Mississippi River to West Texas and Eastern New Mexico. The New Mexico Soils Group under the leadership of Dr. James Anderson is classifying the land areas of the State to determine their suitability for irrigation. The Soil Conservation Service is preparing a series of maps and tabulations concerned with soils, vegetation and agricultural development and practices. The State Engineer and Interstate Stream Commission are working on various phases of the report and have completed or essentially completed a land ownership map, land status map and are developing water use coefficients for the various economic sectors. The State Engineer Office have entered a contract with the Office of Saline Water to study desalting possibilities at several locations in the State. Other State and Federal agencies are also preparing various inputs for the study.

We believe we are proceeding in an orderly and effective manner which will result in a valuable product to the state with the report scheduled to be completed in fiscal year 1973.

IRRIGABILITY CLASSIFICATION OF NEW MEXICO LANDS

J. U. Anderson[1]/

This project involves the cooperative efforts of the New Mexico Water Resources Research Institute, the Soil Conservation Service, the U. S. Bureau of Reclamation, the New Mexico Interstates Streams Commission, the Forest Service, and the Bureau of Indian Affairs under the leadership of the NMSU Agronomy Department in classifying the lands of New Mexico on the basis of their suitability for irrigation. This is being done primarily because various water importation plans have been proposed, and are receiving serious consideration. If water is to be imported for any purposes which include irrigated agriculture, we must be able to provide evidence that their uses will be socially and economically beneficial. Justification for importing water for irrigation necessarily raises questions about the extent, nature, and distribution of irrigable land. The primary purpose of this project is to provide answers to these questions.

PROCEDURE

The procedure which is being used consists of obtaining the best available soil survey information, and interpreting this to obtain the irrigation land classification for each soil type. This procedure has several advantages. First, it permits the use of soil survey information which is already available for some of the counties in New Mexico, and is badly needed for the rest. Second, it permits us to make the interpretations from the soil survey information in addition to the irrigation land class; and finally, it permits us to make an irrigation land classification which is consistent throughout the state with respect to soils.

For those counties for which a detailed soil survey is not available, soil association mapping is being used. Because soil associations are groups of soils which occur together, and which are not necessarily similar to one another, the irrigation land classification is applied to the individual soils, and statements about the entire asssociation are based on knowledge of the percent of the various soils in the association.

The irrigation land classification standards which are being used are those proposed at the 1967 conference organized by the Federal Water Resources Council[1], as modified on January 12, 1968. These criteria were agreed upon by authorities from several organizations concerned with soil classification, and thus appear to have particularly high reliability. In order to assure uniform and consistent application of these criteria and standards, the New Mexico Soils Work Group has issued guidelines and clarifications as needed and appropriate. The classification system establishes four classes of irrigable land and one class of non-irrigable land. Class 1 land has few or no limitations for irrigation; class 4 land has very severe limitations; class 6 land is non-irrigable. The

1/ Agronomist, Agricultural Experiment Station, NMSU

criteria used to determine irrigation land class are shown in table 1.

These standards do not take into account such factors as climate, availability of water, or relationships to markets. While these and other factors are clearly important it seems more appropriate to consider them separately, and thus avoid confusion with soil variables.

RESULTS

The results thus far show that the suitability of New Mexico lands for irrigation is highly variable, and also that we have a great deal of land which is well suited to irrigation. In the counties which have been studied in eastern New Mexico, the amount of class 1 land varies from 61.5 percent in Curry County to 1 percent in Lea County, and the total irrigable land varies from 94 percent in Curry to 34 percent in Eddy County. In southwestern New Mexico Luna County has 13 percent class 1 and 64 percent total irrigable land. In Hidalgo the comparable figures are 10 and 46 percent. The factors that most frequently limit the suitability of New Mexico soils for irrigation are insufficient available water holding capacity, and insufficient effective soil depth. However, the results do show extensive areas which are in classes 1 and 2, and are thus very well suited to irrigation.

In addition to land classification for irrigation, the reports for all but three counties are to include a soil association map, a brief discussion of each soil association, and information about soil characteristics and the suitability of soils for various purposes. They are, therefore, useful as sources of information about soils for many kinds of general or broad area planning. This information is not included for Curry and Roosevelt counties which have recently published SCS soil surveys, or for Torrance County which is to have such a survey published in the very near future.

Research reports covering the results of this work have now been published for Curry, Roosevelt and San Juan Counties. Similar reports for Eddy, Harding, Hidalgo, Lea and Luna Counties are in press or are awaiting publication. Work is in progress for Dona Ana, Chaves, Lincoln, Quay, Sandoval and Torrance Counties.

[1] Proceedings Water Resources Council, Irrigation Land Classification Seminar, Salt Lake City, Utah. July 1967.

Table 1. Land classification specifications for Pacific Southwest Basin irrigation land classes[1]

Land Characteristics	Class 1	Class 2	Class 3	Class 4	Non-irrigable Class 6
Soils					
Texture (Surface 12")[2]	LVFS-CL	LS-C Peat, Muck	MS-C	MS-C	All other lands not meeting criteria for arability
Moisture Retention (AWHC-48")[3]	> 6.0"	4.5" 6.0"	3.0" 4.5"	2.5" 3.0"	
Effective Depth (inches)	> 40[4]	30- 40	20 - 30	10 - 20	
Salinity ($EC_e \times 10^3$ - equil.)	< 4	4 - 8	8 - 12	12 - 16	
Sodic Conditions[5]					
Percent area affected	< 5	5 -15	15 - 25	25 - 35	
Severity of problem[6]	Slight	Moderate	Moderate	Moderate	
Permeability (in place - in/hr)	0.2-5.0	0.05-5.0	0.05-10.0	Any	
Permissible coarse fragments (% by vol.)					
Gravel	15	35	55	70	
Cobbles	5	10	15[7]	35[7]	
Rock Outcrops (distance apart in feet)	200	100	50	30	
Soil Erosion (for all classes)	Severely eroded soils will be downgraded one class. Less severely eroded soils may be downgraded one class, depending on other conditions.				
Topography (or land development items)[8]					
Stone for Removal (cubic yards per acre)	10	25	50	70	
Slope (percent)					
Moderately to severely erodible	< 2	2 - 5	5 - 10	10 - 20	
Slightly erodible	< 4	4 - 10	10 - 20	20 - 25	
Surface Leveling or Tree Removal (amount of cover)	Light	Medium	Medium heavy	Medium heavy	
Irrigation Method	Lands unsuited to gravity irrigation where land grading would permanently reduce soil fertility below arable limits or exceed permissible costs, or field pattern too complex, may be considered for sprinkler. Land must meet other requirements for arability. Designate by "S" - example, 3-S.				
Drainage					
Soil Wetness (depth to water table during growing season with or without drainage)					
Loam or finer	> 60"	40" - 60"	20" - 40"	10" - 20"	
Sandy	> 50"	30" - 50"	20" - 30"	10" - 20"	
Surface Drainage	Good	Good	Restricted	Restricted	
Depth to Drainage Barrier (in feet)	> 7	6 - 7	5 - 6	1.5 - 5	
Air Drainage[9]	No Problem	Minor	Restricted	Restricted	

[1]Specifications are representative of conditions after land is developed for irrigation. Each individual factor represents a minimum requirement, and unless all other factors are near optimum two or more interacting deficiencies may result in land being placed in lower class or designated class 6 -- non-irrigable.

[2]Finer textures may be required than those indicated for each class in areas subject to critical hot spells or wind; coarser textures may sometimes be permissible.

[3]In areas of very warm growing season 3" may be required for class 4 and in cold areas as little as 5" may be permitted for class 1.

[4]Depth of 60" or more is required for class 1 where deep-rooted crops are important.

[5]More extensive and severe sodic problems may be tolerated in areas of wide crop adaptability.

[6]Severity of problem: **Slight** - ESP less than 15% or less than 25% if dominated by nonswelling clays; **moderate** - ESP less than 20% or less than 30% if clay minerals favorable; **severe** - ESP less than 30%; with certain soil minerals may range above 50% as measured by usual techniques.

[7]May range above 50% in subsoil for certain crops if surface soil is favorable.

[8]Special crop and management practices may justify exceeding the limits for stone removal or slope in class 4; irregularity of slope may necessitate downgrading of class unless deficiency is compensated for by possibility of sprinkler irrigation.

[9]Air drainage is a consideration mainly in areas adapted to fruit or to early or late vegetables.

Abbreviations:

LVFS	- loamy very fine sand	CL	- clay loam
LS	- loamy sand	C	- clay
MS	- medium sand	AWHC	- available water holding capacity
		ESP	- exchangeable sodium percentage

SOCIAL AND ECONOMIC CONSIDERATIONS IN STATE WATER USE PLANNING

George R. Dawson

Planning is viewed basically as a means of assembling facts, evaluating them and then selecting a course of action to fulfill or achieve a specified objective. Therefore, a plan is a scheme which projects and thus implies an imaginative scope and vision. Evidence is abundant that we have failed as planners in the past and there is little evidence that we have gained any major improvement in our vision. Obviously we have not had the "facts" or we have failed to use them.

Our basic conflict arises out of not being able to specify our common objectives in resource allocation. Research, in contrast to planning, is the organized search for new knowledge with the emphasis on understanding of the basic relationships. Understanding the basic relationships is essential in evaluating plans. I am convinced that we have not made full use of available research in our planning as it relates to the basic relationships of man to his environment, his needs and wants. What is or should be the social and economic objectives of a state water plan? How should they be determined?

The word social is defined as pertaining to the welfare of human society. Our water planning has been difficult due to our inability to delineate a common meaning of welfare. Economics by definition would imply that welfare is considered in the laws affecting production, distribution and consumption of wealth or the material means of satisfying human desires. The word economic is defined as pertaining to the management or development of natural resources in satisfying man's needs. If economics did in fact provide for the satisfaction of man's needs, as implied by definition, we would be home "scot free" because it has been primarily economics which has served as our tool for resource allocation plans (plus a lot of politics). Yet, we now know that our social goals have not been clear and are giving much lip service to this failure in meeting social objectives that provide for the "good life".

Our plans have, with limited exception, avoided the basic relationship of man to his environment in the long-run. Our social and economic objectives have been primarily short-run in scope and vision, and I might add, heavily due to the interaction of political factors, rather than a "void of vision". Our planning tends to conform to tenure terms of political office rather than to the long-run needs of man.

Previous speakers at this and former water conferences have discussed in detail the mechanics of the development of a state-wide water plan (4, 3). They have done this well and a concentrated effort is underway to prepare a state-wide water and related land resource use plan.

1/ Professor and Head, Department of Agricultural Economics and Agricultural Business, New Mexico State University

Slingerland summarized the four steps being followed in developing the long-range statewide water plan. Those four steps appear to be all inclusive of considerations encompassing physical and engineering aspects of our water supplies both present and future and as this supply relates to population changes (4).

I would like to use one of the presently known facts about our water supply to raise a question on the social and economic relationships on any water plan. The fact is that we have a given supply of water that is known to be diminishing as a result of "mining" underground water supplies for agricultural, industrial and municipal uses (4). Accepting this as fact and assuming we know the approximate "mining rate", how should we as members of society allocate this water for the long-run maximum benefit to society? Mining occurs, in part, because of short-run economic goals of the users of that water. However, such goals could and are believed by this speaker to be out of tune with both desired economic and social goals in the long-run.

Max Linn (2) states much of my argument well in his article "Planning for Equilibrium". Man cannot ignore the facts of nature and expect to come out the winner. Linn states that "the one hopeful situation is that this state still possesses the major portion of her natural resources despite considerable exploitation and could, therefore, move to set up equilibrium if New Mexicans can find and apply the necessary wisdom; if we can turn away from growth and quantity as measures of success and turn, instead toward quality--quality in social services, quality in residential and work environments, quality in education, quality in all human opportunities". He further states that "the long-run objective of our present plans seems nothing short of disaster". I would tend to agree with this but am hopeful that we are smart enough to avoid that condition.

Every city and county in New Mexico is pushing for "economic development", and I am not opposed to this, but I do question the long-run product of much of our past experienced "economic development" that has ignored the social aspects of development. We need economic development but I am convinced that we are pursuing this objective before having clearly defined our social <u>and</u> economic objectives as they are interrelated to determine how much "give and take" will be required to provide New Mexicans with the maximum benefits over the long-run. We observe headlong plunges to achieve economic growth at any cost. We should be constantly considering the overall effect of each action and what the values are in both natural and human terms. Oliver Goldsmith in 1770 is reported to have said "Ill fares the land, to hastening ills a prey, where wealth accumulates and men decay." Now, before someone brands me as being against wealth or economic growth, the market price system or any basic tenet of our form of government, let me state that my main concern is not against what we have <u>done</u> but rather to focus on that which we must do if we hope to survive on this earth. New Mexicans have a golden opportunity to reverse the "decay" process and to implement the plans for long-run benefits of our natural resources to man, namely water. In some areas it will require reversals of present use plans. I would at this point call your attention to the work by Hughes and Harman which specifies the projected life of water resources in the High Plains underground reservoir(1).

Many will argue that by technology man can solve any problem. I disagree and say that while technology may be able to solve any technological problem, technology, by itself, cannot and should not be used to solve social problems. Man has used technology to gain much but he is now threatened by much of that same technology. Technology is no substitute for planning. Technology will not save us from ourselves.

My closing remarks can be summarized by stating my concern about our long-run social and economic objectives in contrast to our present short-run generally political oriented objectives. Our allocation schemes do not account for the social or economic costs to man in the long-run. What I am alluding to is distasteful to bankers, storekeepers, religious leaders and politicians as I am suggesting that we move rapidly to stabilize population to provide time to learn if the spaceship earth can in fact afford 3.5, 7, or 20 billion people and still provide the "good life", however that may be defined. We are doomed to failure by not planning our population while we also plan for the "good life" through the wise use of all natural resources. Those resources are threatened by a seemingly uncontrollable population growth resulting in fewer and fewer resources per man in the years to come. To permit unchecked population growth on the premise that we can by technology solve the many ills now confronting man is nothing less than blind optimism. We must plan for equilibrium in the man-to-resource relationship. No present social or economic objective will hold without controls on population growth.

In New Mexico, we can and must look at the man-to-water equation and plan or modify plans to allow us to reach desired social and economic goals. If our water will only support one-million people, then we should plan for those activities that provide for only one-million people. This same concept is applicable nation- and world-wide.

The people as well as planning agencies through an interdisciplinary approach, need to make greater efforts to jointly determine our long-run objectives--social and economic-- before we finalize our state-wide water plans. The people should be kept informed as to the nature of the plan and the objectives assumed so they can accept or reject the alternatives by reacting throughout the planning process.

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PRESERVING NEW MEXICO'S WATER RESOURCES

Ed Foreman[1]

As this great nation continues to grow at a rapid rate...the question of adequate water ranks among our major problems. Here in New Mexico...we are daily faced with new problems involving our water supplies...and because of the type of land...the control of our water in the form of flood protection.

Since New Mexico's primary water source is from precipitation...it is necessary that our state continue to rapidly improve our storage system, to plan for the continuing growth of this state.

Federal projects have played an important part in the development of our water and water-use programs. Such projects as the Navajo Irrigation project...the Roswell saline water plant...and the San Juan-Chama diversion projects are examples. Presently, the majority of New Mexico's cities obtain their water from wells. However, as these cities grow the need for more water grows.

The U. S. Army Corps of Engineers has been the Federal Government's principal water resources development agency since 1824. Through its Civil Works program...the Corps carries out a nationwide comprehensive water resources planning, construction, and operations effort in cooperation with all other interested agencies of the government at all levels.

Additionally, the Corps of Engineers have been assigned the responsibility of flood control. This has been one of New Mexico's most trying problems. Las Cruces is now working thru, and with, the Corps of Engineers programs to try to solve their flood problems.

Municipal and industrial water supplies are gaining increasing importance as one of the major benefits of the Army Engineers' multiple purpose water conservation projects. Through the Civil Works program, the Corps of Engineers provides for more public recreation than any other agency.

When local interests feel that a need exists for any type of flood control, water supplies or other improvements...it will be most profitable for them to consult at the outset...the District Engineer of the U. S. Army Corps of Engineers.

Another Federal Agency that plays a vitally important role in the development of water supplies in New Mexico is the Soil Conservation Service of the U. S. Department of Agriculture. The SCS is responsible for developing and carrying out a national soil and water conservation program in cooperation with individuals, community agencies, regional resource groups, and

1/ United States Congressman from New Mexico other federal, state and local bodies. The program is carried on through technical help to more than 3,000 soil conservation districts covering almost 2 billion acres in all of the states.

In 1965 Congress approved the Water Quality Act and created the Federal Water Pollution Control Administration now under the Department of Interior. This agency is responsible for enhancing and improving the quality of water in the Nation's streams, lakes, and other sources with the express purpose of providing adequate supplies for all foreseeable appropriate uses. The technology now exists for improving water quality and for making productive use of municipal sewage plant effluents and industrial effluents. However, construction of new facilities and the conversion of present facilities will require considerable money and time. The Water Resources Council has estimated capital outlays required for waste treatment, sanitary sewers and water cooling requirements at $20 billion for the five year period of 1969 to 1973. President Nixon has authorized Interior Secretary Hickel to spend the $800 million appropriated by Congress for FY 1970 for sewage treatment plants alone.

During the first session of the 91st Congress the House and the Senate passed slightly differing versions of the Water Quality Improvement Act. Final Congressional action is still pending. The House version authorized $348 million over a three year period to protect public waters from pollution and to authorize grants for water quality research and education.

In his State of the Union address President Nixon announced he would propose a five year, $10 billion nationwide clean waters program to put modern waste treatment plants in every place where they are needed. The Clean Waters Act he is proposing will authorize $4 billion immediately for fiscal year 1971, to cover the full federal share of the total $10 billion cost on a matching fund basis.

These funds would be allocated at a rate of $1 billion a year for the next four years, with a reassessment in 1973 of needs for 1975 and subsequent years. The President has proposed creation of a new ENVIRONMENTAL FINANCING AUTHORITY to ensure that every municipality in the country has an opportunity to sell waste treatment plant construction bonds. Under this plan, if a municipality cannot sell waste treatment construction bonds, the Environmental Financing Authority will buy them and sell its own bonds on the taxable market. Thus, construction of pollution control facilities will not necessarily depend on a community's credit rating, so much as in some instances, but on its waste disposal needs.

The President has proposed that the present rigid grant allocation formula be revised so that special emphasis can be given to areas where facilities are most needed and where the greatest improvements in water quality will result.

The elimination of water pollution will, of course, provide a major step forward in new water resources. The leading source of controllable man-made water pollutants in the U. S. is manufacturing. Domestic wastes are second. However, percentage-wise, here in the Southwest domestic wastes rank higher because of limited manufacturing. To enforce the controls of water pollution from industrial and municipal wastes, the President has proposed that the failure to meet established water quality standards or implementation schedules be made subject to court imposed fines...and, further, that federal operating grants to State pollution control enforcement agencies be tripled over the next five years.

The Water Resources Council has made the following findings concerning the nation's water resources needs based on a projected population of approximately 468 million in the year 2020...only 50 years from now:

Requirements for municipal water systems are expected to triple.
Industrial water use will increase by over 300%
Electric power is projected to increase its fresh water needs from 63 billion to 411 billion gallons per day
About one-fourth of all outdoor recreation is, and will continue to be, dependent on water...and pleasure crafts are estimated to increase from about 8 million to 30 million.

The proposals made by President Nixon to this session of Congress, calling for a massive clean up of this nation's environment have been received with enthusiasm. At the same time..this is an election year...and the proposals have started a political game of "one-upmanship"...whereby the politically motivated are already attempting to out-spend and out-innovate the President.

Although some individuals are calling for the expenditure of $25 billion for water pollution abatement...the President's request for $4 billion in Federal funds, to be combined with $6 billion from state and local governments, is based on the best estimates of total investment needs to bring the Nation up-to-date on waste treatment facilities. The 1970 "Cost of Clean Water Study" has estimated the need for about $9.9 billion. A canvass of the states by the Federal Water Pollution Control Administration has arrived at about the same figure.

While actions to clean up our air, water, and land are urgently needed; it is also important that we not permit ourselves to be misled into thinking that massive outlays of money will solve all our problems. In the search for a cleaner Nation, as well as in the day-to-day search for better national defense and use of human resources, we must always be mindful that allocating money is one thing...but how it is spent is also most important.

We must do what needs to be done...while realizing that what one wants is not always what one needs or what one can afford. The National Administration needs your support in this battle to meet tomorrows water needs. I look forward to continued progress in assisting the people of New Mexico to develop, conserve and wisely use their most precious natural resource... for in the future of water development...is the future of our State.