THE STATUS OF A HAIL SUPPRESSION PROGRAM IN TEXAS

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ABSTRACT

The weather modification program sponsored by Better Weather Incorporated was conceived in 1970 as a result of investigations by concerned farmers into the status of modern cloud seeding technology. During the 1970-1972 period, BWI joined with the Plains Weather Improvement Association of Plainview, Texas, in a program designed primarily to reduce hail damage over portions of Hale and Lamb Counties plus smaller adjacent areas. During the 1973-74 period, BWI separated their program from the PWIA group and continued with the services of Atmospherics Incorporated of Fresno, California for an expanded and upgraded program headquartered at Littlefield, Texas.

The program has continued to use radar equipment as a supervisory and evaluation tool. The actual seeding has been limited to the airborne dispersal of silver iodide at specific inflow areas near cloud base. A number of general and statistical evaluations have been conducted independently by respected scientists working in the fields of meteorology, climatology, hydrology and statistics. These analyses have shown at a reasonably high significance level that (1) numbers of hail days per season appear to have been reduced, (2) hail damage appears to have been reduced in the range of 40% - 50% and (3) the rainfall within and adjacent to the protected area has not been modified.

I BACKGROUND AND INTRODUCTION

In the United States, annual agricultural losses from hail damage exceed $450,000. From the Rocky Mountains eastward across the Great Plains, there exists an area particularly prone to hail development and subsequent crop damage. National Weather Service statistics indicate that the area within the counties of Lamb, Castro, Hockley and Parmer is one of the the most severe hail areas in the U.S. During the May through October period each year, hail is noted somewhere in these counties on an average of 25 - 30 separate days.

Crop hail damage occurs on cotton, wheat, soybeans, sorghum, sunflowers, and a limited acerage of other crops. Because of the high crop density inside these counties, there is a corresponding high probability of damage from any storms producing hail. For several years prior to 1970, it appeared that hail frequency was increasing at the same time crop yields were increasing. As a result, crop-loss insurance rates were being raised to the point where such protection could not be easily afforded by the typical High Plains farmers.

Against this background, in 1970 several farmers in Lamb County voluntarily organized a group now known as Better Weather Incorporated (BWI). Additional support for this organization later developed in the counties of Castro, Hockley and Parmer. The initial BWI objective was to investigate weather modification technology as a means of reducing crop losses from hail damage. Based on results from applied research and various operational weather modification projects in other parts of the world, BWI decided to move toward an operational hail suppression program in 1970. Jointly with the Plains Weather Improvement Association (PWIA), a similar group of individuals from Hale County, BWI subsequently contracted the services of Atmospherics Incorporated (AI) of Fresno, California. In 1973, PWIA organized a program within their own group and BWI continued with the services of AI, expanding their own operational area to the north including sections of Castro County.

Atmospherics Incorporated is a firm having considerable experience in both operational weather modification programs and cloud physics research throughout the United States and abroad. People within the group have been involved in weather modification research and operations dating to 1948. The conclusion of the 1974 weather modification program completed the fifth consecutive operational season AI has provided these cloud seeding services to BWI.

In 1974, the total area of primary concern occupied approximately 1300 sq. miles, 60% of which is in Lamb County, 27% in Castro County, and the remaining 13% distributed nearly equally between Hockley and Parmer Counties. In the 1973 and 1974 seasons, AI located its operational field headquarters at Littlefield, Texas. A weather radar system and aircraft were stationed at the Littlefield Airport with professional personnel moving to that area each year in late April. The decision to contract seasonal operations from 1 May to 31 October was determined by the area climatology, the type of crops, and the growing season throughout the operational area.

The following sections of this report summarize the weather modification activities during the five year period from 1970 through 1974. Operations are continuing during the current 1975 season.

II CLIMATOLOGY

The BWI weather modification operational area is located in the South Plains region of Northwest Texas. This particular area within the High Plains receives an average of about 18 inches of precipitation per year. Normal annual precipitation data for the period 1941 - 1970 are presented in Figure 1. In the Lamb-Castro County area, approximately 75% of the precipitation occurs during the summer months as a result of thunderstorm activity. This leads to an extremely wide variability in the annual, monthly and daily amounts, as well as similar variations over short distances. Climatologically speaking, the average rainfall distribution in this area is bi-modal. One rainfall maximum occurs during the May-June period and a second somewhat smaller maximum is noted in September.

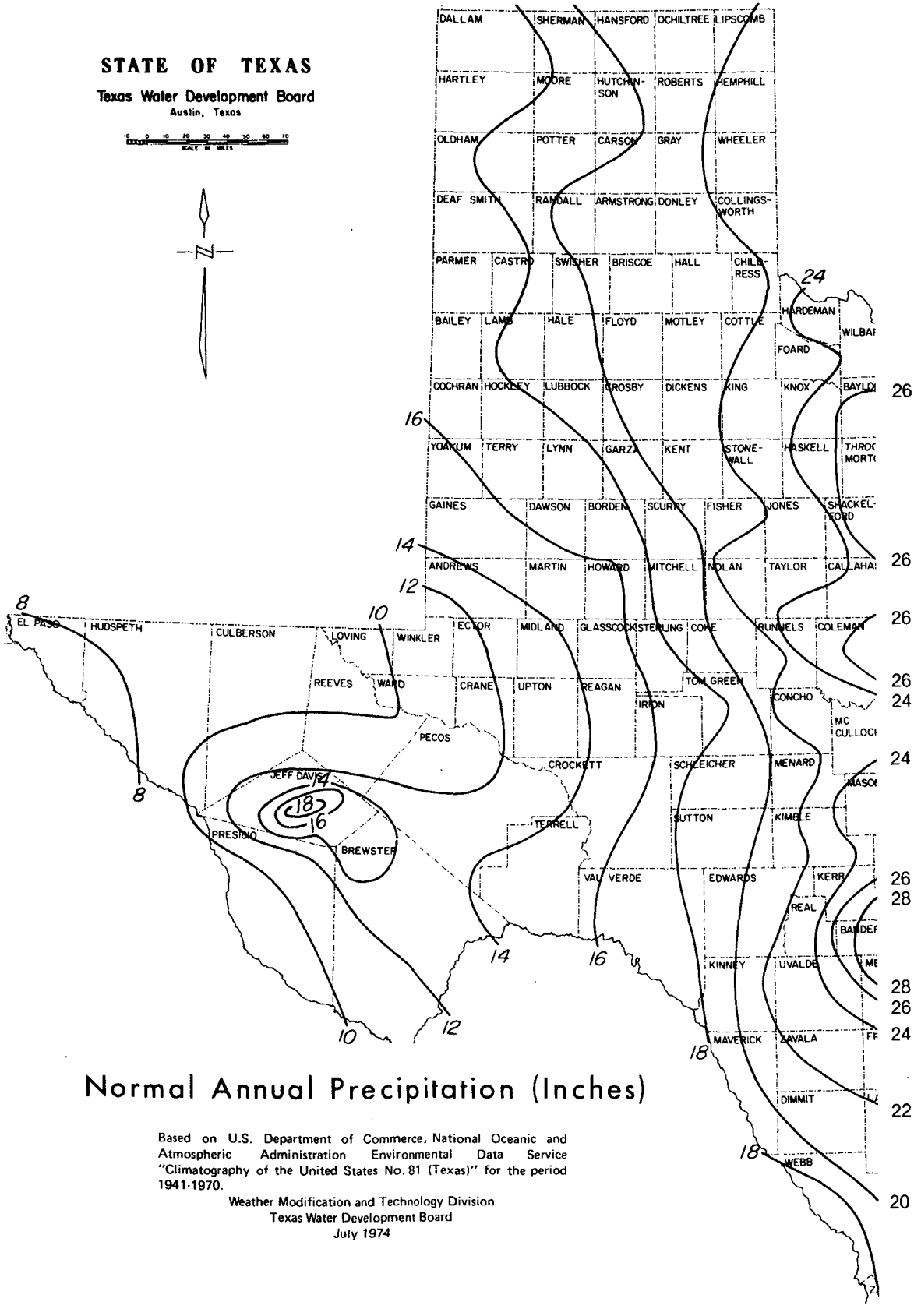
The wide variations in precipitation are related to the sources of continental air from the north and the concurrent low level inflow from moisture-rich regions, principally the Gulf of Mexico. When the prevailing winds switch from westerly to the moist southeasterly, and the upper level colder air moves over the area from the north and northwest, the convergence line of these two air masses provides the optimum breeding ground for large cumulus developments.

Thunderstorms in this area can generally be categorized in two specific groups. The first includes air mass varieties which form during the late morning or afternoon in the warm, humid and very unstable air which has penetrated northwestward into Texas from the Gulf of Mexico. The second group can be classified as those which form frontal zones of convergence as Pacific and Continental polar air masses collide with the warmer moist Gulf air. Squall lines are sometimes a feature of the local severe weather. Hail occurrences in April, May and June are closely associated with the development of these air mass thunderstorms and squall lines. Hailfall usually peaks during May or June and is not normally as frequent in August.

The last group results primarily from two weather situations which bring infrequent periods of significant rainfall to the Texas Plains in late summer and autumn. First, the heavier late summer and early autumn rainfall over most of Texas occasionally comes from tropical disturbances moving northward and westward from the Gulf of Mexico into the interior of Texas. Second, when late autumn rains are heavier than normal, they usually result from cold fronts which move through the Plains and become stationary in Central or Southern Texas. After becoming stationary, the cold front begins a retrograde movement to the north, setting off warm-front type continuous precipitation over a wide area caused by moist Gulf air over-running a shallow layer of colder, continental polar air at the ground. In this situation, light to moderate precipitation sometimes falls intermittently for periods of five days or more.

FIGURE 1

NORMAL ANNUAL PRECIPITATION
(1941 - 1970 Data)



Normal Annual Precipitation (Inches)

Based on U.S. Department of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service "Climatography of the United States No. 81 (Texas)" for the period 1941-1970.

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A point hailfall analysis as constructed from the official climatological station record does not adequately describe the total hail problem within any given area. In the design of a hail suppression project which covers an area in excess of a few square miles, there is a need to establish the total number of days which produce hail within the total area. The larger the area examined the greater the expected number of total hail days within any given boundary. Studies accomplished by Atmospherics Incorporated and the Illinois Water Survey indicate that hail can be expected 25-30 days within the BWI operational area during any summer period.

III GENERAL OPERATIONS

A. Project Design

The 1970-1974 BWI Weather Modification Program was organized as an operational cloud seeding effort conducted over specific areas to help alleviate severe hail damage within an important agricultural community. Its fundamental design was not focused on pure research activity, although the data obtained during this five-year period is proving beneficial to other weather modification programs conducted in the Panhandle area of Texas, as well as adjacent areas in the United States. It has combined many of its own technological innovations with other recent tested and proven advances within the field of weather modification to provide a project design which has successfully attained these objectives during the past five operational seasons.

No randomization was included in the basic design because of the sponsors' desire to suppress all possible hail damage. Contributors to the program expressed a willingness to accept any evaluation uncertainties associated with this operational approach. On the other hand, various representatives of the sponsoring group indicated a keen interest in the acquisition of all data which might point the way towards apparent results. The continuing data acquisition and evaluation programs have been a strong part of all operations since the program began in 1970.

Fundamental to significant crop hail damage reduction over the BWI area is the requirement to correctly identify a potential hail-producing cloud in its early stages of development then, through airborne application, quickly deliver the required amount of nuclei to the cloud intended for modification. Equally important, the nuclei must be correctly placed in the cloud base updraft areas which are important to the development of that volume of cloud responsible for breeding hailstones.

For high accuracy in identifying potential hail-bearing clouds, a weather radar system is essential. Radar rapidly measures significant cloud characteristics including the cloud positions and movements. The radar system is operated by a radar meteorologists whose function is to assimilate and interpret radar data and meteorological data before and during operations and to provide the necessary decisions regarding aircraft launching positioning the aircraft for cloud seeding purposes, and terminating flight operations.

The 5cm radar system now used on the BWI program provides vertical and horizontal measurements of clouds including heights, intensities and areal coverage. Also appearing simultaneously on the radar display at any given time are the positions of the cloud seeding aircraft. After being directed to the cloud intended for modification, pilots rely upon visual identification of updraft locations before seeding begins. During complex rapidly changing storm periods and/or nighttime operations, radar becomes indispensable in providing assistance to pilots seeking the prefered updrafts around cloud bases.

During each of the five operational seasons, the total program has included the airborne application of artificial ice nuclei to various cloud formations. Nuclei sources have been limited to silver iodide smoke particles generated from pyrotechnic devices and liquid fuel wing tip generators. There are two types of pyrotechnic seeding devices used with individual silver iodide dispersal rates from 2 grams to 10 grams per minute. A 2% solution of silver iodide by weight in acetone (silver iodide/ammonium iodide) has been used in the liquid fuel generators.

Attempts have been made to maintain freezing nuclei concentrations of 10^5 per m^3 (effective at -10C) within that volume of cloud which gives birth to, and allows growth of, hailstones. Most of the aircraft seeding has been conducted on cumulus cloud developments along the strong inflow areas at cloud base. Air mass thunderstorms are treated in the updraft regions primarily found along the storms' trailing edges. Squall lines have been seeded in the frontal zone ahead of each embedded cell or precipitation area. By using the aircraft measurements of both inflow velocity and dimensions plus radar data, one can calculate the amount of silver iodide required to meet the desired concentration.

In recent years, the operational aspects of this program have been controlled from the radar site located at the airport near Littlefield (Lamb County), Texas. This radar site serves as the field headquarters for project operations and, along with meteorological data received from Amarillo and Lubbock offices of the National Weather Service, provide information necessary for all flight launch decisions. A communications link operating on 151.625 MHz provides the information transfer between the radar and operating aircraft.

The primary ingredients for all activities during this five-year operational period continues to be the combination of concentrated radar surveillance, proper airborne applications of seeding material, a strong communication link and a team of dedicated professional personnel.

B. Operations Summary

The routine weather forecasts as prepared by the National Weather Service (NWS) are not sufficient in themselves for conducting an operational hail suppression program. These forecasts are assembled and distributed for consumption for the general public and provide neither the detail nor the finite area coverage necessary for decision-making within the operational area. However, the basic weather forecasts as provided by NWS are quite

adequate for a first-order decision on potential cloud development occurrence in the general project area. Once cloud development begins, the radar system is utilized as the primary tool to monitor further developments.

The primary radar equipment used on this project is the WR100, a 5cm weather radar system built by Enterprise Electronics Incorporated. It operates on a frequency of 5500-5600 MHz and has a peak power of 250,000 watts. The system has a maximum range of 250 nautical miles and information is presented on two 12-inch plan position indicators (PPI). One of the indicators is used for general viewing during all storm periods and the other is used for documentary photography. Also integrated into the system is an interrogator/transponder system which allows location and presentation of cloud seeding aircraft.

Supplied to this project are three turbocharged Piper Twin Comanche aircraft. All aircraft are equipped with wing tip liquid fuel generators and special holding racks for the pyrotechnic seeding devices. When seeding clouds, pilots dispense silver iodide freezing nuclei by igniting pyrotechnic devices and/or burning the liquid fuel from the wing tip generators. In this manner, proper seeding rates can be closely adjusted to changes in individual storm characteristics.

A summary of operations for each year from 1970 through 1974 is shown in Table 1.

IV EVALUATIONS

The most objective evaluation of the Texas Hail Suppression Program has been conducted by Stanley A. Changnon, Jr., of the Illinois State Water Survey in Urbana, Illinois. His work has been published in the Journal of Weather Modification, Vol. 7, No. 1, April 1975. The analytical details will not be included in this report but his conclusions are as follows:

> "Most of the data examined strongly suggest that the suppression was successful. The best single measure is considered to be the 48% temporal reduction in loss-costs. Another estimate showing 56% reduction is afforded by the simple average of values from hail day data, two-county liability values, two-county losses, and two-county lost-cost."

Mr. Changnon's research was done under the Applied Research Directorate of the National Science Foundation, Grant GI-37859. The advice of P. T. Schickedanz of the Water Survey was helpful, and E. Ray Fosse of Crop Hail Insurance Actuarial Association furnished useful hail data and information.

The 1974 Texas hail insurance statistics from CHIAA have recently been compiled. This past year, Lamb County shows a total liability of $2,101,000 with losses of $17,000. This produces a loss-cost of $.80 compared with an average loss-cost from the eleven surrounding counties of $7.69 (an apparent reduction of about 90%).

TABLE 1

OPERATIONAL SUMMARY

BWI WEATHER MODIFICATION PROGRAM

1970 - 1974

	1970	1971	1972	1973	1974	TOTAL
Number of Operational Seeding Days	22	20	29	19	35	125
Number of Seeding Flights	53	47	67	45	83	295
Flight Time (hrs.)	100.7	89.3	127.2	80.1	149.7	547.0
Number of Observation Flights and Others	70	59	78	55	94	356
Flight Time (hrs.)	50.4	41.3	46.8	38.2	51.2	227.9
Total Number of Flights	123	106	145	100	177	651
Total Flight Time	151.1	130.6	174.0	118.3	200.9	774.9
Number of Pyrotechnics used	348	262	396	309	505	1,820
Grams of AgI	24,012	18,340	26,928	22,866	34,658	126,804
Liquid Generator Time (minutes)	-	1,922	2,910	4,655	8,475	17,962
Grams of AgI	-	5,189	7,566	21,785	17,797	52,337
Total Amount of AgI used (grams)	24,012	23,538	34,494	44,651	52,455	179,150
	(52.89 lbs)	(51.85 lbs)	(75.98 lbs)	(98.36 lbs)	(115.54 lbs)	(394.62 lbs.)

In addition to hailfall analyses, a number of investigations have been conducted on rainfall throughout this same 12-county area. Independent analyses were initiated to answer the question "has the rainfall been decreased or increased as a result of the hail suppression cloud seeding activities?"

Foremost among the rainfall analyses has been the work by Paul T. Schickedanz of the Illinois State Water Survey. His conclusions covering the four year period 1970-1973 are as follows:

> "The expected values of precipitation were determined from predictor equations utilizing all of the pertinent area and temporal information contained in this investigation. The application of the "t" test to differences from expectation revealed that the precipitation does not depart significantly from expectation. Thus, it is concluded that the rainfall within the target area has not been modified during the hail suppression cloud seeding period."

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