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WORKSHOP

FOR

AN ASSESSMENT OF THE PRESENT AND POTENTIAL ROLE OF WEATHER MODIFICATION IN AGRICULTURAL PRODUCTION

COMPILED BY

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V-32 POSSIBLE SHORT-TERM EFFECTS OF WEATHER MODIFICATION ON RUNOFF FROM RANGELAND WATERSHEDS IN THE SOUTHWEST[1]

H. B. Osborn[2]

In the Southwest, most runoff occurs from snowmelt or thunderstorm rainfall. Most of the land surface of Arizona and New Mexico is arid or semiarid, and in these lands, summer thunderstorms are the major source of runoff. On rangelands in southeastern Arizona, for example, about 70 percent of the rainfall and almost all runoff results from intense thunderstorm rains.

Thunderstorm runoff results from short-duration, intense rain of limited areal extent. Runoff producing rainfall on a semiarid rangeland watershed such as the USDA 58-square-mile (150 km^2) Walnut Gulch Experimental Watershed in southeastern Arizona, results from thunderstorm cells that cover only a portion of the watershed (Figure 1). Efforts to increase runoff generally are concentrated on increasing the duration or intensity rather than increasing the areal extent (and thus decreasing the intensity).

A simple schematic cross section of thunderstorm rainfall with maximum depth of 0.1 in. (2.54 mm) is shown in Figure 2. For this analysis, as a simple, first approximation, the assumed result of cloud seeding, 0.3 in. (7.6 mm) is added to the center depth with no increase in areal extent.

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1 Excerpt from a paper entitled, "Effect of Cloud Seeding on Runoff in Arizona and New Mexico", H. B. Osborn, and L. J. Lane, ASAE Annual Meeting, Davis, California, June, 1975.

2 Research Hydraulic Engineer, United States Department of Agriculture, Agricultural Research Service, Western Region, Southwest Watershed Research Center, 442 East Seventh, Tucson, Arizona 85705.

Radar or mathematical models are used in most efforts to estimate the effects of convective cloud modification. In this analysis, storm center depth and runoff were determined for all storms on Walnut Gulch for 12 years of record (1960 - 1971). Storms were grouped in 0.1 in. (2.54 mm) increments, 0 to 0.10 in.(0 to 2.5 mm), 0.10 to 0.20 in. (2.5 to 5.1 mm), etc. Total runoff for all storms in each 0.1 in. (2.5 mm) increment and average runoff per incremental storm center depth were plotted against sotrm center depth (Figure 3). Storms were grouped by increments because the accuracy of estimating runoff from individual thunderstorms is highly uncertain. Twelve years were used so the less frequent exceptional storms were included.

The greatest volume of runoff resulted from storms of about 1.5 in. (3.8 mm). Above 1.5 in., the number of events decreased more rapidly than the increase in runoff per event. The two incremental curves cross between 2.6 and 3.0 in., indicating that an event in this range probably has a recurrence interval of about 12 years. In 12 years of record, there were two storms that produced runoff equal to the average annual runoff from Walnut Gulch. Obviously, such events can bias cloud seeding programs based on seasonal or annual runoff as well as randomized cloud seeding experiments.

Total runoff for 12 years of record on Walnut Gulch was about 3,500 acre-ft (4.32×10^6 m^3). Rainfall increments were combined to look at theoretical rainfall and runoff increases from an assumed increase of 0.3 inch in each event. The combined increments were 0 to 0.40 in.(0 to 10.2 mm), 0.40 to 0.80 in.(10.2 to 20.3 mm), and 0.80 to 1.20 in.(20.3 to 30.5 mm) (Table 1). Roughly 320 events of less than 0.4 in.(10.2 mm) center depth occurred in the 12 years of

record. Total rainfall for these events was about 29,000 acre-ft (3.58×10^7 m^3). Assuming an increase of 0.3 in.(7.6 mm) center depth for each event, rainfall volume was increased to about 77,000 acre-ft (9.49×10^7 m^3) which is a large and appreciable increase in rainfall for range forage and small stock pond storage, for example. However, the predicted increase in runoff from Walnut Gulch is almost negligible because runoff production is normally small for such small events, and what does runoff is abstracted within the ephemeral sand channels before reaching the watershed outlet. The projected increase in runoff for 12 years was roughly 3 percent.

There were 160 storms in the next combined increment, 0.40 to 0.80 in.(10.2 to 20.3 mm) and about 47,000 acre-ft (5.8×10^7 m^3) of rainfall. The theoretical increase from seeding was about 50 percent to 72,000 acre-ft (8.88×10^7 m^3), which resulted in an estimated increase of 17 percent in total runoff. For the 75 storms between 0.80 and 1.20 in.(20.3 to 30.55 mm), seeding increased rainfall from 37,000 acre-ft (4.56×10^7 m^3) to 48,000 acre-ft (5.92×10^7 m^3), and runoff again by about 17 percent. For 32 storms between 1.20 and 1.60 in.(30.3 and 40.4 mm), seeding increased rainfall from 23,000 acre-ft (2.81×10^7 m^3) to 27,000 acre-ft (3.33×10^7 m^3), and runoff by about 9 percent. Adding 0.3 in.to the approximately 600 thunderstorm rains would increase the runoff by about 50 percent.

Increases in summer rainfall in the Southwest are normally most desired early in the thunderstorm season when the storms are most likely to be small. Successful seeding of these events would improve range conditions, but would have little effect on runoff from larger watersheds.

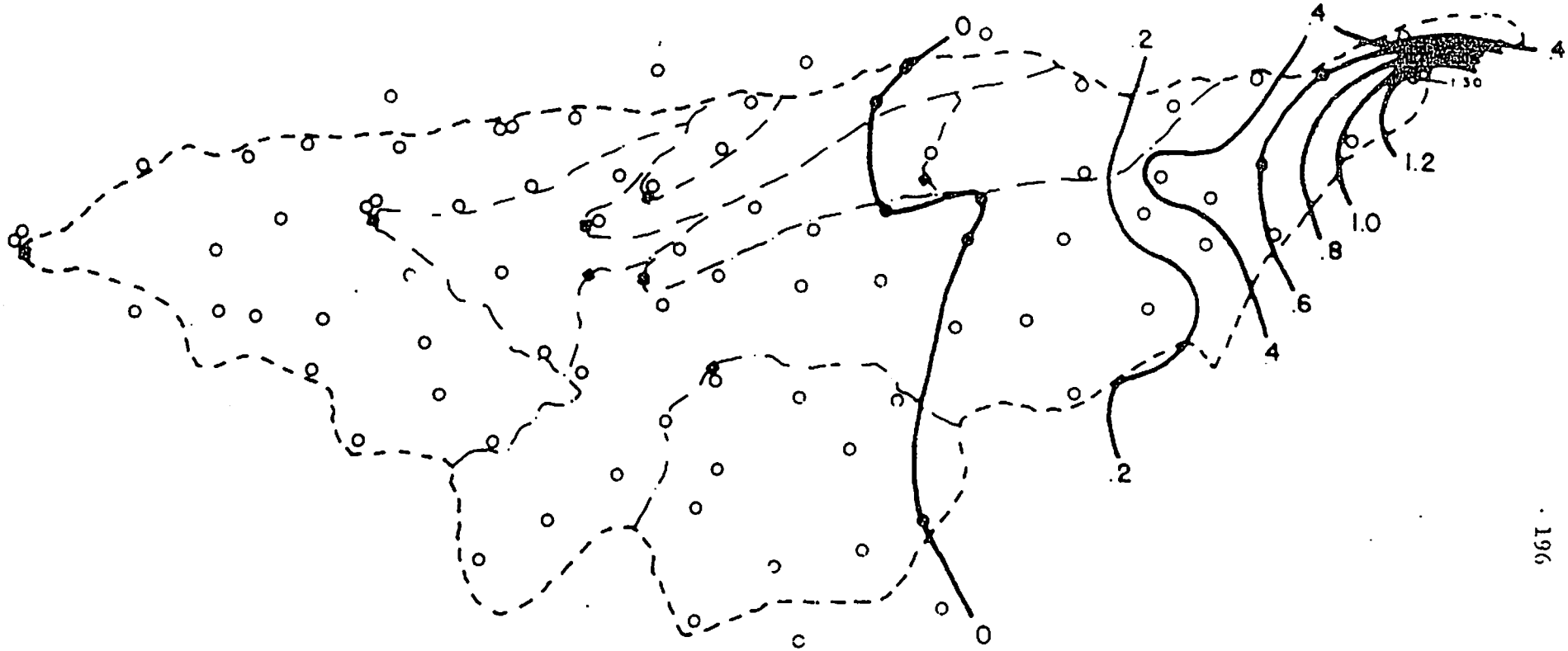
For downstream water users, the greatest value from cloud seeding would be to increase rainfall from the moderate-sized storms.

TABLE 1

Actual versus theoretical seeding values for rainfall and runoff on Walnut Gulch, 12 years of record.

P	Events	P (ac-ft)	ΔP^* (ac-ft)	Q_p (ac-ft)	ΔQ^* (ac-ft)	$\Delta Q/Q^{**}$
0 - .4	320	29,000	48,000	1	95	.03
.4 - .8	160	47,000	25,000	210	600	.17
.8 - 1.2	75	37,000	11,000	540	600	.17
1.2 - 1.6	32	23,000	4,000	770	300	.09

* Indicates seeded conditions
** Q = 3,500 ac-ft (total Walnut Gulch runoff, 1960 - 1971)



WALNUT GULCH WATERSHED

ISOHYETAL MAP

STORM OF JULY 21, 1964

Fig. 1

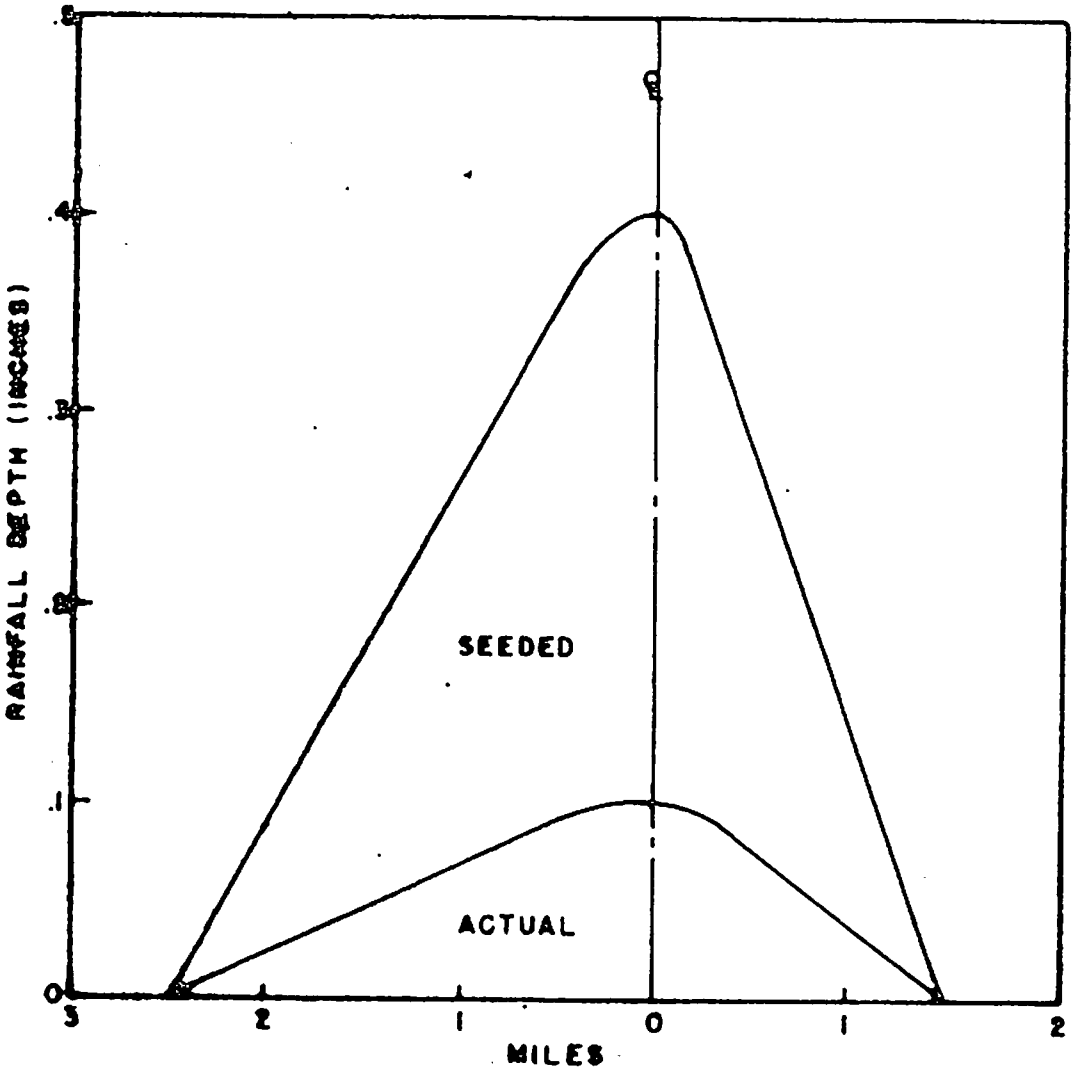


Fig. 2

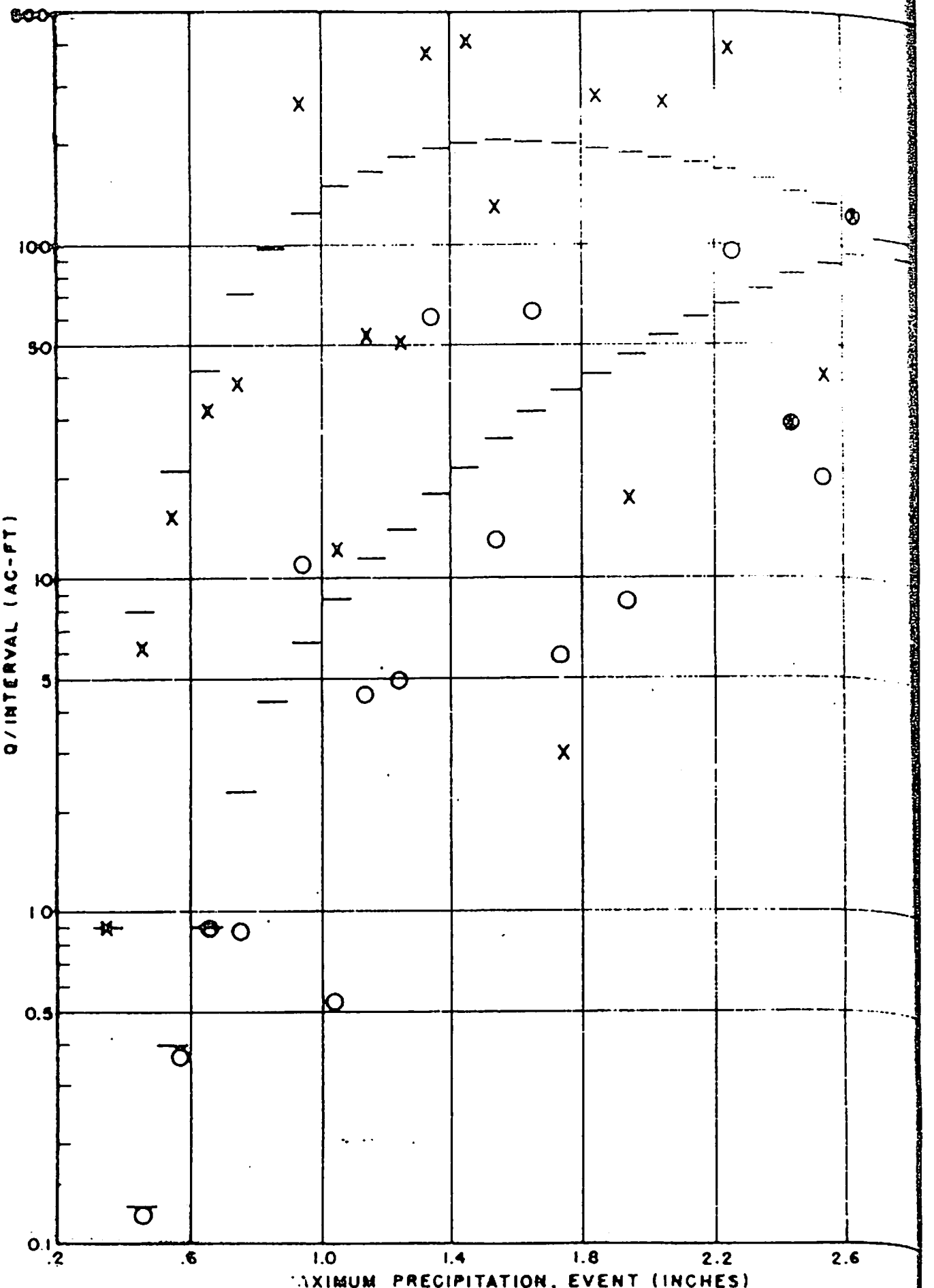

500
100
50
10
5
1.0
0.5
0.1
Q/INTERVAL (AC-FT)
.2
.6
1.0
1.4
1.8
2.2
2.6
MAXIMUM PRECIPITATION, EVENT (INCHES)

FIG. 3

V-33. WENDELL MORDY*, CENTER FOR THE FUTURE

There are organizational problems and there are problems of learning and it is cheap to seed clouds and it is expensive to evaluate seeding experiments. One of the most interesting freudian slips that has occurred was that the leader of the hail project at NCAR spoke about "hell" suppression and it passed almost unnoticed in the meeting. But in a sense no one has anything good to say about hail and nobody has anything bad to say about food. And in a sense we are talking about things that we can do without and cannot do without. But we are forgetting, I think, that the weather doesn't just affect the crops, it affects people as a group and I don't think that we are talking just about the Sierra Club.

I sat with Jules Charney who is chairman of the Department of Meteorology at MIT a few weeks ago and we were talking about policy formation with regard to weather modification. He said "Well, I don't think much of weather modification". I asked him why, and thought the response would be because he didn't believe the technology was ready yet, but no he said "I don't think people ought to fool around with the weather". Well, it was interesting because we had been talking just a few minutes before this about his own work, in which he had been working on the dynamics of deserts and he has found that the common explanation for the formation and development of deserts is inadequate and that the dominant factor in the enlargement and growth of deserts is a change in the albedo and the sinking of air. That deserts are not sources of heat as people might think, but sinks for heat, and the radiative cooling at night, low heat storage capacity in the daytime, causes the very dry high atmospheric air to sink and produce the very arid conditions that represent desert climate. He said if they really want to do something about the weather, they can plant trees along the Mediterrean Coast in Algeria and change the weather on a global scale. He is working with one of the most sophisticated simulation models in existence at this time. The feedback is enormous and the work is of considerable significance. I said Jules - your're in the weather modification business and I think he was gentleman enough to admit it when he made the remark and he was seriously considering the fact that there could be some beneficial effects from altering land use in some desert areas as a result of the implications of his work.

One of the things we can do most effectively in this kind of conference is to look at the means of effecting better communication and arriving at consensus. I thought Earl Droessler's remarks this morning were eloquent in that they addressed in a way that we all understood questions that have to be answered. I think weather modification research is essential. I am not talking about weather modification in the narrow sense. I am not just talking about cloud seeding. The meteorologists among us I think can all put forward suggestions where weather on small or large scale can be significantly altered. And altered and even fine tuned. I'll give you an example. On the Island of Oahu the rainfall gradients are very steep. There is a very sharp escarpment on the windward side and deeply eroded valleys running inland. The rainfall varies from 300-inches just

near the eroded valleys. Now, it wouldn't take a lot of earth moving equipment to alter the rainfall regime here. But nobody in his right mind would go to the legislators and suggest doing this. People live there because they like to look at the waterfalls, they like to grow something. There are all kinds of reasons and people could not agree on how conditions should be changed.

In a general sense, that is the kind of problem we are going to have to deal with. In order to deal with it, we are going to have to know, if we know we are going to have to study it. People live in cities and people will decide. We aren't just talking to each other. I don't think that is enough. Since they live in cities, it has already been pointed out that the vast majority of people in this country, Changnon has repeatedly said this, live in man-altered climates. The big weather modification areas are Los Angeles, Mexico City, no one can deny that smog is weather. The fact is that we are going to have to deal with these subjects and the problem is how do we deal with it in a way where we can arrive at consensus. This means studying and the study will come and it should come in a way that optimizes the benefits for us all.