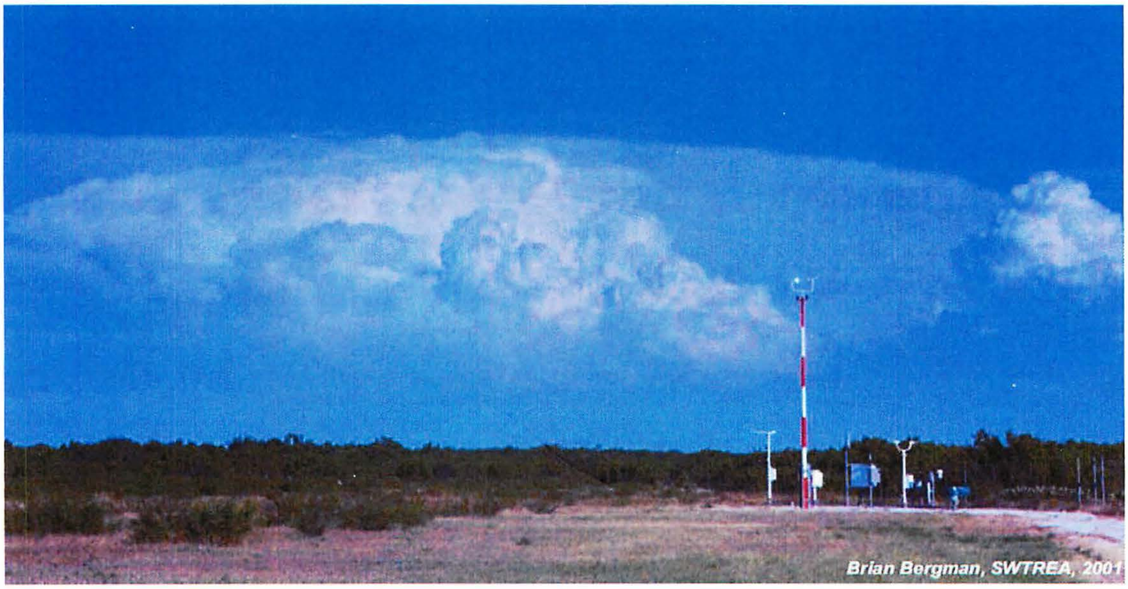
SOUTHWEST TEXAS RAIN ENHANCMENT ASSOCIATON
2003 EAA FINAL REPORT

PREPARED BY:

DAVID A. COUSINS
WITH HELP FROM:
JASON M. STRAUB
WALTER E. GEIGER, III

2003 PROJECT STAFF

Ed Walker
Project Manager, PIC
Jason M. Straub
Project Meteorologist (March 15 – May 11)
Andrew Clausen
Project Meteorologist (May 11 – September 1)
David A Cousins
Project Meteorologist (September 5 – November 15)
Debbie Farmer
Secretary
Rich Speigel
Chief Pilot/ PIC/Aircraft Mechanic
Cole Van Cleve
PIC



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I. WEATHER MODIFICATION BACKGROUND

With some question, the first scientific based rain stimulation proposal may have been by James P. Espy, in the April 5, 1839 issue of the National Gazette and Literary Register of Philadelphia. Espy proposed building large fires thus generating thermal updrafts. James Espy's reasoning was that in an atmosphere with sufficient moisture, cumulus clouds would eventually develop from the warm raising air over the fire to produce rain. No records exist indicating that the proposed scheme led to any field trials, but in the 1880's Congress appropriated $10,000 to conduct field experiments based on an old, widely-held idea that "it always rains after a battle". After the appropriation, tests were conducted utilizing explosive charges carried aloft by balloons. Favorable reports followed after the field tests. In the 1930's, work completed by Tor Bergeron and W. Findeisen led to the concept that clouds may contain both liquid supercooled water and ice crystals existing within the same medium. This led further to the concepts of "warm rain" and "cold rain".

Modern scientific cloud modification was started in the late 1940s in the General Electric Laboratories at Schenectady, New York. Drs. Schaefer, Vonnegut and Langmuir used silver iodide and dry ice for ice nucleating agents during in these early laboratory and field experiments. The ice nucleating agents for cloud seeding have dramatically changed with time. Various formulations of Silver Iodide are still the chemical of choice for rain enhancement and hail suppression today. Other formulations such as carbon dioxide and hygroscopic seeding agents also work for rain enhancement while dry ice works of both rain enhancement and hail suppression.

Prior to 1967, weather modification activities in Texas were unregulated by any governmental entity. The Texas Weather Modification Act of 1967 (Chapter 14 of the Texas Water Code) provided the mechanism for identifying and regulating cloud seeding programs in the State through the issuance of licenses and permits. By 1976, the original Texas Water Development Board had granted licenses to seven firms and issued 27 permits. In more recent years the responsibilities for granting licenses and permits was passed to the Texas Department of Licensing and Registration (TDLR).

In early December 1998, The Southwest Texas Rain Enhancement Association (SWTREA) circulated a Request for Proposal covering a cloud seeding program targeted to begin in May 1999. Ultimately, Atmospherics Incorporated; Fresno, California won the contract to conduct the seeding project. The counties that were serviced under the umbrella of rain enhancement by the SWTREA were Dimmit, La Salle, Webb, and Zavala Counties. The 1999 SWTREA cloud seeding project was operational during the period 1 May through 31 October and was deemed a success.

During the latter months of 1999, the SWTREA took steps to establish a means for which the association would conduct its own weather modification program instead of relying on services rendered by seeding contractor companies. The Southwest Texas Rain Enhancement purchased a ground-based 5-cm radar, cloud seeding aircraft, systems for acquisition of meteorological data and various cloud seeding devices. The SWTREA also employed a meteorologist and three pilots. The cloud seeding project completed its second year of operations in a seeding season that ran from April 12, 2000 to November 15, 2000. Daytime rain enhancement and hail suppression services were provided to the participating counties in the target area of Dimmit, La Salle, Webb, Zapata and Zavala

Counties. During the last month of the season, some nighttime seeding was also carried out for the first time in the history of any cloud seeding project in Texas. The year 2000 project was also deemed a success.

2001 marked the third year of the project and the first full season of 24-hour, 7-day per week seeding readiness. The year represented an aggressive effort of rain enhancement and hail suppression in the same five counties as last year (see target area map Fig. 1). An additional seeding plane was purchased (twin-engine Cessna 340) in an effort to enhance operational readiness of the program, address more seedable clouds and to increase our effectiveness in hail suppression. Only two planes were used however this year. One of our crew, Richard Foster, a pilot for the program since its inception in 1999 became ill with a brain tumor during the early portion of the season. Mr. Foster died September 19th, 2001. His presence has not only been missed in terms of an operational standpoint and friend to us all, but sorely missed by myself as he was a close friend of mine ever since I came onto the program in February of 2000.

Steps were taken during the early portion of the season to add an additional pilot to the program so that we could utilize the third plane at the outset of the 2002 season. A pilot was hired and has been in training this year so that he will be in a position to be a pilot-in-command (PIC) for the third plane in 2002. At the same time the decision to hire another pilot was decided, steps were also taken to begin training Mr. Walker, SWTREA program manager, as a "stand-in" pilot for times when a full-time pilot was unavailable for a mission or for ferrying a plane. During mid-season, it was also decided to begin a pilot internship program. It was recognized that in the ever-changing world of weather modification, pilots and meteorologists typically use the experience gained in this field as a stepping stone for jobs that become available in other fields in the future. It is envisioned that at least one intern pilot and one intern meteorologist would be present on the program every year should a pilot or meteorologist decide to move on thus avoiding the creation of a critical vacancy in the project staff. With my decision to transfer my services to another weather modification project in Kansas, the program has taken steps to hire and train my replacement so that no seeding opportunities will be lost in the seeding season of 2002 due to the absence of a meteorologist. As the 2001 season came to a close, it was extremely evident that this year's seeding efforts were very successful. Details of the results for this year are provided in section B of chapter IV.

2002 Marked the fourth year of the project, the second year of 24 hour-a-day operational time. A new meteorologist with previous weather modification experience was hired late in 2001. This year also marked the addition of the new Cessna 340 to operational use, bringing the project to 3 full time aircraft. This year also saw the addition of a sixth county to the target area. Uvalde County was added on May 1 as the Edwards Aquifer Authority rearranged it cloud seeding activities. This brought the project totals to 3 aircraft, 6 available pilots, for 6 counties. The 2002 project ended on November 15th, bringing to a close a fourth successful year of cloud seeding.

2003 Was the fifth year of the project, and the third year of 24 hour-a-day weather modification operations. Three different meteorologists worked on the project this year. All had previous experience in weather modification. This year saw the project area decrease by one county as Zapata County left the association. The project again used 3 aircraft for the 2003 season with 4 available pilots. One pilot ended up leaving before the completion of the project. The project came to a close on November 15th ending the fifth successful year of cloud seeding for the SWTREA.

2003 SWTREA TARGET AREA

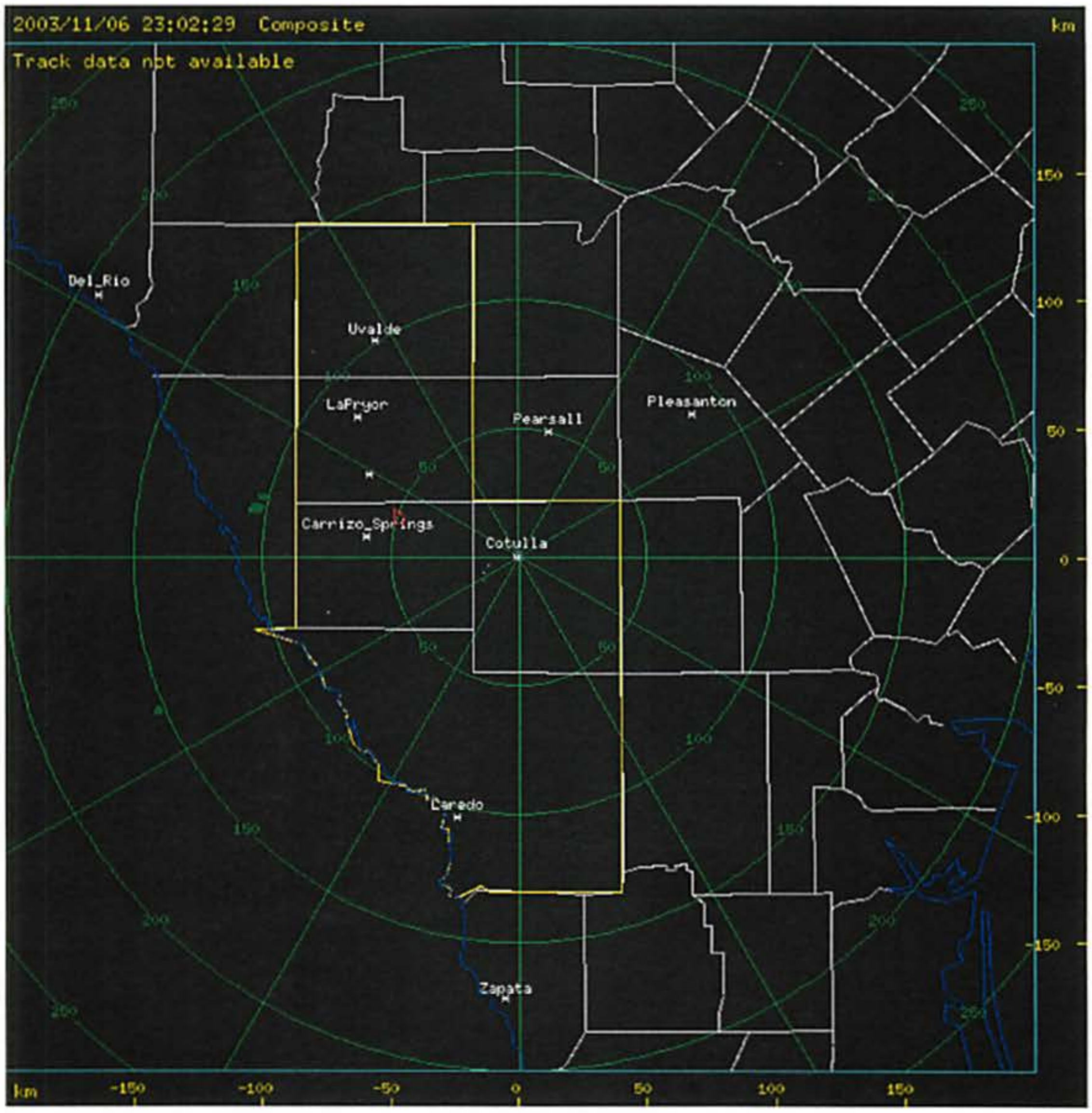


Fig. 1

II. THE PHYSICAL BASIS FOR CLOUD SEEDING

Even today, scientists still have much to learn about how some clouds grow, mature and dissipate over time, especially very severe storms. During the spring through summer months, rapidly growing convective clouds can become severe rapidly, producing highly destructive hail and surface winds which destroy crops and property, not to mention causing flooding and the occasional tornado. The occurrence of severe weather in South Texas is not nearly as great as in the Plains states, but the overall dynamics of a convective storm is the same in both areas. The following is simplified explanations of how convective clouds can grow to become severe and of the generally accepted theory supporting the feasibility of seeding to increase rain and reduce hail.

A convective cloud forms when rising air containing water vapor cools by adiabatic expansion to a temperature at which condensation occurs forming water droplets. Condensation begins first upon microscopic aerosols, or particles, called cloud condensation nuclei (CCN). CCN are relatively abundant in the atmosphere and includes dust, smoke and salt particles. When a collection of these water droplets have grown to sufficient size, they become visible as clouds. In Southern Texas some of the mechanisms causing rising air to form convective clouds are:

(1) Surface heating which returns solar radiation to the atmosphere → warm air rising

(2) Advancing cold and warm frontal systems → forces air to be lifted over its boundary

(3) Relatively cold air in the upper atmosphere sinking into warmer air ahead of it → causes warm, moist air to be displaced and forced upward

(4) Regions of horizontal convergence created by troughing at the earth's surface, or aloft → forces air to rise as it is squeezed together

(5) Convective scale interaction resulting from thunderstorm outflows digging under warm, humid air → acts much like a mini-cold front forcing air ahead of it to lift rapidly (an extremely important mechanism once storms mature and collapse

(6) Sea breeze moving west over the warm earth surface → acts much like thunderstorm outflows or a mini-cold front (storms caused by a sea breeze are only active during daylight hours)

(7) Hurricanes, tropical storms, tropical depressions and tropical waves → promote intense shower and thunderstorm activity because of an unstable, high moisture environment

Other various atmospheric aerosols are present in the atmosphere and known as ice nuclei (IN). These particles, if found in condensed water droplets, enhance droplet freezing. Ice crystals also may form upon IN directly from water vapor.

Despite the abundance of CCN, there is a relative scarcity of IN. In nature, most convective clouds fundamentally lack sufficient numbers of IN which causes clouds to fail to precipitate efficiently, or help form damaging hail. Cloud seeding can usually provide the needed numbers of IN to correct the imbalances found in most cloud systems.

Clouds can be made up of unfrozen water droplets, ice crystals or a combination of both. Within a convective cloud having a portion of it colder than freezing, some of the sub-freezing water droplets remain in a liquid state, termed "supercooled water". Convective clouds often create a condition in which both unfrozen water droplets and ice crystals co-exist simultaneously. It is the supercooled cloud volume that is critical in Southern Texas to the formation of hail and rain (given the absence of tropical systems producing rain in a "warm cloud" environment). Supercooled water can remain unfrozen to as low as -40 C (-40 F) before spontaneously changing to ice. When such spontaneous freezing occurs, it is termed homogeneous nucleation.

Supercooled water droplets containing ice nuclei are the first to freeze. The speed that supercooled water droplets convert into ice crystals increases as cloud temperature decreases. That is, as cloud tops grow higher above the freezing level, ice crystal production normally increases. A process called vapor deposition then starts to have a significant effect within clouds when ice crystals and supercooled water exist in the same medium. Surface pressures over ice crystals are lower than those over water droplets creating a pressure gradient between them that causes liquid to flow from the droplets to the ice crystals reducing the cloud water. They continue growing rapidly feeding on the surrounding water vapor and cloud water from nearby water droplets. Continuous unequal movements of water droplets and ice particles inside convective clouds ensure random collisions of ice and water droplets which promote the processes of coalescence, accretion and aggregation to a greater or lesser extent, all of which increases ice multiplication in clouds.

Coalescence is a process in which the unfrozen water droplets collect other water droplets by impact, freezing occurring after the impact.

Accretion, or riming, occurs when droplets freeze upon impact with cloud ice particles.

Aggregation is the process in which ice particles collect or attach to other ice particles. In advanced stages of cloud growth, ice particles will shatter, coalesce, grow larger and repetitively collide in a complex manner through the processes just mentioned.

When the various sizes of ice particles eventually fall out of the cloud and drop below the freezing level, they begin melting. If melting is not complete, then hail, graupel or snow reaches the ground as precipitation instead of rainfall.

The varied concentration and size of all nuclei present in the atmosphere as well as their chemical and electrical properties all combine in important ways to determine how efficiently a singular cloud or cloud system produces precipitation. An extremely massive amount of water vapor can be present in the atmosphere at any given time, but precipitation will not occur if certain conditions required for the formation of precipitation are absent. This is why the SWTREA is not up flying everyday when clouds are present over the target area. There may be clouds, but certain conditions may not be present to allow precipitation formation even though the clouds overhead "look" seedable. It is important to realize that seeding a non-precipitating cloud that would otherwise remain non-precipitating in its natural state is not going to produce precipitation in a modified state. Weather modification projects are in the business of enhancing rainfall not making rainfall. The cloud must already be precipitating to some degree or exhibit the potential to precipitate before seeding can be effective.

Two cloud types produce all precipitation: "warm clouds" and "cold clouds". A warm cloud is one in, which nowhere in its volume is its temperature below freezing producing ice crystals. The warm cloud is characterized most often by relatively slow growth. Cloud water droplets eventually may grow to a sufficient size and weight to fall out of the cloud if given enough time. While falling, cloud droplets collect other cloud droplets by scavenging them along their downward paths. This type of cloud often appears in Southern Texas during mid-summer months but it is not the dominant type of cloud producing precipitation here. However, large size warm-rain drops can be important embryo sources in the production of hail when they merge into the sub-freezing cold clouds and are carried aloft rapidly by updrafts whereupon they freeze and grow larger into hail.

Most important to Southern Texas is the "cold" cloud. Cold clouds have a portion of their volume that has grown into temperatures below freezing. When these clouds form, it is the interaction between the supercooled water drops and ice crystals within the cloud that initiates the process most responsible for producing significant precipitation in Southern Texas. Also, cold clouds tend to be much taller than warm clouds and, therefore, make considerably more moisture available to the eventual precipitation process developing in the cloud.

The hypothesis under which the Southwest Texas Rain Enhancement Association (SWTREA) hail suppression portion of the project operates is called "beneficial competition". The reason hailstones grow to large sizes in thunderstorms is due to the lack of sufficient numbers of IN particles while developing. That insufficiency of IN particles capable of converting to ice crystals causes relatively abundant supercooled cloud water to collect upon the relatively few numbers of ice crystals formed. Too often those ice particles grow into hailstones so large they can't melt before reaching the earth's surface. By vastly increasing the concentration of ice crystals within these ice crystal-deficient clouds, competition for available cloud water strongly increases, thereby preventing hailstones from growing to sizes large enough to damage crops and property. Hail growth and movement within storms, especially very severe ones, can be very complex. Hail damage is determined by the type of property or crop, what stage of growth the crop was in, hail size and whether or not it was wind-driven. The rain enhancement portion of the SWTREA project is also born from the theory of beneficial competition. Typically, non severe clouds contain so few IN particles that only a very small percent of available cloud water is actually converted to rain water. By vastly increasing the concentration of ice crystals with these extremely ice crystal-deficient clouds, competition for available cloud water strongly increases, thereby enhancing nature's relatively non-efficient rain production process.

The rain enhancement and hail suppression seeding agents used by the SWTREA program contain silver iodide in the formulation and are delivered into the updraft zones of growing cumulus clouds by aircraft. Silver iodide (AgI) seeding agents are combusted then vaporized by burning AgI flares and liquid AgI solution from wing tip generators and wing mounted flare racks. AgI seeding agents produce IN particles, which promote ice crystals to form through a process, called heterogeneous nucleation. Heterogeneous nucleation is when ice crystal concentrations increase with respect to decreasing temperatures.

Although hygroscopic flares were not used during the 2000 season, they may need to be considered for use in future years. The primary purpose of hygroscopic flares is to increase rainfall while they are of no use for the suppression of hail according to current research. The word "hygroscopic" means water attracting. The chemicals within a hygroscopic flare produce a particle that has an affinity for moisture. Unlike the silver iodide seeding agents, hygroscopic seeding agents enhance rainfall in warm and cold cloud environments. Silver iodide seeding agents promote additional rainfall in the cold cloud environment.

Seeding agents work within the region of the cloud called the supercooled region. Here, liquid water and solid water coexist in sub-freezing temperatures. It has even been theorized that liquid water exists at –40C but has yet to be documented in nature. Liquid water has been found at –38C in experiments conducted over Texas during the late 1990's. In the supercooled region, there are areas in which the ice crystals that do form tend to grow in characteristic shapes. The shape of the crystal is dependent upon the actual temperature of the water drop at the time the liquid converts to ice. Around –10C the habit of water drops changing to ice crystal is that it forms large ice crystals. Large ice crystals generally grow much faster than needle or column shaped smaller ice crystals. Therefore, to obtain the desired seeding effects each cloud must be treated within the proper time interval, or seeding window, to produce the optimum ice crystal concentration and size in clouds naturally deficient in them. A cloud growing to maturity must be seeded with enough time allowed so that the generated ice nuclei can be lifted by updrafts into and through that appropriate temperature and moisture regime, residing there for a sufficient time to interact with the supercooled cloud water. If the seeding window is missed when conducting rainfall enhancement, clouds may collapse prematurely resulting in a wasted effort. The residence time of a supercooled cloud volume is critical to the success of weather modification.

Convective cloud growth can be modified through a process called the "dynamic effect." If certain atmospheric conditions are met, clouds may be stimulated to grow larger and rain for longer periods than would the case if otherwise left unseeded. For the dynamic effect to be successful, a sufficient amount of seeding agent must quickly be placed into the supercooled portion of the cloud to promote the rapid conversion of cloud water droplets to ice crystals. When the seeding agent delivery is done correctly and within the seeding window of opportunity, the water-to-ice conversion process occurs rapidly. This water-to-ice conversion releases latent heat of fusion on a massive scale thus making the cloud slightly warmer and more buoyant. Also, the cloud updrafts are expected to be invigorated, thereby drawing in greater amounts of water vapor into the cloud supplying more moisture, additional growth, and rainfall. These processes cause the cloud to remain active longer and produce more rain that if left in its natural unseeded state.

The convective cloud systems listed below, and their variations, are most responsible for producing rain and hail in South Texas.

(1) the air-mass thunderstorm complex
(2) the multiple-celled thunderstorm complex
(3) the squall line

Air mass convective storms are often seen in South Texas during the late spring and summer months. These storms are characterized by having a defined non-precipitation updraft cloud base with associated precipitation shaft. Air-mass storms typically last no longer than one hour but new growth cloud often develops in the updraft area of the parent storm. These storms are not classically known as being severe but they can become strong enough to produce small hail. Isolated air-mass storms account for roughly 40 - 50 percent of the storms seen over the SWTREA target area. Air-mass storms may merge or develop multiple cloud turrets. Once the merger takes place, storm movements can become unpredictable depending on several factors such as storm severity, storm dynamics, cloud height, variability of wind speed and direction with height, terrain effects plus the blocking and steering winds caused by cloud systems upwind. A diagram of the air-mass storm and seeding strategy is provided in figure 2(next page.

Air-mass storms often develop or converge with surrounding cloud to produce multi-celled thunderstorm complexes. Typically in South Texas, the multi-celled storms develop on days when the regular air-mass storms are forecasted. The lifetime of multi-celled storms varies greatly from 45 minutes to as long as three hours. Updrafts found on both the air mass and multi-celled storms are usually on the upwind side but in some situations can be found just about anywhere or areas not normally noted to contain updrafts in a traditional sense. Most often, updrafts pertinent to the hail process are found along the trailing edge or upwind side of the storm below cloud base at some distance behind the precipitation shaft.

SEEDING A TYPICAL AIR-MASS STORM

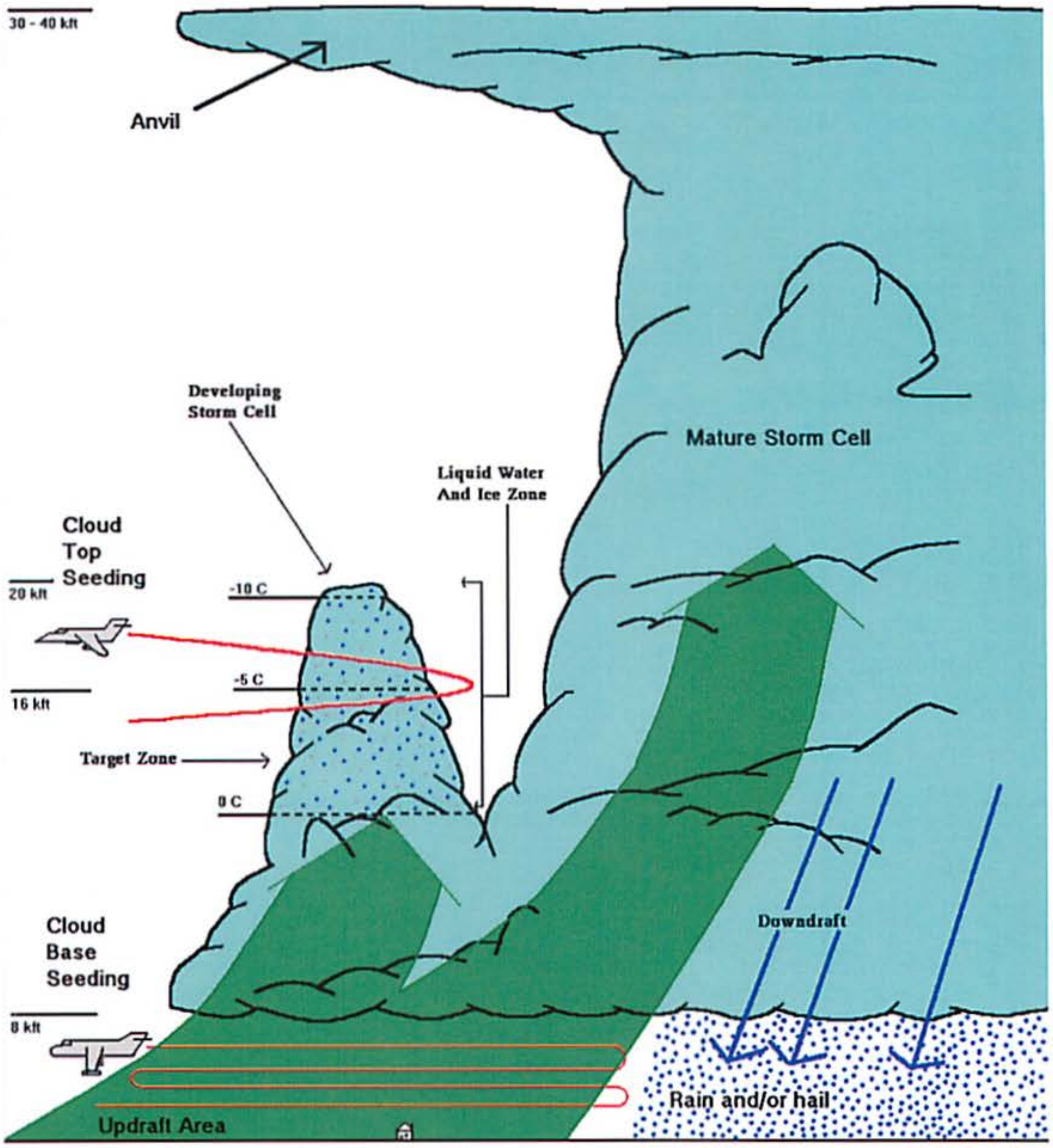


Fig. 3

Air-mass storms can transition into a line of storms containing multiple cells showing characteristics more similar to those of a squall line. During the gradual development of a squall line type system, cloud base updrafts frequently shift around although they are still found near some of the individual cell elements comprising it making seeding treatment quite difficult at times. Squall line storms are mostly seen during the spring and fall months in South Texas as they ride along cold fronts pushing south through west central Texas. They often last well into the night as they are dynamically driven unlike air-mass storms that form mostly from heating of the day. A diagram of the squall line storm and seeding strategy is provided in figure 4(next page).

Under some strong dynamical conditions, singular air-mass storms and/or multi-celled storms may become very large, developing several new growth areas at the same time with distinct cores growing embedded in and around the periphery of the cloud boundary. The dynamical conditions are high atmospheric energy, dense moisture extending from the earth's surface to some level in the atmosphere, strong winds with a change in direction with height, and a lifting force such as a cold front, dryline or intense surface heating. Once all these conditions are in place over a certain area, the ordinary air-mass storm or multi-celled storm may transition into a supercell. The supercell is without a doubt the strongest localized storm on earth exhibiting damaging hail, dangerous lightning, high winds, and torrential rainfall with possible flooding. One characteristic of a supercell is that at some point it begins to turn right and move away from the normal direction of regular clouds. The right turn is brought about as the supercell initiates a self-driving wind environment relative to the direction of the mean steering wind. Supercells can be quite dangerous to seeding aircraft as well as crops and property since hail is capable of being ejected from the cloud at long distances in all directions. Occasionally hail is ejected into the flight paths of seeding aircraft. Supercells produce the most destructive tornadoes; however, not all supercells produce tornadoes. Seeding supercell storms require close attention to detail and safety from both the meteorologist and seeding pilots when working these storms. However, seeding supercells can be safely accomplished with experienced personal even as the supercell is producing tornadoes.

A process called "convective scale interaction" is a term given to the process in which a collapsing storm produces precipitation and downdrafts, which promote subsequent new cloud growth. Downdraft air, also called the gust front or outflow boundary, spreads out below the cloud base undercutting the relatively warm, moist air. If moisture is sufficient in the air being lifted above the gust front, it can rise into an unstable atmosphere and grow rapidly into another new severe storm, which quickly reaches maturity. Then, that storm collapses producing a strong downdraft, thereby repeating the sequence again and again. Single outflow boundaries have been known to be strong enough to travel 100 – 300 miles, or more, from its parent storm. These outflow boundaries can be seen on satellite pictures as a semi-circular, fan shaped line of clouds known as "arc-clouds." Some of these clouds themselves can develop into large, severe convective storm systems. Single storms, multiple storms, bow-echos, and supercells all have been identified as forming along these gust fronts.

Two, or more, colliding gust fronts frequently create extremely severe storms, although the severe storms are often short lived. Severe aircraft turbulence is frequently found in the gust front air between the parent storm and the leading edge of the gust front. Ahead of the gust front, the air is generally smooth. When gust fronts drop out of high-based clouds, microburst activity occurs which has been known to flatten buildings, crops and cause aircraft accidents during landing and take-off.

Under some conditions rainfall enhancement over large areas have been produced by seeding atop the leading edge of a gust front as air is lifted over it which causes only

SEEDING A TYPICAL SQUALL LINE THUNDERSTORM

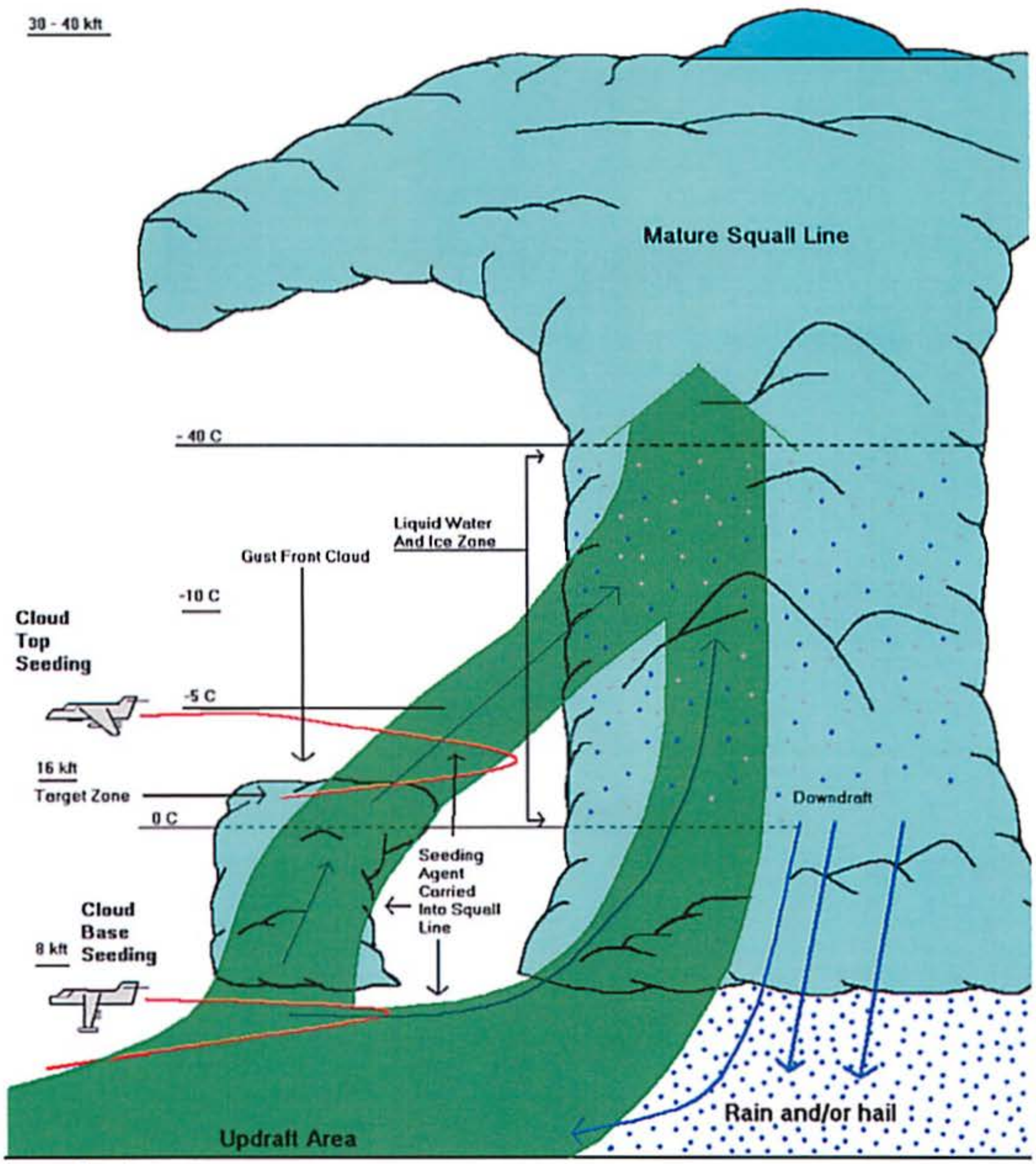


Fig. 4

weak cumuliform clouds to form. Updrafts found above gust fronts have a wide variability in updraft speeds from 100 – 500 feet per minute to a more normal 1,000 – 1,500 feet per minute, or more. If this particular condition occurs at night with little threat of hail developing from new storm growth and weak updrafts are prevalent, rainfall enhancement seeding can be highly productive over large areas using wing generators. It is likely under these conditions the dynamic effect is altered, whereas, the static seeding effect is being achieved. In such cases, seeding is altering the cloud's microphysical characteristics. It is likely that hygroscopic seeding above a gust front may also produce good results.

Another storm sequence, particularly frustrating to cloud base seeders, occurs somewhat often. This particular type of storm is often part of a line of storms and it may, or may not, have been seeded. The storm collapses sending out a large gust front, however, there remains strong, new feeder storms attached to the parent storm. While the parent had been obtaining most of the moisture from below cloud base, as the storm collapses it appears that it maintains strong feeder growth due to mid-level convergence and sufficient mid-level moisture which is present.

What makes this storm difficult to seed is that no steady updrafts can be found and what updrafts are found below cloud base are embedded in heavy turbulence along with equally sharp downdrafts. Sustained, steady updrafts are not found; however, above cloud base the feeder cells continue to grow rapidly, eventually producing precipitation cores containing property and crop damaging hail. This type of storm can only be seeded properly above cloud base with cloud-top aircraft.

III. GENERAL OPERATIONS – PROJECT DESIGN

In 1999, the SWTREA was originally designed to be an operational cloud seeding effort to enhance rainfall over participating counties in Southwestern Texas. In 2000, a hail suppression permit was obtained thus changing the seeding protocol of the project. Currently, the SWTREA is the only operational cloud seeding program in the state of Texas with a permit for hail suppression. Other projects around the state are making amendments to their licenses to allow for seeding of severe storms for rain enhancement only rather than a rain enhancement and hail suppression combination. Although the overall objective of weather modification has not changed over the past three years with the exception of the hail permit, slight design changes have been made to better accomplish the program's goals and priorities. The changes made were due mostly to technological innovations, current research and the need to conduct night operations to take advantage of significant weather systems affecting the target area during the night. Currently, the SWTREA is the only weather modification program in the state of Texas that conducts seeding missions during nighttime hours. During the last month of the 2000 operating season, the decision to purchase a third aircraft was made. The aircraft purchase enabled the program to address "on-top" seeding in future years but for the 2001, 2002, and 2003 seasons, the plane was used as a third cloud base seeding aircraft in our fleet. Perhaps the current and future research into on-top seeding will yield significant results into the effectiveness of cloud penetrating missions. If those research results come to fruition, it would then be worthwhile for the SWTREA to begin on-top seeding. The logistics of all the SWTREA aircraft will be presented in the aircraft chapter later in this report.

A. PROJECT ORGANIZATIONAL STRUCTURE

The Southwest Texas Rain Enhancement Association (SWTREA) was created by the signing of Interlocal Agreements with The Wintergarden Groundwater Conservation District (WGCD), City of Laredo—Webb County, and the Edwards Aquifer Authority (Uvalde County). The Association is governed by a Board of Directors who supervises the administration and operation of the Association. Official Bylaws were adopted to authorize and govern the operation of the Association. The Board of Directors is composed of eleven members of which WGCD provides 6 and one at-large, City of Laredo—Webb County provides 2, and EAA(Uvalde County) provide 2. Each county represented must have one director whom must be an elected official of the entity. The Officers of the Board consisting of a Chairman, a Vice-Chairman, a Secretary, and a Treasurer serve two-year terms. Management to SWTREA is furnished by WGCD who employs a General Manager to be chief administrative officer with full authority to manage and operate the affairs of the District and the Association, subject to Board orders. The General Manager is responsible for employing all persons necessary for the proper handling of business and operation. The General Manager delegates duties to the WGCD Secretary/Bookkeeper; SWTREA Meteorologist; SWTREA Pilots and Pilot/A&P Mechanic. See figure 5.

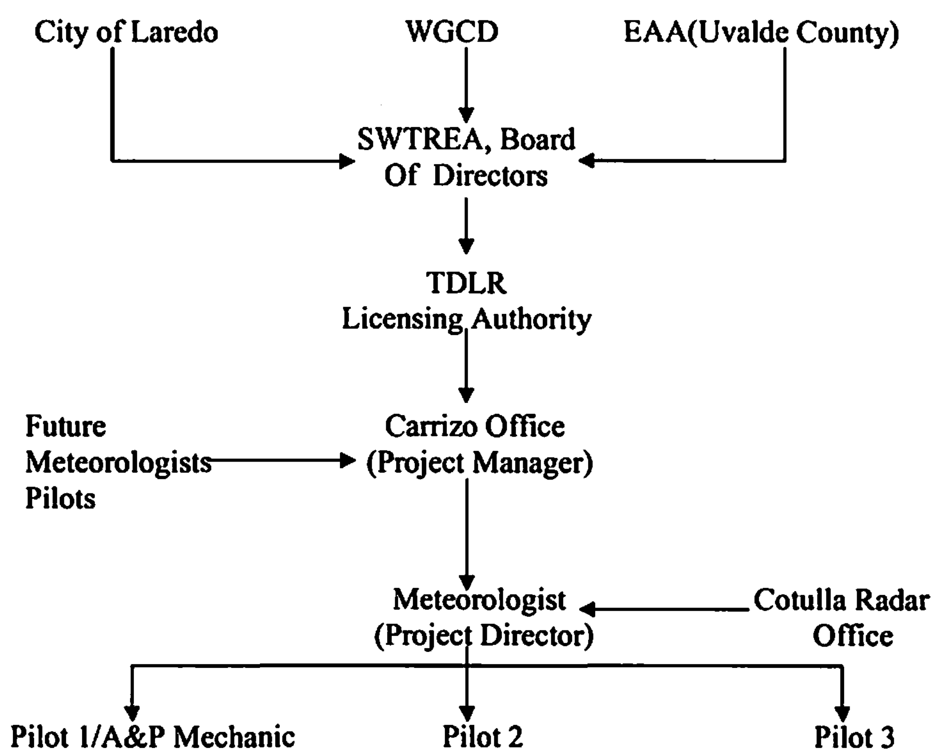


Figure 5-SWTREA Organizational Structure

B. PROJECT FUNDING STRUCTURE

Funding for the Southwest Texas Rain Enhancement Association (SWTREA) program is accomplished by assessment of funds to each of the Association's member entities on a per acre basis, shared equally by all sponsoring entities. Currently, the Association membership consists of the Wintergarden Groundwater Conservation District [(WGCD) Dimmit, LaSalle, and Zavala Counties], City of Laredo--Webb County, and the Edwards Aquifer Authority (Uvalde County), each of which are bound to the program via Interlocal Cooperation Agreements. Each entity enters an agreement with WGCD who serves as a political subdivision of the State of Texas and furnishes management for operations. The Texas Department of Agriculture (TDA) provides 50% match funds to the program for all expenses and purchases incurred via an interlocal agreement with WGCD, the political subdivision. See figure 6.

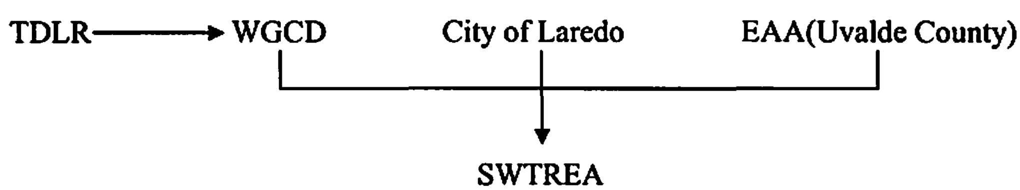
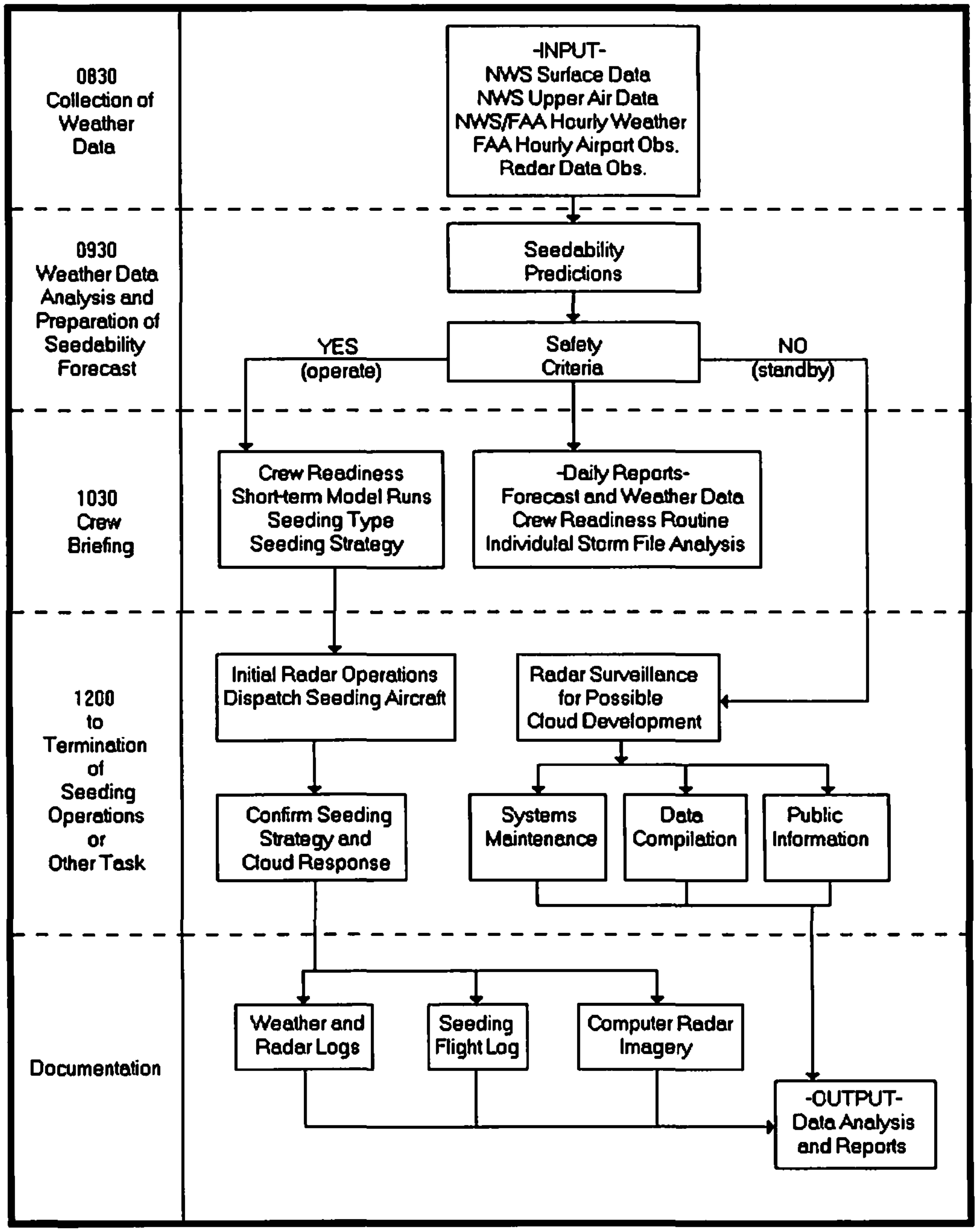


Figure 6 – Funding Structure

C. WEATHER FORECASTING AND DAILY OPERATIONAL PLANNING

The SWTREA project meteorologist is responsible for the preparation of daily weather forecasts concentrating on the southern region of Texas and northeast Mexico for thunderstorm potential. Early detection of a "thunderstorm environment" is essential for a successful weather modification program as the extra lead-time allows project personnel to prepare properly prior to a seeding mission. Most weather maps and information used to forecast stormy weather becomes available via the Internet during the morning hours around 8:30 a.m. to 9:00 a.m. of each day. The meteorologist analyzes the data to determine if thunderstorms will develop. After it is determined that the atmosphere is conducive to thunderstorm development, the meteorologist will determine how, when and where the first signs of storm development will begin and how long it will last. An outline of the daily operations flow diagram is shown in figure 7.

Fig. 7 **Operations Flow Diagram**



A major design change in weather surveillance was necessary to enable the project to address nighttime thunderstorms and seeding of those storms. The project was responsible for any and all thunderstorms that threatened the target area no matter what hour. Normally, most projects that conduct both night and day missions have two or more meteorologists who work in shifts to cover the workload. Although the SWTREA has only one meteorologist, the program was still able to monitor all night storm opportunities that occurred during the season. Shifts were divvied up between the meteorologist and pilots on those nights when weather was expected. Even on those nights when no weather was expected but did occur, at least one member of the staff was awake and aware of the situation. I would like to personally thank all the pilots and the WGCD secretary who aided my efforts in monitoring thunderstorm potential on the many sleepless nights we had this year. Thank you.

Not enough can be said about the growth and dominance of the Internet in providing weather information. The early 1990's marked an explosion for Internet weather products available to both the general public and the scientific community. Almost all meteorological information used by the SWTREA comes from the National Weather Service, Storm Prediction Center, National Center for Environmental Prediction, University Centers for Atmospheric Research, and many university and public sites via the Internet.

A small host of various media weather products are also very useful to the SWTREA. One media company almost all of us are familiar with is The Weather Channel. The Weather Channel is probably the most viewed channel on television by weather modification personnel. TWC usually does a good job of providing accurate 24-hour-a-day non-stop weather information in the form of regional radar, satellite images, forecasts and immediate information concerning severe weather. However, it should be noted that a radar image displayed on TWC is generally fifteen minutes old. TWC is monitored by SWTREA personnel at home or in other places, but is not at the Cotulla office because cable is not available at the airport. SWTREA personnel also periodically view local television networks for weather information. The Cotulla office utilizes the most powerful Internet-based weather information service available called WeatherTap. WeatherTap is also the primary source for radar images used by all project personnel during pre-operational weather surveillance on nights when weather is expected in the area. WeatherTap provides a variety of important information such as current NEXRAD data for any National Weather Service radar site, satellite and lightning data from around the United States, forecasts, current local observations, aviation weather data, immediate severe weather data and other data. Most of the data provided by WeatherTap is also available in a looping sequence.000

D. RADAR SURVEILLANCE AND DISPLAYS

For cloud seeding operations within the target area, 5cm C-band weather surveillance radar was employed. The radar is located at the SWTREA field office at La Salle County Airport near Cotulla. The digitized system incorporated both a Plan Position Indicator display (PPI) and Range Height Indicator (RHI). The radar has a cloud echo sampling range of 118 nautical miles in a full 360 degree volume scan with receiver sensitivity sufficient to provide a detectable signal with precipitation rates of 1mm/hour at 70 nautical miles. A full volume-scan for echo sampling in 3-D takes roughly 3 minutes at 4 RPM.

The radar system includes two software programs RDAS (Radar Data Acquisition System) and TITAN (Thunderstorm Identification, Tracking, Analysis and Now-Casting). Developed by a group in South Africa with inputs from the National Center for Atmospheric Research in Boulder, Colorado, these computer programs collect, analyze and display up to ten different radar data in real-time, as well as perform and record many functions which are useful for post-analysis of seeding operations. These functions include vertical cross section of any portion of the storm, radar estimated precipitation for 1hr or 24hr intervals, storm reflectivity, Vertically Integrated Liquid (VIL), VIL density, storm movement and a long list of other parameters useful for subsequent evaluations.

Another powerful tool incorporated into the TITAN and RDAS systems is an aircraft tracking device labeled by SWTREA personal as the "black box". This aircraft tracking technology is relatively new as it was developed only a couple of years ago. An electronic specialist from South Africa also developed the black box devices for both the operations office and the seeding aircraft. The black box allows the meteorologist to monitor aircraft positions with respect to storm location as well as distance and radial measurements from the Cotulla field office. The information from the tracking system is overlaid directly onto the operational radar computer screen used for seeding operations. The tracking systems transmit GPS data, as well as time and place of seeding material release. Weather radar incorporating the RDAS and TITAN systems is the most advanced weather monitoring/aircraft tracking system available today for cloud seeding.

Radar observations of cloud motions were used to direct and re-direct all seeding operations. After being directed to the cloud or weather system intended for rain enhancement or hail suppression, pilots aid in the determination of seedability by visually identifying general cloud characteristics and storm severity. Within complex rapidly changing storm systems and/or nighttime operations, weather radar was indispensable in providing assistance to pilots while identifying the preferred seeding areas and dispensing the nucleating material at the proper time and location. Weather radar might best be described as the "big eye in the sky" for seeding operations.

E. NUCLEI DISPENSING SYSTEMS

Two primary systems of dispensing ice nuclei compositions are a part of the SWTREA inventory along with another under consideration in future years.

(1) Burn-In-Place Pyrotechnic Device (BIP)
(2) Airborne Liquid Fuel Generators (ALFG)
(3) ***Under consideration*** – Ejectable Pyrotechnic Seeding Device (EJEC)

The Texas Weather Modification Association (TWMA) has pioneered and developed various airborne systems for dispensing silver iodide ice nuclei compositions throughout the state of Texas and elsewhere. The state association has made new improvements in the last three years with the development of advanced seeding agent formulations as well. The following is a description of both the delivery mechanisms.

Burn-In-Place Pyrotechnic Device (BIP)

Each SWTREA cloud seeding aircraft is equipped with two special wing racks that accommodate a total of 24 or 48 BIP units. The devices each contain forty grams of effective silver iodide or sodium iodide consumed in less than one minute. They are chosen for use whenever confined strong inflows are identified and high rates of silver iodide or sodium iodide are required as the priority seeding method. The units are electronically ignited from a control console within the aircraft cabin. The only downfall of BIP seeding is that a rather small supply of BIP's are available for any particular seeding mission and the pilot must land often to reload BIP units on severe weather days. The SWTREA currently uses the "RS-3" silver iodide and "SF1" sodium iodide BIP manufactured by the TWMA in San Angelo. The RS-3 is probably the state-of-the-art in BIP's. Unlike most BIP units manufactured elsewhere, the RS-3 is able to convert all of the silver iodide to ice nuclei in less than two minutes when other BIP formulations convert to all ice nuclei in ten minutes. This is a tremendous advantage in that seeding effects are realized much faster and the seeding window of opportunity is lengthened. The SF1 is a brand new experimental salt flare used for hygroscopic research on our program this year. A picture of the BIP unit is displayed in Fig. 8.

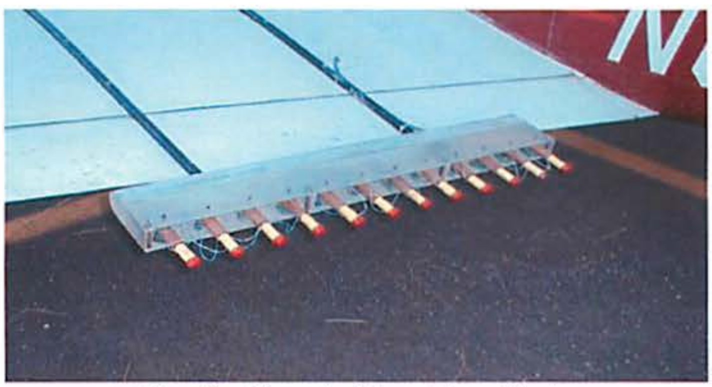


Fig. 8 – Burn-In-Place Flare Rack

Airborne Liquid Fuel Generators (ALFG)

Each SWTREA cloud seeding aircraft is equipped with two wing tip ALFG's. These devices are composed of air-tank containing nitrogen, liquid tank containing the silver iodide solution and a combustion chamber. The nitrogen is used to compress the liquid silver iodide solution within the liquid tank so that the solution may be forced through a small aperture in the combustion chamber and combusted into usable silver iodide ice nuclei. The ALFG can hold roughly 6.5 gallons of liquid solution and is expelled through the aperture at a rate of 2.5 gallons per hour to produce 6.25 grams of usable silver iodide ice nuclei per minute. The seeding aircraft is able to burn the ALFG's for just under 3 hours continuously at a liquid tank compression of 40 psi. During the latter half of the 2000 operating season, the SWTREA began using a new formulation of liquid silver iodide seeding agent from GFS chemical company in Ohio. Unlike the silver iodide agent in powder form from the TWMA in San Angelo, the GFS composition is delivered from the company already in liquid solution. Thus, no mixing is required by the user and it has been observed by the author that the "pre-mixed" solution burns much more cleanly and efficiently than the powder mix available from the TWMA.

However, cleaning of the combustion chamber is required after every seeding day so that the ALFG will work properly for the next seeding mission. ALFG seeding is the preferred method on clouds with weaker updrafts around 100 – 500 feet per minute. The use of ALFG's is also valuable in that a pilot is able to stay on a storm longer then using BIP's alone where the pilot must return to the airport to reload BIP's more frequently. A picture of the ALFG unit is displayed in Fig. 9.

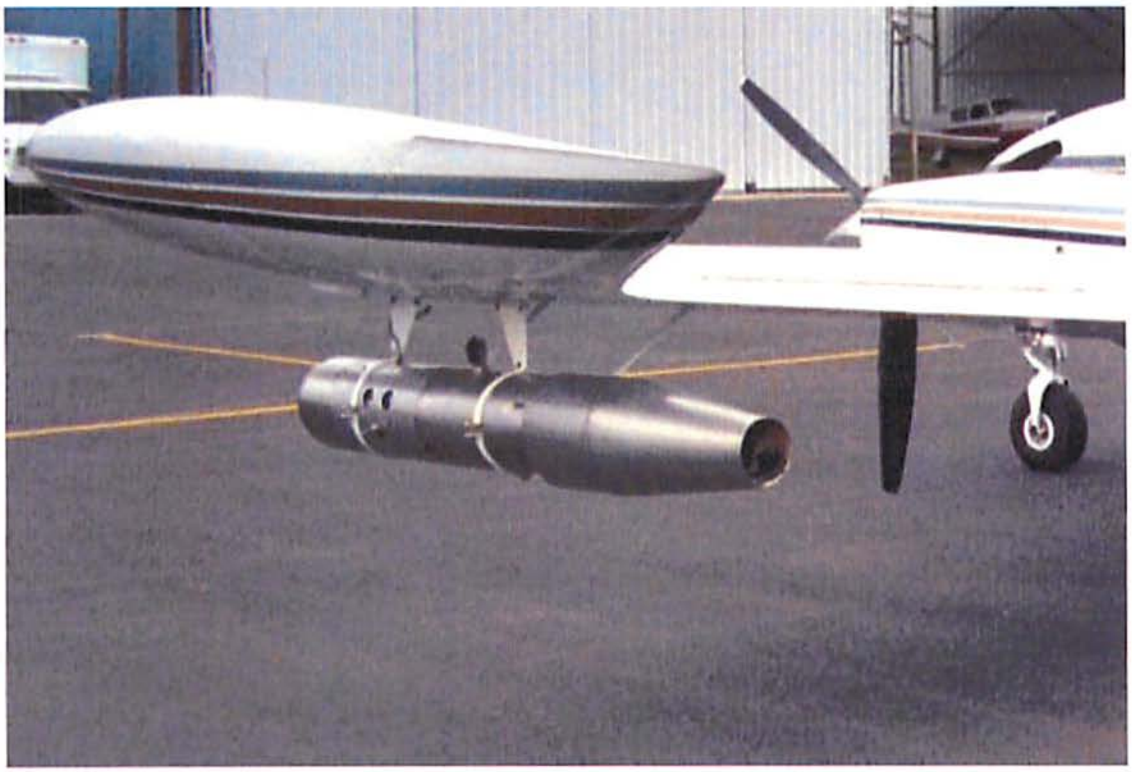


Fig. 9 – Airborne Liquid Fuel Generator attached at wingtip.

Ejectable Pyrotechnic Seeding Device (EJEC)

Although the SWTREA is currently not using EJEC's on any of the seeding aircraft, the Cessna 340 aircraft will likely be equipped to utilize this seeding method in the future. The EJEC is composed of a special fuselage-mounted rack for holding the ejectable seeding units. The EJEC rack can be fitted to handle 40 – 200 ejectables, each unit having a burn time of 30 seconds and 60 seconds for the 10 gram and 20 gram units respectively. In order to utilize the EJEC's for cloud seeding, the aircraft must be capable of being able to seed clouds "on-top". On-top seeding is not new to weather modification, but takes specially trained personnel with a complete understanding of cloud processes before seeding can safely be accomplished. On-top seeding requires that the aircraft penetrate the feeder cells of a thunderstorm complex to judge the amount of liquid water available. This is especially difficult in it that it requires Instrument Flight (IFR) rather than Visual Flight (VFR) and a pilot well trained in understanding the information displayed on the aircraft radar system. On-top seeding is more dangerous than base seeding but can be accomplished safely with experienced pilots. The SWTREA is considering on top seeding in the future.

F. CLOUD SEEDING AIRCRAFT

The cloud base seeding aircraft type used in 2002 were:

1-single-engine Piper Aircraft Comanche, PA24-250 (Fig. 10)

1-single-engine Piper Aircraft Comanche, PA24-260

1-twin-engine Cessna Aircraft Cessna 340 (Fig. 11)

The Piper Comanche Aircraft has been a cloud-base aircraft of choice for many weather modification projects around the United States. One big advantage of the aircraft is that it is far more economical over its weather modification rival the Cessna 340. For the purpose of cloud-base seeding, the Comanche performs very well and has the proven track record it its ability to handle the tasks at hand.

Fig. 10 – Comanche PA24-250

The twin-engine Cessna 340 has become a popular seeding aircraft used on many of the projects in Texas. Although the SWTREA currently uses the plane as a cloud base seeder, the main benefit of the plane is realized when applied to cloud top missions. Because of the pressurized cabin and onboard radar, the aircraft becomes a plane of choice for higher altitude cloud-top storm penetrating missions utilizing ejectable flares.

Fig. 11-Cesna 340

All aircraft are equipped with Global Positioning System (GPS) units which allow pilots and meteorologists too precisely reference distance and direction from the radar site. The GPS system is coupled with a telemetry/tracking device that transmits critical information every four seconds to the field office such as GPS coordinates transposed onto the office radar as well as event locations and times for flare and liquid generator usage and aircraft airspeed. The telemetry/tracking device also records the above data onto a memory card labeled by SWTREA employees at the "black box". In the event of lost radio communications with the radar field office, all data contained on the black box is available for retrieval once the aircraft has completed a seeding mission.

All cloud base planes are equipped with 12-position or 24-position, stainless steel wing racks mounted to the trailing edges of the wings which hold the flares in place as they burn in place to a stub.

The design of the SWTREA is similar to other seeding programs of its kind. The meteorologist makes the decision to launch aircraft, then guides the pilots to the desired seeding positions during operations. Once a pilot arrives at a storm, he confers with the meteorologist and a seeding decision is made. Unless an aircraft runs into emergencies, runs out of seeding agent or is low on fuel, flight termination decisions are made by the meteorologist. SWTREA pilots are trained personnel and most obtain a complete season of seeding experience as a co-pilot prior to flying as pilot-in-command. Communications and teamwork must work well in order for the SWTREA to operate effectively and be successful.

G. COMMUNICATIONS

SWTREA considers a strong and reliable communications network one of the most important components of its weather modification program. For the purposes of communications between pilots and the meteorologist, a dual channel Icom amplified base station is used at the radar office with King dual channel aviation radios used in the seeding aircraft. SWTREA is licensed for two frequencies under FCC regulations for operation of the base station and aircraft radios.

The primary voice frequency used by the program is UHF 122.925 MHz. A backup frequency UHF 122.850 MHz is also used on occasions. Communications systems are used on the project to coordinate radar operations and aircraft seeding flights. Cell phones are also used for communication with pilots prior to seeding missions and forecasts. Interested parties may listen in to the operations with scanners or aircraft band radios.

Equipment has been bought to increase our communications coverage to allow for extended distance coverage beyond our current range. On occasions, communications is lost due to low flight altitudes and/or seeding distant storms beyond our target area. Repositioning of radio equipment at the radar site greatly increased communication range during the 2002 season to cover most of the target area without interruption, even with the increase in the target area.

Much discussion has come about concerning the use of FM radio communications instead of the standard UHF communications used by most weather modification projects in Texas. The SWTREA target area is configured in a rather non-symmetric fashion. The target area runs 151 nautical miles in a north to south fashion and only 76 nautical miles east to west. This configuration is somewhat cumbersome in terms of communication feasibility for a weather modification project. In the hypothetical world, one would much rather have target areas as symmetrical as possible with equal radio signal strength in any direction from the field office. With the installation of the new communications equipment for the 2002 season, the project has sufficient radio coverage for the current target area. However, communications will become a significant issue if any county on the southern or northern boundaries of the current target area wishes to become part of our project. In the event that another county in those said areas wishes to become a part of the project, the use of FM radio communications and a repeater network will become necessary. The SWTREA has already made some unofficial plans for such an action if it should take place.

H. ADMINISTRATIVE AND PUBLIC RELATIONS

There is a continuous stream of paperwork and documentation which needs to be dealt with during the seeding season. Forecasts are distributed via email to interested parties on a daily basis. Detailed individual seeding reports and climate outlooks are also disseminated on an as needed basis. Monthly summaries are compiled and sent to the TDA and to the head SWTREA office in Carrizo Springs to satisfy their requirements. An initial report and final yearly seeding summary is sent in at the end of the season to the National Oceanic and Atmospheric Administration (NOAA) as well as this final report available to the board of directors and the public at the end of each seeding season. From time to time there are numerous other responses needed, answering public inquiries, researching data, and the large volume of phone calls to the field office during seeding events.

Public relations provide a valuable contribution to this program, long-term. Without the continuing effort to maintain favorable public attention, we run the risk of marginalizing our program. Occasionally, newly elected officials serving as commissioners may not be as well acquainted with our program or its results as some of their predecessors. In order to ensure that the current participating counties feel justified in continuing to support the program, some periodic educational effort is necessary. Typically, most of the public relations efforts are directed toward individuals and groups visiting the radar site and our remote aircraft locations. School classes for some of the group visitations as well as periodic presentations to service organizations and other groups with are spoken to at regularly scheduled meetings or annual meetings. Public relations is one of the top priorities of the SWTREA. The program is always happy and willing to speak at public functions or simply answer questions over the phone. Interested parties can also find program information and real-time radar images on our web page: http://www.swtrea.org

IV. Operational Summary

May 2003: The first twenty-one days were very quiet and dry. Several dry cool fronts pushed through the area in very stable environments so no showers or thunderstorms formed along these fronts. On the morning of May 22 some widely scattered showers and thunderstorms popped up in the target area but none strong enough to seed formed in Uvalde County. Mostly sunny skies returned to the region again on the 23rd and 24th with mostly cloudy skies returning on the 25th. Very late on the evening a line of showers formed to the west and then moved into the target area early on the 26th and a reconnaissance flight was launched over Uvalde County to explore the line. A reconnaissance flight was launched in the early morning hours to explore these. A stationary upper level system and its associated cool front moved through the area early on the 27th and one seeding flight was launched for rain enhancement. As high pressure was building into the area on the 28th a couple daytime heating showers popped up over Webb County and a rain enhancement mission was flown in the early afternoon. This was the last flight of May as high pressure took firm control that afternoon and stayed in control through the 31st. May was a slow month as only two flights was flown.

June 2003: June was a very active and wet month over the target area. June got off to a quick start with high pressure moving out of the 1st. A line of thunderstorms formed along a frontal boundary moving south through Texas. The line came through the area in the early evening but the portion of the line in Uvalde County was too weak to seed. On The 3rd and the 4th a shortwave trough moved across the area but seedable conditions didn't exist until the 4th. The flight on the 4th came at midnight for a rain enhancement over Uvalde County. Early on the 5th a line of thunderstorms moving southeast came through the project area. The first flight of the day took place in midmorning for rain enhancement over Uvalde County along this line. A second flight was also launched during midmorning for rain enhancement/hail suppression over Uvalde County. A cool front pushed through the area that night giving way to high pressure from the 6th through the 9th. On the 10th another cool front pushed through the area bringing another round of showers and thunderstorms. One seeding flight and one reconnaissance flight were flown in the early morning as the cool front and line pushed through Uvalde County. Tranquil weather occurred on the 11th and 12th. A shortwave pushing through the area on the 13th bringing a line of thunderstorms through the area during the evening hours but no flights were launched On the evening of the 14th another line of thunderstorms pushed by to the north of the target area. Another line of thunderstorms broke out in the early morning hours of the 15th. A seeding flight took place over Uvalde County. No activity occurred from the 16th through the 25th but the heat and humidity were in place from the 23rd on. On the 26th a line of showers and thunderstorms moved through the area from the north during the evening hour but were no strong enough for seeding until it left Uvalde County. A shortwave trough moving east through Texas combined with the sea breeze in the early afternoon hours to produce an area of showers and thunderstorms from Uvalde County southward. A seeding flight took place that afternoon for Uvalde County at the showers and thunderstorms moved to the east. The same triggers that kicked off the activity on the 27th continued through to the 30th. These storms tended to be isolated to scattered and very weak so no seeding operations were conducted. A total of five flights were flown during the month.

July: July 2003 was another wet month. On the 1st, daytime heating showers and thunderstorms popped across the target area but they were too weak to seed. On the 2nd a upper level trough over Northern Mexico helped to spark another round of showers and thunderstorms. The only flight of the day was a rain enhancement mission took place over Uvalde County in the early evening. Nothing changed weather wise from the 2nd to the 3rd so everything was in place for another day of convective activity. In the late afternoon a weak thunderstorms popped up in Uvalde County and an aircraft was dispatched for reconnaissance purposes. On the 4th and 5th the upper level trough was stalled over south Texas providing good lift but cloud cover inhibited any convection. The trough that dominated the weather for the first part of the month drifted westward taking with it, the best chance of precipitation. However the atmosphere was still unstable enough to pop some showers and thunderstorms across the area from the 6th through the 8th. One these days showers formed and were too weak to seed. The low weakened on the 9th as high pressure in through the 12th. The 13th and 14th were also calm days over the forecast area as high pressure combined with dry air to hold back convection. On the 15th and 16th Tropical Storm Claudette moved through the target area. Seeding missions were not conducted on the 15th due to the prospect of heavy rain and flooding. On the 16th as the remnants of Claudette moved westward, more shower and thunderstorm developed in the afternoon. A rain enhancement/hail suppression flight was flown in the early to late afternoon over Uvalde County. The unstable air mass remained in place on the 17th but only weak showers developed. High pressure built into the area on the 18th and kept the weather quiet through the 22nd. On the 23rd scattered showers and thunderstorms developed along a cool front moving through south Texas. One rain enhancement mission was flown during the late afternoon over Uvalde County. With the front past the area on the 24th high pressure would build in through the next day. High pressure was in place on the 26th, but moisture streaming into Texas from the south brought some instability to the area. The atmosphere was unstable through the 31st when a cool front sagging southward brought some light shower activity to northern sections of the forecast area. A total of 3 flights took place during the month.

August: From August 1st through the 8th strong high pressure controlled the weather in south Texas. On the 9th the area of high pressure began to weaken allowing energy from a convective complex in northeast Texas to come our way. This energy came through the target area during peak heating and it touched off some widely scattered weak showers and thunderstorms across the target area There was no seedable weather on the 10th but showers and thunderstorms would return again on the 11th. High moisture values and a trough were coming into place on the 11th and stayed through the 16th. One reconnaissance flight was flown in the early morning hours of the 12th over Uvalde County. Later in the afternoon of the 12th scattered showers and thunderstorms popped up over Uvalde County for the 2nd flight of the day. During the late morning hours of the 13th, a round of showers and thunderstorms popped up over Uvalde County giving us another rain enhancement mission. No more flights took place during the remainder of the period. A stable air mass moved into place in the wake of the tropical moisture from

Erika as it passed south of the region. This more stable air mass stayed in place through the 21st. A shortwave riding underneath the south side of an area high pressure brought widespread but weak showers and thunderstorms to the forecast area late in the day on the 22nd. After the shortwave passed through the area, a unstable atmosphere remained in place across south Texas from the 23rd to the 25th. On the 24th one rain enhancement mission took place over Uvalde County. The atmosphere began to stabilize on the 26th but a chance of showers and thunderstorms still existed. On the 26th the atmosphere continued to stabilize and would remain that way through the 30th. On the 31st a very complex weather pattern was in place over south Texas. The remnants of Tropical Storm Grace was coming inland near Port O'Connor and stationary front extending southward from a surface low in southern Oklahoma through Maverick County. Mainly unseedable conditions were in place with the showers and embedded thunderstorms. Three flights took place during the month.

September: The remnants of Tropical Storm Grace combined with a stationary front brought shower and thunderstorm activity from the 1st through the 5th. Uvalde County would not see any seeding activity from this until the 4th and again on the 5th The first flight of September took place in the mid-afternoon. On the 5th another rain enhancement flight took place in mid-afternoon. High pressure started to build in late on the 5th and continued to be in firm control through the 8th. On the 9th moisture and daytime heating popped some widely scattered thunderstorms across the target area. On the 11th as a cold front moving southeastward across Texas touched off numerous showers and thunderstorms and two flights were flown over Uvalde County. The first flight took place in the late afternoon as some showers and thunderstorms popped up. The second flight took place late on the 11th and lasted into the 12th. This flight was a long a very strong line of showers and thunderstorms moving just out ahead of the cold front. Weak high pressure built into the area behind this front on the 12th through the 13th. On the 14th a shortwave trough moving across Texas to the north of the target area touched off to rounds of showers and thunderstorms. This prompted a rain enhancement flight during the morning hours. Shortwave troughs brought the chance of showers and thunderstorms to the area from the 15th through the 22nd. Most of the showers and thunderstorms were very weak. A weak cool front pushed through the region on the 19th bringing slightly drier weather through the 20th. The night of the 20th light rain showers moved through the area as an upper air disturbance approached the region. Light to moderate rain continued through the 21st. Although rain was in place rain showers were too weak too seed. The 22nd through 25th was a quiet period as most systems stayed far to our west. The system approached the area on the 26th with most of the precipitation staying off to our northwest. The cool front, which caused this precipitation, passed through the area on the 27th bringing drier and more stable weather from the 28th through the 30th. A total of 5 flights were flown during the month

October: October starts out warm and dry with a dry cool front moving through the area on the 1st. High pressure would build into the area on the 2nd and stay through the 3rd when another cool front would approach. The cool front stalled out north of the target area with some weak shower activity moving through the target area on the 4th. A disturbance moving eastward along this front on the 5th brought some shower activity to our area. Another disturbance was moving along the front on the 6th bringing more weak shower and thunderstorm activity to the region. Later that evening a rain enhancement flight took place over La Salle and Uvalde County. A weak area of high pressure remained in control but very high moisture values remained in place with the sea breeze kicking off some showers and thunderstorms on the 7th. All activity was weak so no seeding was done for this activity. High moisture values in conjunction with a disturbance moving across north Texas brought some showers across the target area through the 9th. On October 11th as another trough was moving toward the target area with very deep moisture present in the atmosphere with a cold front close on its heals for the 12th. Heavy rain and thunderstorms formed over the target area that night but low cloud ceilings and nightfall prevented the possibility of flight. Very heavy rain fell throughout the target area until early Sunday morning. Flash flood warnings were issued within two hours of the onset of the event. Light showers fell in the forecast area until a strong but dry cold front pushed through the area on the 14th. High pressure quickly built into the area and remained in control until another dry cold front pushed through the area on the morning of the 17 and high pressure quickly built in through the weekend. High pressure remained in control through the 24th. Another dry cold front pushed through the target area late in the day on the 25th. The cold front was shallow and allowed warm moist air to remain in place above the cold air. This caused some very weak showers across the area on the 26th and 27th. On the 28th high pressure took control through the 30th with increasing moisture each day. On the 31st the increase in humidity brought some weak showers to the target area. October was very slow with only one flight flown.

Table 1: MAY 2003 EAA FLIGHT SUMMARY

(Seeded as Target Area)

Flight #	Date	Aircraft	Total Time	Counties	Materials Used	Total Seeding
			(hours)			Material
R-6	5/26/2003	N7370P	0.33	Uvalde	n/a	n/a
S-11	5/27/2003	N7370P	0.58	Uvalde	3 BIP Flares (80g)	240g AgI
TOTALS			**0.91**		**3 BIP Flares (80g)**	**240g AgI**

Table 2: JUNE 2003 EAA FLIGHT SUMMARY

(Seeded as Target Area)

Flight #	Date	Aircraft	Total Time (hours)	Counties	Materials Used	Total Seeding Material
S-18	6/4/2003	N9370P	1.25	Uvalde	3 BIP Flares (80g)	240g AgI
S-19	6/5/2003	N6498P	1.5	Uvalde	20 BIP Flares (80g)	1,600g AgI
S-21	6/10/2003	N6498P	1	Uvalde	3 BIP Flares (80g)	240g AgI
S-24	6/15/2003	N9370P	1.33	Uvalde	3 BIP Flares (80g)	240g AgI
S-26	6/26/2003	N6498P	1	Uvalde	3 BIP Flares (80g)	240g AgI
TOTALS			**6.08**		**32 BIP Flares (80g)**	**2,560g AgI**

Table 3: JULY 2003 EAA FLIGHT SUMMARY

(Seeded as Target Area)

Flight #	Date	Aircraft	Total Time (hours)	Counties	Materials Used	Total Seeding Material
S-33	7/2/2003	N6498P	1.25	Uvalde	10 BIP Flares (80g)	800g AgI
S-38	7/16/2003	N9370P	1	Uvalde	1 BIP Flare (80g)	80g AgI
S-39	7/23/2003	N6498P	2.58	Uvalde	12 BIP Flares (80g)	1,410g AgI
					90 minutes 2 Generators	
TOTALS			**4.83**		**23 BIP-80g Flares** **3 Generator Hours**	**2,290g AgI**

Table 4: AUGUST 2003 EAA FLIGHT SUMMARY

(Seeded as Target Area)

Flight #	Date	Aircraft	Total Time (hours)	Counties	Materials Used	Total Seeding Material
S-47	8/12/2003	N7622Q	0.75	Uvalde	4 BIP Flares (40g)	160g AgI
S-48	8/13/2003	N7622Q	1.25	Uvalde	6 BIP Flares (40g)	720g AgI
					6 BIP Flares (80g)	
S-54	8/24/2003	N7622Q	2.5	Uvalde	12 BIP Flares (40g)	640g AgI
					2 BIP Flares (80g)	
TOTALS			4.5		22 (40g) BIP Flares 8 (80g) BIP Flares	1520g AgI

Table 5: SEPTEMBER 2003 EAA SUMMARY

(Seeded as Target Area)

Flight #	Date	Aircraft	Total Time (hours)	Counties	Materials Used	Total Seeding Material
S-60	9/3/2003	N7622Q	0.25	Uvalde	2 BIP Flares (40g)	80g AgI
S-63	9/4/2003	6498P	0.66	Uvalde	1 BIP Flare (40g)	200g AgI
					2 BIP Flares (80g)	
S-65	9/5/2003	6498P	0.42	Uvalde	4 BIP Flares (40g)	320g AgI
					2 BIP Flares (80g)	
S-67	9/11/2003	98P	1.56	Uvalde	2 BIP Flares (40g)	400g AgI
					4 BIP Flares (80g)	
S-68	9/11/2003	N7622Q	1.52	Uvalde	14 BIP Flares (40g)	560g AgI
S-69	9/14/2003	N7622Q	2.53	Uvalde	11 BIP Flares (40g)	440g AgI
TOTALS			6.94 hrs		34 BIP Flares (40g) 8 BIP Flares (80g)	2000g AgI

Table 6: OCTOBER 2003 EAA FLIGHT SUMMARY

(Seeded as Target Area)

S-73	10/6/2003	370P	0.63	Uvalde	1 (40g) BIP Flare	40g AgI
TOTALS			**0.63**		**1 (40g) BIP Flare**	**40g AgI**

Table 7: 2002/2003 EAA COMPARISON

YEAR	2002			2003		
MONTH	**# of flights**	**Total Seeding Material**	**# of seeding days**	**# of flights**	**Total Seeding Material**	**# of seeding days**
MAY	5	6,380g AgI	3	2	240g AgI	1
JUNE	7	8,525.3g AgI	4	5	2,560g AgI	5
JULY	2	331g AgI	1	3	2,290g AgI	3
AUGUST	2	491g AgI	2	3	1,520g AgI	3
SEPTEMBER	0	0g AgI	0	6	2,000g AgI	5
OCTOBER	1	280g AgI	1	1	40g AgI	1
TOTAL	**17**	**16,0673.3g AgI**	**11**	**20**	**8,650g AgI**	**18**

V. 30-YEAR AVERAGE ANNUAL PRECIPITATION MAPS

The following maps show the 30-year average rainfall distribution of the SWTREA target area. The contours on the maps are in ¼ inch intervals. The maps show the average rainfall distribution per month for the years 1971 to 1990. Although the maps are historically accurate they do not show the rainfall that may have fallen for any particular month during that 30-year period. Also the maps do not show areas where flooding may have occurred during the 30-year period.

These maps clearly show a vast contrast in the amount of rainfall received over the target area. The first contrast that can be seen in the map is the rainfall difference between the eastern (La Salle and Webb Counties) and western (Dimmit, Uvalde and Webb Counties) portions of the target area. There are a few meteorological reasons why this contrast may occur. One of the culprits may be the "sea breeze" which occurs during the summer months. The sea breeze is generated because land and water heat differently causing a contrast in temperatures. These temperature contrasts help to initiate the sea breeze. As the breeze moves on shore, it creates shower and thunderstorm activity, which propagates inland with the breeze. The sea breeze shower and thunderstorm activity usually enters La Salle and Webb County in the late afternoon. Why don't these showers and thunderstorms continue to propagate inland? By late afternoon the sun begins to set and as the sunsets the sea breeze looses its energy. Over time the land cools more rapidly than the water, which causes a temperature difference. This difference causes the wind to shift direction and become a land breeze cutting off the shower and thunderstorm activity's main feeding mechanism. Once this occurs, shower and thunderstorm activity dies before it exits La Salle or Webb County; thus the precipitation never makes it to the western target area. Another reason for the rainfall contrast may be the tropical disturbances that move along or inland from the coast from June through late October. This is evident on this year's maps as Tropical Storms brought heavy rainfall to the target area in July and September.

These maps also show a large difference in rainfall between northern (Dimmit, La Salle, Uvalde, and Zavala Counties) and southern (Webb) sections of the target area. Historically, the northern portion of the target area receives more rainfall than the southern portion of the target area. The difference mainly occurs during the spring and fall months, which is one cold fronts and drylines. These systems can move through the target area at anytime. This happened many times this year as several cold fronts moved through or stalled over the target area in June and July. Even when the cold fronts do not make it to south Texas we can still receive thunderstorms as supercell, squall lines and mulitcell storms can propagate out to 100 miles from the a cold front or dryline. Historically, Texas receives most of its rainfall during the spring and fall months instead of the summer.

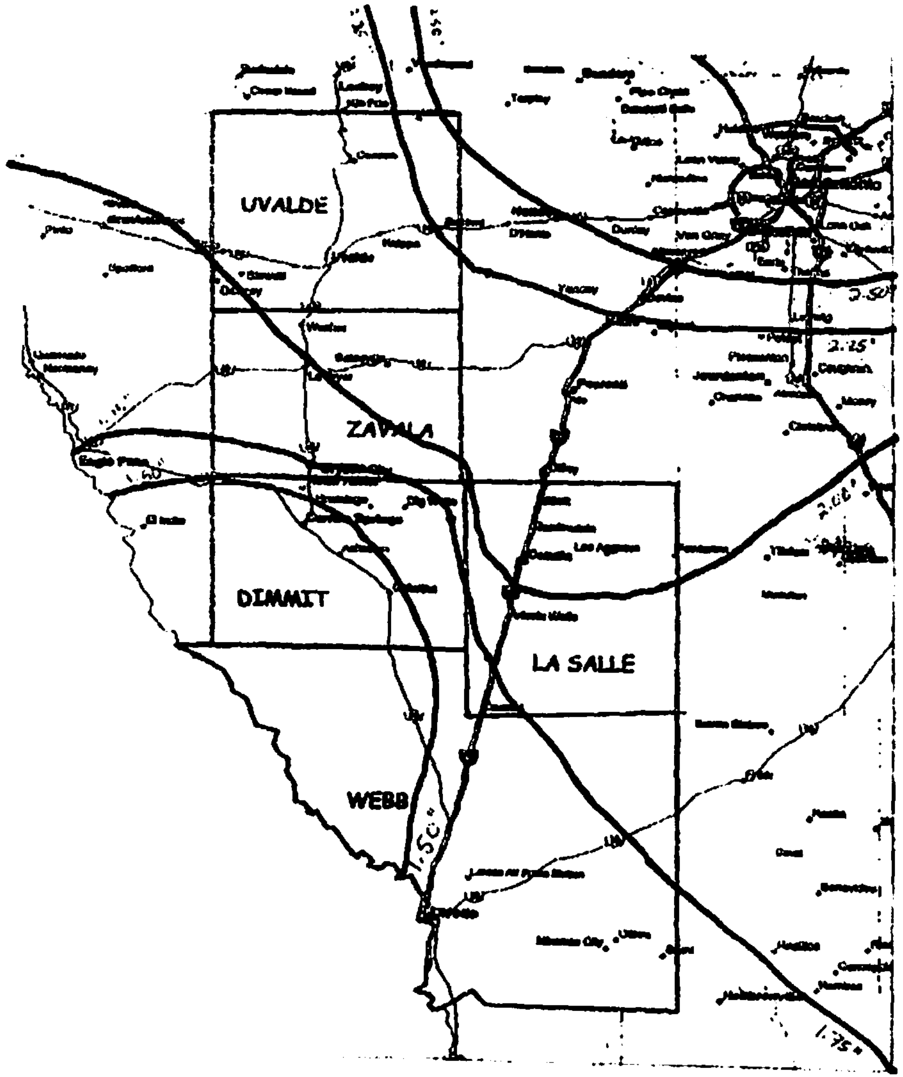


Fig. 12-May 30-year Average Rainfall

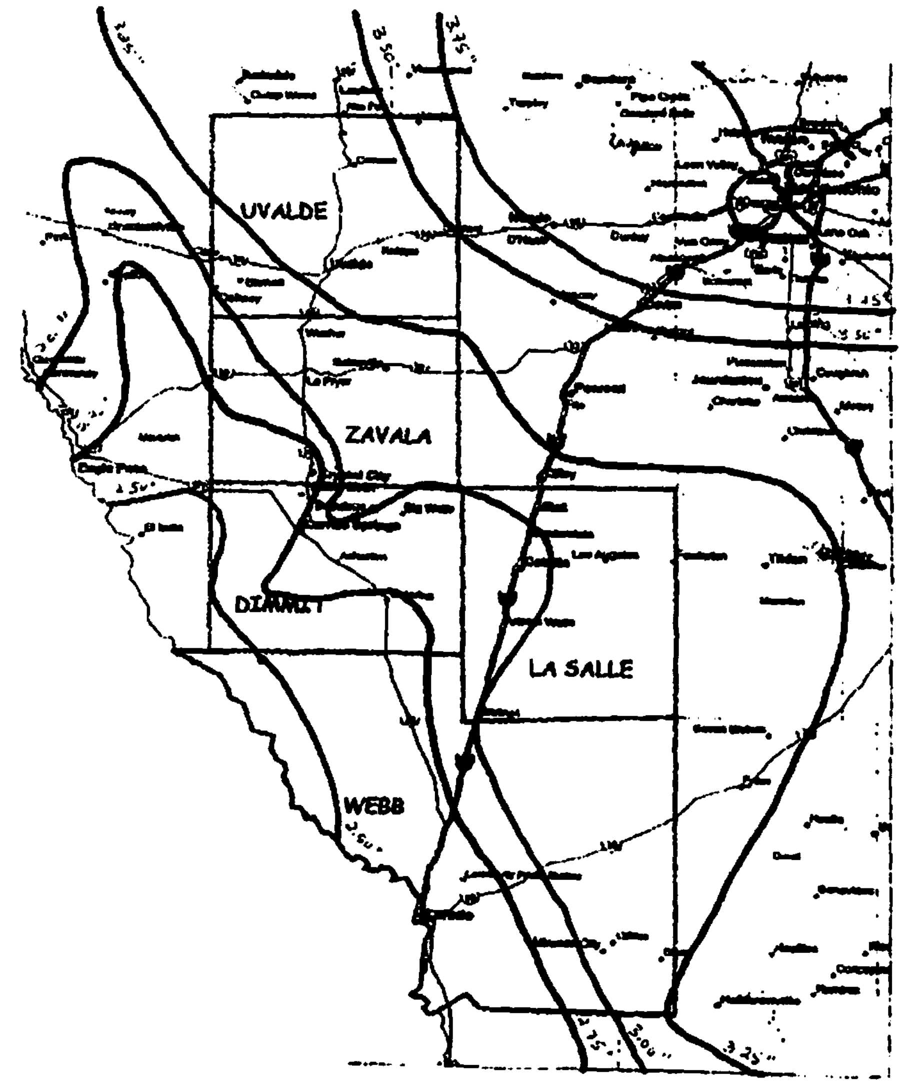


Figure 13-June 30-year Average Rainfall

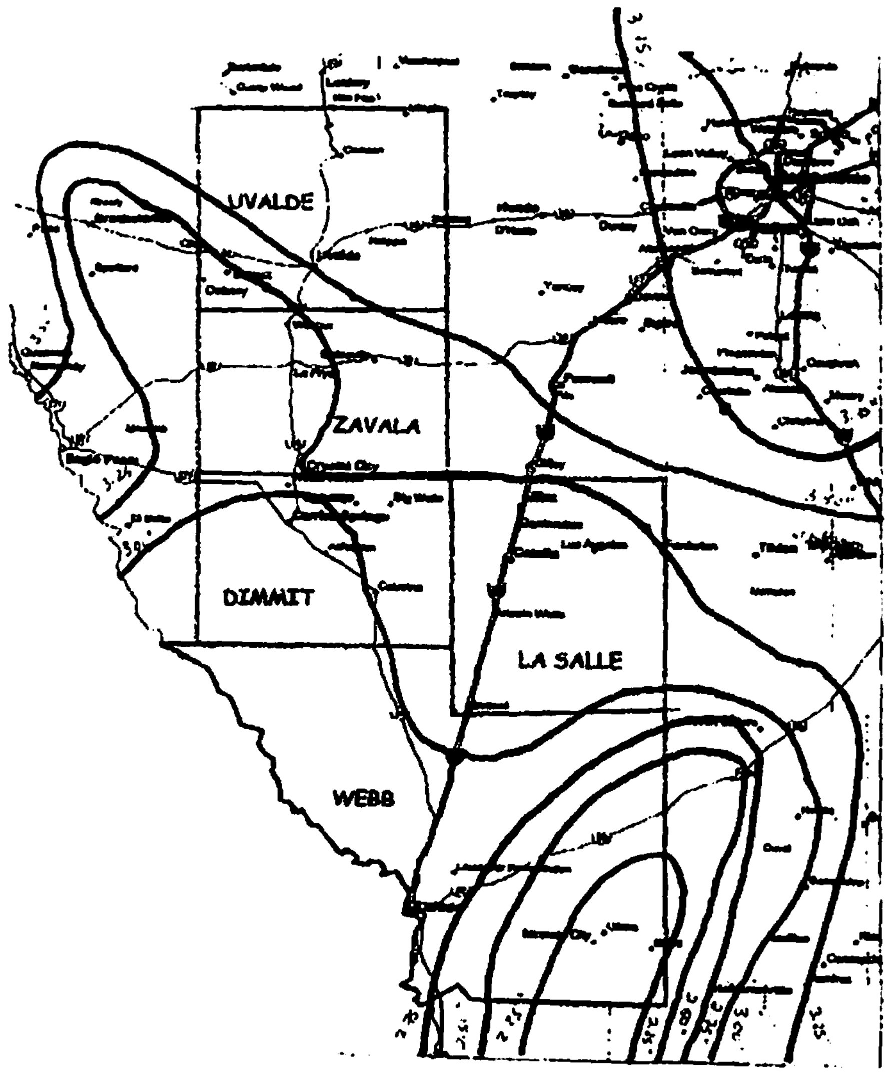


Figure 14-July 30-year Average Rainfall

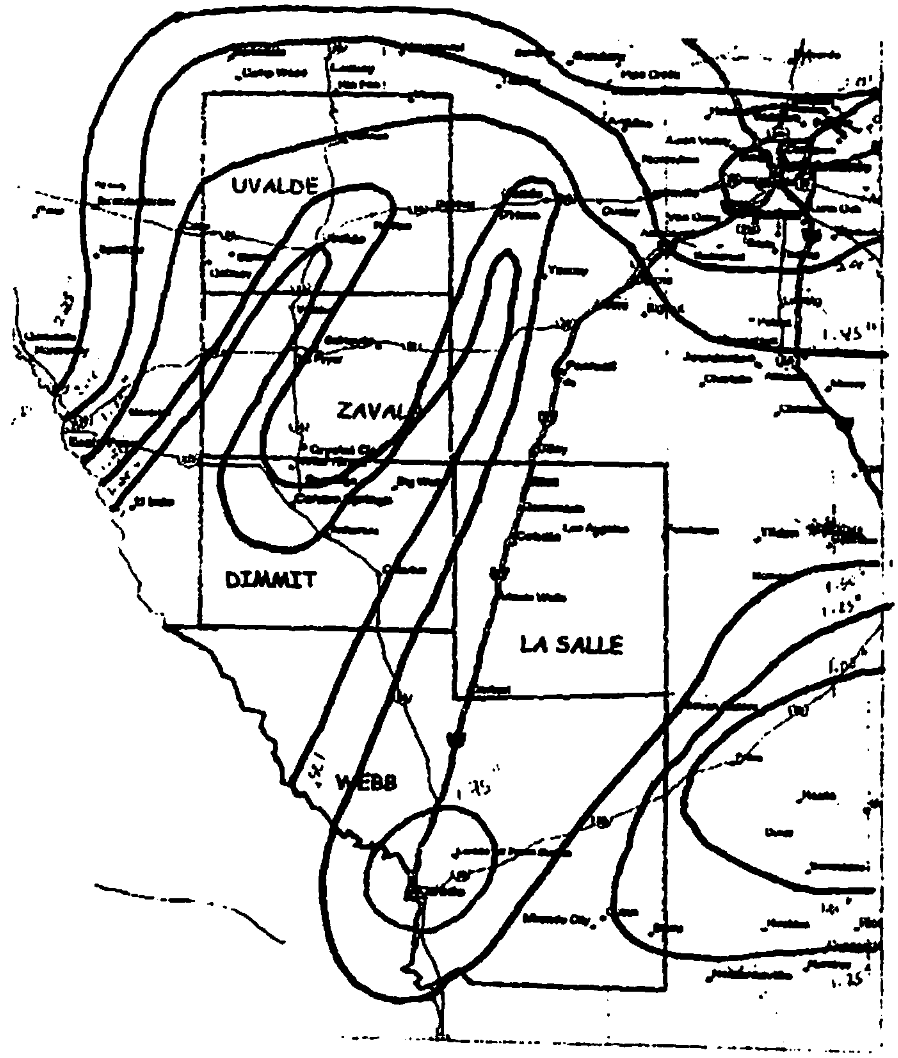


Figure 15-August 30-year Average Rainfall

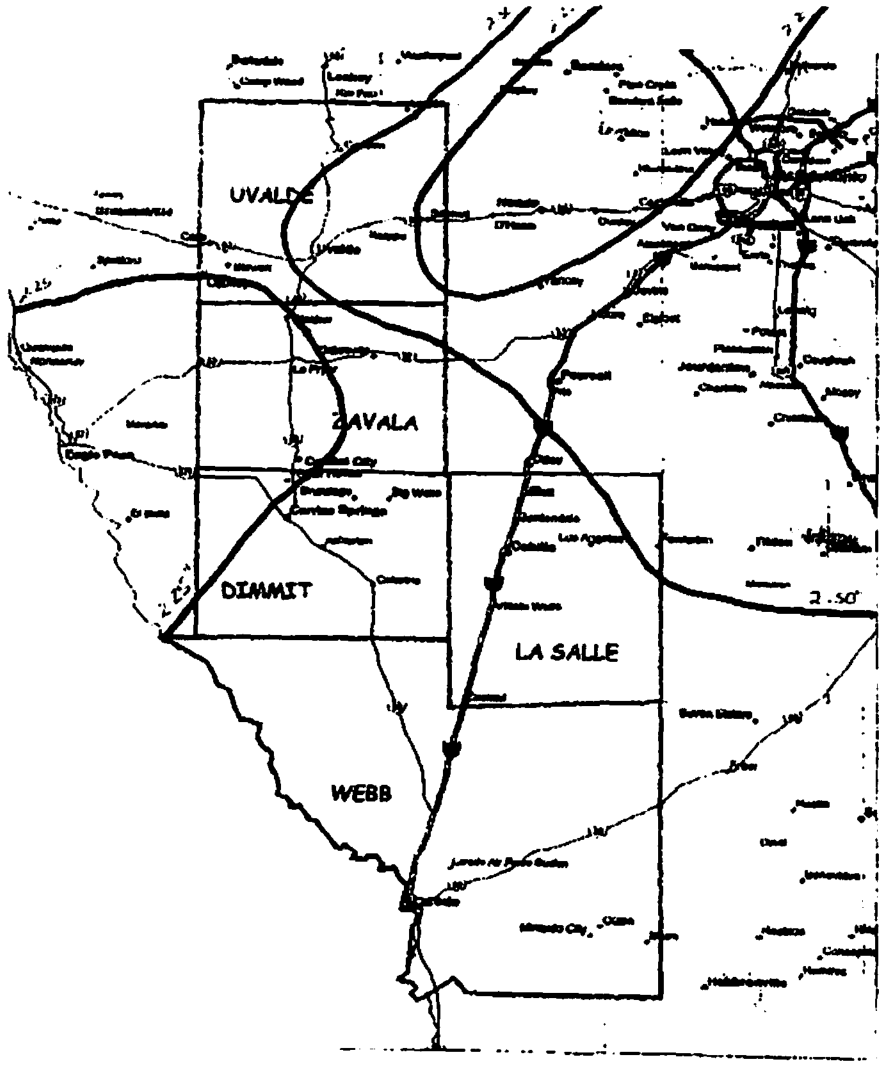


Figure 16-September 30-year Average Rainfall

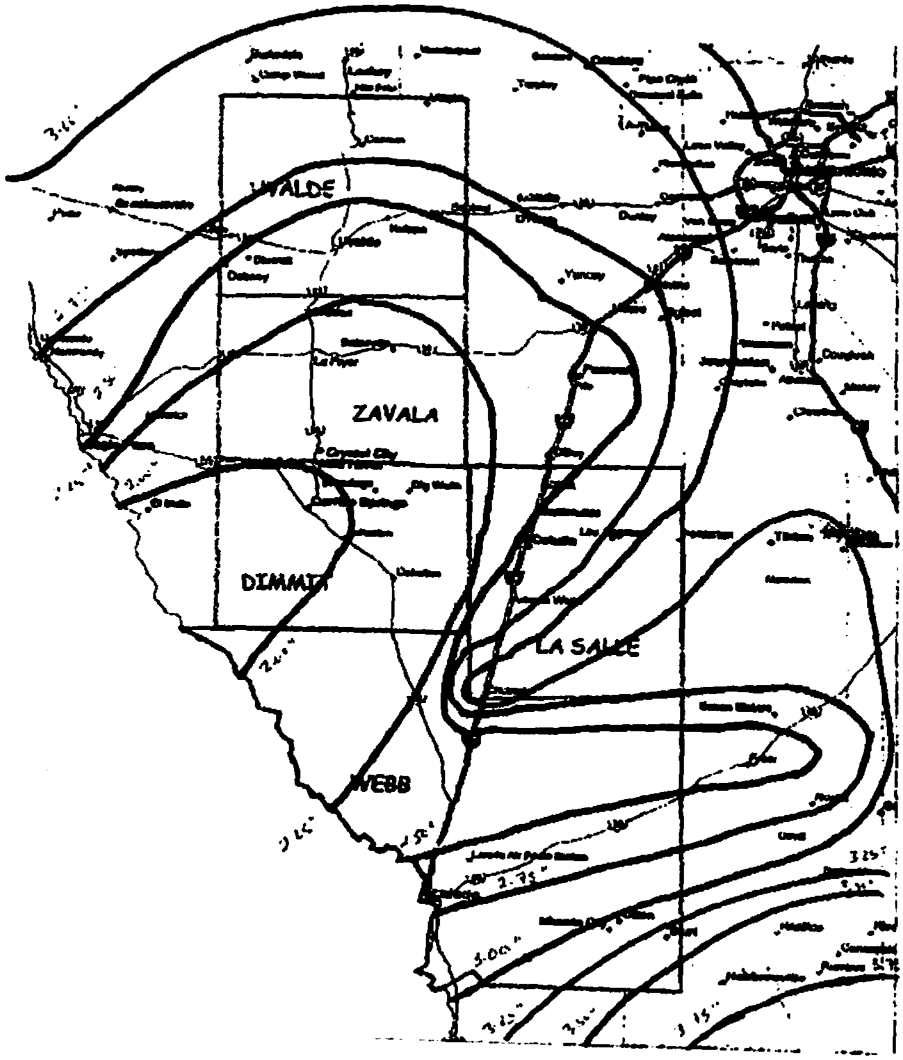


Figure 17-October 30-year Average Rainfall

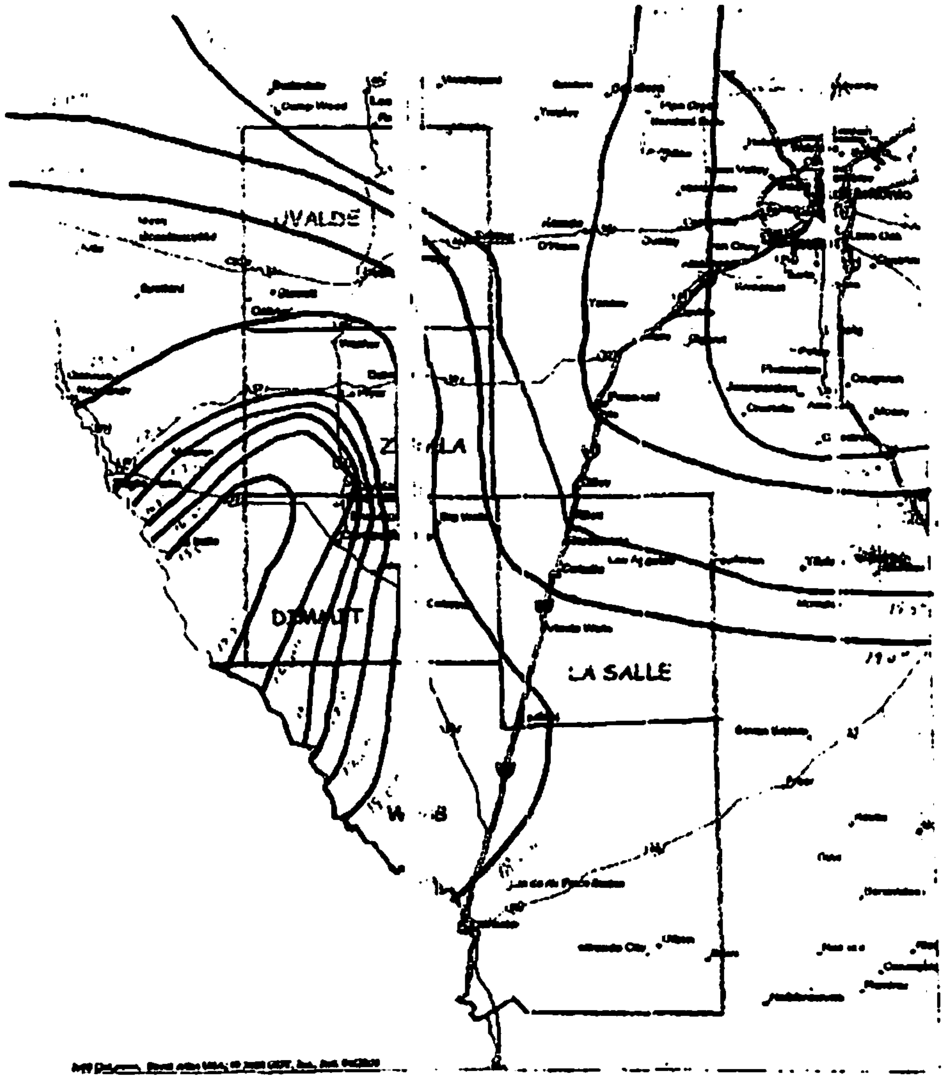


Figure 18 – Total of the 30-Year Average Rainfall (May – October)

VI. MONTHLY PRECIPITATION MAPS

The following maps show the rainfall received over the target area from May through October. November rainfall reports were not available for the entire target area at the time this report was written. The contour intervals vary from month to month on these maps due the fact that during certain months the rainfall distribution was very large. During the months of May and August the contour intervals is 1/4inch. The interval for June is ½ inch. The interval for July, September and October is 1 inch. Finally the contour interval for the May – October Map is 2". The months of May and August were average while May was well below average for the target area. June, July and September were all above average for the target area due to numerous summer cold fronts and the remnants of two Tropical Storms moving through the target area. One rain event in October from the 11th to the 12th is what brought the high amounts of precipitation to the target area for the month. A Mesoscale Convective System stalled out over the southern half of the target area that night and brought very heavy rainfall to the area.

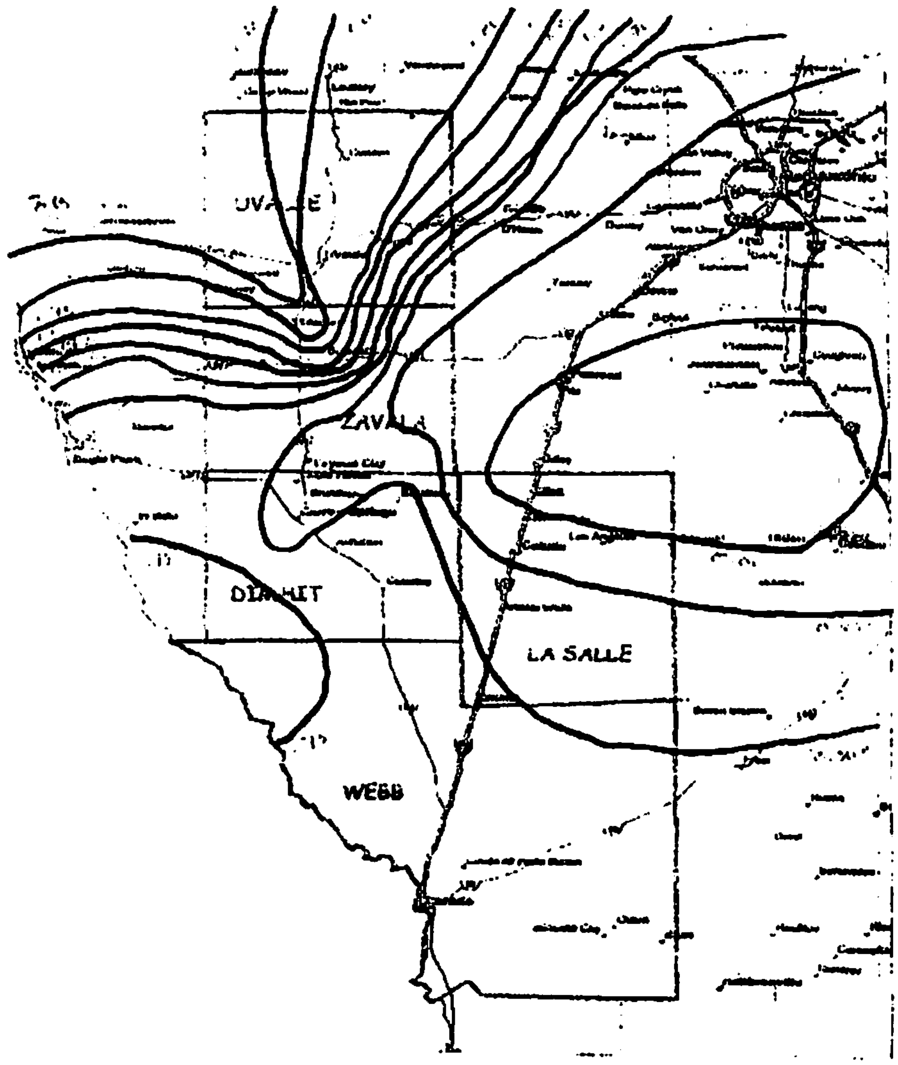


Figure 19-May 2003 Rainfall

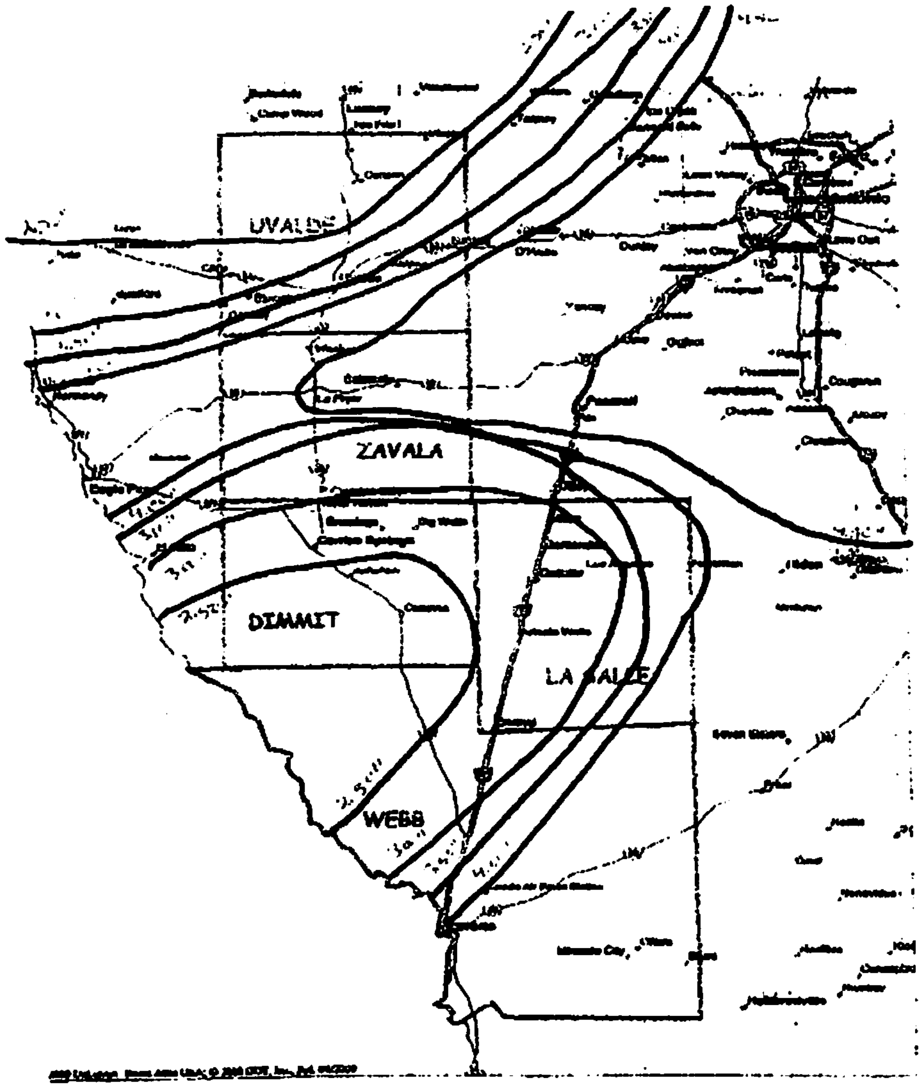


Figure 20-June 2003 Rainfall

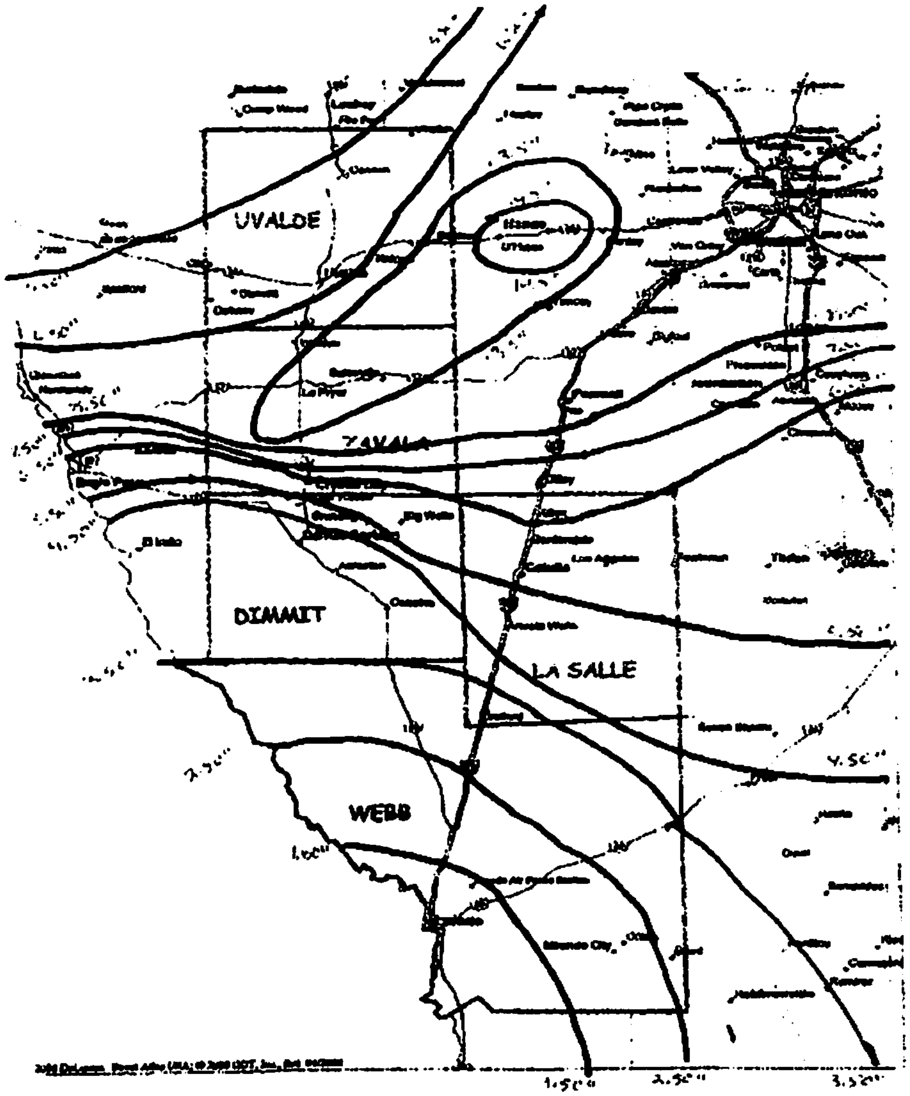


Figure 21-July 2003 Rainfall

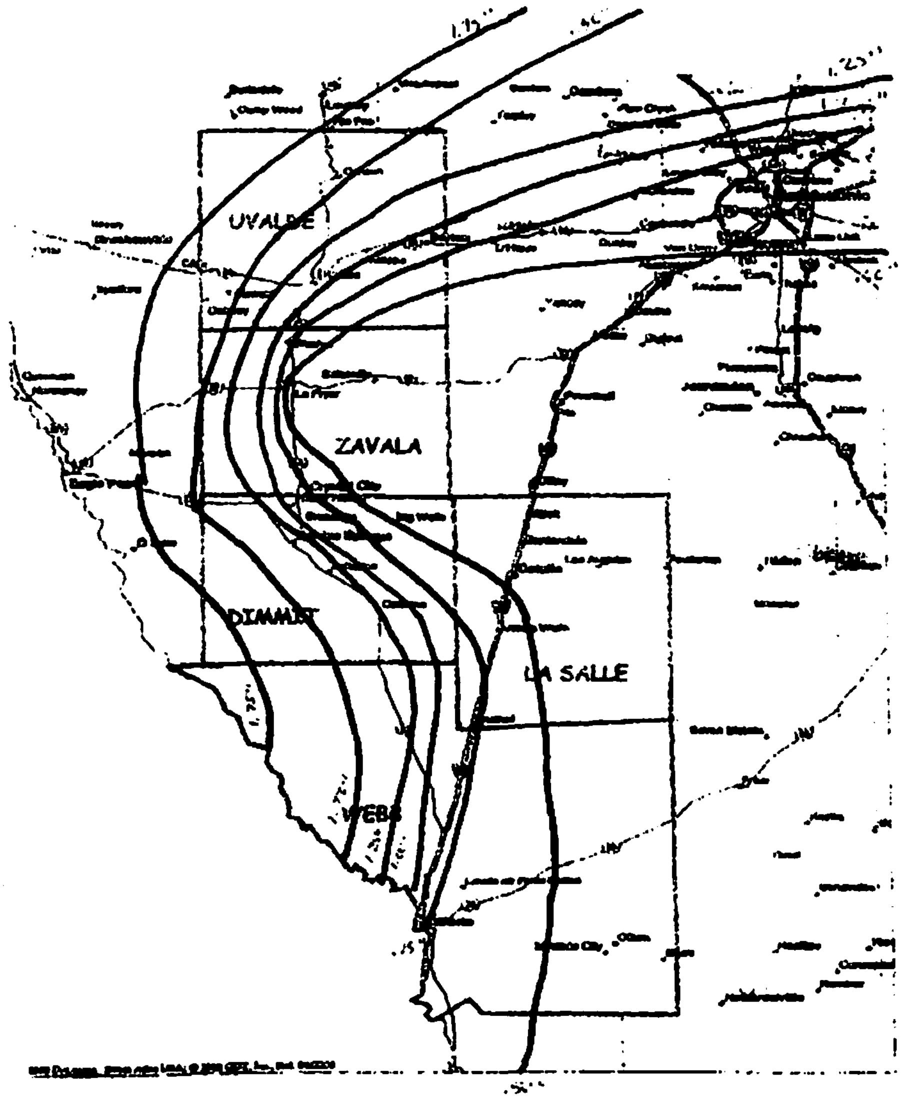


Figure 22-August 2003 Precipitation

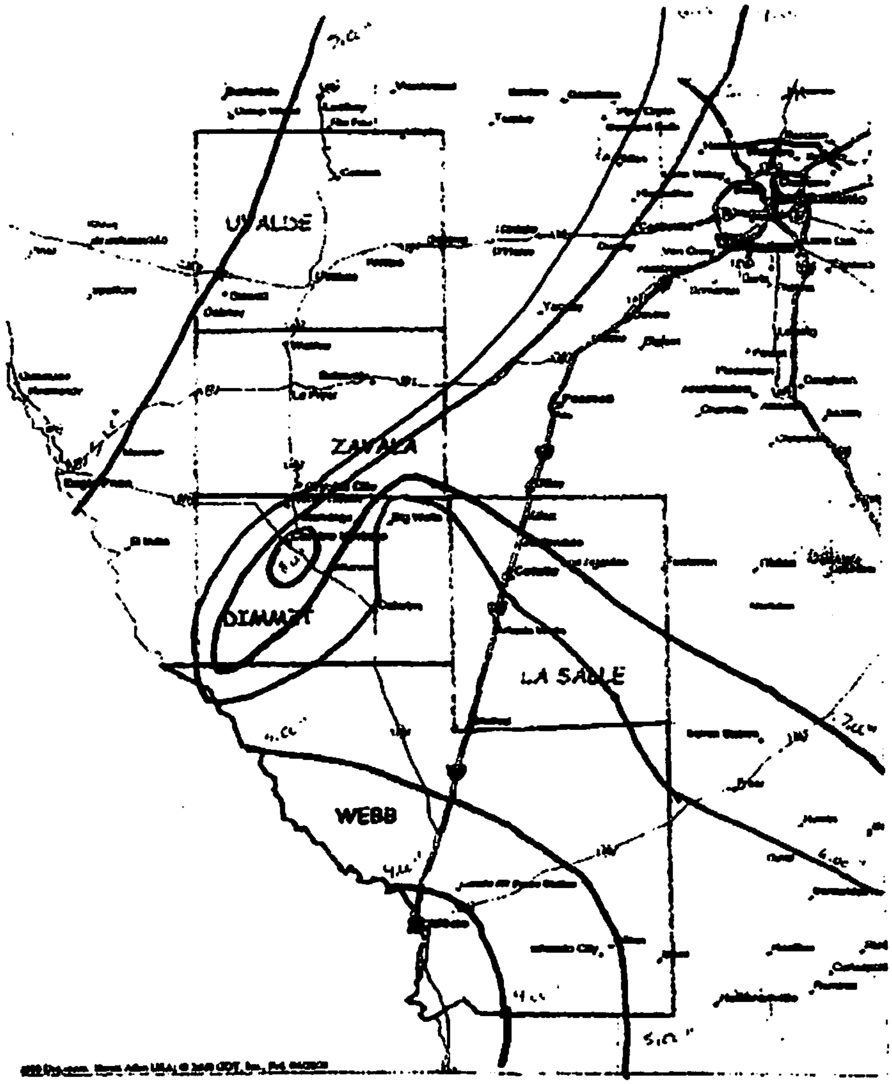


Figure 23-September 2003 Precipitation

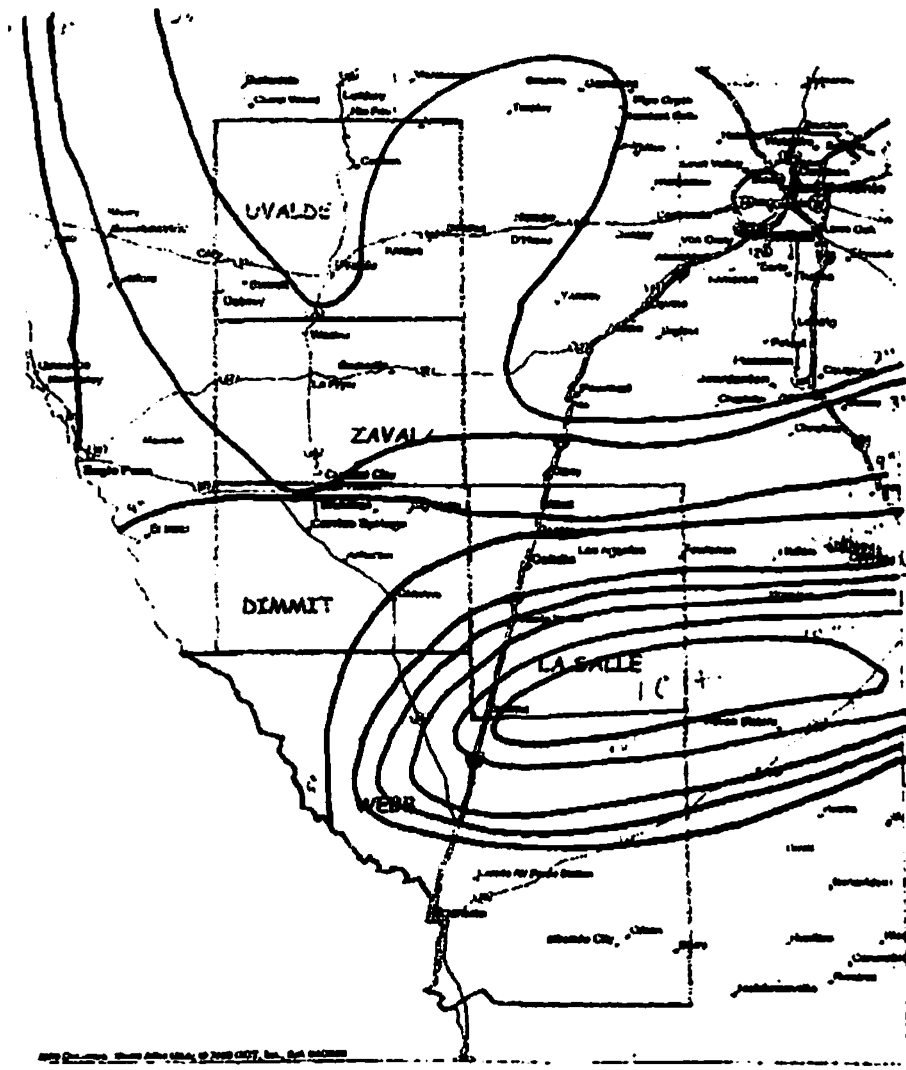


Figure 24– October 2003 Rainfall

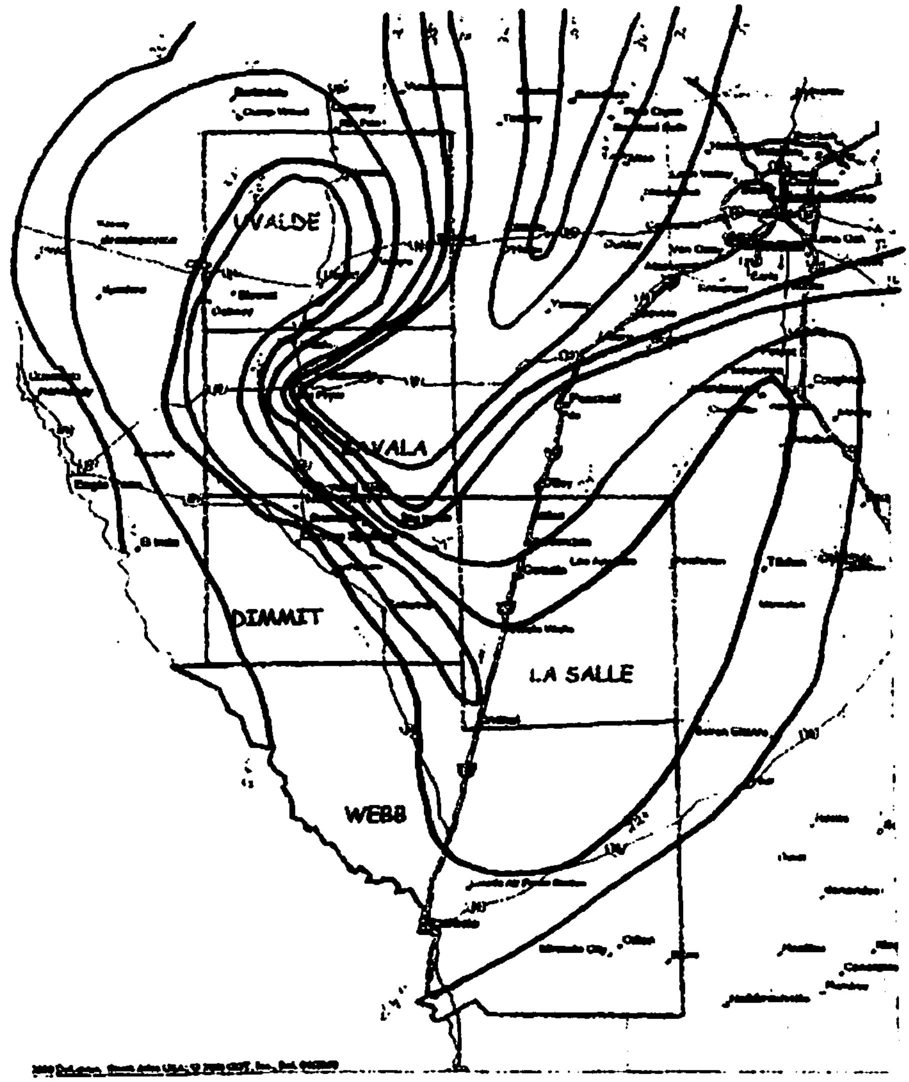


Figure 25 – 2003 Total Rainfall (May – October)

VII. CONCLUSIONS AND EVALUATIONS

The Southwest Texas Rain Enhancement Association has just now completed its fifth year of operations and the third full year of 24-hour 7-day per week cloud seeding. This was a very active year weather wise. There were 100 flights during this year's 8-month season. Of the 100 flights, 28(20 during the contracted season with the Edwards Aquifer Authority) took place over Uvalde County. The SWTREA continued to serve as a demonstration program to many of the other weather modification programs in Texas demonstrating effective rain enhancement and hail suppression techniques on many different types of storms at any time of the day or night.

As per table 7 on page 30, one can see that the 2003 was more active in terms of the number of flights taking place over Uvalde County than the 2003 season. Again the total number of flights in 2003 were 20 as compared to 17 in 2002. One can Also when you compare the 2003 total season rainfall for May through October with the same total for the 30 year average precipitation one will find that the rainfall for 2003 was slightly above normal for Uvalde County. One can also This is supported by the Ruiz Assessment in Appendix A, which shows that an additional 36.733-acre feet of rainfall was created for Uvalde County from cloud seeding activities.

Further more, by looking at the Ruiz Assessment in Appendix A, one can see that the SWTREA aircraft were on time for 87% of the small clouds and 100% on time for large clouds, which formed inside the target area. Timing for type B clouds, clouds that formed outside the target area and are at least 1-hour old, was 48%. The reader may ask why is there such a large on time difference in timing for clouds that form inside the target area and Type B clouds. This is due to the fact that the project must wait for the cloud to enter the operational area to be legally seeded. Therefore one can quickly see that the proper procedure for delivering the agent in the first half-life of the cloud is often not possible. The reader can then infer that the poor timing on type B clouds is often beyond our control.

VIII. ACKNOWLEDGEMENTS
People behind the 2003 SWTREA project

The SWTREA has now completed its fourth year of as a self-sufficient weather modification project. As a result of many hours of consultation, hard work, training, and perseverance, we are confident our ability to continue seeding storms in 2004 and beyond will exhibit the same aggressive and determined manor as this year's performance.

Our Association would like to acknowledge the many individuals that guided and encourage us during the 2003 season. I personally express my utmost thanks to all the tremendous people, many of them listed in this section, who guided me this year on this extraordinary project both professionally and personally. Their brilliance, experience, and dedication were the resources we were able to tap into allowing us to accomplish our goal of continuing our self-sufficient, weather modification project. With immense gratitude we wish to acknowledge and give credit to the following individuals:

The Southwest Texas Rain Enhancement Association Board of Directors:
Bill Martin, Chairman
Chris Hinojosa, Vice-Chairman
Randy Grissom, Secretary
Jay Meyers, Treasurer
Lewis Bracy Jr., Advisor/Director
Bill Dillard, Advisor/Director
Mike Kirk, Director
Joe Finely Jr., Director
John Petry, Director
John Galo, Director
Chris Meyer, Director

APPENDIX A

2003 Results for Uvalde County (EAA) (by Arquimedes Ruiz)

19 clouds were seeded over these counties in 17 operational days.
(3 small clouds, 2 large clouds, 13 type B clouds, and 1 npf case)

Table A: Small seeded clouds(formed inside the Operational Area) versus their control clouds (3 cases)

Variable	**Seeded Sample**	**Control Sample**	**Simple Ratio**	**Increases (%)**
Lifetime	140 min	110 min	1.27	22 **(16)**
Area	119.8 km^2	100.4 km^2	1.19	19 **(26)**
Prec.Flux	554.3 m^3/s	407.4 m^3/s	1.34	34 **(41)**
Prec.Mass	3803.1 kton	2573.9 kton	1.48	48 **(54)**

A total of **15 flares** were used in this sub-sample. Timing was very excellent **(87%)** for an effective dose was about **65 ice-nuclei per liter.**
An increase of 54% in precipitation mass for a control value of 2573.9 kton in 3 cases means:

Δ_1 – 3 x 0.54 x 2573.9 kton = 4 170 kton = 3 382 ac-f

Large clouds

Table B: Large seeded clouds(formed inside the Operational Area) versus their virtual control clouds (2 cases)

Variable	**Seeded Sample**	**Control Sample**	**Simple Ratio**	**Increases (%)**
Lifetime	160 min	145 min	1.10	10
Area	382 km^2	361 km^2	1.06	6
Prec.Flux	2007 m^3/s	1775 m^3/s	1.13	13
Prec.Mass	12 961 kton	8 691 kton	1.49	49

A total of **27 flares** were used in this sub-sample. Timing was excellent **(100%)** for an effective dose was about **25 ice-nuclei per liter** which may have reached higher values in some particular cells.
An increase of 49% in precipitation mass for a control value of 8 691 kton in 2 cases may mean:

Δ_2 = 2 x 9.49 x 8 691 kton = 8 517 kton = 6 907 ac-f

Type B clouds

Table C: Type seeded clouds (formed outside Operational Area) versus their virtual control clouds (13 cases)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	220 min	210 min	1.05	5
Area	1788 km^2	1657 km^2	1.08	8
Prec.Flux	8598 m^3/s	7711 m^3/s	1.11	11
Prec.Mass	22 026 kton	19 323 kton	1.13	13

A total of **179 flares** were used in this sub-sample. Timing was mediocre **(48%)** for an effective dose was about **15 ice-nuclei per liter** which may have reached higher values in some particular cells.
An increase of 13% in precipitation mass for a control value of 19 323 kton in 13 cases may mean:

Δ_3 = 13 x 0.13 x 19 323 kton = 32 656 kton = 26 484 ac-f

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 36 773 ac-f