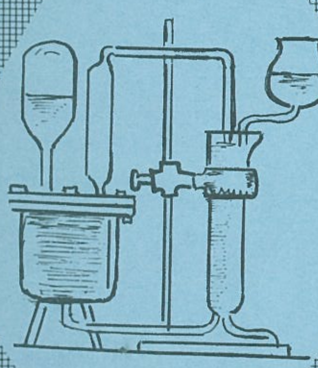
Theme: Research- The Key to the Future in Water Management

Ninth Annual New Mexico Water Conference

March 19 & 20, 1964



UNIVERSITY PARK, NEW MEXICO

NEW MEXICO STATE UNIVERSITY

NEW MEXICO WATER CONFERENCE

Sponsored by

NEW MEXICO STATE UNIVERSITY, DIVISIONS

of

Agricultural Experiment Station
Agricultural Extension Service
College of Agriculture

College of Engineering
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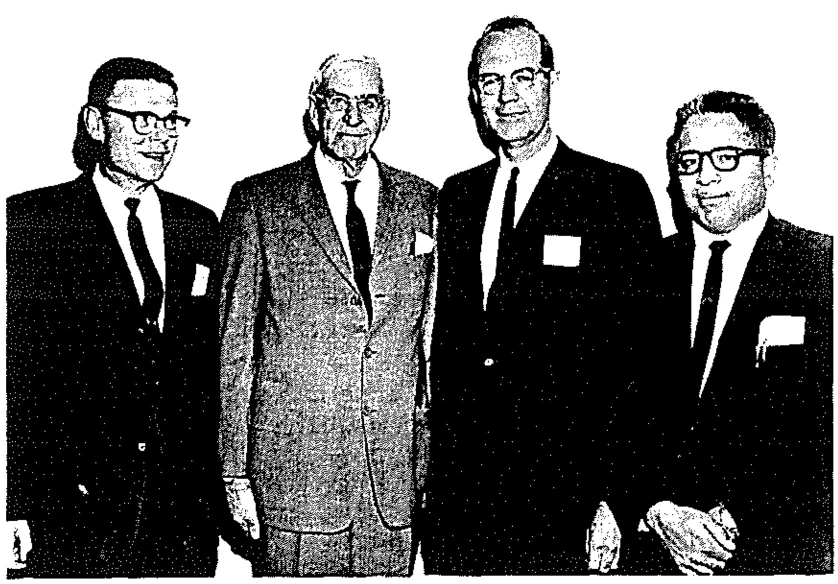
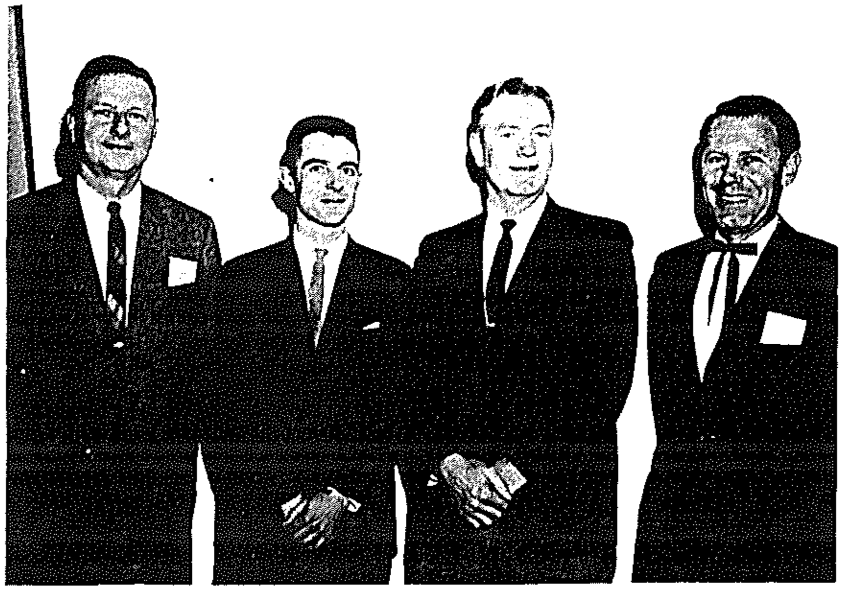
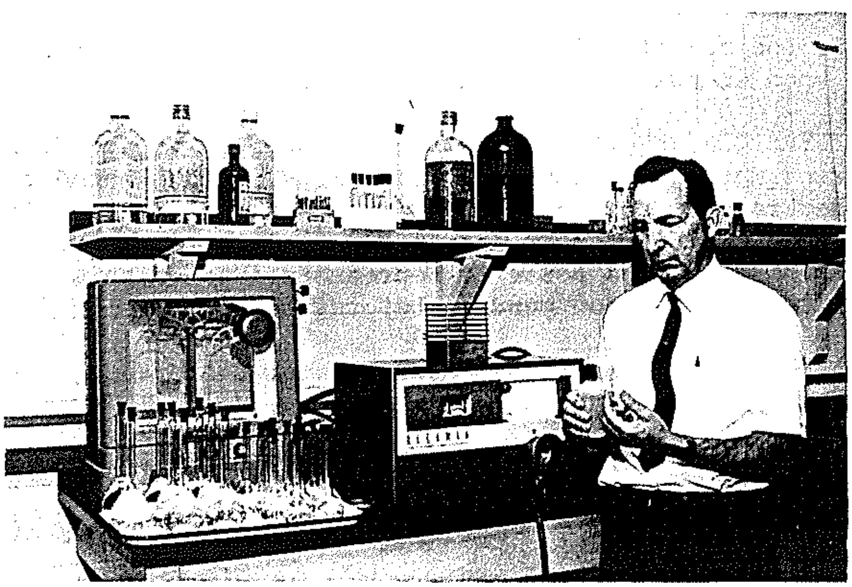
H. R. Stucky, second from right, chairman of the Water Conference and chairman of the New Mexico State University Water Resources Research Institute is given a toast (water, of course) by delegates to the two-day conference. Left to Right: Lloyd Calhoun, Industrial Development Corporation, Hobbs; Leonard Dworsky, Department of Health, Education and Welfare, Washington, D.C.; H. R. Stucky, Agricultural Economics Department, NMSU; E. O. Moore, State Soil Conservation Committee, Roswell.



Left to Right: Harold Busey, physicist and scientific advisor to Governor Jack M. Campbell, Los Alamos; W. H. Gary, Interstate Streams Commission, Hatch; Philip J. Leyendecker, Dean and Director, College of Agriculture and Home Economics; and Narendra N. Gunaji, Department of Civil Engineering, NMSU.



Left to Right: Rogers Aston, Southspring Foundation, Roswell; John O'C. Young, ESSO Research and Engineering Company, Linden, New Jersey; C. A. Tidwell, Soil Conservation Service, Albuquerque; and W. P. Stephens, Agricultural Economics Department, NMSU.



Above is Vernal H. Gledhill, Extension Specialist, NMSU, preparing water samples for measures on the Flame Photometer.

FOREWORD

RESEARCH--THE KEY TO THE FUTURE IN WATER MANAGEMENT was the theme of the Ninth Annual New Mexico Water Conference, held at University Park, New Mexico. Emphasis on research was appropriate at this Conference since so much research is being done and so much legislation is in the offing to increase research in water management.

The establishment of the New Mexico Water Resources Research Institute by the New Mexico State University Board of Regents in February 1963, was a great step forward in water research. The purpose of the Institute is to stimulate and sponsor investigations, both basic and applied, in the field of water and related resources.

Senate Bill S.2. to establish Water Resources Research Institutes at the Land-Grant Colleges in each of the states was passed by the Senate on April 8, 1963. This Bill was sponsored by Senator Clinton P. Anderson. Action is pending in the House of Representatives on the House version of the Act referred to as the Water Resources Research Act of 1964. This Act will greatly emphasize the National interest in water research. NOTE: The House Bill was passed June 4, 1964.

The increase in population in New Mexico and in the Southwest, roughly twice the rate for the Nation as a whole, is bringing the need for water research in this area into focus faster than in some other parts of the Nation.

A Resolution calling for the passage of the Senate Bill S.2. is presented on the following page. This is only the third resolution passed by the Water Conference since the first conference held in 1956.

The Water Conferences are sponsored by New Mexico State University through the Agricultural Experiment Station, Agricultural Extension Service, College of Agriculture, College of Engineering, and Cooperative Agencies of USDA-Agricultural Research Service, and Soil Conservation Service, with the cooperation of the Water Conference Advisory Committee.

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

H. R. Stucky

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

R E S O L U T I O N

Passed By

NINTH ANNUAL NEW MEXICO WATER CONFERENCE
MEETING AT NEW MEXICO STATE UNIVERSITY
UNIVERSITY PARK, NEW MEXICO
MARCH 20, 1964

WHEREAS, the problems of water supply, water pollution, and flood control are of major importance and consideration to all areas of the United States and the world, and

WHEREAS, only through broad-based and wide-ranging basic scientific research can the problems of quantitative and qualitative water supply be solved, and

WHEREAS, historically the major burden of water resources research has been borne by the Nation's land-grant colleges whose staffs are eminently trained and experienced in all phases of the field of water research, and

WHEREAS, the demands on the limited water supplies of the arid Southwest and on those of the State of New Mexico presently pose grave problems in the face of a rapidly growing population unequaled elsewhere in the Nation, and

WHEREAS, the ability of New Mexico to grow and prosper depends entirely upon adequate future water supplies.

BE IT THEREFORE RESOLVED, that those assembled at the Ninth Annual New Mexico Water Conference, in unanimous action, commend and support the recent action of the United States Senate in passing Senate Bill S. 2, and respectfully urge similar support and action by the United States House of Representatives on this vitally important legislation now pending before that body.

Voted at the Ninth Annual New Mexico Water Conference, University Park, New Mexico, March 20, 1964.

H.R. Stucky

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

NEW MEXICO WATER CONFERENCE
March 19, and 20, 1964

THEME OF CONFERENCE - "RESEARCH--THE KEY TO THE FUTURE IN WATER MANAGEMENT"

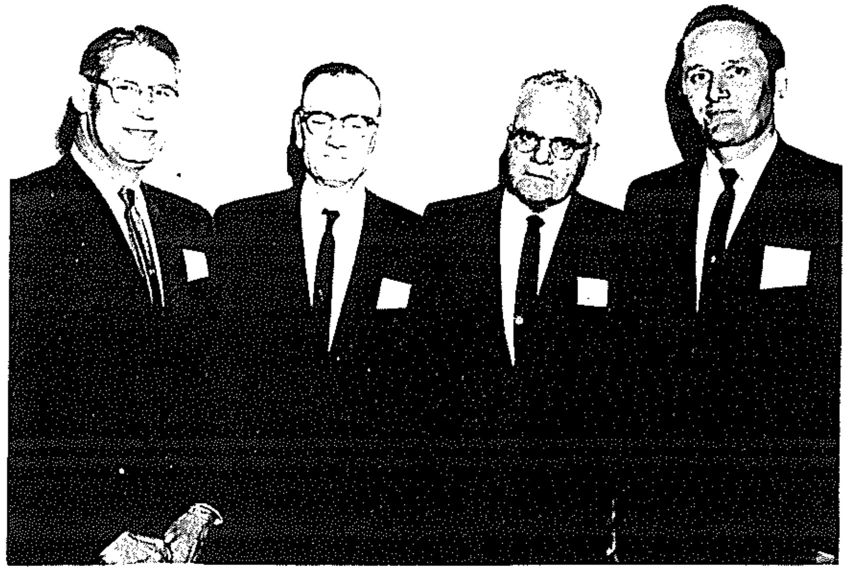
ADDRESS OF WELCOME

Dr. Roger B. Corbett, President, New Mexico State University, welcomed the Ninth Annual New Mexico Water Conference to the Campus. He called attention to the importance of water research to New Mexico and to the importance of increasing the research effort in water problems. Specific reference was made to the banquet speech by Senator Clinton P. Anderson and the importance to New Mexico, the Southwest, and the Nation of the S. 2 Water Resources Research Legislation sponsored in Congress by Senator Anderson.

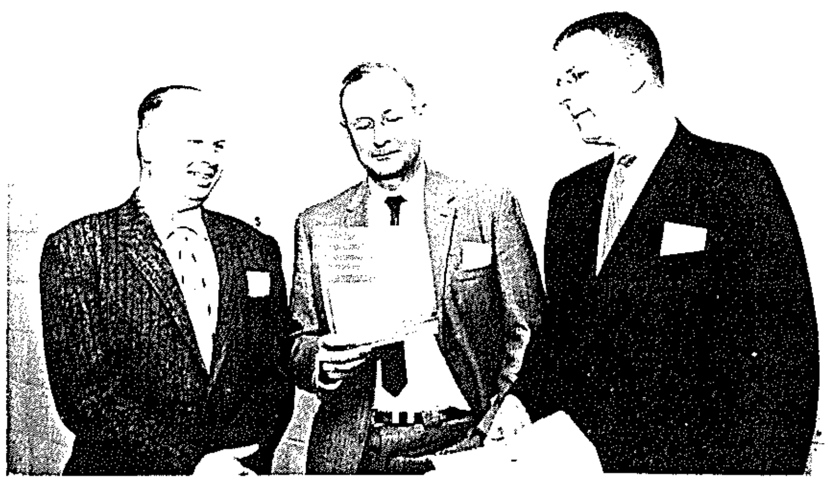
Dr. Corbett also invited the Conference people to feel at home on "their" New Mexico State University Campus; and to note its rapid growth. He invited everyone to attend the dedication of the Clinton P. Anderson Physical Science Research Building on the Campus during the Annual Water Conference.

NOTE: There was a full-house attendance for the dedication held at 4:00 p.m., March 19, 1964.

Left to Right: Governor Jack Campbell, New Mexico; Senator Clinton P. Anderson, New Mexico; and President Roger B. Corbett, New Mexico State University who took part in the dedication of the Clinton P. Anderson Physical Science Laboratory Building at 4:00 in the afternoon on the first day of the Water Conference. President Corbett gave the Welcoming Address at the Water Conference and Senator Anderson was the Banquet Speaker.



Left to Right: Ross Leamer, Agricultural Research Service, NMSU; Ralph Charles, Bureau of Reclamation, Albuquerque; Boyd E. Turbeville, El Paso Electric Company, El Paso; and Eugene E. Hughes, Agricultural Research Service, Los Lunas.



Left to Right: Jack G. Koogler, State Engineer Office, Santa Fe; Charles Diebold, Soil Conservation Service, Albuquerque; and Eldon Hanson, Agricultural Engineering Department, NMSU, discuss the newly organized Water Resources Research Institute at New Mexico State University.

RESPONSE
TO DR. ROGER B. CORBETT'S WELCOMING ADDRESS TO THE
NINTH ANNUAL NEW MEXICO WATER CONFERENCE

Lloyd A. Calhoun[1/]

Thank you, President Corbett, for your warm and cordial welcome to this, the Ninth Annual New Mexico Water Conference.

May I, in response, express to you our most earnest appreciation for this forum and program which you and your highly competent and fully dedicated staff members have made available to the people of New Mexico during the past eight years.

Much has been accomplished toward the objective of assuring the future water supply needs of New Mexico and, indeed, the entire Southwest through the medium of these conferences.

Much more needs to be done if we are to fulfill the destiny of our great state.

What is New Mexico's destiny? Practically all of the knowledgeable forecasters agree that we are one of the few Western States in which the highest rate of population growth in the Nation will take place during the remainder of the twentieth century. We tend to look only into that promising future when we think of population--sizeable population--in New Mexico.

Few people realize that we here in New Mexico are in the midst of a major population concentration already--today! Would you believe that within 500 miles of the Lea County Courthouse there are nearly as many souls as are within the same distance of the Los Angeles City Hall, sixteen million as compared with seventeen million, plus as a matter of fact?

What does this present and future population trend mean to New Mexico?

It probably means that it's later than we think--waterwise. It means that New Mexico needs to accelerate her efforts to provide the water necessary to supply her exploding population in 1970, 1980, 2000, and beyond.

We need to eliminate wasteful practices of water usage; we must research every feasible means of converting our vast surface and underground stores of brackish water to fresh, potable water.

Sewage effluent must be treated for reuse rather than drained into streams, lakes, the sea or onto land where it serves no purpose

1/ Director, Industrial Development Corporation, Hobbs, New Mexico

but to pollute. Careless irrigation practices, one of the most flagrant wastes of our precious water supplies, cannot be allowed to continue.

We might even be faced one day soon with the painful duty of being a bit more definite in our loosely used term "beneficial use." We might even someday find the phrase "priority of use" creeping into our aquatic nomenclature here in New Mexico.

Research is a fitting--perhaps even an overdue--theme for this meeting. It should be an underlying theme in all future meetings.

A plentiful and continuing water supply will be the all-important single key to the future of New Mexico as a major industrial state. Today, we are a long way from that goal.

In comparison with other states, we are woefully underdeveloped industrially. Yet, no other state offers more to industry in available new products for manufacture than does New Mexico.

There are more than 80 commercial minerals within our borders. We produce nearly one-half of the Nation's uranium ore.

Now, not many people in New Mexico need to be reminded that there is now an oversupply of uranium in the open market. In all probability, this situation will exist for a number of years to come.

However, in relation to projected energy requirements beyond 1980, the amount of uranium available, according to present estimates, is not very large. By 1980, it will be necessary to develop improved converters and breeder reactors to develop the full potential of our nuclear fuels and extend the utilization of our nuclear resources.

The Federal Power Commission in July of last year published the results of its National Power Survey on Nuclear Development. It was reported that recent experience with nuclear reactor power plants has demonstrated their capabilities of much higher power outputs than had been provided for in their original conservative design.

The report forecasts that privately owned single reactor plants of 300 to 500 megawatt capacity, if built for service in 1966, are expected to compete in operating costs with fossil-fuel plants.

The present installed nuclear power plant capacity in the United States is approaching one million kilowatts, or about half of one percent of the Nation's total power capacity. By 1980, the nuclear capability may be 40 million kilowatts or about ten percent of total United States capacity.

Demand for water to generate electric power is expected to be more than double the 1960 requirements in 1970 in New Mexico. By 1980, the demand will be between two and three times the 1970 requirements.

We produce in New Mexico 90 percent of the Nation's potash. We rank fourth in the production of natural gas and copper, seventh in the production of oil. Lea County alone produces more oil and gas than any other county in the United States.

We should be a major manufacturing state in the production of intermediate and finished materials from our vast wealth of natural resources. But we are not. Practically all of our mineral products are simply extracted from the earth and shipped in the raw state to processing plants in other parts of the country.

Among the top seven oil-producing states, only New Mexico fails to produce its own requirements in gasoline. Only 49 percent of the State's consumption is refined in New Mexico. Texas, on the other hand, refines nearly four times as much gasoline as it uses, Louisiana nearly six times as much and California, the country's largest user of motor fuel, consumes less than three-fourths of its refined output.

The State of Hawaii, in which there is absolutely no oil or gas production, refines 3300 barrels per day more crude oil than New Mexico.

The future welfare of New Mexico depends on research and development activity at an accelerated pace in the field of water. All of us here today and every citizen of this fabulous state should be vitally interested in this activity. To postpone an aggressive research and development program for even a year or two would cause our state to fall by the wayside in the growth of the western United States. Nor can our research be limited to the field of water. There is a real need now for research in finding ways and means for improving our position industrially in relation to other states. Research in the fields of taxes, transportation, materials handling, manpower training and development is long past due.

President Corbett, we are fortunate indeed to have the opportunity of meeting here today and tomorrow in this conference.

Each of us conferees will benefit greatly from the excellent papers and discussions which will be presented here. Through this medium we individually must become more emphatically aware of our future water problems in New Mexico. Unless we take vigorous and immediate action to solve them, the future of New Mexico will suffer greatly.

We appreciate your warm hospitality. We hope our contributions now and in the years ahead will be worthy of it.

NEW HORIZONS IN WATER RESEARCH

Gordon E. McCallum[1]

This is my initial attendance at your Annual New Mexico Water Conference and I am very pleased to be present. A keynote speech is an exacting assignment, and I consider it a distinct honor that Dr. Corbett invited me here for this purpose. Together we are to explore the theme, "Research--Key to the Future in Water Management." In my own topic, "New Horizons in Water Research," I hope to contribute a new idea or two and help set the stage for the very timely discussions to follow.

I detect here a sharp professional awareness of the water needs of New Mexico--for industry, agriculture and your whole economy. Your key concept is growth. Much of your state is generally deficient in rainfall. Within its borders are vivid contrasts in climate and topography. It is an area increasingly attractive to tourists and utilized extensively by the military for some of its unique installations. New Mexico nevertheless is still a land of wide open spaces, whose waters fortunately have not suffered the intense pollution experienced by some of her more heavily populated and industrialized sister states. Thus, I am not surprised that much of your concerns at this Annual Conference have been oriented to water <u>quantity</u>--to capturing, conserving and putting to maximum beneficial use <u>as much</u> water as can be made available.

My business happens to be water <u>quality</u>--more specifically, water pollution control. I represent the federal government's program of water pollution control in the Public Health Service and its parent agency, the U.S. Department of Health, Education, and Welfare. I should like to keynote this Conference on the premise that <u>quantity</u> and <u>quality</u> are rather closely related in water resource development. They are inescapably linked in reservoir construction; in evaporation control; in irrigation projects; in programs of ground-water recharge. Certainly, quantity and quality also go hand in hand in our water <u>research</u> programs.

Your own Dr. Viessman of the Civil Engineering Department here at New Mexico State University made some poignant statements bearing on this at your Conference last year. That Conference, you recall, centered around the saline water conversion plant at Roswell where the Department of Interior is test-piloting its interesting findings of the past decade. It is a program full of promise for New Mexico and the whole Southwest.

Dr. Viessman warned of the enormous quantities of wastes which accrue from desalted water--residues which will constitute a major

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1/ Assistant Surgeon General and Chief, Division of Water Supply and Pollution Control, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C.

pollution and cost headache unless researchers can find some safe and inexpensive method of disposal. In delivering one million gallons of pure water daily, Dr. Viessman said, the Roswell plant will also produce about one-third this quantity of waste effluent. He estimates that a community of 40,000 getting 15 percent of its average daily water supply from saline water conversion will also get an unwanted bonus of solid waste 16 times greater than the volume from its entire sewage treatment operation.

Please note that Dr. Viessman emphasized that research must find some additional answers in the saline water program which up to a point has been so successfully launched.

Very often success in one area calls for further investigation in another. In this age of rapid technological advance, growing populations and production, nothing in research or research needs remains static. This is borne out in the accelerated research and development we have witnessed across the board since World War II.

President Johnson's first budget allocated $15.3 billion for research and development for the coming fiscal year. It is nearly five times what the Government spent for these items just 12 years ago.

Let me say, however, that until very recently, those of us long involved in the water business were rather keenly aware of needs and deficiencies in water research. Thus, when Congress some two years ago became intensely concerned over the rapid rise in government research, we had misgivings. There were inquiries and reviews by Congressional committees, the Executive Department and others, and these, we felt, might well lead to retrenchment in water research.

But reports now coming out of the special inquiries are heartening. To quote a report issued in Washington only last month by the House Select Committee on Government Research:

> "Additional funds requested for research and development in the coming fiscal year are less than $1 billion, the lowest annual increase in recent years...The Federal Government's marriage to research and development has been marked by an amazingly long and luxurious honeymoon. This is due mainly to the exhilarating nuclear age atmosphere in which the union was finally fused and unsparingly nurtured. Noting the recently slackening annual increase of Federal funds for research and development activities, some say the honeymoon is over. Be that as it may, it is certain the marriage will endure. And while it is not so certain what precise course this permanent venture will take, what must be made certain is that some plans are now provided to help avoid the diversions and obstacles and problems of all sorts that inevitably lie in the road ahead. At the same time it is the task of this committee to

insure that the incentives for engaging in research and development are strengthened and safeguarded rather than strangled by excessive controls and red-tape."

Here indeed is new opportunity to overtake the horizons in water research--horizons which for a long time were receding, even as our water problems pressed alarmingly closer.

This year's water research and development activities costing some $65 million are carried out by eight Federal agencies. The term "research and development" includes activities in which the primary aim is either to develop new knowledge or to apply existing knowledge to new uses. These activities may be carried out in government installations, in colleges and universities, or in other state, local or private facilities using Federal funds. Involved are the multiple uses of water--for agriculture, industry, hydro-power, recreation, fish and wildlife, public water supplies, and a wide variety of activities.

They range from investigations in weather modification to increase precipitation and how to reduce reservoir evaporation so studies in the control of seepage in water distribution systems and developing water application rates for the many crop and soil types of various regions. Some of the research, as I have already indicated, relates to demineralization of saline and brackish waters; and some to the control of phreatophytes, the deep-rooted, water-consuming trees and shrubs of the semi-arid lands. These are but a few of the many studies under way in the Government's $65 million-a-year water research effort. You will hear more about these programs in the discussions today and tomorrow.

In my own field of water pollution control, research has outgrown the traditional concerns of bacterial contamination arising from domestic sewage and the older types of organic industrial wastes. The growing demands for clean water have forced us to re-examine our methods for controlling water quality.

Today we are seeking answers to the complex chemicals finding their way into our waters--including such troublesome substances as foaming detergents, agricultural pesticides, and the taste-and-odor causing phenols. We are concerned, too, about such problems as acid mine drainage; about sediments which fill stream channels and reservoirs, cause corrosion, affect the fishery, and increase the cost of water treatment. Radioactive pollution is being kept under constant surveillance. Temperature increases which result from industry's use of water for cooling purposes, may have harmful effects on fish and aquatic life and reduce the capacity of the receiving water to assimilate wastes. Too little study has been made of ground-water contamination in our growing "septic tank suburbias." The build-up of salt in return-flow irrigation waters is increasingly troublesome. These are but a few of today's water pollution problems to which we do not have the full answers--to which we must find the answers through research and development.

For more than three years the Public Health Service has been engaged in an intriguing research project in the field of waste water renovation. This program, which has come to be known as our "Advanced Waste Treatment Project," has two ultimate objectives. One is to help abate our nation's growing water pollution problems, and the other, more startling in concept, is to renovate waste water--sewage, if you please--for direct and deliberate reuse for all legitimate purposes.

Waste waters are this country's most immediately available water source. They do not have to be pumped over mountains or from deep underground sources. If we can learn how to remove the contaminants from these waters efficiently and economically, then these waters can be used again and again. In a single step such a new technology would alleviate both our water pollution and our water supply problems.

Technically, advanced waste treatment may be looked upon as a two-step process: (1) separating concentrated contaminants from the purified water "product" and (2) disposing of these contaminants in a way that will render them forever innocuous. The need for developing this two-step treatment process if more than economic, even though its success will be measured by economics. Many of the inorganic and organic contaminants now entering our water resist every phase of present day treatment--sewage treatment, natural purification in streams, and water treatment.

We have explored half a dozen principles of physical-chemical separation--some of them similar to the salt water conversion processes--and we have others under study. We are exploring these both in our own laboratories and by contract with industrial and university laboratories. We are ready to go into large scale testing of two methods--carbon adsorption and electrodialysis.

We can speculate that the future water renovation plant will encompass a number of processes, in series and perhaps in parallel. Some of these processes may be those we use today in municipal water and waste treatment, while others--for example, foaming or freezing--will probably be new to sanitary engineering. Disposal processes will be a part of the entire system and may include landfill, digestion, incineration, and injection.

We can expect, within this framework, that a variety of degrees of renovation will exist, depending upon the intended water use. For irrigation and for recreational, and some industrial uses, partial renovation may be adequate; but plants designed to produce water of potable quality must be capable of rather complete renovation.

Waste water reclamation is already contributing significantly to solution of some of southern California's complex water problems. The Public Health Service is supporting a project which, for almost two years, has been using reclaimed waste water to replenish ground-water supplies on which the Los Angeles Metropolitan Area depends. The Whittier Narrows Water Reclamation Plant, built by the County of Los Angeles and operated by the Sanitation District, reclaims 12 million gallons of water daily from a nearby trunk sewer. The water is sold at $12.75 per acre-foot--the same as is paid for Colorado River water imported for the same purpose--to recharge ground-water supplies used by the City of Los Angeles. The Sanitation District is currently considering expansion of the program at a cost of $20 million for eight additional plants to reclaim 100 million gallons daily--approximately one-third of the District's sewered waste waters.

Similar use of ground-water recharge is being made along the southern California coast to correct the serious intrusion of salt water where the fresh-water aquifer has been overmined.

Perhaps the most interesting use of reclaimed waste water is occurring at what we call the Santee Project, inland from San Diego about 17 miles. Here the Public Health Service is cooperating in an experimental use of reclaimed waste waters for recreational purposes. Initiated in 1959, the project which comprises four recreational lakes, has been well accepted by the public for boating, fishing, and as a picnic and golfing area. Santee, let me say, has completely exploded the myth that the public will not accept reclaimed sewage waters for purposes other than irrigation. The count of visitors in a single day has been as high as 10,000. We are presently investigating the health aspects of this recreational use of reclaimed waste water, before permitting swimming, water-skiing and eating of the fish that are caught.

Reclaimed waste water figures prominently in the Southwest Water Plan in which your own State of New Mexico is involved. Interestingly, the plan makes the point that water <u>management</u> is as important to this five-state area as is the development of new supplies. Six management procedures are names, and the amount of water that can be expected to accrue from each is delineated.

Five of these procedures--lining or sealing of irrigation canals, channelization, control of phreatophytes, ground-water recovery, and evaporation suppression--would provide the Southwest some 655 billion gallons of water per year. The sixth procedure--urban return flows, which is the waste water reclamation technique I have been talking about--would provide more than all the others combined, 880 billion gallons per year.

Now, gentlemen, I want to talk for a moment about cooperation as a part of the "New Horizons in Water Research." Three weeks ago in New York City I told an industry group that the first requisite of any cooperative effort is good communication. If we are to help regions, states, cities or people solve problems, or if they seek our help in solving problems, we must know <u>who</u> they are, <u>where</u> they are, <u>what</u> is needed--and they must know the same about us.

We know that water problems requiring research are growing, both in number and complexity. I have mentioned that some eight Government agencies are involved in water research. And here let me stress that every effort is made to avoid overlap and duplication of effort to derive maximum benefit from research dollars. We in Government recognize our great responsibility in research. We are equally aware that we must cooperate with others in seeking solutions to problems. But to be truly effective, you and we must do an effective job of communicating with each other. Conferences such as this are most helpful.

I have also said that the Government's $15 billion a year investment in research and development is being spent in part in the colleges and universities, as well as in state, local and private facilities. In this connection, I want to tell you of one of the greatest opportunities for cooperative research that has ever presented itself in my own field of water pollution control.

Seven regional water pollution control laboratories have been authorized by the Congress in various parts of the country, and they will have a profound impact on maintaining and improving the purity of our waters. For the first time, our research program will have its resources deployed in the heart of the areas where water pollution problems occur.

Supporters of the laboratories and the Congress itself realized that water pollution problems vary greatly from one part of the country to another; they were aware also that the laboratories should be located in sections of the country which have special problems due to natural causes, climate, geographical features, or man's habits. These points are reflected in the legislation, which also makes a third and, I feel, very wise provision. It specifies that, insofar as practicable, each such facility is to be located near an institution of higher learning--in which graduate training in water pollution research might be carried out.

The laboratory which will serve New Mexico is to be located at Eastern State College, Ada, Oklahoma. It will open in about one year, but already we are assembling a nucleus staff there. When complete, it will be staffed by about 100 scientist and technical personnel, plus 50 supporting workers.

We believe our relationships with the schools will be the key to our cooperative research in the future. We interpret the provisions of the legislation authorizing these facilities to mean that we are to work with these institutions in every feasible manner. We further believe that the Congress intended us to work with several institutions and not merely those on whose campus the facility may be located. Consequently, we are developing plans with many schools which we hope will ultimately include all of the eligible institutions in the general area to be served by each laboratory.

Helping us to interpret the Congressional Act is this paragraph from a recent report presented to the President by the Federal Council for Science and Technology:

> "Where possible, cooperative arrangements between Federal research establishments and the universities should be strengthened and extended in order to permit the outstanding scientific competence that exists in Government agencies to contribute to the training of new scientists. These include authorization and arrangements for Government scientists to teach and engage in research at educational institutions, locations of some Government research activities at educational institutions, and increased opportunity for graduate-thesis work at Government laboratories under arrangements with the universities."

In 1962, the Congress provided for two additional water pollution research centers, to serve as national water quality standards laboratories. One facility will focus on fresh water at the University of Minnesota's Duluth campus and the salt water laboratory will be at the University of Rhode Island.

For the past year we have been meeting with state, university, and industrial people to map out research projects in different parts of the country. We are moving toward a partnership which will bring together the scientific competencies of industry, Government and our great institutions of learning. Let me assure you, however, that we are not going to duplicate any of the fine work that is already being performed or can better be done at the universities.

The Public Health Service also maintains a program of grant-supported research in the universities, now numbering close to 300 projects. They include a number of fellowships, training projects and field demonstrations, in addition to basic research by individuals. Here at New Mexico State University, for example, one of the grants is supporting a study in "Aerobic Treatment and the Biochemical Oxygen Demand Test."

We feel strongly that the degree of success attained by these grant-supported projects will be directly measured by the freedom with which we permit them to operate in the universities. Nevertheless, the persons involved welcome and need assistance and leadership. Most of all, they need encouragement and recognition in some tangible form. Also, it is evident that if the gap in knowledge in the water pollution field is to be filled, some organization and coordination must be supplied through administrative circles.

As I see it, one of the functions of our scientists at the regional laboratories would be to encourage departments in the various schools--schools not heretofore concerned with water pollution control--to apply for research grants, demonstration grants, and training grants, or to assist students in applying for research fellowships. In this way, we can gradually bring new brain power and skills to our many unsolved, and emerging new, problems.

So, the new regional centers will be more than laboratories and research facilities, per se. They will serve much as does the Public Health Service's Sanitary Engineering Center at Cincinnati--as focal points for training, for demonstrations and pilot plant studies, and for technical and scientific assistance. We will certainly expect the individual states to make known to us the types of technical training and other assistance they would like to have from the seven regional water research centers.

When he had been some 18 months in office, our late President Kennedy expressed to the Congress his belief in "concentrated and coordinated research programs...directed to such specific problems as desalinization of water, improving water quality...and preventing water evaporation." He said that "just as our investment of scientific talent, money, and time is better utilized in well-coordinated and complementary programs within the Federal Government and by the closest working relationships with state and local governments, the academic community and industry, so our efforts should be meshed with those of the other countries of the world."

It is on this note that I should like to close my remarks. The growing needs for water have created interests and pressures that have brought this resource into the highest councils. It is evident that the sweep of research and development having to do with the water resource is more than nationwide--is now worldwide in scope. We find ourselves, for example, involved in such developments as UNESCO's International Hydrological Decade and the establishment of a Scientific Committee on Water for the International Council of Scientific Unions. My own program two years ago helped organize an International Conference on Water Pollution Research, the second session of which will meet in Tokyo in August of this year.

We live amid nuclear power and jet propulsion which have shrunk our planet to very small proportions indeed. In managing its resources we can no longer proceed on a narrow nation-by-nation basis. Rather, we must share--we are sharing--our knowledge and findings nation-to-nation. Whatever the research undertakings--whatever the useful information and technological applications developed by any nation--they must be shared to advance the cause of all mankind.

WEATHER, WATER, AND RESEARCH

Herbert C. Fletcher[1/]

This is an extremely broad subject and the field we are canvassing is so vast that the best I can hope to do is cut out only a small corner of the problem for inspection. Hence, I will not try to cover all material related to the subject, or answer all objections, or solve all the problems. Rather, I would like to stimulate your interest and thinking in one direction--weather and water as part of watershed research and what can be done to influence them. We have heard a great deal about weather and water, and their importance to the Nation. Weather is a favoriate topic of conversation and is cussed and discussed more than any other subject. To most people, it is either beautiful or lousy. Water, on the other hand, reaches its ultimate as a problem to each citizen when he turns on the tap and no water gushes out. When this occurs, the water supply problem is in his lap. President Kennedy focused attention on the weather and water problems of the Nation in two of his natural resource messages to Congress. The National Center for Atmospheric Research, which has as its objective a concerted attack on a broad range of problems that bear on the development of fundamental and quantitative theory relating to the general circulation and long-term climatic change, has given a tremendous stimulus to weather and its various problems. The Kerr Committee report forcibly spelled out the national water problems, and Senator Anderson has introduced legislation into the Congress, based on the Kerr Report, which would greatly expand water research. Testimony presented in support of this legislation emphasizes the urgent need for all kinds of water research. The research field of water and weather is now serious business. It calls for our very best thinking, best planning, and perhaps above all, ultimate coordination of the various kinds of water research activities.

WEATHER

One of the greatest upsetters and interrupters of human plans and activities is weather. It must constantly be taken into account in the calculations of most individuals. Like the Postal Service, the Weather Service is used by many people with little thought of how it operates. Very few hours of the day go by without some report on the radio or television about the weather. This demand has given present day weather information a new stimulus and place in our lives.

1/ Chief, Division of Watershed Management Research, Forest Service, U. S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University.

The scientific approach to weather has to provide the basis for the reports we like in one or two words--clear, fair, cloudy, rain, snow. Those reports that are wrong are the ones that remain in our minds rather than those that are correct from day-to-day. Nowhere in this Nation has weather influenced the patterns of settlement and culture more definitely than here in the Southwest. However, it has given rise to certain basic problems where man has adapted specialized techniques and disciplines to make his settlement a success. Anyone familiar with the dry streambeds of this area can rightly assume we are losing a lot of precipitation somewhere. It is generally recognized the portion of the total precipitation that returns directly to the air is highly variable both in time and space. Per unit volume, its contribution to our requirements is far less than the fraction that runs off or sinks into the ground, because a considerable portion of this latter fraction can be controlled and distributed in accordance with our needs.

In the Colorado River basin, for example, less than 6 percent of the precipitation appears as streamflow. Ninety-four percent of the precipitation is retained where it falls. Part of this retained precipitation is used by vegetation or percolates into the underground aquifers. The major portion soaks into the dry, thirsty desertlands, however, and is later evaporated into the air. Here in New Mexico over 90 million acre-feet of water fall annually on the State. This comes in the form of rain and snow. Only about 2.5 million acre-feet appears as streamflow. Here, again, the major portion soaks into the dry watersheds.

The ability to control weather and climate even to a small degree would be of the greatest importance to everyone. Whether a measure of control can be obtained will remain uncertain until we understand the natural processes in the atmosphere much better than we do now.

WATER

Now let us look at the water picture. Much has been written about the possible water shortages that may appear. These shortages are not supported on a national basis. Of the country's 30 inches of average annual precipitation, about 9 inches or 1,160 billion gallons per day appears as streamflow. Approximately one-third of this amount that appears as streamflow is withdrawn and consumed in use. Twenty-one inches is consumed by evapotranspiration. By the year 2000, about 900 billion gallons per day, or three-fourths of the amount of streamflow will be required and withdrawn for use. Unfortunately, regional needs and problems do not correspond to the national averages. In the 17 Western States water waste amounts to 2.5 times the amount used for public supplies in the United States. This waste amounts to approximately 43 million acre-feet per year. Water problems are vital to this region now and many of the existing problems will become more acute before they are solved.

When good water is plentiful and cheap it is taken for granted; when it is poor in quality, costly or scarce, everyone is concerned. Water can never be a permanent part of any man's property, even though he may catch and store it; when it serves a use some or all of it will get away through the air or down the river. No water supply problem ever arose that was not brought on by use. Wherever research leads to a more efficient use, it leads also to a mitigation of the supply problem. We may influence water supply by modifying the climate, by reducing sea water to fresh water, or by changing or modifying the water yield from watersheds. Each of these topics presents spectacular possibilities of great interest to most of us, and the potential developments could have a major impact on the water supplies of a region.

The amount of water we may have for our needs and how we use it depends on nature's gigantic water-gathering mechanisms, our watersheds. The good or bad management of these watersheds is a personal matter and a paramount public responsibility. The rate small watersheds feed precipitation into larger streams determines the difference between a maintained flow over a long period or a flood crest downstream. Many of the same factors determine the quality of water in the lower areas and the degree and type of use which can be made of that water at any point in transit.

The water problem then becomes not one but many, the people who are affected are not many but everybody. Hence, the need for many approaches. If we could increase our total available water supply in the West alone through the reduction of evapotranspiration or other management practices, we would solve many of the local problems. Water is the life blood of agriculture, industry, commerce, of life itself. It cuts across every segment of our society, our economy, our daily lives.

Early peoples in the Southwest used the same resources available to us today. Obviously, there are more people now and more uses for these water resources, but the difference between our use and theirs is far more than merely more intensive development. The great difference is the tools available to modern man. We can wreak changes in the landscape which, even in geologic time, are nearly irreversible. We do more than use our water resources intensively--we start chain reactions in the environment, the end results of which we cannot visualize and certainly cannot see. The development and management of land, forests, and water have multiple and interlocking effects on this environment. The management techniques of the future, founded on sound water research programs, must be based on a knowledge of these effects. Otherwise, we cannot hope to reduce adverse uses to a minimum.

It is encouraging that we are now coming to recognize generally the difficulties we face in managing our water resources. Our problems are already acute in many local situations. If our population continues to explode as experts predict, we could be overwhelmed with problems unless we take action now.

RESEARCH

Research offers the major opportunity to extend existing water supplies over our increased demands. Successful accomplishment of research goals can have a significant effect upon future adequacy of our water resources. What we haven't recognized so far is this: First, research can keep us from getting into trouble, and second, research can provide us greater opportunities in using our water resources. The lack of research data is a serious limiting factor to more efficient action programs and water resource development. Agencies have frequently been forced to move ahead on a minimum of research data and, in many cases, a research basis for the solution of a critical problem is completely lacking.

Let me illustrate the kind of problem in multiple use of land and water that we face in the Forest Service by citing some research work we have underway, and the objectives of the Beaver Creek Project in central Arizona.

The basic purpose of the Beaver Creek Project is to determine the effects of forest treatments on streamflow from watersheds of 10,000 to 15,000 acres, and to evaluate the technical and economic feasibility of increasing water yields by modifying the vegetal cover through various land treatments. This research is set up to try to provide action programs with answers to the following major questions:

1. What is the amount of additional water that may be realized by land treatment measures?

2. What are the optimum uses and benefits from large flood flows?

3. What are the costs of producing and making available the additional water, and the sacrifices or gains in income from other uses?

4. What is the best multiple-use management of the watershed for water, timber, range forage, recreation, and wildlife?

You will recognize that competing and complementary land uses must be evaluated in terms of the best management of each resource and the most beneficial use of the resulting products. Otherwise, we would not have a fair comparison of the relative benefits from each of the many combinations of land uses in this area.

In this research we must determine the additional benefits that would accrue from increased water yields, if such can be achieved by land management adjustments, together with the costs of land treatment and water delivery and the gains or losses in income from timber and other associated uses. You can see this is a typical problem of marginal costs and benefits, and may bear little resemblance to average costs or benefits associated with the present uses of water.

Values of increased water yields can only be estimated equitably if water is put to optimum uses in complete watershed development programs. The evaluation problems faced in this Arizona project are by no means unique. They occur, in some degree, wherever protection and management of forest lands have a measurable effect on the quality and amount of water supplies. Water development must not only be multipurpose, it involves people, agencies, and the use of multiple skills of scientists, engineers, economists, and politicians, as well as land administrators.

Research programs must not only show the way to increasing water supplies by such means as vegetation management, as on the Beaver Creek Project; it must also determine the relations between ground- and surface-water supplies and the best use of available water with a minimum waste of that water. Successful accomplishment of research goals in these fields can have a very significant effect on the future adequancy of our water resources. While many of the research fields are very promising from the scientific standpoint, successful accomplishment of research goals is by no means assured.

Many of the difficulties in understanding the role and status of water in soils and plants, stem from the dynamic behavior of water in living plants and plant parts. Within the last two decades advances in scientific theory of instrumentation have made it possible to develop a more fundamental approach to the study of plant-water relations. For example, a new instrument to measure moisture flow in stems, called a heat pulse meter, is being evaluated. A pulse of heat is inserted into a stem, and the difference in rate of movement of the heat pulse upstem and downstem is computed to measure sap velocity. This information will be useful in understanding movement of water into and through the plant. Research in this area is seriously hampered, however, by lack of measurement techniques for determining the free-energy status and flow characteristics of water in living plants under field conditions, or experimentally induced environmental conditions. Control over the process of water movement from the soil through the plant to the atmosphere would be an important step in developing methods for improving water yield by vegetation management on watersheds, and in improving other techniques of water conservation.

Atmospheric phenomena of water present many challenging fronts. Water travelling through the hydrologic cycle is subject to many atmospheric forces and processes which tend to affect its movements to and from the land. Some of these are temperature, solar energy, wind, humidity, and evaporation. Evaporation is one of the most important factors in water supply and water consumption, and is largely controlled by air temperature, humidity, wind, and solar radiation. Because basic data are very limited, an improved understanding of their characteristics is essential so that water losses from evaporation can be more readily controlled on mountain watersheds and storage reservoirs.

Closely allied with evaporation are the processes of deposition, sublimation, and melting of snow, which are not well understood. Yet, they are major considerations in many of our critical water supplies.

Detailed studies of snow physics at Fraser Experimental Forest in the Colorado Rockies are revealing how some of these complex processes operate.

In the Rocky Mountain area, the winter snow cover is relatively fluffy and dry, allowing extensive air movement. These movements generally occur in response to the unstable temperature gradients found in the snowpack. Warm moist air from the layers near the soil surface rises to be replaced by colder air from upper atmospheric layers. This causes water vapor loss to take place throughout the snowpack, not just the surface layers. Snow crystals change their shape and arrangement continuously. Each new snowfall forms a distinct layer that develops unique properties which depend on its location in the pack. Moisture migrates from layer to layer under strong temperature gradients. These changes in the snowpack have a strong influence on melt rate, evaporation, and how much water is available for streamflow.

Alpine snow research has also shown that alpine snowfields are significant contributors to late summer streamflow. As spring advances the snow disappears progressively from the lower elevations to the higher. When one-half of the snow has disappeared, the spring peak in streamflow is generally approached; when 80 percent of the snow is melted streamflow is declining.

At present, there is little concentrated research on the hydraulics of water movement over the land surfaces of watersheds. Overland flow and small channel flow are basic to an understanding of the refinement and design criteria for mechanical structures to prevent erosion damage and reduce flood peaks. Accurate streamflow measurements from mountain watersheds are extremely difficult and expensive to install because of steep gradients, sediment or trash-laden flows, or inaccessible gaging sites. New telementry devices and flow meters for streamflow measurements are badly needed.

Full understanding of fundamental erosion and sedimentation processes is a prerequisite for planning and execution of successful programs for water resource development and utilization. Basic research, directed to isolating and evaluating soil characteristics that govern the erodibility and the effects of rainfall, snow topography, and vegetal cover on the rates of erosion and sediment yield from watershed lands, have not been clearly defined. The processes creating streambank and gully erosion and soil piping, and the mechanics of sediment entrainment and transportation from rangelands require reliable refined procedures for estimating and evaluating the effects on water quality and quantity. The application and capabilities of electronic computers, radioisotopes, and ultrasonics are being considered for this type of research.

On the forested upstream watersheds, better understanding of the hydrologic and site production effects of different management practices is urgently needed to provide the best integration of timber, forage, and mechanical structures for minimum sediment damage. New information, new patterns, and systems of timber harvesting on steep, unstable slopes must be developed if we are to control sediment movement from these areas.

The limited research already done shows possibilities of higher water yields through improved vegetation management. Harvesting timber by alternate clear-cut strips running across the contours on the Fool Creek watershed in Colorado has increased streamflow by an average of 2.9 inches yearly for the 7 post-treatment years. On the North Fork of Workman Creek in Arizona, clear-cutting all moist-site timber (one-third of the total area) and planting to perennial grass, has increased streamflow by 50 percent during the 4 years since treatment. Further research is needed to develop principles, methods, and techniques for improving the amount, rate, timing, and quality of water yielded from watersheds.

The opportunities for increasing water yields under different conditions of soils, climate, topography, and plant cover, cannot be assessed until more research is done, but it appears that possibilities are greatest in those areas of highest precipitation. Research in the dryer zones could have great economic significance, however, because even a small water yield increase may mean a considerable percentage difference in total yield. On a 76-acre chaparral watershed in central Arizona, sprayed yearly for shrub control since 1960, the average increase in water yield over the water yield expected from an untreated adjacent watershed has exceeded 3 inches during the past 2 water years.

Practices that may improve or increase water yields are (1) converting to more efficient vegetation covers, (2) reducing the density of forest or brush cover to permit more precipitation to reach the ground and to reduce the number of plants using water, (3) cutting forests in snowpack areas to develop special patterns to increase snow accumulation and control melt, and (4) influencing the drifting of snow by artificial means in high-elevation areas to develop more uniform streamflow. In short, research must find out how to use vegetation to increase water yields and control sediment from watershed lands, rather than how to use water to produce more vegetation.

The recharging of ground-water supplies in watersheds is less direct and often more difficult to measure and to trace, but has great possibilities. We need to know more about the path taken by absorbed water from watersheds. Tracing and timing of underground-water movement from mountain watersheds is needed to determine whether water becomes available for use elsewhere and how it reappears. Methods for conducting such research are yet to be developed. Problems to be investigated include (1) methods for handling sediments to improve infiltration, (2) streambed percolation rates, (3) tools and techniques for characterizing recharge sites, (4) effects of prolonged pumping and recharge, (5) effects high mountain bog meadows have on ground-water flow and stabilization, and (6) techniques for using floodwaters to recharge ground-water aquifers and the use of aquifers to store water supplies. These are only a few of the problems requiring research.

No blanket answers can be given to problems of watershed management. No two catchment basins are exactly alike. Each ground surface and all the soil and rock materials underlying the surface affect the way water will begin its travels down the slopes of a watershed. The amount of precipitation and the climatic factors determine the kinds of vegetation and plant types that affect the runoff. These and many other factors combine to affect the way water is delivered from our small watersheds to our major streams. We cannot modify the major phases of the hydrologic cycle. Neither can we greatly change the amount of precipitation we receive. Clouds can be forced to drop their moisture loads by "seeding," but the main pattern of climate, the gross precipitation, is beyond our present control.

Therefore, through our research efforts we are constantly seeking to effectively modify those factors which influence our supplies and make it possible to meet our spiraling water uses. History records the stories of many civilizations that have fallen by the wayside because they did not manage their soil and water resources wisely.

In the Southwest the handwriting is on the wall. As Secretary Udall stated when he presented the Southwest water plan, "The Pacific Southwest is the Nation's fastest growing and driest region. In the next 40 years its population will triple. The region's supply of water is now inadequate to sustain development, and cannot provide adequately for future growth. Ground-water supplies are being overdrafted at an alarming rate. Unless additional water is made available, the economy of this region will decline--with serious consequences to the area and the Nation."

RESEARCH--THE KEY TO THE FUTURE IN WATER MANAGEMENT

H. R. Stucky[1/]

Research, the key to the future in water management has been selected as the title for this paper, first because that is the theme of the Ninth Annual New Mexico Water Conference, and second because I wish to point out the research which is underway at New Mexico State University, the plans for future research, and the need for coordination of research.

That there are water problems, that these problems are difficult and that research is needed to contribute to the solution of these problems is highlighted by the following news headlines from Southwest publications which I have picked up during the past year.

* Three Inches of Water Allocated for Irrigation in the Elephant Butte Project
* Storage in State Reservoirs Low in 1964
* Sewage Disposal is Polluting Streams
* Fish are Killed by Industrial Wastes
* More Water Needed for Recreation
* What Effect Do Crops Grown on Salty Land Have on the Nutrition of Animals and People?
* Are Residues from Fertilizers and Insecticides Carried into the Water Supply?
* Watersheds Eroding
* Water Sources are being Strained by the Growth of El Paso
* Water is Foaming from Detergents
* Little Children get Diarrhea from Wells in Suburbs
* Water Limited for Irrigating Lawns in Denver
* How Can Our Saline Water be Made Economically Usable?

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

* Cities Consider Piping Water from Tucumcari to Clovis, Hobbs, Roswell, Carlsbad, and Other Eastern New Mexico Communities

* Floods in Albuquerque

* Floods in Las Cruces

* Group Foresees National Water Rationing by 1985

The wide range of subjects in these headlines indicates the range in research which will be needed in the solution of the water problems in New Mexico, the Southwest, and the United States. Problems in chemistry, biology, hydrology, agronomy, economics, and engineering, to mention just a few of the more obvious, are indicated. Public health, our food supply, our water supply, and our general well-being are dependent on a solution of many of these pressing problems in the immediate future. No one scientific discipline can go far toward the solution without research help from many other disciplines.

Dr. Abel Wolman, Johns Hopkins University, in a National Academy Water Resources Committee report emphasized that "interdisciplinary training of personnel is most important in the solution of water problems." His committee pointed out that "the most critical shortage in the field of water resources, by far, is the very real shortage of broadly trained people capable of planning and executing effective research programs."

The Committee stated "that the ultimate objective should be the development of a new structure and a new generation of well-rounded water scientists ready and able to approach the Nation's multidisciplinary water-resources problems in a unified manner."

Research in water cuts across many lines of sciences and no one group or no one set of scientists can solve these problems.

For example, take the Roswell saline water conversion plant and list a few of the operations required there. This list will indicate the interdisciplinary requirements even of this single operation.

* Geologists were required to determine the water movements.

* Chemists were needed to analyze the salts at various test well locations.

* Engineers were required to design the plant.

* Economists were needed to study costs and probable returns.

* Lawyers were required to clear title to the land and arrange contracts.

* Legislators were required to pass certain legislation to permit the financing.

* City water system operators were required to determine uses.

* Research contracts have been signed which involve many phases such as--how much of the water should be produced as pure water and how much as sludge. At present about 1,300,000 gallons are pumped, which produce 1,000,000 gallons of usable water and about 300,000 gallons of waste.

* Research is underway at New Mexico State University on the problem of what to do with the sludge. At present it is being placed in (20 to 40 acre) plastic lined shallow tanks where the water is evaporated and the salts remain as residue. One question arises as to what to do with the salts. Another is what commercial value may these salts have? Many other questions could be listed.

* Business and economics entered the picture to determine how best to use the 1,000,000 gallons. Certain plants such as canneries and chemicals need nearly pure water. Housewives find that the new water requires less soap. Water works maintenance men find that the pure water dissolves some pipe corrosion which cause the older pipes to leak.

The city is finding that less water treatment is necessary for the total city. This would be especially true if the million gallons of nearly pure water could be mixed more thoroughly into the entire supply for the city. It may be found that it would pay to produce more product water for such mixing.

The same interdisciplinary need is indicated if you start to look at a river such as the Rio Grande. Some questions which arise are:

* How much water is there?

* How can water be saved?
    a. by killing water-loving plants
    b. channelling the water around these plants
    c. by providing low flow channels and prevent large seepage losses from the meandering river basin
    d. how much water may be saved by improved irrigation practices

* How is the river being polluted?

* How can pollution in the river be prevented?

* If polluted, how can it be cleaned up?

* How much water is to be needed for waste disposal?

* How much will it cost to do anything about pollution?

* How much would it cost to do nothing?

* How will the total supply be used?
    a. how much for industry
    b. how much for municipal
    c. how much for recreation
    d. how much for agriculture

* The economic system will make some of these decisions.

* The law will make others of these.

* The social conditions will make others.

* Will houses be built on all of the agricultural land without restriction and thus eliminate the agricultural uses? If this happens, will we arrive at a land-man ratio when we have more people to feed than the food supply will support--because the land and water were often unnecessarily used for other purposes?

Cooperation with many agencies and all groups of people in all areas of New Mexico and the states involved with us on the rivers systems will be required.

Senate Bill S.2.--Water Resources Research Institutes

In recognition of the interdisciplinary nature of the water resource problem, Senator Clinton P. Anderson of New Mexico introduced into the United States Senate, in July 1962, Senate Bill S.2. which would establish Water Resources Research Institutes in each of the states. This bill passed the Senate in April 1963. Hearings were completed in the House in November of 1963. It is expected that the Bill will reach the House soon for House action.

The passage of the Bill would give a boost to the water research work across the country just as the Agricultural Experiment Station Act boosted research in agricultural production when it was passed in 1887.

Senator Anderson stated that Title I of the S.2. Bill "is essentially a copy of the Hatch Act of 1887 which brought about the establishment of the agricultural research stations at the land-grant colleges and state universities."

The purpose of the Water Research Bill would be to support research in all its phases--municipal, industrial, recreational, and agricultural--and to develop trained personnel to work in this field. It is felt that it is important to have the research done at universities where teaching is in progress so students may become involved and interested in the water resources field and become trained as professional people in water research and management.

New Mexico Water Resources Research Institute

The New Mexico State University Board of Regents, in February 1963, established a University-wide Water Resources Research Institute as a part of the University. The Institute will bring research and teaching programs related to water together into an operating unit at the University to serve the state of New Mexico more effectively.

The purpose of the Institute is to stimulate and sponsor investigations and experiments in the field of water and related resources.

The basic or applied research to be conducted or encouraged by the Water Resources Research Institute will include, but not be limited to, aspects of the hydrologic cycle; supply of and demand for water; conservation and best use of available supplies; methods of increasing supplies; economic, legal, social, engineering, recreation, biological, geographic, ecological, and other aspects of water problems, giving due regard to water research projects being conducted by agencies of the federal government, the agricultural and engineering experiment stations, and other agencies.

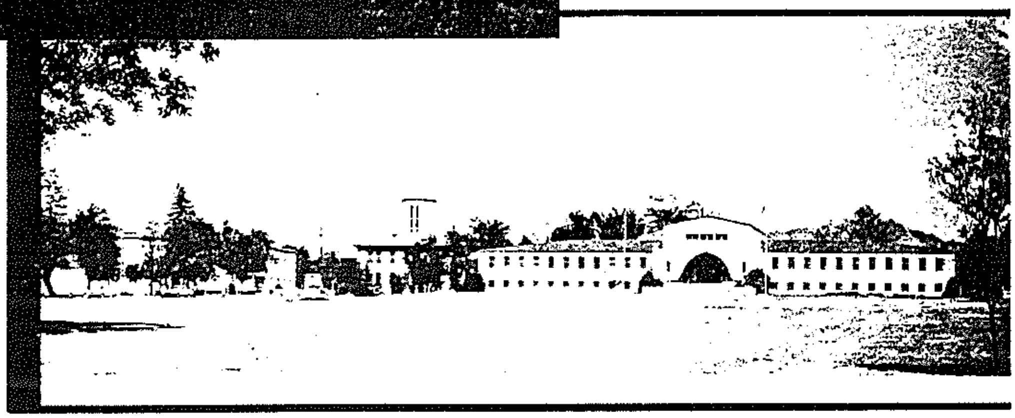
The Institute will provide education and training for undergraduate and graduate students through research employment and assistantships. It will assist in developing a professional and technical staff in water resources research and teaching.

The Institute will publish or encourage the publication of research results for public information, education, and forums on water and will assist in developing information which would permit the development of a sound water program to meet the needs of New Mexico.

This Institute will permit interdisciplinary research to be conducted with contributions being made by two or more departments as the problem demands.

In case the S.2. Bill should pass, additional funds would be made available for water research in all its phases through this Institute. It is expected that this coordinated effort will assist in the solution of many of New Mexico's more difficult water problems.

Water Resources Research Institute



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Technical Report No. 17 prepared by the Civil Engineering Department lists the various water research projects now in operation at New Mexico State University. These project listings were brought together through the work of Dr. Warren Viessman of the Civil Engineering Department in cooperation with the newly created New Mexico State University Water Resources Research Institute.

Review of this technical report will show that New Mexico State University is presently carrying on 32 water research projects with 9 separate university departments involved. The number of projects and the number of departments involved should be materially increased through the efforts of the Water Resources Research Institute.

Research truely is the key to the future in water management. It is hoped that the emphasis this water conference and the emphasis which may be generated through the Water Resources Research Institute and eventually through the passage of the S.2. Bill, that research may be stepped up to the place that it may help to solve many of the water problems of New Mexico, the Southwest, and even the entire United States.

FACTORS AFFECTING FARM IRRIGATION EFFICIENCY IN THE MIDDLE RIO GRANDE VALLEY

Charles H. Diebold[1]

How much progress have we made in improving farm irrigation efficiency in the Middle Rio Grande Valley?

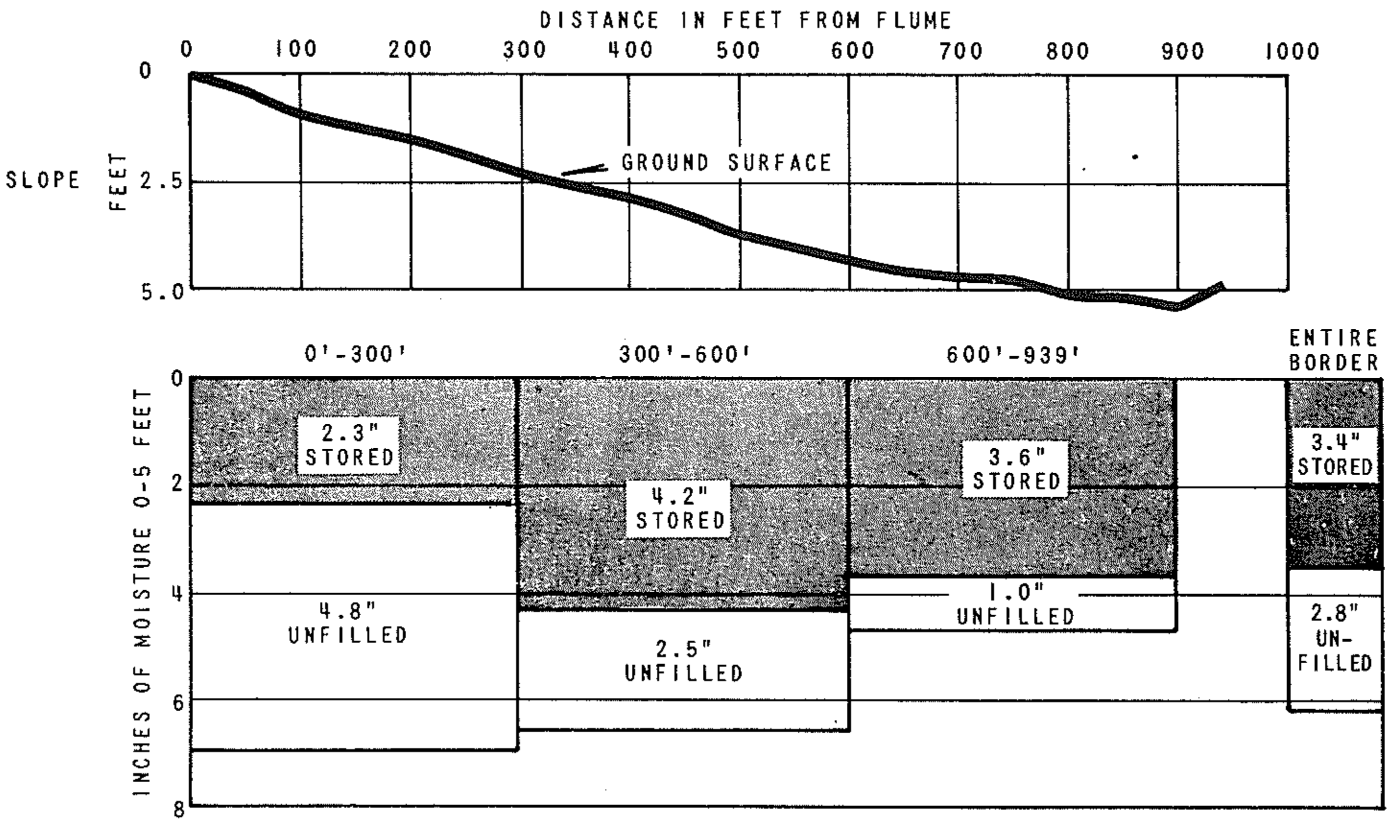
First, we think of land leveling. Approximately 60 percent of the land has been leveled under the technical guidance of the Soil Conservation Service. Let us look at the irrigation trial in Figure 1. Note the 4.8 inches unfilled storage in the upper third of this unleveled border of alfalfa on Gila clay loam. We failed to fill this part because we were forced to stop irrigation too soon. The uneven cross slope forced us to use a flow of 1.5 cubic feet per second (c.f.s.) in order to cover. When 780 feet of the border was covered, we cut off the water at the ditch. In a few minutes more, the entire 939-foot border was covered. If we had run water longer, the border ridges would have broken. Such an irrigation results in either low crop yields or frequent irrigation since we filled less than half of the capacity to store readily available moisture in the upper third of the border. Since we had no waste water and no deep percolation, this irrigation was highly efficient--over 90 percent. But, it failed to give the farmer a satisfactory refill.

So, we level land with little or no cross slope. Figure 2 shows a trial also in alfalfa on land leveled to a uniform 0.1-foot fall per 100 feet near Socorro. The soil was Vinton clay moderately deep over sand. We examined the soil before irrigation and estimated a 3-inch irrigation would fill it. Actually, we normally would have waited until a 4-inch refill was needed. But, some farmers irrigate too soon.

First of all, we had trouble to hold the small stream of 1.2 c.f.s. on the border. We lost about 12 percent on the adjacent borders due to the low border ridges. Even cutting the water off 130 feet from the end, we still lost an inch of water to deep percolation below the root zone. You can see that by leveling, we easily filled the root zone. Unfortunately, the field irrigation efficiency was only 64 percent. If we had had higher border ridges and could have used a larger stream, we could have applied less water and increased our efficiency. If we had waited another week to irrigate, our efficiency would have increased since we were not able to apply the small amount needed when moderately wet.

What field irrigation efficiency should one expect under good management? Note I said good, not the best. To answer this

1/ Soil Specialist, Soil Conservation Service, U. S. Department of Agriculture, Albuquerque, New Mexico



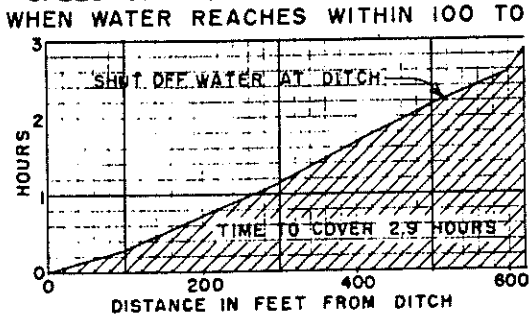
LARGE AMOUNT OF UNFILLED STORAGE DUE TO UNEVEN CROSS SLOPE REQUIRING FLOW OF 1.5 CFS TO COVER STEEP BORDER OF ALFALFA, 35x939 FEET, GILA CLAY LOAM, BERNALILLO, N. M.
WATER CUT OFF 160 FEET FROM END TO AVOID SPILL INTO NEXT BORDER.

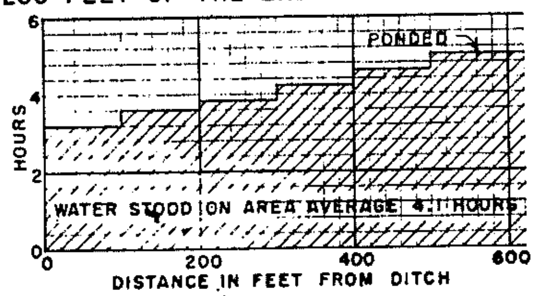
U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, ALBUQUERQUE, NEW MEXICO 3-64 4-R-18797-8 of 9

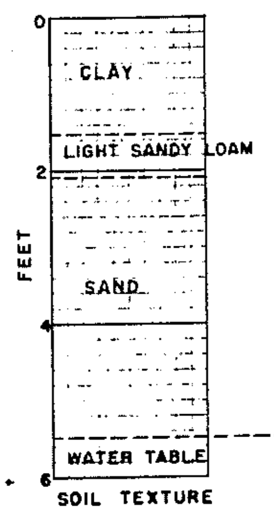
BORDER IRRIGATION TRIAL ON CLAY SURFACE SOIL
SAND AT TWO FEET

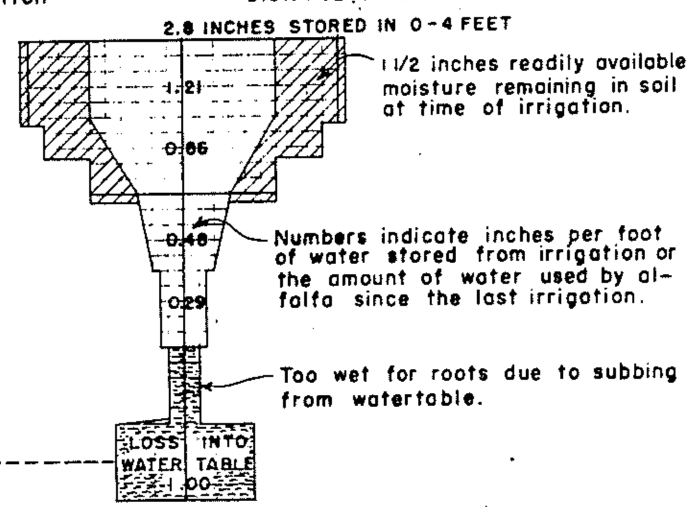
Crop	Alfalfa	Date	July 25, 1952
Height	16 inches	Size of border	42' x 640'
Soil unit	14P2	Average flow	1.20 c.f.s.
Moisture needed 0-4 feet	3 inches	Time applied	2.22 hours
Surface foot		Depth applied	4.35 inches
Readily available		Average irrigation intake rate	0.92 in/hr.
Moisture prior irrigation	1/2	Surface waste water	0.00
Compaction class	Mod. compact	Estimated evaporation	0.1
Effective pores per sq. ft.	3	Loss into adjacent borders owing to low borders	0.5
Grade, fall per 100 feet	0.1	Loss into watertable below 4 feet	1.0
Time since last irrigation	2 weeks		

SPEED UP YOUR IRRIGATION ON CLAY SOILS BY SHUTTING OFF THE FLOW WHEN WATER REACHES WITHIN 100 TO 200 FEET OF THE END OF THE BORDER









Border irrigation trial on clay surface soil, soil unit 14P2, grade 0.1% in alfalfa, and the moisture stored two days after irrigation, Socorro Soil Conservation District.

question in part, we took soil moisture samples before irrigation and 2 days after irrigation from about 75 trials where we carefully measured the water. In Table 1, we estimate that on deep soils of medium to moderately fine texture on slopes of 0.0 to 0.3 percent, we should expect 80 percent irrigation efficiency by good irrigators. This means 80 percent of the water applied would be used by crops. These soils normally require a 5-inch refill irrigation about every 3 weeks to keep a crop such as alfalfa growing rapidly. For shallow soils of similar texture but underlain by sand, refill 3 inches, we would expect 70 percent field irrigation efficiency.

Under good management, the major loss is deep percolation. You can expect to lose 15 percent of your water on deep medium textured soils by deep percolation. On shallow medium textured soils it may be 25 percent. Under average management these figures are estimated at 30 percent for the deep soils and 40 percent for the shallow soils in the Middle Rio Grande Valley.

What can be done to reduce deep percolation losses? Let's first assume that your border size has already been designed by us for efficient irrigation for a given stream size.

Farmers need to use the design stream size, but unfortunately, most farmers have not installed measuring devices. One of the cheapest devices is a 2-foot rectangular weir, cost $20.00. Note Figure 3 shows a staff gage mounted on a board with numbers painted in cubic feet per second. In Figure 4 we show a one-foot Parshall flume also marked in cubic feet per second. The metal flume costs $80.00. It will measure accurately muddy flows of water whereas the weir tends to silt up and under-read the flow of water. These devices are often used to measure water for 30 to 50 acres; their cost is about that of leveling one or two acres.

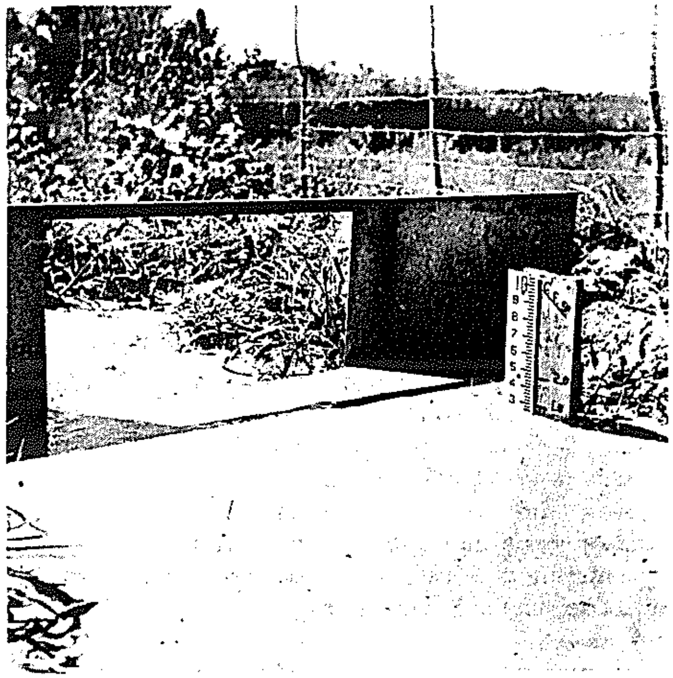
Why measure water? The kind of soil you have, how fast it takes water, how much water it holds, the grade, the size of border are all considered for a design stream size. This is the stream size that saves the most water. We want that stream to cover as fast as possible but slow enough to refill the root zone with little deep percolation, without waste water.

You say the water in the canal fluctuates. Another reason you should measure water, so your irrigator can quickly change the flow to the design flow. Have you enough water to irrigate 1, 2, or 3 borders? Measuring water takes out the guess work just as a feeler gage takes the guess work out of valve grinding. If you measure water and use the same design stream, there is a place in each border where you can cut off the water at the ditch so that it will just nicely cover. Cutting the water off 100 to 200 feet from the end may save 1 to 2 inches of deep percolation loss.

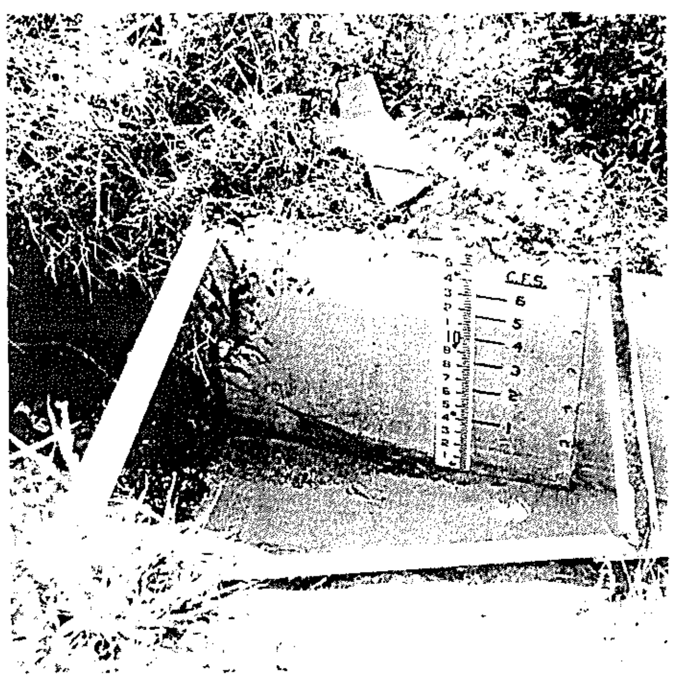
How much of an effort should one make to eliminate high spots of .1 to .2 in flat leveled borders? We found it took 0.5 to 1.0

TABLE 1. Relation Between Design Refill Capacity, Field Irrigation Efficiency and Losses, Grades 0.0 to 0.3 Foot Per 100 Feet

Refill Inches	Surface Texture	Field Irrigation Efficiency	Deep Perco-lation	Waste Water	Evapor-ation
5	Fine to Mod. Fine	80	15	0	5
	Medium	80	15	0	5
4	Fine to Mod. Fine	75	20	0	5
	Medium	80	15	0	5
	Sandy	75	20	0	5
3	Fine to Mod. Fine	70	25	0	5
	Medium	70	25	0	5
	Sandy	65	30	0	5



One-Foot Parshall Flume



Two-Foot Rectangular Weir

inch more water to cover these high spots. Usually these high spots were the first to show stress at our Albuquerque Soil Conservation Service Nursery.

How much do concrete pipe lines and concrete ditches save water? A hard question to answer. In the Albuquerque Area about 40 percent of the field ditches are lined; at Socorro about 10 percent. For example, on clays and clay loams, Table 2 indicates a small loss of .02 c.f.s. per 1,000 feet of ditch. For deep sandy soils the loss may be as high as .25 c.f.s. per 1,000 feet.

Ditch losses are usually small percentagewise where streams of 2 to 5 c.f.s. are used. For example, Table 3 shows that Gila loam, a deep medium textured soil would have a ditch loss of 0.3 inch for a gross application of 6.0 inches when using a flow of 2.5 c.f.s. on a border 42 feet wide and 800 feet long. The farm ditch is assumed to be 1,000 feet long and to have a loss of 0.12 c.f.s. per 1,000 feet of ditch. If we were to double the flow to 5.0 c.f.s. and irrigate 2 borders at the same time, we could cut this small ditch loss about one-half or less than 5 percent.

Suppose we let the water run on this same border 0.3 hour or 18 minutes longer than necessary--irrigation efficiency drops 12 percent or over twice the ditch loss. If we went off and let the water run 54 minutes too long our irrigation efficiency drops from 83 to 55 percent; in this 54 minues, we lost 1.9 inches more water by deep percolation.

On the other hand, if you were irrigating with a weak well or a small stream of 1 c.f.s., ditch loss could be more important than deep percolation, Table 3.

On sandy soils ditch loss can also be important, Table 4. But if you irrigated a sandy soil like Vinton loamy fine sand 21 minutes longer than necessary, deep percolation loss would be 3 times that of the ditch loss for a flow of 2.5 c.f.s. on a border 42 X 500 feet.

How often do you need to irrigate? Years ago I wrote an article on the ball test for Crops and Soils which was reprinted in 15 different publications. It is still the cheapest and simplest method I know. Just dig down with a spade to 6-12 inches, if the ball of soil breaks with less than 5 tosses, it is time to irrigate in the next 2 or 3 days.

In Table 5 we are fortunate to summarize the number of irrigations for alfalfa and the field yields by a cooperator in the East Valencia Soil Conservation District, who measures water, who uses design flows, who cuts off the water as far as possible from the end and still have it all get wet.

On the Glendale loamy for 6 years there was an average of 7 6-inch irrigations and a yield of 6.9 tons per acre. Note that the

TABLE 2. Ditch Loss in Cubic Feet Per Second Per 1,000 Feet by Surface Texture and Subsoil Permeability, Tentative

Surface Texture	Permeability: Very Slow to Slow	Moderate	Rapid
Fine to Mod. Fine	.02	.08	.08
Medium		.12	.20
Sandy		.15	.25

TABLE 3. Relation Between Size of Stream, Hours Applied, and Farm Irrigation Efficiency for a Border 42 Feet Wide, 800 Feet Long, Factor 1.3, Gila Loam

Flow cfs	Depth Applied Per Hour Inches	Hours Applied	Depth Inches	Refill Needed	Farm Irrigation Efficiency %	Ditch Loss[a] Inches	Deep Percolation Inches
2.5	3.2	1.9	6.0	5.0	83	0.3	0.5
		2.2	7.0	5.0	71	0.3	1.5
		2.5	8.0	5.0	62	0.4	2.4
		2.8	9.0	5.0	55	0.4	3.4
1.0	1.3	4.6	6.0	5.0	83	0.7	0.1
		5.4	7.0	5.0	71	0.9	0.9
		6.2	8.0	5.0	62	1.0	1.8

a/ Assumes 1,000 Feet of Ditch

TABLE 4. Relation Between Size of Stream, Hours Applied, Depth Applied, and Farm Irrigation Efficiency for a Border 42 Feet Wide, 500 Feet Long, Factor 2.1, Vinton Loamy Fine Sand

Flow cfs	Depth Applied Per Hour Inches	Time Applied Hrs-Min		Depth Inches	Refill Needed	Farm Irrigation Efficiency %	Ditch Loss[a] Inches	Deep Percolation Inches
2.5	4.2	1	4	4.5	3.0	67	0.5	0.8
		1	25	6.0	3.0	50	0.7	2.1
		1	40	7.0	3.0	43	.8	3.0

a/ Assumes 1,000 Feet of Ditch

TABLE 5. Field Yields of Fall Planted Ranger Alfalfa as Related to Annual Number of Irrigations - Scale Weights, Four Cuttings

SOIL	GLENDALE LOAM		GILA LOAM and CLAY LOAM		GLENDALE CLAY LOAM and GILA CLAY LOAM	
Size:	42 X 740		42 X 700		42 X 900	
Grade:	0.1 %		1.0 %		0.0 %	
Stream:	2.0 c.f.s.		0.5 c.f.s.		2.7 c.f.s.	
Year	6-Inch Irrig.	Yield Tons/Acre	4-Inch Irrig.	Yield Tons/Acre	7-Inch Irrig.	Yield Tons/Acre
1958	9	6.2			7	6.2
1959	7	6.9	11	6.1		
1960	7	7.2	8	7.7	5	5.4
1961	7	7.9	9	7.3	6	6.7
1962	8	7.1	10	7.6	6	6.3
1963	5	6.3	7	6.8	5	6.7
Average	7	6.9	9	7.1	6	6.2

highest yield was made in 1961 on 7 irrigations. The following year, one more irrigation produced 0.8 tons less per acre. Even in the dry year of 1963, 5 irrigations produced 6.3 tons per acre for this 7-year old stand.

Now some people like light frequent irrigations. In Table 3, data are shown for a 1 percent slope on a deep soil, Gila, which has a medium textured permeable subsoil. Ten irrigations of about 4 inches gave a yield of 7.6 tons in 1962, but 8 irrigations produced as much alfalfa in 1960 and 7 irrigations produced 6.8 tons per acre in dry 1963. Light irrigations were used on this relatively steep field to avoid waste water. An average of 9 irrigations produced 7.1 tons per acre over a 6-year period. The least amount of water annually was used on this field.

Some people like flat grades on heavy soils that take water slowly. This field was found to yield alfalfa better with only one heavy 7-inch irrigation between cuttings. On this Glendale clay loam and Gila clay loam, an average of 6 7-inch irrigations produced 6.2 tons per acre.

The most important part in automobile driving is the nut behind the wheel. So, the farmer is the most important factor in improved water management. You can increase irrigation efficiency and refill the root zone:

1. Level your land to flat cross slope, uniform grade lengthwise.
2. Install a designed irrigation system.
3. Use the ball test at the 6-to 12-inch depth to determine when to irrigate.
4. Measure and use the design flow for each irrigation.
5. Cut off the water as far as possible from the end and still have the entire area covered and refilled.
6. Record each date of irrigation by fields.
7. Line ditches where ditch losses are significant.
8. Build and maintain good border ridges 6 to 10 inches above the average level of each border.

WATER USE AND EFFICIENCY IN THE PECOS VALLEY

E. O. Moore[1]

Because of the limited time allotted for the members of the panel, I will present a graph, prepared by Mr. Russell E. Crawford, Engineer and Manager of the Pecos Valley Artesian Conservancy District, which shows quite clearly and accurately the situation as it has developed in the Pecos Valley Basin, which differs from other basins in which ground water is used for irrigation, only in having a measured average recharge of 235,000 acre-feet per year.

The first line of the graph covering the period from 1938, just one year after the basin was closed by order of the State Engineer to further acreage expansion and development, to 1962. Here is shown a continual and generally uniform increase in pumpage from 287,000 acre-feet in 1938 to 431,000 acre-feet in 1962, with an exception in 1941 when there was 34.61 inches of precipitation in comparison with the long time average of slightly under 10 inches. This annual precipitation is shown on line four and with the exception of 1941 shows only a comparatively slight deviation from the average.

Also, in line five the recharge to the artesian basin is shown to correspond rather faithfully to the annual rainfall with the years of greater or less than average indicated quite clearly, but showing no particular cycle of either wet or dry years.

Line six shows acre-feet drawn from storage, a direction or combination of directions, influenced by the variations in annual precipitation and by the gradually increasing amount of pumpage ending with 431,000 acre-feet pumped in 1962 or 196,000 acre-feet drawn from storage in that year. Again, 1941 is conspicuous in showing addition to storage, being the only year in which the withdrawal was less than the recharge.

The bottom line shows what has happened to the water level as measured in six test wells in which continual gauges are kept. This is the average annual measurement from the land surface and is the annual average of the winter highs and the summer lows, beginning at surface level in 1938 and ending at 65.6 feet below the surface in 1962 (the compilation for 1963 is not yet available). The winter highs are at or slightly above the surface and the summer lows are from 120 to 200 feet below, depending upon the location of the well which is pumped.

1/ Farmer and Chairman, State Soil Conservation Committee, Roswell, New Mexico

CHART 1. Pumpage, Acres Irrigated, Acre-Feet Pumped, and Change in Water Table, Pecos Valley, 1939-1962

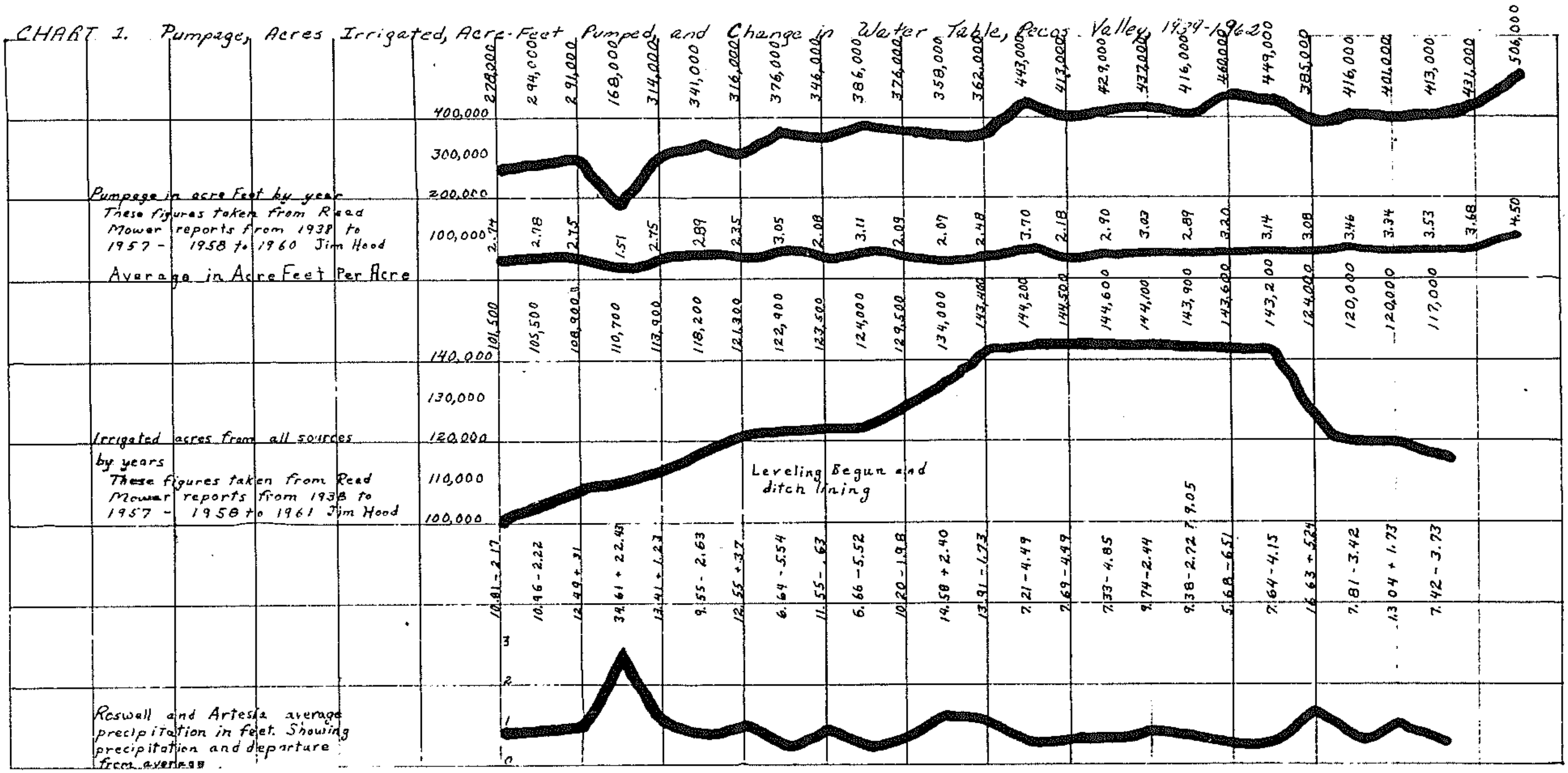
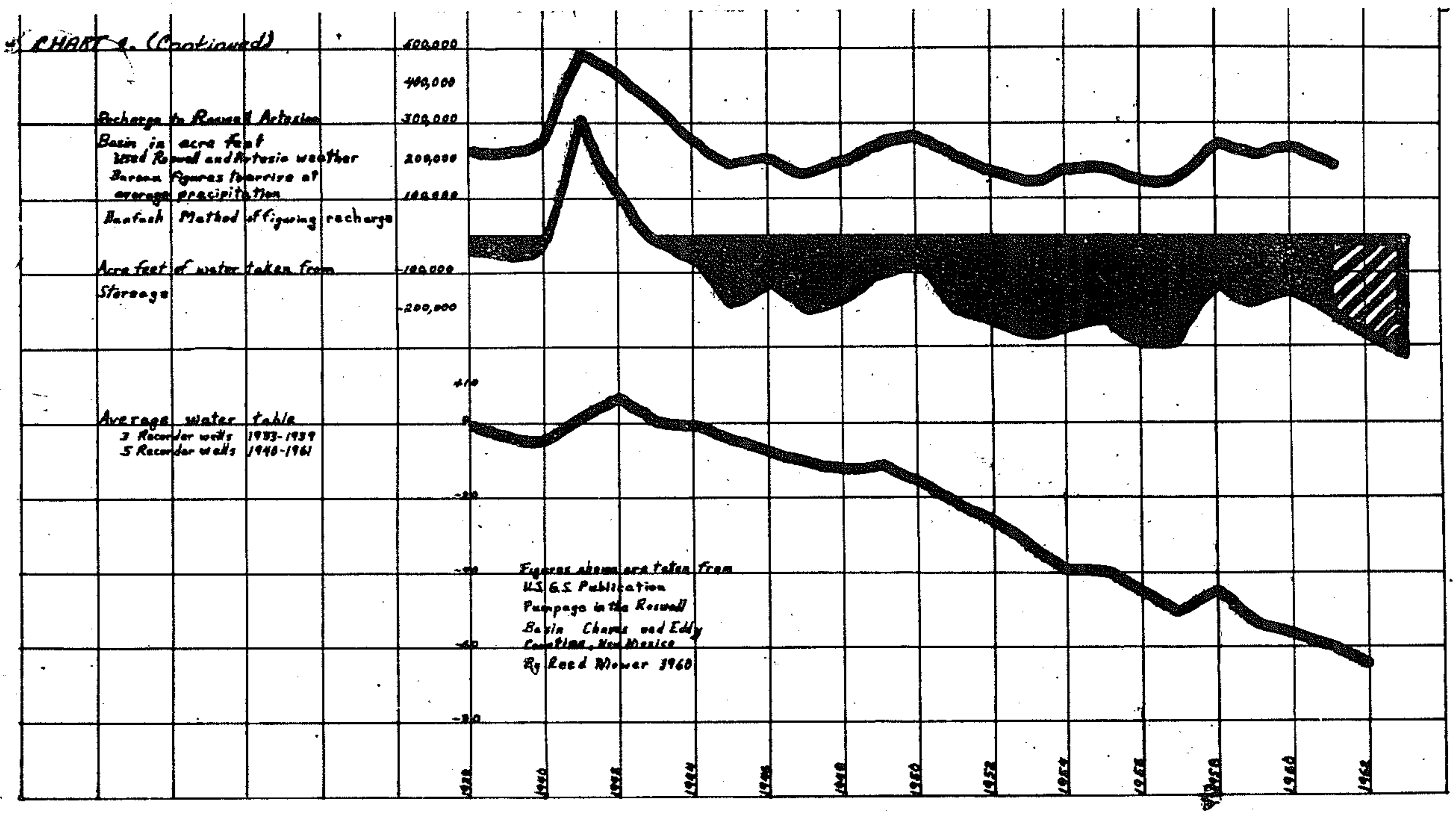


CHART 4. (Continued)



Let us look now at line three which shows the total of irrigated acres during the period and we notice a rather sharp increase from 1938 to 1950 and a sort of plateau from 1950 to 1957, reaching a peak of 144,600 acres in 1953 and looking again at the top line we find a pumpage of 460,000 acre-feet in this period (1956). Also, we find an abandonment of 1,400 acres during this plateau period, due to the failure of wells in some unfavorably located areas. There is a noticeable and very sharp drop in the acreage line beginning in 1957 and continuing less sharply into 1962. This shows the effect of the adjudication proceedings which began in 1957 and are now about completed. The decisions of this court had the effect of eliminating from legal sanction the lands which were not included in the approved water right grants and for the most part consisted of small acreages above the number of acres actually allowed in the grant. It is noticeable that there was no corresponding decline of the amount of water pumped even though the adjudication reduced the legally qualified appropriators to 117,000 acres, a reduction of 26,200 acres and the abandonment from failure of wells was 1,400 acres, a total of 27,600 acres.

To add to the occurrences which might have been expected to reduce the demand on water resources there was the adoption and fully 80 percent completion of the program of land leveling and ditch linings. There is no doubt that these practices did reduce waste and unnecessary evaporation to a considerable degree as they were intended to do and certainly they are good and necessary operations. We who were and are sincerely interested in soil and water conservation felt justified in promising that eliminating water waste by this method would tend to reduce the necessary withdrawals and so tend to balance the draft-recharge relation, but our faces were very red when we found that the amount of overdraft had increased during the entire period, not only in the total amount, but also in the amount used per acre, as shown in line two of the graph.

It is true that the increase in production per acre was even greater than the increase in water pumped per acre, it seems that the saving accomplished by the elimination of waste was transferred to greater production. This would be altogether desirable if it did not maintain and actually add to the already critical overdraft and result in abandonment of lands belonging to other farmers whose legal rights were the same as their more fortunately located neighbors.

These graphs are shown with the intention of showing what the situation is now in the Pecos Valley and probably in other basins of New Mexico for it seems reasonable to assume that efficiency in water used for irrigation should be considered under the conditions which exist, and the regulations which have been put into effect under the laws, and are intended to bring about an equitable allocation of the right to appropriate.

A quick look at these lines on the chart would seem to indicate the entire lack of control, or the complete ineffectiveness of such controls as have been attempted. Such a conclusion would be far from justified for there have been many controls and most of them have been effective.

The design of the basin itself with storage capacity of some thing more than 4,000,000 acre-feet (the estimated overdraft in the last 26 years) and the nature of the aquifers which limit the annual flow to the areas where pumpage can be economically feasible have prevented us from depleting the reserve supply as we could have done had it been from an open lake.

The laws under which we are granted the right to appropriate and the regulations under those laws which stopped further development of irrigated acres from the artesian source in 1931 and with water from the shallow ground supply in 1937 have served to prevent an over-development which certainly would have been disastrous, even though they have not worked perfectly.

The various studies by the U. S. Geological Survey have had a controlling effect in guiding the authorities and furnishing information to the users and general public as to how much we have and what is happening to it.

The Pecos Valley Artesian Conservancy District which was authorized at the request of the property owners, by special act of the State Legislature, has been helpful in control, requiring leaky wells to be repaired or plugged, granting loans for ditch lining and land leveling and otherwise supplementing the regulations of the Office of the State Engineer.

The controlling regulations have been imposed in the hope that the amount of water drawn from the underground sources would thereby be limited to the three acre-feet agreed upon by the appropriator and the State in the original grant and upon this agreement must be decided whether efficiency in the use of water in irrigation may be accomplished, and a profitable farm operation be realized.

I shall not attempt to discuss the many items of farm programming which have been indicated both by experience and laboratory research as helpful in attaining a high production with the use of a minimum amount of water but will go directly to what has been done on farms here in the Pecos Valley where the total amount drawn from the wells has been under or only slightly above three acre-feet per acre per year. This is the case in three of the six metered wells in the period of 1959, the first year in which the meters were installed by the Pecos Valley Artesian Conservancy District Board in the six wells located fairly evenly from north to south in the valley, measured to 1961. These three farms were not and are not low production farms, but are all at least average. Two of these were close to the three acre allowance in 1963 which was the dryest year on record. We may conclude from this that probably one-third to one-half of the farms in the valley are operating somewhat closely to the agreed amount.

One farm which I know intimately has been limited, I am sure, to three acre-feet or less since its beginning as farm land, irrigated farm land, that is, in 1930. Limitation to the granted amount was not due to the desire of the operator, but because it seemed to be the maximum amount available. I am sure, however, that the available amount was never greater than in 1959 and 1961, when the meters showed a 2.89 acre-feet average for the two years.

Due to the limitation of water, everything that was considered in the program for this farm was of necessity considered with reference to its relation to water use. It took the first ten years to bring the entire 312 acres into satisfactory production with a division of cropland about 1/3 cotton, 1/3 alfalfa, and 1/3 forage crops such as grain sorghum with occasionally barley or some other small grain as suitable. Attention was given to depth of tillage especially in preparation for planting, shallow plowing followed by light subsoiling was found to be helpful in controlling depth of penetration so that it was uniform without going to far below the root zone. Analysis of the soil in each field, each year gave information as to the kind and amount of fertilizer to be added and the percentage of organic matter present. It was believed that proper fertilization is closely associated with soil structure and that the organic material present is highly important both in its plant nutrient contribution and also in the reception and retention of moisture.

From the beinning this farm was planned as a cotton and livestock farm both because that seemed to be the best way to get everything that was produced into the market, in the form of lint cotton or fat cattle, but also offered the best water economy program and the least soil depletion. There seems to be nothing that will supply organic matter as readily available as livestock manure. Nothing except cotton and cattle have been sold from this farm in the last twenty years.

It now appears that the custom of light and minimum tillage in effect on this farm is approved by soil scientists as being favorable to the availability of the soil moisture to the plant roots by preventing its being locked up by the multiplicity of soil particles which is the result of overtillage, fine mulching and in combination with increased travel of farm implements encourages compaction.

Lining of ditches with concrete was begun in 1961, following a program of land leveling which had been in effect beginning about 1950, and the installation of 1/2 mile of underground pipe to carry the water from one well to a reservoir located on high ground and used to store water from two other wells.

Whether or not this farm was always "short on water" is a question for discussion but has nothing to do with the fact that it never had more than three acre-feet and "made out" with that amount. It is significant that generally it was operated at a profit with production that was at least average for the irrigated farms of the basin. And, it is obvious that whatever success the operators realized was due to an intense effort to use everything possible in order to get the greatest benefit from the limited supply of water, which was less than three acre-feet per acre.

There is another idea suggested here which could lead to some argument and possibility of suggestions. As was stated earlier, ditch lining was not begun until 1961 and the measurements which average 2.89 per acre were obtained in 1959 and 1960, the first two years of metering. Now, if the estimate of the engineers that 30 percent of the water was lost through seepage and other ditch losses in an open system such as this where the open ditch runs average 3/4 mile then only 70 percent of the water pumped was actually applied to the land and whatever beneficial use there was realized was the use of 70 percent of 2.89 acre-feet or 2.023 acre-feet per year and it would seem possible that with the elimination of all unnecessary losses such preventable evaporation, by the use of monomolecular film, chemical weed control and all the available water saving practices we could reach the point of profitable, economical and efficient irrigation farming which could exist with the withdrawal of as little as two acre-feet per acre from the underground source and thus, be within our recharge average. Until that time, it is certainly possible to live within the decreed amount of three acre-feet with the controls now in effect provided there is added the one of required measurement at the point of withdrawal and without which the other controls will continue to be regrettably ineffective, but with a continuous flow meter on every well, we can with perfect confidence leave the institution of a suitable farm program to the ingenuity of the farm operators.

As stated before, the acreage determined by adjudication to be entitled to the use of three acre-feet of water per acre per year is 117,000 making a total adjudicated appropriation of 351,000 from an income of 235,000 an overdraft legally authorized of 116,000 acre-feet. Eventually, even this will have to be adjusted in some way. The storage will not stand an overdraft forever, then it may be necessary for efficient water use to be considered as limited to 2 acre-feet, under a strict rationing program. We think it can be done provided:

A continuous flow meter is required for each well discharge.
The controls now in effect be rigorously enforced.
Better management of farm programming is instituted.
When we farmers substitute thinking and planning for the rat race for more pumping.

APPLICATION OF WATER ON THE CONTOUR IN THE PECOS VALLEY

Cooper Malone[1/]

Research has determined that on sloping fields up to 40 percent more land may be irrigated with a given amount of water using contoured rows rather than straight down-slope rows. Contouring of row crop furrows can furnish for sloping fields the efficiency of water use attained by bench leveled land at only a fraction of the capital investment outlay.

In that we have utilized contoured furrows for row crops on our Pecos Valley farm for many years, I'd like to briefly mention some of their benefits and some of their shortcomings.

To begin with the right circumstances to justify their use probably need to be present--such conditions as:

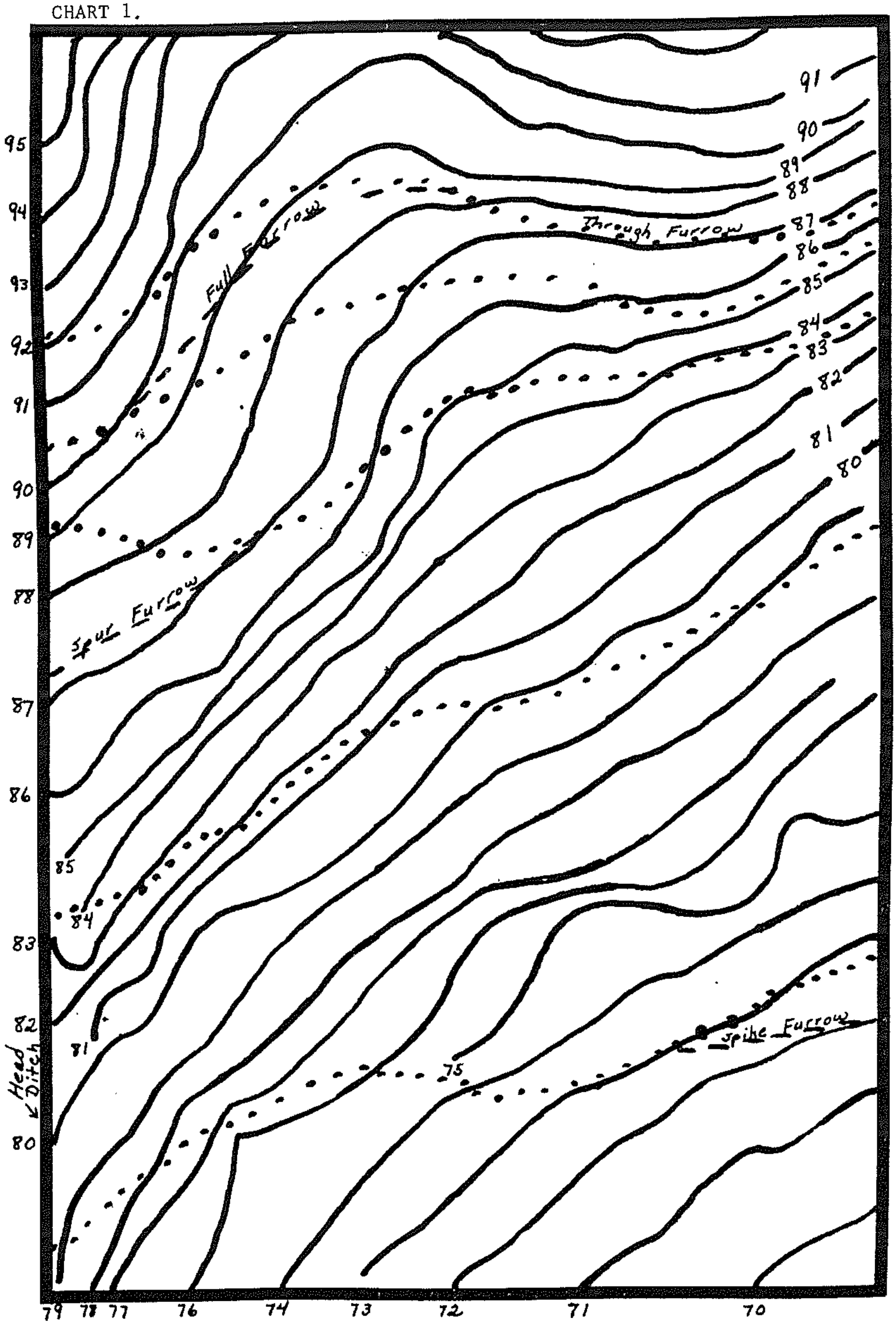
1. Soil too shallow to permit bench leveling, or
2. Capital too limited to permit the expense of land leveling, or
3. Desire not to disturb the topsoil and thereby lose its fertility for several years.

A glance at my first chart, a topographic map of one quadrant of our farm, shows a condition where contour furrows have been beneficially used. The steep and irregular topography of the land will be seen in the many contour lines shown in black solid lines. The soils here are light in character and vary from deep to shallow and rocky, and therefore do not lend themselves to bench leveling. By using contoured furrows on this land, we have been able to produce yields equal to those on our more level fields. I have drawn in a few typical row patterns as they might lie on a contoured furrow layout of this field. Shown in (----) are the through rows reaching from the head ditch to the fields' end while the nonthrough point rows are shown in (....).

Our local SCS officer at Artesia, Mr. Bob Bishop, has made some studies on the efficiency of the contoured rows on our farm. The next charts show his results. Chart 2 demonstrates the very efficient water intake during an August irrigation of cotton on contoured rows 1200 feet long. He estimated that 3 inches of water was needed at this irrigation as indicated on the chart. By measuring the water flow at 100-foot intervals away from the head ditch, he determined the intake at such intervals. The very uniform water intake curve is indicated by the other line on the chart. The small amount of water wasted is indicated by the hatched area.

1/ Farmer and Farm Bureau Representative, Lake Arthur, New Mexico

CHART 1.



95
94
93
92
91
90
89
88
87
86
83
82
Head Ditch
80
91
90
89
88
87
86
85
84
83
82
81
80
Full Furrow
Through Furrow
Spur Furrow
Spike Furrow
85
84
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75
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72
71
70

CHART 2. Moisture Distribution

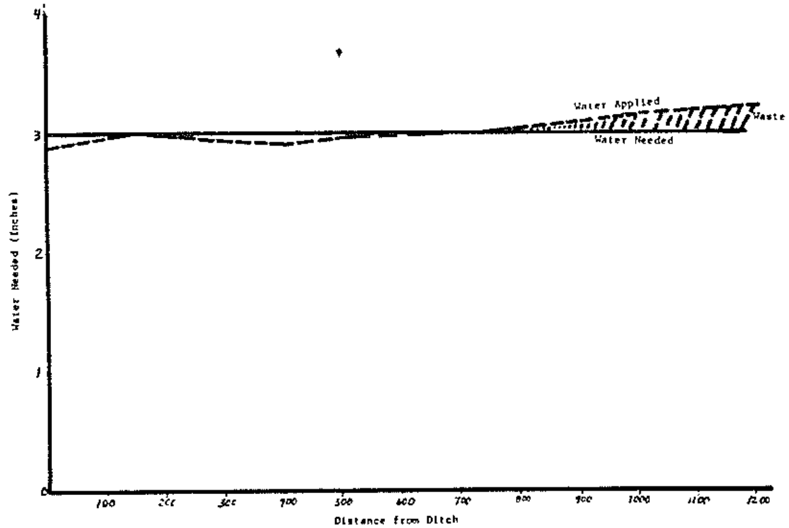


CHART 3. Moisture Distribution

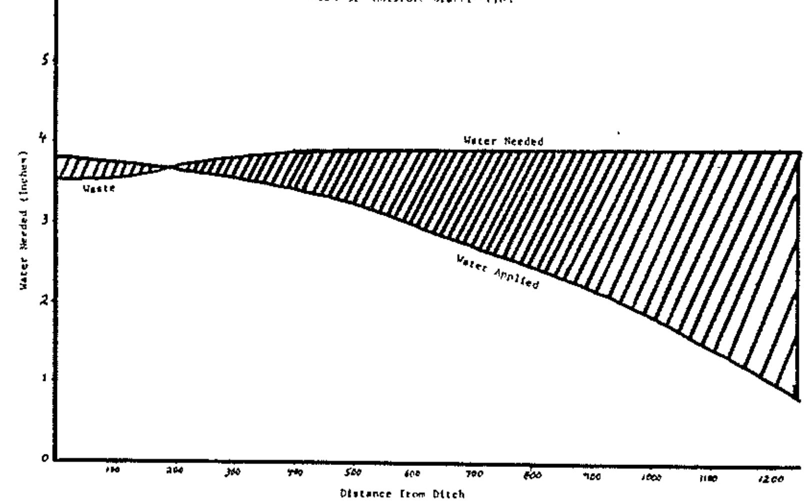


CHART 4. Time Water Running in Furrow.

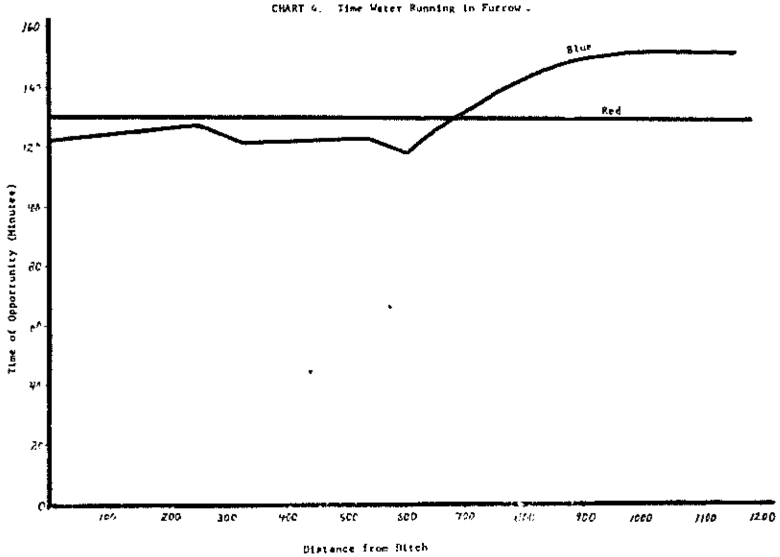
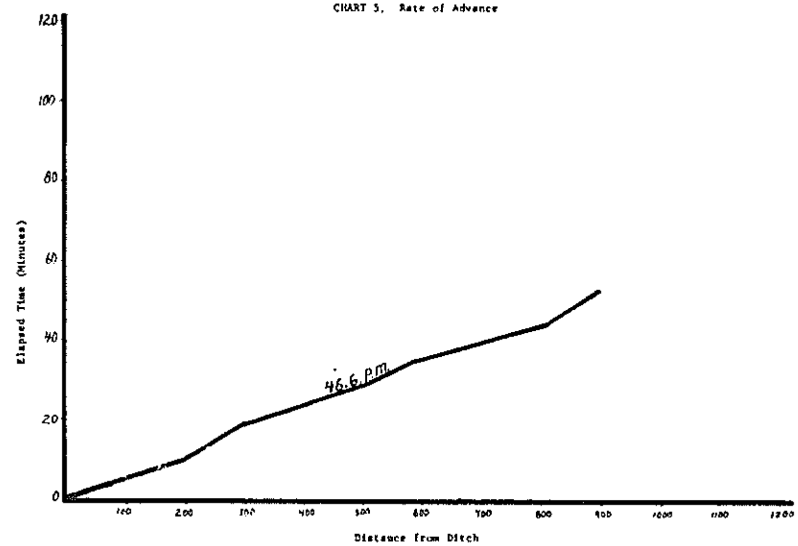


CHART 5. Rate of Advance



In contrast to this efficient irrigation on rather steeply sloping land is the following chart, Chart 3 which indicates the ineffectiveness of an irrigation using down the slope rows on a field of similar grade. Again, these measurements were made by Mr. Bishop in rows of about 1200-feet length. As is seen from the chart, the water applied varied from nearly 4 inches at the row's head down to less than 1 inch near the row's end. The large hatched area indicates the water still needed.

On Chart 4 is indicated the span of time that water was standing in each 100-foot segment of row. We estimated that each set needed to remain 125 minutes or approximately 2 hours in order to apply the 3 inches needed of moisture, as is shown by the red marked line. The blue line indicates the amount of time that water actually was running in the furrow, and as is seen it nearly equalled the planned figure.

On the next chart is shown the rate of advance of the water down the furrows. From it will be seen that a 46-gallon per minute head in a furrow had run 750 feet down the row in 40 minutes on a sandy loam soil. Each farmer using contour row needs to work out his lown plan for row gradient for his own type soil and for the kind of crop that he is planting. The use of siphon tubes to lift water to the furrow from the ditch provides the irrigator with considerable leeway in that he may use many or only a few tubes to furnish the necessary head to give the desired penetration. One of the disadvantages of using a contour row lay-out is that since the water is carried across the slope of the field, the head ditch from which the water is taken often needs to be run down slope necessitating the use of special equipment, such as either gated distribution pipe, or else several scissors tarps together with siphon tubes to prevent eroding of the ditch.

To summarize contour-furrowing of row crops provides a low cost means of efficient water application. The practice could fulfill a water saving role in our water-short state and will probably be more widely used whenever it becomes economically profitable to do so. The extra planning time required for the row lay-out and the some time extra labor needed for irrigation, may be more than compensated for by extra yield, by higher quality or by disease-free crops. The equipment needed for engineering the layout should cost less than a hundred dollars and could be operated by any farmer.

RESEARCH IN DITCH LININGS TO SAVE IRRIGATION WATER

Eldon G. Hanson[1/]

The influence of ditch linings in southern New Mexico on reducing seepage losses and ditch operation and maintenance expenses is being determined in a joint research project with the Agricultural Engineering Department and the Agricultural Economics Department of the New Mexico Agricultural Experiment Station. The research program will concentrate on farm ditches which total approximately 1,400 miles in New Mexico and west Texas under the Elephant Butte Dam.

To determine savings of water, and operation and maintenance costs, an intensive sampling throughout the area including sixteen case farms is being made. pertaining to:

1. Sizes of farm ditches, lined and unlined, and proportion of ditches that have been lined.

2. The proportion of farm ditches that are used as conveyance ditches and head ditches and the relative time of duration that each type of ditch is used throughout the irrigation season.

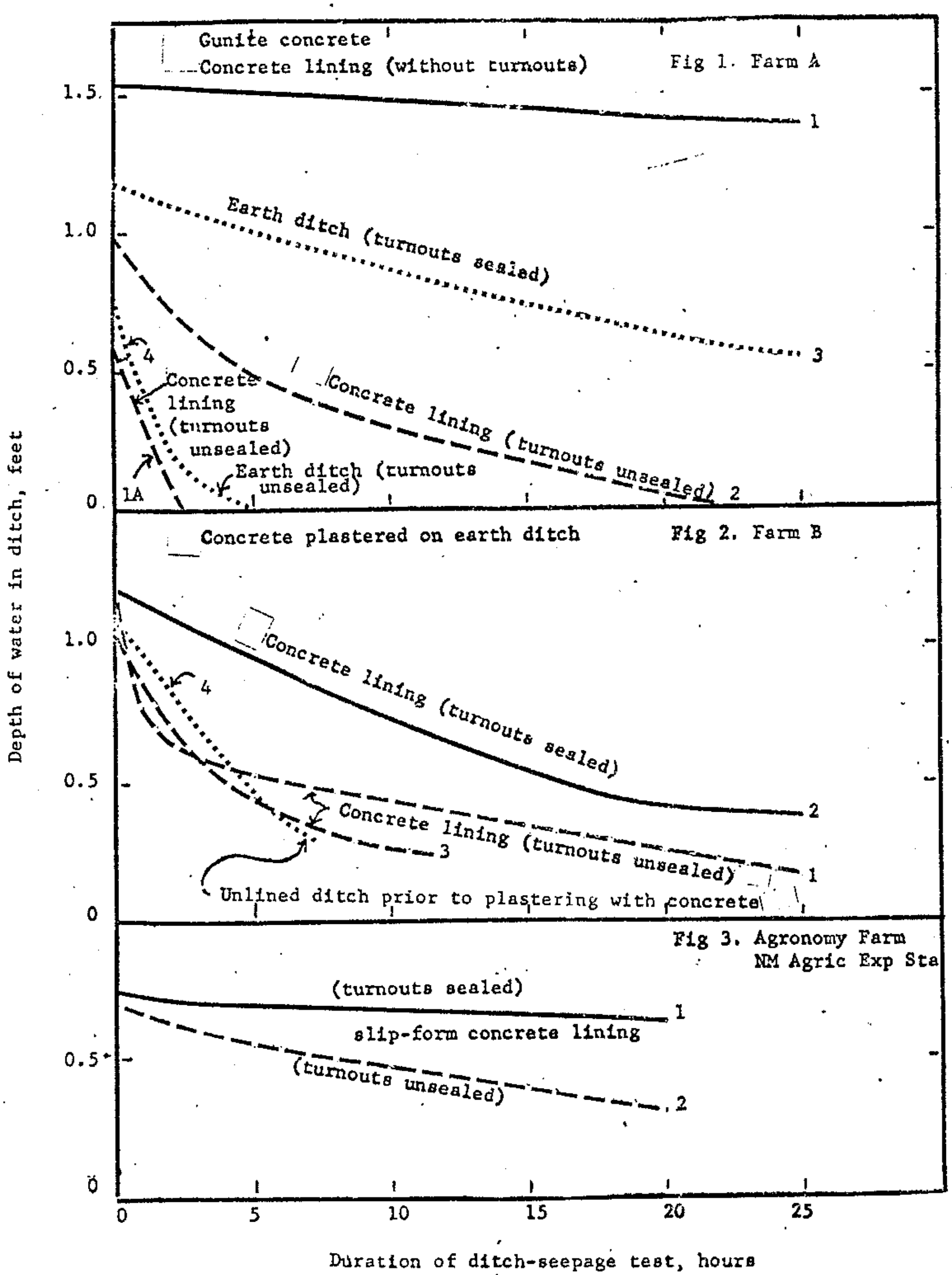
3. Savings in time, materials, and labor with lined ditches as compared to unlined.

4. Reduction of seepage losses from lined ditches by types of linings and turnouts as compared to unlined ditches.

This report presents the results of some of the seepage measurements which have been made. All of the seepage measurements have been made with water stage recorders placed in dammed sections of farm ditches. Figures 1 through 3 present the results of seepage measurements on some of the ditches from three farms.

In Figure 1 for farm A, curves 1 and 1A pertain to two adjacent sections of the same ditch. Curve 1 represents rate of loss in a section that had no turnouts and curve 1A shows the loss measured in a section with turnouts closed but not sealed. The loss from the section with turnouts leaking is approximately 35 times greater than that from the section without turnouts. Curves 2 and 3 compare losses from two ditches located near each other on another section of the same farm. Curve 2 for a concrete lined ditch with turnouts unsealed shows a rate of water loss to be greater than that from the nearby earth ditch indicated by curve 3. The curve for the earth ditch shows only seepage through the soil since the water surface was not sufficiently high to leak through the turnouts in this test. Curve 4 shows

1/ Head of Agricultural Engineering Department, New Mexico State University



Gunite concrete
Concrete lining (without turnouts)
Fig 1. Farm A
1.5
1.0
0.5
0
1
Earth ditch (turnouts sealed)
3
Concrete lining (turnouts unsealed) 2
4
Concrete lining (turnouts unsealed)
1A
Earth ditch (turnouts unsealed)
Concrete plastered on earth ditch
Fig 2. Farm B
Concrete lining (turnouts sealed)
2
Concrete lining (turnouts unsealed)
1
3
Unlined ditch prior to plastering with concrete
Fig 3. Agronomy Farm NM Agric Exp Sta
(turnouts sealed)
slip-form concrete lining
(turnouts unsealed)
Depth of water in ditch, feet
0
5
10
15
20
25
Duration of ditch-seepage test, hours

the seepage rate in a nearby earth ditch from which water was leaking through unsealed turnouts. A comparison of curves 1A and 4 shows a rate of water loss from the lined ditch to be greater than the loss from the unlined ditch.

In Figure 2 for farm B, curves 1, 2, and 3 represent three adjacent sections of a concrete lined ditch which has been plastered with concrete by farm labor. The center section (curve 2) had turnouts sealed and the sections on either side (curves 1 and 3) had turnouts unsealed. The losses from the unsealed sections were more than four times as great as those from the sealed section. Curve 4 represents seepage losses from the ditch as it existed without lining approximately one year before the concrete lining was installed. Soil had been packed by each turnout when this test was made.

Figure 3 shows losses from a concrete lined ditch which was constructed with the slip-form method on the agronomy farm of the New Mexico Agricultural Experiment Station. The seepage loss from the section of the ditch with turnouts unsealed (curve 2) is more than three times as great as the loss from the section with the turnouts sealed (curve 1). The slope of curve 1 on this figure is approximately the same as that of curve 1 in Figure 1 where the ditch had no turnouts. This slope represents approximately the minimum rate of loss that has been measured to date on all farms.

These figures emphasize the need for better low-cost turnouts, and greater care in installing linings and turnouts when lined ditches are constructed.

A summary of 69 tests to date shows that 69 percent of the total losses from lined ditches occurred through leaking turnouts, and in unlined ditches, 62 percent leaked through turnouts. The high rate of leakage through turnouts has largely cancelled the water-saving potential of existing lined ditches. The average losses from lined ditches with turnouts unsealed were only 21 percent lower than losses from unlined ditches with turnouts unsealed. A summary of measurements from the better lined ditches shows that reasonably good concrete linings with "above average" turnouts in the areas where the measurements were made, have a potential of reducing seepage to about one-tenth that occurring in existing unlined farm ditches with unsealed turnouts. The better lined ditches without turnouts, which may be used with siphons, have a potential for reducing the losses to approximately one-thirtieth of the rate occurring from unlined ditches with turnouts unsealed. The reduction of losses would be considerably higher if lined ditches were built with the quality of the ditches which are represented by the curves showing the minimum seepage losses in Figures 1 and 3.

WATER--ONE OF THE MOST SERIOUS PROBLEMS CONFRONTING THIS PART OF THE NATION

Senator Clinton P. Anderson[1/]

I am especially pleased to participate this evening in the New Mexico Water Conference. You are dealing with one of the most serious problems confronting this part of the nation. But, your accomplishments in the water field will have an impact far beyond the borders of our own Southwest. I say this because the basic knowledge that you gain and the application of that knowledge to achieve practical solutions is applicable to many other areas of this continent and the rest of the world.

Your conference is dedicated to the exchange of information and the cross-pollination of ideas. This process of exchange is fundamental to the advancement of science and technology. Without it, the solution to problems would never come within reach.

Another reason for this conference is to promote cooperation among many professional disciplines because the water problem is so complex that it defies easy assignment to one specialty. And, in the same way, there must be cooperation among the states of a region because the problems involved in water extend beyond state lines.

I think Harold E. Thomas and Luna B. Leopold said this quite clearly in their recent article in "Science." They wrote:

> "Water habitually does not subscribe to our efforts at compartmentalization according to special interests in irrigation, industrial use, recreational use, municipal use; or to allocations of fields for the chemist, for the geologist, for the sanitary engineer, for the physicist, for this or that government agency, any more than it does to separation into areas bounded by property lines, county lines, state lines, or even some river basin boundaries. As the areas of heavy demand expand toward each other and the necessity for water management increases, these artificial boundaries and classifications will have to yield more and more to the realities of the hydrologic cycle."

Additionally, the projects which we hope will assure the water essential to water needs are vast enterprises; and if they are to be successful, they require the mutual effort of several states.

1/ Senator from New Mexico, Speech given at New Mexico Water Conference Banquet.

This is the kind of joining of hands proposed in the Pacific Southwest Water Plan, which is now under review by the Bureau of the Budget. In the words of the Department of the Interior, the plan proposes that "the States of the Pacific Southwest put aside the long and wearisome controversies that have plagued Lower Colorado Basin development for over half a century, a unite in support of a broad regional approach to assure that water as required would be developed and made available to meet all needs within the region wherever they occur."

And those needs grow greater each day. Population of the Pacific Southwest, now in the neighborhood of 11 million, is forecast to multiply threefold by the year 2000. I need not ask: Are we prepared for such a growth? Obviously, we are not; and far-sighted planning and far-reaching action are needed now.

The cost of the portion of the Plan proposed for immediate authorization is estimated to be $1,704,000,000 of which 92 percent would be fully reimbursable. The total construction cost of the entire initial Plan--to meet just the most immediate needs--is estimated at $3,126,000,000 of which 95 percent would be fully reimbursable. While these costs may seem high, they are modest in relation to the value of the extensive and diversified economy of the five-state area.

We cloud-watchers in Congress who come from the Southwest must debate long and hard with our friends from the rest of the country over support for reclamation. But, I believe the economic facts favor us.

Soon after the Reclamation Act of 1902 brought the Federal Government full square into the water development picture, the Carlsbad and the Rio Grande projects were authorized. Today, they furnish irrigation for nearly a quarter of a million acres of land and provide municipal and industrial water--as well as some electric energy--for the area. The cumulative gross value of crops grown on these projects over the years amounts to nearly 39 times the cost of construction of the projects. Other returns, in the form of taxes generated by development in the area, and industrial and transportation profits would materially increase that figure. This is wise use of available water.

But the Rio Grande, the San Juan, the Pecos and the Canadian rivers, and our ground-water basins underlying the Mimbres and Roswell areas are very close to--or beyond--full development for appropriation and use. After completion of the San Juan-Chama and Navajo Indian projects, and after the building of Hooker Dam on the Gila River, there will be only a relatively few, relatively small, water projects remaining to be developed in New Mexico.

Incidentally, I understand that a week from today bids will be opened on the contract for construction of Azotea Tunnel, the first and probably the biggest job of the $86 million San Juan-Chama project. The Bureau of Reclamation expects to call for bids on a contract for more tunnels in about December, and the one for the final tunnel will in all probability be let next year.

We know that present and impending population growth is rapidly outstripping available water resources. The University of New Mexico's Bureau of Business Research estimates that our population, which grew from 530,000 in 1940 to 960,000 in 1959, will grow about 2-1/4 million by 1980. What does that mean in terms of our water problem? In 1959, State Engineer Steve Reynolds estimated that about 125,000 acre-feet of water was being withdrawn for municipal and industrial uses. With the prospect of population more than doubling by 1980, it is a very conservative view to expect at least a doubling of the 125,000 acre-feet for municipal and industrial use. Those figures, it seems to me, typify New Mexico's water problem. What can we do to get practical solutions?

One of the key recommendations of the Senate Select Committee on National Water Resources was for markedly increased research in all phases of water resources conservation and development. That certainly makes sense in this state. New Mexico's average annual precipitation is about 90 million acre-feet; but the runoff from our watersheds averages only slightly more than 3 million acre-feet per year. We are not getting the greatest possible use out of the 90 million acre-feet of precipitation that we should.

We know, for example, that we have only begun conservation of water lost through evaporation from the surface of reservoirs and from the lands. That loss is estimated at 332,000 acre-feet annually--more than double the withdrawal for municipal and industrial use.

We have only begun to salvage the water lost through nonbeneficial phreatophyte growth in the stream courses and low lands. But we are making some headway. A major program of channelization, carried on by the Bureau of Reclamation since 1951, has saved approximately 700,000 acre-feet of Rio Grande water. Estimates are that when the work is completed about 100,000 acre-feet will be saved annually. Poured into an empty Alamogordo Dam, this amount of water would leave it more than three-quarters full.

We have only begun to conserve the water lost through seepage from the canals and ditches in the valleys. Seepage is a real villain in the water story. Irrigation systems on farms are estimated to deliver only about two-thirds of the water diverted into them, and the application efficiency is rated at anywhere from 65 percent down to 35 percent.

The Senate Select Committee on National Water Resources identified 18 major subjects on which additional research is needed for improved water conservation and utilization. I believe that such research into every one of those subjects is pertinent in New Mexico.

Let me digress a bit to illustrate why I have confidence in the promise of research. Some years ago, I sponsored legislation to authorize the Department of the Interior to construct and operate saline and brackish water conversion demonstration plants. Some of us in Congress felt that 1960 was not one bit too soon to start acquiring information and competence in the construction and operation of large-scale conversion plants. But there were others who thought that this was unrealistic and visionary.

As you are all aware, about two months ago Cuba shut off the flow of fresh water to the United States Naval Base at Guantanamo. Within 48 hours the Navy arranged to move the Interior Department saline water demonstration plant--built under the 1958 legislation--from near San Diego to Guantanamo. The year of operating the plant showed that not only is it capable of producing the one million gallons of water per day for which it was designed; but that, in fact--by improved operating procedures--the plant is actually capable of producing about 50 percent more than its design capacity. As a consequence of what some people considered was impractical just a few years ago, the Navy will have a saline water plant capable of supplying a substantial part of the fresh water requirement at Guantanamo.

If Congress approves, another demonstration plant will be built at San Diego designed to operate at higher temperatures than any of the other demonstration plants.

While I am on this subject, I will mention that the Interior Department is now giving very active consideration to a research proposal from Dr. N. N Gunaji of the New Mexico State University. His proposal involves the utilization of solar energy in connection with the brine effluent from the Roswell desalting plant.

In October 1962, here at State University, I joined in the observance of the 100th Anniversary of the establishment of Land Grant Colleges. My remarks to that centennial celebration touched briefly on the past century of the land grant colleges and, at somewhat greater length, looked forward to their next century. The land grant colleges' great contributions to increasing agricultural productivity, I suggested, can be matched in the years ahead by equally great contributions in other resources fields. One of these is water resources.

Toward that end, I sponsored a water resources research act in 1962. This bill was circulated among experts in the field of research and education for their advice and suggestions for perfecting it. Early in 1963, I introduced the improved bill known as S. 2. The bill was passed by the Senate last April. A more limited bill has been reported out of the House Interior Committee. I am hopeful that a measure will be formulated acceptable to both Houses of Congress and to the President and that action may come early enough to permit at least a modest start in the universities next fall.

Some people ask what university water research will do that is not being done by the eight major Federal agencies engaged in such activity. And they also ask how much larger the total program of water resources research should be. In the year ending June 30, Federal support of water resources research will total about $71 million, and about $73 million is requested for next fiscal year.

Isn't that large amount enough? Well, let's do some comparing. The proposed $73 million for water research is less than 6 percent of the $1-1/4 billion per year that the Federal Government now spends on national programs of water conservation and development. It is only 7/10ths of one percent of the approximately $10 billion that is spent each year for Federal, state and local goverment and private water facilities; about double that rate of annual expenditure for water facilities will have to be made to meet water needs. In contrast, the oil and gas industry annually spends about 3 percent on research and development, in the chemical industry the figure is about 6 percent, and in the automotive industry it is around 12-1/2 percent. Less than one percent for water research is too little.

If water research expenditures were only 3 percent of the present $10 billion annual expenditure for water facilities, it would be $300 million, or more than three times the present water research program. It seems to me that water research activities are not by any means overly endowed. If research enables us to improve the efficiency of water conservation and development by only five percent, it could reduce our annual capital investment in water facilities by $500 million alone.

One major difficulty in expanding water resources research activities, however, is that qualified research people are in short supply. In this matter, universities are eminently well suited to produce the needed research personnel. Universisites can do this in the field of water resources in the same way that they have done it in agriculture, or nuclear energy, or the space sciences--by training graduate students through association with the research work of senior faculty scientists.

Even more than the size of the water resources research program, we are concerned with the character of the research. The water research programs of the Federal agencies, in general, are excellent.

There are, however, certain limiting characteristics built into Federal research programs. The research done by Federal agencies, quite properly, is directed to national rather than to local problems. While this provides the technical basis for national programs, it is not well suited for solving the specific problems that are important to specific localities--the Roswell Basin, or to the Mesilla Valley, or the Estancia Valley, for example. Such specific problems are understood best by research workers who are smiliar with the special physical and economic characteristics of the local situation. I believe that many such specific problems can be worked out best by a combination of the broad general research results obtained from nationwide investigations together with their specific application to local areas.

University research can make another important contribution more readily than can most Federal agencies. Increasingly, water resources problems are not just engineering problems or just legal problems, or problems amenable to any one technology or any one scientific discipline. Solution of almost any major water problem now requires a mixture of engineering, biology, hydrology, law, chemistry, economics and other technical subjects. Although the multidisciplinary character of water matters is generally an accepted fact, few, if any, Federal agencies are in a position to deal with them in those terms. This is a limitation that is built into most of the agencies, and not much can be done to modify that aspect of agency organization.

Universities, on the other hand, embrace many disciplines by their very nature. Most universities have on the same campus faculties representing some or all of the elements involved in water problems--engineering, law, the physical, biological, and social sciences, and other branches of knowledge. This makes for an ideal setting for water resources research. At a number of universities there is encouraging evidence that cross-discipline seminars and research teams already are coming to grips with water resources matters.

It seems to me that the water resources research centers to be supported under the proposed legislation would be one of its major accomplishments. Such centers could be influential not only in university research; they should also be influential in orientation of the new crop of water scientists who will receive advanced training in a multidisciplinary climate. Furthermore, through research work under the auspices of those centers, badly needed new research methods intertying various callings should become widely available to others, including the Federal water resources agencies.

A realistic view of the universities in most states reveals that many of them are equipped with faculty competence in less than the full range of subjects that are needed for effective, broad-gauged research. The systems of higher education of many states are geographically dispersed through the state. Generally, there will be several more or less coordinated educational institutions in each state, often with some specialization at each institution. One university will have a strong college of law, another will have a strong college of medicine, one may be strong in economics and other social sciences, while engineering and physical sciences may be dominant elsewhere.

To a considerable degree this is the situation in a number of the western states, including New Mexico. It will be extremely important that in each state ways be worked out to assure the full participation in the water research program of all the institutions of higher education. That will be necessary in order to conserve and take full advantage of limited resources of competent manpower. I certainly hope that this will be in the pattern in New Mexico.

This brings me to a final comment on water resources research. In addition to stressing the need for more research, the Senate Select Committee on National Water Resources strongly recommended comprehensive river basin planning as essential for full conservation and use of our limited resources. President Kennedy accepted that recommendation and he directed the Federal executive agencies to carry out their responsibilities in that undertaking. Congressional authorization is necessary especially to provide for appropriate participation by the state and local governments. I intoduced S. 1111 in this Congress to provide such authorization. It passed the Senate last December, and is now pending before the House of Representatives. I hope that early enactment of the measure will clear the road for vigorous progress in the much needed Federal-State river basin planning work.

The specific point I make in this connection is that effective river basin planning will need to rely heavily on knowledge and understanding of water resources, and that means that there will need to be a considerable involvement of research workers in the planning activities. The water resources research centers at the universities, I am confident, will have an important role in river basin planning.

Some years ago, Dr. Warren Weaver, then vice-president of the Rockefeller Institute, said that science cannot avoid being practical. By that he meant that research that adds to our knowledge and understanding becomes a basis for some applied use--just as theoretical physics became the basis for the great developments in nuclear energy. I am confident that university research, both basic and applied, will make important contributions to solving water resources problems, and I am confident that New Mexico's institutions of higher education will participate fully in this effort. I come here to wish you well in that endeavor.

RESEARCH IN CHEMICAL LAND TREATMENT FOR WATER CONSERVATION

John C. O'C. Young[1]

I would like to begin by thanking your organizing committee for this opportunity to talk to you about some of my Company's activities in the field of water research.

Specifically, I have been asked to outline our work on "the chemical treatment of land for water conservation." Within this broad frame of reference, I propose to outline four of our many studies relating to the development of new water sources and the more efficient utilization of existing supplies.

The first of these studies is concerned with the retardation of moisture losses, the second with increasing runoff and the third with the stabilization of windblown sands. The fourth aims at doing all of these things and something else as well.

Starting, then, with moisture loss retardation; in this area, I have chosen to talk about our efforts to develop cheaper and better canal linings to reduce the dual problems of water loss and damage to the surrounding land.

Our laboratory and field studies have led to the development of stabilized butyl rubber formulations which make highly durable sheet linings for canals at reasonable annual cost levels. Currently, we are working to develop even better and cheaper lining materials: one experimental product has shown considerable promise and is now being evaluated by the Bureau of Reclamation at Denver.

My second topic, our work on techniques for increasing runoff, centers on the concept of the Artificial Watershed. As you know, the water-producing efficiency of a natural watershed is usually quite low, because most of the precipitation falling upon it is returned to the atmosphere by evaporation and evapo-transpiration from vegetation. This situation is generally quite tolerable because our natural watersheds provide many other benefits besides water.

However, in areas in which water supply problems grow daily more critical, there is an increasing justification for using land solely or primarily for water production purposes: such a situation has existed for many years in several Caribbean Islands, where land has been cleared and water-proofed with concrete to provide water collection surfaces that harvest essentially all of the rain falling upon them. The runoff is collected and stored in surface tanks until required. Needless to say, water supplies obtained in this way are quite expensive.

1/ Chemical Engineer, ESSO Research and Engineering Company, Linden, New Jersey

In 1957, we initiated a project to reduce the cost of obtaining water from an Artificial Watershed. We hoped to develop cheap bituminous coating materials that could be sprayed directly on the ground to produce durable water collection surfaces. We now have promising materials, plus the application techniques and spraying equipment necessary. One outcome of this work is the 10-acre watershed that we have recently installed near Las Cruces in cooperation with the U. S. Geological Survey.

Besides these spray coatings, we have also developed sheet-liners for watersheds. Stabilized butyl rubber formulations are used for this purpose, and they have been shown to make very durable collection surfaces. Some 30 such sheet-lined watersheds have already been installed in cooperation with the USDA in several western locations. Incidentally, I might mention that the Artificial Watershed has recently been approved for up to 60 percent Federal cost-sharing in part of Wyoming.

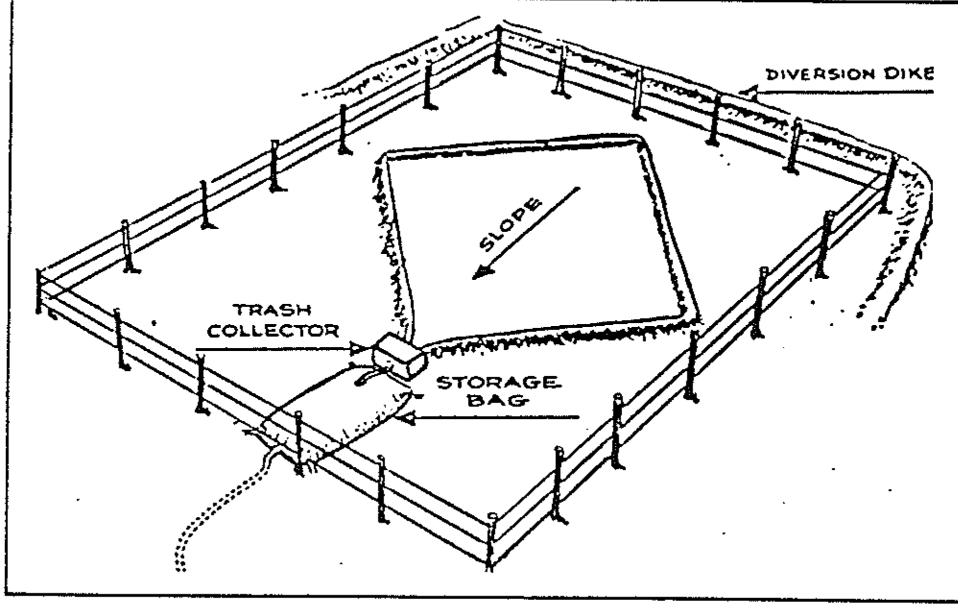
We envisage two major applications for the Artificial Watershed. Small units of the type shown in Figure 1 could provide stock-water supplies: this installation consists of a sprayed or sheet-lined catchment area, a butyl water storage bag and a drinking trough (not shown). On a more grand scale, large areas of natural watershed could be spray-coated to augment stream flows, or to reduce well drafts and salinity by ground-water recharge of the water harvest.

In conclusion of this section of my talk, I'd like to give you some idea of the cost of obtaining new water supplies from an Artificial Watershed. This will clearly depend on the cost of the coating material, the size of the installation, site factors and local rainfall level. However, rough estimates for this and other methods of obtaining new water supplies are given in Figure 2. We believe that small supplies for stock watering might be obtained at less than 50¢/M gal., exclusive of cost-sharing benefits. For larger installations, this cost should be between 10 and 30¢/M gal., based on the use of spray coatings in both instances.

My third topic concerns the techniques we have developed to stabilize windblown sands. For several years now, we have been studying the problems of stabilizing Maritime and Continental dunes with a special oil. Quite recently, we carried out an extensive series of field tests in Libya to prove out our specially designed spray vehicle and methods of application. This vehicle, which is shown in Figure 3, can carry a 4-ton load of coating material up a soft sand slope of 20° and can typically stabilize 15 acres of dune per day. Using proper methods, it appears that satisfactory stabilization can be achieved using only a few hundred gallons of oil per acre. Our experimental work on this project should be completed shortly.

My final topic concerns the idea that retards moisture losses, increases runoff, stabilizes windblown sand and does something else as well. That something else is Weather Modification to increase rainfall--artificial rain-making, if you like.

1. ARTIFICIAL WATERSHED LAYOUT



2. COMPARATIVE COSTS OF OBTAINING NEW WATER SUPPLIES

METHOD	¢/M GAL.
TANK CAR TRANSPORTATION	200-500
DESALINATION	50-200
ARTIFICIAL W/S (STOCK PONDS)	40-50*
SURFACE WATER DEVELOPMENT (NEW PROJECTS)	30-40
ARTIFICIAL W/S (LARGE SCALE)	10-30*

* COSTS QUOTED ARE FOR BITUMEN SPRAY COATINGS

The principle involved is illustrated in Figure 4. I am sure that you have all seen thermal up-currents rising above a road on a hot day. These thermals form because a black surface is a particular strong absorber of the sun's energy, which it then re-emits as long-wave radiation causing strong heating of the air above.

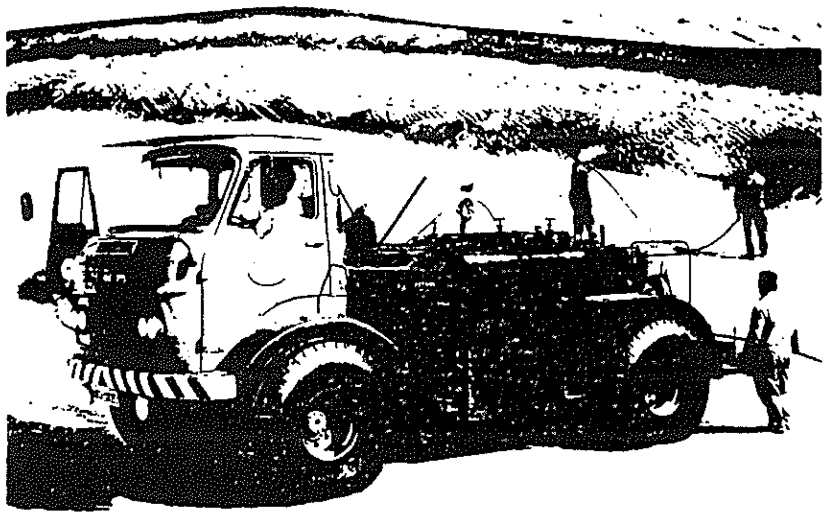
If we were to construct a very large black surface of perhaps 20-100 square miles, we could create a large, strong convective up-draft. If warm moist air were present at ground level, the updraft would carry it from ground level up to higher and cooler altitudes. If the lifted parcel of air were cooled sufficiently, condensation would occur leading to cloud formation and rain--and there you have it--artificial rainmaking.

To do this, we need to lay down a coating to blacken, seal and stabilize the soil. Any rain falling on the coating could be collected to provide bulk water supplies. However, it is anticipated that the major part of the additional rainfall induced will fall downwind of the coating, raising the annual precipitation level in the surrounding area.

We are currently carrying out computer studies of the meteorology of this concept and are developing cheap coating materials and application techniques. We are quite hopeful that we may be able to carry out a 20-50 square mile pilot demonstration of the idea in the near future.

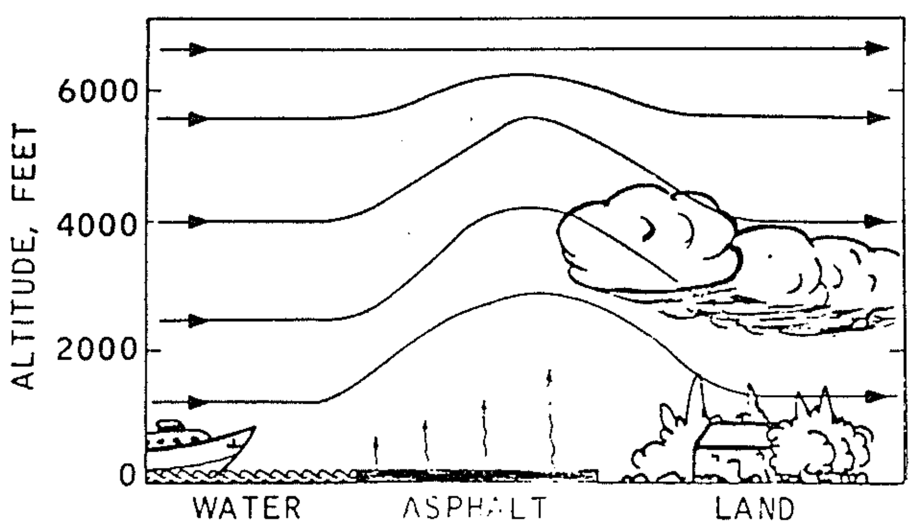
Summing up, I have made brief reference to some of our activities in the field of water research. I have mentioned our canal lining materials, our water harvesting techniques to produce new bulk water supplies, our dune stabilization work and our large-scale Weather Modification Project.

3. DUNE STABILIZATION SPRAY VEHICLE



DOUGLAS 4 X 4 VEHICLE - SPRAYING OPERATION

4. PRINCIPLE OF WEATHER MODIFICATION SCHEME



DETERGENTS AND WATER

W. K. Griesinger[1/]

One of the blessings of civilization is the appreciation of cleanliness and to most people this means soap and water, or in today's world more correctly detergent and water. For out of the turmoil of supply and demand associated with World War II, there came a cheap, efficient cleaner or detergent perfected almost simultaneously in the research laboratories of Germany and America and derived from an abundant raw material, petroleum.

This new detergent--Alkylbenzene Sulfonate or ABS--could be readily made from petroleum in almost any desired quantity at stable, economically attractive prices. In addition, it was more efficient than soap. It didn't form precipitates with hard water leading to the familiar ring in the bathtub. It didn't form curds in slightly acidic water. In fact, it could be used in almost any kind of water to give a solution having the same acidity (pH) as the water itself. Soap always is alkaline. This meant that detergents could be made neutral, a most desirable property which permitted their use for washing fibers like wool without causing shrinking. Also, these neutral cleaners were shown to be easier on the hands.

Finally, ABS was found to be more soluble in water than soap, and washing and rinsing processes could be carried out at lower temperatures with equal or better results.

With all these favorable features, it is hardly any wonder that within a few years after their introduction synthetic detergents largely replaced soap in the cleaning compounds sold, not only in the United States, but all over the world.

The problems of making specific products having not only utilitarian but advertising appeal were quickly solved and I am sure most of you wonder at the myriad of solutions that became evident with each season's fare of "detergent operas."

Detergents do well the job they were designed to do--Clean. But, cleaning is only the first part of the cycle involved in this wonderful product of civilization. If the subject or surroundings are to show the benefits of the operation, the grime removed and the detergent and water used have to be discarded--which is no problem if you happen to have some bottomless pit like the Pacific Ocean as the sump--and if you don't have to use the water and detergent over again.

1/ Manager of Development, The Atlantic Refining Company, Philadelphia, Pennsylvania

Speaking for the detergent industry, I can happily say that we can spare the detergent, but speaking for most of mankind, I can't say that we can spare the water.

Obviously, this is why we have waste disposal systems designed to decompose or remove the contaminants in waste water, hopefully to the point where that water is sufficiently pure to permit its reuse as is or with reasonable dilution with fresh water. Activated sludge plants, trickling filters, septic tanks and cesspools are of course typical systems for carrying out this process with varying degrees of efficiency.

Soon after detergents were introduced it became apparent that something different was happening in the country's waste disposal plants. Foam, that universal indicator for a surface active material, began to appear in the sewage plants themselves, in the effluent, and occasionally in some of the receiving rivers and streams. All the problems associated with sewage plant operation and water pollution were immediately placed on the culprit--synthetic detergent or ABS.

The soap and detergent industry recognized the problem and in the early 1950's formed a technical committee to study the subject and advise appropriate action.

This committee systematically looked at all the aspects of the problem and after several years of research carried out in member laboratories and at the best sanitary engineering and toxicology laboratories in the country, including M.I.T., the University of California, the University of Wisconsin, Johns Hopkins, Hazelton Laboratories, and the Philadelphia Academy of Natural Sciences came up with the following observations:

1. ABS does not interfere with the normal operation of a waste disposal system. Other organics in the system are readily decomposed in the presence of ABS.

2. ABS may cause foam in an activated sludge plant, but this foam can be controlled by the use of defoamers or water sprays.

3. Depending on the system, from 40 to 80 percent of the ABS entering the system is removed during processing.

4. Although some ABS gets through waste disposal plants, it is not building up in the country's water supplies. Continued monitoring of the Ohio and Mississippi rivers for several years showed no increase in the ABS level which was first measured at 0.16 parts per million in 1959 and has not increased since.

5. ABS can not be tasted in concentrations below 16 ppm which is of course well in excess of any concentration which might be found in water normally used for human consumption, and certainly well above the level of 0.5 ppm of ABS suggested by the U. S. Public Health Service as the upper limit for potable water.

Incidentally, the USPHS set this limit for aesthetic rather than health reasons. Water which contains more than 0.5 ppm of ABS along with other impurities may foam slightly.

6. ABS in concentrations up to 50 ppm does not impart an odor to water nor accentuate other already present odors which might be characterized as fishy, sulfidy, or chlorine-like.

7. ABS in concentrations 1000 times those which might be associated with food were found not to be harmful to either rats or beagle dogs. In the dog toxicity tests the beagles were fed about 1/4 pound of ABS over a two-year period with no harmful results. If the same ratio of detergent to body weight were applied to man and all the detergent were put in his drinking water, the man would consume about two pounds of detergent in the form of a 250 ppm water solution in the same two-year period. This is about one-half the concentration recommended for washing clothes.

8. Below 5 ppm ABS is not harmful to fish, snails or diatoms. In Santee, California, fish thrive in an artificial lake supplied with reclaimed water containing 5-7 ppm ABS.

These findings seemed to present a fairly reasonable case that ABS was not really a noxious contaminant of water. However, it does cause foam and public officials don't like the threat of foam in their drinking water and something had to be done about it.

Several approaches were suggested without too much success. These included:

(A) Replacement of the ABS with a low foaming detergent. Unfortunately, the low foamers in the washing machine give more foam than ABS upon equivalent dilution in waste waters.

(B) Redesign the waste disposal plants. Some success was achieved here but it was soon realized that anything but a simple modification to an existing plant would be too costly to be acceptable.

(C) Remove the ABS by foaming. This is successfully being done at the Whittier Narrows Water Reclamation Project outside Los Angeles, California, where water is being recharged to the ground at less than 2.0 ppm ABS and with lower than normal organic impurities. This method may offer good possibilities for removing all organic impurities from water. In this instance the problems associated with disposal of the foam containing the impurities may be substantial.

(D) Change the chemistry of the ABS so that it will be biodegradable. This approach makes the most sense and is being actively pursued by the soap and detergent industry. Research on the mechanisms of biological degradation in a waste disposal plant showed that ABS which is a highly branched organic molecule is not readily broken down by living organisms whereas similar chemicals with so-called straight chain or linear structures are more readily decomposed. Newer materials having these structures as well as the same desirable detergent properties have been synthesized from petroleum and will be offered to the consuming public possibly within the next year and certainly before December 1965, the date promised by the industry for complete conversion to the new "biodegradable product" called Linear Alkylate Sulfonate (LAS) to differentiate it from ABS.

In coming up with this new material the various members of the industry have individually spent years of independent research on the problem while working together and with the Department of Health, Education and Welfare on appropriate laboratory test methods to be used to identify acceptably degradable products. In addition, cooperative data have been obtained on the extent of biodegradability which might be expected in typical activated sludge plants and septic tanks. Whereas, in controlled field tests ABS shows an average of 50 percent disappearance, in typical installations LAS shows better than 90 percent.

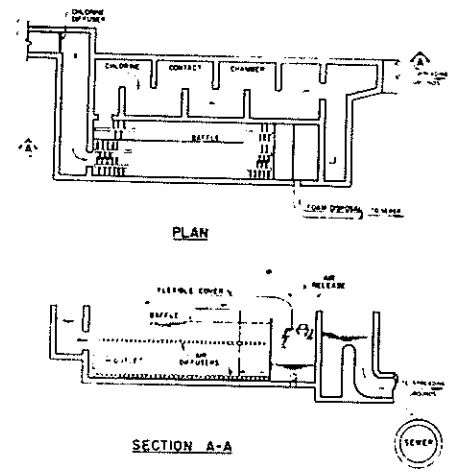
In addition to our work in the United States, we have followed closely the experiments in England and Germany. Perhaps you are familiar with the highly publicized field trials of "soft ABS" at Luton England. Here, with the use of a product probably not as good as that which we expect to produce in the United States, significantly improved but not perfect control of foaming of the effluent from the town sewage works was obtained.

The Germans have legislated soft ABS into being. We hope we can avoid this in America as legislative controls may be a detriment to progress in an industry which has never hesitated to spend money for research on better products.

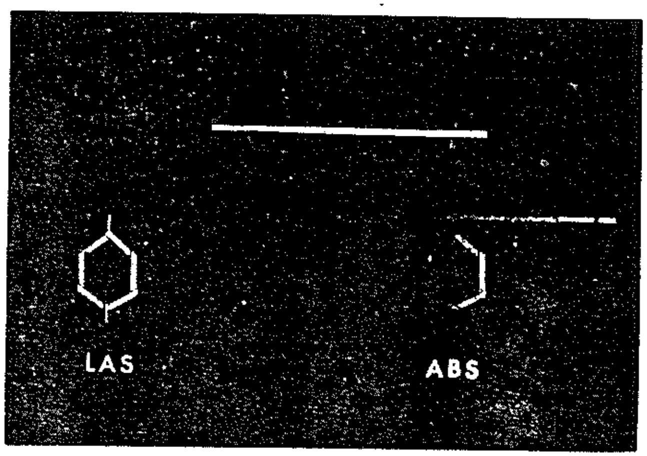
While the Europeans have been concerned chiefly with large municipal-type disposal plants, we have extended our studies to find out what happens in that almost exclusive American system--the septic

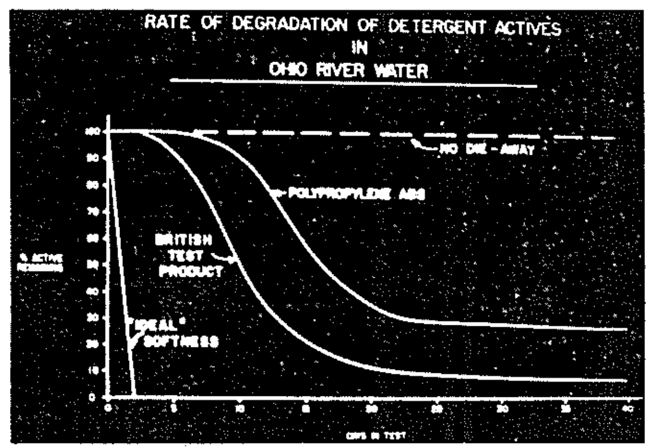
TABLE I
DEGRADATION & REMOVAL IN SEPTIC TANKS (%)

DET.	ALONE		+ FIELD	
	DEG.	REM.	DEG.	REM.
PP	3.8	16.3	60.5	78+
SC	~0	9.6	87.3	97-
ALC	21-	60.8	54.3	99.6



WHITTIER NARROWS WATER RECLAMATION PLANT
FOAM FRACTIONATION PROCESS
FOR REMOVAL OF ALKYL BENZENE SULFONATE (ABS) DETERGENTS





tank. This work was done at the University of California and points out that these new biodegradable materials only disappear satisfactorily in an aerobic system. A septic tank with a properly designed tile field is aerobic.

In an anaerobic system which is typical of a cesspool or septic tank operation discharging directly into the ground water without an intervening tile field, little if any degradation of LAS, ABS or other organics is found to occur. Such a system can not be considered an adequate waste disposal operation. In fact, we in the detergent industry see no easy or cheap answers to sloppy or inadequate waste disposal systems. ABS has been a very effective indicator of contamination in such systems and whereas we have seen that it in itself was not harmful, the same can not be said for the other contaminants which may have accompanied it. The foam on contaminated water raised the flag of caution. Who is going to question the same water when the indicator is gone?

We in the detergent industry feel that in changing our products at a great capital expense to the producers, but at no extra cost to the consuming public we have done our part in helping to keep the Nation's water clean. We hope in turn the public will also recognize its responsibility and provide the necessary and proper waste disposal facilities to insure that waste water capable of purification can be properly reclaimed. After all, detergents need clean water too.

USES OF MONOMOLECULAR FILM TO REDUCE EVAPORATION ON THE ELEPHANT BUTTE RESERVOIR

Narendra N. Gunaji[1/]

INTRODUCTION

The increasing population of our planet, Earth, and the ever increasing standards of living have precipitated in a growing demand for water. In 1950, over 175 billion gallons of water were used daily in the U. S. This figure jumped to 220 billion gallons per day in 1955. This was over 20 percent increase in five years. It is estimated that by 1985, the daily demand for water in the United States will reach 600 billion gallons, which is almost double the demand that exists today.

We receive about 20 percent of our water resources from ground water and 80 percent from surface supplies. Twenty-five years from now, a significant proportion of our water will come from desalinization plants and reclamation of waste water. In conserving our water resources, attempts are in progress to develop methods of suppressing evaporation from reservoirs. The research efforts so far indicate that the conservation of water by evaporation reduction may be economically possible.

The loss of water by evaporation from inland reservoirs is considerable. The water lost to the atmosphere by evaporation in eleven western states, exclusive of Alaska and Hawaii, amounts to 11.5 million acre-feet a year, enough to supply the municipal needs of San Francisco for about 90 years. Evaporation losses are quite significant in New Mexico when considered in connection with the present drought conditions and supply of irrigation water in the Lower Rio Grande Valley. In this valley, the water line divides the rich land from waste land and distinguishes prosperity from economic failure. Every citizen in this region is aware that water is the key to the present and future economy.

At Elephant Butte Reservoir, which is a source of water for the Lower Rio Grande Project, the record from evaporation pan shows an average annual loss by evaporation of 99.561 inches. By using the correction coefficients of pans, the estimated annual evaporation from Elephant Butte Reservoir is approximately 75 inches. The surface area of the reservoir, at the normal level, when 1,250,000 acre-feet of water are in the lake is 27,000 acres. The normal loss of water from Elephant Butte Reservoir by evaporation therefore, is 162,000 acre-feet annually, an amount sufficient enough to irrigate an additional 50,000 acres. In fact, the suppression of evaporation from Elephant Butte Reservoir will be a blessing to

1/ Associate Professor of Civil Engineering Department, New Mexico State University

the Lower Rio Grande Project when viewed in the light of past and present droughts. The results of our study of evaporation suppression could lead to a partial solution of domestic and international water problems in our region.

MEASUREMENT OF EVAPORATION

The process of evaporation, viewed as a problem in turbulent transfer in the atmosphere, has been marked by little influx of new ideas except through the related problems in heat and momentum transfer. Consequently, the practical approaches to the determination of evaporation still lie along two main paths. The first approach concentrates attention on the mechanism of removal of the fluid vapor by diffusion and is primarily applicable to the determination of evaporation rates. The second approach does not require any knowledge of the details of the evaporation process but relies on estimating the amount of energy used in the change from liquid to vapor phase, and, hence, the rate at which water is being removed. The two approaches are referred to as "mass-transfer" and "energy budget method," respectively. In each of these approaches, some assumptions are required to be made relating to the transfer mechanism for fluid vapor to that of heat or momentum. This is likely to remain the situation until direct measurement of evaporation by method of heat energy flux is more widely explored. So far, such measurements of evaporation have tended to lag behind those of heat and shear stress on an air-fluid surface.

ENERGY BUDGET METHOD

The energy budget approach to measure evaporation was first applied by Schimdt (1), in 1915, to estimate annual evaporation from the ocean. Richardson (2), in 1931, applied the conservation of energy principle to evaporation of lakes. Extensive investigation of the energy budget method for estimating evaporation was conducted in 1952-53 on Lake Hefner (3). The results of the Lake Hefner studies illustrated that evaporation from reservoirs could be accurately determined by the energy budget method. This method has since been used to determine evaporation from several lakes.

The energy budget method is fundamentally an application of the principle of conservation of energy. The principle may be applied to a reservoir to determine evaporation. Basically, it means that the energy which comes into a reservoir must equal the gain in stored energy plus the amount of energy leaving the reservoir. Incoming energy to a reservoir comes from the sun, atmosphere, rainfall and surface run-off. Outgoing energy goes into radiation, heat conduction, evaporated water and surface outflow. The energy budget equation can be stated as:

$$Q_s - Q_r + Q_a - Q_{ar} + Q_v - Q_{bs} - Q_e - Q_h - Q_w = Q_0 \qquad (1)$$

where:

Q_s = Solar Radiation Incident on Water Surface (cal/cm^2 day)
Q_r = Reflected Solar Radiation (cal/cm^2 day)
Q_a = Incoming Long Wave Radiation from Atmosphere (cal/cm^2 day)
Q_{ar} = Reflected Long Wave Radiation (cal/cm^2 day)
Q_{bs} = Long Wave Radiation Emitted by Body of Water (cal/cm^2 day)
Q_e = Energy Used in Evaporation (cal/cm^2 day)
Q_h = Energy Conducted from Body of Water as Sensible Heat (cal/cm^2 day)
Q_v = Net Energy Advected into Body of Water (cal/cm^2 day)
Q_w = Energy Advected by Evaporated Water (cal/cm^2 day)
Q_o = Increase in Energy Stored in the Body of Water (cal/cm^2 day)

Heating due to chemical changes, biological processes are neglected as is the component which pertains to energy transfer into and out of the shores and bottom of the reservoir. These components are small for large reservoirs when compared with other terms in the heat energy equation.

To determine energy used for evaporation (Q_e), one needs only to rearrange equation (1) and substitute the following functional relations:

$$\beta = \frac{Q_h}{Q_e} \tag{2}$$

where β is Bowen Ratio (4) defined as the ratio of sensible heat to energy used in evaporation.

$$Q_w = \frac{C_p Q_e (T_e - T_b)}{L} \tag{3}$$

where: C_p = Specific heat of water (cal/gm^{o}C)
L = Latent heat of vaporization (cal/gm)
T_e = Temperature of Evaporated Water (0_c)
T_b = Temperature of arbitrary base (0_c). Usually taken as 0^o Co

The resulting relation for evaporation energy is:

$$Q_e = \frac{Q_s - Q_r + Q_a - Q_{ar} - Q_{bs} - Q_o + Q_v}{1 + \beta + \frac{C_p (T_e - T_b)}{L}} \tag{4}$$

When all quantities on the right hand side of equation (4) are measured, evaporation can be determined for any length of a time period. The energy budget used to determine the evaporation from reservoirs is not considered accurate for periods shorter than ten days because of the accuracy of measurement of some of the items in equation (4). This limitation was verified in the Lake Hefner Investigations (3).

INSTRUMENTATION FOR ENERGY BUDGET STUDIES AT ELEPHANT BUTTE RESERVOIR

Various instruments are needed to determine the quantities in the heat-budget approach to determine evaporation. An energy budget station is maintained on the west side of the Elephant Butte Reservoir at Long Point. The station consists of radiation instruments, thermocouple psychrometer, rain gages, wind vane, wind anemometer, Cummings Radiation Integrator and a house trailer to hold the potetiometric and portable recorders as well as to serve as a field workshop and storage facility. The following variables are observed on the three recorders housed in the air-conditioned trailer:

1. Epply pyrheliometer
2. Flat plate radiometer
3. Relative humidity
4. Flat plate temperature
5. Dry bulb temperature
6. Wet bulb temperature
7. Humidity air temperature
8. Surface temperature in CRI
9. Bulk temperature in CRI
10. Wind velocity
11. Wind direction

SOLAR RADIATION - Q_s

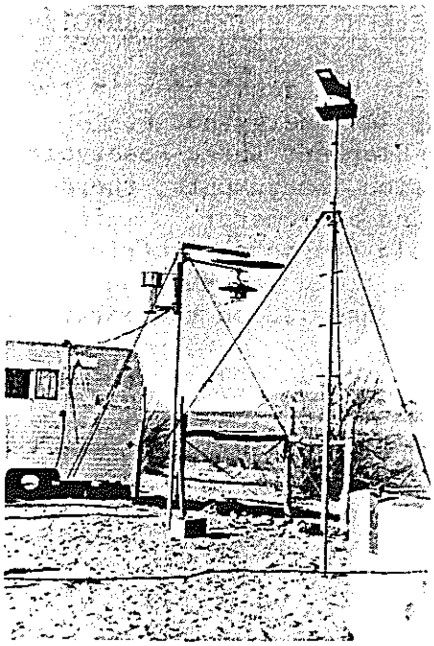
Solar radiation, Q_s, is measured with an Epply Pyrheliometer located at the energy budget station. This instrument is placed at the top of a 15-foot pole. The milivolt output from the pyrheliometer is directly recorded in cal/cm^2 on the recorder.

REFLECTED SOLAR RADIATION - Q_r

The quantity, Q_r, will be indirectly obtained from solar radiation measurement using the method postulated by Koberg (5). Koberg has developed the relationship between reflected solar radiation and incoming solar radiation for clear and cloudy days. A clear day is defined as one in which the ratio of solar radiation to clear-sky radiation exceeds 0.8 and a cloudy day is one in which the ratio is less than 0.8.

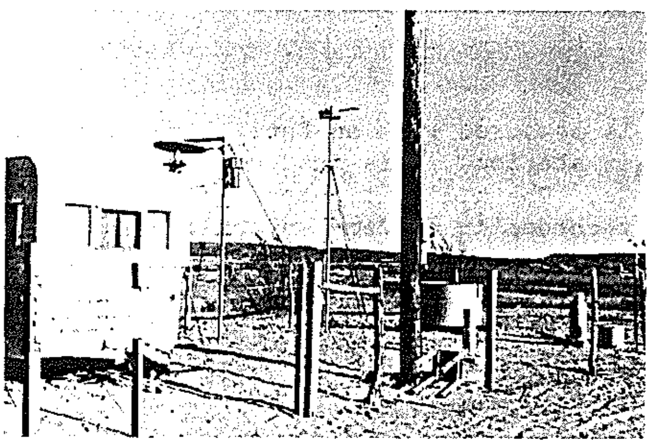
ATMOSPHERIC RADIATION - Q_a

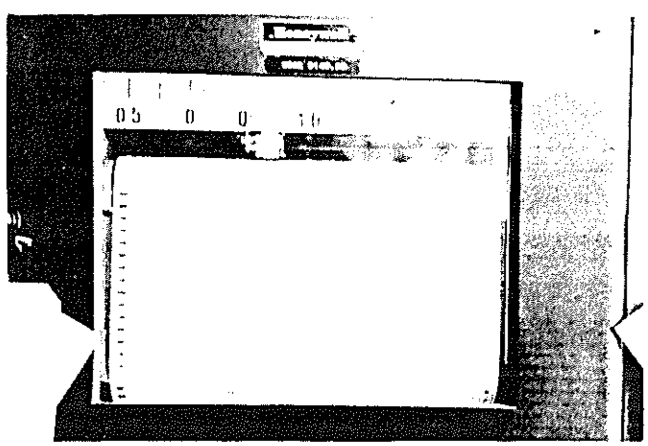
The incoming atmospheric radiation, (long wave), Q_a is measured by a flat-plate radiometer. This instrument is also mounted at the top of a 15-foot pole. The output is directly recorded on the recorder in cal/cm^2.



Instruments Used at Elephant Butte Reservoir to record data in evaporation control.

Experiments Sponsored By:
U. S. Bureau of Reclamation





REFLECTED ATMOSPHERIC RADIATION - Q_{ar}

The reflectivity of water surface for atmospheric radiation is about 3.0 percent for a water temperature range of 0^oC to 30^oC as shown by measurements of Gier and Dunkle (6). This quantity will be evaluated after sufficient data are accumulated.

LONG WAVE RADIATION FROM THE RESERVOIR - Q_{bs}

Long wave radiation, Q_{bs}, from the reservoir will be calculated from Stefan-Boltzman Law for black body radiation. In this computation an emissivity of 0.97 will be used for water suface.

The water surface temperature is recorded at five rafts which are located at different places on the reservoir. Water surface temperature recorders are mounted in boxes on instrument rafts with censer bulb attached to the raft at water surface.

BOWEN RATIO -

The Bowen Ratio is used to determine the relation between the sensible heat, Q_h, and energy going into evaporation Q_e. This ratio can be expressed as follows:

$$\beta = \lambda \cdot \frac{P}{1000} \cdot \frac{T_o - T_a}{e_o - e_a} \quad (5)$$

where
λ = Bowen Ratio Constant = 0.61 (mb/o_c)
P = Atmospheric pressure (mb)
T_o = Water surface temperature (o_c)
T_a = Temperature of air (o_c)
e_o = Saturated vapor pressure of water at water surface temperature (mb)
e_a = Vapor pressure of air (mb)

ADVECTED ENERGY - Q_v

The net advected energy, Q_v, is the gain in energy from inflow, outflow and rainfall. The volume of inflow is gauged at a station near San Marcial maintained by U.S. Geological Survey. The temperature of the inflow to the reservoir is recorded at Mitchel Point near the entrance of the water into the Lake. The volume of outflow is measured by the U.S. Bureau of Reclamation through their power and irrigation releases at Elephant Butte Dam. An outflow temperature recorder measures the temperature of water released through the dam. The rainfall is measured at the energy budget station with both U. S. Weather Bureau nonrecording and recording type gage. The rainfall temperature will be taken as that of wet bulb temperature at the time of the rain.

STORED ENERGY - Q_o

The energy stored, Q_o, in the lake is determined at the beginning and end of each thermal-survey period. At the present, the thermal survey is taken at every two-week interval. The reservoir temperature profile is taken at about 50 sites, out of which 46 are presently accessible, with a Whitney Underwater Thermometer accurate to 0.1°C. The calibration is constantly maintained and checked before and after the thermal survey.

SUPPRESSION OF EVAPORATION

When a monomolecular film is applied to a lake to suppress evaporation, determination of evaporation, and, more important, the estimate of decrease of evaporation as a consequence of the film becomes complex. A method has been developed by Harbeck and Koberg (7) to determine evaporation reduction which makes use of the heat-budget and mass transfer techniques.

Harbeck and Koberg postulated that when evaporation is reduced, there is an increase in lake surface temperature and the energy which is not utilized in evaporation is returned to the atmosphere by back radiation and conduction. Harbeck and Koberg method also assumes that the film has no effect on net solar radiation, atmospheric radiation, the net advected energy and long time energy storage. Harbeck and Koberg also illustrated that any effect of the film on reflected long wave radiation, Q_{ar}, will be largely counterbalanced by a compensating influence on long wave radiation, Q_{bs}, emitted by the body of water. The assumption that the film has little influence on the energy storage below the surface may be subject to some doubts, but, at present, it is difficult to determine the magnitude and influence of the additional storage of energy as the result of the film. Harbeck and Koberg assumes it to be negligible. Assuming that the quantities which are appreciably influenced by the film are Q_e, Q_{bs}, and Q_h, it follows that the net sum of the effects with and without the film must be zero, or

$$(Q'_{bs} - Q_{bs}) + (Q'_e - Q_e) + (Q'_h - Q_h) = 0 \qquad (6)$$

in which the symbols with primes refer to the reservoir with a film and the symbols without the primes to the same reservoir without a film.

During the pretreatment period, heat energy utilized in evaporation and conduction are related to their respective mass-and heat-transfer equation as stated below.

$$Q_e = NU\,(e_o - e_a) \qquad (7)$$
$$Q_h = KU\,(T_o - T_a) \qquad (8)$$

Where U = wind speed in MPH
N = constant in cal/cm^2 day mph^{o}C
K = constant in cal/cm^2 day mph^{o}C

The constants K and N are determined during pretreatment period. Substituting equation (7) and (8) along with equation for back radiation $Q_{bs} = 0.970 (T_o + 273)^4$ in equation (6), the following equation is obtained:

$$0.970 [(T'_o + 273)^4 - (T_o + 273)^4] + [\gamma_e \text{ EL-NU } (e_o - e_a)] + KU (T'_o - T_o) = 0 \quad (9)$$

The above equation is a function of T_o only since e_o is a single valued function of T_o. Equation (9) can be solved for T_o and the corresponding values for e_o can be substituted in equation (7) to give the evaporation that would have taken place had the film not been present. The evaporation suppression now can be determined by considering the actual evaporation as computed by equation (1) and the estimated evaporation had no film been present.

In reality, the mass-and heat-transfer coefficients viz. N & K in equation (7) and (8) for no film period are not the same as those for film period as was pointed out by Mansfield (8). Also, the wind profile near the water surface would not be the same for periods with and without film, since the presence of film reduces the development of waves. These influences, however, are considered to be very small on transport constants N and K.

CHARACTERISTICS OF THE FILM

Following are the most desirable characteristics of film-forming chemicals which are used for suppression of evaporation.

a. The film should have good healing properties
b. The chemical must be inexpensive
c. The chemical should not be consumed too rapidly by bacteria
d. It should be easily applicable
e. It must effectively retard evaporation
f. The material should be insoluble, nontoxic and tasteless.

At Elephant Butte, it is proposed to use Hexadecanol ($CH_3(CH_2)_{15}OH$) also known as cetyl alcohol for evaporation suppression.

APPLICATION OF THE CHEMICAL

Many different methods of application of the chemical have been tried and proven successful. Hexadecanol is a white, waxy solid at ordinary temperatures. It can be grinded to a fine powder or is obtainable in flake form. The chemical can also be pelletized. The melting point of Hexadecanol is 130°F. It also can be dissolved in solvents like kerosene and petroleum ether. It can be applied to the water surface from wire screen flots, by hand as powder or flakes, as a mechanical suspension sprayed onto water surface under pressure, as solution dissolved in solvent, application as emulsion, and spread onto water in molten condition. At Elephant Butte, it is proposed to apply the chemical by the method developed by Israelsen and Hansen (9) of Utah State University. This method uses an aircraft which dispenses evaporation retardants in liquid or powder form. The parts of the reservoir not accessible by the aircraft will be sprayed by a Robertson-Grinder-Duster mounted on a boat.

FILM DETECTION AND COVERAGE

The detection of the film and the determination of area covered by the film is one of the formidable tasks of evaporation suppression investigation. At Elephant Butte, it is proposed to make hourly determination during daylight hours of the area covered by film. These determinations include film mapping from land vantage points using a plane table, photographs from various vantage points, film pressure measurements using indicator oils and infrared scanner.

COST OF EVAPORATION SUPPRESSION

Various investigators have quoted the cost of conservation of water from suppression of evaporation by the use of monomolecular films. Costs as low as $6.00/acre-foot have been reported; but these seem to be unrealistic. The table below gives the representative costs reported by the Bureau of Reclamation (10). It is anticipated that the saving of water by the application of monomolecular films on reservoirs may range from $20 to $35 per acre-foot once the technique and methodology is perfected. However, it should be realized that the above figure applies to those selected reservoirs which have proper size, shape, moderate winds and high evaporation.

SUMMARY

It can be concluded that reduction in evaporation by means of monomolecular films may become a popular method of saving water in arid and semi-arid regions. A comparison with costs of alternate sources of water reported by Dr. Franzini (11) of Stanford University is shown in the table below. This table shows that the monomolecular film method is competitive. It should be also noted that reduction in evaporation will not result in large quantities of water.

With respect to Elephant Butte Evaporation reduction investigation no general conclusion can be drawn since the project is in progress. It is hoped that significant savings in water and lower

COST OF EVAPORATION SUPPRESSION

Lake	Test Period	Evaporation Suppression	Cost/Acre-Ft. of Water Saved
Lake Hefner Oklahoma City Oklahoma	July 7- Oct. 2, 1958	9 ± 5%	$61
Sahuaro Lake Near Phoenix Arizona	Oct. 1-Nov. 17 1960, Total Test Period.	14 ± 5%	$69
	Oct. 19- Nov. 17, 1960 Continuous Treatment	22 ± 5%	$58
Lake Cachuma Near Saint Barbara, Calif.	July 31-Sept. 24, 1961 Total Test Period	8 ± 5%	$68
	Aug. 14-28, 1961 2nd Thermal Survey	22 ± 5%	$28
Pactola Reservoir Near Rapid City South Dakota	July 5-Sept. 1, 1962	Unknown Until Completion of Final Report	Unknown Until Completion of Final Report
Elephant Butte Reservoir Elephant Butte New Mexico	Summer of 1965 or 1966	?	?

COST OF RAW WATER

	Dollars Per Acre-Foot
Local Runoff	$3.00 - 10.00
Ground Water	$3.00 - 10.00
Imported Water	Variable
Reclaimed Waste Water	$25.00- 40.00
Sea Water Conversion	
Distillation	$250 - 600
Solar Stills	$350
Freezing	$700
Ion Exchange	$8,000*
Electrolytic Action	$500*
Ion-Permeable Membranes	$3,000*
Evaporation Suppression	$20.00 - 35.00

* Considerably lower for brackish water

cost of evaporation suppression will be achieved. It is also hoped that the techniques of evaporation determinations and its suppression will be improved. It is also realized that extensive amounts of research and development technique need to be performed before the capabilities of water conservation through evaporation suppression are formulated.

ACKNOWLEDGEMENT

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RESEARCH ON CONTROL OF PHREATOPHYTES

Eugene E. Hughes[1/]

INTRODUCTION

Phreatophytes are plants that grow where their roots can extend into the water table or the capillary fringe above the water table. In the arid Southwest, there are about 75 species of plants that have been identified as phreatophytes (Robinson, 1958). In New Mexico there are five genera or species considered as problem phreatophytes: willow (Salix spp.), cottonwood (Populus spp.), Russian olive (Elaeangus angustifolia), screw-bean mesquite (Prosopis pubescens), and salt cedar (Tamarix spp.). Growth of these plants in the major river beds of the Southwest has greatly increased in the past twenty years. These plants not only create flood hazards by blocking river channels and present rapid flow of water into reservoirs, but they use excessive amounts of water. Robinson (1963) reports that willows use 2.5 acre-feet of water per surface acre, cottonwood uses about 5.2 to 7.6 acre-feet, and salt cedar from 6.0 to 7.2 acre-feet. Since salt cedar occupies the greatest land area, some 900,000 acres in the Southwest in 1961 (Robinson, 1963), it has received the most attention.

In New Mexico there are 42,500 acres of salt cedar on the Pecos River from Alamagordo Dam to the Texas state line, alone (Thompson, 1957). If a conservative water-use figure of 5 acre-feet per acre were used, savings on the Pecos River, alone, could amount to 212,500 acre-feet yearly if salt cedar were controlled.

Previous Work on Control

Federal and state government agencies have found that willows, Russian olive, cottonwood, and screw-bean mesquite are quite susceptible to phenoxy herbicides but salt cedar has proven very resistant. Top kills are relatively easy to obtain but salt cedar sprouts from the root crown and may regrow as much as 6 feet in one year. Before 1961, less than one man-year was devoted to research on control of phreatophytes by the Agricultural Research Service, U. S. Department of Agriculture, and all other state and federal government agencies combined (Timmons, 1963). In June of 1961, in cooperation with the New Mexico Agricultural Experiment Station, the Crops Research Division of the Agricultural Research Service employed a full-time research scientist at Los Lunas, New Mexico to carry out field and greenhouse studies on control of phreatophytes. A second research scientist was added in May 1962, to conduct physiological and biochemical studies on phreatophytes.

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Studies on Control of Salt Cedar

Since 1961, nearly all the research work on control of phreatophytes has been devoted to salt cedar. Lines of research have centered around four main projects:

1) Field studies on control of individual salt cedar trees, such as are found on ditch banks.

2) Field studies on control of large area stands that exist on the flood plains of rivers.

3) Field studies on the factors affecting the growth of salt cedar and its response to herbicides.

4) Greenhouse studies designed to study factors that cannot be controlled in the field. These studies involve ecological, as well as physiological, problems.

Individual Tree Control Studies

Treatments for control of individual salt cedar plants have consisted of basal spray, granular and wettable-powder herbicides applied to the soil, and of dormant cane spraying. Basal spray treatments, spraying around the base of the stem or trunk from ground level up 18 inches, using 8 pounds acid equivalent of silvex ester per hundred gallons of diesel oil, are very effective (Table 1). Treatments should be made any time from December to March. Granular applications of dicamba at 5 pounds per acre, on an active ingredient basis, will kill a high percentage of salt cedar trees. Applications should be made in early June or before the expected period of summer rains. Wettable powder herbicides sprayed on the soil surface have been ineffective.

Dormant cane treatment consists of spraying all of the dormant stems with diesel oil containing an ester of silvex. This method is particularly suited to thick stands of small, many-stemmed salt cedar. Results of studies initiated this winter will not be known until the summer of 1964 but previous work on other plants has shown much promise.

Foliage Applications of Herbicides

Foliar application consists of spraying the tops of plants while they are in full foliage, using a ground spray rig with a boom, an airplane, or a helicopter. Results of two years of aerial application research in Arizona, New Mexico, and Texas have shown that 4 pounds acid equivalent of silvex ester in a 1:9 oil:water emulsion per acre, or a total of 10 gallons volume per acre, is the most promising treatment. Plots sprayed in mid-May of 1962 near Phoenix, Arizona, showed

TABLE 1. Results* of basal spray treatments on salt cedar on R. Anderson farm, Picacho, New Mexico. (There were ten trees in each treatment.)

Chemical	Rate aehg (lb.)	Carrier	Area Treated	Average Diameter (in.)	Percentage Kill
Silvex ester	8	Oil	Cut stump	8	100
Silvex ester	8	Oil	Basal 2 ft.	8	70
Silvex oil-soluble amine	8	Oil	Cut stump	6	100
Silvex oil-soluble amine	8	Oil	Basal 2 ft.	6	100

* Treatments made in March 1962, and results evaluated in September 1963.

that silvex ester at 4 pounds/A reduced salt cedar stands 92 percent. Although very promising, such high percentages of root kill from aerial applications have not been observed before or since, using the same chemical, rate, and date of application. Research during the past year has shown that the stage of growth of salt cedar is apparently extremely important, so future research along this line should prove fruitful.

Mechanical and/or Chemical Treatments

Studies initiated in 1962 showed that, if plots were mowed or burned off in the winter and allowed to regrow in the spring, then sprayed in early June with 4 pounds ae/A of silvex ester, a 50 percent reduction in the stand of salt cedar could be obtained. If plants were not mowed or burned off, only 20 percent reduction was obtained. Plots mowed in the winter but mowed every two months afterward for two years, during the growing season, stunted the plants but did not kill them. Current research has shown that plots sprayed with 5 pounds ae/A of silvex ester then mowed 2-4 days after spraying, also appeared to reduce the stand at least 50 percent. These treatments are particularly useful where removal of the tops, as well as killing the plants, is desirable.

Ecological Studies

In 1962, studies were initiated to determine if weather factors (temperature, humidity, solar radiation, etc.), soil factors (moisture, salinity, etc.), and others, such as quality of ground water, variations in water table, etc., could be used to predict growth, storage of carbohydrates, and susceptibility of salt cedar to silvex ester. After two years' work, it appears that growth may be predicted. Neither susceptibility to herbicides or to carbohydate storage appeared to be closely related to any variable measured. Work on their relationship will be continued for another year.

Germination studies with salt cedar seeds using 100, 500, 1,000, 5,000, 10,000, 20,000, and 40,000 ppm sodium, magnesium, potassium and calcium chloride (concentrations were based on the cation) have shown that even at 40,000 ppm, 20 percent of the seeds still germinate compared to 85 percent in distilled water. This indicates that salt cedar plants may be able to establish in highly saline soil conditions. Studies are planned to study seedling establishment under highly saline conditions.

Control Studies on Other Phreatophytes

Field studies initiated during the winter of 1962-63 have shown that Russian olive and screw-bean mesquite are susceptible to 6 pounds aehg of silvex ester when applied on a dormant basal spray. Frill treatments on cottonwood in December (herbicide placed in fresh axe cuts), using a 50:50 mixture of 2,4-D and 2,4,5-T amine, have shown that 3 cc of herbicide placed in 2 cuts per foot of circumference is moderately effective. Additional studies are planned on all three species.

SUMMARY

Previous research on control of salt cedar and other phreatophytes has shown that salt cedar is very resistant to herbicides, while most of the other phreatophytes are susceptible. Salt cedar occupies some 900,000 acres in the Southwest and grows in river channels, creating flood hazards as well as wasting water. Research has shown that scattered stands, such as on ditch banks, can be effectively controlled with a basal spray of 8 pounds aehg of silvex ester in diesel oil. Granular applications of 5 pounds ae/A of dicamba on the soil surface will reduce stands of salt cedar 50 percent or more.

Aerial application of herbicides to salt cedar in Texas, New Mexico, and Arizona has shown that 4 pounds ae/A of silvex ester in a 1:9 oil:water emulsion, or 10 gallons volumes per acre, is the most effective. Erratic results between years and areas indicate that stage of growth must be extremely important for effective control.

Spraying regrowth from mowed or burned salt cedar is nearly three times more effective than spraying undisturbed plants. Mowing 2-4 days after spraying appears to be promising.

Germination studies with salt cedar seed have shown that, even at 40,000 ppm of sodium, calcium, potassium, and magnesium ion (chemicals in chloride form) 20 percent still germinate. Studies on the inter-relations of factors affecting growth, carbohydrate storage, and susceptibility to herbicides of salt cedar are in progress.

Research on control of other phreatophytes has shown that 6 pounds aehg of silvex ester in diesel oil is effective as a dormant basal spray on Russian olive and screw-bean mesquite. Frill treatments on cottonwood, using 3 cc of a mixture (50:50) of 2,4-D and 2,4,5-T amine applied to axe cuts spaced 2 per foot of circumference, was moderately effective. Additional research is planned on control of these species.

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PHREATOPHYTE CONTROL OPERATIONS IN NEW MEXICO

Ralph Charles[1/]

I would like to express my pleasure at this opportunity to discuss the more important phreatophyte control operations in New Mexico. While technically these operations may not come under our conference theme, essentially all of them have developed or improved the procedures and techniques used in phreatophyte control. Thus, they have contributed greatly to the available store of knowledge.

In my brief discussion I will simply outline the two general areas of the state where water loss by nonbeneficial phreatophytes is the most serious, describe the more significant of the activities that are providing some measure of control, and point out the remedial action presently under consideration. The location of these features is shown on the sketch map, Major Phreatophyte Areas.

I believe all who have studied the problem will agree that the two areas in New Mexico that offer the greatest opportunity for phreatophyte control are the Pecos River Basin from the New Mexico-Texas State line upstream to Alamogordo Dam, and the Rio Grande Basin from the Narrows of Elephant Butte Reservoir upstream to Velarde on the main stem, and to Abiquiu Dam on the Rio Chama. This area in the Rio Grande consists of what is commonly known as the Middle Rio Grande and Espanola valleys. In both basins, the areas outlined are located in the broad flood plains of main rivers, and consist of dense vegetative growth in relatively large blocks.

In the Pecos Basin area, there were some 38,000 acres of phreatophytes in 1960, primarily salt cedars. They were estimated to be consuming an average of about 118,000 acre-feet of water annually. Considerable study has been made of this area. However, the hydrologic factors involved are quite complicated and there has yet been no agreement on the control measures that might be effective or the amount of water that might be salvaged.

One engineering feature, a low-flow channel through the McMillan Delta, is reducing consumptive waste in this area. It was initiated in 1948 by the Carlsbad project, to permit the passage of river flows through the salt cedar-choked delta. It gradually has been enlarged and extended upstream, with the help of the Bureau, to the vicinity of Artesia Bridge. It likely is preventing average losses of from 10,000 to 15,000 acre-feet annually.

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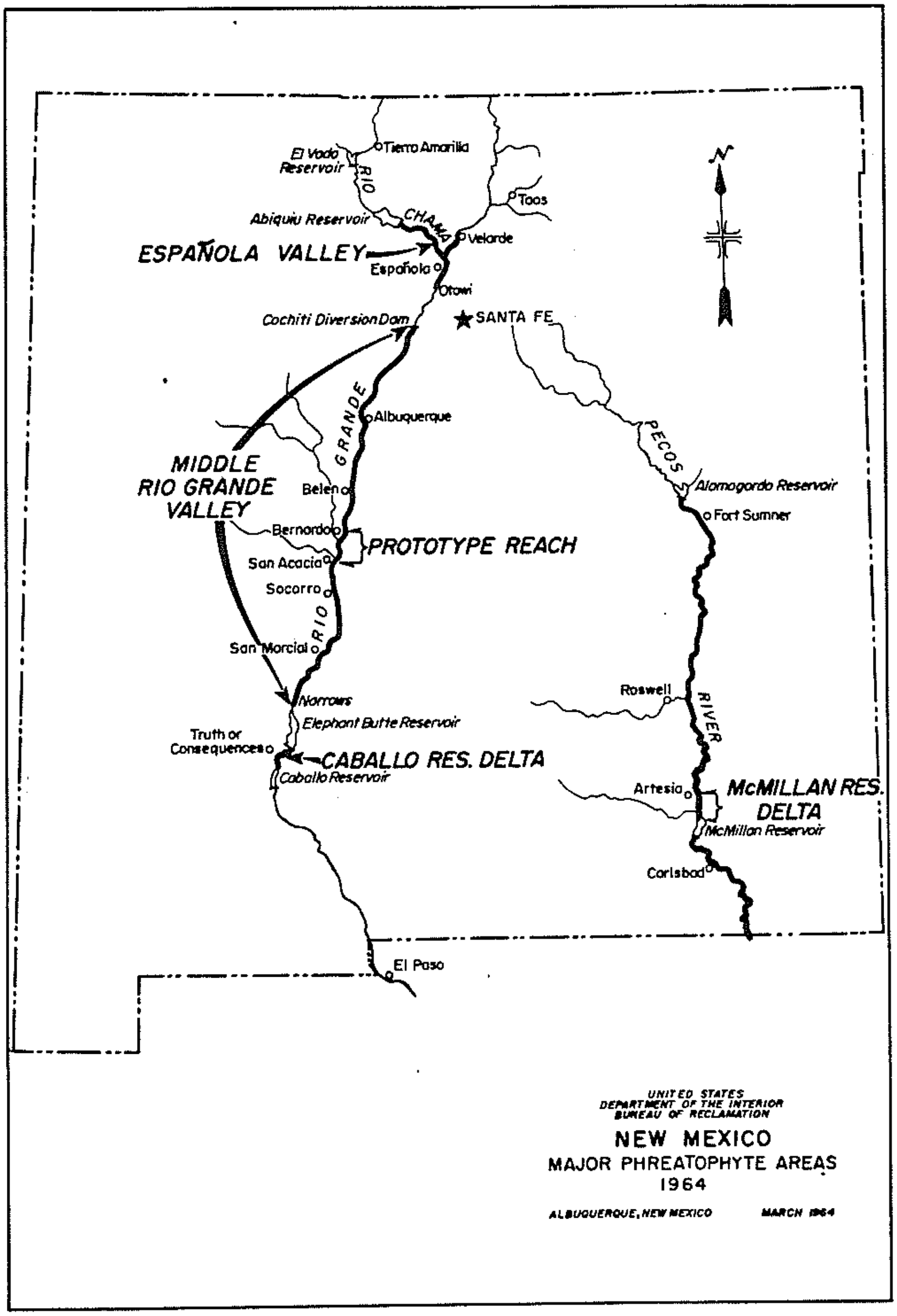
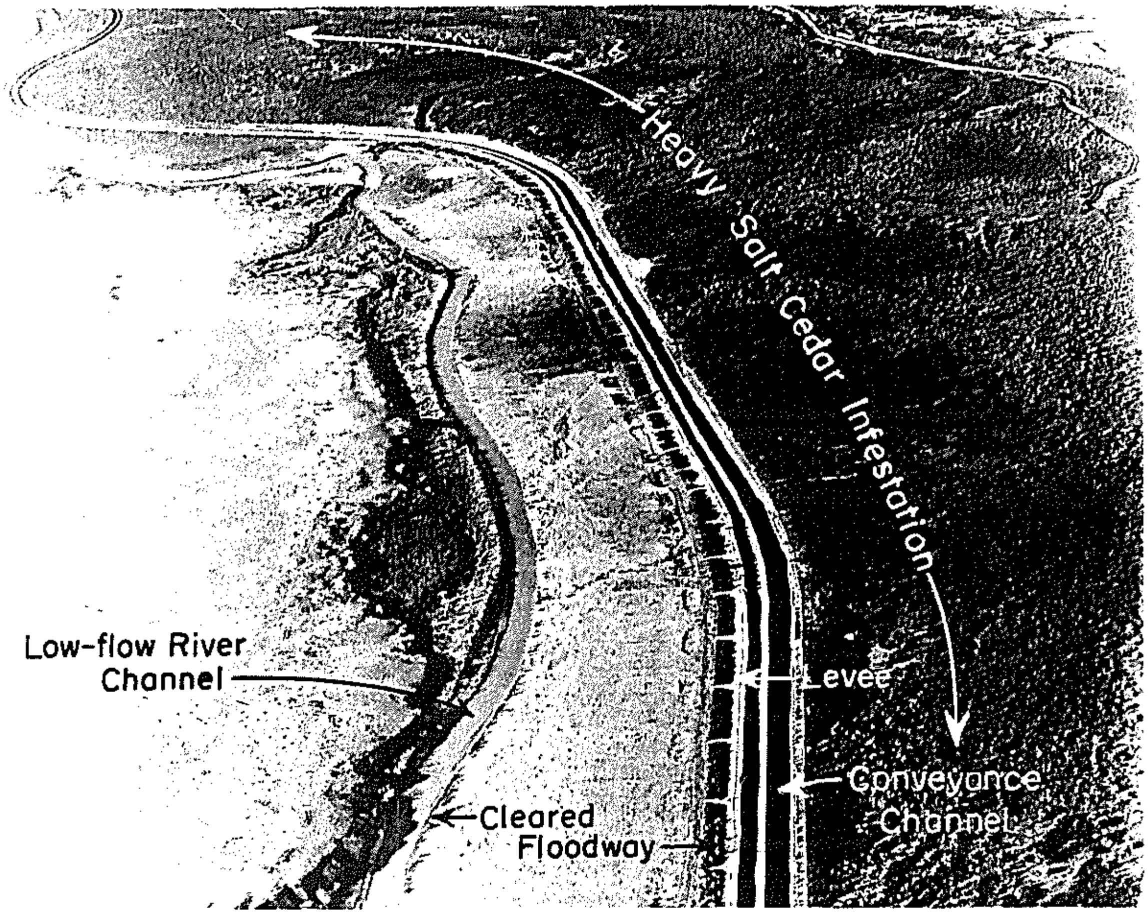

Tierra Amarilla
El Vado Reservoir
RIO
CHAMA
Taos
Abiquiu Reservoir
Velarde
ESPAÑOLA VALLEY
Española
Otowi
Cochiti Diversion Dam
SANTA FE
GRANDE
Albuquerque
MIDDLE RIO GRANDE VALLEY
Belen
Bernardo
PROTOTYPE REACH
San Acacia
Socorro
RIO
San Marcial
PECOS
Alamogordo Reservoir
Fort Sumner
Roswell
RIVER
Narrows
Elephant Butte Reservoir
Truth or Consequences
CABALLO RES. DELTA
Caballo Reservoir
Artesia
McMILLAN RES. DELTA
McMillan Reservoir
Carlsbad
El Paso
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
NEW MEXICO
MAJOR PHREATOPHYTE AREAS
1964
ALBUQUERQUE, NEW MEXICO
MARCH 1964

In the Middle Rio Grande and Espanola valleys, a reconnaissance study in 1960 indicated there were about 48,000 acres of phreatophytes consisting mainly of salt cedars, cottonwoods, willows, and Russian olive. These plants are wasting an average of about 200,000 acre-feet of water annually. While all of this waste cannot be prevented, it is likely that at least 60,000 acre-feet could be salvaged annually by phreatophyte removal and control.

There are two projects in this portion of the basin that are important as control operations. The state is participating financially in both. The first is the multiple-purpose Middle Rio Grande project which extends throughout the Middle Valley from Cochiti diversion dam on the north to the Narrows of Elephant Butte on the south, a distance of almost 200 river miles. One of the important phreatophyte control features is a cleared floodway, containing a low-flow river channel along the full 200 miles of the river. The cleared floodway varies from 600 to 1,000 feet in width. The channel and floodway are controlled and protected by fields of Kellner jetties and are under constant maintenance by the Bureau. These features provide both flood control and water salvage. Water use is reduced on more than 15,000 acres of phreatophytes that were cleared in constructing this feature.

Another feature, the most important from the phreatophyte control standpoint, is the 75-mile-long levee and conveyance channel from the San Acacia diversion dam to the Narrows. The levee restricts all high river flows to the eastern 2,000 feet of the valley and prevents these flows from spreading through some 20,000 acres of dense vegetation on the flood plain. The conveyance channel transports all low flows through the phreatophyte infested areas and into the reservoir. Some 50 miles of the levee, as well as the 75-mile conveyance channel, are new construction specifically for water salvage. The conveyance channel, averaging some 10 feet deep, has lowered the water table throughout this river reach. Thus, water is salvaged in four ways: first, by keeping surface flows out of the sandy river channel where it would be lost through evaporation and deep percolation; second, by keeping it from spreading over the phreatophyte infested area; third, by lowering the water table and reducing the use by plants; and, fourth, by clearing and maintaining the cleared floodway. Our analyses show we have salvaged almost 700,000 acre-feet of water in the Middle Rio Grande Basin since the start of construction, and have averaged more than 62,000 acre-feet a year over the last 10 years.

The other activity in this area is the water salvage investigation which we initiated in fiscal year 1961, in compliance with P.L. 858, to determine feasible ways and means of reducing non-beneficial consumptive use in the Rio Grande Valley. In carrying out this investigation, we have selected a prototype reach extending from U. S. Highway No. 60 at Bernardo to the San Acacia diversion dam 16 miles downstream. We have instrumented this area and obtained a three-year record of water use while it is infested with phreatophytes.



Typical view of cleared floodway, levee, and conveyance channel along the Rio Grande in the vicinity of San Marcial. Bureau of Reclamation photograph. View looking downstream from an elevation of 7,000 feet.

We are now clearing the area, a total of some 6,400 acres, and will continue with the measurements of water use for at least a two-year period while the area is being maintained free of regrowth.

Three methods are being used to determine water use, the inflow-outflow method, the transpiration well method, and the evapotranspiration tank method. Soil moisture measurements are obtained at each well installation with a neutron moisture meter. We are hopeful that the difference in water use before and after clearing--the actual water salvaged--can be satisfactorily measured. The results will then be expanded over the entire Middle Rio Grande and Espanola valleys in the development of a plan for water salvage in the Rio Grande Basin.

The remaining significant control project is the clearing and maintenance of some 5,500 acres in the Caballo Reservoir Delta. This is a cooperative effort of the Rio Grande Project and the State, initiated in 1957. It is the only project in which clearing has been done solely to salvage water, and is justified on the basis of an estimated average annual water savings amounting to about 15,000 acre-feet. A number of experiments on both mechanical and chemical control measures have been carried out on this project. Moreover, it has proven the most satisfactory from the standpoint of natural revegetation with useful grasses.

In summarizing, it should be noted that, to date, water salvage has been accomplished primarily by engineering works that control the water supply. Clearing has been relatively minor in comparison. Nevertheless, we have cleared and are maintaining more than 25,000 acres free from phreatophytes, and have used all known methods of clearing and of maintenance, except the large Le Tourneau tree crusher. None of these are entirely satisfactory and I am hoping that some new method will be perfected by research, possibly some application of the Lazer beam.

As for the future--when water becomes more valuable, control programs will be intensified. The phreatophyte problem is so acute in the Pecos Basin now that the Pecos River Commission has secured the introduction in Congress of Senate Joint Resolution No. 49, providing for the control of nonbeneficial vegetation from the headwaters in New Mexico to Girvin, Texas. This bill has passed the Senate and hearings have been scheduled by the House for next week.

A great deal of effort and money is already being put into control programs in the Rio Grande Basin. These, no doubt, will be continued. The demands for water, however, are constantly increasing and some of the additional supplies which will be needed within the next 10 to 20 years could logically come from a water salvage program. The study we are now making will result in a plan for such a program. We hope we can develop a plan that is both economically and financially feasible. The study is scheduled to be completed in fiscal year 1968.