



TEXAS DEPARTMENT OF WATER RESOURCES

REPORT 219

WEATHER MODIFICATION ACTIVITIES
IN TEXAS, 1974-77

Prepared by

Weather Modification and Technology Section
Texas Department of Water Resources

August 1978

TEXAS DEPARTMENT OF WATER RESOURCES

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FOREWORD

Effective September 1, 1977, Texas three water resources agencies, the Texas Water Rights Commission, the Texas Water Development Board, and the Texas Water Quality Board, were consolidated to form the Texas Department of Water Resources. A number of publications prepared under the auspices of the predecessor agencies are being published by the TDWR. To effect as little delay as possible in production of these publications, references to these predecessor agencies will not be altered except on their covers and title pages.

A handwritten signature in cursive script that reads "Harvey Davis". The signature is written in dark ink and is positioned above the printed name and title.

Harvey Davis
Executive Director

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WEATHER MODIFICATION ACTIVITIES IN TEXAS, 1974-77

INTRODUCTION

Deliberate attempts to change or control the weather in Texas were for the most part unregulated and undocumented prior to 1967. Literature contains records of only a few "rainmaking" programs, the earliest of which occurred on the Texas High Plains in the early 1890's. This particular endeavor is best remembered as consisting of simulated, heavy artillery bombardment of surrounding hills in an attempt to produce rain.

The State of Texas joined a number of other states which enacted weather modification legislation during the 1960's with enactment in 1967 of the present Texas Weather Modification Act. Six years later the Act was codified as Chapter 14 of the Texas Water Code, and it is the current State authority for regulating weather modification activities in Texas. Under provisions of this Act, the Texas Water Development Board was charged with the administration of the Act. In carrying out its statutory responsibilities, the Board established two advisory committees and formulated standards and instructions which were necessary to carry out weather modification research programs by cooperative agreements and contracts with public and private organizations. Effective September 1, 1977, Texas' three water resources agencies, the Texas Water Rights Commission, the Texas Water Development Board, and the Texas Water Quality Board, were consolidated to form the Texas Department of Water Resources. The authority for regulating weather modification activities in Texas was transferred to the new Department on that date.

An outstanding feature of the authority given the Department by the Act relates to a weather modification license and permit system. The Act requires that potential weather modifiers first obtain a license and a permit before beginning a project. A license is granted solely on the basis of the knowledge and ability of the applicant. A permit can be granted only to an applicant who holds a license. A separate permit must be obtained, however, for each separate project contemplated by a licensee. Permits are granted to a licensee based on the merits of the proposed project.

Although the Act does not specify the procedures for obtaining licenses and permits, it does authorize the Department to make regulations which establish procedures and conditions for their issuance. These regulations and procedures were developed shortly after the Act became law and have been amended from time to time. The revised rules, regulations and modes of procedure relating to the Texas Weather Modification Act, which were issued by the Texas Department of Water Resources on September 1, 1977, are currently in force. The conditions under which a license may be issued to an applicant are that the applicant:

- (1) submit a properly completed application;
- (2) pay the license fee; and
- (3) demonstrate competence in the field of meteorology which is reasonably necessary to engage in weather modification and control activities.

If, however, the applicant is an organization, competence must be demonstrated by the individual or individuals who are to be in control and in charge of operations for the applicant. The Department considers the competency of the individuals engaged in the operations to be of great significance. All of the powers authorized by the Act are exercised to insure that only well qualified weather modifiers are granted a license.

The Act is rather inflexible regarding the issuance of permits to applicants. The best interests of the public are always dominant; statutorily, however, an applicant need meet only four conditions before being granted a permit. The applicant is required to:

- (1) hold a valid weather modification license;
- (2) submit a properly executed application;
- (3) pay the permit fee;
- (4) furnish proof of financial responsibility;
- (5) publish a notice of intent and submit proof of publication as required by the Act; and,

- (6) if the operation is to be conducted under contract, state the term of the contract.

(Anyone desiring to obtain a Texas weather modification license or permit is advised to secure from the Department a copy of the official rules, regulations and modes of procedure relative to the Texas Weather Modification Act, which are briefly described above.)

The following is a numerical summary of the various types of weather modification projects conducted in Texas during the period 1974-77:

	Number of projects			
	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
Operational cloud-seeding programs				
Rainfall enhancement	4	3	6	6
Hail suppression (primarily)	2	2	2	2
Precipitation management research programs	0	1	1	1
Scientific evaluation programs	1	1	1	0

The Colorado River Municipal Water District contracted with Atmospherics Incorporated of Fresno, California to conduct a program of rainfall enhancement in 1974, then conducted its own cloud-seeding program in 1975, 1976, and 1977. Better Weather, Incorporated contracted with Atmospherics Incorporated, who performed hail-suppression activities on the High Plains during the warm seasons of each of the four years 1974-77. Plains Weather Improvement Association, Inc. both sponsored and conducted a similar project on the High Plains during the same period. These three operational projects utilized aircraft with silver iodide dispensing flare racks affixed to the aircraft's wings to deliver the seeding material directly into the clouds at cloud-base level.¹ Meteorology Research, Inc. conducted both phases (data collection during 1973-75 and analysis during 1974-76) of an evaluation, using radar, of the District's rainfall-augmentation program.

¹ Amounts of silver iodide tabulated in this report are expressed in grams; to convert to pounds, multiply by 0.0022.

Irving P. Krick, Inc. of Texas used ground-based silver iodide generators with the intent of increasing rainfall over a number of target regions. During 1974 and 1975, Krick's programs consisted of the operation of generators located in Texas near the Oklahoma border intending to increase rainfall in several target areas in Oklahoma. In 1976, however, Krick, Inc. expanded its operations to include two programs intended to increase rainfall over target areas within the State of Texas. These latter two programs continued in 1977.

Programs of research and development in weather modification technology also were important during the period 1974-77. In cooperation with the U.S. Department of the Interior, Bureau of Reclamation, the Texas Water Development Board participated in a comprehensive research program, known as the High Plains Cooperative Program (HIPLEX), to develop a capability for producing additional rain from summertime convective clouds in the State's High Plains region. In addition, the Board also sponsored a scientific evaluation of one of the privately sponsored cloud-seeding programs—that of the Colorado River Municipal Water District at Big Spring—during the period 1974-76.

This report describes those activities which were conducted during the period 1974-77 under the cited licenses and permits. A description of those activities which occurred in years prior to 1974 is contained in previous reports; Texas Water Development Board Report 175 describes weather modification activities for the period 1970-72, and Board Report 187 covers activities for 1973. Table 1 lists the projects for which Texas weather modification licenses and permits were issued for the period 1974-77.

No attempt has been made in this report to analyze the degree of success or failure of these activities. The great variability of natural weather phenomena in Texas makes results extremely difficult to ascertain. A number of years is usually required before the results of a particular program can be determined.

Table 1.—Weather Modification Programs for Which Licenses and Permits Were Issued, 1974-77

<u>Fiscal year, license and permit numbers</u>	<u>Licensed operator</u>	<u>Sponsor</u>	<u>Target area</u>	<u>Objective</u>
CALENDAR YEAR 1974				
74-1-1	Atmospherics Incorporated 5652 E. Dayton Avenue Fresno, California 93727	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Martin, Howard, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall augmentation
74-2-2	Atmospherics Incorporated 5652 E. Dayton Avenue Fresno, California 93727	Better Weather, Incorporated c/o James Welch, President Route 1 Littlefield, Texas 79339	Portions of Parmer, Castro, Lamb and Hockley Counties	Hail suppression and rainfall enhancement
74-3	Meteorology Research, Inc. Post Office Box 637 Altadena, California 91001	None	None	None
74-4-1	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Arbuckle Weather Modification District, Inc. Cotton County Services, Inc. City of Lawton, Oklahoma	No target area in Texas. Oklahoma target area: Caddo, Carter, Comanche, Cotton, Jefferson, Johnston, Kiowa, Murray, and Love Counties	Rainfall augmentation
74-4-2	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Henry C. Hitch Ranch, Inc. Beaver County Weather, Inc. Harper County Weather, Inc. Woodward County Cloud- Seeding Association Ellis County Weather, Inc. Washita County Weather Modification Association Kiowa County Weather Modification Association	No target area in Texas. Oklahoma target area: Beaver, Harper, Woodward, Ellis, Washita, and Kiowa Counties and parts of Texas and Woods Counties	Rainfall augmentation
74-4-3	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Cotton County Services, Inc. and the Oklahoma counties of Carter, Love, Murray, Johnston, and Jefferson	No target area in Texas. Oklahoma target area: Jefferson, Carter, Murray, Johnston, Love, and Cotton Counties	Rainfall augmentation
74-6-1	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	All of Hale County and portions of Castro, Swisher, Floyd, and Lubbock Counties	Hail suppression

Table 1.—Weather Modification Programs for Which Licenses and Permits Were Issued, 1974-77—Continued

<u>Fiscal year, license and permit numbers</u>	<u>Licensed operator</u>	<u>Sponsor</u>	<u>Target area</u>	<u>Objective</u>
CALENDAR YEAR 1975				
75-1-1	Atmospherics Incorporated 5652 E. Dayton Avenue Fresno, California 93727	Better Weather, Incorporated c/o James Welch, President Route 1 Littlefield, Texas 79339	All of Castro County and portions of Parmer, Swisher, Lamb, Hale, and Hockley Counties	Hail suppression and rainfall enhancement
75-2	Meteorology Research, Inc. P.O. Box 637 Altadena, California 91001	None	None	None
75-3-1	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Cotton County Services, Inc. Kiowa County Weather Modification Association	No target area in Texas. Oklahoma target area: Cotton and Kiowa Counties	Rainfall augmentation
75-3-2	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Henry C. Hitch Ranch, Inc. Beaver County Weather, Inc. Harper County Weather, Inc. Woodward County Cloud- Seeding Association Ellis County Weather, Inc. Kiowa County Weather Modification Association	No target area in Texas. Oklahoma target area: Beaver, Ellis, Harper, Kiowa, and Woodward Counties and a portion of Texas County	Rainfall augmentation
75-4-1	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	All of Hale County and portions of Castro, Swisher, Floyd, and Lubbock Counties	Hail suppression
75-5-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Martin, Howard, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall augmentation
CALENDAR YEAR 1976				
76-1-1	Atmospherics Incorporated 5652 E. Dayton Avenue Fresno, California 93727	Better Weather, Incorporated c/o James Welch, President Route 1 Littlefield, Texas 79339	Portions of Parmer, Castro, Swisher, Bailey, Lamb, Hale, and Hockley Counties	Hail suppression and rainfall enhancement

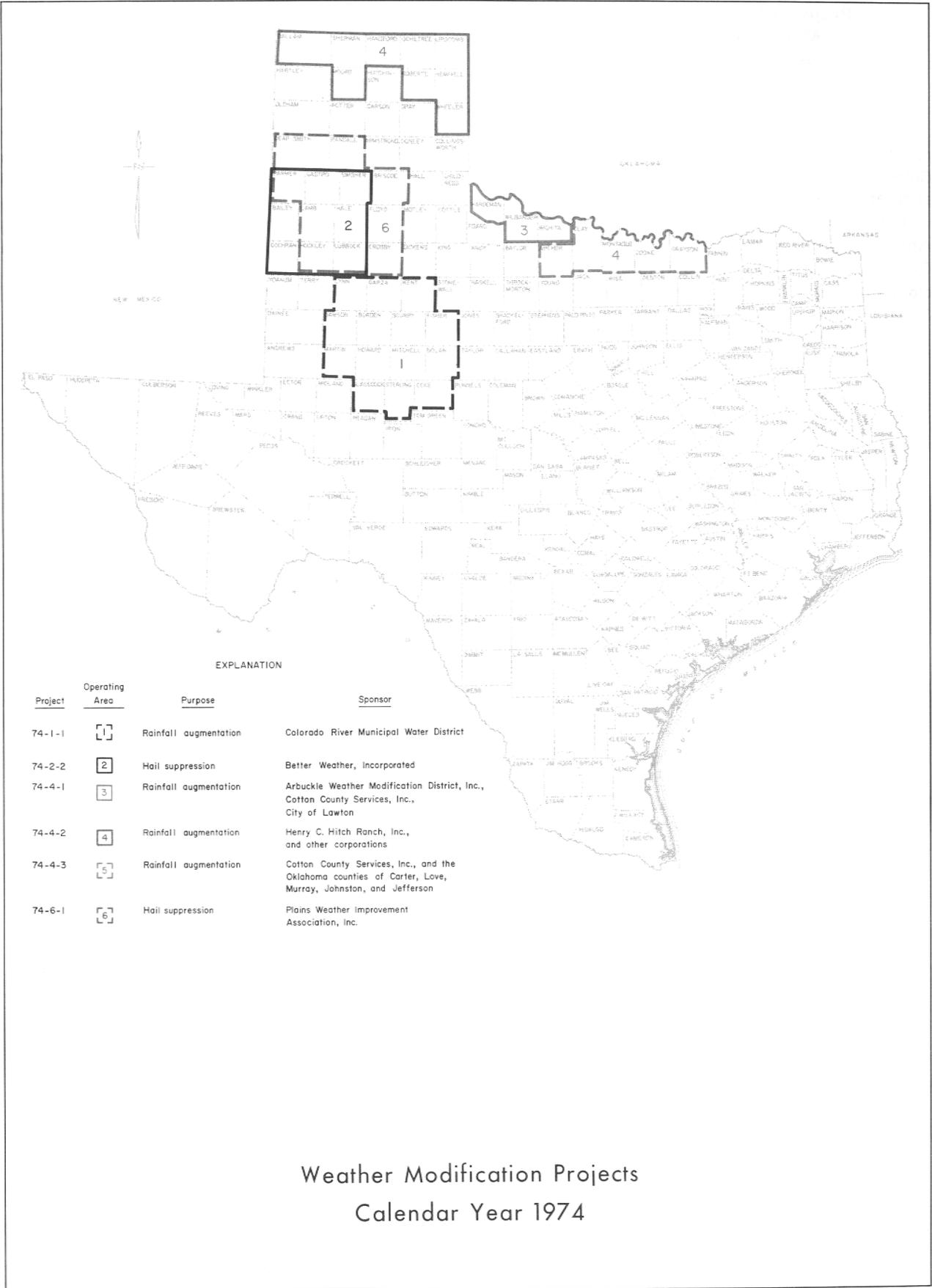
Table 1.—Weather Modification Programs for Which Licenses and Permits Were Issued, 1974-77—Continued

<u>Fiscal year, license and permit numbers</u>	<u>Licensed operator</u>	<u>Sponsor</u>	<u>Target area</u>	<u>Objective</u>
76-2-3	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Cotton County Services, Inc.	No target area in Texas. Oklahoma target area: Cotton County	Rainfall augmentation
76-2-4	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Henry C. Hitch Ranch, Inc. Harper County Weather, Inc. Woodward County Cloud- Seeding Association Ellis County Weather, Inc. Beaver County Weather, Inc.	No target area in Texas. Oklahoma target area: Beaver, Ellis, Harper, and Woodward Counties and a portion of Texas County	Rainfall augmentation
76-2-5	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Harper County Weather, Inc. Woodward County Cloud- Seeding Association Ellis County Weather, Inc. Beaver County Weather, Inc. Henry C. Hitch Ranch, Inc.	No target area in Texas. Oklahoma target area: Ellis, Harper, Beaver, and Woodward Counties and a portion of Texas County	Rainfall augmentation
76-2-6	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Weather Modification, Inc. Box 604 Throckmorton, Texas 76083	All of Throckmorton, Shackelford, Young, and Stephens Counties	Rainfall augmentation
76-2-7	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, Texas 92262	Red Bluff Water Power Control District 111 W. Second Street Pecos, Texas 79772	Northern portions of Culberson and Reeves Counties	Rainfall augmentation
76-3	Meteorology Research, Inc. P.O. Box 637 Altadena, California 91001	None	None	None
76-4-1	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	All of Hale County and portions of Castro, Swisher, Floyd, and Lubbock Counties	Hail suppression and rainfall augmentation
76-5-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Nolan, Glasscock, Sterling, Martin, and Coke Counties	Rainfall augmentation

Table 1.—Weather Modification Programs for Which Licenses and Permits Were Issued, 1974-77—Continued

<u>Fiscal year, license and permit numbers</u>	<u>Licensed operator</u>	<u>Sponsor</u>	<u>Target area</u>	<u>Objective</u>
CALENDAR YEAR 1977				
77-1-1	Atmospherics Incorporated 5652 E. Dayton Avenue Fresno, California 93727	Better Weather, Incorporated c/o James Welch, President Route 1 Littlefield, Texas 79339	Portions of Castro, Lamb, Hale, Swisher, Parmer, Bailey, Hockley, and Lubbock Counties	Hail suppression and rainfall augmentation
77-2-3	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Cotton County Services, Inc.	No target area in Texas. Oklahoma target area: Cotton County	Rainfall augmentation
77-2-4	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Henry C. Hitch Ranch, Inc.	No target area in Texas. Oklahoma target area: a portion of Texas County	Rainfall augmentation
77-2-5	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Henry C. Hitch Ranch, Inc.	No target area in Texas. Oklahoma target area: a portion of Texas County	Rainfall augmentation
77-2-6	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Weather Modification, Inc. Box 604 Throckmorton, Texas 76083	All of Throckmorton, Shackelford, Young, and Stephens Counties	Rainfall augmentation
77-2-7	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Red Bluff Water Power Control District 111 W. Second Street Pecos, Texas 79772	Portions of Culberson and Reeves Counties	Rainfall augmentation
77-3	Meteorology Research, Inc. Post Office Box 637 Altadena, California 91001	None	None	None
77-4-1	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	Plains Weather Improvement Association, Inc. P.O. Box 1627 Plainview, Texas 79072	All of Hale and portions of Castro, Swisher, Floyd, and Lubbock Counties	Hail suppression and rainfall augmentation
77-5-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall augmentation

WEATHER MODIFICATION PROJECTS
CALENDAR YEAR 1974



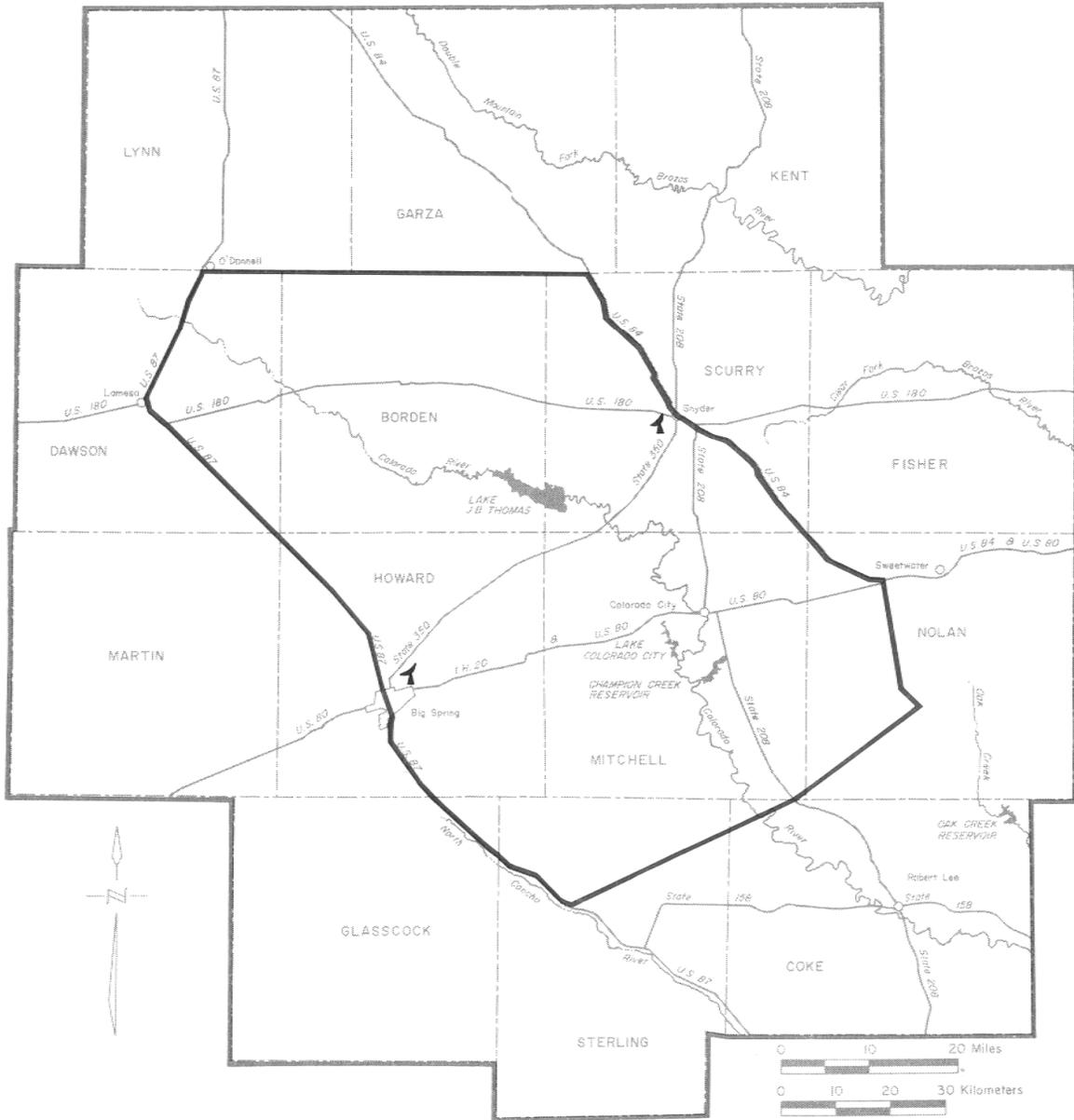
Weather Modification Projects
Calendar Year 1974

Project 74-1-1.—Colorado River Municipal Water District Rainfall-Enhancement Program

An effort to provide supplemental rainfall and runoff into the reservoir and distribution system of the Colorado River Municipal Water District through the application of weather modification technology was undertaken by the District in 1974. By contract with Atmosphericics Incorporated of Fresno, California, the District sponsored for the fourth consecutive year a cloud-seeding program designed to increase water runoff

into the storage lakes owned and operated by the District.

The District project area is located in the Permian Basin region of West Texas, with project headquarters at Big Spring. The target area, within which precipitation is intended to be enhanced, consists of Mitchell and Borden Counties and portions of Howard, Martin, Dawson, Scurry, Nolan, Glasscock, Sterling, and Coke Counties. The District's cloud-seeding aircraft could be operated within a 14-county operational area which encompassed the target area.



Note: Operating area is the area in which weather modifiers can legally perform their operations.
Target area is the only area to be affected by weather modification.

EXPLANATION

- Operating area boundary
- Target area boundary
- ▲ Radar installation site

To begin a meaningful evaluation of the District's weather modification program, a randomization scheme for cloud seeding was implemented in 1974. The evaluation design was intended to interfere as little as possible with normal rainfall-enhancement operations, yet acquire data from a desired number of test cases in order to complete a meaningful and objective analysis. In an attempt to satisfy these requirements, 25 percent of all seeding operations used "dummy" silver iodide pyrotechnic devices (flares).

The aircraft used in the seeding activities was a turbocharged Piper Twin Comanche. It was equipped with special holding racks for the pyrotechnic devices. The aircraft was guided to each potential rain-bearing cloud system by the project meteorologist, who tracked the storm systems with an ATMOS IV 3-cm radar system having a range of 160 miles.

**Project 74-1-1
Colorado River Municipal Water District
1974 Operational Summary**

Period of Flight Operations: April 18-August 29, 1974

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
Apr.	4	2	1.8	4	4.8	414
May	2	0	0	3	4.5	450
June	3	0	0	3	3.4	198
July	5	0	0	5	6.0	414
Aug.	8	4	3.0	9	15.0	1,482
Total	22	6	4.8	24	33.7	2,958

Colorado River Municipal Water District Evaluation Program, 1974

A program attempting to evaluate precipitation management technology in the Big Spring area of Texas was sponsored by the Texas Water Development Board in 1974. The research effort, begun in 1973 when the Board awarded a contract to Meteorology Research, Inc. of Altadena, California, centered upon an examination of the cloud-seeding activities of the Colorado River Municipal Water District during 1973 and 1974.

Modifications were made to an M-33 radar system located at Winston Field in Snyder, Texas to enable personnel of Meteorology Research, Inc. to make quantitative rainfall measurements over the District's weather modification target area. The installation and calibration of 10- and 3-cm radar units paved the way for the acquisition of data

which were useful in analyzing both seeded and non-seeded cloud systems.

Video tape recording equipment was utilized with the radar units to record quantitative echo signals from precipitation occurring over the study region. These signals were subsequently converted into rainfall data through a system composed of digitizers, range sorters, and computers. Balloons were launched and tracked by radar to determine the velocities of winds in the upper atmosphere and to detect the rate of movement of storm clouds.

A 75-25 percent randomization scheme of cloud seeding was conducted by the District to accommodate the evaluation effort. Such a scheme helped to eliminate the possibility of bias in the selection of cases for study.

The evaluation program was conducted throughout 1974.

Municipal Airport. Three cloud-seeding aircraft—turbocharged Piper Twin Comanches—equipped with silver iodide flares and liquid fuel wing-tip generators were used to dispense the seeding agent into both thunderstorm systems believed to have the potential for producing hail and other cloud systems with rain-producing potential. Dispersal rates of the cloud-seeding agent ranged from 2 to 10 grams of silver

iodide per minute. The radar system was used by the project meteorologist to track the cloud systems being seeded and to provide all seeding aircraft with information on storm position and intensity. Once the pilot of the seeding aircraft had located the area of maximum inflow into the cloud system from below—the updraft region—silver iodide freezing nuclei were produced by igniting the flares or burning the liquid fuel from the wing-tip generators.

**Project 74-2-2
Better Weather, Incorporated
1974 Operational Summary**

Period of Flight Operations: May 4-October 30, 1974

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
May	6	6	3.2	17	30.4	5,775
June	11	9	3.9	23	42.7	18,900
July	8	5	2.8	12	22.9	5,722
Aug.	12	3	1.5	21	39.7	15,861
Sept.	0	0	0	0	0	0
Oct.	6	6	2.9	10	15.0	6,197
Total	43	29	14.3	83	150.7	52,455

Project 74-4-1.—Oklahoma Rainfall-Stimulation Program (Upper Red River Valley)

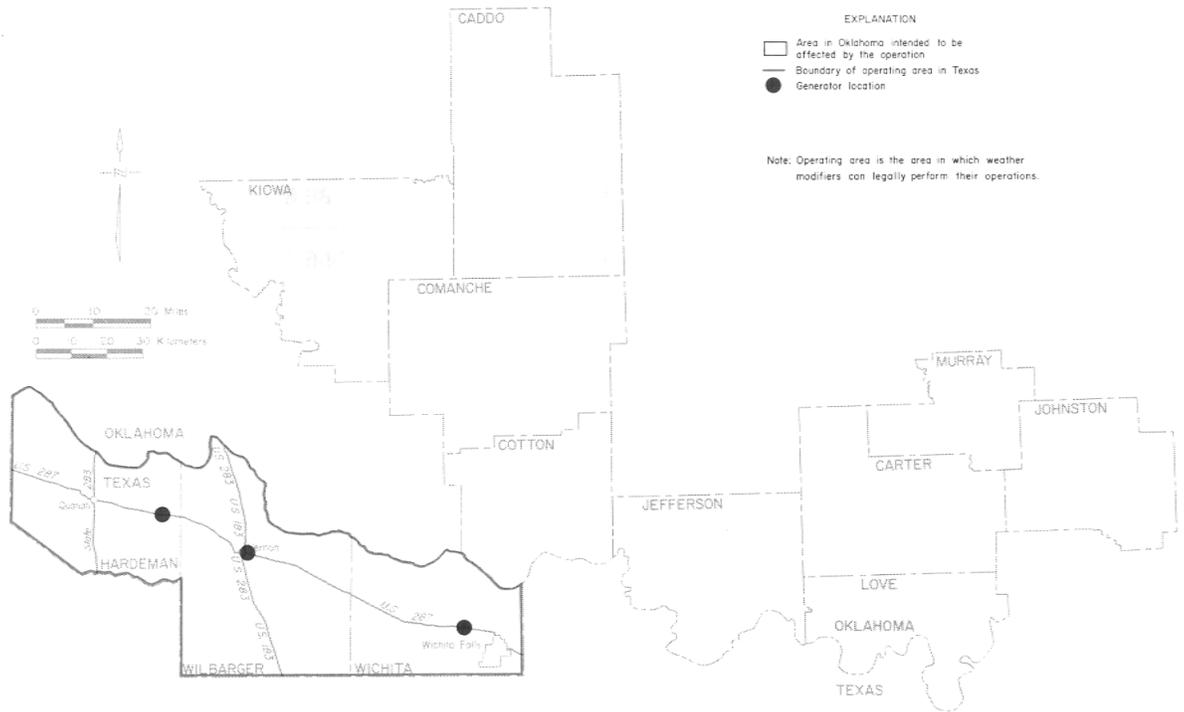
Irving P. Krick, Inc. of Texas continued for the third consecutive year a rainfall-augmentation program designed to increase rainfall on behalf of farmers and ranchers in southern Oklahoma. Equipment used in the program included three ground-based silver iodide generators located in a three-county area of Texas bordering the Red River. The target area was composed of farm and ranch lands within the Oklahoma counties of Caddo, Carter, Comanche, Cotton, Jefferson, Johnston, Kiowa, Murray, and Love. Included in the target area were the watersheds of Lakes Lawtonka and Ellsworth in portions of Caddo, Comanche, and Kiowa Counties.

The maximum intentional effect of the cloud-seeding program centered within the target area,

but other regions within 15 to 20 miles of the target area within the State of Oklahoma were also subject to the effects of the operations. No significant effect in Texas was intended by the operation of any of the ground-based generators. The permit applicant sought to operate dispensers in Texas counties near the Texas-Oklahoma border, not to affect the occurrence of rainfall in any area of Texas.

The dispensers used in the program were silver iodide electric arc ground-based generators having an output of an optimum amount of 1/2 gram of silver iodide per hour per dispenser. The generators were operated by local residents under the direction and control of a project meteorologist employed by Krick, Inc. Radar equipment was not used at the project site.

The Krick operations were performed for the following clients: Arbuckle Weather Modification District, Inc., Cotton County Services, Inc., and city of Lawton.



Project 74-4-1
Oklahoma Rainfall-Stimulation Program (Upper Red River Valley)
1974 Operational Summary

Period of Operation: January 5-September 19, 1974

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Jan.	3	2	30.0	15.0
Feb.	8	3	63.0	31.5
Mar.	6	3	73.0	36.5
Apr.	12	3	212.5	77.0
May	14	3	157.2	78.6
June	4	2	25.0	12.5
July	3	1	33.0	16.5
Aug.	16	3	276.2	138.2
Sept.	6	3	86.8	43.4
Total	72	23	956.7	449.2

**Project 74-4-2.—Oklahoma Rainfall-
Stimulation Program (Texas
Panhandle)**

A cloud-seeding program using ground-based silver iodide generators to increase rainfall over western Oklahoma continued during 1974. Irving P. Krick, Inc. of Texas conducted the weather modification program on behalf of farmers and ranchers in that area of the State of Oklahoma.

Eleven ground-based electric arc silver iodide dispensers were located and operated from within a nine-county area of the Texas Panhandle region. The area of intended effects from the cloud-seeding operations consisted of Beaver, Ellis, Harper, Kiowa, Washita, and Woodward Counties and parts of Texas and Woods Counties of Oklahoma. The weather in a region adjacent to the eight-county target area was also subject to any effects caused by the program. No significant

effect upon the weather in Texas was intended by this operation. The program design was to install and operate generators in Texas but to affect the weather over Oklahoma only.

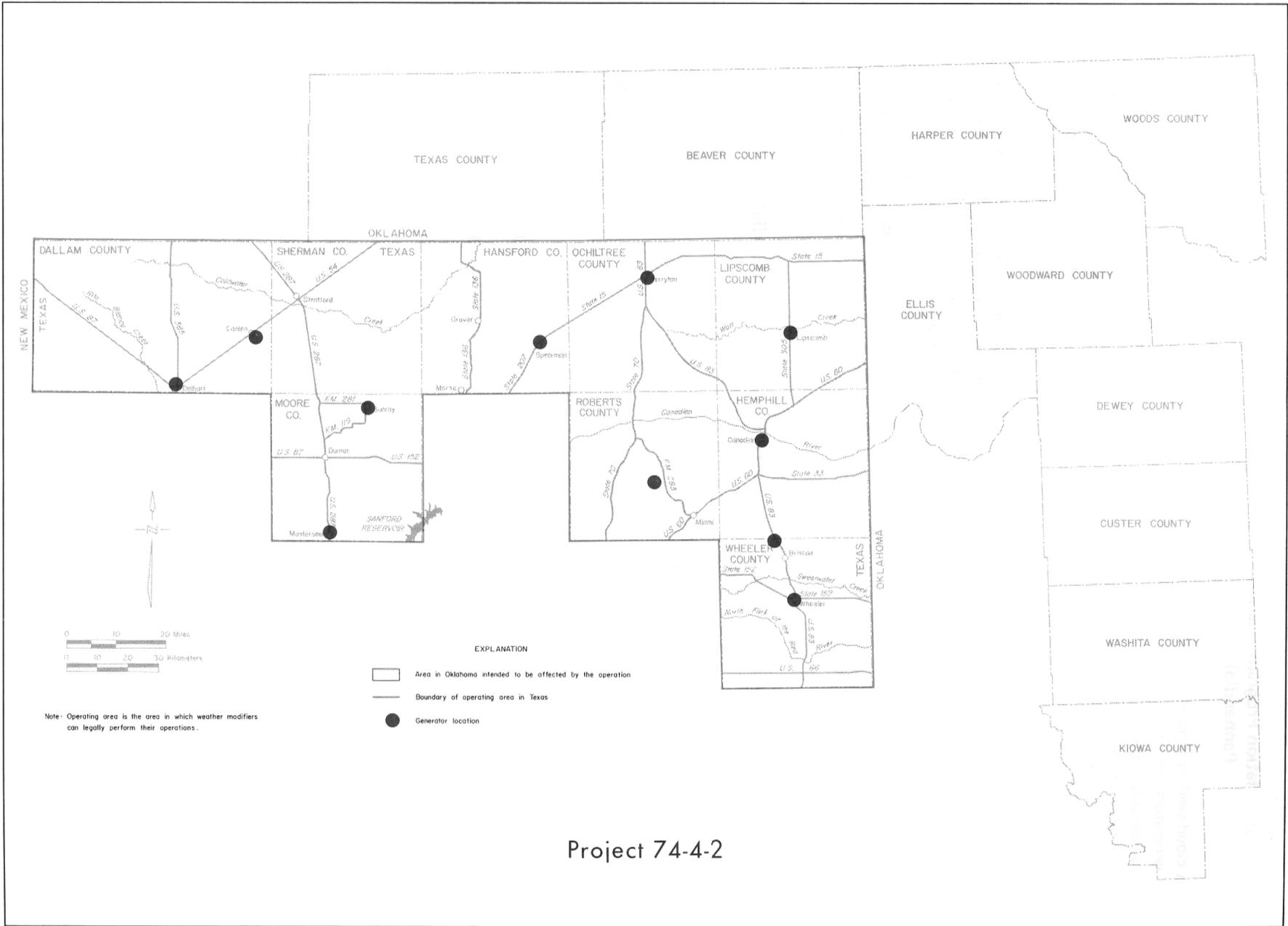
Residents within the nine-county operational area of Texas operated the generators under the direction and control of a Krick, Inc. project meteorologist. No radar equipment was employed in the program. The electric arc generators dispensed silver iodide at a rate of from ½ to 2 grams per hour per generator.

The cloud-seeding program was performed by Krick, Inc. for clients which included: Henry C. Hitch Ranch, Inc.; Beaver County Weather, Inc.; Harper County Weather, Inc.; Woodward County Cloud-Seeding Association; Ellis County Weather, Incorporated; Washita County Weather Modification Association; and Kiowa County Weather Modification Association. The seeding operations were conducted throughout 1974.

**Project 74-4-2
Oklahoma Rainfall-Stimulation Program (Texas Panhandle)
1974 Operational Summary**

Period of Operation: April 2-October 13, 1974

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Apr.	18	9	497.50	248.75
May	21	11	506.50	253.25
June	10	9	249.25	124.62
July	15	7	170.50	85.25
Aug.	23	11	806.20	544.26
Sept.	12	8	227.75	113.87
Oct.	6	9	226.70	154.00
Total	105	64	2,684.40	1,524.00



Project 74-4-3.—Oklahoma Rainfall-Stimulation Program (Mid-Red River Valley)

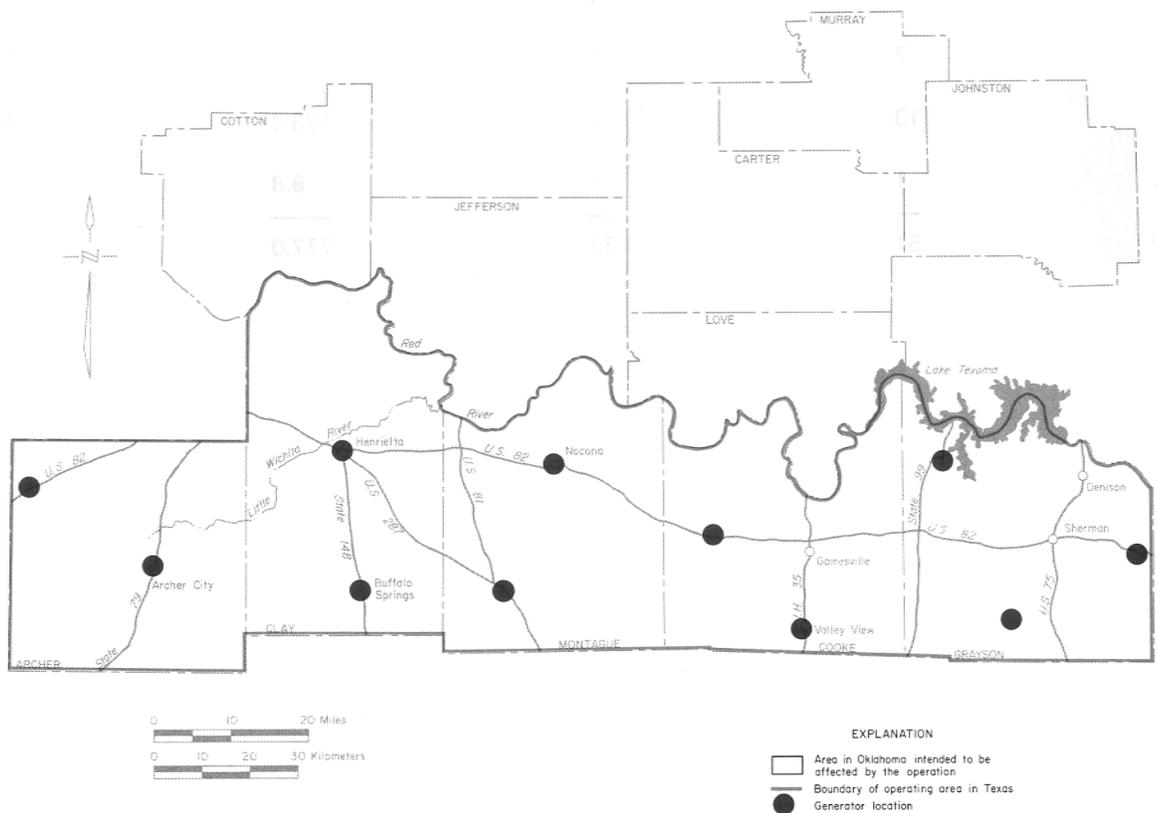
An association of farmers and ranchers in Cotton County, Oklahoma and County Commissioners of five other Oklahoma counties sponsored a cloud-seeding program in southern Oklahoma during 1974. The project, conducted by Irving P. Krick, Inc. of Texas, was designed to increase precipitation on behalf of farmers and ranchers living in the sponsoring counties.

A network of eleven ground-based silver iodide electric arc generators was operated from within a five-county area of north-central Texas consisting of Archer, Clay, Montague, Cooke, and Grayson Counties. Silver iodide released from these generators was intended to affect cloud systems over the six-county target area in

Oklahoma composed of Cotton, Jefferson, Carter, Murray, Johnston, and Love Counties.

In addition, the weather in other areas adjacent to and within 15 to 20 miles of the target area was subject to the effects of the cloud-seeding operations. No significant effect on Texas weather was intended by the program. A permit was obtained by Krick, Inc. from the Texas Water Development Board to install and operate the silver iodide dispensers in Texas but not to affect the rainfall over any portion of the State of Texas.

The electric arc generators dispensed silver iodide at a rate of from 1/2 to 2 grams per hour per generator. The operations were conducted throughout the year. The program was sponsored by Cotton County Services, Inc., and the Oklahoma counties of Jefferson, Carter, Murray, Johnston, and Love acting through their County Commissioners.



Note: Operating area is the area in which weather modifiers can legally perform their operations.

Project 74-4-3
 Oklahoma Rainfall-Stimulation Program (Mid-Red River Valley)
 1974 Operational Summary

Period of Operation: February 17-September 1, 1974

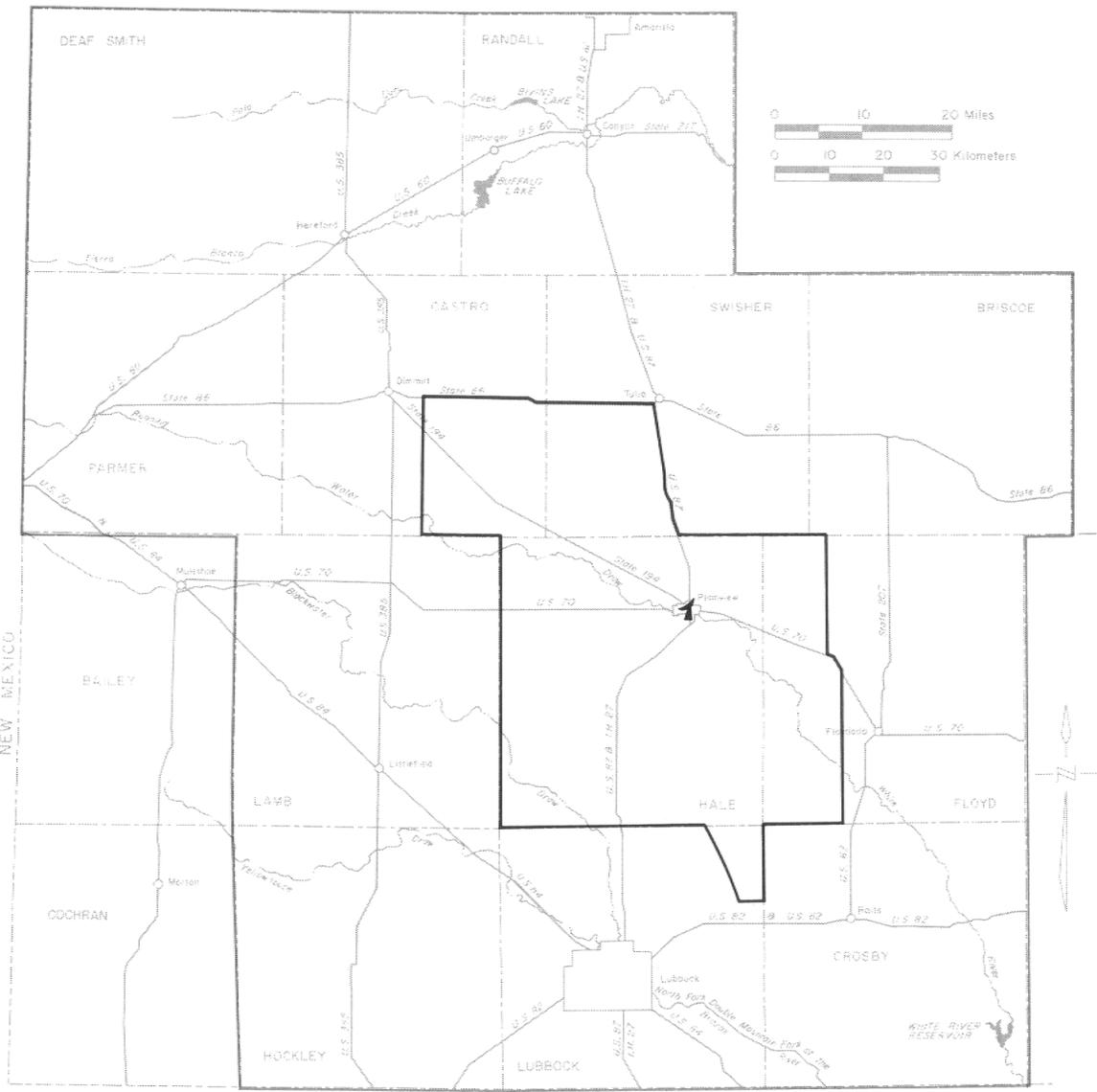
<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Feb.	2	1	12.0	6.0
Mar.	4	2	52.0	26.0
Apr.	6	2	83.0	41.5
May	13	6	241.0	120.5
June	5	5	79.0	39.5
July	7	7	127.0	63.5
Aug.	13	8	173.2	86.6
Sept.	1	1	9.8	4.9
Total	51	32	777.0	388.5

Project 74-6-1.—Plains Weather Improvement Association, Inc., Hail-Suppression Program

An operational cloud-seeding project designed to suppress the occurrence of damaging hailstorms was conducted during the spring, summer, and fall of 1974 on the Texas High Plains by Plains Weather Improvement Association, Inc. of Plainview. The 1974 program marked the fifth consecutive year of weather modification operations on the High Plains. Like the program of the previous year, the 1974 program was carried out with the Association's own personnel and equipment.

The 1974 program was conducted solely for the suppression of hail in an area that included all of Hale County and portions of Castro, Swisher, Floyd, and Lubbock Counties. The cloud-seeding equipment was operated in a larger, 12-county area that encompassed the target area. Periodically, cloud-seeding aircraft operated within this 12-county operational area and treated cloud systems expected to move over the target area.

The program involved the airborne application of artificial ice nuclei, silver iodide, to various cloud formations which, in the judgment of the project meteorologist, possessed the hail-producing potential.



- EXPLANATION**
- Operating area boundary
 - Target area boundary
 - ① Project radar site

Note: Operating area is the area in which weather modifiers can legally perform their operations. Target area is the only area to be affected by weather modification.

Silver iodide smoke particles were generated from pyrotechnic devices (flares) mounted on the wings of the seeding aircraft. The base of cloud-seeding operations, located at the Plainview airport, included three seeding aircraft and a weather radar system in its inventory of equipment. The radar was used to locate and identify

potential hail-producing thunderstorms which threatened the target area and to direct the seeding aircraft to the storm systems so seeding operations could be initiated. The silver iodide was dispensed from the wings of the aircraft into the updraft region of the cloud systems being seeded.

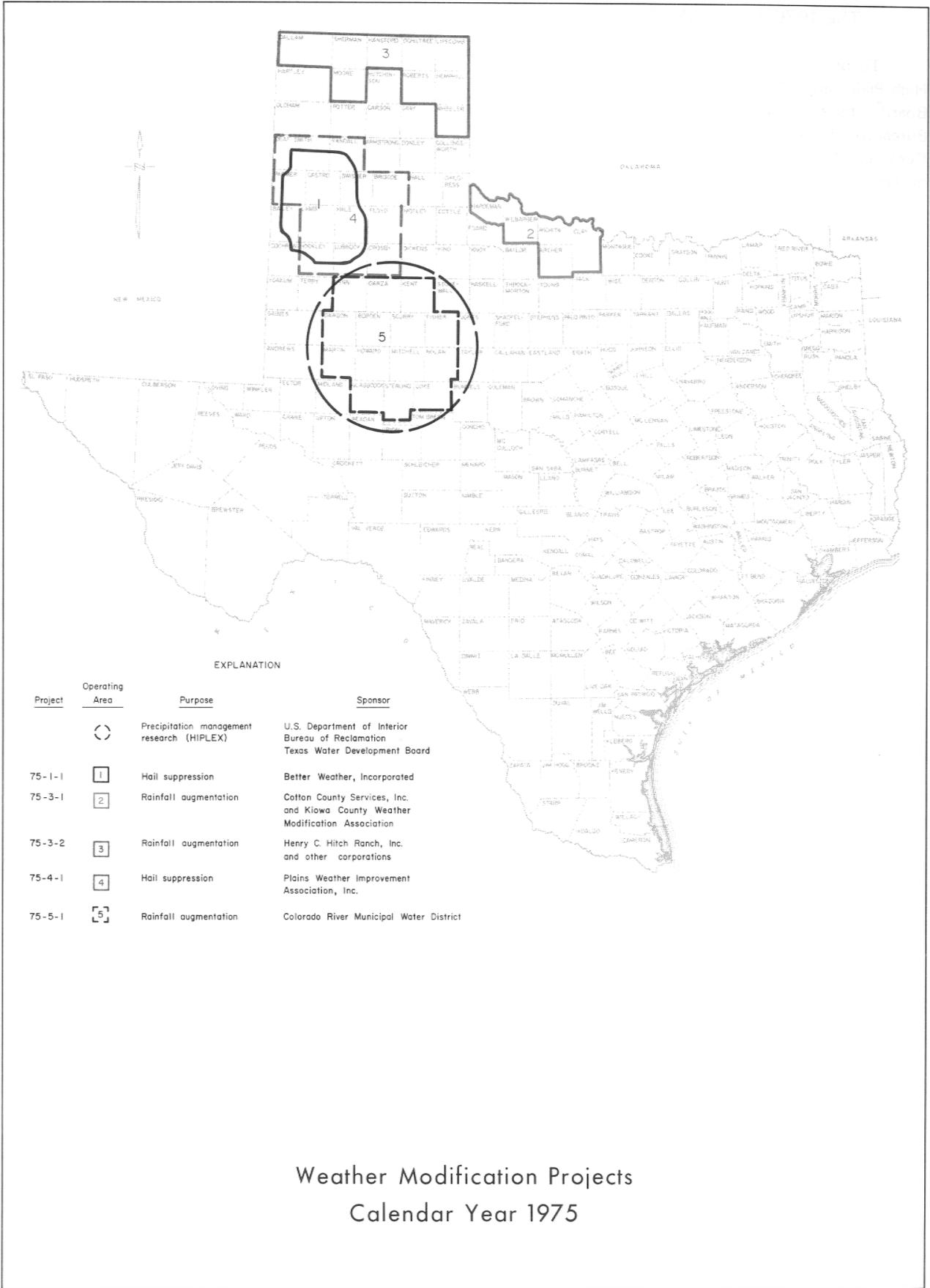
**Project 74-6-1
Plains Weather Improvement Association, Inc.
1974 Operational Summary**

**Periods of Flight Operations: April 28-August 24, 1974
October 5-November 2, 1974**

<u>Month</u>	<u>Number of operational days</u>	<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	
Apr.	2	9	8.4	10,463.0
May	5	15	10.7	13,822.0
June	6	29	30.2	47,989.0
July	1	3	5.7	5,312.0
Aug.	6	16	13.4	12,845.0
Oct.	3	6	3.4	3,703.0
Nov.	1	2	2.0	1,914.0
Total	24	80	73.8	96,048.0

WEATHER MODIFICATION PROJECTS

CALENDAR YEAR 1975



Weather Modification Projects
Calendar Year 1975

water needs. The goals of the HIPLEX program are to establish both a verified, working technology and an operational management framework which would be capable of producing additional rain from cumulus clouds in the High Plains States east of the Continental Divide.

An area of western Texas which encompassed the target area of the Colorado River Municipal Water District's weather modification program was selected as the Texas HIPLEX study site. The site was determined to be representative of the crops, climate, and water needs of the Southern Great Plains.

Funds for the Texas portion of HIPLEX were allocated by both the Bureau of Reclamation and the State of Texas through the Texas Water Development Board. Using available Federal and State funds, the Texas Water Development Board entered into contracts with a number of research groups for HIPLEX-support services.

A five-member Texas HIPLEX Advisory Committee was established by the Board to define goals and objectives for the Texas HIPLEX program and to assure that the program in Texas is coordinated with similar HIPLEX experiments being conducted in Kansas and Montana. To this end, the Committee devised a Texas HIPLEX Work Plan whereby the goals, objectives, and study priorities of the program were clearly defined.

Using funds made available from the Bureau, the Board contracted with the Colorado River Municipal Water District to operate a raingage and rawinsonde network and to conduct studies in the Big Spring-Snyder area of western Texas during the period April-June 1975.

The Board contracted with Meteorology Research, Inc. (MRI) to prepare, deploy, and calibrate radar equipment and to perform on-site cloud-characteristics investigations through radar operations in the Big Spring-Snyder area during the summer of 1975.

By the end of 1975, two new contracts were awarded MRI and the District in connection with the Texas HIPLEX program. MRI expanded its on-site radar operations to include digitization and analysis of the radar data accumulated. The District continued maintaining an extensive raingage system and operating a rawinsonde unit, and provided the Board with the services of a radar meteorologist.

Under contract with the Bureau, the Board's staff of economists conducted a study of the effects of increased rainfall on cropland yields in the Big Spring-Snyder area. Data on crop yields as they relate to rainfall, cropping patterns, arable soil acreage; and rainfall distribution were collected, verified, and coded by the staff. Then extensive, statistical analyses were performed on the data, and results showed that "there could be substantial direct increases in agricultural incomes resulting from assumed increased in average precipitation." In particular, the study indicated that "each dollar of direct income gain would lead to between 50 and 64 cents additional activity as a result of multiplier effects. The total regional effects of a 10 percent increase in average March rain were shown to be approximately \$500,000." A report on the study was prepared, and a copy of it is available for reading in the Texas Department of Water Resources library in Austin or in the offices of the Division of Atmospheric Water Resources Management, Bureau of Reclamation in Denver.

convective cloud systems. The suitability of seeding the cloud systems was ascertained by radar. All of the silver

iodide was released at cloud base from pyrotechnic flares attached to the wings of the seeding aircraft.

**Project 75-1-1
Better Weather, Incorporated
1976 Operational Summary**

Period of Flight Operations: May 4-October 31, 1975

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
May	15	10	7.2	31	46.5	24,769
June	14	8	7.2	30	41.6	14,066
July	13	7	4.7	22	36.4	15,216
Aug.	7	4	3.1	15	21.2	9,982
Sept.	1	0	0	3	7.8	5,170
Oct.	2	3	2.4	0	0	0
Total	52	32	24.6	101	153.5	69,203

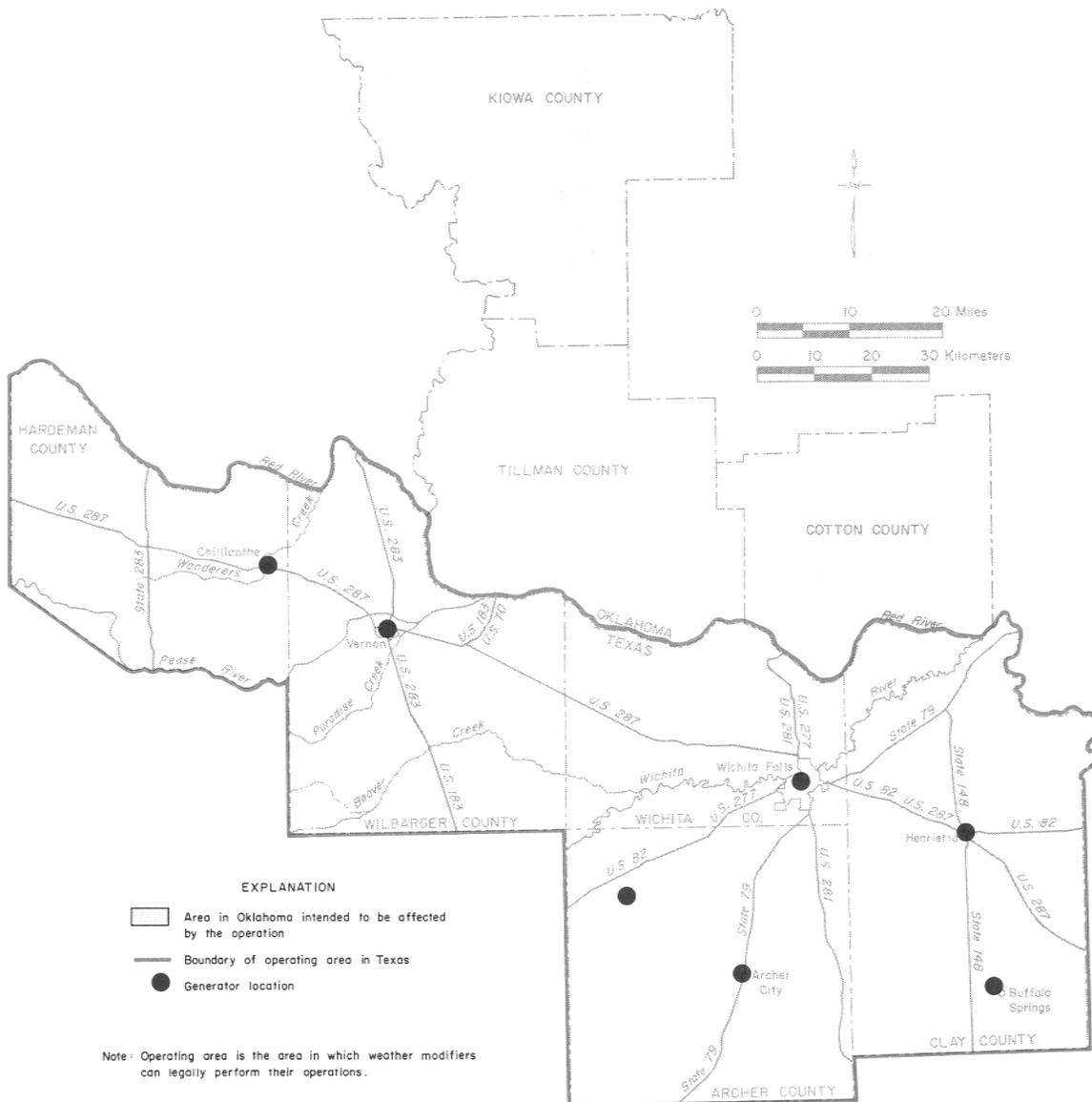
Project 75-3-1.—Oklahoma Rainfall-Stimulation Program (Red River Valley)

Seven ground-based silver iodide generators situated in a five-county area of Texas along the Red River were utilized by Irving P. Krick, Inc. of Texas during 1975 to continue for the fourth year a rainfall augmentation program. This weather modification effort was conducted on behalf of farmers and ranchers in two areas of Oklahoma. Whereas the generators were located in Archer, Clay, Hardeman, Wichita, and Wilbarger Counties of Texas, the target area—or the area of intended effects on the weather—consisted of farm and ranch lands within the Oklahoma counties of Cotton and

Kiowa. No effect on Texas weather was intended by the program.

The generators used in the operations were silver iodide electric arc ground-based dispensers having an output in the range of ½ to 2 grams per hour per dispenser. The equipment in the five-county operational area of Texas was operated by local residents under the direction of a Krick, Inc. meteorologist. Neither radar nor aircraft was utilized. Cloud systems were treated which, in the judgment of the project meteorologist, were considered to be suitable for seeding.

The operations were performed in 1975 for the following clients: Cotton County Services, Inc. and Kiowa County Weather Modification Association.



Project 75-3-1
 Oklahoma Rainfall-Stimulation Program (Red River Valley)
 1975 Operational Summary

Periods of Operation: April 6-May 29, 1975
 September 9-December 14, 1975

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Apr.	14	6	212.0	106.0
May	13	4	201.5	100.8
Sept.	4	1	35.0	17.5
Oct.	1	1	4.0	2.0
Nov.	6	3	69.0	34.5
Dec.	2	4	54.5	27.2
Total	40	19	576.0	288.0

Project 75-3-2.—Oklahoma Rainfall-Stimulation Program (Texas Panhandle)

An effort to augment rainfall in Oklahoma using ground-based generators located in the Panhandle region of Texas was continued for the fourth year by Irving P. Krick, Inc. of Texas. Ten silver iodide generators, strategically positioned in nine Texas Panhandle counties, were operated by local residents under the guidance and supervision of a project meteorologist of Krick, Inc. of Texas.

It was not the intent of the program to augment rainfall in Texas. Rather, the sole purpose was to increase precipitation in a target area of Oklahoma consisting of farm and ranch lands within Beaver, Ellis, Harper, Kiowa, and Woodward Counties and a portion of Texas County. The areas adjacent to the target area which may have been subject to effects of the operations were identified in the permit application to be within

the State of Oklahoma and generally within 15 to 20 miles of the target area. The maximum intentional effect was in the target area, but some downwind effect may have occurred in Oklahoma, mostly to the immediate northeast of the target area.

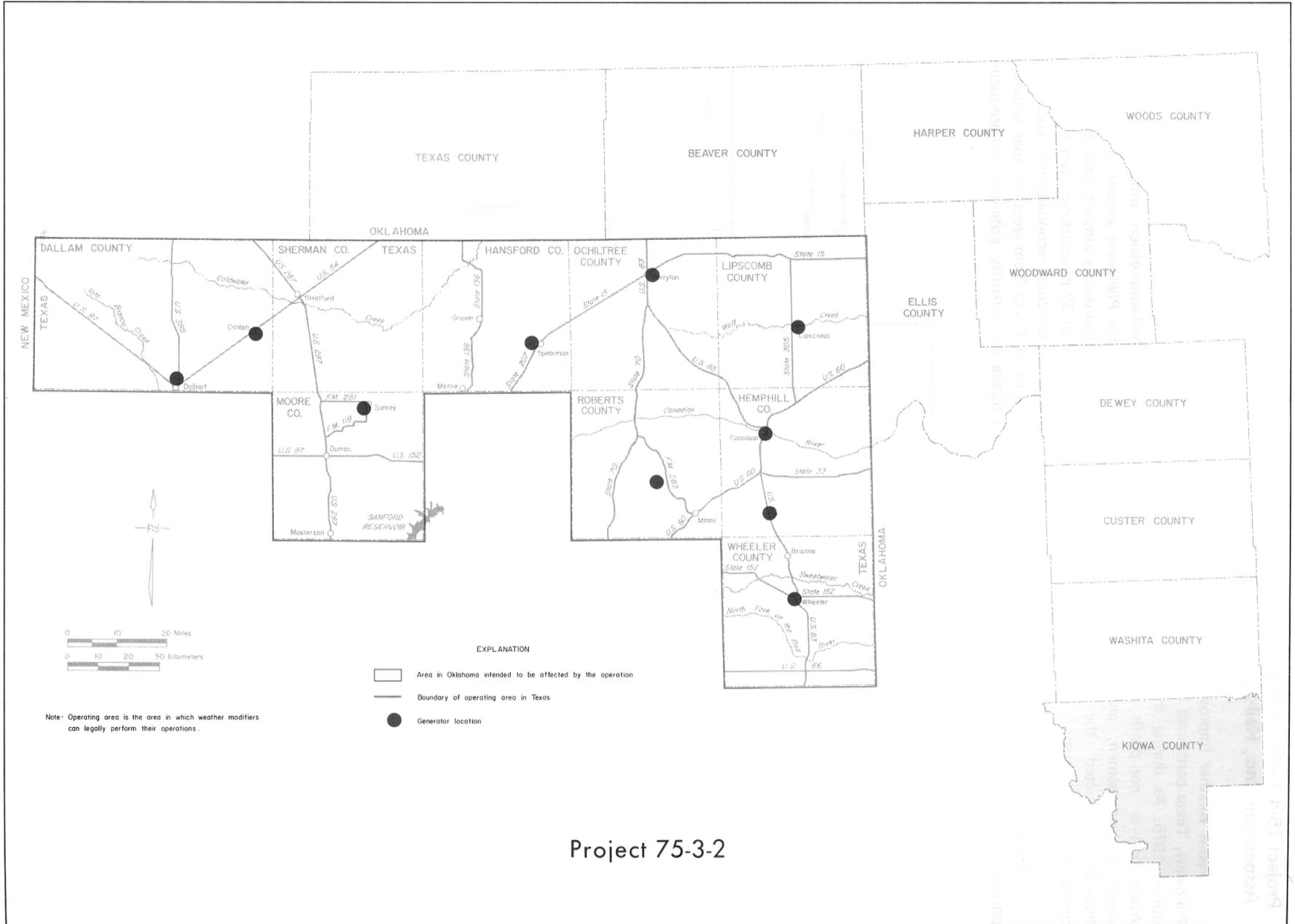
The dispensers, each with a capacity to deliver a silver iodide output in the range of ½ to 2 grams per hour, were operated when the synoptic weather conditions were deemed by the project meteorologist to be suitable for transporting the seeding agent to cloud bases over the Oklahoma target area. No radar equipment or aircraft were utilized.

The cloud-seeding program was performed by Krick, Inc. for the following clients: Henry C. Hitch Ranch, Inc.; Beaver County Weather, Inc.; Harper County Weather, Inc.; Woodward County Cloud-Seeding Association; Ellis County Weather, Inc. and Kiowa County Weather Modification Association. The seeding operations were conducted throughout most of 1975.

**Project 75-3-2
Oklahoma Rainfall-Stimulation Program (Texas Panhandle)
1975 Operational Summary**

Period of Operation: March 8-December 14, 1975

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Mar.	12	8	191.00	128.50
Apr.	13	7	241.00	141.00
May	16	10	580.25	383.12
June	5	7	75.00	46.50
July	16	9	349.75	206.38
Aug.	8	7	169.50	99.74
Sept.	6	6	95.00	47.50
Oct.	4	4	48.50	32.50
Nov.	8	9	289.50	213.00
Dec.	2	6	71.00	47.75
Total	90	73	2,110.50	1,345.99



that threatened the target area. When a potential hail producer was identified, the radar meteorologist directed

the seeding aircraft to the thunderstorm to initiate the seeding operation.

**Project 75-4-1
Plains Weather Improvement Association, Inc.
1975 Operational Summary**

Period of Flight Operations: April 25-October 31, 1975

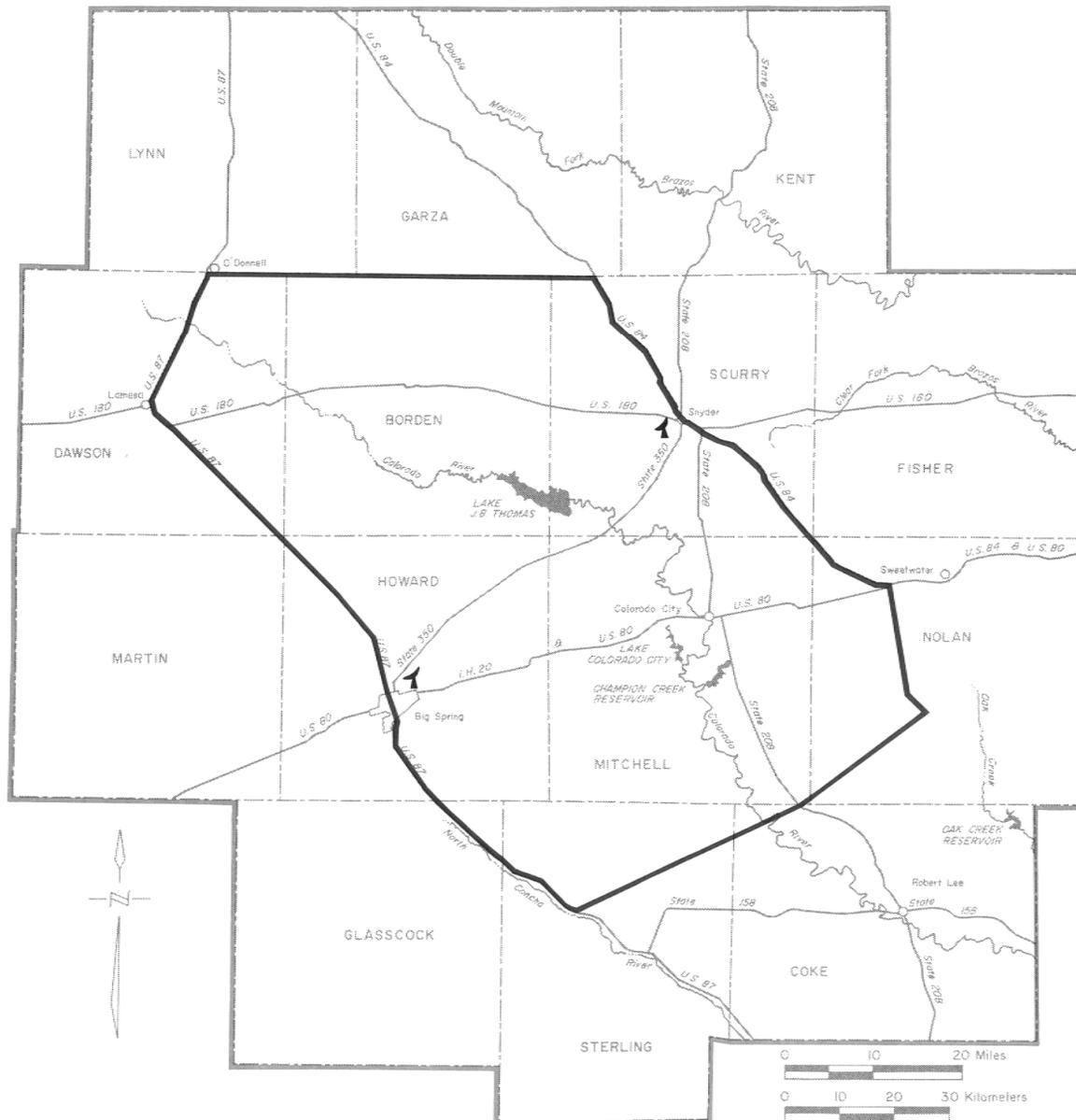
<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
Apr.	2	4	2.4	0	0	0
May	17	15	16.1	33	63.1	20,200
June	13	12	9.3	25	51.2	22,700
July	11	7	4.1	14	26.6	10,300
Aug.	4	3	1.9	10	17.3	8,700
Sept.	1	0	0	3	6.2	2,700
Oct.	2	2	1.3	1	1.7	1,200
Total	50	43	35.1	86	166.1	65,800

Project 75-5-1.—Colorado River Municipal Water District Rainfall- Enhancement Program

The Colorado River Municipal Water District continued for the fifth straight year a rainfall-stimulation program to supplement surface-water runoff into two reservoirs owned and operated by the District. Unlike the previous four years, when the District conducted the cloud-seeding operations under contract with a private cloud-seeding firm, the District in

1975 secured its own professional staff and equipment and conducted the rainfall stimulation program on its own.

Cloud seeding was accomplished through the aerial application of silver iodide. The silver iodide was dispensed from the District's Piper Aztec cloud-seeding aircraft which flew below the base of cumulus cloud cells determined to have seeding potential. The silver iodide nuclei were released into the updraft regions from flare racks mounted on the wings of the aircraft.



Note: Operating area is the area in which weather modifiers can legally perform their operations.
Target area is the only area to be affected by weather modification.

EXPLANATION
 — Operating area boundary
 — Target area boundary
 ↗ Radar installation site

To accommodate the 1975 statistical evaluation of the District's program by Meteorology Research, Inc., randomized field experiments were conducted. These experiments involved a randomization scheme of 75:25 seed to no-seed operations and were accomplished through the use of "dummy" flares identical in appearance to those containing silver iodide.

The District's project director and radar meteorologist operated a 3-cm radar to locate clouds believed to have seeding potential and then directed the seeding aircraft to them.

To help the project meteorologist determine if a seed or no-seed day could be expected, an RD-65 rawinsonde unite was utilized to track balloons carrying weather instrument packages up into the atmosphere. Meteorological parameters such as air temperature, atmospheric pressure, humidity, and wind speed and

direction were sensed by the instrument package and transmitted back to the receiving unit. A computer analysis of these data helped the project meteorologist determine if a particular day might be an operational one.

The District's cloud-seeding project area is situated in the Permian Basin of West Texas. The target area located within the project area includes the primary watersheds above Lake J. B. Thomas and Lake E. V. Spence.

To more efficiently measure the effects of the District's program, a network of more than 80 raingages was deployed and monitored during the operational period, which began on April 15 and ended on October 15, 1975. The gages, of both conventional and recording types, were strategically deployed over the target area to provide an adequate description of the variable rainfall patterns that normally occur over the region.

**Project 75-5-1
Colorado River Municipal Water District
1975 Operational Summary**

Period of Flight Operations: April 21-September 5, 1975

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
Apr.	3	1	0.6	2	2.5	140
May	4	0	0	5	13.0	1,080
June	6	4	3.4	4	6.6	300
July	14	7	5.1	17	29.1	1,480
Aug.	7	4	3.6	6	12.8	720
Sept.	2	1	1.0	1	1.0	20
Total	36	17	13.7	35	65.0	3,740

Colorado River Municipal Water District Evaluation Program, 1975

An attempt that was begun in 1973 to evaluate the cloud-seeding program of the Colorado River Municipal Water District was continued in 1975 by Meteorology Research, Inc. of Altadena, California, under contract with the Texas Water Development Board. The evaluation focused upon the District's rainfall-stimulation activities conducted during the periods August-September 1973 and May-October 1974.

Following the installation and calibration of a modified M-33 radar system at Winston Field in Snyder, the part of the system consisting of a 10-cm radar was used to measure rainfall over the District's weather modification project area. A second unit—a 3-cm radar—measured heights of the tops of clouds in both seeded and unseeded areas, so that changes could be detected in the heights of these clouds which might be associated with seeding. In addition, an aircraft was flown into areas beneath precipitating cloud systems to obtain meteorological data on both seeded and unseeded clouds. These data were also used to verify the calibration of the radar system.

Cloud-seeding activities performed during the study periods were based upon a randomization scheme involving the use of "dummy" flares 25 percent of the time. This randomization of seeding activities made possible a variety of meaningful analyses which would not otherwise have been possible. These included not only examinations of variations in rainfall amounts but also the extent to which seeding may have influenced cloud-top heights, rainfall rates, the size of individual rain cells, and the duration of rainfall. The analyses were

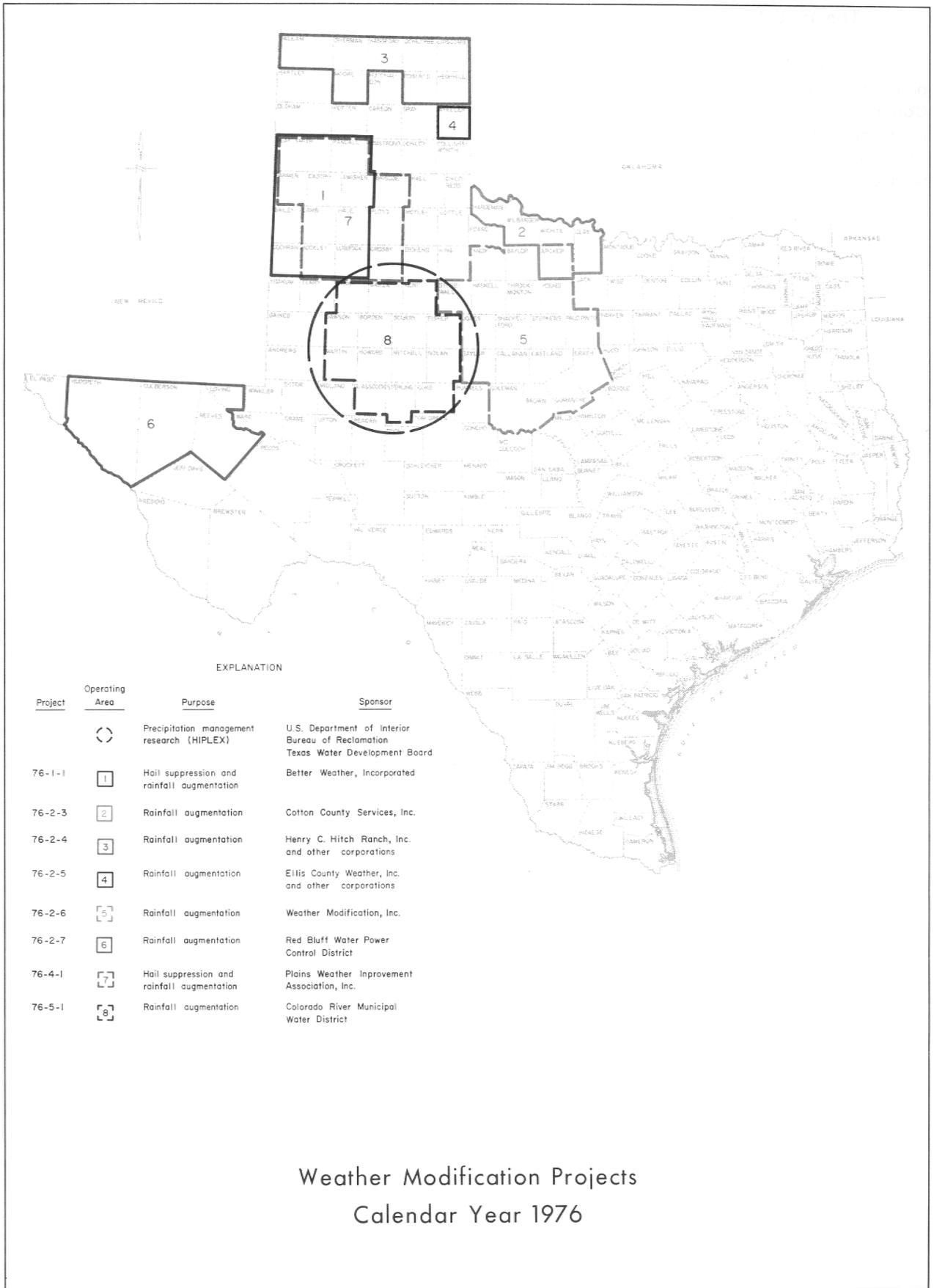
made all the more meaningful, since randomization removed the likelihood of bias in the selection of study cases.

The analytical phase of the study by Meteorology Research, Inc. consisted of a comparison of seeded and unseeded events in terms of total amounts of precipitation which could be considered to be associated with given cloud systems. Other comparisons were made of cloud-top heights for seeded and unseeded cloud systems. The objective of the studies was to define as clearly as possible the rainfall associated with each seeding event.

Analyses of the 1973-74 data revealed that "... approximately half of the events were treated in a manner where there was considerable doubt about the possible effectiveness of the seeding." The other half of the total events "... were seeded in a timely manner and showed evidence of changes in cloud structure which might be associated with seeding." The author cautioned that "The possibility of these changes resulting from natural variability could not be discounted, however."

Unfortunately, because of an insufficient amount of data, results of the study were inconclusive, and a new contract was let by the Texas Water Development Board in 1976 to Meteorology Research, Inc. to extend the evaluation to include the District's 1975 cloud-seeding program. In 1977, a report of the results from the 1973-74 data was combined with a report on the analyses of 1975 data, and the final report, entitled "Radar Evaluation of Big Spring Weather Modification Program," is available for the reader's inspection in the Texas Department of Water Resources library in Austin.

WEATHER MODIFICATION PROJECTS
CALENDAR YEAR 1976



EXPLANATION

Project	Operating Area	Purpose	Sponsor
		Precipitation management research (HIPLEX)	U.S. Department of Interior Bureau of Reclamation Texas Water Development Board
76-1-1		Hail suppression and rainfall augmentation	Better Weather, Incorporated
76-2-3		Rainfall augmentation	Cotton County Services, Inc.
76-2-4		Rainfall augmentation	Henry C. Hitch Ranch, Inc. and other corporations
76-2-5		Rainfall augmentation	Ellis County Weather, Inc. and other corporations
76-2-6		Rainfall augmentation	Weather Modification, Inc.
76-2-7		Rainfall augmentation	Red Bluff Water Power Control District
76-4-1		Hail suppression and rainfall augmentation	Plains Weather Improvement Association, Inc.
76-5-1		Rainfall augmentation	Colorado River Municipal Water District

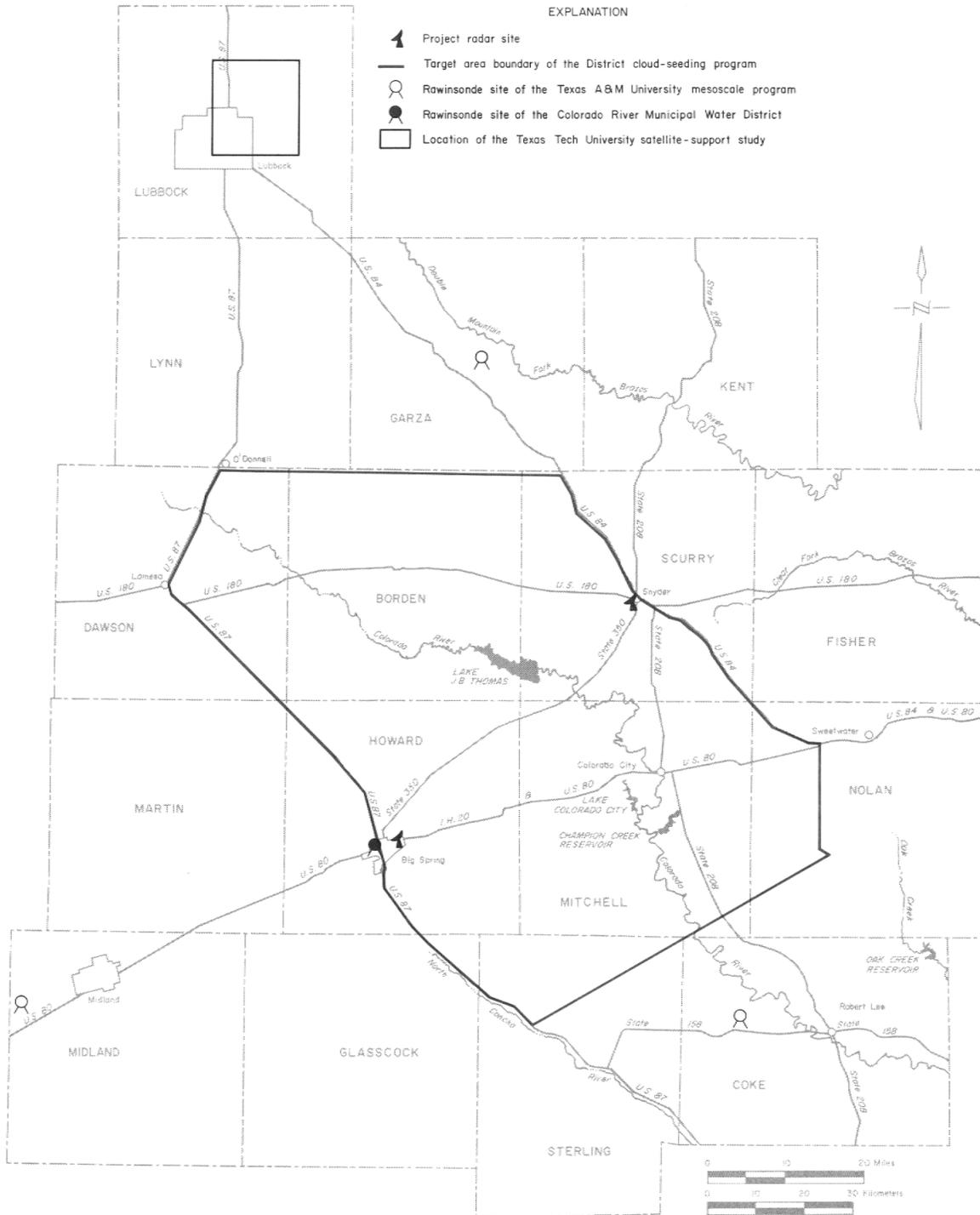
Weather Modification Projects
Calendar Year 1976

The 1976 Texas HIPLEX Program

The Texas Water Development Board continued its participation in the Texas portion of the High Plains Cooperative Program (HIPLEX) during 1976. The program, which is designed to establish a viable technology management framework capable of producing additional rain from cumulus clouds in the

Texas High Plains region, was conducted in 1976 on a scale greater than that of the previous two years.

Funds appropriated by the 64th Texas Legislature amounting to about \$67,000 were spent on the Texas HIPLEX program during State fiscal year 1976 (September 1, 1975 to August 31, 1976). An additional \$51,000 was allocated to the program for State fiscal



year 1977 (which began on September 1, 1976). Approximately \$200,000 in Federal funds was provided by the Department of the Interior, Bureau of Reclamation for the Texas HIPLEX program for each of State fiscal years 1976 and 1977.

Using these State and Federal funds, the Board in 1976 let contracts with a number of organizations and institutions involved in research or operationally oriented weather modification activities for services in support of the Texas HIPLEX program. The following is a summary of the work performed in 1976 by the Board and each organization participating in HIPLEX.

Texas Water Development Board

In 1976, the Texas Water Development Board operated a meteorological facility at Howard County airport in Big Spring to provide forecasting support services for the Texas HIPLEX project and the Colorado River Municipal Water District's cloud-seeding program. During the 1976 cloud-seeding season, which ended on September 30, the on-site Board meteorologist received and utilized surface and upper-air weather data to prepare terminal forecasts for use by personnel of the Colorado River Municipal Water District in planning and preparing for cloud-seeding operations. The forecasts were also used by other organizations contributing to the HIPLEX program.

In 1976, at Board headquarters in Austin, the staff completed studies which dealt with the effects rainfall increases would have on crop production, rangeland forage production, the livestock industry, and the impact of increased livestock production on the economy of the region encompassing the Texas HIPLEX area. Other studies focused on refining methods for forecasting atmospheric conditions considered to be responsive to cloud seeding.

Colorado River Municipal Water District

Some of the State and Federal funds for HIPLEX were used in 1976 by the Colorado River Municipal Water District to collect and document rainfall data from a network of more than 50 recording raingages and about 81 wedge-type fencepost raingages. In support of the HIPLEX program in Texas, the District also operated an RD-65 rawinsonde unit to measure atmospheric temperature, wind, and humidity profiles on days when the HIPLEX program was in operation.

Meteorology Research, Inc.

Another portion of the HIPLEX funds was used in 1976 by Meteorology Research, Inc. of Altadena, California to maintain an M-33 radar system owned by the Bureau of Reclamation and located at Winston Field in Snyder. This radar system was utilized to measure a number of cloud parameters for use in analyzing certain cloud characteristics and for determining the degree of seedability of clouds in the Texas HIPLEX area.

Texas Tech University

In 1976, the Department of Geosciences of Texas Tech University conducted for the Board and the Bureau of Reclamation cloud studies using remote sensing techniques. Scientists performed qualitative analyses of satellite imagery to determine selected physical cloud properties and to observe the behavior of these clouds as they interact with each other and the environment. The cloud imagery study concentrated on clouds found in the Texas HIPLEX study area.

Texas A&M University

The Center for Applied Geosciences at Texas A&M University conducted for the Board a measurement project to resolve small (meso-) scale features associated with convective cloud systems in the Texas HIPLEX project area. Initial field experiments in 1976 were performed to determine what conditions and factors are associated with, and are responsible for, the development, growth, size, duration, intensity, and movement of convective clouds. Hopefully, it will eventually be possible to determine the extent to which storm systems modify the atmosphere within a particular region.

Big Spring Aircraft, Inc.

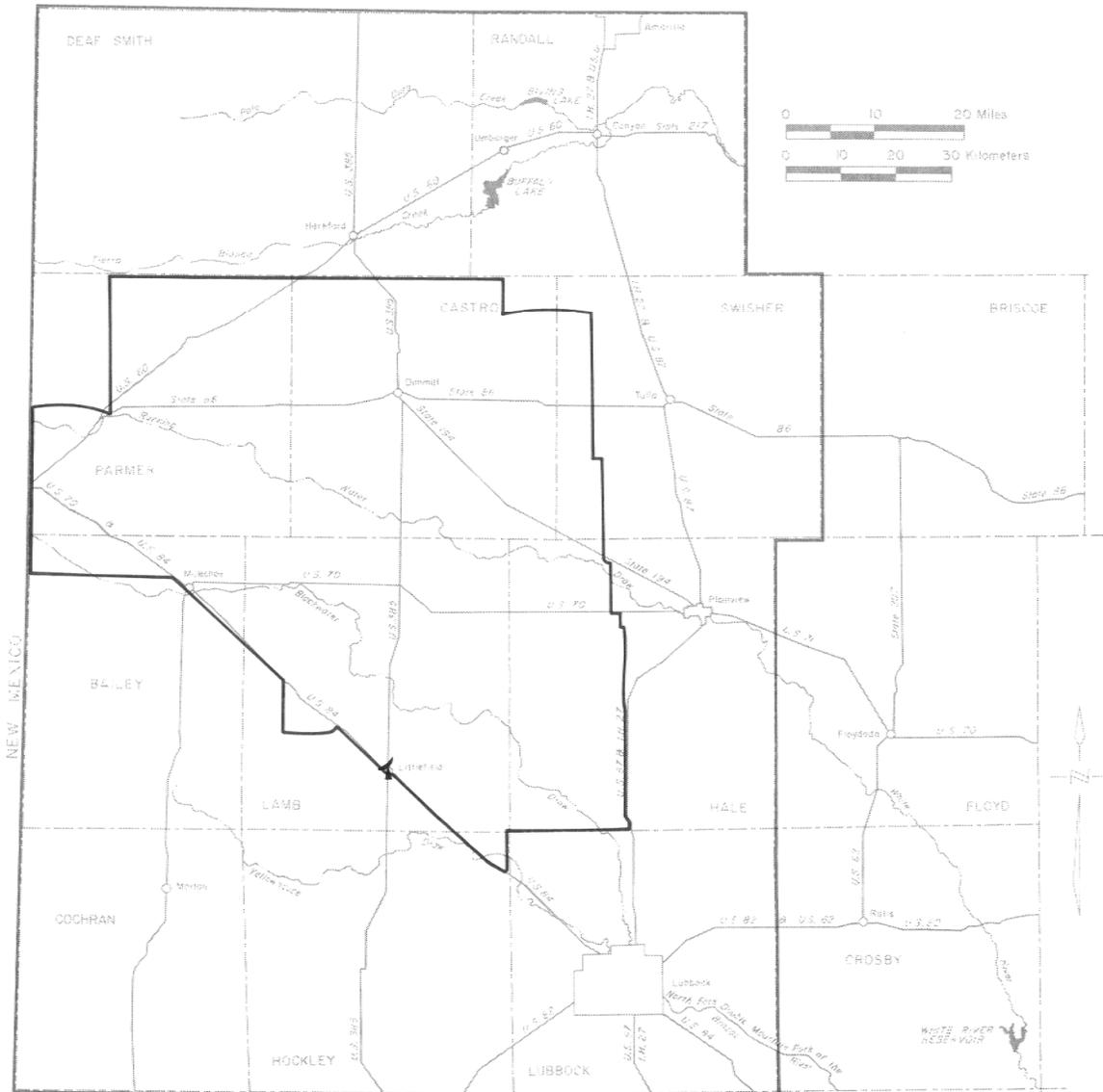
Under contract with the Board, a fully equipped aircraft was provided by Big Spring Aircraft, Inc. for gathering meteorological data at cloud-base level on days when the HIPLEX program was in operation. The cloud-survey aircraft obtained sub-cloud variables such as wet and dry bulb temperatures at cloud base and measured the updrafts of a large sample of clouds. Twenty-six cloud-sampling missions were flown during the period May 20-July 29, 1976, all of which were conducted within 50 miles of base headquarters at Big Spring.

Project 76-1-1.—Better Weather, Incorporated, Hail-Suppression/ Rainfall-Enhancement Program

Atmospherics Incorporated of Fresno, California conducted a hail-suppression and rainfall-stimulation program through cloud seeding on behalf of Better Weather, Incorporated of Littlefield, Texas in 1976. An organization of farmers, ranchers, and businessmen sponsored this seeding of convective cloud systems for the suppression of hail in portions of seven counties on

the Texas High Plains. The 1976 program marked the fifth consecutive year for cloud-seeding activities in the vicinity of Littlefield.

The target area—that portion of the High Plains area where hail was intended to be suppressed—was composed of virtually all of Castro and Parmer Counties and portions of Lamb, Hale, Swisher, Hockley, and Bailey Counties. Aircraft were permitted to operate in a larger, operational area consisting of all of 11 High Plains counties to treat cloud systems expected, by the project meteorologist, to move into the target area.



- EXPLANATION**
- Operating area boundary
 - Target area boundary
 - ▲ Project radar site

Note: Operating area is the area in which weather modifiers can legally perform their operations. Target area is the only area to be affected by weather modification.

The operational period of the hail-suppression program extended from May 7 to October 31, 1976. Headquarters for the operations was based at the Lamb County airport near Littlefield. A highly sophisticated WR-100, 5-cm radar unit was utilized by the meteorologist both to identify and track potential hail-producing storms and to direct three cloud-seeding

aircraft to these storm systems. Silver iodide nuclei were released into the updraft regions of these clouds from wing-mounted pyrotechnic flares and generators. All cloud-seeding activities were reported monthly to the Texas Water Development Board and the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

**Project 76-1-1
Better Weather, Incorporated
1976 Operational Summary**

Period of Flight Operations: May 8-October 18, 1976

Month	Number of operational days	Observation flights		Seeding flights		Amount of silver iodide (grams)
		Number	Hours flown	Number	Hours flown	
May	9	3	1.6	21	39.9	14,570
June	17	5	4.1	41	85.6	28,662
July	14	8	6.4	33	72.4	18,784
Aug.	10	4	2.9	20	43.0	16,914
Sept.	8	8	6.6	6	11.9	3,218
Oct.	1	1	.6	0	0	0
Total	59	29	22.2	121	252.8	82,148

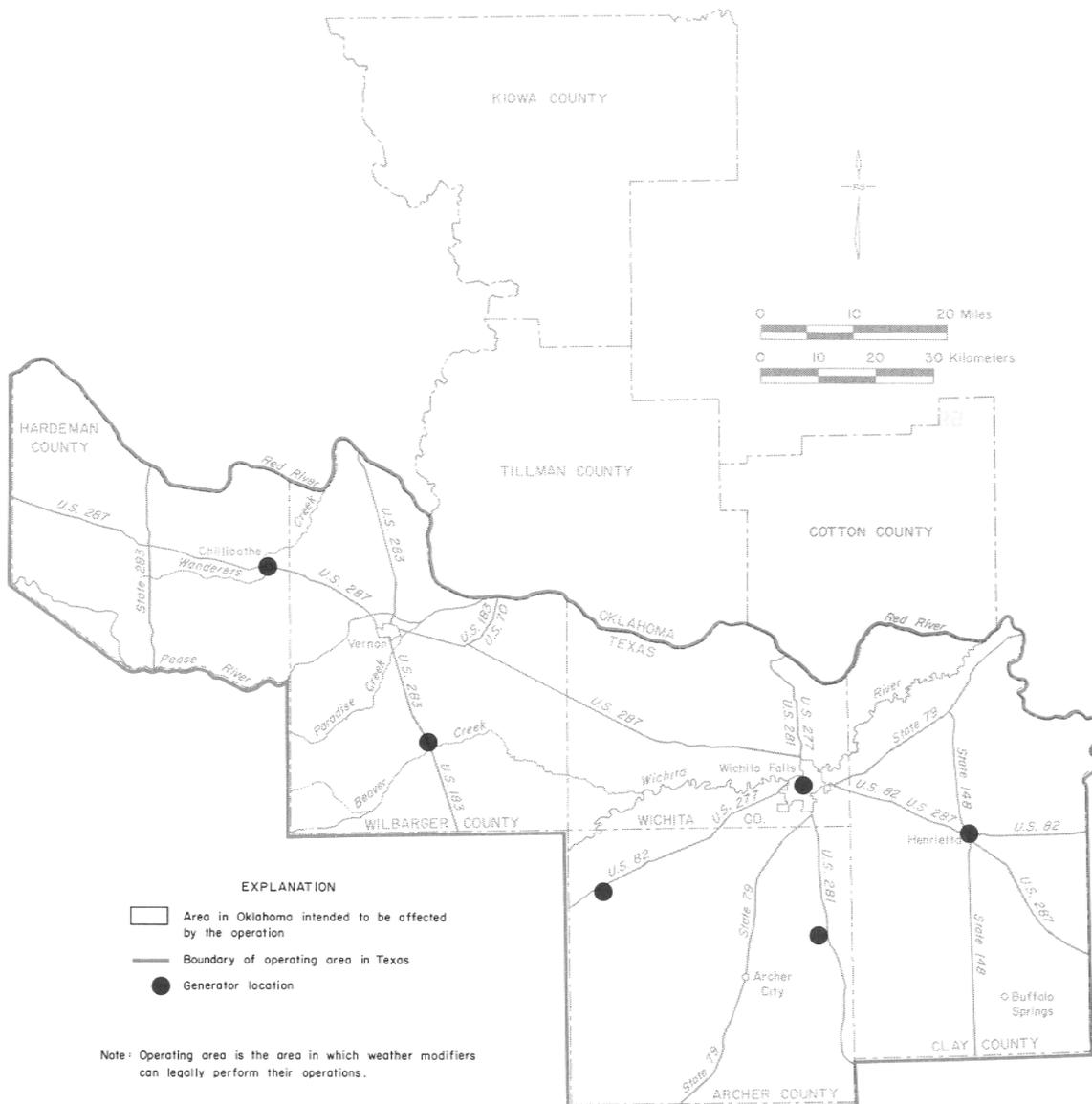
Project 76-2-3.—Oklahoma Rainfall-Stimulation Program (Red River Valley)

Irving P. Krick, Inc. of Texas conducted for the fifth year a rainfall-augmentation program in a five-county area of Texas along the Red River. The program was designed to increase rainfall in Cotton County of southwestern Oklahoma on behalf of Cotton County Services, Inc.

Six ground-based silver iodide generators located within Hardeman, Wilbarger, Wichita, Archer, and Clay Counties of Texas were used to release cloud-seeding

material into the atmosphere when the Krick project meteorologist deemed weather conditions to be suitable for seeding. These dispensers had an output ranging from 1/2 to 2 grams per hour.

While the generators were situated in Texas, the target area—the region of intended effects on the occurrence of rainfall—consisted of Cotton County in Oklahoma. No effect on rainfall occurrence in Texas was intended by the cloud-seeding operations. Neither on-site radar equipment nor aircraft were utilized in the program. Areas adjacent to the Oklahoma target area which may have been subject to the effects of the cloud seeding were also confined to the State of Oklahoma.



Project 76-2-3
Oklahoma Rainfall-Stimulation Program (Red River Valley)
1976 Operational Summary

Period of Operation: April 7-September 13, 1976

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Apr.	21	4	297.0	148.5
May	9	5	166.0	83.0
June	9	4	145.0	72.5
July	18	5	261.5	130.7
Aug.	22	5	211.5	105.8
Sept.	8	5	109.0	54.5
Total	87	28	1,190.0	595.0

**Project 76-2-4.—Oklahoma Rainfall-
Stimulation Program (Texas
Panhandle)**

A rainfall-augmentation program using ground-based generators located in the Panhandle region of Texas was conducted in 1976 for the fifth consecutive year by Irving P. Krick, Inc. of Texas. The purpose of the program was to increase rainfall in several counties in Oklahoma for the following sponsors: Henry C. Hitch Ranch, Inc., Beaver County Weather, Inc., Harper County Weather, Inc., Woodward County Cloud-Seeding Association, and Ellis County Weather, Inc.

The cloud-seeding method employed by the Krick firm involved the release of silver iodide nuclei into the atmosphere from ground level and in areas upwind of

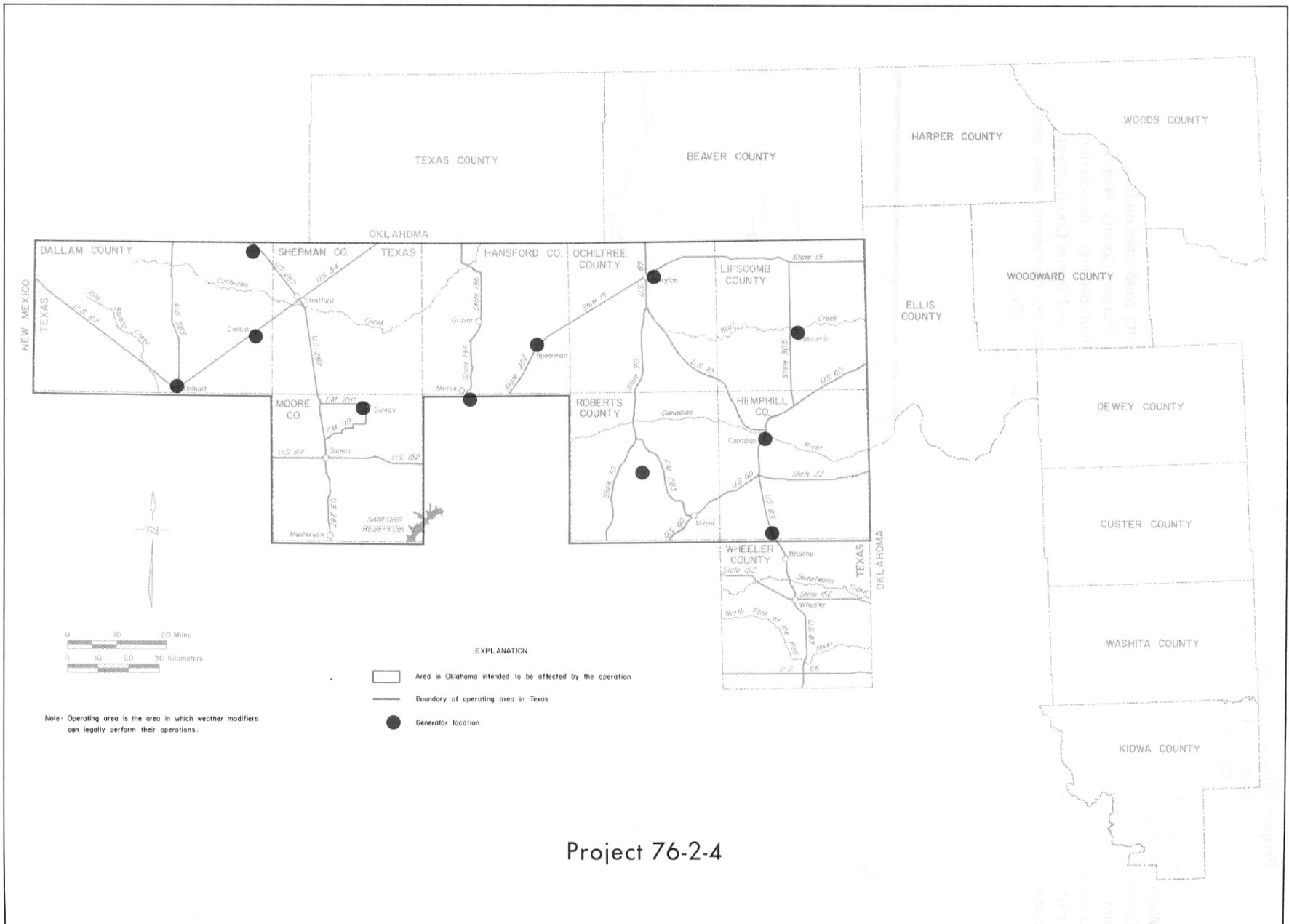
where effects on rainfall occurrence were intended. Eleven silver iodide dispensers were situated in the operational area in the Texas Panhandle region and were operated by local residents receiving guidance from a staff meteorologist of the Krick firm. Silver iodide was released from these electric arc dispensers at the rate of ½ to 2 grams per hour per dispenser. Operation of the dispensers was depended upon weather conditions prevailing in the region. No on-site radar equipment or aircraft were utilized.

The program was not designed to augment rainfall in any area of Texas. Rather, the only purpose was to affect the occurrence of rainfall in Beaver, Ellis, Harper, and Woodward Counties and a portion of Texas County, all in Oklahoma. Some areas within 15 to 20 miles of the target area may have been subject to effects of the operation, but these areas also were situated in Oklahoma.

**Project 76-2-4
Oklahoma Rainfall-Stimulation Program (Texas Panhandle)
1976 Operational Summary**

Period of Operation: February 13-November 14, 1976

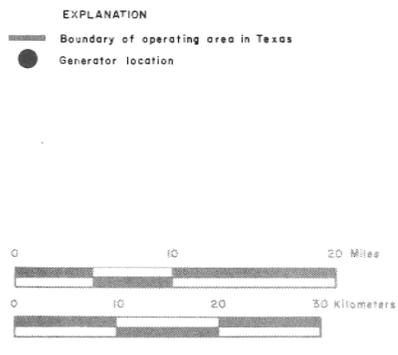
<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Feb.	2	2	25.0	12.5
Mar.	3	2	34.0	17.0
Apr.	20	9	572.00	319.45
May	14	7	361.00	200.00
June	16	7	283.00	140.51
July	13	7	230.50	133.25
Aug.	12	5	216.50	115.75
Sept.	14	7	472.75	249.38
Oct.	10	9	281.00	173.50
Nov.	2	1	22.0	11.0
Total	106	56	2,497.75	1,372.34



Project 76-2-5.—Oklahoma Rainfall- Stimulation Program (Wheeler County)

Irving P. Krick, Inc. of Texas obtained a Texas Water Development Board permit to conduct in Wheeler County, Texas a program of rainfall augmentation similar in design to that of Project 76-2-4. The sole purpose of the program was to affect the occurrence of rainfall in portions of Oklahoma; no effect on Texas weather was intended.

A silver iodide ground-based generator was located at Wheeler, Texas by the Krick firm to seed cloud systems for the purpose of increasing rainfall in the Oklahoma counties of Beaver, Ellis, Harper, Woodward, and a portion of Texas County. The program was intended to be a continuation of the 1975 program in Wheeler County conducted on behalf of: Henry C. Hitch Ranch Inc.; Harper County Weather Inc.; Woodward County Cloud-Seeding Association; Ellis County Weather, Inc.; and Beaver County Weather Inc. However, no cloud-seeding operations were performed during calendar year 1976.



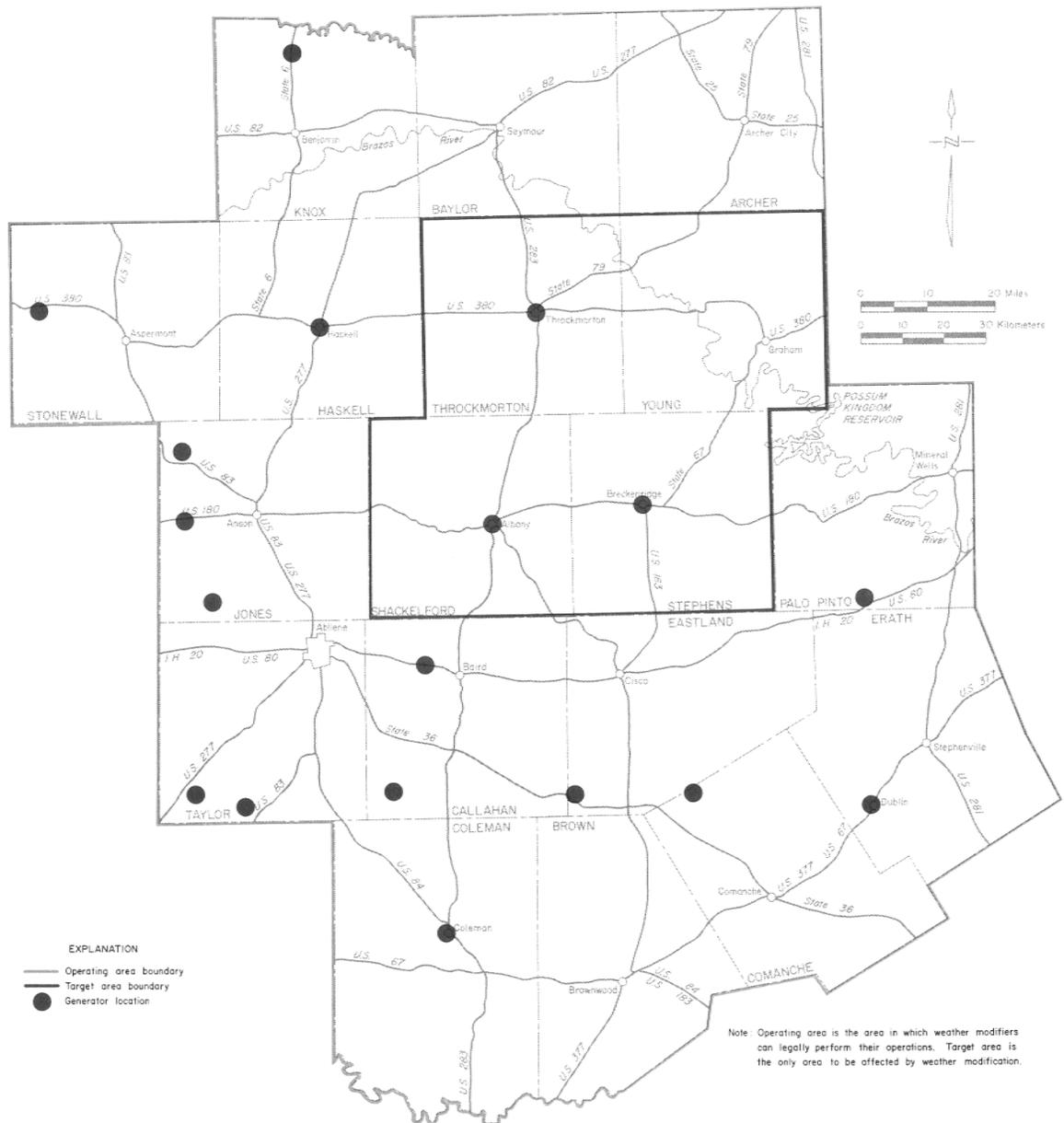
Note: Operating area is the area in which weather modifiers can legally perform their operations.



Project 76-2-6.—West-Central Texas Rainfall-Augmentation Program

In 1976, Irving P. Krick, Inc. of Texas conducted for the first time a rainfall-augmentation program in the west-central portion of Texas on behalf of Weather Modification, Inc. of Throckmorton, Texas. The program's objective was to increase rainfall in the four counties of Shackelford, Stephens, Throckmorton, and Young by operating 18 silver iodide generators in an 18-county area encompassing the target region.

Residents in the 18-county operational area operated these generators under the guidance of a Krick project meteorologist, who monitored weather conditions in the region and initiated cloud-seeding activities when these conditions were believed to be conducive to cloud seeding. The generators dispensed silver iodide at a rate ranging from 1/2 to 2 grams per hour per dispenser. No on-site radar equipment or aircraft were used in the seeding program. Cloud-seeding operations began on May 7 and continued through October 26, 1976.



Project 76-2-6
West-Central Texas Rainfall-Augmentation Program
1976 Operational Summary

Period of Operation: May 7-October 26, 1976

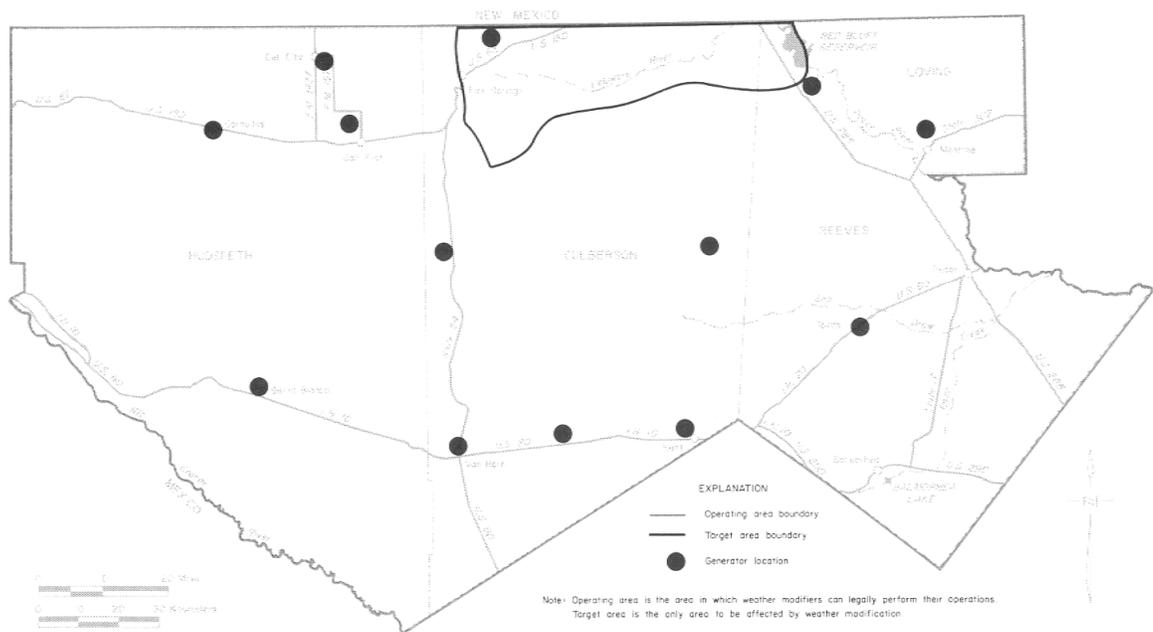
<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
May	15	15	583.0	676.7
June	17	17	741.2	847.6
July	19	17	851.5	915.8
Aug.	17	14	568.5	481.0
Sept.	18	15	797.5	770.0
Oct.	12	11	307.0	494.0
Total	98	89	3,848.7	4,185.1

Project 76-2-7.—Trans-Pecos Rainfall-Augmentation Program

A cloud-seeding program to augment rainfall in the Trans-Pecos region of Texas was initiated on September 20, 1976 and was continued for the duration of 1976 by Irving P. Krick, Inc. of Texas. The purpose of the program was to change or attempt to change through the use of silver iodide the natural development of cloud systems to increase rainfall on behalf of the Red Bluff Water Power Control District of Pecos, Texas. The target area—where increases in rainfall were intended—consisted of the watershed of Delaware

Creek in northern portions of Culberson and Reeves Counties.

Thirteen ground-based silver iodide generators located within Culberson, Hudspeth, Reeves, and Loving Counties were used to dispense the cloud-seeding material. These generators were operated by residents under the guidance of a Krick project meteorologist and each had an output in the range of ½ to 2 grams of silver iodide per hour. No on-site radar equipment or aircraft were used during the program. The generators were operated when atmospheric conditions were believed by the project meteorologist to be responsive to cloud seeding.



Project 76-2-7
 Trans-Pecos Rainfall-Augmentation Program
 1976 Operational Summary

Period of Operation: September 20-December 31, 1976

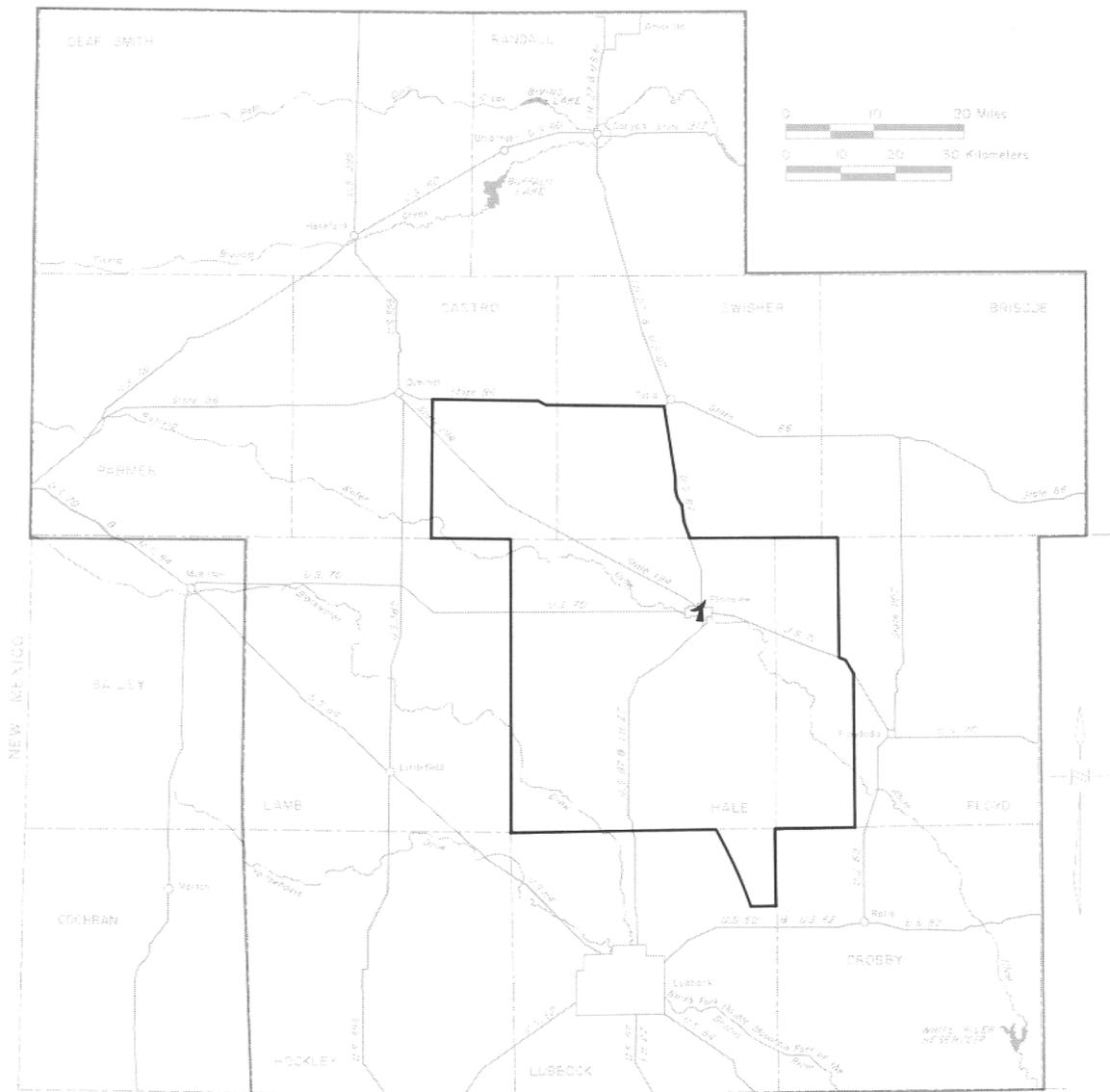
<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Sept.	7	8	195.0	390.0
Oct.	15	12	403.0	806.0
Nov.	4	9	208.0	416.0
Dec.	11	8	145.0	290.0
Total	<u>37</u>	<u>37</u>	<u>951.0</u>	<u>1,902.0</u>

Project 76-4-1.—Plains Weather Improvement Association, Inc., Hail-Suppression/Rainfall-Augmentation Program

Efforts to suppress the occurrence of hail continued for the seventh consecutive year in the vicinity of Plainview during 1976. The weather modification program was sponsored and conducted by Plains Weather Improvement Association, Inc. of Plainview, using its own personnel and equipment. Rainfall-augmentation was also an objective of the program.

The area in which hail was intended to be suppressed was confined to all of Hale County and portions of the adjacent counties of Castro, Swisher, Floyd, and Lubbock. The Association operated its aircraft over a much larger operational area, consisting of 12 High Plains counties, to seed clouds of hail-producing potential which were expected to move into the smaller, target area.

Attempts to suppress the occurrence of hail involved the airborne application of silver iodide into various storm systems believed by the project



- EXPLANATION
- Operating area boundary
 - Target area boundary
 - Project radar site

Note: Operating area is the area in which weather modifiers can legally perform their operations. Target area is the only area to be affected by weather modification.

meteorologist to possess the potential for producing hail. The dispensation of the seeding material was accomplished by burning wing-mounted pyrotechnic flares and by igniting liquid-fuel wing-tip generators.

The cloud-seeding program was operated under the guidance and supervision of a project meteorologist

headquartered at the Plainview Municipal Airport. A weather radar system was used by the meteorologist to identify and track storm systems and to direct the seeding aircraft to them to initiate seeding. The program began on May 7 and continued through November 30, 1976.

**Project 76-4-1
Plains Weather Improvement Association, Inc.
1976 Operational Summary**

Period of Flight Operations: May 20-October 19, 1976

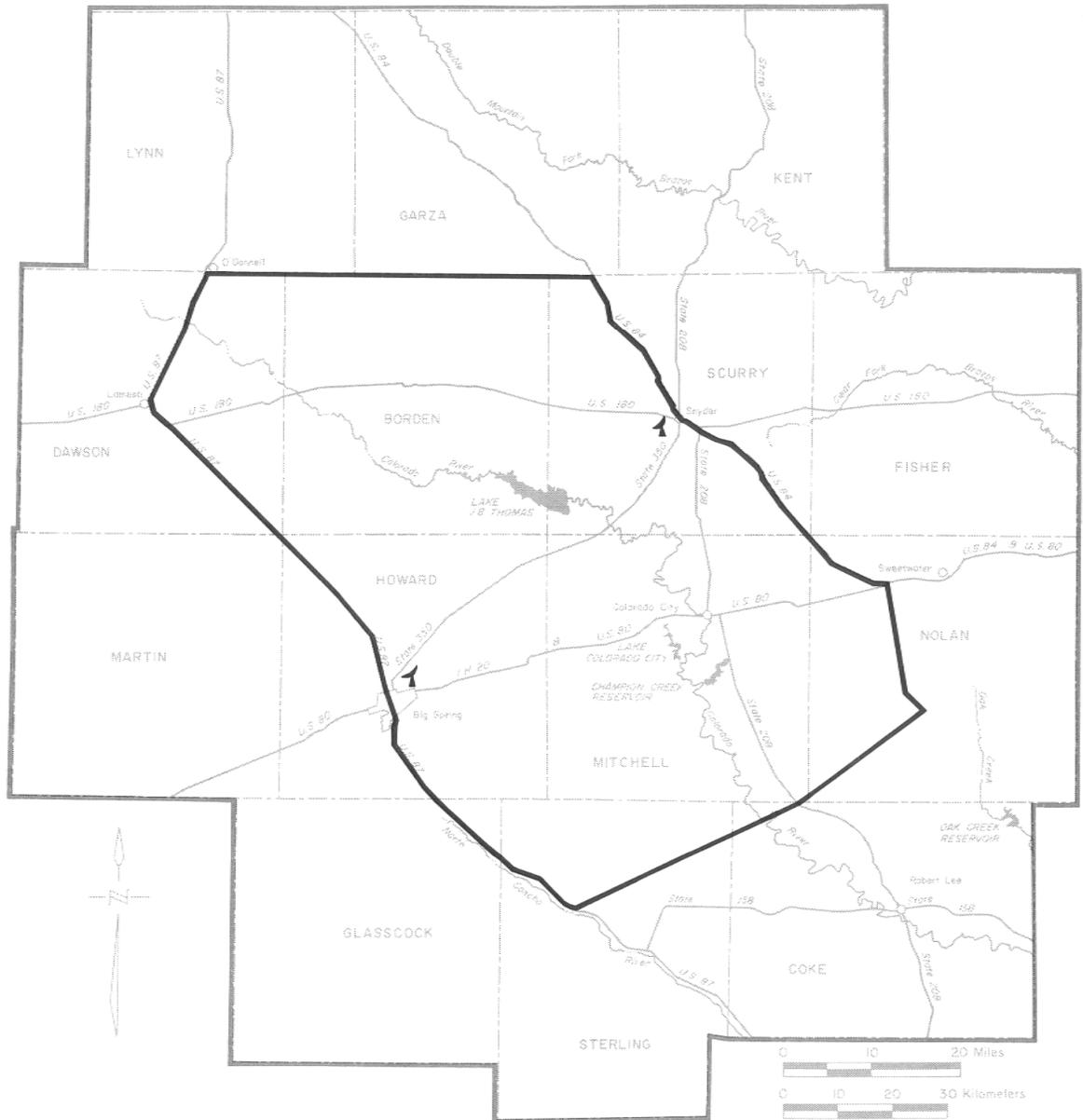
<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
May	8	9	6.9	18	32.9	17,420
June	18	16	11.0	29	44.5	11,480
July	8	8	4.0	18	28.1	7,640
Aug.	8	4	2.1	18	25.9	9,800
Sept.	7	4	3.4	6	7.5	1,640
Oct.	1	1	.5	0	0	0
Total	50	42	27.9	89	138.9	47,980

Project 76-5-1.—Colorado River Municipal Water District Rainfall-Enhancement Program

The 1976 weather modification program of the Colorado River Municipal Water District marked the sixth consecutive year for rainfall enhancement in the Big Spring area of Texas. Cloud seeding for the purpose of stimulating and augmenting rainfall was conducted over a 3,700-square-mile area consisting of agricultural and range lands which drain into the Colorado River. The purpose of the seeding activities was to increase

runoff into reservoirs on the Colorado River northwest of Robert Lee, Texas.

The target area—where increases in rainfall were intended—was made up of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties and included the watersheds of Lake J. B. Thomas and Lake E. V. Spence. The District's aircraft that was used for seeding clouds operated in a larger, operational area which consisted of 14 counties encompassing the target area.



Note: Operating area is the area in which weather modifiers can legally perform their operations.
Target area is the only area to be affected by weather modification.

EXPLANATION
 — Operating area boundary
 — Target area boundary
 ▲ Radar installation site

Seeding convective cloud systems within the operational area was accomplished through the use of an aircraft which dispensed ice nuclei (silver iodide) into the updraft regions of clouds which appeared to contain sufficient moisture for the production of precipitation. On seeding missions, pyrotechnic devices (flares) containing a mixture of silver iodide and combustible materials were ignited to generate a smoke which was then carried by updrafts into the cloud systems.

The District's project meteorologist operated an Atmos IV 3-cm radar system to monitor weather conditions in the area and to guide the District's cloud-seeding aircraft to the proper location beneath treatable cloud systems. In addition, the radar unit was used to gather information, on cloud characteristics and movement, vital for conducting an efficient cloud-seeding program.

A fully equipped Piper Aztec aircraft was used to dispense the cloud-seeding materials. The pilot of the

aircraft recorded data such as the temperature and heights of the bases of clouds being treated, as well as the magnitude and extent of updrafts in these clouds.

An RD-65 rawinsonde unit was used to track balloons carrying packages of weather instruments high into the atmosphere. Among the data provided by the rawinsondes were air temperature, humidity, atmospheric pressure, and wind speed and direction. These data were then analyzed with the aid of a computer to help the project meteorologist determine if a particular day might be an opportune one for seeding clouds.

Rainfall data were collected from a vast network of recording and fence-post raingages. These data were useful in providing the District with an effective measure of the effects of the cloud-seeding program on the occurrence of rainfall. The District's program began on March 1 and continued through October 15, 1976.

**Project 76-5-1
Colorado River Municipal Water District
1976 Operational Summary**

Period of Flight Operations: March 11-October 4, 1976

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
Mar.	2	1	0.8	1	1.5	80
Apr.	7	2	2.2	8	16.2	1,680
May	7	1	1.2	9	13.4	1,000
June	11	7	5.5	6	11.5	660
July	15	8	5.6	13	19.7	1,260
Aug.	7	3	2.6	7	9.9	1,020
Sept.	8	5	2.6	6	11.4	820
Oct.	1	1	.7	2	3.8	380
Total	58	28	21.2	52	87.4	6,900

Colorado River Municipal Water District Evaluation Program, 1976-77

One of the findings that resulted from Meteorology Research, Inc.'s 1975 evaluation of the rainfall-enhancement activities of the Colorado River Municipal Water District was that, unless cloud-seeding operations are carried out over a period of at least several years, results from any evaluative effort are likely to be inconclusive. Meteorology Research, Inc.'s evaluation of the District's 1973 and 1974 operations was of limited value because not enough data on individual cloud-seeding operations were available to permit an exhaustive and definitive study to be made of the effects of the operations.

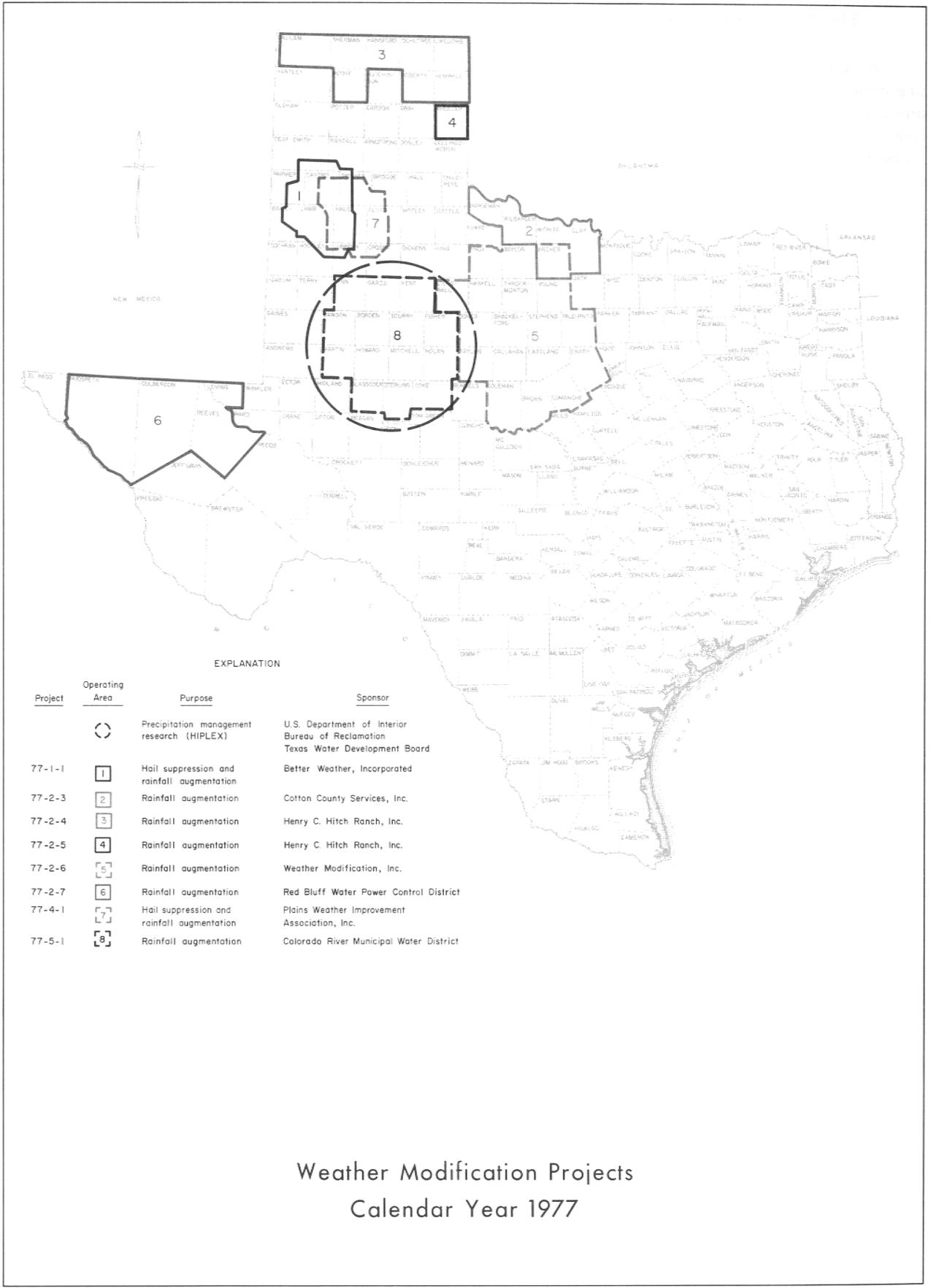
Consequently, under a new contract awarded by the Texas Water Development Board to Meteorology Research, Inc. in 1976, an attempt was made to extend the results of the previous evaluation by examining cloud-seeding events which occurred in the summer of 1975. This evaluation, which was completed in early 1977, provides a summary of the impact and effectiveness of cloud-seeding events conducted by the District for the period August 1973 to August 1975.

Like the evaluation of cloud-seeding data obtained for the summer periods of 1973 and 1974, the evaluation of 1975 data involved an analysis of heights of tops of cloud systems seeded and of the extent and intensity of rainfall occurrences. The evaluation centered on a number of individual "test" cases to provide meaningful statistical comparisons of the characteristics of seeded and unseeded clouds.

Analyses of the 1975 cloud-seeding data showed that "No appreciable difference was found . . ." when seeded cases were compared with non-seeding cases. However, it was emphasized that "The results of the present study should not be construed to mean that effects of seeding in the area do not exist," since "The techniques used in the evaluation are not sensitive to small variations and effects may have occurred in areas which were not examined."

A report, entitled "Radar Evaluation of Big Spring Weather Modification Program," was prepared in 1977 and contains results of the analyses of the 1973-75 data. A copy of it is available for review in the Texas Department of Water Resources library in Austin.

WEATHER MODIFICATION PROJECTS
CALENDAR YEAR 1977



EXPLANATION

Project	Operating Area	Purpose	Sponsor
		Precipitation management research (HIPLEX)	U.S. Department of Interior Bureau of Reclamation Texas Water Development Board
77-1-1		Hail suppression and rainfall augmentation	Better Weather, Incorporated
77-2-3		Rainfall augmentation	Colton County Services, Inc.
77-2-4		Rainfall augmentation	Henry C. Hitch Ranch, Inc.
77-2-5		Rainfall augmentation	Henry C. Hitch Ranch, Inc.
77-2-6		Rainfall augmentation	Weather Modification, Inc.
77-2-7		Rainfall augmentation	Red Bluff Water Power Control District
77-4-1		Hail suppression and rainfall augmentation	Plains Weather Improvement Association, Inc.
77-5-1		Rainfall augmentation	Colorado River Municipal Water District

**Weather Modification Projects
Calendar Year 1977**

made available for the program for State fiscal year 1978 (which began on September 1, 1977).

The State of Texas and the Bureau of Reclamation cooperated in the extensive research efforts during 1977, having entered into an agreement three years earlier to promote weather modification research activities in the Texas High Plains region. Under the terms of this agreement, the Texas Water Development Board, the State agency responsible for administering the Texas Weather Modification Act, awarded contracts to a number of institutions and organizations for services in support of the program. The following is a summary of the work performed in 1977 by the Department and each institution and organization participating in the Texas HIPLEX program.

Texas Water Development Board

To coordinate all program-related activities and to assure that those activities were in consonance with overall HIPLEX program objectives, the Texas Water Development Board provided an on-site Program Manager during the 1977 field program, which extended from June 1 through July 15. In addition, for the second year in a row, the Board maintained a meteorological facility at Howard County airport near Big Spring. A resident Board meteorologist routinely analyzed teletyped meteorological data and, from these analyses, prepared and issued weather forecasts in support of each day's field operations. Once the field program ended on July 15, the Board meteorologist continued to maintain the meteorological facility and provided forecasting services in support of the cloud-seeding program of the Colorado River Municipal Water District. Using a computer data terminal at the Board's meteorological facility, the resident meteorologist processed and analyzed data obtained from rawinsondes—also known as "weather balloons"—for use in preparing local and next-day forecasts. (On September 1, 1977, the Board's HIPLEX-related responsibilities were assumed by the Texas Department of Water Resources, and the resident meteorologist continued to perform the same duties under the new Department.)

Other tasks performed by the resident meteorologist during 1977 included the daily collection of surface weather observations at Big Spring, photographic data of the sky, and ice nuclei data from a millipore sampling unit at Howard County airport. The meteorologist also conducted studies to evaluate the forecasting technology used during the HIPLEX field program in an effort to refine and improve methods of predicting the occurrence of weather conditions believed to be conducive to cloud seeding.

At Board headquarters in Austin, the Board staff administered the various contracts between the Board and the institutions and organizations participating in the program and maintained liaison with those personnel conducting post-program studies at their respective institutions. Staff meteorologists and statisticians also developed a computer model for predicting the occurrence of thunderstorms in the Big Spring area. Other staff studies centered on the agro-economic aspects of weather modification, with a goal of determining how much economic value could be expected from a controlled increase in rainfall, and who would realize the benefit.

Colorado River Municipal Water District

The Colorado River Municipal Water District, which conducts a rainfall-enhancement program of its own in the Big Spring area, provided various types of technical support for the conduct of the 1977 HIPLEX field program. Under contract with the Board, the District maintained and monitored an extensive network of recording raingages for the collection of rainfall data. A district technician also operated an RD-65 rawinsonde unit for measuring and recording weather information at various levels of the atmosphere within the Texas HIPLEX region. In addition, the District also provided the services of a radar meteorologist for various aspects of the field program.

Meteorology Research, Inc.

By contract with the Board, Meteorology Research, Inc. maintained an M-33 radar system at Snyder, Texas during the 45-day field program of 1977. This sophisticated radar system routinely scanned the atmosphere within the Texas HIPLEX project area and measured parameters such as the time of occurrence of convective cloud systems and the heights of the tops of these cloud systems. The radar permitted Meteorology Research, Inc. scientists to quantitatively estimate the amount of precipitation falling in various parts of the project area. Various kinds of data were recorded digitally on magnetic tape for later analysis.

In addition to manning an elaborate radar system on-site, Meteorology Research, Inc. processed data obtained through a network of mechanical weather stations spread over the project area and by an aircraft which flew on numerous occasions at cloud-base level within the project area. Too, data obtained during 1976 by the M-33 radar unit at Snyder were processed and analyzed by computer.

Texas A&M University

The Center for Applied Geosciences and the Department of Meteorology at Texas A&M University contributed to the performance of the field and analytical phases of the Texas HIPLEX program by conducting a mesoscale measurement project in the Big Spring area during the June 1-July 15 period. A network of rawinsonde stations similar to that operated by the Colorado River Municipal Water District was manned by the University personnel to collect data at various levels of the atmosphere.

A team of Texas A&M University researchers conducted an extensive analysis of mesoscale data collected during the 1976 HIPLEX field program prior to the beginning of the 1977 field program. Processing and analyzing of data obtained during 1977 was begun when the 1977 field program ended. An attempt was made to determine from these data what conditions are associated with, and are responsible for, the development, growth, size, duration, intensity, and movement of convective clouds in the Texas HIPLEX region.

Other work accomplished at Texas A&M University during 1977 included the development of a radar-echo history as related to the climatology of the Texas HIPLEX area. Separate radar-echo time histories were constructed for seeded and unseeded areas of the Southern High Plains region of Texas during the years 1973-1976. These histories furnished information on the size, time of occurrence, length of time cycle, and speed and direction of movement of clouds detected by conventional radar in the area. Work was begun in the latter part of 1977 on associating the various features of these echoes to different weather conditions such as cool fronts and squall lines.

Texas Tech University

At the Department of Geosciences at Texas Tech University, work begun in 1976 continued

during 1977 as visible and infrared radiance data from the Geostationary Operational Environmental Satellite (GOES) were processed and analyzed. Studies were made to determine the number of clouds, the percent of cloud cover, and the direction and speed of cloud movement which occurred in the Texas HIPLEX project area during the summers of 1975 and 1976. In addition, a study of visual-wavelength, satellite photography for the summer of 1976 was made and results were compared to those derived from the studies of the radiance data. The University scientists hope to use these data to learn more about the behavior of seeded and unseeded cloud systems as they interact with each other and with the environment.

Another study by Texas Tech University meteorologists consisted of the determination of spatial variations in the occurrence of precipitation within the Texas HIPLEX region. Rainfall data were analyzed to describe "natural" precipitation variability which is characteristic of the region. Results from these and other analyses have provided information which will be useful in the development of prediction models and in the design of criteria for evaluating seeding programs.

Big Spring Aircraft, Inc.

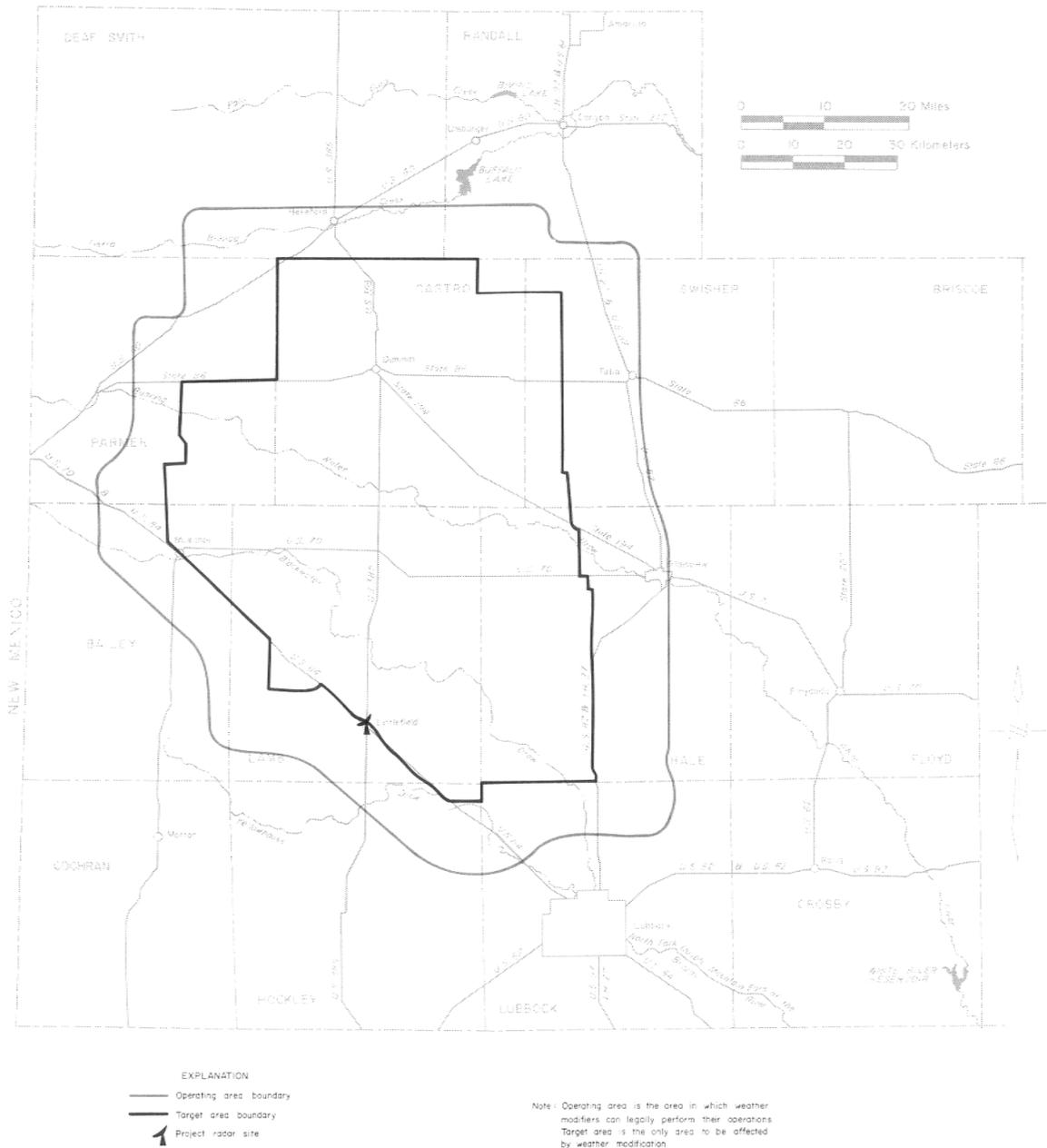
A fully equipped Cherokee aircraft was provided during the 1977 field program by Big Spring Aircraft, Inc. for collecting meteorological data at cloud-base level on operational days. The aircraft functioned as a cloud-survey airborne platform and allowed a Meteorology Research, Inc. technician to gather such information as dry and wet-bulb temperatures at cloud base and profiles of updraft regions of a large sample of clouds. Six cloud-sampling missions, the duration of which totalled 21.5 hours, were flown during the 1977 field program.

Project 77-1-1.—Better Weather, Incorporated, Hail-Suppression/Rainfall-Augmentation Program

Another effort to alleviate severe hail damage and enhance rainfall through the application of weather modification technology was made in the Littlefield area of the High Plains during the summer of 1977. Better Weather, Incorporated (BWI), an organization of farmers in and around Lamb and Castro Counties, was the sponsor of the program and contracted with Atmospherics Incorporated (AI) of Fresno, California for the cloud-seeding services. The

conclusion of the 1977 AI weather modification program marked the eighth consecutive operational season during which AI has provided these cloud-seeding services to BWI.

In 1977, the total area of primary concern—the target area—occupied approximately 1,400 square miles, including nearly all of Castro County, much of Lamb and Hale Counties, and part of Swisher, Parmer, Bailey, Hockley, and Lubbock Counties. AI obtained a permit on June 2 from the Texas Water Development Board, one of three predecessor agencies to the Texas Department of Water Resources, to



operate its aircraft over the target area and an 8-mile wide band surrounding the target area. This operational area on the perimeter of the target area enabled AI to treat cloud systems within the operational area in an effort to produce maximum results from clouds observed to be moving toward the target area.

AI's operational field headquarters were located at the Littlefield Municipal Airport near Littlefield, Texas. Professional personnel operated a weather radar system and three aircraft based at the field headquarters. AI began its cloud-seeding activities on June 2, the day the Board permit was granted.

With the passage of legislation by the 75th Texas Legislature permitting elections to be held in areas affected by hail-suppression operations, residents of the target and operational areas went to the polls in July and August and cast ballots which reflected their opinions relative to the desirability of the hail-suppression and rainfall-enhancement operations of AI and a neighboring program based at Plainview. The outcome of these elections led the Texas Department of Water Resources to issue an order terminating the programs on September 7. Consequently, AI's last cloud-seeding mission of 1977 occurred on September 5.

In response to claims of residents living outside of the AI operational area that AI aircraft were conducting illegal cloud-seeding missions, a Texas Water Development Board meteorologist began monitoring the AI operations from Littlefield on June 11. The Board monitor tracked and documented the positions of the AI aircraft during each cloud-seeding mission and collected

data on the location, size, movement, and intensity of cloud systems in the area. By contract with the Texas Agricultural Experiment Station (TAES), the Department shifted the monitoring duties to the TAES on September 1, and a TAES meteorologist continued monitoring the AI operations until they were terminated on September 7.

The primary radar equipment used in the AI program was a WR 100 5-cm weather radar system having a maximum range of 250 miles. This system permitted the project meteorologist to observe and document the presence of storm systems in the area and, with the aid of an interrogator/transponder system, to track the position of the AI aircraft with appropriate presentation on the 5-cm radar display system. The interrogator/transponder unit allowed the AI meteorologist to provide all of the seeding aircraft with information on storm position and intensity and contributed safer seeding missions during nighttime operations.

Three turbocharged Piper Twin Comanches, with a cruise speed of at least 120 knots and a service ceiling of 30,000 feet (mean sea level), were used to carry out the seeding operations. These aircraft were equipped with wing-tip liquid-fuel generators and special holding racks for pyrotechnic seeding devices (flares). When clouds were seeded, the AI pilots produced silver iodide freezing nuclei by igniting the pyrotechnic devices and/or burning the liquid fuel from the wing-tip generators. In this way proper seeding rates were closely adjusted to changes in the individual storm characteristics.

**Project 77-1-1
Better Weather, Incorporated
1977 Operational Summary**

Period of Flight Operations: June 2-September 5, 1977

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
June	17	10	10.1	34	76.5	27,112
July	10	5	5.8	15	29.5	12,054
Aug.	14	8	5.3	17	31.5	10,078
Sept.	2	2	2.8	2	2.1	406
Total	43	25	24.0	68	139.6	49,650

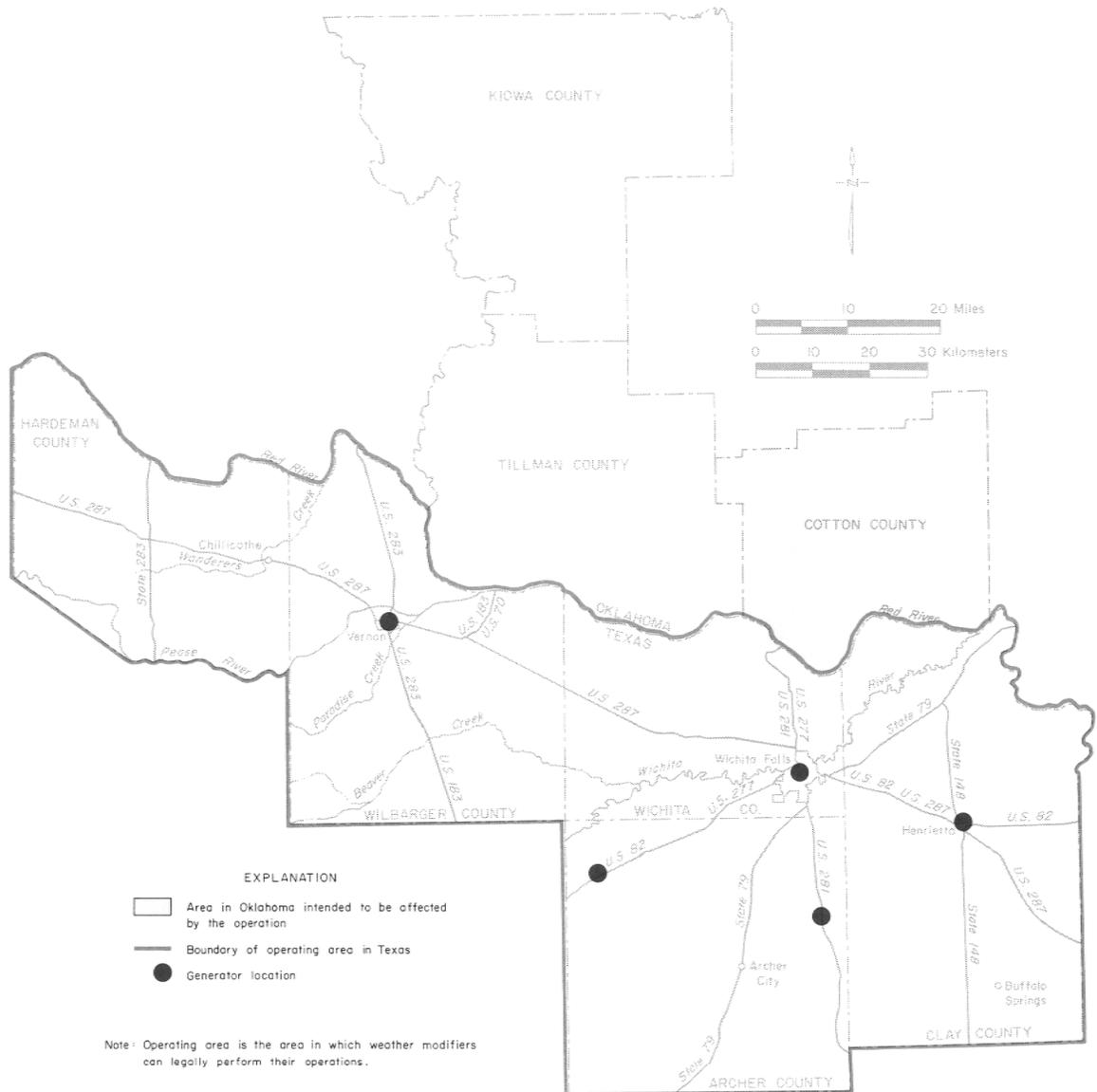
Project 77-2-3.—Oklahoma Rainfall-Stimulation Program (Red River Valley)

For the sixth consecutive year, cloud seeding with the use of ground-based generators was carried out in a five-county area of Texas along the Red River to increase precipitation in southwestern Oklahoma. The weather modification program was conducted by Irving P. Krick, Inc. of Texas on behalf of Cotton County Services, Inc. of Oklahoma.

Five electric-arc generators located in Archer, Clay, Hardeman, Wichita, and Wilbarger Counties of Texas were used to dispense silver iodide into the atmosphere. The target area, where effects of the cloud

seeding were intended, consisted of Cotton County, Oklahoma. Whereas some downwind effect of the seeding may have occurred in Oklahoma, no effect on the weather in Texas was intended by the operation of the ground-based dispensers.

The generators were operated continuously during favorable weather conditions. As with the other Krick weather modification programs in Texas, Krick staff meteorologists routinely studied various teletype weather data and other information to ascertain whether any storms, frontal systems, or squall lines would be affecting the target area. Once they determined that cloud-seeding operations would be conducted, and prior to the development of the "seedable" clouds in the target area, a decision was then made as to which of the ground-based generators were to be operated. Contacts



with operators of the generators were maintained throughout the period, and instructions were given as to when the generators were to be operated.

No on-site radar equipment or aircraft were used by the Krick firm during the cloud-seeding operations.

**Project 77-2-3
Oklahoma Rainfall-Stimulation Program (Red River Valley)
1977 Operational Summary**

Period of Operation: March 17-September 13, 1977

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Mar.	4	4	75.5	88.7
Apr.	16	5	406.2	436.7
May	14	5	296.0	308.5
June	10	5	209.5	259.2
July	13	4	198.2	293.3
Aug.	10	5	157.0	197.0
Sept.	5	2	50.5	71.0
Total	72	30	1,392.9	1,654.4

**Project 77-2-4.—Oklahoma Rainfall-
Stimulation Program (Texas
Panhandle)**

Cloud-seeding activities were conducted by Irving P. Krick, Inc. of Texas in an eight-county area of the Panhandle region of Texas for increasing rainfall in the western portion of Oklahoma. The weather modification program was conducted for and sponsored by Henry C. Hitch, Inc., of Guymon, Oklahoma.

Eight ground-based generators located in the Texas counties of Dallam, Hansford, Moore, Ochiltree, and Sherman were used to dispense silver iodide into cloud systems which were expected by the project meteorologists to affect the western portion of Oklahoma. These generators consisted of an electric arc,

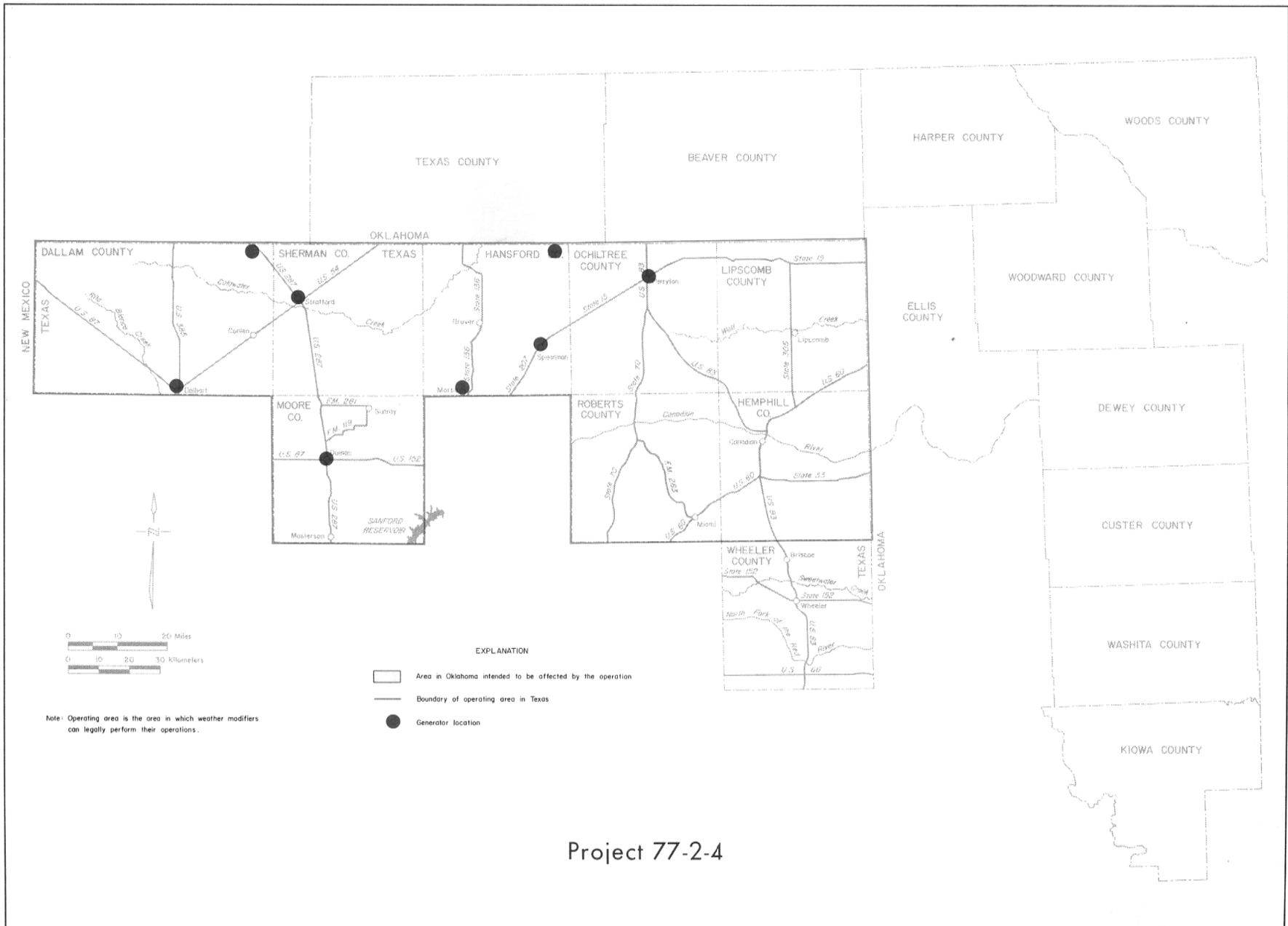
two rods of pure silver iodide, a small electric blower, and a control box. Heat from the arc vaporized the silver iodide, and silver iodide crystals were formed as the vapor cooled. The blower expelled the crystals from inside the generator to the atmosphere, where the chemical was carried aloft by air currents. The theory upon which the cloud-seeding activities were carried out suggests that, under proper conditions, the silver iodide crystals are carried up into storm clouds, where they collect moisture which otherwise could not be obtained from the clouds. The generators were operated by personnel of the Krick firm under the supervision and guidance of a Krick project meteorologist.

The cloud-seeding operations were not intended to produce effects on the weather over Texas. No on-site aircraft or radar equipment were used in the operations.

**Project 77-2-4
Oklahoma Rainfall-Stimulation Program (Texas Panhandle)
1977 Operational Summary**

Period of Operation: March 23-October 31, 1977

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Mar.	8	6	121.5	118.5
Apr.	16	7	337.5	330.0
May	21	6	382.7	383.7
June	19	8	255.7	185.6
July	20	7	207.0	165.0
Aug.	22	8	285.7	202.8
Sept.	11	6	136.0	138.5
Oct.	7	4	96.7	82.9
Total	124	52	1,822.8	1,607.0

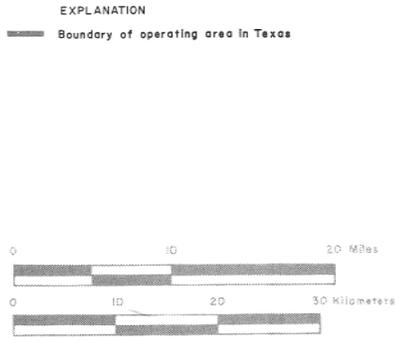


Project 77-2-4

**Project 77-2-5.—Oklahoma Rainfall-Stimulation Program
(Wheeler County)**

Although the weather modification firm of Irving P. Krick, Inc. of Texas possessed a Texas weather modification permit to operate cloud-seeding equipment in Wheeler County, Texas during 1977, no weather

modification activities were conducted there during the year. In previous years the Krick firm had operated a silver iodide, ground-based dispenser at Wheeler, Texas to seed cloud systems for the purpose of augmenting rainfall in a large area of western Oklahoma. However, the generator was removed from Wheeler County prior to the beginning of the 1977 cloud-seeding season, and no operations occurred within Wheeler County during the year.



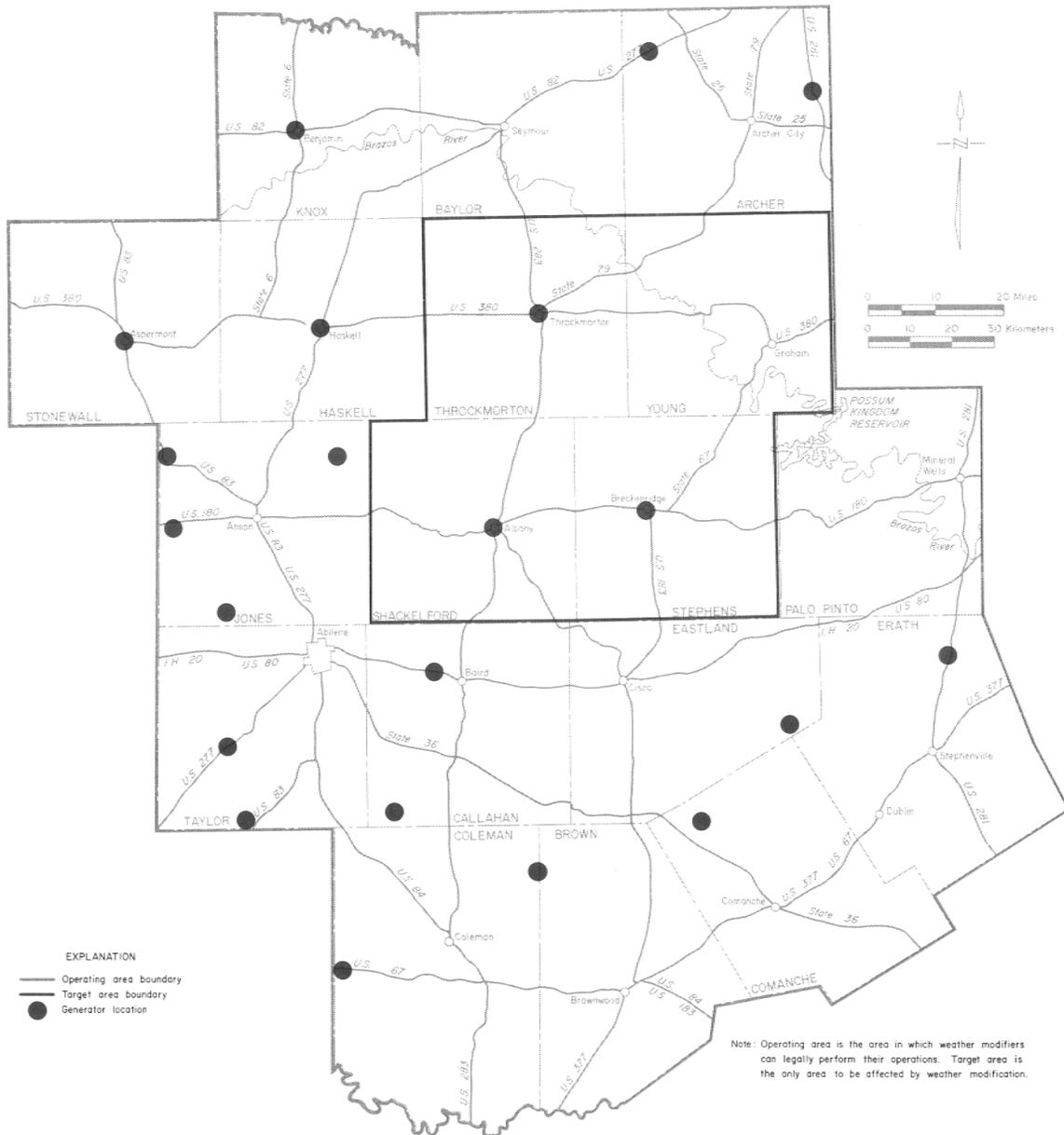
Note: Operating area is the area in which weather modifiers can legally perform their operations.



Project 77-2-6.—West-Central Texas Weather Modification Program

As in 1976, a program of cloud seeding for precipitation enhancement was conducted in 1977 in the west-central portion of Texas by Irving P. Krick, Inc. of Texas. The weather modification operations were intended to increase natural precipitation to provide additional water for and on behalf of Weather Modification, Inc. of Throckmorton, Texas. The region in which the effects of the cloud-seeding activities were intended consisted of Throckmorton, Shackelford, Young, and Stephens Counties of Texas.

To accomplish the seeding of clouds believed by the project meteorologist to have the potential of producing more precipitation, a network of dispensers strategically located over an 18-county area, including the four-county target region, was used to dispense silver iodide into the atmosphere at a rate ranging from ½ to 2 grams per hour per dispenser. This network consisted of 21 ground-based, electric-arc generators and was operated continuously during favorable weather situations. The generators were put into operation prior to the development of the cloud systems as well as during the passage of these systems over the project area. A project meteorologist continually monitored weather



conditions in the area from hourly weather teletype data and from conversations with operators of the generators. The Krick firm retained the option to suspend

operations when potentially hazardous conditions developed within the area. No on-site radar equipment or aircraft were used in the seeding program.

**Project 77-2-6
West-Central Texas Weather Modification Program
1977 Operational Summary**

Period of Operation: April 3-November 30, 1977

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Apr.	12	14	595.0	872.0
May	16	16	412.5	628.8
June	11	12	464.9	673.3
July	12	14	517.7	609.5
Aug.	22	19	804.0	756.0
Sept.	13	16	416.0	479.5
Oct.	14	17	709.3	892.4
Nov.	5	11	229.0	293.0
Total	105	119	4,148.4	5,204.5

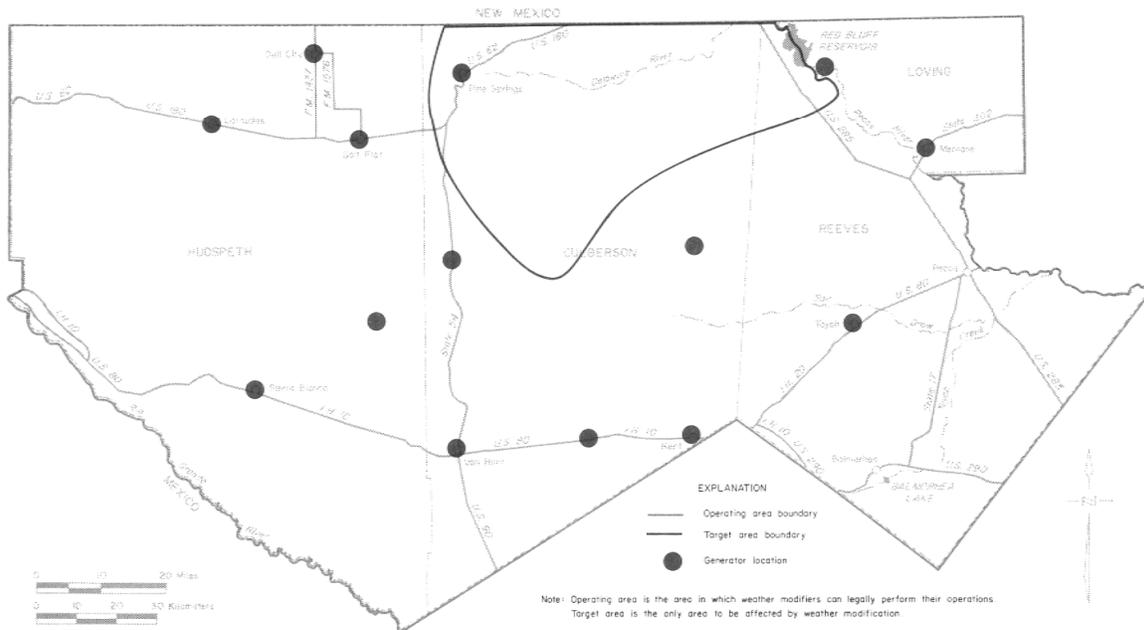
Project 77-2-7.—Trans-Pecos Rainfall-Augmentation Program

The seeding of clouds in a four-county area of Texas west of the Pecos River was performed by Irving P. Krick, Inc. of Texas during 1977. The weather modification program, in its second year of existence, was designed to increase precipitation on behalf of the Red Bluff Water Power Control District of Pecos, Texas. Cloud seeding was initiated on January 1 and was limited to the counties of Hudspeth, Culberson, Reeves, and Loving in Texas.

A network of 14 ground-based generators was used to dispense silver iodide crystals—believed to be one of the most effective agents for enhancing natural rainfall in suitable cloud systems—into the atmosphere. The theory upon which the program was based states that,

when the seeding material reaches the cloud level where temperatures are only a few degrees colder than freezing, ice crystals begin to grow immediately on these artificial ice nuclei. The crystals grow at the expense of neighboring water droplets and become large enough to fall through the rising motions in the clouds.

Meteorologists of the Krick firm determined from available weather information the conditions in the atmosphere which appeared to be the most promising for cloud seeding. The project meteorologist directed operators of the generators scattered throughout the four-county operational area to activate the seeding devices whenever conditions warranted their operation. This occurred after the meteorologists determined which of the generators were to be operated. No on-site radar equipment or aircraft were used in the program.



Project 77-2-7
 Trans-Pecos Rainfall-Augmentation Program
 1977 Operational Summary

Period of Operation: January 1-December 30, 1977

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Jan.	13	11	352.0	704.0
Feb.	7	6	104.0	208.0
Mar.	7	7	104.0	208.0
Apr.	15	11	348.8	697.5
May	15	11	290.0	580.0
June	23	10	380.3	760.5
July	23	8	440.2	846.0
Aug.	28	11	489.0	978.0
Sept.	16	6	193.5	387.0
Oct.	16	10	319.0	638.0
Nov.	5	7	74.0	148.0
Dec.	8	4	186.5	373.0
Total	<u>176</u>	<u>102</u>	<u>3,281.3</u>	<u>6,528.0</u>

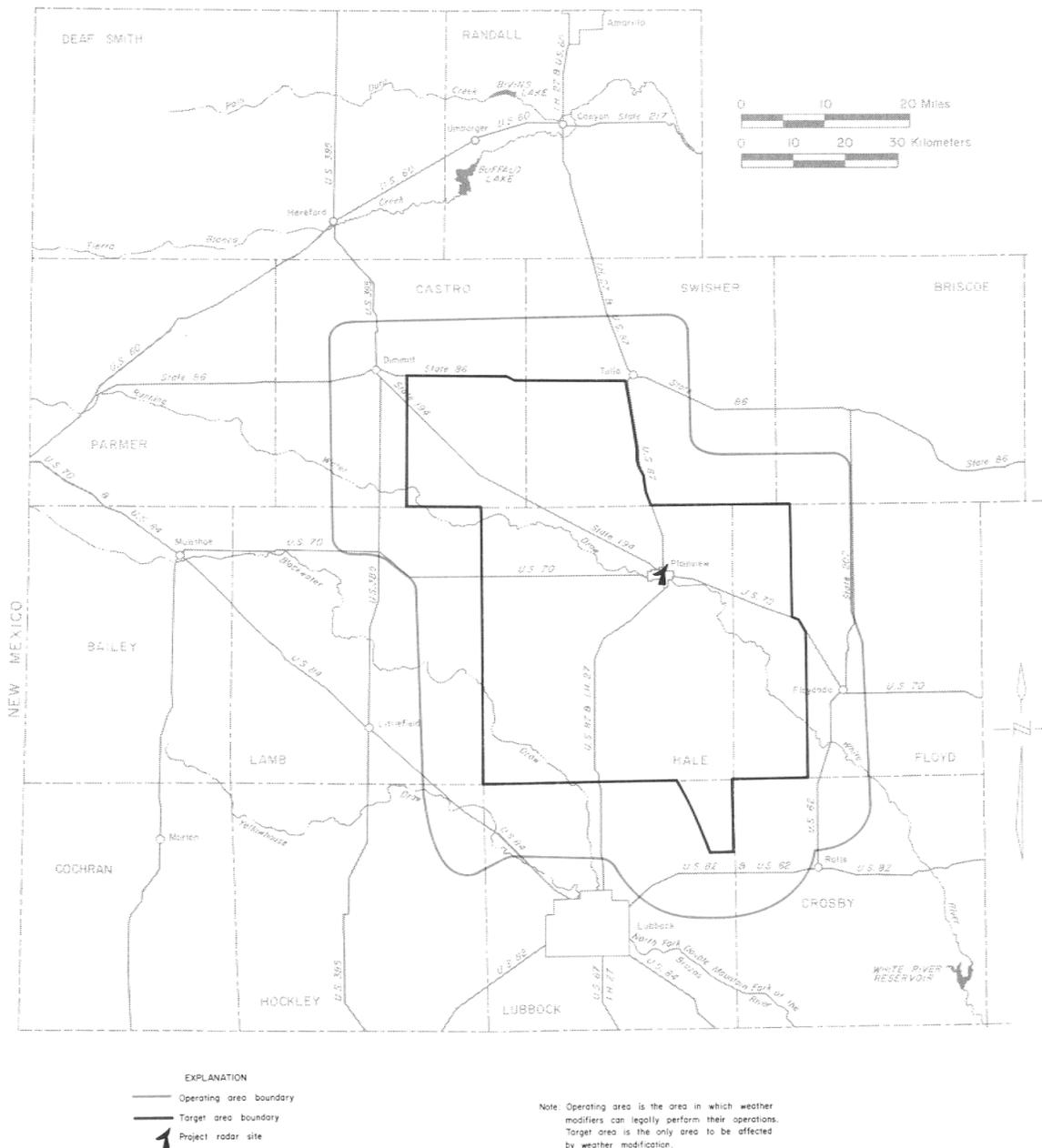
Project 77-4-1.—Plains Weather Improvement Association, Inc., Hail-Suppression/Rainfall-Augmentation Program

Cloud seeding to suppress hail and increase rainfall occurred on the High Plains of Texas in the area of Plainview during a three-month period during 1977. The weather modification program was sponsored and conducted by Plains Weather Improvement Association, Inc. (PWIA), a non-profit organization comprised of farmers, ranchers, businessmen, and residents living within 35 miles of Plainview. The 1977 program marked

the seventh consecutive year in which hail-suppression activities have been performed in the Plainview area.

The area in which the effects of the cloud-seeding operations were intended—the target area—consisted of all of Hale County and portions of Castro, Swisher, Floyd, and Lubbock Counties. The aircraft which were used to dispense the seeding agent were permitted to operate over the target area and a 7-mile-wide operational area surrounding the target area.

PWIA's cloud-seeding activities began on June 2, when the Texas Water Development Board, one of the



Department's three predecessor agencies, granted the firm a permit to conduct its weather modification program. As a result of legislation passed by the 65th Texas Legislature, elections were held in parts of counties included in either the target or operational areas of the PWIA program and those of a neighboring program. These elections were held to allow citizens affected by the program to express their opinions relative to the desirability of the hail-suppression and rainfall-enhancement operations of PWIA and those of the neighboring program. As a result of the elections, the Department acted on September 7 to terminate the programs. Consequently, PWIA's last cloud-seeding mission was conducted on September 4.

Three turbocharged Piper Twin Comanche aircraft owned and operated by PWIA were used to seed convective cloud systems which were judged by the project meteorologist to have the potential of producing hail or additional rainfall. Pyrotechnic devices (flares) and generators mounted on the wings of the aircraft were employed to dispense silver iodide, the chemical agent used throughout the seeding program. Various sizes of flares were used, depending upon whether the objective was to suppress hail or increase rainfall.

The project meteorologist used a Decca 3-cm radar to track storm systems as they moved into, over, and out of the target area. Radar contact with the pilots was maintained during each seeding mission, and instructions were given by the meteorologist as to when and where the silver iodide was to be released.

**Project 77-4-1
Plains Weather Improvement Association, Inc.
1977 Operational Summary**

Period of Flight Operations: June 2-September 4, 1977

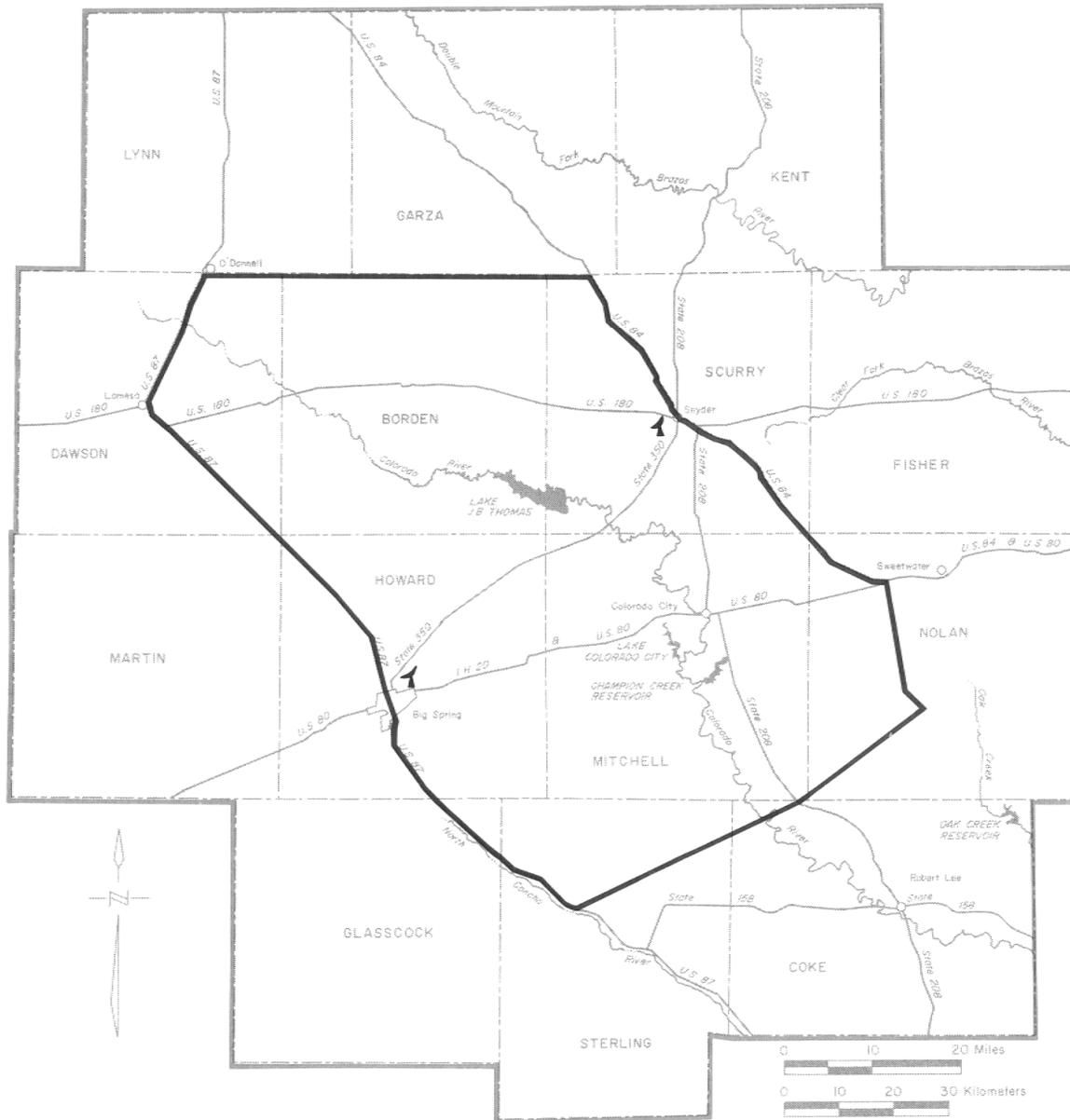
<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
June	12	11	12.3	14	28.2	5,784
July	7	6	5.0	6	9.6	524
Aug.	8	4	3.2	11	39.4	5,204
Sept.	1	0	0	3	5.5	1,621
Total	28	21	20.5	34	82.7	13,133

Project 77-5-1.—Colorado River Municipal Water District Precipitation-Enhancement Program

A program of seeding convective cloud systems to increase surface-water runoff over the Colorado River drainage basin northwest of Robert Lee, Texas was continued in 1977 by the Colorado River Municipal Water District for the seventh consecutive year. As in previous years, the cloud-seeding program was financed and conducted by the District. The District's project area consisted of a 14-county region of the Permian Basin, with emphasis on enhancing rainfall in a

3,700-square-mile area including the Lake J. B. Thomas and Lake E. V. Spence watersheds. Cloud-seeding activities were conducted in the spring and summer of 1977.

A fully equipped and instrumented Piper Aztec aircraft was used to dispense artificial ice nuclei—silver iodide—into the updraft regions of those clouds over the District's project area which, in the judgment of the project meteorologist, appeared to contain sufficient moisture for the production of precipitation. Burning pyrotechnic devices (flares) mounted on the wings of the aircraft generated the ice nuclei as a smoke as the



aircraft flew below the bases of the clouds being treated. Cloud seeding on a typical operational day began with the first suitable opportunity and continued at the discretion of the meteorologist. The meteorologist consulted rawinsonde data obtained from the RD-65 rawinsonde unit operated by a District technician, numerical cloud models provided by computer, and other data by way of teletype circuitry from the National Weather Service.

An Atmos IV radar unit was used by the project meteorologist to track storm systems moving across the District's project area. The meteorologist used the 3-cm detection system to observe and document the size, position, and movement of storm cells in the region. Two-way radar enabled the meteorologist to communicate with the aircraft pilot.

Data such as the temperature and height of bases of treated clouds, the magnitudes of updraft regions within the clouds, and the horizontal extent of these regions were logged on each mission by the aircraft pilot.

An extensive network of 81 fence-post non-recording raingages was maintained and monitored by the District for the duration of the program. Data collected from these gages were used by District personnel to evaluate the effects of the cloud-seeding activities.

Instrument packages attached to balloons—rawinsondes—were launched routinely during the District's 1977 program. These measuring devices were carried aloft high into the atmosphere and transmitted back to the District's base station at Howard County airport valuable data, such as the temperature and moisture content of various layers of the earth's atmosphere. Tracking the rawinsondes with radar also enabled project personnel to determine wind speed and direction at various altitudes. All of these data were entered into a computer, processed, and analyzed, and the end product was used by on-site meteorologists to make forecasts of the likelihood of occurrence of weather situations believed to be conducive to cloud seeding.

**Project 77-5-1
Colorado River Municipal Water District
1977 Operational Summary**

Period of Flight Operations: April 14-September 17, 1977

<u>Month</u>	<u>Number of operational days</u>	<u>Observation flights</u>		<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	<u>Number</u>	<u>Hours flown</u>	
Apr.	6	2	1.1	9	8.3	1,520
May	11	4	2.6	10	13.5	2,840
June	9	4	2.5	10	10.2	2,920
July	14	3	2.2	4	5.3	1,200
Aug.	8	3	1.8	9	4.2	1,540
Sept.	0	1	.7	0	0	0
Total	48	17	10.9	42	41.5	10,020



A thunderstorm on the High Plains region of Texas. This type of convective cloud system was studied in the High Plains Cooperative Program (HIPLEX) to determine whether cloud seeding is an effective method of enhancing the occurrence of rainfall on the Texas High Plains.

