WEATHER MODIFICATION

HEARING

BEFORE THE

SUBCOMMITTEE ON IRRIGATION AND RECLAMATION

OF THE

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS UNITED STATES SENATE

EIGHTY-EIGHTH CONGRESS

SECOND SESSION

ON

A PROGRAM FOR INCREASING PRECIPITATION IN THE COLORADO RIVER BASIN BY ARTIFICIAL MEANS

MAY 21, 1964

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WEATHER MODIFICATION

THURSDAY, MAY 21, 1964

U.S. SENATE,
SUBCOMMITTEE ON IRRIGATION AND RECLAMATION
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m. in room 3110, New Senate Office Building, Senator Frank E. Moss (chairman) presiding.

Present: Senators Anderson, Moss, Bible, McGovern, and Jordan of Idaho.

Also present: Jerry T. Verkler, staff director; Stewart French, chief counsel; Roy M. Whitacre, professional staff member; Thomas S. Foley, special counsel.

Senator Moss. The hearing today before the Irrigation and Reclamation Subcommittee has been called for the purpose of providing information to the members on the possibility of increasing precipitation in the Colorado River Basin by artificial means.

The committee is aware that on April 21, 1964, Senator Bible questioned members of the Interior Department at the hearings on the public works appropriation bill as to the possibility of increasing the runoff of the Colorado River through a program of weather modification. At that time, it was suggested that the Department would be in a position to use an additional million dollars in a program of applied research directed primarily at increasing rain or snowfall during the coming year. We are well aware of the terrific problems that the Colorado River water and power users face as a result of the continuing drought that has afflicted this section of the country. We know that neither the Department of the Interior nor the National Science Foundation, nor anyone else, is in a position to guarantee the results of such a program.

However, it appears to me that if, within the present available knowledge, the slightest opportunity exists whereby this can be accomplished, it is well worth the expenditure of the amount suggested.

I sincerely hope that the testimony to be presented here today will give the members of the committee a clearer picture of the advantages, as well as the disadvantages, of this program and enable us to form some kind of judgment as to its value. If the testimony is favorable, I trust that the committee will adopt a resolution directed to the Appropriations Committee endorsing the proposal that the funds for this program be increased from $100,000 to $1,100,000 for the specific purpose of attempting to increase precipitation in the Colorado River Basin.

I am submitting for the record a memorandum prepared by the staff of the committee outlining the history and activities of the

weather modification program. The information will be of particular interest to those concerned with the history of the actions of the Congress in this very vital field.

(The document referred to follows:)

MEMORANDUM

To: Senator Moss.
From: Robert H. Bendt.
Subject: Weather modification highlights.

In 1892 the belief that rainfall could be caused by the detonation of explosives was investigated with Federal funds. But not until the World War II investigation of fog particles by Drs. Langmuir and Schaefer of the General Electric Co. was it demonstrated that clouds might be modified and rain produced by scientific methods. The military possibilities of the discovery led the Department of Defense to initiate Project Cirrus in 1947, and the civilian implications were investigated by the cloud physics program of the U.S. Weather Bureau in 1948. Commercial rainmaking activities on a multimillion-dollar scale were soon underway.

Controversies that developed from the inflated claims of some "rainmakers," countered by severe criticism from the scientific community, led Congress in 1953 to create an Advisory Committee on Weather Control "to study and evaluate public and private experiments in weather modification." In December of 1958 the Advisory Committee on Weather Conrtol recommended that—

(1) Encouragement be given to the widest possible competent research in meteorology and related fields;

(2) The Government increase its sponsorship of research more vigorously;

(3) Government-sponsored research provide freedom and latitude in choosing methods and goals in their specific projects;

(4) An agency, the National Science Foundation, be designated to promote and support research in the needed fields, and to coordinate projects;

(5) Facilities required to achieve projects should be provided by the appropriate agency whenever the project has the endorsement of the National Science Foundation.

1959

Public Law 85–510 on July 11, 1958, directed the National Science Foundation "to initiate and support a program of study, research, and evaluation in the field of weather modification." During fiscal year 1959 the Foundation expended $1,141,000 for research projects.

While the National Science Foundation provided the largest measure of Government support for research on weather modification, the following Federal agencies also were conducting research in atmospheric sciences:

Department of Commerce.
Department of Agriculture.
Department of the Army.
Department of the Navy
Department of Health, Education, and Welfare.
Department of the Air Force.
Department of the Interior.

In addition, State and local agencies and five commercial companies were conducting activities in cloud and weather modification in 1959.

1960

In fiscal year 1960, the National Science Foundation expended a total of $1,391,000 for research and evaluation projects. With the National Science Foundation, weather modification projects are only a portion of their much broader program for atmospheric sciences. In their broader program they spent an additional $3 million in 1960 to support basic research projects varying from ocean-air interface problems to the global circulation of the atmosphere.

The research programs supported by the National Science Foundation in 1960 fell into four general categories: laboratory research, field investigation, planning conferences, and special publications. Grants to other Government activities were continued to the same Federal agencies that were supported in 1959, with the exception of the Department of Health, Education, and Welfare.

The Departments of Commerce and Agriculture were the only Federal agencies conducting weather modification projects that received National Science Foundation grant assistance. Commerce received $40,000 and Agriculture $63,900 to assist the Forest Service in their research work over a 2½-year period. State and local governments continued work with their own facilities or through contracts with commercial cloud seeders.

During 1960, 34 separate commercial projects were conducted by 4 commercial companies. The projects were conducted in 16 States, mostly in the West. Encouraging research work was also being conducted in a number of foreign countries. It was found that the work being conducted in the foreign experiments were different from those in the United States only in details.

The National Science Foundation reported that the most significant event in the study of atmospheric sciences during 1960 was the launching of the 270-pound weather satellite Tiros I. Early information from Tiros I is considered significant in being able to obtain advanced knowledge of the development of major weather patterns and in locating the birth of a storm at a stage when man may be able to influence its growth.

1961

By 1961, there was a considerable increase in the national program in atmospheric sciences and a comparable increase pertinent to weather modification. However, the short supply of skilled manpower to conduct competent projects existed. The National Science Foundation, in their 1961 annual report, stated that "with weather control becoming increasingly more probable, the stimulation of early interest in atmospheric sciences is a national responsibility of profound importance."

Since about 1958, activity in weather modification was assuming a sound and realistic tone and was being conducted on a scientific basis. The sensationalism of the early 1950's with the claims of fantastic successes and ensuing refutations had died down almost completely.

(1) GRANTS AND CONTRACTS AWARDED IN 1961

University of California:
Study of California rainfall processes ($151,000).
Growth of ice crystals and cloud drops ($99,100).
Nebraska State Teachers College: Physical evaluation of the effects of silver iodide seeding on the suppression of hail ($14,200).
University of Nevada: The solidification and melting of water ($52,100).
New York University: Feasibility of the artificial modification of tropical storms ($221,000).
University of Oklahoma: Electrical effects on certain types of tornadoes ($29,900).
Raven Industries, Inc. (Sioux Falls, S. Dak): Hail suppression by modification of potential hail-producing clouds ($17,000).
Research continuing from previous year grants:
University of Chicago: Cloud physics.
University of Arizona: Surface properties of condensation nuclei.
University of Vermont: Vapor condensation in the absence of nuclei.
National Bureau of Standards: Crystalographic study of silver iodide.

(2) FIELD INVESTIGATION RESEARCH GRANTS AND CONTRACTS IN 1961

Atmospherics, Inc. (Kings River, Calif., Conservation District): A cloud-seeding program, using radar for storm tracking, aircraft for seeding Dry Ice pellets, and a network of silver iodide ground generators ($11,400).
Colorado State University:
Characteristics of mountain clouds and their changes when artificial ice nuclei are supplied ($70,000).
Hail research ($19,400).
Loren W. Crow (consulting meteorologist), Panama: Life cycles of tropical cumulus clouds in connection with a weather modification project near Puerto Armuelles ($22,600).
University of Illinois (and Office of Naval Research): Dust particles to be electrically charged by 20,000-volt potential from 30 miles of wire strung at random over a 60-square-mile area ($134,200).

Arthur D. Little, Inc. (and Office of Naval Research): NSF transferred $66,500 to the Navy to continue this cooperative effort. Cloud electrification program near Mount Withington in conjunction with the staff of the New Mexico Institute of Mining and Technology ($150,000).

State University of New York (work conducted in Yellowstone National Park): Rate of growth, crystal types, and optical effects produced by CO_2 and AgI seedings, studies of supersaturation produced by local seeding with various types of condensation nuclei in the vicinity of hot springs and geysers ($9,600).

U.S. Weather Bureau: Modification of severe storms and hurricanes with the use of standard cloud-seeding methods ($21,305).

Weather Engineering Corp. of Canada Ltd.: Studies with the use of standard weather modification techniques to change the state of water from liquid to crystal snowflakes ($14,100).

Field studies continuing from previous year grants:

Aerometric Research, Inc.: Processes of Pacific coast storms.

University of Arizona: Cloud seeding with silver iodide.

University of Chicago: Cloud seeding over the Great Plains.

Texas A. & M.: Cloud structures.

University of Arizona: Development of a model for lightning discharge.

Atmospheric Research Group: Characteristics of small cumulus clouds.

Colorado State University: Characteristics of hail.

Oregon State College: Study of hailfalls in Oregon.

U.S. Forest Service: Continued Project Skyfire—lightning research begun in 1954.

U.S. Weather Bureau: Upper-air studies.

Grants awarded for statistical evaluations in 1961:

University of Missouri: Analysis of rain gage data from 35 stations used in this project ($3,200).

Washington State University: Study of methods of evaluating weather modification activities.

University of Washington and Washington State University (jointly): ($50,000).

(3) FUNDS GRANTED FOR FACILITIES AND INSTRUMENTATION IN 1961

University of Arizona: For construction of a pulse doppler radar set mounted on a trailer ($200,000).

New Mexico Institute of Mining & Technology: For construction of a small observational site and facility on South Baldy Peak ($200,000).

(4) FUNDS GRANTED FOR CONFERENCES IN 1961

The National Science Foundation supported one conference held at South Dakota School of Mines & Technology where an Institute for Atmospheric Sciences has been established ($3,000).

Funding summary of all weather modification programs in fiscal year 1961

Department of Agriculture	$63,900
Department of Commerce	59,305
Department of Defense	749,116
National Science Foundation (by grants)	1,545,500
Total (all Government)	2,417,821

The Government departments were engaged in both basic and applied research programs, whereas the National Science Foundation generally directed their grants more to obtaining basic data.

It is also known that the Department of the Interior through the Geological Survey and Bureau of Reclamation engaged in research in weather-climate modification dealing with the reduction of water evaporation in 1961.

Some State and local government activities occurred in 1961 and were concerned primarily with direct programs in producing rainfall.

Thirty-three separate commercial-type projects were conducted in 1961 by 9 commercial companies in 23 States. About 8 aircraft and 500 ground-based silver-iodide generators were used for seeding purposes.

In 1961 there were 13 experimental weather modification projects using cloud seeding as a research tool; 29 applied research projects involving seeding as a means of obtaining economic or operational benefits, and 42 projects closely re-

lated to the science of weather modification, but where there was no actual cloud seeding involved.

1962

The 1962 National Science Foundation annual report on weather modification stated: "The promise of useful weather modification techniques is sufficiently great that research into its full potential should be pushed urgently." To this end, NSF recommended as rapid as possible progress be made to:

Continue to attract new, creative talent to weather modification, and to the atmospheric sciences as a whole;

Broaden research by supporing theoretical and field research into potential new methods of modification or control with new emphasis on long-range weather and climate control on regional or continental scales;

Shorten the time gap between the development of theory and the start of field research so that new techniques may be tested as soon as a sound theoretical basis is established.

The National Science Foundation felt that the rewards to be gained from methods of large-scale weather control may equal or surpass atomic energy in dealing with the world's population explosion and other problems requiring maximized benefits from natural resources.

The use of mathematical models now makes it possible to test such weather modification ideas as damming the Bering Strait between Alaska and Siberia, laying a chemical film on the ocean to lessen evaporation, or changing the radiative balance of the polar regions by coating icecaps with carbon black. Such experiments are simulated in a computer, and the total effect can be then analyzed.

In 1962, the Foundation provided a total of $6,615,000 in support of its overall atmospheric sciences program. Of this sum, $1,340,000 went for weather modification, $3,300,000 for basic research in the atmospheric sciences, $1,200,000 for the National Center for Atmospheric Sciences (Boulder, Colo.), and $775,000 for the International Indian Ocean Expedition.

(1) GRANTS AND CONTRACTS AWARDED IN 1962

University of Chicago: Physical effects of silver iodide seeding in cumulus clouds ($200,000).
Massachusetts Institute of Technology: Cellular activity in the precipitation process in clouds ($241,000).
National Bureau of Standards: Study of silver iodide ($50,000).
University of Nevada: Numerical computation of the growth of cloud droplets ($44,800).
University of New England (Australia): Ice crystal nucleation theory ($12,500).
University of Utah: Nucleation of ice ($59,400).
University of Missouri: Analysis of rain gage records ($7,500).

Research continuing from previous year grants:

University of Arizona
University of Vermont
University of California at Los Angeles
Nebraska State Teachers College
University of Nevada
New York University
University of Oklahoma

(2) FIELD INVESTIGATION RESEARCH GRANTS AND CONTRACTS IN 1962

University of Chicago: Cloud seeding trials in southern Missouri ($300,000).
University of Arizona: Physics of clouds and cloud formations ($92,500).
Colorado State University: Hailstorms in the high plains ($115,800).
Hokkaido University (Japan): Formation and structure of snowfall ($49,000).
Oregon State University: Showers of small hail and related atmospheric phenomena ($26,000).
State University of New York: Cloud physics field research ($17,400).
University of Washington: Winter cloud studies on blue glaciers ($64,400).

Field studies continuing from previous years grants:

Aerometric Research Inc.
Texas A. & M.
University of Arizona
Atmospheric Research Group
U.S. Weather Bureau
Atmospherics, Inc.
Colorado State University
Loren W. Crow
University of Illinois
Weather Engineering Corp. of Canada

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(3) FUNDS GRANTED FOR FACILITIES AND INSTRUMENTATION IN 1962

Grants awarded in 1962: None.
Continuing work from previous grants:
University of Arizona: Mobile pulse-doppler radar set ($100,000).
New Mexico Institute of Mining & Technology: Construction of observation site ($100,000).

(4) FUNDS GRANTED FOR CONFERENCES AND PUBLICATIONS IN 1962

Rand Corp.: A five-man team received support for a 6-month study of the desirable directions for future weather modification research ($62,600).
Continuing work from previous grants:
American meteorological Society: For compilation and publication of a cumulative bibliography.

Funding summary of all weather modification programs for fiscal year 1962

Department of Agriculture	$119,000
Department of Commerce	224,500
Department of Defense	2,745,561
Federal Aviation Agency	37,300
Department of the Interior	100,000
National Science Foundation	1,342,900
Total (all Government)	4,569,261

In 1962, there were 14 experimental weather modification projects using cloud seeding as a research tool; 30 applied research projects involving seeding as a means of obtaining economic and operational benefits, and 28 projects closely related to the science of weather modifications, but where there was no actual cloud seeding involved.

Comparison of weather modification projects 1961 and 1962

Project	1961	1962
Cloud seeding as a research tool	13	14
Cloud seeding as a means of obtaining economical or operational benefits	29	30
Projects related to modification, but no actual cloud seeding involved	42	28

Comparison of funding, 1961 and 1962

Agency	1961	1962
Department of Agriculture	$63,900	$119,000
Department of Commerce	59,305	224,500
Department of Defense	743,116	2,745,561
National Science Foundation (by grants)	1,545,500	1,342,900
Federal Aviation Agency		37,300
Department of the Interior		100,000
Total	2,417,821	4,569,261

General recommendations resulting from the Rand Corp.'s 1962 study of directions to now be taken in weather modification

Must be approached in a cohesive and organized manner;
Suggest that thought be given by the National Science Foundation as to the formation of a permanent working group of competent scientists and engineers;
This group to be capable of continuously examining data with a view to furthering weather modification.

Also capable of carrying out an experimental and theoretical program in this field.

The group should also become the nucleus for weather-modification research in this country.

Senator Moss. I also would like to submit for the record a copy of a telegram I received from Douglas T. Simpson, chairman of the

Weather Modification Committee of Utah endorsing the general purpose of this hearing.

(The telegram is as follows:)

SALT LAKE CITY, *May 20, 1964.*

Senator FRANK E. MOSS,
Washington, D.C.:

Sorry we cannot attend your hearing tomorrow on weather modification. We endorse your proposal for a $1 million appropriation per year to advance weather modification in the Colorado River Basin. We recommend extensive application of known cloud seeding techniques in selected upper basin watersheds accompanied by scientific work to accomplish simultaneous scientific progress advancement of technology and water production under your applied research proposal.

This should not be 1 year's program but should be carried on from year to year until the problems are solved.

DOUGLAS T. SIMPSON,
Chairman, Water Modification Committee.
VERN HALES,
Secretary-Treasurer.

Senator Moss. Senator Anderson has a statement.

STATEMENT OF HON. CLINTON P. ANDERSON, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator ANDERSON. Mr. Chairman, as you know, last year on March 7, I was joined with other members of the committee in sponsoring S. 1020, a bill to direct the Secretary of the Interior to conduct a program in five areas of the United States to increase usable precipitation and for other purposes. This bill was only one in a series of endeavors I have made to actually determine whether sufficient know-how is in the hands of the scientists to enter into a program to increase the rain and snowfall in the southwestern portions of the United States. Although the bill was directed to five areas and was patterned after the very successful saline water program, I had in mind primarily the Colorado River Basin.

Since no progress has been made to date on this bill, I am very happy to join other members of the committee in the new approach that has been suggested. We have been assured that the Bureau of Reclamation has adequate authority to conduct a weather modification program if sufficient funds are available. Apparently, there is considerable confidence that if an appropriation in the neighborhood of $1,100,000 is authorized by the Appropriations Committee, the Bureau will be in a position to test some of the basic research that has been developed since we originally became involved in this program in 1958.

I think it pertinent to repeat at this time a statement I made at the time S. 1020 was introduced. I quote from a special report prepared by the Water Information Center, Inc.:

> Actually, more than six times as much water flows across the United States in the atmosphere than is carried by all of the country's rivers. Some of this water vapor has traveled 3,000 miles without ever having fallen on land below—and has passed over arid and semiarid parts of the country that could become highly developed if rain could be induced to fall. The economic value of this potential rainfall is immense. A mere 15-percent increase in total precipitation, for example, on a 1,000-square-mile watershed having a normal annual rainfall of 15 inches, would yield an additional 100,000 acre-feet of water. If this water

were to fall in the drier parts of the Southwestern United States, it would have an estimated monetary value of $2,000 per square mile if used for crop irrigation, or $5,000 per square mile if used for municipal water supplies (assuming its worth to be $20 per acre-foot for irrigation and 15 cents per 1,000 gallons for water supply).

It is readily apparent that it is vital to the public interest to reassess the position of weather modification research with a view toward paralleling Government-supported basic research with more extensive field applications of processes already known to be adapted to practical application.

I would also like to point out that this should be only the first step in enactment of far-reaching studies of weather control.

I can well recall the warning of Dr. John von Neumann, Atomic Energy Commission Commissioner, that weather manipulation, not the ICBM, would be the ultimate weapon for the protection of the free world. Although I recognize that the pending matter is directed solely to increasing precipitation in the Colorado River Basin, it is still a first faltering step toward the ultimate solution of our weather problems.

(Subsequently the statement of Senator Bible was ordered printed at this point:)

STATEMENT BY HON. ALAN BIBLE, A U.S. SENATOR FROM THE STATE OF NEVADA

Senator BIBLE. Mr. Chairman, I appreciate the opportunity to appear before this committee in support of an accelerated weather modification program in the upper reaches of the Colorado River. I will be brief and explicit.

My purpose is this: To seek this committee's backing on a $1 million increase in funds to the Bureau of Reclamation for implementing a full-scale campaign to increase precipitation on the Colorado—a river which we all know too well is running critically low on water this year. This is a matter I am putting before the Appropriations Subcommittee on Public Works, which, as you may know, heard lengthy testimony on the subject last month from Commissioner of Reclamation, Floyd Dominy and Walter U. Garstka, Chief of the Bureau's Water Conservation Branch, Division of Research.

Dr. Garstka informed us the upper Colorado area provides an ideal location for cloud seeding and other weather modification techniques because of its position in regard to other watersheds and because much of the region is federally owned. Mr. Dominy added that, as he put it, "No other organization has more incentive, more know-how and desire," than the Bureau of Reclamation in this area of manmade rainfall.

Data supplied by the Bureau of Reclamation indicate the benefits of increased rainfall through weather modification could be tremendous. An additional inch of precipitation above Glen Canyon Dam would produce a runoff of 575,000 acre-feet. This extra amount of flow through Federal powerplants could boost income, on established power rates, by $2.5 million. Naturally, this additional water could be available for agricultural, municipal and industrial uses. Allowing for losses in runoff, this added inch of precipitation would still provide 500,000 acre-feet of water for irrigation which, based on a 1962 water-crop benefit formula, would produce a gross crop income of

$24.7 million. Municipal and industrial uses, of course, would increase the value of this extra precipitation even more.

When we consider that the expected Colorado River flow this summer will be little better than half the average since 1923, we see all too plainly that the possibilities of an effective weather modification program are enormous and exciting. The water pinch on the Colorado at this very moment serves to dramatize this.

I am not attempting to tell this committee that the Bureau of Reclamation can deliver this golden egg this year or next year. Nor is the Bureau. Every scientist involved in weather modification research, Dr. Garstka among them, will be quick to tell you there is much, much more to learn about the methods and the approaches to tapping more moisture from Mother Nature's airborne reservoirs. This accelerated program must, by necessity, include more lengthy research. And the more scientists learn about weather modification, the more equipment they need—and the more money.

The Bureau of Reclamation estimate is that the accelerated program we are discussing will cost $1 million a year and perhaps more. And to be effective it should be carried over at least one or two decades. So we are talking on a long-range basis of a $10 million or more program.

I submit the time to start is now, when we have the impetus of drought years, when we are feeling the shortage of water throughout the Southwest. Admittedly, this is a million-dollar gamble. But the possible benefits are worth it a thousand times over. As in all of man's quests to improve his environment and produce a better life, we are limited only by our initiative and our imagination.

This is not a reckless gamble. The Bureau of Reclamation, in cooperation with the U.S. Weather Bureau and the National Science Foundation, has the experience and knowledge to tackle a substantial weather modification program with direction and effectiveness. I could not have said that 2 or 3 years ago.

I should recognize in passing, that we have before us in the Senate separate legislation dealing with this same topic of weather modification. One bill, S. 1020, would direct the Secretary of the Interior, in cooperation with the National Science Foundation, to conduct ambitious weather modification programs in five different areas of the United States. This bill, of which I am a cosponsor, would authorize an appropriation of $20 million.

I have supported this measure, and I still do. The program we are talking about on the upper Colorado is not at cross-purposes with the aims of this bill. Should any legislation along the lines of weather modification be enacted, the Colorado River application could easily be incorporated in the broader programs.

This is a year of economy in budget. Thus every request for additional spending falls under more than normal scrutiny. Nevertheless, the challenges and opportunities that await us in this vital area justify an immediate expenditure.

Let us—finally—do something about the weather.

Senator Moss. Senator Jordan, do you wish to make a statement?

Senator JORDAN. I will be interested in this whole program, but I would like to wait to hear the testimony. If we were able to, through weather modification, get another inch of rain, it might make the difference of whether we could generate power or be deficient. It would

make considerable difference if water could be delivered for municipal purposes throughout the river basin. It is a vital field and we should learn all we can about it. There are doubtless those detractors who think weather modification is not feasible yet, but many others claim the state of the art is well advanced.

Senator Moss. We will now proceed to the first witness, Dr. John C. Calhoun, Jr., science adviser to the Secretary of the Interior. Dr. Calhoun, we would be pleased to have you place your statement in the record.

STATEMENT OF DR. JOHN C. CALHOUN, JR., SCIENCE ADVISER TO THE SECRETARY OF THE INTERIOR

Dr. CALHOUN. Mr. Chairman and members of the subcommittee, I am pleased to be here on behalf of the Department to discuss this matter of weather modification. I have a prepared statement, copies of which are before you. I would like to read my statement although I may ad lib as I go along.

Mr. Chairman, I am pleased to be here today on behalf of the Department to discuss the subject of weather modification. My purpose is to furnish information on what we believe to be an important role for the Department of the Interior in research and development programs which have as their objective increased water supplies through weather modification.

The past 2 years of subnormal precipitation and runoff in the Colorado River Basin and the subsequent low water conditions in Lake Powell behind the newly completed Glen Canyon Dam are fresh in our minds. This has impressed upon us even more firmly than in previous years the fact that all means should be sought to maintain the supply of water to these projects which are vital to the agricultural and power industries and to the public dependent upon them. Even a small percentage increase in the average annual precipitation would result in extensive economic and operational advantages to everyone dependent upon the projects in the Colorado River Basin. Hence, investigations for increasing the supply of water by weather modification techniques are fully justified as one of the water management methods to accomplish the Department's responsibilities with respect to the extensive network of hydroelectric and irrigation projects throughout the Western States.

It is not my intent to comment on the economic justication or detailed advantages of the program which we propose or to give you details of the program now in progress. The other representatives from the Department, Commissioner Dominy and Mr. Garstka of the Bureau of Reclamation are much more able to do this than I am because they have been closely allied with this effort over the past years. I would like, however, to discuss briefly the present status of the science of weather modification, to provide information for judging the desirability of proceeding at an accelerated rate on research and development programs to increase our water supply by controlling precipitation, and to comment on the type of program which I believe is most logical.

Truly, there are some risks involved that a payoff will be forthcoming in the relatively near future or even that meaningful results will be obtained in the distant future as far as present day water needs

are concerned. We think, however, that the situation justifies expansion of research and development. Even though this subject is a controversial one, there is considerable support for our position among competent meteorological scientists in both Government and university situations.

To place this discussion in perspective, it is important to note that the history of present-day cloud modification experiments extends back a relatively few years. It has only been in the late 1940's and in the 1950's that success in increasing precipitation by modifications of clouds was considered a possibility. Even during this time, only a few competent scientists wished to become associated with rainmaking because the majority regarded it as unsound, scientifically. This attitude is now changing, fortunately, due in a great part to expanded research in the total field of weather modification and to the fact that more scientists have come to recognize the importance which weather modification can have on human activities. Moreover, advances in the technologies of measurement, data processing, and computer capability have opened up new experimental possibilities.

Reports by the National Science Foundation for fiscal year 1963 show that the total Federal effort in weather modification research was something over $3 million. At the present time, experiments are underway on lightning-storm modification, hurricane modification, fog reduction, and cloud modification. Also being studied are many aspects of basic cloud physics and studies on precipitation processes which are important to weather modification related to increasing rainfall and snowfall. Much of the work carried out by the Department of Defense, Weather Bureau, the National Science Foundation, and Interior has a direct bearing on understanding precipitation processes and the effects of cloud seeding which is the commonly practiced method in attempting to increase precipitation from moisture-bearing clouds.

The research which has been conducted in the past leads to the following rather tenuous conclusion. Under certain conditions, precipitation can be increased, perhaps as much as 10 to 15 percent from clouds which are a part of the cold winter storms produced when airmasses moving from the ocean are forced to rise in elevation as they approach mountain ranges. No single experiment has been identified as proving that such storms produce more precipitation when seeded but the weight of many experiments shows that some increase in precipitation is possible.

There is no conclusive evidence of any positive increased precipitation from seeding clouds in summer storms or those usually known as convective or cyclonic. In fact, I might say parenthetically that the evidence seems to indicate there can be decreased precipitation in those conditions.

It is surprising that this situation is true when, in fact, many practitioners have continued cloud seeding work, some for extended periods of time and at the expenditure of considerable private and public funds. The seeding operations of industrial operators have been conducted in such a manner as to preclude the possibility of assessment of results on sound scientific principles. The majority of the clients of the cloud seeding operations have not required such an assessment. Consequently these industrial operations can proceed just as the operator wishes to carry them on.

Sufficient information now exists so that an expansion of research, based primarily on orographic cloud seeding experiments, is justified. We have reached this decision on recommendation of several competent meteorologists who have been performing research on the basic physics of clouds. One of them has stated to us: "that the present real need is for seeding projects which will establish beyond reasonable doubt the extent to which local changes in clouds can lead to useful changes in a weather element over an appreciable area."

This type of development research, which is still far from the routine application of weather modification techniques, would be an extension of a search for basic knowledge about clouds and precipitation mechanisms. If successful it would lead to precipitation increases.

So, in summary at this point, our evaluation shows that the time has arrived for larger scale, well-planned field experiments. Testing and evaluation of results are an essential part of such experiments in contrast to the numerous industrial applications which have led to so much confusion and misunderstanding on this subject.

Recognizing that the efforts of several other Government agencies and some local agencies will continue to contribute knowledge important to developing weather modification techniques, we envision the Department's future role to fall in two places. We should, first, bring the results of the existing programs being carried out for other purposes to bear on our own problems, regardless of the reasons for which other research may be done. We think it is our job to be knowledgeable of these research programs both in Government agencies and in the universities and to insure that the results from them apply to the Department's mission in this field.

Second, and more specifically, however, we think that the departmental role should include the sponsoring of a continuing program primarily directed toward improving precipitation from winter storms. This program should be highly flexible to take advantage of new developments which may appear from university or other research. We should have as the end goal for this program the increase of water supply problems but we should undertake it in a research atmosphere.

This work should be handled by the Bureau of Reclamation. In cooperation with other interested groups the Bureau should be responsible for organization and support of a long-term, cloud-seeding project to test whether or not it is possible to increase precipitation from winter storms in such a way that there will be a positive benefit to water storage projects.

The Bureau will wish to call upon the competence in meteorological research which rests in the Weather Bureau, in the National Science Foundation, in the universities and industrial meteorological consultants. In order to accomplish this, appropriate planning and coordinating mechanisms will have to be derived. To augment the Bureau's staff there would be employed a panel of specialists to conduct feasibility studies and advise on the broad aspects of experiments. The actual experimental designs, completion of experiments and evaluations would be done via Bureau of Reclamation support to either Government or non-Government research and development groups identified as being the most competent and capable of carrying on this work.

The Bureau would exercise overall coordination and supervision. Their main task would be to maintain the continuity of the effort, coordinate it with other research and to bring the impact of the Department's competence in water management to bear on this problem.

To make our present position clear, we believe that the Department has a responsibility to encourage and support weather modification and research if there is a reasonable chance that it will help the water supply problem, and we think there is such a chance.

However, we realize that much more research is required before routine practical applications can be made.

To proceed into operational phases now without completely understanding the processes involved could lead to undesirable effects. These might range from decreases rather than increases in precipitation, to gross atmospheric contamination leading to adverse weather and to possible handicaps to future research. So we believe it is essential that any new effort in weather modification be approached as carefully planned development research, which will take into account probable environmental consequences of experimental actions each step of the way.

There is no doubt weather modification to increase precipitation and runoff in a significant way must ultimately involve large-scale operations covering vast watershed areas. Without question then this program of research could lead to large-scale environmental changes and they should receive a thorough preliminary review.

There is considerable renewed interest on the part of Government agencies in the study of the whole subject of weather modification. This interest includes not only the scientific and technical requirements but the legal and social aspects which will have an important bearing on how technological advances can be used. The U.S. Weather Bureau now has a study in progress to reevaluate their future rule on weather modification research. The National Academy of Sciences Committee on Atmospheric Sciences has decided to set up a special panel on weather and climate modification, and I understand that group will work very closely with the National Science Foundation, which is in the process of appointing a Commission made up of specialists in various fields of science, government, and industry to advise on weather modification potentials.

We hope to take advantage of all of this renewed interest and competencies that are represented by it.

The Department has a representative on the Interdepartmental Committee on Atmospheric Sciences of the Federal Council for Science and Technology which will make recommendations to the President and Bureau of the Budget on soundness of weather modification programs. Thus, Interior is not alone in its interest in this subject. With the close cooperation of these other groups which have available the advice of the best meteorological scientists in the United States, I am sure that we will be able to advance a program of research which will tell us whether or not we can increase water supplies in areas where shortages are critical.

Thank you, Mr. Chairman. That is the end of my prepared statement.

Senator Moss. Thank you, Dr. Calhoun, for your very fine statement.

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I understand from your testimony in general that there still is a a great deal to be learned and proved out, as it were, with long-range control activity in this field of weather modification?

Dr. CALHOUN. Yes, that is so. As concisely as I can sum it up, we are not yet at the point where we can say weather modification operations can be carried on on a routine basis and we can produce precipitation at will. We are quite a way from that.

Senator MOSS. We appreciate your testimony. I am sure that members of the committee are going to have a few questions they would like to ask, and I will ask Senator Anderson if he has any questions.

Senator ANDERSON. Dr. Calhoun, I start at the top of the first page where I see you are science advisor to the Secretary of the Interior.

Is that a position he has had regularly for a long time?

Dr. CALHOUN. This position has existed, I understand, since 1961. There have been two occupants of the position—Dr. Roger Ravelle was the first person to hold this assignment; I succeeded Dr. Ravelle.

Senator ANDERSON. Is he the man interested in oceanography?

Dr. CALHOUN. Yes, he is with the Scripps Institution and I believe is the dean of research at the University of California.

Senator ANDERSON. On page 3 you say it has only been the late 1940's and early 1950's that success was considered possible, that even during this time few competent scientists wished to become associated with rainmaking because they regarded it as unsound scientifically?

Where did you get that information?

Dr. CALHOUN. Well, sir, I should probably say this is just general knowledge. I know some specifically who hesitated to have themselves associated with it.

Senator ANDERSON. In the late 1940's?

Dr. CALHOUN. Yes.

Senator ANDERSON. Because it was unsound?

Dr. CALHOUN. Pardon?

Senator ANDERSON. Because they felt it unsound?

Dr. CALHOUN. Yes.

Senator ANDERSON. Could you name some of them? I can match it with some who didn't think it was unsound.

Dr. CALHOUN. I am sure you could. This has been a controversial subject for many years. Perhaps I could have worded this a little differently, more accurately, to say that all during this time some competent scientists hesitated to become affiliated with or identified with this. But there have been strong proponents of this as well as strong detractors.

Senator ANDERSON. Do you know a man named Dr. John Von Neumann?

Dr. CALHOUN. Yes, sir.

Senator ANDERSON. Would you regard him as a competent scientist?

Dr. CALHOUN. Very definitely, sir.

Senator ANDERSON. Did you ever see his article in a magazine with regard to cloud seeding?

Dr. CALHOUN. No, I did not.

Senator ANDERSON. It was interesting reading.

Do you know Dr. Irving Langmuir?

Dr. CALHOUN. Yes, sir.

Senator ANDERSON. Do you regard him as a competent scientist?

Dr. CALHOUN. Yes, sir, he has been a strong advocate of this.

Senator ANDERSON. He stated the ultimate threat was weather manipulation, not missiles. You could control the march of armies and everything with weather modification.

A great many weather scientists were interested in it. All the ones I suggested it to 15 or 20 years ago said we are not going to do it because we cannot get a controlled experiment.

As you may know, we tried to pass a bill 10 or 15 years ago, I have forgotten how long—it was the 81st Congress—anyhow, the rainmakers organizations, the people who were making money by being paid by the cattle raisers and the wool and vegetable growers, and so forth, hired a very effective lobbyist and the bill died, but a great many scientists at that time thought if we could get a bill through for a controlled experiment nationwide much good might result.

My attention has been called to an article that appeared in 1961 in which it said that I have been interested in the danger of weather manipulation by hostile powers since Dr. John Von Neumann, former AEC Commissioner, felt that this—not the ICBM—was the ultimate dangerous threat.

(The article referred to follows:)

[From the Washington News, Feb. 11, 1961]

WEATHER CONTROL STUDY?

Senate Interior Committee may start far-reaching study of weather control.

Chairman Clinton P. Anderson, Democrat, of New Mexico, has been interested in danger of weather manipulation by hostile power since Dr. John Von Neumann, former AEC Commissioner, warned that this—not ICBM—was the ultimately dangerous threat. Other scientists have agreed.

But so far, weather control research has dealt only with limited possibility of seeding clouds for rain or snow, not large-scale climate changes.

Dr. Von Neumann forecast atmospheric and climatic controls in a few decades. Dr. Edward Teller has spoken on peril to the United States if Soviets controlled weather on big scale. So has Henry G. Houghton, MIT meteorologist.

Final report of President's Advisory Committee on Weather Control, made more than 3 years ago, recommended speeding up basic research program in this field.

This has never been undertaken, but Senator Anderson's committee may try to get project back on track.

Senator ANDERSON. I only want to say if people of Dr. Von Neumann's talent felt you could do something if you could get completely controlled experiments, that might be something to suggest in this field.

Dr. CALHOUN. Senator Anderson, I agree with you wholeheartedly. We are all aware of your long interest in this field, backed up by the advice that you had.

Perhaps I could clarify what I was trying to state here by the use of the word "rainmaking."

What the scientists shied away from was, exactly as you suggested, rainmaking which was going on on an uncontrolled basis. Scientists are always in favor of controlled experiments, and I think this is what we are stating now as our position. As we go into this weather modification, if it is authorized, we believe that it should still be done on a controlled experimental basis. We do not want it to be interpreted as "rainmaking" in the sense of the hit-and-miss kind of operation that we think has gone on in the past.

Senator ANDERSON. Of course, there was a group of firms that developed a silver iodide machine. They sold them to ranchers. A

rancher in my State had a 15-year-old boy running the cooker. As soon as he saw what he thought was a good-looking cloud, he would turn it on and run it. This same individual got into an airplane when there was a very heavy rain cloud over his ranch and seeded it with Dry Ice. The cloud dissipated and just left, and he said, "I didn't get any rain from it at all," which was exactly what Dr. Von Neumann stated. He said sometimes the rains are made up in the Gulf of Alaska, I hope I am not misquoting him, and overseeding would lift them over the mountains and drop the rain where it was needed on the other side of the range.

I do believe there were a great many people who were profoundly interested in a controlled experiment. Others suggested we put ships out in the Pacific Ocean and let them try to increase the moisture being carried by clouds and try to handle it, but we were never able to get the law through the Congress to stop the other people from seeding the clouds with silver iodide.

I only hope that could be borne in mind.

If that were to be the purpose, what would be the effect of having all these activities scattered through the National Science Foundation, the Weather Bureau, and so forth?

Dr. CALHOUN. Sir, I was not proposing that we would scatter activities through a number of agencies except in the sense of going to these people for the appropriate scientific advice and assistance when it was deemed most desirable to do so. The intent would be to have the program supervised and coordinated in one spot—the Bureau of Reclamation. But the Bureau of Reclamation does not now have the competency within its structure to design fully these experiments. In order to get a full design it would have to call upon competencies that exist in other Government agencies and in the universities.

Senator ANDERSON. I don't want to open up an old wound, but if you ask the Weather Bureau, I am sure their testimony would be there is no possibility in this field. That was the position it took all the way through this endeavor, but the Bureau of Reclamation is acutely conscious of the shortage of water in certain areas of the country.

Let me read again from Dr. Von Neumann.

In 1956 he said:

> Our knowledge of the dynamics and controlling processes in the atmosphere is rapidly approaching a level that will make possible, in a few decades, intervention in atmospheric and climatic matters. It will probably unfold on a scale difficult to imagine at present. There is little doubt one could intervene on any desired scale, and ultimately achieve rather fantastic effects.

He thought it would be possible to spread a blanket of water all over these areas of the country. He saw reservoirs being emptied and he thought the country should do something about it then. I agreed with him then and I still do now.

Page 7, you say:

> To make our present position clear we believe the Department has a responsibility to encourage and support weather modification research if there is reasonable chance it will help the water supply problem.

Now, that means that before they should go ahead with it they have to solve the question whether it will help the water supply problem and if you don't try, how are you going to find out?

Dr. CALHOUN. Well, you cannot, sir. And I added an ad lib at that point that we thought there was a reasonable chance that it would help

to solve the water supply problem. But, you are exactly correct. You have to start somewhere and this is what we are proposing to do.

Senator ANDERSON. I was told one time that if, in developing the atomic bomb, they had followed the established rules of science and never done anything until they had proved it out we would hope to have one by the year 2100. We had one before that because we didn't wait. I would hope the Department of the Interior, recognizing the great water shortage we have, would be trying to go up to Idaho and trying to sneak a little water out of the Snake River some time, and I imagine the Senator from Idaho will have something to say about that. That being the case all over the country, might it not be a good plan to start work now?

Dr. CALHOUN. Yes, sir, I agree. And our approach to the problem would be that our end goal is an increased water supply.

Senator ANDERSON. There is hardly a State in the union that is not going to have some problems of water in the next 50 years. It may not be, but the temperatures have been rising gradually.

You say:

> To proceed into operational phases now without completely understanding the processes involved could lead to undesirable effects from decreases, rather than increases in precipitation, to gross atmospheric contamination leading to adverse weather and to possible handicaps to future research.

What are the possible undesirable effects from going ahead without fully understanding everything?

Dr. CALHOUN. Well, one of the possible undesirable effects is that precipitation would be decreased.

Senator ANDERSON. You can overseed as much as you can underseed?

Dr. CALHOUN. That is right.

Another possible undesirable effect which has been suggested is the possible contamination by a large amount of foreign nuclei placed in the atmosphere.

A third possible disadvantage is messing up the atmosphere and the atmospheric processes to such an extent at this stage that we destroy the possibility of learning what we need to know about the natural processes.

There are a group of scientists who believe that our state of understanding is such that we would be much better advised to observe situations for some time to come before we place any large amount of seeding material or other contaminants in the atmosphere.

Senator ANDERSON. But we have been for a long period of years and the supply of water in the Colorado River is getting smaller and smaller?

Dr. CALHOUN. Yes, sir. In spite of these possible disadvantages we believe that we should go ahead.

What I was attempting to point out here is, again, if one proceeded willy-nilly into cloud seeding on an operational basis rather than on a developmental research basis, that one might produce adverse effects. We must plan our experiments so that we can recognize adverse effects when they are occurring as well as beneficial effects.

We must design our experiments so that we do not leave ourselves open for a great many of these things.

As in any environmental problem you always want to protect yourself from going too far and destroying the situation you are working

with until you really know what you are doing, but at the same time you proceed cautiously.

Senator ANDERSON. One of the great problems in the early days was that the question of damages was unsettled. When three scientists of General Electric tried a controlled experiment in controlling a hurricane they succeeded in their plan, but the storm came back along the borders of the United States at a considerable height. If it had stayed down low General Electric might have some real suits against them. They asked the Government to do it, and the Government said, no, if it is dangerous we will not do it either. There was no work done. I was only hopeful that the Interior would feel, "Damn the consequences, full speed ahead," whatever the torpedo phrase was.

Dr. CALHOUN. I think we are saying this in effect.

Senator ANDERSON. In this statement?

Dr. CALHOUN. And I was trying to point out here, not damages resulting from landowners or suits, I was trying to point out the possible disadvantages that would result in a technological sense.

Well, sir, if I do not give the impression that I don't mean damn the torpedoes, full speed ahead, let me say that in spite of some of the hesitancies and controversies in this subject we think that we are right at the point where some large-scale experiments are necessary and desirable and that we ought to move forward with all speed which is commensurate with good planning to find out once and for all whether or not we can increase the water supply in the Colorado Rockies, and particularly the Colorado Basin, by weather modification techniques.

Senator ANDERSON. Thank you very much. That was what I was hoping to get to and I was going to quit questioning when I got that statement from you.

Thank you.

Senator Moss. As a good lawyer, which Senator Anderson always explains he is not, he finally got the testimony from the witness he wanted and now, no more cross examination.

Dr. CALHOUN. I am sorry I was so unclear in saying it.

Senator ANDERSON. Thank you.

Senator Moss. Senator Jordan?

Senator JORDAN. Dr. Calhoun, you have opened up a very interesting subject and believe me, I am just as interested as anyone in supplying a good water supply for the thirsty Southwest, and I thought I had offered a reasonable alternative but the suggestion was not received well in some quarters. I am, of course, interested in finding water for this area.

You raise some interesting points and I refer now to your testimony on page 7 where you say that:

> To make our present position clear we believe the Department has the responsibility to encourage and support weather modification research if there is a reasonable chance it will help the water supply problem.

You have indicated that you do believe it will help the water supply problem. That is what I get from your last statement. I, like Senator Anderson, hoped that you would be a little more vigorous in your insistence that you had a reasonable chance for success.

Turn now to your page 8 where you suggest that there is a renewed interest on the part of Government and Government agencies in the study of the whole subject of weather modification. And you continue that this interest includes not only the scientific and technical

requirements but the legal and social aspects which will have an important bearing on how technological advances can be used.

I think that is important if we are going to research the scientific aspects of it. Certainly the legal aspects must be investigated, too.

I had some experience in working out the St. Lawrence Seaway and power development. When we changed the level of Lake Ontario from the state of nature, we thought we were doing good for all of the people concerned by taking some of the flood waters off of the top and by reducing some of the minimum levels from the bottom but we found we were in great difficulty with everyone because we had taken control of the levels of Lake Ontario from the natural state and made it man made and everyone who was injured thereafter thought they had legal recourse against someone.

So, I think along with your scientific research it is very important that we do explore fully the legal and social aspects that are found to be tied in whith any scientific research.

My question is, Would your investigation go into the legal and social aspects of the problem as well as the scientific?

Dr. CALHOUN. I believe that Commissioner Dominy would be in a better position to answer this later.

My interpretation is that we would not get into research on the legal and social aspects. There may be such problems arise but it was not my thought that our research should cover this. There will be and are some studies going on in this, and particularly I understand the Commission on Weather Modification which the National Science Foundation is appointing does have as one of its goals the consideration of the total spectrum of problems dealing with this subject.

Senator JORDAN. I will ask the question later.

Senator Moss. Thank you, Senator Jordan.

Senator Bible?

Senator BIBLE. Thank you, Mr. Chairman.

First I would like permission to file a statement which I have prepared supporting the request of $1 million increase in funds to the Bureau of Reclamation to enable this work to go forward without delay. I would point to one statement that was made by Commissioner Dominy at the time he appeared before the Public Works Subcommittee of the Appropriations Committee which I thought better pinpointed the enthusiasm that I felt emanated from the Bureau of Reclamation on this subject for an increase in funds to permit an acceleration in the area of weather modification.

He said, among other things, "No other organization has more incentive, more know-how, and more desire," than the Bureau of Reclamation in this area of manmade rainfall. And I am sure, though I have heard your statement with some understandable reservations, that you would share that enthusiasm with him.

Dr. CALHOUN. Yes, I share the enthusiasm and I also agree that the Bureau of Reclamation has a strong mission within this field. It has the enthusiasm, and it has an operational group whose capabilities certainly can be brought to bear effectively on this important problem.

What my reservations implied or otherwise in my statement mean is simply that I do not want to oversell you gentlemen. I would not have you think that the scientific understanding of this process has arrived at the point where we can turn on and off water supplies by cloud seeding or any other weather modification technique.

The other reservation is simply that if I were going to make a judgment as to the best place to try out weather modification from a purely scientific point of view I might not choose the Colorado Basin area; that I might go someplace else.

Now, this I do not know at this time, but I have to admit the possibility. So, again, this may be the basis for some reservation.

The third basis for the reservation is simply that in order to carry on a controlled experiment which can be evaluated when we are all through, it is going to take a considerable amount of time and so, if we go ahead with this program we might not have our answer next year or the year after. The time scale is very definitely a long one, so my lack of enthusiasm, perhaps, is simply a means of hoping that we do not oversell you on the optimism associated with this.

Senator BIBLE. Well, I say, of course, in my statement that I do not presume that the Bureau of Reclamation would deliver this whole thing this year. I would hope that you would go forward with enthusiasm, and I particularly pointed this to the Colorado River Basin and I did it purposely, because if I understand my statistics correctly, this year and the last year are the alltime 2 dry years in the Colorado. So this pointed out an area which was badly in need of help. Those of us in the lower basin already feel the impact of a slight change in attitude on the part of the Secretary of Interior on the filling criteria as far as Glen Canyon is concerned. I am not going to get into that. I do want to indicate this poses some problems.

When the Bureau of Reclamation testified before our Appropriations Committee that an additional inch of precipitation above Glen Canyon would produce a runoff of 575,000 acre-feet, believe me that sounded like something that should be accelerated without delay.

Also, statisticwise his statement to me that this amount of increased rainfall, 1 inch of rainfall above Glen Canyon in this basin, not only would produce 575,000 feet of water, but it would also increase revenues in the neighborhood of $2,500,000 just for the power revenues alone, without the increase in values created in agriculture, municipal, and industrial water systems.

So it seemed to me that here in this great Southwest we had a basin that is admirably fit for some accelerated weather modifications, and I cannot too strongly urge, Mr. Chairman, that immediate attention be given to this problem, and I would ask permission that I file my statement in full on this point.

I might say that I was privileged to join with the leader in trying and challenging weather modification. Back in 1957 a bill was introduced by Senator Case for himself and Senator Anderson, Senator Magnuson, I believe, and Senator Watkins, your predecessor. I was a member of the Commerce Committee at the time and we were privileged at that time to help with the bill. This was the bill that put the National Science Foundation in this field.

I think it is time now that we move forward with even greater speed.

Senator Moss. Thank you, Senator Bible. The statement will be filed immediately following the statement of Senator Anderson, before the statement of Mr. Calhoun, that will keep us, I think, in proper sequence here in the record.

Senator Moss. I think Senator Bible's point is well made about the reason for concentrating on the Colorado Basin. It may not have all

of the logical scientific reasons but it has so many other urgencies that we can generate this greater enthusiasm we have been talking about because of the pressures there.

Mr. CALHOUN. Mr. Chairman, I appreciate this and I agree with Senator Bible, but this is simply another one of those examples of why it is you go to work where the problem needs to be solved and it is on this basis that I accept the advisability of carrying on this program in the Colorado River Basin.

Senator Moss. Thank you.

Senator Anderson?

Senator ANDERSON. I want to state what you said basically, by saying to you, when a group got together and discussed what we would do if we had a chance to have an experiment it was suggested by them there were three ways to go at it: One, take the Gulf of Mexico and try to overseed there where the winds sweep the clouds toward New Mexico and turn them eastward so the great southern section of the country would be served; the second was to go out to the Pacific and by stationing ships offshore as cloud-seeding bases, water would come to the State of California, perhaps be lifted over the mountains there and dropped on Arizona; and the third was to seed heavily in the Gulf of Alaska and try to bring it down from that angle. Their concept was to find out what was the best possibility of the three. Then you could apply that wherever it was needed in the United States. Therefore, when I agree fully with the Senators that this is an area that needs desperately to be served, I do hope the experiments will show what would be the best to go ahead with in other parts of the country.

Mr. CALHOUN. You expressed it better than I did.

Senator Moss. Thank you, Dr. Calhoun. We appreciate your coming here and opening this very interesting subject before the subcommittee. It is something which the members of this subcommittee have felt should be explored for a long time and we are continuing and perhaps accelerating our interest now.

We are very glad to have the Commissioner of Reclamation, Mr. Floyd Dominy, come this morning to testify and we will ask that you go ahead, Mr. Commissioner.

STATEMENT OF FLOYD E. DOMINY, COMMISSIONER, BUREAU OF RECLAMATION

Mr. DOMINY. I would like to file my statement for the record and just make a short summary because I know your time is short.

Senator Moss. Thank you. I might say we have a slight reprieve this morning in that the Senate does not go in session this morning at 10, so we are not pressed for time and we would like to have you express yourself fully as you care to do. Your prepared statement will be printed at this point.

(The statement referred to follows:)

STATEMENT OF FLOYD E. DOMINY, COMMISSIONER, BUREAU OF RECLAMATION

Dr. Calhoun has briefly described the Bureau of Reclamation's responsibility for water supply. In our 62 years of operation, we have developed irrigation facilities to serve 4,385,000 acres of new land and to provide supplemental water to 3,955,000 acres. In accomplishing this, we have constructed 180 reservoirs, having a total storage capacity of 171 million acre-feet. In connection with this

development, we have installed a total of 5,344,000 kilowatts of hydro generating capacity in 43 projects, divisions, or units. Much of the water supply for irrigation and power generation depends upon holdover storage—water that is stored in periods of favorable precipitation and held for either dry seasons or years. Our total investment in water resource projects in the 17 western contiguous States is over $5 billion.

The design of these water facilities has been based upon historical records of streamflow. Failure to secure streamflow of the magnitude contemplated in the original plans has serious implications in terms of both service and financial commitments of this system. We are particularly aware of this situation now in the case of the Colorado River. Much has been said and written in recent weeks about the filling of Lake Powell behind Glen Canyon Dam. The historical flow of the Colorado River since 1923 at the Grand Canyon, Ariz., gaging station, which prior to closure of Glen Canyon Dam was considered as the inflow into Lake Mead, has averaged approximately 12,200,000 acre-feet per year, with 8,200,000 acre-feet of this occurring during the runoff months of April through July. The water supply forecast for inflow into Lake Mead as of May 1, 1964, indicates that the much below normal winter precipitation in the upper basin of the Colorado River will result in a probable mean flow of only 5,100,000 acre-feet during the April-July period of 1964. This is sufficient to accumulate storage in Lake Powell to start power generation operations in 1964. Meanwhile, the contractual requirements below Hoover Dam will need to be satisfied essentially out of Lake Mead storage.

Current downstream requirements below Hoover call for a total release from Lake Mead of about 8,600,000 acre-feet per year, of which 1,500,000 acre-feet will be delivered to Mexico.

On May 8, 1964, Lake Mead was at elevation 1,123.77 feet, with an active storage of 14,601,000 acre-feet, of which 14,500,000 acre-feet (elevation 1,123) is needed to maintain rated power head for the Hoover powerplant. Lake Powell, as of May 8, was at elevation 3,395.1 feet with a total storage of 2,576,000 acre-feet—nearly 3,500,000 acre-feet short of the storage necessary for minimum power head at elevation 3,490.

Secretary of the Interior Stewart L. Udall announced on May 11 that, on the recommendation of the Commissioner of Reclamation, he ordered the outlet gates at Glen Canyon Dam to be closed sufficiently to bypass only 1,000 second-feet. This decision was based on the increased May forecast resulting from above average April precipitation in the upper basin.

Arrangements are being consummated to replace the losses in generation and plant capacity at Hoover Dam incident to lowering Lake Mead below elevation of 1,123 feet.

This present situation has naturally directed much attention toward the possibility of increasing precipitation on the Colorado River watershed through rainmaking programs. Dr. Calhoun has commented on the state of the arts regarding this matter. I do not need to duplicate his testimony. I do want to make several observations, however. Private and public agencies have been experimenting with rainmaking in this country for some 15 to 20 years, and as yet, the scientific community is not convinced that these programs have either increased or decreased precipitation. There are some individuals of recognized technical competence who are of the opinion that increases have been secured, but this is not universally accepted because of lack of proof sufficient to withstand the scrutiny of scientific engineering inquiry.

Even though we do not know whether we can increase precipitation by artificial means, our scientists tell us that there is more of a possibility of doing it in mountainous areas than in open, flat areas. This is because in mountainous areas, storms result from uplifting air masses by the terrain and cooling of the air. Some storms are referred to as orographic in contrast to convective storms in flat terrain.

Our scientists also tell us that there would be no chance for a program being successful in a period when there is no moisture in the atmosphere. In other words, a program should be carried out when conditions for precipitation are favorable. Generally, most people are not interested in rainmaking programs at such times. That is not the case with us, however. We are interested in precipitation whenever we can get it, since we have a system of reservoirs in which we can catch and store the runoff.

The water supply for the Colorado River is largely derived from orographic winter storms. The river is highly developed and has about 56 million acre-feet of active storage capacity which can regulate a large runoff. Also, the Colo-

rado River waters are used in one of the most productive areas of the United States. Judging on the basis of our present knowledge, the Colorado River might not represent the most ideal conditions for carrying out all aspects of a weather modification research program. However, it is an area which offers exceptional opportunity for fruitful research on a drainage basin aspect and, at the same time, if successful, could help to meet our needs for water supply. Although the Bureau's major objective of such a program is increased water supply, we recognize that if a rainmaking program were initiated, it must be approached on an experimental basis.

I would not want to hold out a definite promise of successfully increasing precipitation; however, we do believe the probabilities for increasing precipitation are good. Otherwise, we would not be taking up the time of this committee discussing this subject with you. Furthermore, if we were to undertake such a program, I definitely would want to hold out the hope of being able to find out whether a rainmaking program can be successfully executed in the physical environment of the Colorado River. If any such program were undertaken, it should be done with the intent of operating it for a sufficient period of time to secure positive conclusions. Any such program should be carefully evaluated constantly to determine the desirability of reorienting it and to take stock of results.

Mr. Garstka, who is Chief of the Water Conservation Branch in our Division of Research in our Denver office is here with me, and is prepared to outline for you the elements of a weather modification program as we now see them, including such things as the technical design of the program, the establishment of instrumentation for recording results, and the collaboration and consultation that would be required with agencies having a technical knowledge and erudition in this scientific area. In this latter connection, we would expect that any program undertaken would be coordinated by the Bureau but would be carried out in partnership with other agencies having such competence and knowledge. We would particularly look to the National Science Foundation and its associated colleges and universities, the Weather Bureau, the Forest Service, the Soil Conservation Service, and other similar agencies and, especially to the States to provide guidance in establishing and carrying out certain parts of the program. Also, if such a program were undertaken, we would take steps to add to our own personnel in this field in order that they could properly coordinate the activities of the various interests and agencies involved.

I might close by indicating that it has been said that water engineering involves a combination of mechanical and theological skills. Perhaps the time is near at hand when we can begin to narrow the range of application for the theological skills.

Mr. DOMINY. The obvious interest of the Bureau of Reclamation on this subject is that we have been, with Federal funds, involved in Federal projects, interested in conserving 8 million acres of irrigated land, with 5½ million kilowatts of installed electrical capacity and all of these projects are dependent upon water storage in some 171 million acre-feet of storage capacity in 180 reservoirs, which are in the arid and semiarid portions of the United States.

The design of these water facilities was based on hydrologic judgment, based again on whatever records were available as to stream runoff.

In the early years of our projects we had very little hydrologic history available to us, so the judgment had to be pretty much that of a man viewing the runoff of a stream for only a year or two. In more recent years we have had hydrologic periods as much as 50 or 60 years, but we find that these are not fully reliable as in the case of the Colorado River. The last 35 years of record is considerably lower in average runoff than the period available to us at the time the compact was arrived at. Consequently, these storage structures are not always able to do the job we thought they would do based on the hydrologic conditions that were known and could be relied upon,

we thought, at the time the structure was designed and the capacity fixed.

For example, the historical flow of the Colorado River at Grand Canyon, Ariz., gaging station, which was considered prior to the construction of Glen Canyon as the influent of Lake Mead, has averaged approximately 12,200,000 acre-feet per year, with 8,200,000 acre-feet of this occurring from the months April to July, but the water supply forecast for the inflow into Lake Mead as of May 1, 1964, indicates that we will not get more than 5,100,000 acre-feet during the April to July period of 1964.

Last year we had a May 1 forecast of around 4½ million for the April to July period and we got only 3,200,000 actual runoff which made it one of the very driest years of our records on the Colorado River.

Now, the current downstream requirements below Hoover Dam call for a total release from Lake Mead of about 8½ million acre-feet per year, including a million and a half to Mexico. You all know the problem of filling Lake Powell without damage to the lower basin needs and the level at Lake Mead which we are being faced with at this very period of history.

Now, the present situation has naturally directed much attention toward this possibility of increasing precipitation on the Colorado River watershed by weather modification methods, and Dr. Calhoun has commented on the state of the art regarding the matter.

I certainly want to avoid any duplication of that testimony.

I want to make, however, some observations concerning private and public agencies and their experimenting with rainmaking in this country for some 15 or 20 years, and as yet the scientific community is not convinced that these programs have either increased or decreased precipitation.

There are, however, as Senator Anderson pointed out, and Dr. Calhoun confirmed, some individuals of recognized technical competence who are of the opinion that increases have been secured, but this is not universally accepted because of lack of proof sufficient to withstand the scrutiny of scientific inquiry.

Even though we do not know with certainty whether we can increase precipitation by artificial means our scientists do tell us that there is more of a possibility of doing it in mountainous areas than in open, flat areas. This is because in mountainous areas, storms result from uplifting air masses by the terrain and the cooling of the air.

Our scientists also tell us that there would be no chance for a program being successful in a period when there is no moisture in the atmosphere, so we certainly do not propose to spend any money that is appropriated to us by Congress merely hiring a group of people to fly up and seed willy-nilly.

A program must be carried out when conditions for precipitation are favorable and we want to base judgment as to when they are favorable on all of the known weather information available from all the scientific experiments that have been made by the Weather Bureau and the National Science Foundation and the universities over the many years that we have been looking into this scientific aspect.

Now, generally, most people are not interested in rainmaking programs at such times. This is not the case with Reclamation. We are

interested in precipitation whenever we can get it since we have a system of reservoirs in which we can catch and store the runoff. In other words, if this next winter we had a real good snow year it would still be to our advantage, Mr. Chairman and members of the committee, to be out there seeding those clouds if we could make additional snow out of them because we have holdover storage reservoirs that can level this out over a period of years, and if we do get dry winters we would not waste money up there trying to seed clouds when there weren't any.

This is the sort of thing we have in mind and why we think a combination of scientific weather modification approach above the huge storage reservoirs of the Bureau of Reclamation, largely on Federal lands, in thinly settled, high mountain areas, is a prudent undertaking and ought to be pursued.

So, the Bureau's major objective in such a program would be increased water supply over a cyclical period as contrasted to the normal approach to rainmaking in the past of trying to get it to rain where there is a drought immediately needing to be alleviated.

I would not want to hold out a definite promise of successfully increasing precipitation, but we do believe the probabilities for increasing precipitation are good. Otherwise we would not be taking up the time of this committee discussing the subject with you.

Furthermore, if we were to undertake such a program I definitely would want to hold out the hope of being able to find out whether a rainmaking program can be successfully executed in the physical environment of the Colorado River Basin and to have definite information that would be accepted by the scientific community that the conclusions drawn from our work would be valid, and accurate.

Any such program should be carefully evaluated and on a constant basis as to desirability—so that we could reorient it and take stock of results.

Now, Mr. Garstka, who is the Chief of the Water Conservation Branch in our Division of Research in our Denver office is here and prepared to outline for you the results of a weather modification program, including such things as the technical design of the program, the establishment of the necessary instrumentation for recording results, and the program for collaboration and consultation that would be required with agencies having technical knowledge and erudition in this scientific area.

In this later connection we would expect that any program undertaken would be coordinated by the Bureau but would be carried out in partnership with other agencies having such competence and scientific knowledge. We would particularly look to the National Science Foundation, to the Weather Bureau, the Forest Service, the Soil Conservation Service, and other similar agencies and especially to the States to provide guidance in establishing and carrying out certain parts of the program.

Also, if such a program were undertaken, we would take steps to add to our own personnel in this field in order that they could properly coordinate the activities of the various interests and agencies involved.

It has been said that water engineering involves a combination of mechanical and theological skills. Perhaps the time is near at hand when we begin to narrow the range of applications for the theological skills.

Now, I reported a few weeks ago to the Appropriations Committee, Mr. Chairman, that if Congress saw fit to put Reclamation into this weather modification picture a little more deeply, that I felt there were three areas that we ought to look into and do advanced experimental work and, of course, this is specifically the most serious problem affecting the largest number of people and where we have made the highest investment in reclamation projects and where the foreseeable need is greatest and here is where I would concentrate the bulk of the moneys available.

I do feel that we ought to be working in the Sierras because here we have a local group that has expended considerable sums of money and I feel we ought to be working with them and to get a practical judgment, scientific judgment of the effectiveness of their work and to supplement their work in that area.

A third area which all of our knowledge to date indicates is the least promising, but which is just as critical, would be in the Great Plains area east of the Rockies where we also have a number of storage reservoirs and large acreages of irrigated land that could be directly benefited if we were to make any progress whatever by increasing precipitation in the type of weather that exists in the Great Plains community.

But I would put the bulk of the funds in the Colorado Basin, and put relatively smaller amounts in these other two areas under a program to really look toward aiding the total job of the Bureau of Reclamation.

Senator Moss. Thank you, commissioner. I think the point you made that if you had this increased program that the scientific means to measure and evaluate would not be in the hands of the Bureau because you want to get it to snow or rain any time you can get it.

I think some of the disrepute that has come on the rainmaking program has come because these private operators wanted it to rain when their crops began to burn up and there may not have been any moisture in the air at all at that time, whereas in the middle of winter they were hoping it would not snow any more and certainly did not want to seed the clouds.

Whereas on this basis there would be an attempt made to get the moisture whenever it happened to be available. If it was in the middle of winter, so much the better. It could be caught and stored.

Commissioner DOMINY. That is right. Our interest would be to see if we could increase the amount of precipitation, even when it was already snowing, for example, or when the snow clouds were there in quantities.

Senator Moss. Thank you. We do appreciate your testimony and the enthusiasm you show for this matter which obviously generates a lot of enthusiasm in the committee.

Senator Bible, do you have any questions of the Commissioner?

Senator BIBLE. I only have a couple of questions I would like to ask the Commissioner.

No. 1, I commend him for his enthusiastic support of this project. We recognize you cannot guarantee ironclad results. I think we ought to move into the weather modification program quickly and I

think we ought to make it a crash program insofar as the overall budgetary restrictions permit.

I certainly will support it in the Appropriations Committee to the best of my ability. I understand that Dr. Garstka will testify as to the framework of the program?

Commissioner DOMINY. That is right, sir.

Senator BIBLE. As I understand your testimony, you are in a position, as you stated before the Appropriations Committee, to justify the expenditure of the $1,100,000 in the first year. You have indicated this is a program that would probably take something in the neighborhood of 10 years. We cannot forecast that with complete accuracy, but it would require funding in the neighborhood of $1 to $2 million in each of the next 10 years.

Commissioner DOMINY. I advised your committee, as I recall, Senator Bible, that I felt 10 years was an absolute minimum. That two decades would be much better. A program of this nature, to satisfy the scientific community that we do have facts that can be relied upon in an area as vast and unknown as the weather modification field, would require an extensive program over an extensive period of time.

Now, the Bureau of Reclamation is not the leading scientific agency in this field, of course. We are an engineering and scientific organization and an action agency combined, and we would need the scientific skills of all of the groups that have been discussed here today that have been working with this area of science for many years.

We would hope to rely upon them for scientific guidance in laying out our program and in setting up controls and procedures that would positively give the type of information that would satisfy the scientific community.

Senator BIBLE. Two further questions. First, I have suggested in meeting informally with some of your people that they be prepared to supply for the record the authority under which you act. Where do you go for your authority to work in this field as a matter of law?

I do not know whether this is directly pointed to you, but if it is not, would it be supplied to you by Dr. Calhoun?

Commissioner DOMINY. I would be pleased to have a letter from the Solicitor of the Department to the committee chairman if you like, put in this——

Senator BIBLE. I think it is helpful. I am convinced that you have all of the authority you need now to move into this area, but I think we better have something in the record that says that, so that you are not expending money without authorization?

Commissioner DOMINY. We will be happy to present a statement on that. The only problem as I see it, is whether or not the funds would have to be reimbursed. I don't think there is any question we have the authority to expand any funds for aiding our projects under general reclamation law. I would think that even though the Congress failed to state specifically that the fund would be reimbursable, they would be under section O of the Funding Act, that this would not be pinpointed to the aid of any specific project.

Mr. Chairman, I think it might be good to have that for the record. I will have the Solicitor prepare a letter on that.

(The information requested is as follows:)

DEPARTMENT OF THE INTERIOR
OFFICE OF THE SOLICITOR,
Washington D. C., June 11, 1964.

Hon. HENRY M. JACKSON,
Chairman, Senate Interior and Insular Affairs Committee,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: During Commissioner Dominy's appearance on May 21, 1964, before the Senate Subcommittee on Irrigation and Reclamation, Senator Bible asked that a formal statement from the Solicitor's Office be prepared which would outline the authority of the Bureau of Reclamation to conduct a research program in the field of weather modification.

Of additional concern in this regard is whether or not funds appropriated for this purpose are to be considered as nonreimbursable.

We are of the opinion that the Bureau has basic authority to conduct weather modification research and that funds appropriated for weather modification research are nonreimbursable funds under the general statutory authority of the Bureau of Reclamation.

The Reclamation Project Act of 1902 (32 Stat. 388); 43 U.S.C. 391 (1958) directs the Bureau of Reclamation to develop water resources for reclamation purposes. Section 1 provides that the reclamation fund may be used, inter alia, "for the * * * development of waters for the reclamation of arid and semiarid lands * * *." The projected weather modification program has as its purpose the initiation of practical methods of inducing precipitation and thus increase runoff that could be stored in surface reservoirs and used for the reclamation of arid and semiarid lands.

The authority of the 1902 act was supplemented by subsection O of section 4 of the Fact Finders Act, as amended (59 Stat. 54); 43 U.S.C. 377 (1958), which so far as pertinent, states: "The cost and expense after June 30, 1945, of the Office of the Commissioner in the District of Columbia, and, except for such cost and expense as are incurred on behalf of specific projects, of *general investigations* * * *, shall be charged to the reclamation fund and *shall not be charged as a part of the reimbursable construction or operation and maintenance costs*" (emphasis added) (43 U.S.C. 377(1958)).

The purpose of this subsection was to enable the Bureau of Reclamation to conduct "general investigations," not related to specific projects, including research work, for the development of water resources without the necessity of making the costs thereof reimbursable.

Subsection O reflected the recommendations of special advisers to the Secretary that costs entailed to acquire a "fund of information covering all the available water resources of the arid and semiarid portion of the United States" be made nonreimbursable. See "Federal Reclamation by Irrigation" (S. Doc. No. 92, 68th Cong., 1st sess., 49 (1924)) and also "Hearings Before the House Committee on Irrigation and Reclamation on the Extension of Time for Payment for Settlers on Government Reclamation Projects" (68th Cong., 1st sess., 265 (1924)). In the 1945 amendment of subsection O, Congress specifically recognized that the authorization would facilitate many basinwide exploratory investigations, the costs of which would be nonreimbursable. See "Hearings Before the House Committee on Irrigation and Reclamation on the Amendment of the Fact Finders Act" (78th Cong., 2d sess., 14 (1964)).

Since fiscal year 1951, the appropriation acts applicable to the Bureau of Reclamation have always provided, in identical terms, that those activities enumerated shall, pursuant to subsection O, be nonreimbursable. Among the functions always listed as nonreimbursable, in accordance with subsection O, are funds appropriated for general engineering and research. The relevant portion of the latest statutory redeclaration of congressional policy, the 1964 Public Works Appropriation Act (77 Stat. 850), reads: "[A]ny appropriation made herein *shall be available* pursuant to the Act of April 19, 1945 (43 U.S.C. 377) * * * for * * * *general engineering and research under the head 'General Investigations.'*" The report of the House Appropriations Committee of the year in which this language was first adopted, fiscal year 1951, indicated that it was added so as to enumerate functions to be placed on a nonreimbursable basis. (See H. Rept. No. 1797, 81st Cong., 2d sess., 173 (1950).) The Bureau of Reclamation has always made its budget requests for weather modification funds under the budget heading "General Engineering and Research."

The first appropriation for weather modification studies by the Bureau of Reclamation was added by the Congress to the 1962 Public Works Appropriation Act under "General Investigation" for "research on increasing rainfall by cloud seedings." In all subsequent budget presentations, the funds for this work have been included under the "General Engineering and Research" heading.

The 1902 act, as supplemented by the Fact Finders Act, was intended to, and does, provide the authority necessary for the Bureau of Reclamation to engage in this significant research program. It is our opinion that funds appropriated for weather modification purposes are expendable on a nonreimbursable basis.

Sincerely yours,

FRANK J. BARRY, *Solicitor.*

Senator BIBLE. This is not really on the question of the modifications, but the obligation of the upper basin States to deliver water to the lower basin States I think is found in the compact, and it says the obligation is to deliver 75 million acre-feet in each consecutive 10-year period of time. Is that correct?

Commissioner DOMINY. This is generally correct; yes, sir.

Senator BIBLE. Now, how do you measure that? For example, in this fiscal year do you measure back 10 years to see whether or not the upper basin States have kept their commitment? Do you go back from 1964 to 1954 to see that 75 million acre-feet was delivered at Lee Ferry? This is a legal question and if it is not your responsibility, and if the Solicitor has not clarified it, may I ask the question and ask you to ask him to give me a legal opinion on it?

Commissioner DOMINY. This problem is a very complex one, as the Senator well recognizes.

Senator BIBLE. I do not want to get astray of the subject.

Commissioner DOMINY. We have not been confronted with accounting under that point of the compact because until 1963, when we closed Glen Canyon, the upper basin had no means of withholding water in the river and whatever was there went on down.

So you take any 10-year period of history and much more than 75 million acre-feet reached Lee Ferry. Now, there are people in the upper basin saying, "That being the case, Mr. Commissioner, why can't you close Glen Canyon Dam and stop all water because we have already gone way above that 75 million acre-feet in the previous 10 years? So we don't need to send down any in 1964; put a zero in for 1964 and knock off the other year and average it out and it will still be 75 million acre-feet."

Senator BIBLE. Of course, you have no obligation; I know that.

Commissioner DOMINY. We felt that was not quite this simple and we had to work out something that would allow everybody on the river to live during this filling period.

Senator BIBLE. I do not want to use this forum as the means of exploring that problem and maybe I could do it possibly better if I address a letter to the Secretary of the Interior and ask a specific question.

I think maybe that is better, Mr. Chairman. I know you have some interest in this as well, and I do not want to cloud this hearing. I thought possibly we already had an opinion on that.

Commissioner DOMINY. I can make one more statement that will be helpful. Our filling criteria which was announced officially and published in the Federal Register in 1962 was based on a rationale that we had to find a way to fill Glen Canyon without disrupting the Federal

investment elsewhere on the river and all the economy that had been built around those investments.

We tried to develop a filling criteria that was not based precisely on legal interpretation of each paragraph and subparagraph of the law of the river and the compact and so on.

We had hoped we could avoid any court action to interpret any of the various portions of the compact.

Senator BIBLE. I would kind of hope you would, too, because the last court action came about as a result of the Santa Fe compact, and this is 20 years later. I am not sure that has been resolved as of this time.

Senator Moss. Thank you.

Senator Jordan?

Senator JORDAN. Commissioner, I want to assure you I am in full accordance with your objectives and I intend to support your requests for appropriations for this research project.

I do have some questions because this Colorado Basin intrigues me with the great capacity you have there for storage. You said in your statement you have storage for 56 million acre-feet in all of the several reservoirs.

Commissioner DOMINY. That is right, sir.

Senator JORDAN. This would be more than four times as much storage capacity as the average annual runoff of the river.

Commissioner DOMINY. That is correct, sir.

Senator JORDAN. I make that comparison, Mr. Chairman, because up in the Pacific Northwest the most we can ever hope to do possibly is to store 30 percent of the annual runoff of the Columbia River in our storage project. So here is a basin where the storage in relation to the annual runoff is tremendously high, so this leads to a question, Mr. Commissioner, as I say, I want to see all the water induced to fall in a water-deficient area that we can provide—by scientific means or otherwise.

I am concerned also to see that we take care of the water after we get it in the reservoir and my question then is directed to that point.

What would be the annual evaporation losses from 56 million acre-feet of storage in the Colorado Basin?

Commissioner DOMINY. On an average in the Colorado area you get evaporation in the range of 5½ vertical feet per acre of the area covered, so if you multiplied 5½ by the surface acres of the reservoirs you would get a pretty good idea of the evaporation loss on an average.

Senator JORDAN. Do you know the surface acres involved in 56 million acre-feet of storage?

Commissioner DOMINY. I do not have it precisely. I could give you a pretty good general idea. We would have about a million and a half to two million acre-feet of evaporation if all of the reservoirs were full.

Now, they will not ordinarily be full, and the lesser the surface area there would be correspondingly less evaporation. I would say the average evaporation would be in the range of about a million acre-feet a year, because the reservoirs would not be full simultaneously except for very small periods of time, if ever.

Senator JORDAN. The reason I followed this line is because it points up to me, Mr. Chairman, the need for research into this area as well, not only to induce water to fall in the basin, but to take care of it after we get it there by retardation of the evaporation losses.

Commissioner DOMINY. I am in full agreement with that, and the Congress has supported that and continues to support it and we are making some progress. The big problem is the wind problem of keeping the film in place under natural conditions.

Senator JORDAN. Thank you, Mr. Chairman.

Senator Moss. Thank you. Senator McGovern.

Senator MCGOVERN. Mr. Chairman, I am not a member of this subcommittee but I am vitally interested in the weather modification program. I would like to ask one or two questions.

Senator Moss. You are very welcome, we recognize your interest in this subject and we are pleased you came to listen to this testimony. You may participate.

Senator MCGOVERN. Mr. Dominy, I did not hear all of your statement, but I intend to read it. The Select Committee on National Water Resources, as you know, published a supply and demand study indicating that the upper Missouri Basin will be out of water by the year 1980. By "out" we mean that all available water will be committed to established uses. There won't be any more water for cities, industries, or irrigation.

In recent years we have already found it necessary to shorten the navigation season in the lower river because of water shortages. The main system dams on the Missouri are now built so that any increase in precipitation could be caught and stored.

I am wondering in view of those facts if the potential benefits of weather modifications in the Missouri River Basin are not comparable to the Colorado River Basin.

Commissioner DOMINY. I think, over the long pull, Senator McGovern, you could benefit as much as the Colorado Basin to increased precipitation in your mountain watersheds. The interest as I see it while we are still in the research and development stage of this science that we ought to concentrate it where the need is greatest now, and the problem is already with us as to water shortage in the Colorado Basin, whereas it has not reached the acute stage yet on the Missouri, and will not yet as I see it until we get all of the comprehensive Missouri Basin plan completed.

As you say that cannot come before 1980, and I think 1980 is probably earlier than it will come because of the years it takes to develop the huge irrigation projects that would be diverting the water from the rivers.

So, I do not disagree with you at all, that whatever we learn from this experiment in the Colorado storage would then be applicable to your areas if the need arose for such a program.

Senator MCGOVERN. Is it not true that there are variations in the weather pattern in the two areas that would make it necessary to do research and development in both fields—that is in both areas—to get all the knowledge that you need?

Commissioner DOMINY. I agree with you in that also. The Missouri Basin drainage area encompasses not only the mountain snowpack type of storage which comes from orographic weather action primarily in the mountain region, but you also have a good bit of your runoff from convection storms in the plains area.

Before you came in I indicated that I felt that research by the Bureau of Reclamation research and development programs in this weather modification area ought to be carried on in three areas—one

in the Sierra Nevada area, one in the Colorado storage basin for the orographic type experimental work in the mountains, and one in the Great Plains country to study and work on convective type storms. So I agree that right now we ought to be continuing research in that area which does encompass a good part of the reclamation area in the Northern Plains.

Senator McGovern. Is hail suppression one of the potentialities of the weather modification program as you see it?

Commissioner Dominy. Yes, Mr. Garstka, who is waiting to testify, can discuss the present knowledge of the science as we understand it. It is one of the possibilities in weather modification that carefully controlled seeding at the proper moment might prevent hail damage.

Senator McGovern. I certainly intend to support in every way I can the Colorado Basin program but I did want to underscore my interest also in the Missouri Basin program.

Thank you very much, Mr. Chairman.

Senator Moss. Thank you, Senator McGovern.

And thank you, Commissioner, for the very fine testimony and you can see we all have great feeling of urgency in this program.

Senator Moss. Mr. Garstka, who is Chief of the Water Conservation Branch of the Division of Research of the Bureau of Reclamation, will be our third witness this morning. We are pleased to have you, Mr. Garstka. I have heard you talk before on weather modification and we look forward to your testimony.

STATEMENT OF WALTER U. GARSTKA, CHIEF, WATER CONSERVATION BRANCH, DIVISION OF RESEARCH, BUREAU OF RECLAMATION

Mr. Garstka. Mr. Chairman, gentlemen, before I look at my statement I would like to clarify a point which may be resting in your minds due to a remark of Dr. Calhoun's.

He mentioned that the Colorado River may not be the best place for cloud-seeding research in weather modification and I completely agree with reference to detailed studies. For example, there is a new nucleating agent that may be much better and is being investigated in the Cascades. The Colorado River Basin is a large basin, it is orographic, it does offer advantages for a drainage basin-type of experiment. This is not at all in conflict with his remarks, with which I agree.

The Bureau of Reclamation's proposed program is aimed at securing a definitive answer as to the role which weather modification may have in increasing water supply.

Since fiscal year 1962 the Bureau of Reclamation has been conducting research in weather modification under contract with three universities:

(*a*) The Desert Research Institute of the University of Nevada, where the Bureau is contributing funds in support of an extensive cloud-seeding program being conducted, chiefly with the funds provided by the National Science Foundation and the State of Nevada, in our Humboldt project area.

(*b*) The Natural Resources Research Institute of the University of Wyoming is conducting research on the inducement of snowfall from cap clouds. I might mention parenthetically that a cap cloud sits like

a cap over the top of the mountain; it is created by the uplift caused by the mountain to the air that is flowing over it.

At Elk Mountain about 1,000 miles of windflow creates this cap cloud that just hangs there. Ordinarily it does not snow. To date, this research has been conducted at Elk Mountain. Results indicate very definitely the possibilities of inducing or increasing snowfall from cap clouds.

Results are much more encouraging and were attained much earlier than was anticipated. This is the type of research we need to conduct before we can go into large-scale operations.

Cap clouds are small, they are self-contained, you can fly all around them, you can see what you are doing. That work is very valuable from the fundamental scientific aspect. The cap cloud itself at Elk Mountain does not cover much area, but what we are finding out there is fundamental to research and activities elsewhere.

A cloud census has been conducted, based at Farson, Wyo., to provide knowledge of the times of occurrence and of the persistence of cap clouds in the area providing the water supply to the Eden project.

(*c*) The South Dakota School of Mines and Technology has been conducting, with Bureau support under a series of contracts, research on the nucleation of clouds under the convective system which prevails in the summer in the Great Plains area.

Since the meteorological scientists have recently established that not all of the precipitation in the Great Plains may result from the ice crystal process, the investigations at the South Dakot School of Mines and Technology are expecially important, since new and unprecedented techniques need to be developed if we are to deal successfully with inducing or increasing precipitation from warm clouds.

I might mention that in many of the mountain areas, the summer rainstorms are convective and not orographic.

The Sierra Nevada Range, in Kern and Tulare Counties, Calif., causes an orographic uplift of maritime air masses which are known to transport great quantities of moisture. This area is outstanding in offering promise for successful research and possibly future operations for increasing water supply by weather modification.

Years before the currently prevailing critical situation of water supply in the Colorado River Basin was recognized, we gave thought to the organization there of both short-term and long-term research on an unprecedented scale.

We want to establish beyond any reasonable scientific and engineering doubt whether or not a water supply can be increased through weather modification.

This immediately introduces the problem of evaluation of results. The Bureau of Reclamation's basic interest is in inflow to our reservoirs, and this interest places a really tough assignment upon the evaluators.

Various approaches may be used in the attempt to evaluate the attainments of a cloud-seeding research of operation. These approaches can be roughly divided into physical, statistical, hydrologic, and economic.

Physical measurements, are necessary and most valuable in developing techniques; however, physical measurements alone as conducted in the clouds may fail to evaluate water supply attainment.

For example, a very successful cloud-seeding operation may produce precipitation which could, upon falling to lower levels, completely evaporate before reaching the ground. What started as a clear-cut cloud physics attainment may be a total failure in increasing the water supply.

One way to evaluate the attainments is to compare the means, the averages, of a series of precipitation gages before and after cloud seeding. This has been shown to be a very weak method. Another method uses the so-called target and control area approach. This, likewise, has been generally nonproductive, since the area to be compared with the target area may differ depending upon the direction of windflow.

In both the comparisons of the mean precipitation before and after seeding and in the target and control area approach, certain elementary statistical reductions of data have been used.

It is generally agreed that, with reference to precipitation measurements, a statistical approach involving randomization is necessary. The purpose of randomized experimental design is to ascertain, by removing any personal bias, whether or not a particular attainment is in fact the result of the treatments applied.

The philosophy underlying randomized statistical experimental design is very well established. However, in order to apply randomization intelligently, the experiment must be capable of producing physically indicative data measuring the variables which describe mathematically in a precise manner the system with which we are dealing.

The utmost care must be exercised in the choice of variables to be measured. Omission of an important variable will be reflected in the results of the statistical analysis, rendering the experiment fruitless.

I might mention parenthetically that many experimentalists have discovered halfway through the stated period that they were not measuring the right thing or not measuring it well enough or that their technique was not good enough, in which case the experiment is dead at that point because one cannot introduce another variable halfway through without in effect starting again at the year 1. This has happened all too often in many experimental approaches. This is a trap we have to guard against in our further work.

It is asking too much of the statistician to give a definitive answer when he has been given nonindicative data. I personally interpret the results of most statistical analysis of cloud seedings to date as proving mathematically that we did not know what we were doing physically. A prime objective of the program would be to make every effort to design potentially productive randomized experimental designs for the various facets of the program.

Randomization can be accomplished in various ways. Perhaps one of the best ways involves the so-called crossover approach in which the area to be treated and the one to be left alone are selected at random for individual cloud seedings at random.

This approach lends itself to analysis by using data from precipitation reaching the ground. Right here, there becomes evident the very great difference between this and the usual type of experiment involving systems of an engineering, physical, and biological nature.

The number of opportunities for the randomized crossover depends upon the number of moisture-bearing storms which come to the drain-

age basin and the timing of their arrival. At the present, these are completely out of our control. It is obvious, therefore, that a randomized crossover experimental design may take many, many years before the atmospheric scientists and engineers can give the statistician sufficient data to meet the requirements of statistical analysis. Physical, hydrologic, and economic analyses provide other possible approaches to control.

The Bureau's interest is in inflow to the reservoirs, which is the result of runoff from the drainage basins. It may not be possible, in a headwater system in which the runoff producing precipitation falls as snow and remains in cold storage until the spring snowmelt season, to segregate, in terms of streamflow, individual cloud-seeding activities.

The higher altitudes of the Rocky Mountains produce the major part of the flow of the main stem of the Colorado River. Most of the land is federally owned, consisting mostly of national forests, national parks, and Bureau of Land Management areas.

The headwaters of the Colorado River secure their runoff mostly from snowmelt resulting from the snowfall season when the orographic influence operate. Mr. Loren Crow, a consulting meteorologist, has indicated that the air mass circulation is such that any augmentation of snowfall from the air masses subjected to the orographic uplift would have very little deleterious effect on the precipitation eastward, since another source of moisture provides the precipitation for the area east of the Rocky Mountains. This source is said to be the Gulf of Mexico.

One way to set up an experiment which has been suggested would involve three sets of two drainage basins each. Each of the six drainage basins would be at the Continental Divide, and they should be roughly comparable in size and other characteristics.

In order to select such areas, an intensive description of the basins would have to be made. The individual basins of each of the pairs would need to be sufficiently far apart so that an experiment or an operation on one of the basins would not carry over to the other basin of this pair and so that one pair of basins would not influence the other basins.

Intensive instrumentation at a scale never yet attained would very likely be required in the experimental areas. The instrumentation would consist of, but not necessarily be limited to, such things as meteorological radar, trajectory-tracing instrumentation for ascertaining the uplift and spread of nucleating agents, photographic observation points, automatic transmitting rain gages, snow density determining equipment, and possibly streamflow recorders.

A thorough micrometeorological network would very likely be needed in the drainage basins on the eastern slope of the Continental Divide to ascertain any carryover effects as well as in the operational area.

Analyses of Tiros and other satellite data would permit advance recognition of potentially seedable moisture transporting air masses. The analysis of the air masses at various levels by atmospheric soundings, coupled with an effort at greatly increased precision of forecasting, would also undoubtedly be required.

I might mention parenthetically that there are only about a dozen storms that bring in the moisture supply to the headquarters of the

Colorado. Those are the storms we need to recognize and those are the ones we need to work on.

These are some of the factors that would likely be considered by the scientists and engineers of the various disciplines who would be responsible for the design of the study and for their particular portions of the work.

It is evident that there is a very fundamental joint interest of the meteorologists, engineers, foresters, and statisticians in deciding upon the type, intensiveness, and character of the instrumentation. It is anticipated that this program would be carried out as a collaborative effort with the universities and scientists under the sponsorship of the National Science Foundation's program, including the National Center for Atmospheric Research, participating in activities and on manners to be agreed upon.

It is obvious that the Weather Bureau has a most important role in the proposed Colorado River Continental Divide program. The Soil Conservation Service's experts in snow surveying are needed to work with all others on a most important phase of the program.

Since we know that forested drainage basins are dynamic and since it is possible that differences in the hydrologic behavior of drainage basins may take place for reasons not at all related to the atmospheric sciences, the active collaboration of the scientists of the Forest Service would be helpful. Private individuals, institutes, and laboratories may be called upon. The defense agencies could be of great assistance.

The States and their universities have a fundamental role in this activity. It is essential that the States make use of the utmost benefit of their authority in issuing weather modification licenses; otherwise, indiscriminate local operations might invalidate years of effort, precluding precise statistical analyses.

Let us keep in mind that the reason for this program is to find out whether or not weather modification can increase the water supply by augmenting the inflow to reclamation reservoirs. It would not be wise, therefore, to embark upon activities before the experimental designs have been agreed upon and the closely related instrumentation placed in service.

There will need to be at the beginning, as Commissioner Dominy mentioned, a period during which research necessary in cloud physics, in verification of the data reporting networks, and in polishing up the logistics of the system will need to be done.

We must be patient and thorough in the early stages so that when the program gets underway, we will secure data that will permit analysis.

It is an absolute essential in the organization of such a program that the individual scientist or group of scientists be allowed the utmost freedom for the design and performance of their particular activities, and it will be the responsibility of all of the participants to see that their individual efforts are within the context of the broad program.

Dr. John C. Calhoun in his introduction said:

> We think, however, the situation justifies expansion of research and even though this subject is a controversial one, there is considerable support for this position amongst competent meteorological scientists, both in Government and university situations.

The program proposal is ambitious, challenging, and difficult. It will take money, effort, and time. It is an endeavor of surpassing

importance to the Nation. It will require a dedicated effort by the Nation's best scientists and engineers if it is to succeed.

We in the Bureau of Reclamation look forward to the possibility of joining with others in launching such a program with a minimum of delay.

Senator Moss. Thank you, Mr. Garstka, for your testimony. I know this is a field in which you are engaged and which you have a great deal of expert knowledge.

After listening to your detail of the needs of setting up the kind of program that we should have I begin to wonder about the time factor.

How long a time do you estimate it would take to conduct an experiment of the kind that you think is needed here to determine whether or not we have a valid weather modification program?

Mr. GARSTKA. Mr. Chairman, it would probably take half a year or so for the scientists, assuming the program goes forward, to consider the experimental design and jointly decide what to install and where. Then it is a matter of supply, transport, accessibility which is tied to the winter season and the summer season, so I would not expect, even if we had the money, today, that we could do more than to begin our installations and our appraisals of watersheds this winter.

Senator Moss. It would be difficult to get ready for this winter, you say?

Mr. GARSTKA. We could start, but we would have to have practically instant money.

Senator Moss. And then once you did get set up, which might take 6 months or a year, over how long a period of time would you have to continue these observations before you would think of getting valid data?

Mr. GARSTKA. That would depend entirely on how good our techniques are, how lucky we are, and how many storms come in so that we can work on them. We need to establish, for example, the fact that when we release nucleating agents that they are getting into the clouds and not just drifting off. Those things would have to be established just like sighting in a rifle. You may have a beautiful gun with a new telescope sight, but you would not think of going hunting without sighting it in.

So that those things will have to be done, as Commissioner Dominy mentioned, as a research shakedown process before we could go into larger scale activities which would then be subjected to continuous physical, hydrologic and, ultimately, statistical analysis.

A physical analysis could be done almost immediately, but it is probably one of the weakest so far as our inflow to reservoirs is concerned. Runoff will take time. The snows melt once per year in quantity, so that I would estimate that it would take a minimum of 10 years before we would know what we are doing and that would depend chiefly on how many storms we get to work on.

Senator Moss. In 10 years, then, we still might get the answer that we had not achieved very much, depending on what you were able—what I want to ask really is: Do we have to wait the full 10 years or would there be earlier readings that might influence the techniques that are being used?

Mr. GARSTKA. There would be evaluations performed as we go along but to establish sufficient data for analysis by the nebulous scientific community would require an accumulation of samples of data. The

statistical analysis is scientifically the strongest, it is also the most indefinite for timing, and possibly the longest.

We trust that with good physical controls and observations and with an intensive snow survey system and rain gage system which would allow us to evaluate what we are doing with individual cloud physics research and short-term operations that we would be continuously gathering experience and information as we go along. If that is so, it would practically make certain that the statistical analyses would verify that result.

Commissioner DOMINY. Let me add just a little bit to that, Mr. Chairman. With the kind of program that we discussed with the Appropriations Committee, starting out with a million dollars a year and as we get it built up over a decade or two, perhaps up as much as $3 million a year, we would actually be doing enough cloud seeding and management of the weather, attempt to manage the weather, that if we are succeeding there would be increased precipitation in the Colorado Basin.

But as Mr. Garstka points out, we will not be able to satisfy ourselves or the scientific community that we have succeeded until we have enough years of record in these various basins of comparison to provide really scientific and statistical evidence.

So, even though we might be accomplishing it we could not prove it to anybody else until after we have had a sufficient length of time.

Senator Moss. Thank you. My next question was going to be on this amount of money to set up the kind of program that you have talked about here with the needs for gaging stations and observations and so on, is $1 million annually an adequate figure?

Commissioner DOMINY. We think that is only adequate for the early years, the first year or two. As we actually get into it we estimate that we would need as much as $3 million a year to carry on an experiment in a basin like the Colorado storage drainage area that would be significant.

Senator Moss. What is your estimate on the number of personnel that would be involved in this work?

Mr. GARSTKA. That is really a tough question, you have to look around a couple of horizons for that one, but our Bureau's approach as we envision it would be not to staff up extensively at all but to welcome and secure the collaboration of the National Science Foundation's system, the Weather Bureau, the extensive erudition which is present in the private meteorologists in the institutes and in the colleges.

Senator Moss. So there would be a degree of contract work available to you, contracted services outside of the Bureau?

Mr. GARSTKA. Yes, either by contract or by concentration of efforts at their own expense depending on the appropriations picture.

Senator Moss. Thank you, Mr. Garstka.

Senator JORDAN. You had a very interesting statement, Mr. Garstka. I understood you to say that the precipitation in the Colorado River Basin comes as a result of about 10 or a dozen storms in a year?

Mr. GARSTKA. That is the major snowfall. The major snowpack comes from just a few heavily laden moisture-bearing storms.

Senator JORDAN. By weather modification if we could get one more average storm we would increase the water supply in the basin by, say a million acre-feet a year?

Mr. GARSTKA. I would not hold out much hope for inducing another average storm, with any techniques we have now, but if we could add, let us say, 5 or 10 percent to each of those storms.

Senator JORDAN. I was coming to that. Either one more average storm or an 8-percent increase in the yield of the storms that are presently supplying our water would accomplish a million acre-feet?

I am getting this thing down——

Mr. GARSTKA. That is right. However, there is another variable; that is when does this storm come? If it comes in the early fall, its snow may evaporate, it may percolate into the soil, it may cause some runoff. It is the late winter and early spring storms that we are after.

Senator JORDAN. That was to be my next question. I can see the advantage of getting cold snow in the late winter that will turn into water rather than inducing rainfall during the hot summer day that is going to go right back up and be lost in evaporation.

Mr. GARSTKA. I was surprised to learn that the distribution of precipitation in the Colorado River Basin between the winter and summer is about equal, but the water yield comes from the accumulated snowpack which melts in the spring.

Senator JORDAN. That is right.

Mr. GARSTKA. Now the other storms which in your country, too, are convective, are very important in maintaining the forest growth and the headwaters flows, but they do not add much to the downstream reservoirs.

Senator JORDAN. Yes.

Mr. GARSTKA. However, there is another potential there that has not been tapped at all for the mountain water supply, and that, of course, is the convective storms. This research would have to be conducted elsewhere.

The Colorado River Basin is not the best place for the research but it could be potentially of great value if we know what to do with a warm, non-ice-freezing convective storm. For that system the extensive work done by the National Science Foundation and others is at the very forefront of science and potentially of tremendous importance throughout the country, including our mountains.

Senator JORDAN. Yes; I think Mr. Dominy testified that about two-thirds of the runoff comes during one-third of the year.

Mr. GARSTKA. That is right.

Senator JORDAN. It is important to accelerate that part of it. You are more likely to get profitable results if you are working on that aspect of it than if you are just trying to bring down a summer shower on some hot desert drainage area.

Mr. GARSTKA. There is not much hope for that at all, because there is not the moisture in the air in the hottest desert in the summer. That is why it is dry.

Senator JORDAN. Very good. Thank you.

Senator MOSS. Thank you, Senator Jordan; thank you, Mr. Garstka. This whole matter is intensively interesting to us as well as one of great concern. I am sure that the questions from the Senator here this morning reflected that. We do congratulate the Bureau for going ahead to the degree it is moving now and on this committee I sense a feeling that we will want to augment your efforts if possible.

We may have further questions we want to propound at a later time, but I think that will complete the hearing for this morning.

We appreciate your coming and we will now adjourn.

(Whereupon, at 11 a.m., the hearing was adjourned, subject to call of the chair.)

(The following letter was ordered printed in the hearing record:)

U.S. SENATE,
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
June 10, 1964.

Hon. FRANK E. MOSS,
Senate Office Building,
Washington, D.C.

DEAR TED: I am enclosing a copy of a statement by Mr. Paul J. Caubin, vice president, marketing, Irving P. Krick Associates, Inc., Denver, Colo.

I would appreciate it if this statement could be incorporated into the record of your hearings held on May 21, 1964, concerning weather modification studies and research by the Bureau of Reclamation.

Sincerely,

PETER H. DOMINICK, *U.S. Senator.*

IRVING P. KRICK ASSOCIATES, INC.,
Denver, Colo.

GENTLEMEN: The vital need for proper applications of weather modification to aid national growth, economy and security, demands a utilization of all top-level talents—both theoretical and practical.

The Irving P. Krick Associates, Inc., having 30 years' experience in meteorology and atmospheric physics—at a long-term academic level, a military level, and a practical business level—is eminently qualified by background, education, and experience to make major contributions to national knowledge and progress in this particular field. Our operational experience in actual field projects exceeds 1,250,000 hours of operation within 28 States and 13 foreign countries—and in most of the climatic zones of the globe.

We have projects that have been in continuous operation since 1950. We have conducted research since 1946 in instrumentation, equipment, cloud physics, particulate diffusion of matter in a turbulent atmosphere, and a myriad of other directly related requirements to insure positive results from weather modification operations. Our clients not only reflect many in number but diverse water interests such as farmers, ranchers, municipalities, power companies, foreign government agencies, paper and pulp, chemical, ski tows, water companies, etc.

Our technical staff, under the inspiring leadership of our president, Dr. Irving P. Krick, is uniquely qualified to cope with the problems in the proposed programs of weather modification.

No long-term weather modification program should be entered into without due consideration of the weather that will occur during the time of operations. Until you can reasonably ascertain, in advance, the coming sequences of weather, large-scale operations become programs of gaining only partial knowledge. Since 1957 most of our projects have been conducted with forecasts for a season or years in advance.

One major problem in the field of weather modification has been evaluation of results. This is basically a function of what the weather would have been without weather modification so that variations caused by weather modification can be determined. In the final analysis, if one can determine upcoming weather and superimpose changes possible through weather modification, activities involving agriculture, hydroelectric operations, metropolitan water supply and the impact of drought, can all be planned realistically and effectively. Regardless of the technique used, the essential consideration in evaluation of weather modification involves an estimate of what the precipitation would have been in comparison with measured precipitation.

When the time is propitious for more specific details on what may be accomplished—when, where, and how—we believe we can offer important contributions.

We have acted as consultants, technicians, overall advisers, and complete contractual operators and do believe there are one or more categories in your proposed programs we could competently handle.

Although we were not called upon to testify, we believe it extremely urgent the role of private enterprise in this activity be accorded serious consideration and respectfully request your committee reflect upon the advantages of integrating this available knowledge within the overall framework of planning.

Sincerely,

PAUL J. CAUBIN,
Vice President, Marketing.

(On June 19, 1964, the Committee on Interior and Insular Affairs adopted the following resolution:)

RESOLUTION

Whereas water is one of our country's most important natural resources; and

Whereas increased and new uses of water in our expanding economy and for our growing population have caused serious present water shortages in several areas of our country, including the Colorado River Basin where conditions are most critical; and

Whereas experts are unanimous in their judgment that within a very few years, water shortages will become nationwide unless action is initiated now to increase supplies of water; and

Whereas modification of the weather to increase precipitation in areas where storage facilities for water exist or are under construction at times most propitious for such storage offers a promising means of increasing supplies of water; and

Whereas the Department of the Interior, under existing law, has statutory authority to explore ways and means of weather modification, either by force account or by contract; and

Whereas on May 21, 1964, the Subcommittee on Irrigation and Reclamation held an open, public hearing on weather modification, receiving testimony from scientific and technical experts in the Department of the Interior on the present stage of development in techniques of weather modification, and of the need for additional funds to carry forward, promptly, exploration and research in weather modification, particularly in the Colorado River Basin; and

Whereas on the basis of factual evidence and expert opinion, it appears that the present development of the science and technique of weather modification to increase precipitation has reached a stage where there is sound reason for hope for substantial success of such a program if adequately financed; and

Whereas the Department of the Interior is prepared and has available, in cooperation with the National Science Foundation and the Weather Bureau of the Department of Commerce, the expert staff to carry out such a program: Now, therefore be it

Resolved, (1) That the Committee on Interior and Insular Affairs of the U.S. Senate, in view of the foregoing facts, does hereby recommend and urge that funds appropriated to the Department of the Interior for fiscal year 1965 be increased by $1 million for exploration, research, and application of weather modification methods for the purpose of increasing precipitation in the Colorado River Basin; and

(2) That copies of this resolution be transmitted to the chairmen of the Appropriations Committees of the Senate and House of Representatives, to the chairman of the House Committee on Interior and Insular Affairs, to the Secretary of the Interior, and to the Commissioner of Reclamation.

SENATE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
By HENRY M. JACKSON, *Chairman.*

Adopted: June 19, 1964.
Attested:

JERRY T. VERKLER, *Chief Clerk.*

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