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OCT 30 2006

Colorado Water Conservation Board

FINAL REPORT

WESTERN KANSAS WEATHER MODIFICATION PROGRAM

2006

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The Western Kansas Weather Modification Program is funded, in part, through the State Water Plan, administered by the Kansas Water Office.

FOREWARD

Seasonal rainfall in Western Kansas in 2006 was below normal to various degrees for most of the target area. Last year, roughly half of the target area counties fell back into the drought while the other half continued an extended moist period going back to 2004. This year, the area had fallen back into the drought entirely for an extended period, which spreads across at least half the United States. For a second year in a row, August turned out to be the best month for rainfall as significant rains fell over much of western Kansas with 64% of target area counties reporting above average rainfall. Also, for a second year in a row, July turned out to be the driest month for the area with only 18% of target area counties reporting a monthly rain surplus. Of course there were some exceptions to this description at each reporting location, but for most of the target area, this scenario fit the area fairly well.

Currently, we can only speculate as to the extent of hail damage sustained to the target area this year. For many years, our program had received hail claim information from a company in north-central Kansas. However, due to a sharp decline in subscribers for the claim information, the company has suspended the dissemination of such information. As a result, we have no information about the extent of hail damage incurred on those who carry crop-hail insurance. Although hail claims alone are not meant to be hard evidence to indicate overall hail reduction, our program used the data to provide us with a fairly quick method of learning the relative amount of crop-hail damage incurred within the target area. However, one could probably say with a fair degree of confidence that crop-hail damage was probably lower than normal given the general lack of storms due to the drought.

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I. BACKGROUND

Probably the first rain stimulation proposal reasonably based upon science was by James P. Espy. In the April 5, 1839 issue of the National Gazette and Literary Register of Philadelphia, Espy proposed building large fires to generate updrafts. He reasoned that in a humid atmosphere cumulus clouds would eventually develop and produce rain. There are no records indicating the scheme led to any field trials, but in the 1880's Congress appropriated $10,000 to conduct some field experiments based on a widely-held idea that "it always rains after a battle". Afterward, tests were performed with explosive charges carried aloft in balloons and optimistic reports followed. However, it was in the 1930s that work done by Tor Bergeron and W. Findeisen which led to the concept that clouds may contain both supercooled water and ice crystals and, in turn, led further to the concepts of "warm rain" and "cold rain" (See Section II).

In 1947 modern scientific cloud modification began in the G.E. Labs at Schenectady, NY. In early laboratory and field trials, Drs. Schaefer, Langmuir and Vonnegut experimented with dry ice and silver iodide as ice nucleating agents. The ice nucleating agents for cloud seeding have changed some with time. However, most seeding agents used today to suppress hail are either dry ice or formulations with silver iodide as one of their components.

In 1972 the Kansas Legislature took a progressive step forward when it enacted the Groundwater Management District Act, an act enabling interested groups to organize and implement area water conservation programs for themselves. Western Kansas Groundwater Management District #1 (WKGMD #1) thus became a legal entity of the State of Kansas.

As WKGMD#1 supporters began identifying program goals and specific objectives, an early objective was to organize, design and implement a perennial weather modification program to seed convective clouds to increase rainfall to help alleviate sub-surface water losses in Western Kansas. The decision to implement such a program came after a thorough review of results from the Kansas Cumulus Project (KANCUP) research program and state-sponsored seeding programs being conducted in North and South Dakota and elsewhere. Hail suppression as an objective fit well into such a program since known results showed rainfall increased when seeding to reduce hail.

WKGMD #1 envisioned its program covering a large area in Western Kansas, operating during the period crops were being planted, grown and harvested. Program objectives were to:

(1) optimize areal rainfall by seeding selected clouds in the absence of severe or potentially severe weather,

(2) decrease the occurrence of crop-damaging hail by seeding potentially severe storms,

(3) demonstrate the feasibility and effectiveness of projects of this type in the Western High Plains states.

The weather modification program implemented in 1975 was first known as the Muddy Roads Program and later changed to the present Western Kansas Weather Modification Program (WKWMP). Fig. 1 shows the year 2006 WKWMP county participants: 11 counties in Western Kansas.

In 1994 a Kansas Water Office evaluation of the WKWMP showed a 27% reduction of crop-hail damage, statistically significant at the 5% level, with a Benefit-to-Cost ratio of 37 : 1. That is, for every $1 in program funding, $37 was returned in increased crop value. Earlier this year, an update to the 1994 KWO evaluation was completed to include the years 1995-2005. The updated evaluation showed the same level of seeding success over the last 10-years as indicated previously in the 1994 study.

2006 Western Kansas Weather Modification
Target Area

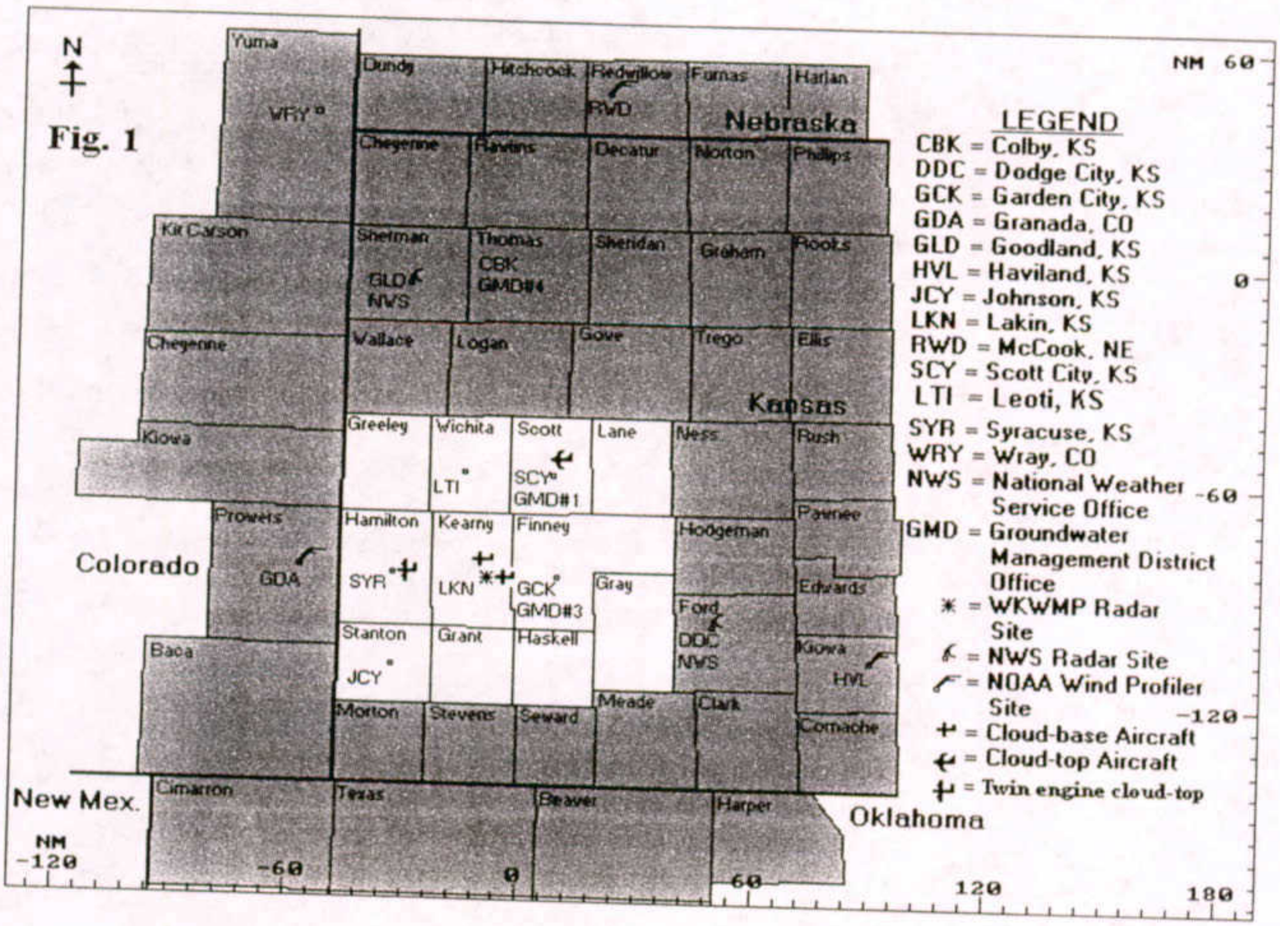


Fig. 1

II. THE PHYSICAL BASIS FOR CLOUD SEEDING

Although a vast amount of knowledge is known generally about clouds, there is still much unknown about those rapidly growing convective (thunderstorm) clouds which can quickly become severe, produce highly destructive hail and surface winds, cause flooding, deadly lightning and produce occasional tornadoes. The following is a simplified explanation of how convective clouds grow to become severe storms as well as the general theory supporting the feasibility of seeding to reduce hail and/or to increase rainfall.

A convective cloud forms when rising air containing water vapor cools by adiabatic expansion reaching a temperature at which condensation occurs to form water droplets. Condensation begins first upon the relatively abundant microscopic atmospheric aerosols, or particles, called cloud condensation nuclei **(CCN)** and include dust, smoke and salt particles. Clouds become visible when a collection of water droplets have grown to sufficient size. The primary mechanisms in Western Kansas causing air to rise and form into convective clouds are:

(1) surface heating

(2) advancing cold and warm frontal systems

(3) relatively cold air in the upper atmosphere sinking into warmer air ahead of it causing warm, moist air to be displaced upward

(4) upslope air flow moving moisture from lower altitudes in Eastern Kansas into higher altitude areas of Western Kansas and Eastern Colorado, usually a post-frontal condition

(5) regions of horizontal convergence created by troughing at the earth's surface, or aloft

(6) Elevated convection---or at least one form of it

(7) upper level low pressure systems (most often associated with low-level convergence, sinking cold air and/or upslope effects)

(8) convective scale interaction resulting from thunderstorm outflows digging under warm, humid air, often forcing a rapid lifting above it into a more unstable atmosphere

(9) gravity waves---very small, internal perturbations traveling through the atmosphere, many of which are created randomly and not easily detectable in real-time. Such waves act much like the effects seen from convective scale interaction.

There is also another atmospheric aerosol present in the atmosphere, termed **ice nuclei (IN)**. These are particles upon which, if found in condensed water droplets, enhance water 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 found in most naturally occurring convective clouds. This fundamental lack of sufficient numbers of IN causes clouds to fail to precipitate efficiently and is thought to be the most significant reason why large, damaging hail can form in clouds. Except in the most complex, chaotic and unstable conditions, cloud seeding is usually able to deliver the needed numbers of IN to correct the imbalances found in most natural cloud systems.

Clouds can be made up of unfrozen water droplets, ice crystals or their combination. 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**." Convective clouds often create a condition in which both unfrozen water droplets and ice crystals simultaneously co-exist; in Western Kansas this is critical to the formation of rain and hail. Super cooled water can remain unfrozen to as low as –40 C (-40 F) before spontaneously changing to ice. When such spontaneous freezing occurs, it is **homogeneous nucleation.**

Supercooled water droplets containing ice nuclei freeze first. The speed at which supercooled water droplets convert into ice crystals increases as cloud temperature decreases. That is, as cloud tops grow higher above the freezing level and temperatures decrease within the cloud, the in-cloud ice crystal production increases. A process called **vapor deposition** 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 which create a pressure gradient between them causing liquid to flow from the droplets to the ice crystals, thereby reducing the cloud water. The ice crystals 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, the unfrozen water subsequently freezing upon impact.

Accretion, or **riming**, occurs when unfrozen water 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 collide repetitively in a complex manner through the processes just mentioned.

When the variously-sized ice particles eventually fall out of the cloud, dropping below the freezing level, they begin melting. If melting is not complete, then hail, graupel (2-5 mm. size snow pellets) or snow reaches the ground as precipitation instead of rainfall.

The sizes and concentrations 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 cloud system can produce precipitation. Although there is a massive amount of water vapor in the atmosphere at any time, precipitation won't occur if certain conditions required for the formation of precipitation are absent. In other words, not every cloud seen overhead is capable of producing precipitation.

Two cloud types produce all precipitation: **"warm clouds"** and **"cold clouds."** A "warm" cloud is one in which the entire cloud volume is at a temperature warmer than freezing and unable to produce ice crystals as a result. The convective warm cloud is characterized most often by relatively slow growth. Warm cloud water droplets eventually may grow to a sufficient size and weight to fall out of the cloud if given enough time. Falling cloud droplets grow larger by scavenging other cloud droplets along their downward paths. Although this type of cloud appears in Western Kansas, it's not the dominant type of cloud producing precipitation here. Interestingly, if warm clouds grow to sufficient heights and transition into cold clouds, the large-sized, warm-rain drops can be important embryo sources in the production of hail when carried aloft rapidly by updrafts into sub-freezing cold cloud environment where eventually they freeze and grow quickly into large hail. While seeding, pilots often find rain falling into below-cloud base updrafts.

However, most important to Western Kansas is the "cold" cloud. Cold clouds tend to be much taller and have more volume than warm clouds, so there is a greater amount of moisture available to the precipitation process developing within the cloud. Cold clouds have a portion of their volume that has risen high enough to have passed into below-freezing atmospheric temperatures. When such clouds form, the interaction between the super cooled water drops and ice crystals within the cloud initiates the process responsible for producing the most significant precipitation in Western Kansas and does so in a relatively short time span compared to warm clouds. Cold clouds are typically the main culprit for heavy flooding rains over a short period of time.

The widely-accepted hypothesis under which the WKWMP hail suppression operates is called "**beneficial competition**." Most, if not all, credible long-term hail suppression programs assume beneficial competition is needed to solve the hail problem. As mentioned earlier, hailstones grow to large sizes in thunderstorms due to the lack of sufficient numbers of IN particles within the cold cloud while it is growing. This natural insufficiency of IN particles allows relatively abundant supercooled water droplets to collect upon the relatively few numbers of ice crystals causing hail to grow to large sizes. 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 increases to the point that hailstones are prevented from attaining sizes large enough to damage crops and property under most circumstances. Hail growth and movement within storms, especially very severe ones, can be very complex. In very strong storms hail may be cast miles away from the storm itself. Hail damage is determined by many factors: the type of crop and the stage of growth the crop was in, the hail size affecting the crop and whether or not it was wind-driven are all important considerations. Those same general factors also apply to any property damaged by hail (i.e. resilience to hail, size of hail, etc.).

The seeding agents used on the WKWMP Program are delivered to clouds by aircraft. Both liquid and solid (flares) complexes of silver iodide (AgI) are used as our cloud base seeding agents of choice. They are vaporized in updrafts at cloud base to produce ice nuclei rising into clouds through the natural action of the cloud's own updraft. Another seeding agent, dry ice, is dropped directly into growing clouds at altitudes above freezing up to −10C while flying through the growing cloud towers feeding the main storm updraft. These "feeder" clouds quickly merge with the parent storm providing it both moisture and potential natural hail embryos. However, the basic effect of seeding is the same in both cases---to promote the formation of abundant numbers of ice crystals within a supercooled cloud volume before large hail can form in that same cloud volume.

AgI-based seeding agents promote ice crystal formation by **heterogeneous nucleation**, when ice crystal numbers increase as temperatures decrease in growing clouds. **Homogeneous nucleation**, however, is the instantaneous change of water droplets into ice crystals at all sub-freezing temperatures such as what happens when dry ice pellets contact water droplets.

Although AgI produces greater numbers of ice nuclei than does dry ice, gram for gram, large numbers of ice nuclei can be produced more quickly by dropping comparatively larger amounts of dry ice directly into the moisture-laden cloud updrafts found in the new-growth feeder cloud towers. Palletized dry ice is dispensed from a container which is augured into a opening in the aircraft floor, subsequently falling directly into the clouds. The container carries about 200 lbs. of dry ice pellets and is released at a rate of 5 lbs. per minute. Relatively large amounts of dry ice are needed to produce the same number of ice crystals from a given mass of AgI, roughly 1,000 to 2,000 grams dry ice is equivalent to a gram of AgI. Dry ice pellets impact clouds water droplets as they fall through the cloud creating ice crystals by homogeneous nucleation. Droplets also may be brought into the wake of the falling dry ice and freeze into ice crystals as well. The main difference in their use is this: AgI based seeding agents, while rising in the cloud, can only begin to create ice crystals at temperatures near –4C to –5C, or roughly 2,000 to 2,500 feet above the freezing level, whereas, dry ice immediately freezes all supercooled cloud water it contacts even down to the freezing level as dry ice has a temperature of –70 Celsius.

High numbers of ice nuclei can be produced by the liquid seeding agent being vaporized in wing-tip generators and exhausted out its tail cone. Generators, one mounted to each wing tip of our cloud base seeding planes, employs a combustion process in which a 3% silver iodide (AgI) liquid seeding solution, produces at its peak, trillions of ice nuclei per gram of AgI consumed. Each generator contains a built-in air pressure tank that forces the liquid seeding solution through an aperture becoming a fine spray. The spray then flows into a combustion chamber where it is vaporized by burning, producing very pure IN particles. These particles exhaust out the tail cone of the generator into updrafts at cloud base where they can be carried aloft by natural action into the cloud's supercooled region.

From 1987 through 1995 the liquid seeding agent was the same: The oxidizers, sodium perchlorate and ammonium perchlorate, were added to a silver iodide-ammonium iodide- water-acetone solution resulting in a solution containing 2% AgI by weight. However, in 1996 the solution was changed to contain AgI, sodium iodide (NaCl), paradichlorobenzene (C6H4Cl2) and acetone. Cloud chamber test results indicated the number of ice crystals produced by the new solution at -10C were nearly equivalent to the old solution containing the perchlorates. Also, these new particles initially acted as hygroscopic CCN which continued to ensure that the vast numbers of water droplets would have a strong tendency to contain IN particles. Another seeding agent composition change came in 2002 as a new formulation came along promoting even more hygroscopic ability as well as activating at a lower temperature. The new seeding agent give us better rainfall optimization capability while at the same time producing high numbers of ice crystals for hail suppression. The new composition contains AgI, ammonium iodide (NH4I), sodium chloride (NaClO4), paradichlorobenzene (C6H4Cl2), water and Acetone. **Contact nucleation** occurs when ice nuclei, initially are not trapped in the water droplets, but eventually are captured by other droplets through random collisions within the cloud, then become ice crystals. The entire process of hygroscopic condensation, followed by freezing and contact nucleation, forms greater numbers of ice crystals at relatively warmer temperatures within a cloud than by simple contact nucleation.

Within supercooled convective clouds there are regions in which the ice crystals that form from water droplets tend to grow into characteristic shapes. This refers to **"crystal habits."** These shapes depend upon the actual temperature of the water when it converts from water droplet to ice crystal. The study of the physical characteristics of ice crystals is complicated, however, there have been some generalized findings which the scientific community appears to accept as repeatable observations:

Near the freezing level, around –3C, super cooled water droplets tend to form into "plate" type crystals which transition into "columns" from –5C to –9C, then back into plates again between –11C and –21C. There are other types of ice crystals within these ranges, but these tend to be the dominant crystal types found. Growth rates of ice crystal mass show a peak at –15C and a smaller one near –7C. Once larger ice crystals are formed they are able to grow in mass much faster than those with smaller crystal shapes, such as needles and columns, and will increase ice crystal formation quickly. Therefore, in order to obtain the desired cloud seeding effects each cloud must be treated within a proper time interval, or window of opportunity, to produce the optimum ice crystal concentrations in clouds naturally deficient in them. A cloud growing to maturity must be treated with enough time allowed so that the generated ice nuclei can be lifted by natural updraft action into, and through, the appropriate temperature and moisture regime and reside there for sufficient time to interact with the supercooled cloud water. If this opportunity window is missed when attempting rainfall stimulation, for instance, clouds can collapse prematurely resulting in wasted effort and resources. Therefore, supercooled cloud volume "**residence time**" is critical to the success of both rain stimulation and hail reduction efforts.

Under certain atmospheric conditions, clouds may be stimulated to grow larger and rain longer than would be the case, if otherwise left unseeded. Weakly and moderately growing cumuliform cloud behavior can be altered through what is called the "**dynamic effect**" theory. The theory runs like this: A sufficiently large amount of seeding agent is inserted quickly into the supercooled portion of a cloud to promote a conversion from water droplets to ice crystals causing a rapid release of the latent heat of fusion from large quantities the droplets thus making the cloud slightly warmer and more buoyant, invigorating cloud updrafts and causing more moisture to enter the cloud to be "processed" into rainfall, eventually raining more, and longer, than if left unseeded.

Most used among the techniques of cloud top seeding aircraft on many other programs is the dropping of ejectable flares from a belly rack on the cloud top plane. This type of seeding is not done on the WKWMP primarily because of high cost for flares. It is a much more expensive to seed with flares than with dry ice, despite the sublimation (evaporation) occurring with dry ice while kept in storage between operational periods. However, using either dry ice or ejectable flares, the seeding technique is essentially the same: an aircraft penetrates a new-growth cloud and delivers the seeding agent of choice into the updraft column.

Over the years, both cloud physics research and results from other programs, much like our own, have been applied to the WKWMP whenever possible to ensure we maintain a reasonable state-of-the-art mode. We test and implement new things ourselves when it appears it will enhance our overall operational capability and keep costs at reasonable levels.

The cloud systems listed below, and variations of them, are most responsible for producing rain and hail in Western Kansas:

(1) the air-mass storm complex

(2) multiple-celled storms

(3) the squall line

Air-mass storms often become complex after starting out as an isolated cloud system having a well-organized cloud base and new growth updraft area usually visible somewhere around its base. Multiple cloud turrets often develop around the initial "parent" storm; subsequent storm movements can become erratic depending upon several factors such as its severity, terrain effects, dynamic factors within the storm, cloud height, variability of wind speed and direction with height plus the blocking of steering winds caused by large upwind cloud systems.

Air-mass storm complexes often transition into large multi-celled systems, a line of storms containing multiple cells showing characteristics similar more to those of a small squall line. During the gradual development of these multi-cellular lines, cloud base updrafts frequently shift around although they are still found near some of the individual cell elements comprising it making proper seeding treatment quite difficult at times.

Fig. 2 shows a "classic" storm with new growth on its upwind (left) side. Updrafts found upwind of a storm's direction of movement are termed "trailing" or "back side." Whereas, the downwind, front side is its leading side. Most often, updrafts pertinent to the hail process are found along its trailing edge below cloud base at some distance behind the precipitation.

SEEDING A TYPICAL AIR-MASS STORM

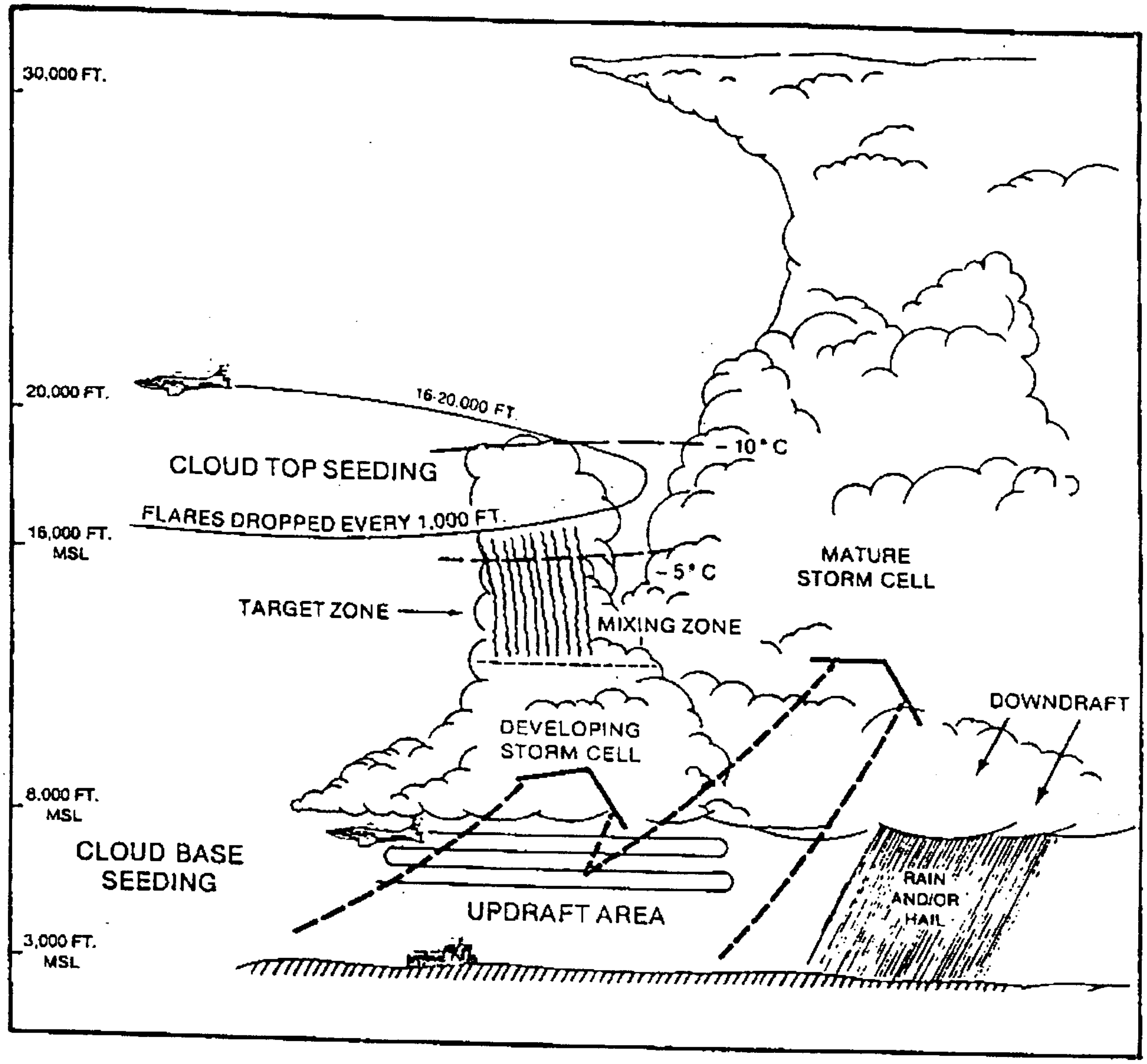


Fig. 2

The locations of updrafts important to the hail process here are along a line on its front side, running from a few miles to many miles in length. Other times, best seeding may be found just on one end of the line. Multi-celled lines can appear as a remnant of a weak squall line or as part of a line of storms associated with fronts, surface troughs and thunderstorm outflows.

Under some conditions multi-celled storms are not linear-shaped; instead, they may become very large, developing several new growth areas simultaneously with several distinct "cores" growing embedded in and around the periphery of the cloud boundary while the cloud system itself is in transition from being a relatively small severe storm into a large **supercell.**

One characteristic of a supercell is that at some point it exhibits a "right-turning" motion relative to the direction of the mean steering wind.

Supercells are among the most dangerous variety of clouds to deal with both from a cloud seeding aspect as well as a crop and property damage aspect. Hail is capable of being ejected from these clouds in any direction and occasionally can endanger seeding aircraft several miles distant from it. Supercells also produce the most destructive tornadoes (on the Fujita Scale types F3 – F5), however, not all supercells produce tornadoes; some estimates indicate about 20%-25% of all supercells may produce a tornado.

During the WKWMP 32-years of seeding supercells to prevent hail we've also had serendipity: We've found out seeding to reduce hail in these storms might also be producing the effect of inadvertent tornado-mitigation. The expectation that cloud seeding can accomplish tornado mitigation is not new and earlier had been theorized by others. The WKWMP is the only cloud seeding group in the USA that has been uniquely able to test the theory over a protracted period of time. We are one of only two cloud seeding programs in the United States that seeds all severe storms. We often prefer to seed storms that have a funnel cloud or a tornado in progress because they are usually the most intense storms; devastating hail almost always accompanies them. They usually travel great distances across our target area and are most responsible for causing a disproportionately large percentage of the total seasonal crop-hail damage on a given day.

Conceptually, it's not completely clear why, or how, a massive water-to-ice conversion process that releases vast amounts of latent heat inside a supercell may be able to mitigate a tornado. Even cloud physicists who are expert in tornado development don't totally understand why tornados form, although they are homing in on this knowledge more all the time, albeit, little by little. However, the relevance of this seeding effect is useful to the general community within the target area we attempt to protect; we have come to expect that the proper seeding of supercells probably mitigate tornado severity in tornado-bearing storms. But, this bears repeating: If inadvertent tornado mitigation really is occurring, **adequate** amounts of seeding agent must be well-dispersed within the new growth clouds which feed into the primary updraft(s) of the complex storm system. Storms which are abandoned, or not well-seeded, often seem to be prone to producing a tornado in short order, because the cloud is returning to its natural, or near-natural, state. This can happen swiftly, too, within perhaps as few as 20-30 minutes (estimated) after seeding ends.

The cloud system known as a **squall line** is an organized line of cumulonimbus clouds many miles in length. Important updraft areas are found along its advancing cloud edges. Updrafts important to the precipitation and hail processes are seldom found along the trailing edges of these lines except at its tail-end, or at significant breaks within the line. Squall lines can be extensive, crossing a few counties within a state, or even crossing several states; frequently squall lines are associated with surface troughing ahead of frontal passages or axis of low-level atmospheric moisture pools along drylines. Updrafts can easily exceed 2,000 - 4,000 feet per minute and produce "scud" clouds visible nearly to the ground. Ahead of the squall line, updraft areas are usually smooth.

Convective Scale Interaction is a term given to a very important process set into motion when a collapsing storm produces precipitation. As the downdraft air, associated with the falling precipitation, nears the ground, "ground effect" turns the rushing air into a horizontal flow of air called a gust front, or outflow boundary. The gust front fans out below its cloud base usually undercutting relatively warm, moist air and other clouds, nearby and distant. If moisture is sufficient in the undercut air being lifted above the gust front, and if it rises into an unstable atmosphere, a cloud can grow very rapidly to become another severe storm which, in turn, quickly reaches maturity and collapses to produce another strong downdraft helping reinforce the original gust front or creating a new one, etc., repeating the earlier sequence. This can happen repeatedly. Single outflow boundaries have been known to be strong enough to travel 100-200 miles, or much further, from its parent storm. Satellite views of clouds forming along these moving gust fronts often show them aligning into a semi-circular, fan-shape orientation which are called **arc- clouds.** Some of these clouds, by themselves can develop into large, severe convective storm systems. Single storms, bow-echo formations, multi-celled storms and supercells all have been identified as forming along these gust fronts.

Earlier research in the southeastern part of the U.S.A. estimated 60%-75% of the storms existing in late afternoon on a typical storm day were caused by this convective scale interaction. Here in Western Kansas we have also identified considerable convective scale interaction effects produced by severe storms. Pilots usually are the first to see them and call them in to the radar meteorologist so tracking them can begin. These outflow boundaries have become the single-most important phenomena to monitor on a continuous basis during operational periods since we obtained the capability to track them. Gust fronts very often provide the operational intelligence that allows us high-predictive capability as to where, in advance, new severe storms are likely to form and/or where will be the most intense area in which to concentrate seeding efforts.

More about gust fronts: Sudden severe new storm growth frequently develops in weak, old non-hail bearing precipitation areas which are being undercut by gust fronts. Satellite imagery can also give advance warning about subsequent new storm development potential which can't be seen immediately on radar or by pilots.

Two, or more, colliding gust fronts frequently create extremely severe storms in between them, although the severe storms are relatively short-lived---having a lifetime of a few tens of minutes. Severe aircraft turbulence is frequently found in gust front air between the parent storm and the leading edge of the gust front. Whereas, in front of a gust front the air is generally smooth (except near the ground where terrain effects dominate). When gust front-air drops out of high-based clouds, micro-burst activity occurs which can flatten buildings, crops and cause aircraft accidents during landing and take-off. Gust fronts are variable in updraft velocity at its leading edge.

Under some conditions rainfall augmentation over large areas has been performed by seeding atop the leading edge of a gust front which was able only to lift the air over it to create small cumuliform clouds with tops to 18,000 – 25,000 feet. Updrafts found above such gust fronts generally might vary around 100 – 200 feet per minute instead of a more typical 1,000 – 2,000 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 stimulation seeding can be highly productive over large areas using wing generators. Its likely under these conditions that dynamic effects is markedly reduced, whereas, a **static** seeding effect is being achieved causing the cloud's micro-physical characteristics to be altered by seeding.

There is another form of cloud system which has occasional important seeding potential for producing precipitation in Kansas: the multiple-celled-convective system (MCCS).

MCCS cloud usually form as a cluster of small, wispy, weak air-mass type of cloud bubbles within a fairly small area---typically 10 – 30 miles in diameter. If one, or more, clouds grow sufficiently and can merge with another, the resulting cloud often tends to enlarge and continue growing. In chain reaction fashion this promotes more mergers of nearby clouds, thus continuing to increase both cloud volume and intensity, etc. Such cloud systems eventually are capable of producing heavy precipitation over large areas and persist much longer than otherwise be the case under normal conditions. Initially, updrafts found within such a system often are embedded and difficult to locate, however, once this cloud system grows to a certain size, updrafts generally organize better and the resulting cloud becomes easier to continue seeding if surrounding cloud and visibility conditions remain safe for flying. Under the unseeded natural condition, MCCS regions often become a "first echo" seen on radar. First echoes have a high correlation to being the day's first severe storm.

Most of the important research on the dynamics of the multiple-celled-convective system was done in the 1980s in West-Central Texas. Radar studies of Northwest Kansas clouds from 1972 to 1974 by Dr. Dean Bark found this area was likely to be a fertile breeding ground for MCCS cloud development. Data comparisons to Western Kansas suggest Western Kansas may be an even better area for similar clouds developing than was the research area in Texas. In earlier years of the WKWMP scant attention was paid to those weak-appearing multiple-celled cloud clusters until one had grown fairly large. If those cloud systems had been inspected and treated in their early stages instead of waiting to see whether they would grow to become larger, most likely greater success in rain stimulation and/or hail suppression would have occurred in them. Today, however, we anticipate these smaller cloud clusters can develop into larger cloud systems and will provide targets of opportunity to produce increased rainfall over large areas, or that these could become regions of initial daily severe storm development. Flights are launched early when such conditions arise. Spectacular results in rain enhancement appear to have occurred when seeding similar cloud systems in the past.

We've identified one type of problem cloud on the WKWMP formed by **elevated convection**. It has been with us forever, but until relatively recently it has not been identified as such, nor widely recognized and considered as a type of "new-growth" cloud to be dealt with, different from a pre-collapse new-growth feeder cloud. It is very likely there are different varieties of elevated convection-generated clouds as well. The following hypothesis is from personal observation, pilot reports and radar data---definitely needing further study and refinement:

New growth clouds initially are produced around severe storms mostly by below-cloud base updrafts; our elevated convection type of cloud, however, masks the difference between it and the below-cloud-base cloud in that they both appear similar-looking with the exception of the updraft locations. For pilots, the world of seeding becomes greatly changed when elevated convection dominates the hail-producing process in severe storms, making seeding even more hazardous.

This is what appears to happen most times: A storm collapses, often it is part of a line of severe storms. A large gust front develops out of it, however, instead of the storm continuing to collapse and die, strong new feeder clouds continue growing attached to the collapsing parent storm giving the severe storm continued life. Normally, feeder clouds obtain their moisture from below-cloud-base air prior to storm collapse, however, post-collapse new-growth feeder clouds continue forming around the parent storm but don't exhibit below-cloud-base updrafts, yet these feeders are still able to continue fueling the hail-producing process. Once hypothesized is that this can only happen due to some mid-level moisture upon which to feed, the new growth clouds will continue to grow only as long as there is moisture sufficient to fuel continued severe convective storm development. When this moisture source is exhausted, storms no longer form.

Presently, it is unknown exactly what is the most important factor, or factors, determining whether or not a parent storm will collapse, or whether, after a short period of re-organization, the storm will resume status as a newly invigorated storm. Some of the factors determining whether such a storm will persist or die appears to depend upon the storm's location relative to other storms, whether or not it is in the multi-celled line, what is its direction of movement, how much atmospheric instability exists, what amount of mid-level (above cloud base) moisture is present, the direction, strength and organization of the winds both at mid-levels and at cloud top---there are undoubtedly other factors as well unmentioned as well.

There may be times when elevated convection is unrelated to post-collapse severe storm conditions such as near the end of a line of storms where strong upwind mid-level air is directly impacting the cloud cluster or line of clouds. Often, the winds near, or above, cloud base are of jet stream velocity helping to force convective clouds to grow quickly on the upwind side and become attached to the last cloud turret, even before the is cloud collapse. Or, mid-level moist air above a cool, stable and dry inversion may promote elevated convection rather than surface based.

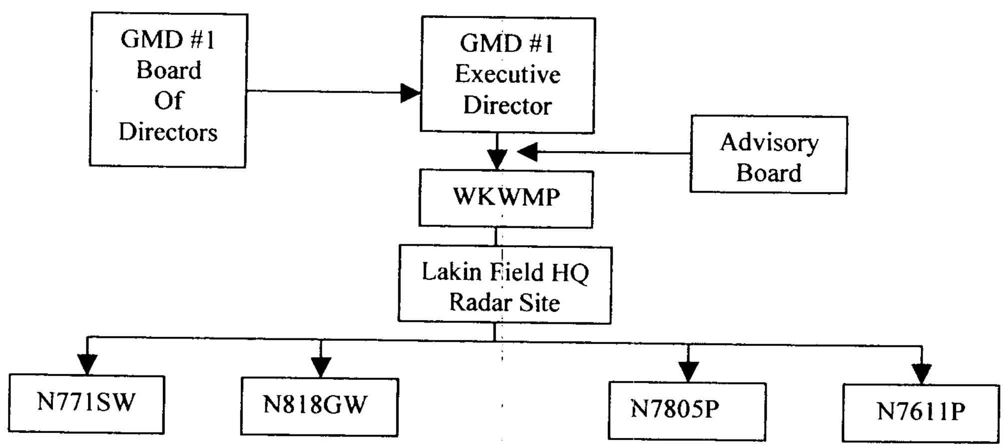
What makes the persistent storm (growing by elevated convection) difficult to treat is that after it has collapsed, no sustained, steady updrafts are found. The updrafts that are found below cloud base are embedded in heavy turbulence along with equally sharp downdrafts. In fact, it is a cloud seeder's "cloud from hell" seeding experience if he wanders into that area. At the same time, above cloud base, the quickly growing feeder cells eventually produce precipitation cores containing hail large enough to damage crops and property. This type of storm can only be seeded effectively above cloud base where pilots report a considerable increase in turbulence inside the new-growth clouds formed by elevated convection---much greater than if penetrating non-elevated clouds. Absent elevated convection, new growth cloud seeding is relatively 'benign'.

III. GENERAL OPERATIONS - PROJECT DESIGN

The WKWMP originally was designed to be an operational cloud seeding effort to optimize precipitation and reduce crop-damaging hail over participating counties in Western and Southwestern Kansas. Although its objectives have not changed over the years, slight design changes have been made to better accomplish its goals. The changes made in previous years were due both to technological innovations and expansion into northwestern Kansas and northeastern Colorado. However, since 2001, the physical portion of the design of the WKWMP has brought us back to where we all began..."back to square one," as the English would say. As a review of Fig. 1 on page 2 shows the 2006 physical boundaries of the current program.

In the past we've tried to be selective in deploying certain technological improvements due mostly to limited annual budgets, however, beginning in 1995 major funding sources from both the Kansas Water Office (1995-2002, 2004-2006) and from GMD #3 (1995-present) allowed us to start making more significant, long-term program improvements. The primary impetus came from the Kansas Water Office (KWO) funding, without which GMD #3 also would not have been able to participate. Funding from the KWO was cut at the end of 2002 but efforts during the winter of 2004 allowed for the restoration of State funding. Fig. 3 shows the current WKWMP organizational structure and its current sources of funding.

WKWMP Organizational Structure



WKWMP Funding Sources

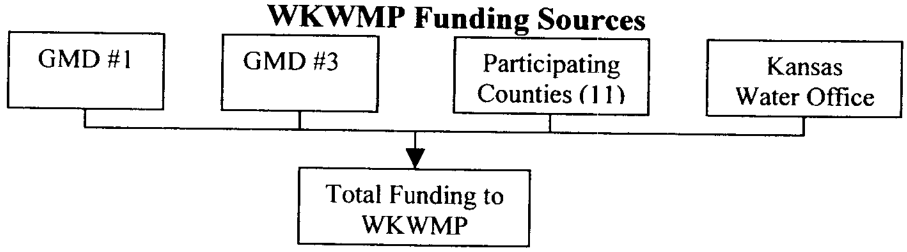


Fig. 3

WKWMP operational activities divide into four major categories:

A. Weather forecasting/operational planning/data collection

B. Weather surveillance – radar, satellite, TV and visual

C. Aircraft seeding operations and maintenance

D. Administrative and public relations

A. WEATHER FORECASTING/OPERATIONAL PLANNING

The Lakin meteorologist prepares a daily weather forecast for the target area and surrounding region. Most weather data used by the WMWMP originates within the National Weather Service, National Center for Atmospheric Research, Climate Prediction Center, Global Hydrology and Climate Center, U.S. Navy or university sites and is processed by them before it is disseminated to the public via the Internet.

The Internet provides the primary means for us to acquire weather information in addition to our own radar. The last few years has seen an explosion of Internet based high-quality weather data products, indispensable to meteorologists, which are available to the general public. A WKWMP home page is maintained and data pertinent to our pilots and to the general public are placed on it. Radar images from past and current operations also are available for public view.

A computer system was put into operation in 1999, called "POPEYE." The system is set up as a multi-tasking system running several weather products singularly, or in loops that continually update in the background while awaiting further commands of whatever product desired by the meteorologist. This system is particularly useful during fast-moving, rapidly changing operational periods when we need to view radar pictures for other sites such as NWS radar for determining storm trends.

With respect to the various media distribution of weather products: The Weather Channel (TWC) generally does an excellent job of providing 24-hour-a-day non-stop television weather updates when viewed on local TV cable. It presents frequent regional radar, forecast and satellite information. TWC is monitored by WKWMP personnel at home and in other places, but not at its field office since local cable lines do not run to the airport. An Internet-based service data provider called WeatherTap has become indispensable to our operations. WeatherTap provides a continuously expanding variety of important weather information such as current radar data from any of the National Weather Service radar sites, satellite and lightning data and, very importantly, VIL data. VIL is the acronym for Vertical Integrated Liquid; it pinpoints the regions within the radar echoes being displayed in which the largest size hail is likely to be falling, if any. For meteorologists and cloud seeders, VIL has been one of the most significant analysis tools to come onto the scene over the past 21 years. Also, significantly important to us is the capability of being able to view animated NEXRAD taken by the National Weather Service

(NWS). Gust fronts, surface troughs and frontal boundaries often are revealed to us in these images providing timely, critical data during operational periods as discussed earlier in the Physical Basis for Cloud Seeding.

Forecasts, current observations, upper air wind profile data, lightning history, DUATS service and other data are also available. Most of the data is received via WeatherTap capable of being put into a looping sequence for time-history detail and can be saved on the computer for possible in-house analysis.

Rawinsondes—those balloon-borne weather-measuring instruments---are launched daily at NWS sites 7 a.m. and at 7 p.m. They contain sensors measuring temperature, pressure and humidity and are tracked for wind speed and direction with height. On the WKWMP the most representative rawinsonde data of the atmosphere over much of the WKWMP target area is taken by the Dodge City site. These data seem to be nearly indispensable to us providing excellent data from which a good short-term forecast of 12 hours, or less, can be made. More and more, satellite derived sounding data has become almost as common as rawinsonde data. The real value of satellite derived soundings is that new data becomes available every hour instead of two times a day from rawinsondes as well as having more locations where data is available instead of just Dodge City.

We continue using upgraded versions of our rawinsonde analysis program called RAOB, developed by Environmental Research Services. This program allows us to analyze upper air data in a variety of ways. Details shown by the RAOB program are such that, when printed, it can very closely replicate a miniature Log-P, Skew-T diagram, a primary analysis tool used often in daily operations by meteorologists. A special feature RAOB is that it is capable of projecting several other sites' rawinsonde data onto the same chart at the same time for comparative analysis.

Another service we use routinely to access weather information is the DIRECT USER ACCESS TERMINAL SYSTEM (DUATS). DUATS is a government-funded weather and flight planning service available to all pilots, accessed via computer terminal and modem. Other analysis software can process and display the weather data collected via DUATS, among them are forecasts, hourly surface observations, weather warnings, forecast discussions and radar summaries. Special use can be made of the hourly surface observations since they can be processed through another analysis program that prints out large-area surface observation data within a few minutes after the data is obtained from it source, then analyzed for whatever detail is desired. Frequently, areas of convergence, divergence, and wind flow fields are shown which provide guidance into continuing operations.

Radio and TV weather programs are two more sources of useful weather information. Occasionally, background TV monitoring in the field office provides access to other weather updates, advisories, alerts and occasional real-time Doppler radar displays during active severe storm periods. The network affiliates' station meteorologists covering this area exhibit a high degree of professionalism and provide the public with timely severe weather information along with their own professional perspectives.

Normally, by 10:30 – 11:00 a.m. the meteorologist has prepared his operational weather forecast and begins disseminating it to the pilots via pagers, or telephone. Figure 4, below, shows our daily operational schedule.

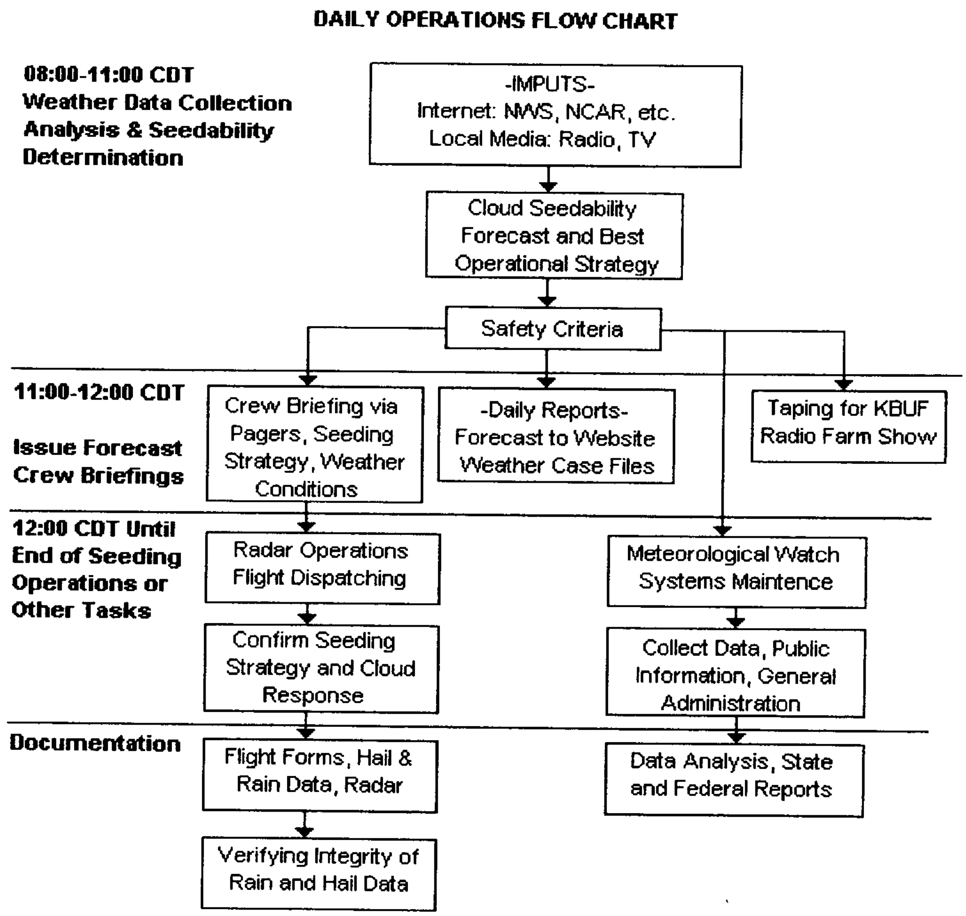


Fig. 4

During the season we often interact with local law enforcement, giving dispatchers information about storm spotter placements; also, occasionally, dispatchers provide feed-back pertinent late- breaking weather-related information to us.

Off-season changes in Internet data collection protocol and upgraded program revisions between seasons were monitored by the program meteorologist. During the season a variety of general information was made accessible to the public via the Internet, among them the Lakin radar displays of operational periods. For regional residents, especially in rural areas, having access to radar data to track storm movements can be very important and timely information for them. The loops are updated every few minutes as operations permit. Storm sequences were usually kept on the web site for 2 - 3 days, or longer, before being moved to the archive files.

The Internet and electronic-mail (e-mail) address are, respectively:

Lakin Internet: www.wkwmp.com Lakin E-mail: hailman@pld.com

B. WEATHER SURVEILLANCE - RADAR, SATELLITE, TV AND VISUAL

Watching for sudden, severe weather developments and being aware of the general suitability of the likelihood of severe weather is a continuous effort throughout the 24-hour day, irrespective of the daily forecast. Although the media provides us with a means of obtaining local area forecasts, breaking weather warnings and radar displays, it is peripheral to our own local sources of information such as our radar, personal observations, satellite imagery, wind profiler displays and the variety of WeatherTap analyses displaying NEXRAD data.

In order to reduce hail effectively, it is important to be able to identify and begin seeding a severe storm as early in its growth stage as possible. Recognizing non-severe storms opposed to potentially destructive ones by visual means requires a fair degree of expertise and experience. At some point WKWMP pilots and meteorologists eventually acquire the ability to do this with a fairly high level of reliability. Often, this recognition skill is critical to getting flights launched in a timely manner. We prefer not to wait for high radar reflectivity in a cloud to be seen on radar before launching aircraft. The reason for this is because in rapidly growing clouds, cloud droplet sizes are not large enough to be "seen" on radar until relatively late in the initial development of severe storms, perhaps as long as 15 minutes, or more. When severe storms are seen on radar it is far too late in their life-cycles to effectively reduce the first hail in them.

Radar becomes an indispensable tool in the identification and tracking of severe storms once they form. The type of radar systems used is the Enterprise Electronics Corporation (EEC) WR-100, 5-cm wavelength models, nearly identical to many weather radars previously used by the National Weather Service which were replaced by their current 10-centimeter wavelength NEXRAD Doppler systems.

Using a computer-interfaced radar system allows us to quickly analyze clouds for hail potential. The height of the 45 dBZ intensity contour within a cloud is evaluated against a "hail threshold" based upon the height of the freezing level. The height of the 45 dBZ intensity level within clouds is used as a test for determining whether crop-damaging hail potential exists in storms and how destructive is its potential relative to other storms. It provides measurable data crucial to making operational decisions regarding aircraft guidance during operations. For instance, with a freezing level of 15,000 feet, the hail threshold would be 3 km higher, or roughly 25,000 feet. If radar showed a 45 dBZ signature in an unseeded cloud at that height, or higher, it would be considered to be able to produce crop-damaging hail at ground level. Generally, the greater the 45 dBZ height is above the hail threshold, the larger is the size of the hailstone formed.

Radar echoes are displayed as colored contours and viewed on a computer monitor. Since 1985 we have used the same basic concept of using the 45 dBZ level to determine hail in clouds. This was done using a variety of methods to make calculations: In earlier years calculations were performed manually, at first using a calculator, then a couple of years later using a computer, then finally arriving at the system now employed. Although one person can operate the system, operations work best when the meteorologist-aircraft controller can focus on aircraft guidance while monitoring the continuous flow of significantly changing weather data while an assistant operates the computer, collects weather data, updates weather information requests from the meteorologist and moves radar images to the Internet for pubic viewing. In the PPI mode the background display shows all regional boundaries, counties, state lines, VOR navigational aids and the locations of regional towns. These are all helpful in providing guidance to aircraft at one time or another.

C. AIRCRAFT SEEDING OPERATIONS AND MAINTENANCE

The aircraft type used in 2006 for cloud-base seeding and cloud-top seeding were:

2-single-engine Piper Aircraft Comanches, PA24-250

1-twin engine turboprop Piper Cheyenne II

1-twin engine Beechcraft Baron, BE95C55

We also kept three other single-engine Comanches as stand-by aircraft to be used in special situations and for backup if maintenance on one of the regularly used aircraft rendered out of operation for more than a few hours.

All cloud base planes were equipped with Carley-type liquid fuel generators, one mounted to each wing tip. Each generator holds 6 gallons of a liquid seeding solution and burns AgI at 4.2 grams per minute in operation that translates into 2.8 gallons of liquid solution being burned per hour of operation. Each full generator carries a total of 540 grams silver iodide and, ideally, it can burn continuously for about 2 hours 9 minutes if correctly configured.

Cloud base planes were stationed at Lakin and Syracuse. The cloud top plane was based in Scott City. Figure 1, at the beginning of this report shows where the aircraft were based.

This is the fifth season in which we have opted to burn a 3% AgI seeding solution at a rate of 4.2 grams per minute. The change was made in response to the drop in operational seeding capability from 2001 to 2006. A stronger seeding rate was expected to help us in seeding the very large storms. When seeding to increase rainfall, relatively short bursts of seeding with one generator was performed on clouds.

Since the change over in 2002, we've noticed slightly more wing generator maintenance than burning at 2.8 grams per minute with the 2% AgI solution used before. Despite increasing our seeding rate by 67%, we have yet to notice significant corrosion and only slight problems pertaining to residue. Wing generator performance remained at high levels in 2006. Only a small degree of regular, competent maintenance is required to keep them clean-burning and totally dependable.

All aircraft are equipped with two Global Positioning System (GPS) units which allows pilots and meteorologists to precisely reference distance and direction from the radar site. The second GPs unit was added in 1998 to record seeding events, flight track information and provide backup for the primary GPS. The second GPS also provides accurate aircraft flight history which, along with a more detailed flight form, is transmitted to the field headquarters later by e-mail.

Also incorporated into our operational radar systems are aircraft interrogator/transponder (IFF) flight tracking systems. From the radar site in Lakin, six discrete transponder codes can be tracked simultaneously. The cloud base planes were licensed to use any of 8 codes assigned to us in our agreement in 1997 with the FAA. Cloud-top flights, which operate under Instrument Flight Rules (IFR), always are assigned a new code for each flight and can be tracked on the system. Although the IFF system is our primary means of pinpointing where seeding aircraft are located at any given time, some problems came again this year where the IFF would function only periodically. The IFF system is indeed old technology and requires constant maintenance. Our electronics technician had fortunately been able to locate the problems with the IFF thus far and we hope that any future problems can also be corrected if we choose to utilize the IFF for 2007 operations.

All cloud base planes are equipped with 12-position, stainless steel wing racks mounted to the trailing edges of each wing. The racks hold flares in place as they burn in-place to a stub preventing any burning remnants of the flare to fall to the ground causing a fire hazard.

The type of flare used in hail suppression this year was an 80-gram silver iodide unit, manufactured by the Concho Cartridge in San Angelo, Texas. Hail suppression flares make possible the addition of significant quantities of ice nuclei to a cloud on an as-needed basis such as when extremely vigorous cloud updrafts are encountered which would otherwise be beyond our capability to seed properly using only wing generators, or when seeding solo on a vigorous cloud that requires more than one plane to seed if it is to be done properly. Our reason for using flares was to add greater capacity to combat severe storms in the early part of the season leading up through wheat harvest. Coincident through that time period is the greatest period of regional crop exposure to hail damage. By the conclusion of wheat harvest in early-to-mid-July, next crops of primary concern are corn and milo, both being generally a little more resilient to small hail-size damage by that time. Although wheat and corn are the two main crops grown in the region, milo, alfalfa, soybeans and sunflowers round out the main crops in the region.

The Cheyenne II turboprop aircraft, acquired in 1999, was equipped with a dry ice dispenser capable of carrying nearly 200 pounds of dry ice which is dispensed at 5 pounds per minute. Reaction time getting to and from storm regions is relatively fast and provides a capability of being able to remain aloft for several hours, normally long enough to dispense the entire seeding load carried. Cloud-top seeding flight paths are either through the tops of newly developing clouds close to the parent storm, or through new storm growth on multi-celled lines.

The design of the WKWMP is similar to other seeding programs of its kind: The launch decision is made by the meteorologist who then guides the pilots to the desired seeding locations during operations. Once a pilot arrives at a target-storm, he/she 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. WKWMP pilots are highly-trained and most have received one, or more, complete seasons of seeding experience as an intern prior to flying as pilot-in-command. Communications, often being relayed through other aircraft, and teamwork in general have worked well on the WKWMP allowing us to operate effectively and successfully.

D. ADMINISTRATIVE AND PUBLIC RELATIONS

There is an ongoing stream of paperwork that needs to be dealt with during the season. After a seeding or observation flight, pilots enter their flight data into their personal computer which carries a pre-loaded form in Excel spreadsheet format and a special program to download GPS data from so that flight track information and waypoints of significance also can be sent. Then, these are e-mailed to the field headquarters from printout and data recording. Required monthly summaries of seeding information are sent to WKGMD#1, the Kansas Water Office, the Dodge City Office of the National Weather Service (not required). A monthly seeding summary is sent in at the end of the season to the National Oceanic and Oceanographic Administration (Appendix D). From time to time numerous other responses are needed, answering public inquiries, researching data, etc.

Public relations provide a valuable contribution to this program, long-term. Without the continuing effort to maintain favorable public attention, we run the risk that the WKWMP will become marginalized. 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 interested parties and groups visiting the radar site and our remote aircraft locations. School classes account for some of the group visitations. However, there has been a push over the past five years to give presentations to various organizations wishing to learn more about the program. Most presentations are given during the winter months when the program is shut down for the season as this period is usually the best time for the meteorologist to get away from the radar site for an extended period of time. Co-operatives and service organizations ask both meteorologists and pilots to speak at regularly scheduled meetings or occasionally at annual meetings also.

A considerable amount of data are put onto the Internet such as weekly newsletters, statistical information, periodic radar data during storm periods and links to other weather information. As the program has grown over the years, the public relations aspect also has grown. Good public relations need to be continuous and planned. There is no substitute for informing customers and should not be overlooked at any time.

IV. OPERATIONAL SUMMARY – 2006

Table 1, on the following page, summarizes the relevant 2006 WKWMP operational flight and seeding information. Each day's flights were broken down into whether an aircraft had performed: (1) hail suppression, (2) rainfall optimization, (3) a combination of both hail suppression and some rain optimization, or (4) an observation flight---a flight for which no seeding was performed. Please note that target area hail-claim numbers for this year are not available, as we were not able to obtain the data.

Other operational information is shown in the Appendices, in the back pages of this report:

Appendix A – Historic Program Operational Activity Summary (seeding and observation flights)
Appendix B – Historic Monthly Number of Seeding Days for Hail and/or Rain Optimization
Appendix C – Historic WKWMP County Participation 1975 – 2006
Appendix D – NOAA Form 17-4A, Final Report on 2006 Monthly Seeding Activities

2006 was a below average seeding season due to a general lack of storm episodes during the drought. Storm frequency from January through July was below normal. Very significant rain fell during the month of August which pushed monthly rain totals above normal for some the of target area counties. Typically, spells of dry weather are usually made up for during the later half of the year when a secondary storm season in late August and September sets in bringing significant rains to the region. This year, the secondary storm season produced only a few instances of severe weather but decent rains finally started falling during October.

Last year, surplus rain occurred over southwest Kansas with near normal rains over west-central and northwest Kansas. This year, everywhere in Kansas had experienced some degree of drought. During the spring, the southern part of the state experienced some drought. The worst of the drought was noted mainly over western Kansas during summer. This fall, periods of rain produced normal conditions over the entire state with the exception being an indicated autumn surplus for southwestern Kansas. Going back for several years, various degrees of dryness have gripped the region more frequently than not.

This year was another below average seeding season with 47 days where seeding for rain optimization and/or hail suppression occurred ranking 2006 the 9th least active seeding season in our 32-year history. Short-term drought conditions in April, May, June, July and a period of September along with a moderate lack of severe weather contributed to the low number of seeding days this year.

WKWMP 2006 GENERAL OPERATIONAL AND HAIL CLAIMS SUMMARY

Date	Opnl. Seeding Day	Total No. of Flights	Number & Type of Flights Per Operational Day	Flight Hours Seeding	Obs.	Total	Total AgI Usage Time (Minutes)	Amount (Grams)	Flare Usage WMG-1	CO2 Used Time (Secs)	Amount (Kgs)	Number of Target Area Hail Claims	Date
17-Apr		Start of Cloud Seeding Season					Start of Cloud Seeding Season						17-Apr
23-Apr	1	3	1R, 1O	1.6	0.9	2.5	30	126				N/A	23-Apr
24-Apr	2	3	3H	4.5		4.5	86	361.2				N/A	24-Apr
27-Apr	3	4	4H	8.7		8.7	239	1003.8	1	502	19.0	N/A	27-Apr
7-May	4	6	6H	19.9		19.9	834	2935.8	54	4637	175.3	N/A	7-May
8-May	5	4	4H	10.7		10.7	363	1524.6	3	2387	90.2	N/A	8-May
22-May	6	3	1H, 2O	2	4.9	6.9				406	15.3	N/A	22-May
23-May	7	2	1H, 1O	1.6	1.6	3.2	12	50.4				N/A	23-May
25-May	8	5	5H	19		19	843	3540.6	17	2522	95.3	N/A	25-May
26-May	9	3	2R, 1O	4.9	2	6.9	111	466.2				N/A	26-May
30-May	10	4	4H	12.7		12.7	239	1003.8		857	32.4	N/A	30-May
31-May	11	4	3H, 1C	13.8		13.8	615	2583	10	1773	67.0	N/A	31-May
3-Jun	12	4	1H, 3C	15.0		15	801	3364.2		278	10.5	N/A	3-Jun
5-Jun	13	4	4H	9.4		9.4	370	1554	6	741	28.0	N/A	5-Jun
9-Jun		1	1O		0.9	0.9						N/A	9-Jun
11-Jun	14	4	4H	7.9		7.9	75	315		895	33.8	N/A	11-Jun
14-Jun	15	3	2C, 1O	9.5	4.0	13.5	384	1612.8	6			N/A	14-Jun
15-Jun	16	8	5H, 3C	25.5		25.5	1430	6006	25	2859	160.9	N/A	15-Jun
16-Jun	17	5	4H, 1O	14.4	9.0	23.4	632	2654.4	26	2665	100.7	N/A	16-Jun
20-Jun	18	3	2H, 1O	3.7	0.6	4.3	55	231				N/A	20-Jun
21-Jun	19	4	4H	15.1		15.1	771	3238.2	46	2577	97.4	N/A	21-Jun
22-Jun	20	4	4H	16.7		16.7	488	2049.6	17	2634	99.6	N/A	22-Jun
29-Jun	21	4	3H, 1C	13.5		13.5	476	1999.2		1330	50.3	N/A	29-Jun
3-Jul	22	3	1H, 2O	1.0	5.0	6				475	18.0	N/A	3-Jul
7-Jul		2	2O		3.2	3.2						N/A	7-Jul
8-Jul	23	4	2H, 2C	12.7		12.7	273	1146.6	5	1437	54.3	N/A	8-Jul
9-Jul	24	7	4H, 2R, 1O	13.0	1.2	14.2	152	638.4		808	30.5	N/A	9-Jul
11-Jul	25	5	4C, 1R	19.2		19.2	867	3641.4	34	2452	92.7	N/A	11-Jul
13-Jul	26	4	2H, 1C, 1O	7.7	2.3	10	118	495.6	9	1463	55.3	N/A	13-Jul
20-Jul	27	4	2H, 1C, 1O	9.2	3.3	12.5	68	285.6		921	34.8	N/A	20-Jul
25-Jul	28	4	4C	11.4		11.4	296	1243.2		989	37.4	N/A	25-Jul
26-Jul	29	3	3R	8		8	101	424.2		1238	46.8	N/A	26-Jul
27-Jul		2	2O		1.0	1						N/A	27-Jul
28-Jul	30	3	2R, 1C	3.9		3.9	66	277.2				N/A	28-Jul
1-Aug	31	3	2R, 1C	11.8		11.8	210	882.0		1193	45.1	N/A	1-Aug
2-Aug	32	3	1R, 2O	1.3	3.1	4.4				68	2.6	N/A	2-Aug
3-Aug	33	1	1R	1.4		1.4	33	138.6				N/A	3-Aug
5-Aug	34	4	2R, 1C, 1O	4.0	2.5	6.5	68	285.6				N/A	5-Aug
6-Aug	35	3	1H, 2O	1.5	3.4	4.9	8	33.6				N/A	6-Aug
7-Aug	36	2	1H, 1R	4.3		4.3	33	138.6		229	8.7	N/A	7-Aug
9-Aug	37	4	3H, 1R	9.1		9.1	240	1008.0		392	14.8	N/A	9-Aug
10-Aug	38	3	2H, 1O	4.2	1.4	5.6	53	222.6				N/A	10-Aug
13-Aug	39	2	2H	6.8		6.8	284	1192.8				N/A	13-Aug
17-Aug	40	4	3H, 1O	6.8	1.3	8.1	369	1549.8	2			N/A	17-Aug
18-Aug	41	4	3H, 1C	10.9		10.9	252	1058.4	1	1008	38.1	N/A	18-Aug
25-Aug	42	4	4H	11.8		11.8	683	2868.6	33	2018	76.3	N/A	25-Aug
27-Aug	43	5	1R, 1H, 2C, 1O	7.5	1.5	9	187	785.4				N/A	27-Aug
31-Aug	44	4	4H	15.6		15.6	974	4090.8	13	1470	55.6	N/A	31-Aug
7-Sep	45	3	3H	5.4		5.4	170	714.0				N/A	7-Sep
9-Sep	46	4	4H	15.9		15.9	616	2587.2		2193	82.9	N/A	9-Sep
15-Sep	47	4	4H	9.8		9.8	438	1839.6		874	33.0	N/A	15-Sep
22-Sep			End of Cloud Seeding Season					End of Cloud Seeding Season					22-Sep
	Totals:	183.0		444.3	53.1	497.4	15413.0	64167.6	308	46291.0	1802.6	N/A	

Symbols for Types of Flights
H = Hail Flights Only
R = Rain Flights Only
C = Combined Flights (Hail & Rain)
O = Observation Only

Type of Flights	Flight Summary Number	Hours
Hail Only	108	307
Rain Only	21	50
Combined	28	88
Observation	26	53
Other	46	49
TOTALS:	**229 flights**	**547 hours**

Seeding Summary

Wing Generators	Time (min)	Amount (gms AgI)
Total:	15413	64167.6

CO2 Dispensed	(secs)	(Kg)
Total:	46291	1802.6

Flares WMG-1 308 (Flare Burn Time = 2 min. each)

LPG Seeding time (hrs)
Cloud Base = 257
Cloud Top = 12.9
Total Hours = 269.9

Number of Days Seeding: 47

Number of Days Obs (only): 3

Number of Hail Days: N/A

TABLE 1

This year the pure hail suppression (only) flights numbered 108, or 59% of all seeding flights and observation flights; whereas, there were only 21 rain optimization flights totaling, 11% of all flights. The combined hail and rain seeding flights added up to 28 for 15% with the remaining 26 flights being observation flights at 14% of the total number of flights.

The distribution of type of seeding days was 41 days upon which some seeding for hail was performed and 23 days with some rain optimization attempted. There were 24 days when the only seeding done was for hail suppression and just 5 seeding days in which only rain optimization seeding was performed.

Silver iodide output this season was 17% lower than the amount released last year...77288 grams in 2005 vs. 64168 grams in 2006. Output would have been higher this year if storm frequency had been at least normal. Dry ice release was higher at 1803 kg this year vs. 1663 kg last year. The higher output of dry ice this year was mostly attributed to the fact that the cloud-top aircraft was utilized much more frequently during weaker storm episodes and rain optimization opportunities than was the case in 2005.

2006 was a very dry to slightly dry year while 2005 was slightly dry to normal, 2004 being wet, and 2002 and 2003 were well within the grips of various stages of strong drought. The primary difference in a drought year over a non-drought year is storm frequency. This frequency can usually be displayed indirectly by the number of days in which seeding operations occurred. In 2001, 61 days of weather modification occurred while only 43 days of seeding was carried out in 2002, 45 days in 2003, 40 days in 2004 and 38 days in 2005. In 2002 and 2003, July had been our trouble month with only 7 days of operations in 2002 and 11 days in 2003. In 2004, dry weather in late May and the first half of June decreased seeding days that year. Although 2005 was generally near normal in precipitation, the low numbers of seeding flights represent a general lack of strong to severe weather for the season. Under near normal or normal seasonal precipitation, this program can expected roughly 57 days of operations from late April to mid September.

V. HAIL DISTRIBUTION

A list of crop-hail damage claims were periodically sent to us from the Kansas/Oklahoma Hail Loss Service, based in Washington, Kansas for many years. However, due to a sharp decline in subscribers for the claim information, the company has suspended the distribution of such information for this year. We do not know if this company will resume distribution in coming years. As a result, we have no information about the extent of hail damage incurred on those who carried crop-hail insurance this year.

We had worked with officials at the Kansas Insurance Commission in Topeka last year to obtain 2005 hail-claim information. However, progress stalled with the result being no new hail claim information. It is our hope that at some point in the future we will be able to get crop-hail damage claim information from a reliable source. Until that time comes, the hail distribution section of this report will remain suspended.

VI. RAINFALL DISTRIBUTION

Seasonal rainfall in Western Kansas in 2006 was below normal to various degrees for most of the target area. Last year, roughly half of the target area counties fell back into the drought while the other half continued an extended moist period going back to 2004. This year, it appears the area has fallen back into the drought, which spreads across at least half the United States. For a second year in a row, August turned out to be the best month for rainfall as significant rains fell over much of western Kansas during the month with 64% of target area counties reporting above average rainfall. For a second year in a row, July turned out to be the driest month for the area with only 18% of target area counties reporting a monthly rain surplus. Of course there were some exceptions to this description at each reporting location, but for most of the target area, this scenario fit the area fairly well.

Table 2 summarizes the county rainfall distribution for this year. Upon inspection, we find that the driest areas occurred mainly across the central, northwestern and south-central section of the target area including Greeley, Kearny and Grant. Interestingly, Haskell County was the only county to report above average rains for the period. Relatively speaking, the driest county was Grant while the wettest was just across the county border in Haskell. Table #2 shows the 2006 May – August rain totals and the deviations from normal for each target area county.

Table #2

MAY – AUGUST 2006 RAINFALL
(WKWMP Target Area)

COUNTY	TOTAL (inches)	NORMAL (inches)	DEPARTURE (inches)	Change (%)
FINNEY	10.79	11.97	-1.18	-10
GRANT	6.82	10.20	-3.38	-33
GRAY	12.29	13.38	-1.09	-8
GREELEY	7.62	10.57	-2.95	-28
HAMILTON	9.54	9.96	-0.42	-4
HASKELL	12.63	11.04	+1.59	+14
KEARNY	8.30	11.36	-3.06	-27
LANE	11.83	12.10	-0.27	-2
SCOTT	11.23	11.65	-0.42	-4
STANTON	8.72	8.80	-0.08	-1
WICHITA	9.65	11.06	-1.41	-13

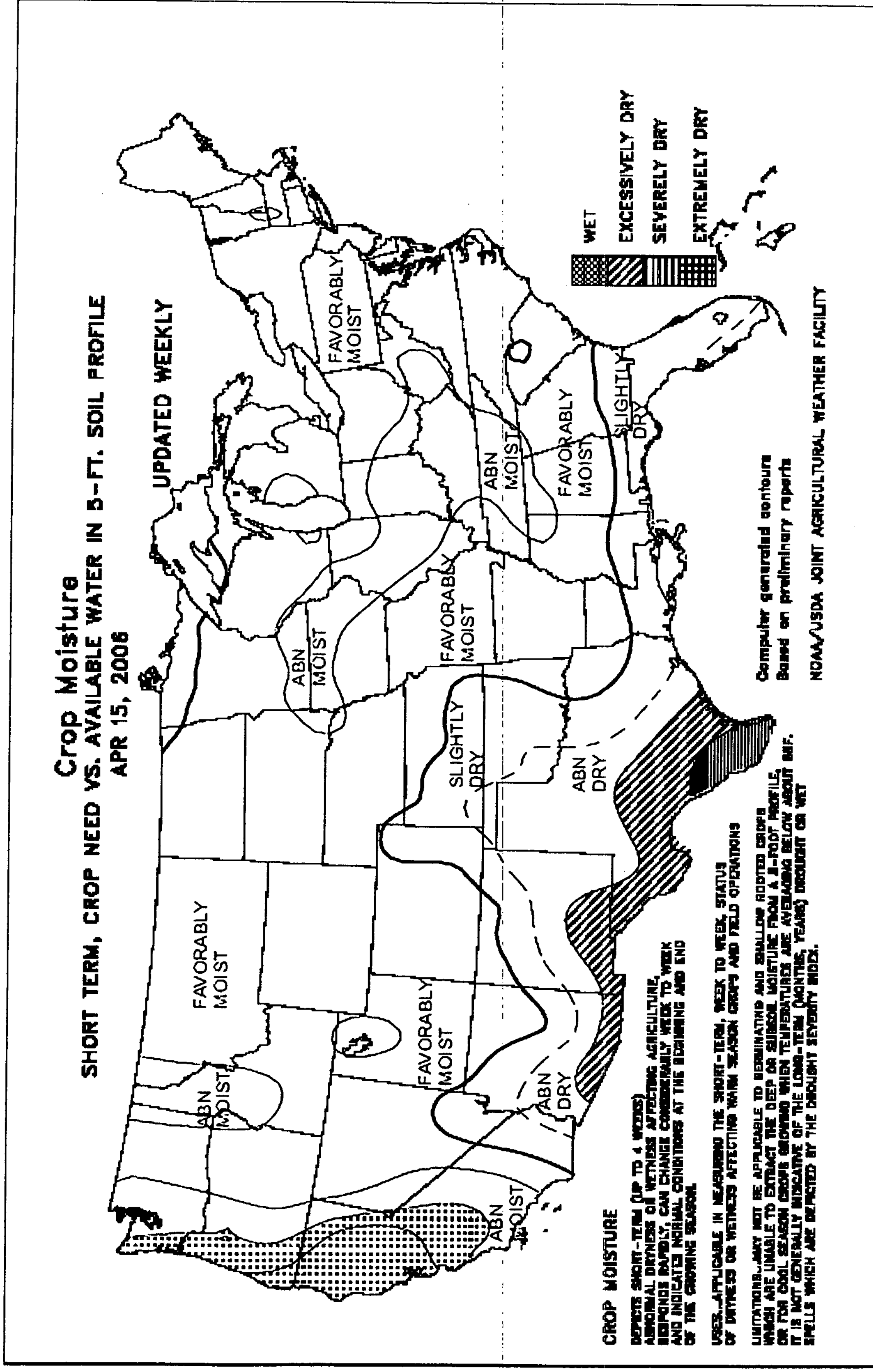
In order to show what the general moisture pattern was like during the growing season we will present several of two types of national moisture maps produced by the NOAA/USDA Joint Agricultural Weather Facility showing: (1) the short-term Crop Moisture index, and (2) the long-term Palmer Drought Severity index. Figs. 5-16 show the short and long-term changes in these indices during the 2006 season. The short-term Crop Moisture index is released every week while the long-term Drought Severity index is released every second week. The periodical, "Weekly Weather and Crop Bulletin" presents these maps as they become available; also, they are archived on the Internet at the Joint Agricultural Weather Facility (JAWF) website and available to the general public.

The **Crop Moisture** index is a measure of the more rapid response to rainfall over a short-term period, almost from week to week. The figures show the changes valid at the dates given for it. Not all months periods are presented.

The Palmer long-term **Drought Severity Index** shows national soil moisture conditions for the period of time that nearly parallels our WKWMP season and is not prone to short-term moisture changes. The index is developed from official measurements made at second-order weather observing sites, around 30 – 40 miles apart in our area. Normally, this index takes periods of weeks or months to change, not days. While not a perfect representation at all geographical locations in small-size areas, what is shown generally tends to replicate the near real-world crop moisture pattern existing in the larger region.

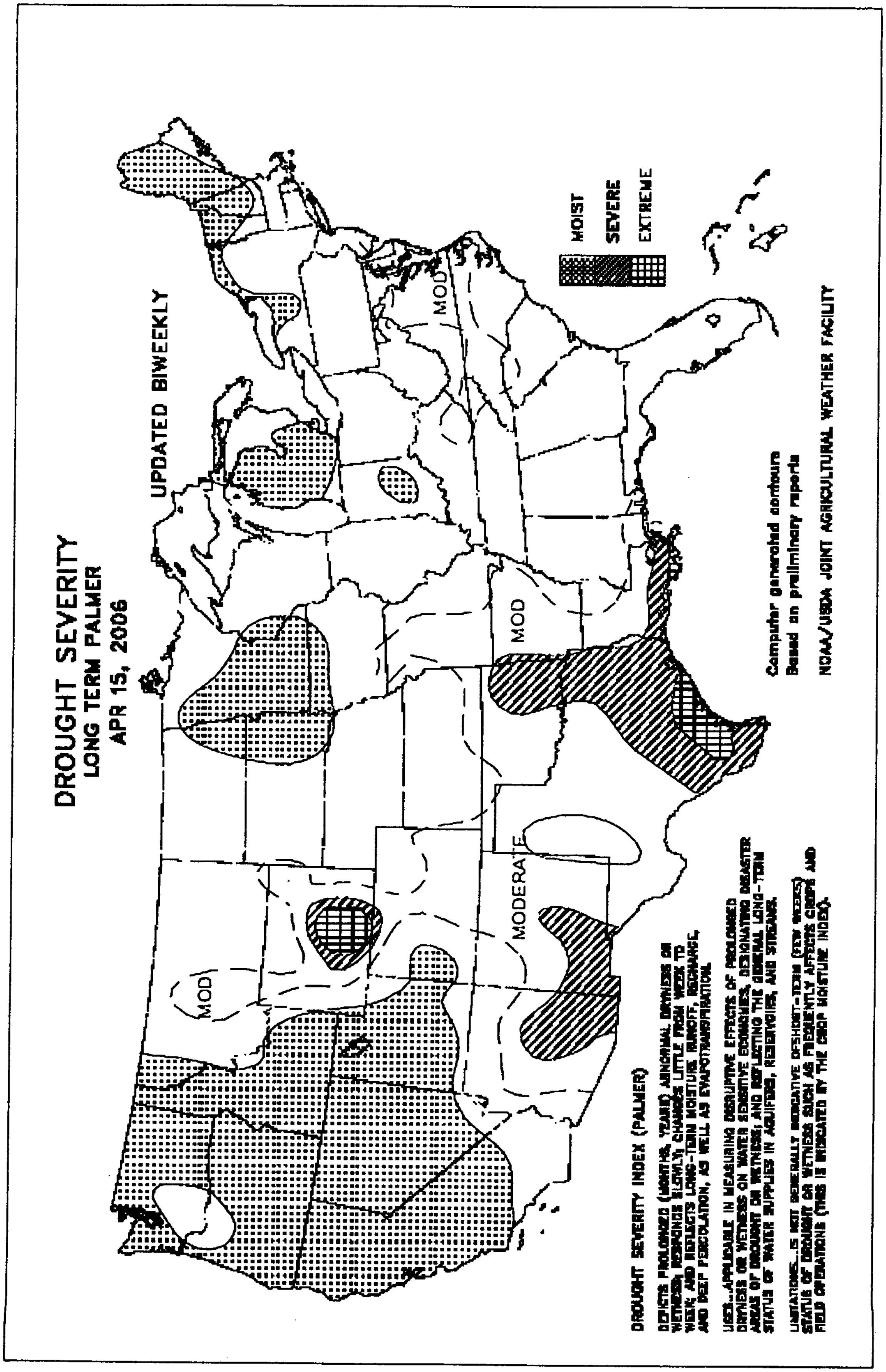
As the crop-year began, both short-term and long-term crop moisture was slightly dry for the target area during April (Figs. 5, 6). Indeed, monthly rain totals for our area were showing a mounting deficit going back to November of 2005. Dry weather continued into May with moisture conditions worsening over the area (Figs. 7, 8). Drought conditions peaked with the worst month of the year for strong drought being June (Figs. 9, 10). Monsoon moisture streamed into Arizona, New Mexico, Colorado and portions of western Kansas during July with the result being some drought relief to the area in the form of increased shower activity (Figs. 11, 12). Extreme heat, windy conditions and a decrease in monsoon moisture resulted in the return of very strong drought for August (Figs. 13, 14). With September being a transitional period and the time of our secondary strong storm season, periods of heavy and widespread rains resulted in a period of near normal moisture conditions (Figs. 15, 16). Unfortunately, a general lack of rain for the year still leaves most locations in a rainfall deficit as of October.

Fig. 5



Crop Moisture
SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE
APR 15, 2006
UPDATED WEEKLY
ABN MOIST
FAVORABLY MOIST
ABN MOIST
FAVORABLY MOIST
FAVORABLY MOIST
SLIGHTLY DRY
FAVORABLY MOIST
ABN MOIST
ABN MOIST
ABN DRY
ABN DRY
FAVORABLY MOIST
SLIGHTLY DRY
WET
EXCESSIVELY DRY
SEVERELY DRY
EXTREMELY DRY
CROP MOISTURE
DEPICTS SHORT-TERM (UP TO 4 WEEKS)
ABNORMAL DRYNESS OR WETNESS AFFECTING AGRICULTURE,
RESPONDS RAPIDLY, CAN CHANGE CONSIDERABLY WEEK TO WEEK
AND INDICATES NORMAL CONDITIONS AT THE BEGINNING AND END
OF THE GROWING SEASON.
USES...APPLICABLE IN MEASURING THE SHORT-TERM, WEEK TO WEEK, STATUS
OF DRYNESS OR WETNESS AFFECTING WARM SEASON CROPS AND FIELD OPERATIONS
LIMITATIONS...MAY NOT BE APPLICABLE TO GERMINATING AND SHALLOW ROOTED CROPS
WHICH ARE UNABLE TO EXTRACT THE DEEP OR SUBSOIL MOISTURE FROM A 5-FOOT PROFILE,
OR FOR COOL SEASON CROPS GROWING WHEN TEMPERATURES ARE AVERAGING BELOW ABOUT 50F.
IT IS NOT GENERALLY INDICATIVE OF THE LONG-TERM (MONTHS, YEARS) DROUGHT OR WET
SPELLS WHICH ARE DEPICTED BY THE DROUGHT SEVERITY INDEX.
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 6



DROUGHT SEVERITY
LONG TERM PALMER
APR 15, 2006
UPDATED BIWEEKLY
MOD
MODERATE
MOD
MOD
MOIST
SEVERE
EXTREME
DROUGHT SEVERITY INDEX (PALMER)
DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG-TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
USES...APPLICABLE IN MEASURING DISRUPTIVE EFFECTS OF PROLONGED DRYNESS OR WETNESS ON WATER SENSITIVE ECONOMIES, DESIGNATING DISASTER AREAS OF DROUGHT OR WETNESS; AND REFLECTING THE GENERAL LONG-TERM STATUS OF WATER SUPPLIES IN AQUIFERS, RESERVOIRS, AND STREAMS.
LIMITATIONS...IS NOT GENERALLY INDICATIVE OF SHORT-TERM (FEW WEEKS) STATUS OF DROUGHT OR WETNESS SUCH AS FREQUENTLY AFFECTS CROPS AND FIELD OPERATIONS (THIS IS INDICATED BY THE CROP MOISTURE INDEX).
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 7

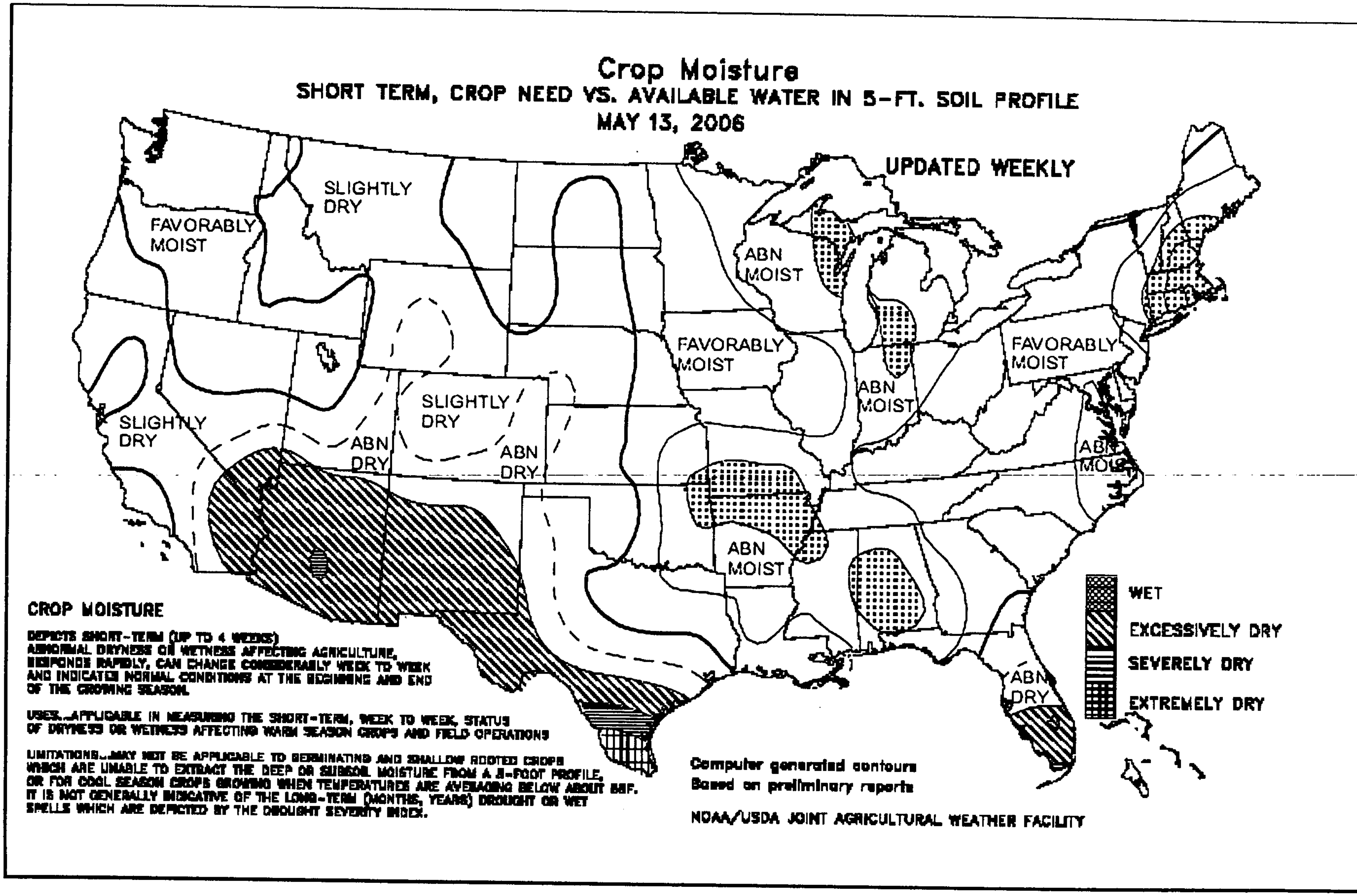
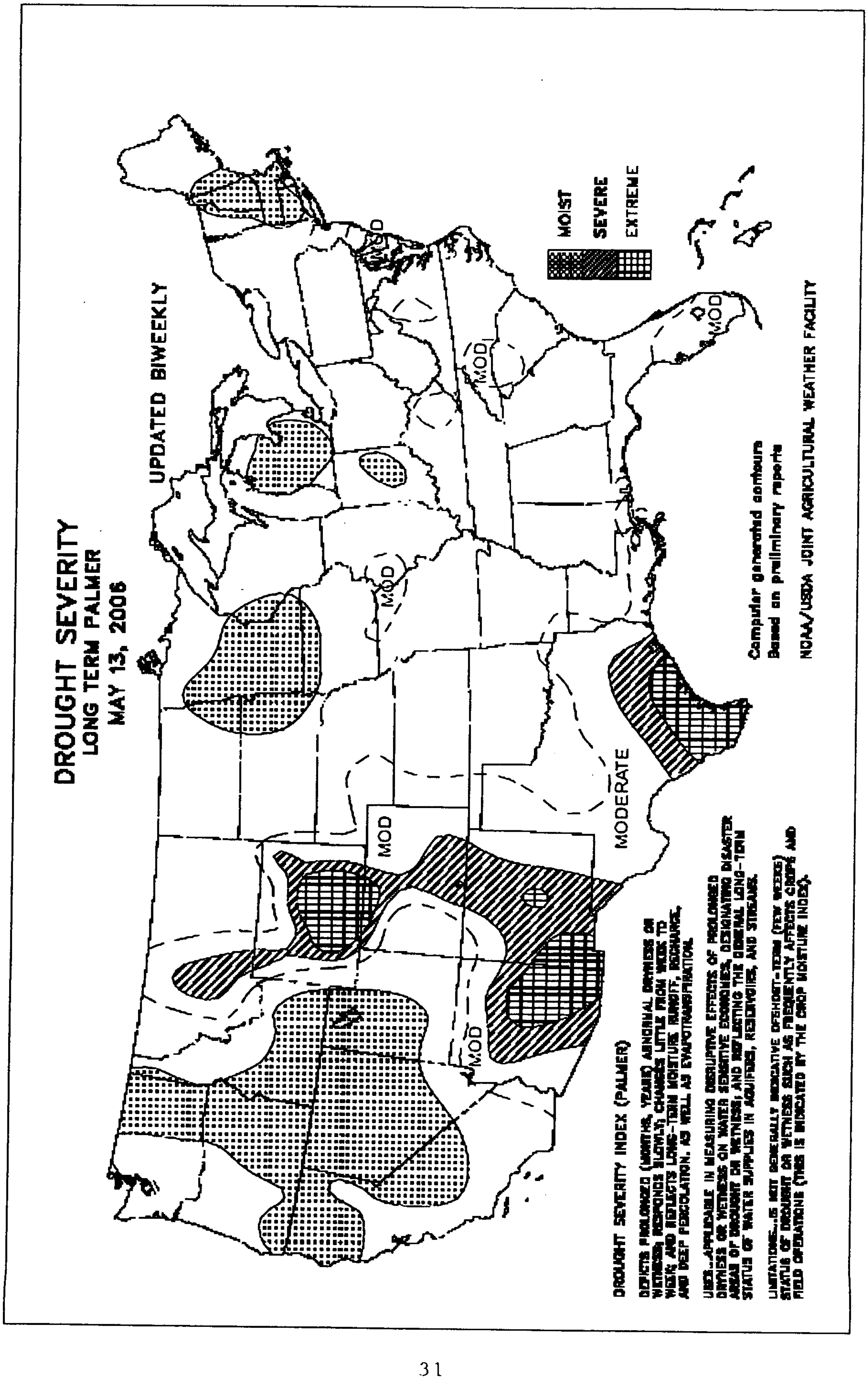

Crop Moisture
SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE
MAY 13, 2006
UPDATED WEEKLY
SLIGHTLY DRY
FAVORABLY MOIST
ABN MOIST
FAVORABLY MOIST
ABN MOIST
FAVORABLY MOIST
SLIGHTLY DRY
ABN DRY
ABN DRY
SLIGHTLY DRY
ABN MOIST
ABN MOIST
ABN DRY
WET
EXCESSIVELY DRY
SEVERELY DRY
EXTREMELY DRY
CROP MOISTURE
DEPICTS SHORT-TERM (UP TO 4 WEEKS) ABNORMAL DRYNESS OR WETNESS AFFECTING AGRICULTURE, RESPONDS RAPIDLY, CAN CHANGE CONSIDERABLY WEEK TO WEEK AND INDICATES NORMAL CONDITIONS AT THE BEGINNING AND END OF THE GROWING SEASON.
USES...APPLICABLE IN MEASURING THE SHORT-TERM, WEEK TO WEEK, STATUS OF DRYNESS OR WETNESS AFFECTING WARM SEASON CROPS AND FIELD OPERATIONS
LIMITATIONS...MAY NOT BE APPLICABLE TO GERMINATING AND SHALLOW ROOTED CROPS WHICH ARE UNABLE TO EXTRACT THE DEEP OR SUBSOIL MOISTURE FROM A 5-FOOT PROFILE, OR FOR COOL SEASON CROPS GROWING WHEN TEMPERATURES ARE AVERAGING BELOW ABOUT 55F. IT IS NOT GENERALLY INDICATIVE OF THE LONG-TERM (MONTHS, YEARS) DROUGHT OR WET SPELLS WHICH ARE DEPICTED BY THE DROUGHT SEVERITY INDEX.
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 8


DROUGHT SEVERITY
LONG TERM PALMER
MAY 13, 2006
UPDATED BIWEEKLY
MOD
MOD
MOD
MOD
MOD
MOD
MODERATE
MOIST
SEVERE
EXTREME
DROUGHT SEVERITY INDEX (PALMER)
DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG-TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
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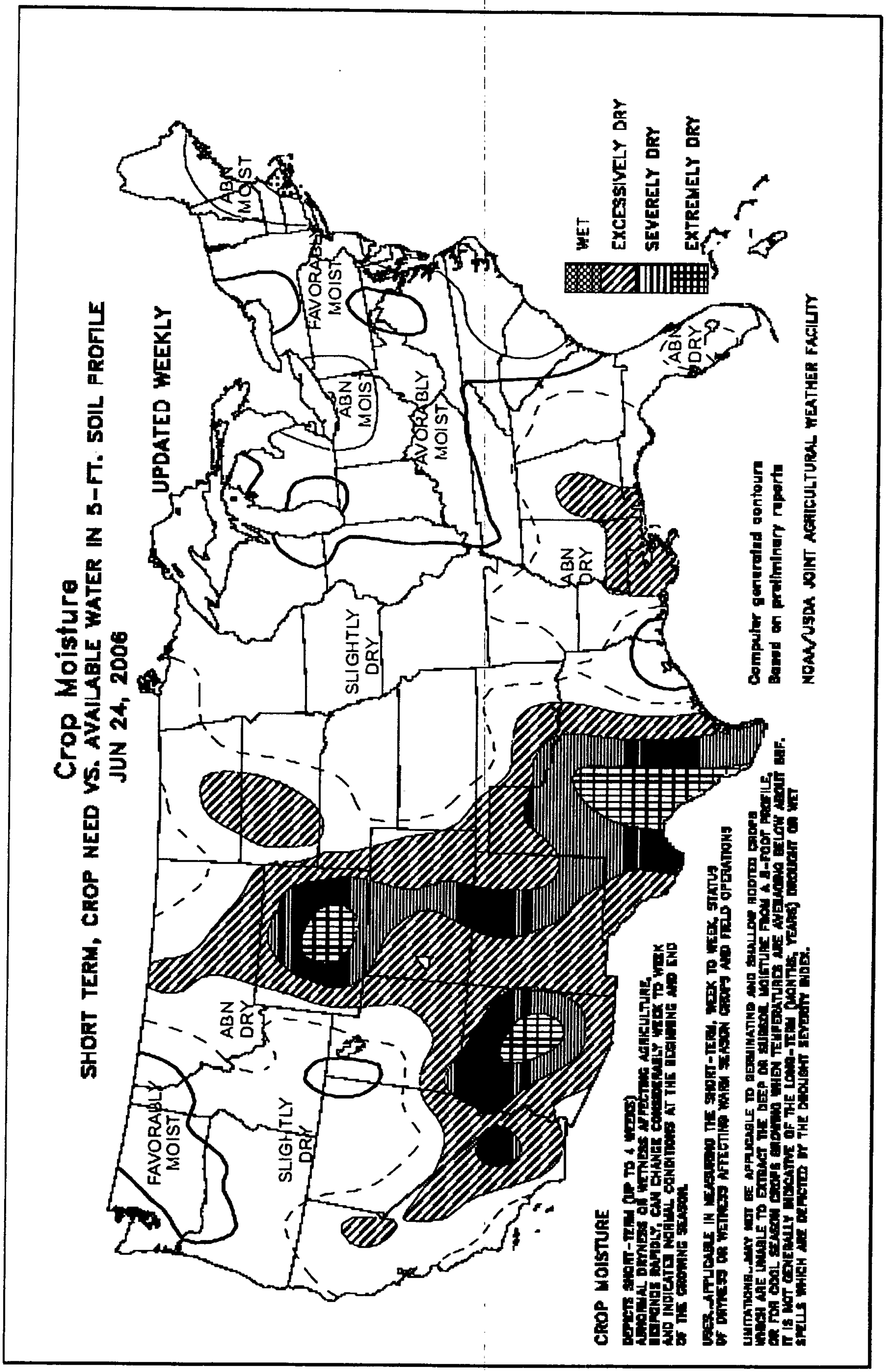
LIMITATIONS...IS NOT GENERALLY INDICATIVE OF SHORT-TERM (FEW WEEKS) STATUS OF DROUGHT OR WETNESS SUCH AS FREQUENTLY AFFECTS CROPS AND FIELD OPERATIONS (THIS IS INDICATED BY THE CROP MOISTURE INDEX).
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 9



Crop Moisture
SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE
JUN 24, 2006
UPDATED WEEKLY
FAVORABLY MOIST
ABN DRY
SLIGHTLY DRY
SLIGHTLY DRY
ABN MOIST
FAVORABLY MOIST
ABN MOIST
FAVORABLY MOIST
ABN DRY
ABN DRY
WET
EXCESSIVELY DRY
SEVERELY DRY
EXTREMELY DRY
CROP MOISTURE
DEPICTS SHORT-TERM (UP TO 4 WEEKS) ABNORMAL DRYNESS OR WETNESS AFFECTING AGRICULTURE, RESPONDS RAPIDLY, CAN CHANGE CONSIDERABLY WEEK TO WEEK AND INDICATES NORMAL CONDITIONS AT THE BEGINNING AND END OF THE GROWING SEASON.
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IT IS NOT GENERALLY INDICATIVE OF THE LONG-TERM (MONTHS, YEARS) DROUGHT OR WET SPELLS WHICH ARE DEPICTED BY THE DROUGHT SEVERITY INDEX.
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 10

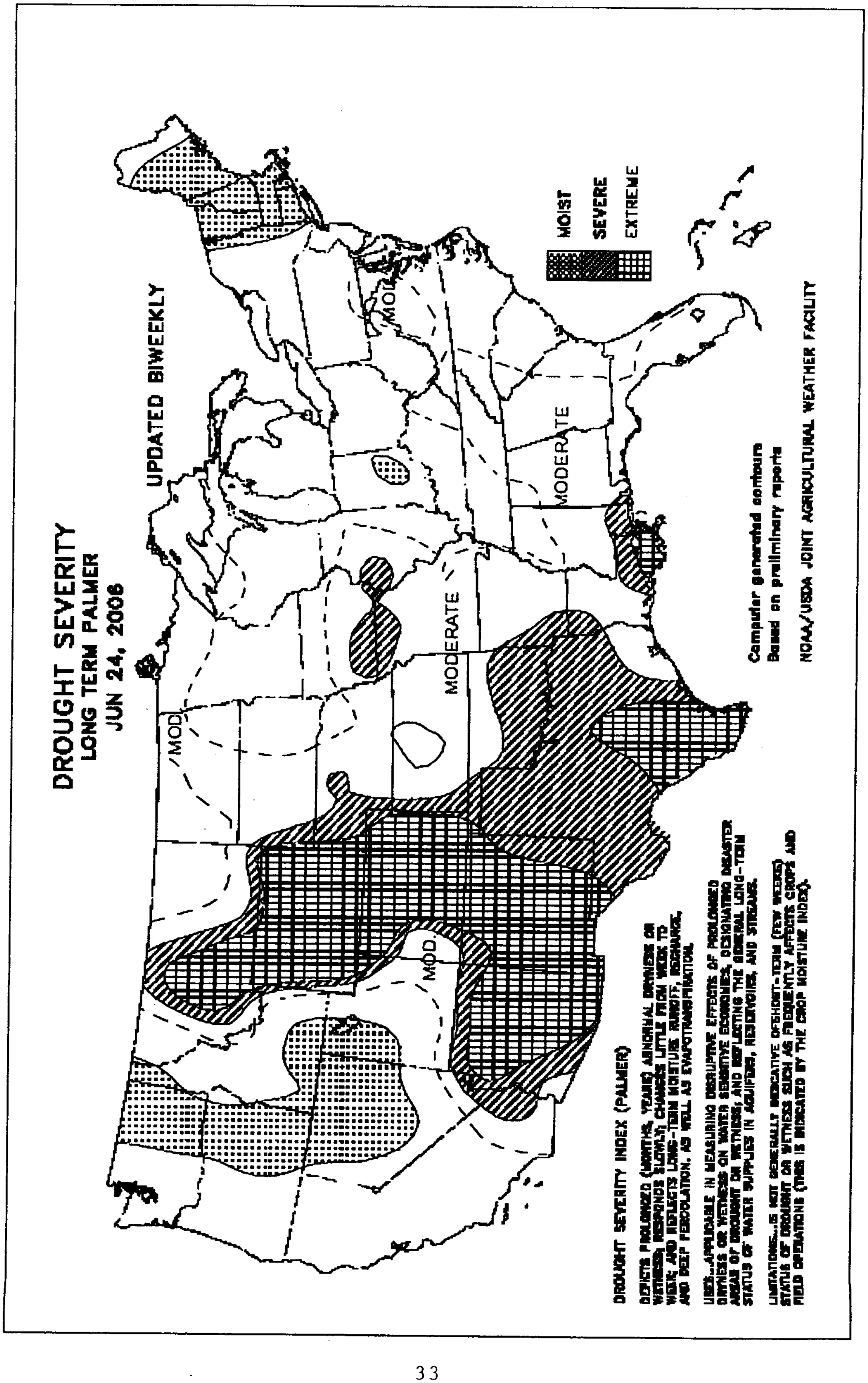
DROUGHT SEVERITY
LONG TERM PALMER
JUN 24, 2006
UPDATED BIWEEKLY
MOIST
SEVERE
EXTREME
MODERATE
MODERATE
MODERATE
MOD
MOD
MOD
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY
DROUGHT SEVERITY INDEX (PALMER)
DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG-TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
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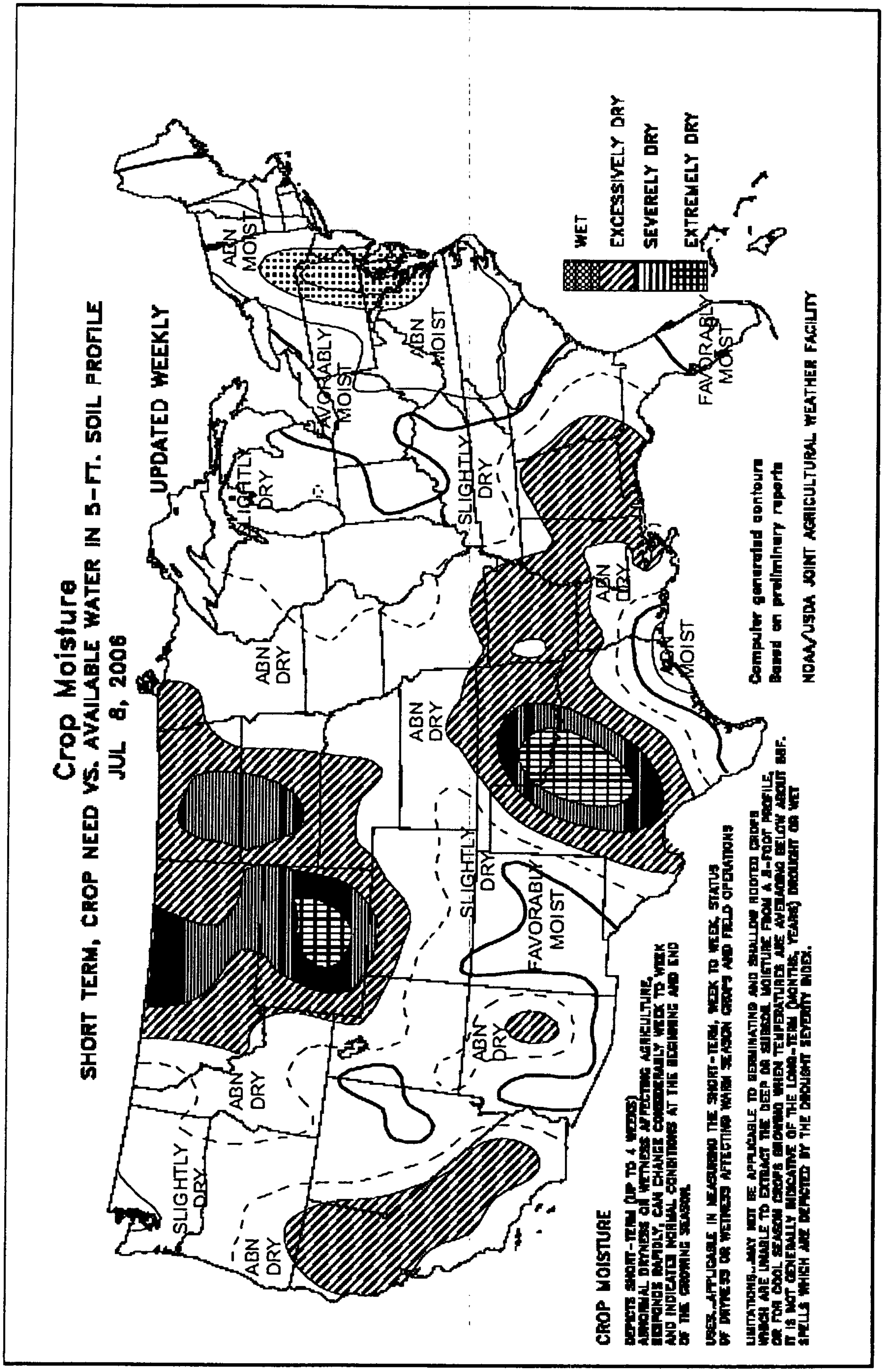
Fig. 11


Crop Moisture
SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE
JUL 8, 2006
UPDATED WEEKLY
SLIGHTLY DRY
ABN DRY
ABN DRY
ABN DRY
FAVORABLY MOIST
SLIGHTLY DRY
ABN DRY
ABN DRY
SLIGHTLY DRY
FAVORABLY MOIST
ABN MOIST
SLIGHTLY DRY
ABN DRY
ABN MOIST
FAVORABLY MOIST
ABN MOIST
WET
EXCESSIVELY DRY
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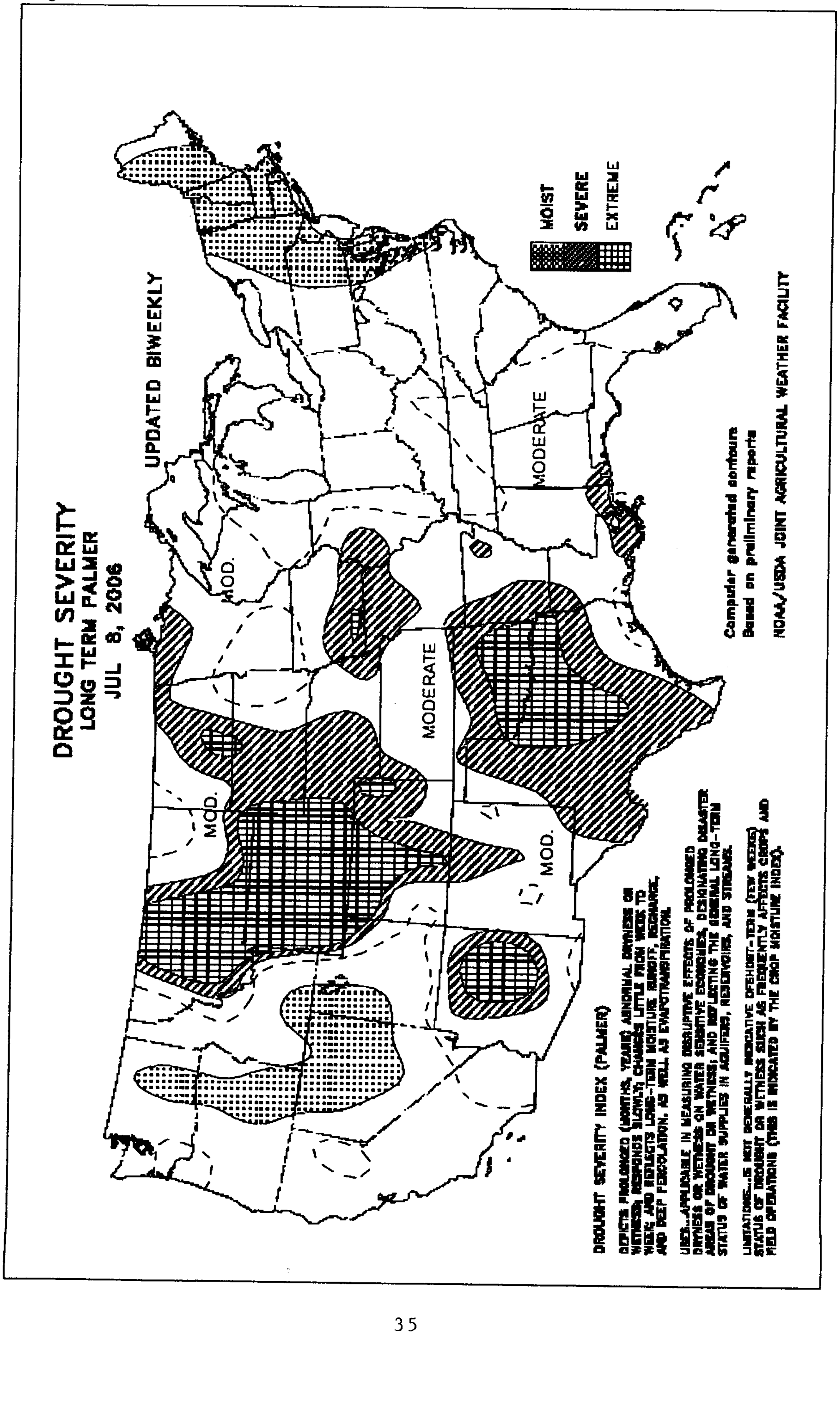
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 12



DROUGHT SEVERITY
LONG TERM PALMER
JUL 8, 2006
UPDATED BIWEEKLY
MOD.
MOD.
MODERATE
MOD.
MODERATE
MOIST
SEVERE
EXTREME
DROUGHT SEVERITY INDEX (PALMER)
DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG-TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
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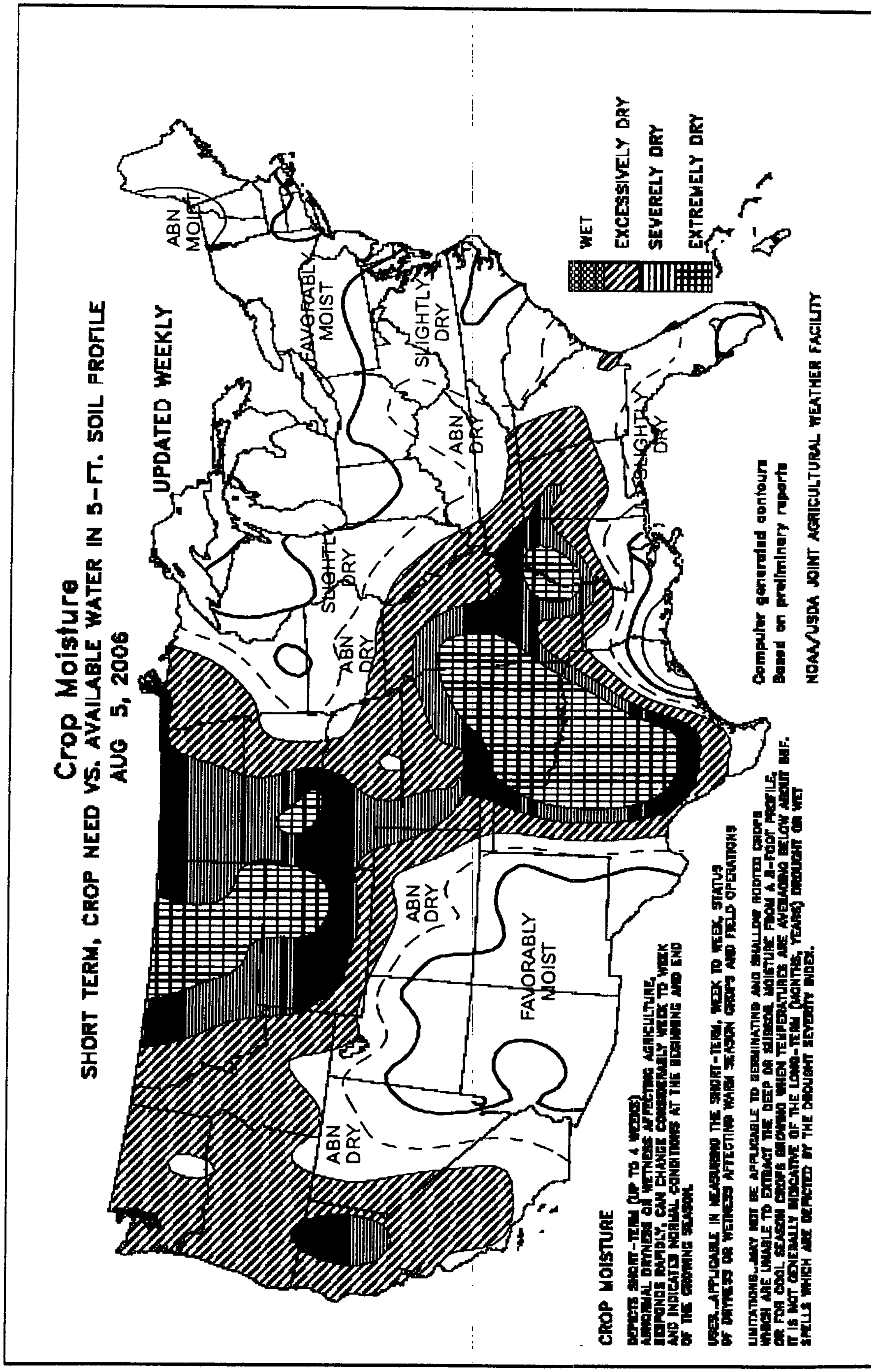
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 13


Crop Moisture
SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE
AUG 5, 2006
UPDATED WEEKLY
ABN MOIST
FAVORABLY MOIST
SLIGHTLY DRY
ABN DRY
SLIGHTLY DRY
ABN DRY
ABN DRY
ABN DRY
FAVORABLY MOIST
SLIGHTLY DRY
WET
EXCESSIVELY DRY
SEVERELY DRY
EXTREMELY DRY
CROP MOISTURE
DEPICTS SHORT-TERM (UP TO 4 WEEKS) ABNORMAL DRYNESS OR WETNESS AFFECTING AGRICULTURE, RESPONDS RAPIDLY, CAN CHANGE CONSIDERABLY WEEK TO WEEK AND INDICATES NORMAL CONDITIONS AT THE BEGINNING AND END OF THE GROWING SEASON.
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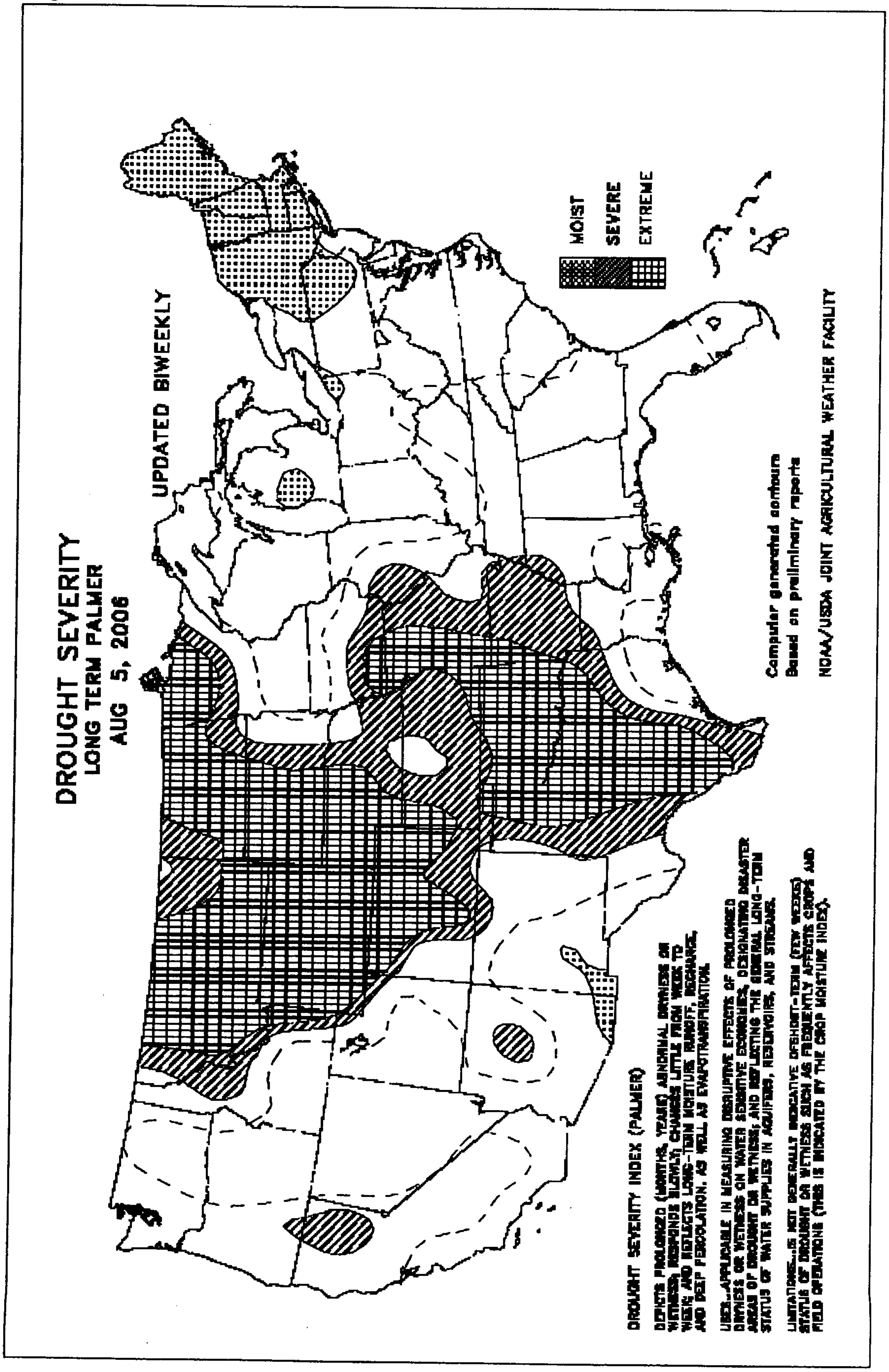
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 14


DROUGHT SEVERITY
LONG TERM PALMER
AUG 5, 2006
UPDATED BIWEEKLY
MOIST
SEVERE
EXTREME
DROUGHT SEVERITY INDEX (PALMER)
DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG-TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
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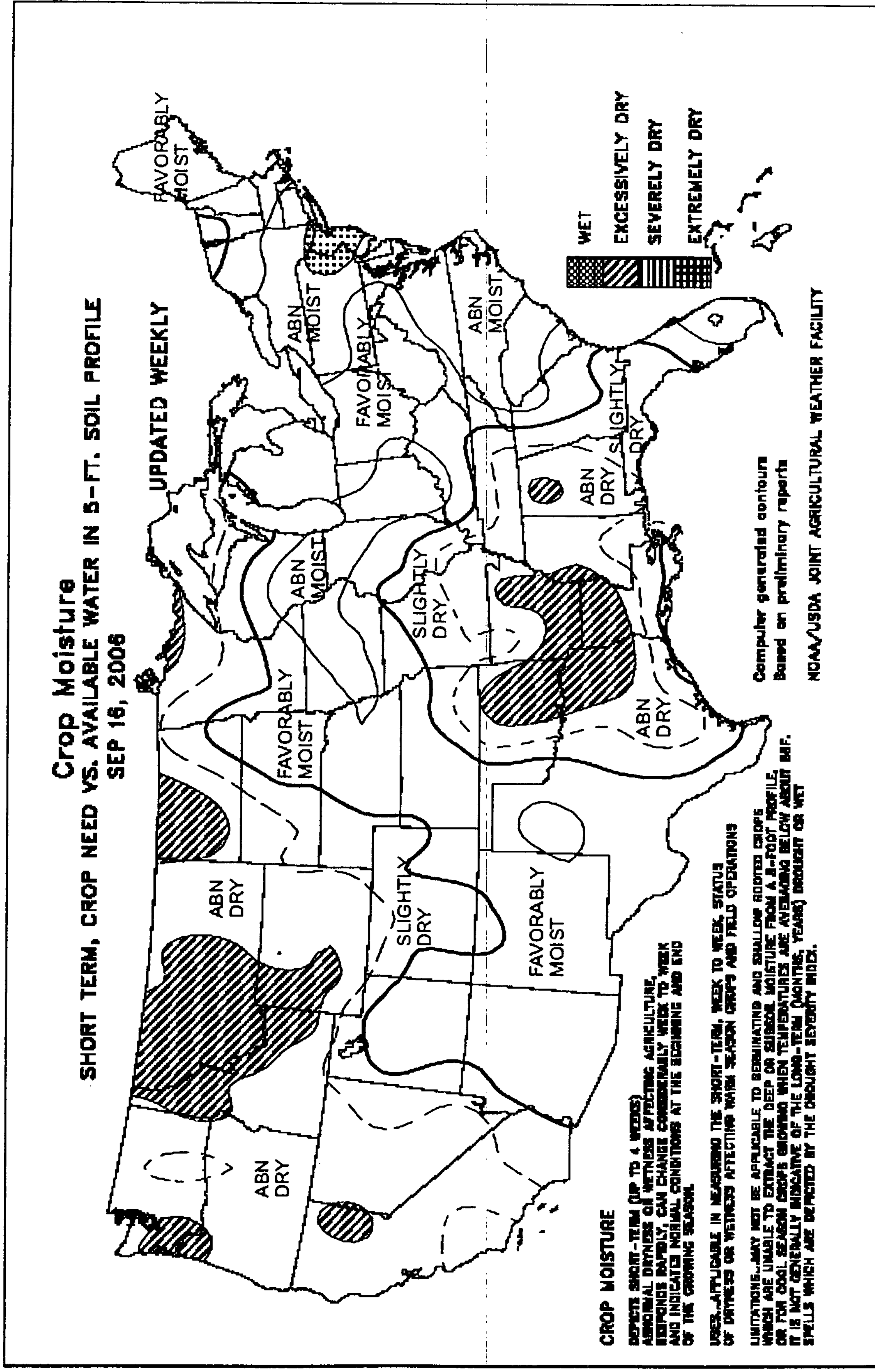
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

Fig. 15


Crop Moisture
SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE
SEP 16, 2006
UPDATED WEEKLY
FAVORABLY MOIST
ABN MOIST
FAVORABLY MOIST
ABN MOIST
ABN MOIST
SLIGHTLY DRY
ABN DRY/SLIGHTLY DRY
SLIGHTLY DRY
FAVORABLY MOIST
ABN DRY
ABN DRY
SLIGHTLY DRY
FAVORABLY MOIST
ABN DRY
WET
EXCESSIVELY DRY
SEVERELY DRY
EXTREMELY DRY
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY
CROP MOISTURE
DEPICTS SHORT-TERM (UP TO 4 WEEKS)
ABNORMAL DRYNESS OR WETNESS AFFECTING AGRICULTURE,
RESPONDS RAPIDLY, CAN CHANGE CONSIDERABLY WEEK TO WEEK
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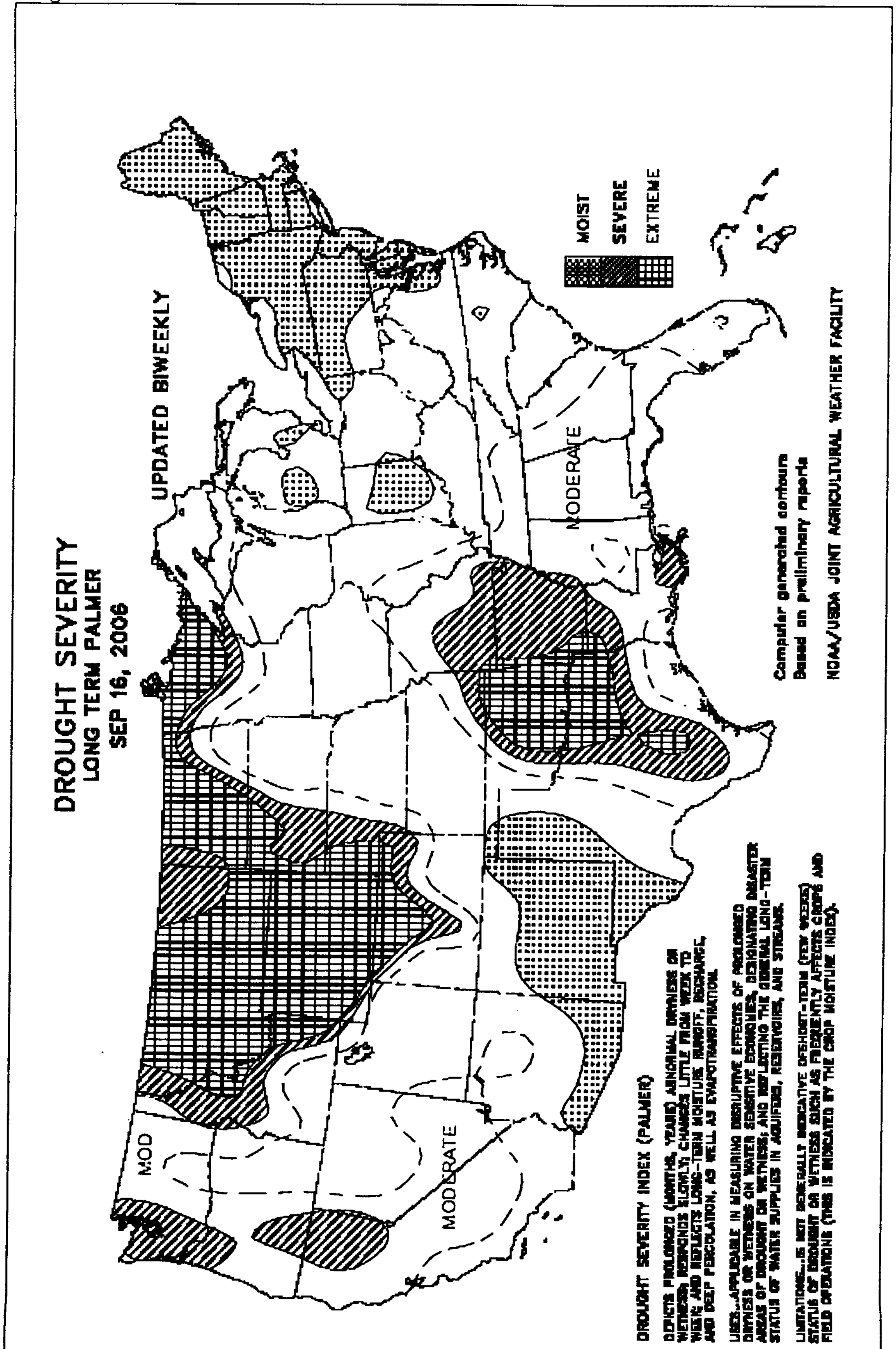
WHICH ARE UNABLE TO EXTRACT THE DEEP OR SUBSOIL MOISTURE FROM A 5-FOOT PROFILE,
OR FOR COOL SEASON CROPS GROWING WHEN TEMPERATURES ARE AVERAGING BELOW ABOUT 55F.
IT IS NOT GENERALLY INDICATIVE OF THE LONG-TERM (MONTHS, YEARS) DROUGHT OR WET
SPELLS WHICH ARE DEPICTED BY THE DROUGHT SEVERITY INDEX.

Fig. 16


DROUGHT SEVERITY
LONG TERM PALMER
SEP 16, 2006
UPDATED BIWEEKLY
MOD
MODERATE
MODERATE
MOIST
SEVERE
EXTREME
DROUGHT SEVERITY INDEX (PALMER)
DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG-TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
USES...APPLICABLE IN MEASURING DISRUPTIVE EFFECTS OF PROLONGED DRYNESS OR WETNESS ON WATER SENSITIVE ECONOMIES, DESIGNATING DISASTER AREAS OF DROUGHT OR WETNESS; AND REFLECTING THE GENERAL LONG-TERM STATUS OF WATER SUPPLIES IN AQUIFERS, RESERVOIRS, AND STREAMS.
LIMITATIONS...IS NOT GENERALLY INDICATIVE OF SHORT-TERM (FEW WEEKS) STATUS OF DROUGHT OR WETNESS SUCH AS FREQUENTLY AFFECTS CROPS AND FIELD OPERATIONS (THIS IS INDICATED BY THE CROP MOISTURE INDEX).
Computer generated contours
Based on preliminary reports
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY

VII. WEATHER AND WEATHER MODIFICATION NEWS OF THE YEAR

The following articles appeared in our WKWMP weekly newsletters this year. This section is meant to highlight some of the more interesting weather related news that occurred during the storm season. This year certainly saw many means and extremes. Some of the more extreme weather events are presented below.

From the WKWMP Weekly Newsletter No. 2006-2, April 22 – April 28

The National Center for Atmospheric Research (NCAR) has begun a five-year study to evaluate snowfall augmentation seeding in Wyoming. As reported in the May/June edition of Weatherwise Magazine, www.weatherwise.org, the NCAR sponsored program will cost $8.8 million over the five-year period. There are three separate target areas for seeding consisting of Wyoming's Medicine Bow, Sierra Madre, and Wind River mountain ranges. For the first year of study, the program will monitor natural snow-producing clouds using both ground-based and airborne instrumentation to document water vapor, the amount of liquid water within snow clouds and presumably the snowfall amounts over the three target areas. Next winter, the cloud seeding phase of the program will commence using aircraft and ground-based seeding instruments from Weather Modification, Inc., a private company based in North Dakota. The seeding agent of choice for this program will be a silver iodide and acetone solution, which is a common solution, used on many snowfall augmentation projects in the United States as well as rain optimization and hail suppression projects such as the Western Kansas Weather Modification Program. The program aims to answer two questions: does snowfall augmentation seeding work over these mountain ranges in Wyoming and if so what is the percent increase attributed to snowfall augmentation seeding. In an interview with Weatherwise, Roelof Bruintjes of NCAR says, "even a 10-percent increase would fall within the range of natural variability of a single storm or a whole season."

Natural variability in precipitation is indeed a big problem when trying to document precipitation increases attributed to seeding efforts in not only snowfall but in rainfall as well. The yearly rainfall variability---or what is considered normal yearly rainfall---during the cloud seeding season in western Kansas can be as much as several inches for a given location. For weather modification programs to show any degree of precipitation increase using either rain gauge data or snow depth measurements, seeding must consistently increase cloud precipitation above what is considered normal for the area during the season. In other words, seeding must increase precipitation to the point where the rainfall total during the cloud seeding season raises above the natural rain variability of that season. If a seeding program increases precipitation by 5% or even 10% over an area where the seeding season rain variability is 10%, it would be extremely difficult to demonstrate that the precipitation increase was attributed to seeding. The increase caused by seeding still falls within the range of natural variability for the area. This is one of the main problems with using rain gauge or snow depth measurements. The increase from seeding can easily be lost within the large amount of "noise" generated due to local precipitation variability. Hopefully, evaluation techniques in the near future, regarding precipitation effects due to seeding, will focus on using radar data, sophisticated cloud physics computer models, natural vs. seeded cloud comparisons, very dense rain gauge networks or a combination of a few or all of the techniques stated above will become more prevalent as methods of evaluation. We hope the NCAR program will be able demonstrate a positive effect. However, unless the seeding can consistently boost snowfall above the natural variability of the three target area mountain ranges, the outcome will likely be inclusive and $8.8 million dollars will have been spent with researchers asking the same question after the program ends as was asked before it started.

From the WKWMP Weekly Newsletter No. 2006-3, April 29 – May 5

<u>County rainfall averages for April</u>

April rainfall was significantly below normal for all WKWMP target area counties. Much needed rain fell during the last few days of the month, but the amount and coverage of those rains put only a small dent in the agricultural and hydrological moisture deficit currently plaguing western Kansas. Rain reports from WKWMP weather observers as well as reports from the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS), http://www.cocorahs.org/, indicate that the highest rainfall averages within the target area were in Finney and Lane counties were the average was at least one inch. April rainfall averages for our area last year were a bit better as six counties reported a rain surplus and only five counties reported a deficit.

The highest 2006 April county rainfall average reported was in Finney County with 1.24 inches (25% below normal for Finney. Following Finney, Lane County reported 1.05 inches (45% below normal for Lane), Grant at 0.58 inches (62% below normal), Kearny with 0.50 inches (67% below), Scott reporting 0.48 inches (72% below), Stanton at 0.44 inches (65% below), and Wichita with 0.41 inches or 72% below normal. The lowest rainfall averages were found over the southeastern and northwestern portion of the target area with Gray reporting 0.37 inches (82% below), Hamilton at 0.32 inches (75% below), Greeley at 0.12 inches (91% below), and Haskell County were only one report was available indicating only 0.10 inches or 97% below normal.

From the WKWMP Weekly Newsletter No. 2006-4, May 6 – May 12

I would like to thank Mr. Jeff Hutton at Dodge City National Weather Service for sharing the following information, in the general interest section of this newsletter, concerning a rapidly growing volunteer weather observation network. I encourage everyone who has access to the internet and an interest in weather observation to participate in this free program.

<u>General Interest:</u> CoCoRaHS (www.cocorahs.org)

CoCoRaHS is an acronym for the Community Collaborative Rain, Hail and Snow Network. CoCoRaHS is a unique, non-profit, community-based network of volunteers of all ages and backgrounds working together to measure and map precipitation (rain, hail and snow). The focus for this program is to provide the highest quality data for natural resource, education and research applications. <u>One of the main goals is to increase the</u>

density of precipitation data available throughout the country by encouraging volunteer weather observing.

The network originated with the Colorado Climate Center at Colorado State University in 1998. In the years since, CoCoRaHS has expanded rapidly with over 2,500 observers in twelve states. This is a community project. Everyone can help, young, old, and in-between. The only requirements are an enthusiasm for watching and reporting weather conditions and access to the internet.

The CoCoRaHS volunteers take measurements of precipitation from as many locations as possible. These precipitation reports are then recorded on the Web site www.cocorahs.org. The data are then displayed and organized for many end users to analyze and apply to daily situations ranging from water resource analysis and severe storm warnings to neighbors comparing how much rain fell in their backyards. The National Weather Service, other meteorologists, hydrologists, emergency managers, city utilities (water supply, water conservation, storm water), insurance adjusters, USDA, engineers, mosquito control, ranchers and farmers, outdoor & recreation interests, teachers, students, and neighbors in the community are just some examples of those who use this data.

By providing daily observations, volunteers can help to fill in a piece of the weather puzzle that affects many across your area in one way or another. If you are willing and able to help and are interested in joining, you can go to the CoCoRaHS website and click on the Join CoCoRaHS link. Or, go to:

http://www.cocorahs.org/Application.aspx

From the WKWMP Weekly Newsletter No. 2006-5, May 13 – May 19

Record Setting April

According to a May 16th report, http://www.ncdc.noaa.gov/oa/climate/research/2006/apr/apr06.html, issued by the National Climatic Data Center (NCDC), preliminary data indicates this past April was the warmest April on record in the contiguous United States. Temperature records span the period from 1895 to the present. The previous warmest April on record was in 1981. April was 4.5°F above the 20th century (1901-2000) average. The report indicates most of the warmth was concentrated in the south-central portion of the country such as Texas and Oklahoma where their April temperatures were the warmest on record as well as Kansas, New Mexico, Arkansas, Missouri and Tennessee which recorded their second warmest April. Throughout the contiguous 48 states, not a single state reported a below average temperature. Alaska, however, did report a cooler than average April temperature.

Near average precipitation was reported for the contiguous United States, ranking 45th wettest in the 1895-2006 record. 12 states, mostly western and north-central states, recorded wetter-than-normal conditions. There were ten states that reported lower than normal precipitation, primarily in the southwestern and southeastern United States.

According to the report, Colorado was the only state, which reported well below normal precipitation, recording its 11th driest April.

Locally, Dodge City recorded its sixth straight month of below normal precipitation as indicated in a report by Dodge City National Weather Service, http://www.crh.noaa.gov/crnews/display_story.php?wfo=ddc&storyid=2412&source=0. Also, Dodge City recorded its second warmest April on record with an average 24-hour temperature of 60.5 degrees, which was 6.6 degrees above average. The Dodge City temperature and precipitation record dates back to 1875. Coincidentally, the old Dodge City recorded for warmest April was 1981 which was also the old record for warmest April in the contiguous United States as stated above.

On a global scale, the combined ocean and land April temperature was the seventh warmest on record since the beginning of reliable records in 1880. The warmest April was in 1998.

From the WKWMP Weekly Newsletter No. 2006-11, June 24 – June 30

Prevailing scientific theory suggests that increases in greenhouse gases, primarily carbon dioxide, would lead to higher crop yields as plants take in more carbon dioxide as fertilizer. Years of tests on this matter even suggested that elevated plant intake of carbon dioxide might even offset the damaging effects of higher atmospheric temperatures and less rainfall due to global warming. However, according to a new study, any potential increase in crop yields from an elevation of the greenhouse gas carbon dioxide would be modest or nonexistent. As reported on the Futures and Commodity Markets News Internet site, http://news.tradingcharts.com/futures/4/2/80356224.html, from the Chicago Tribune news. Researchers at the University of Illinois conducted field tests in Illinois, Arizona, New Zealand, Japan and Switzerland which concluded that potential benefits from higher atmospheric carbon dioxide levels are limited by a crop's ability to absorb more carbon dioxide. The U.S. Department of Agriculture funded the study.

By 2050, atmospheric carbon dioxide levels are expected to be twice as much as today mainly due to human activities. University of Illinois researchers' point out that their findings are more accurate since the study used crop plots in fields surrounded by tube rings that spray carbon dioxide and ozone over the crops. Previous research dealt with crops grown in a greenhouse.

The study results show that corn yields did not increase at all while wheat and soybean yields increased only half of what was previously thought would occur when using carbon dioxide levels matching those expected to be present in the atmosphere in 2050. "These results are very important," said Bert Drake, a plant pathologist at the Smithsonian Environmental Research Center. "There hasn't been much of an effort to develop plants that will respond to projected conditions." Illinois researchers conclude that lower-than-expected crop yields could mean dire consequences for the world's food supply and called upon the research community to increase development of plant varieties that could withstand carbon dioxide levels expected in the near future.

From the WKWMP Weekly Newsletter No. 2006-20, August 26 – September 1

Lengthening of summer-like conditions

A new study from a research team lead by Paul Dirmeyer of the Center for Ocean-Land-Atmosphere Studies show the link between wind, evaporation and precipitation suggest more summer-like conditions during spring and fall months than had previously occurred. A brief description of the study can be found at http://www.msnbc.msn.com/id/14604811/from/RS.3/. The scientists were looking for trends in water recycling or the fraction of rain falling over a location that had originated from that same location from evaporation. In the United States, wintertime evaporation is at a minimum because of the cold while evaporation during the summer is high. Also, winds are generally higher during the winter than summer. In the winter, there's little evaporation and the winds are stronger, so what little moisture does evaporate tends to get blow away, said Dirmeyer. Dirmeyer found that especially in North America, there is an increase in the yearly trend of water recycling during the winter, spring and to a slightly lesser extent during the fall. An increase in water recycling during the spring and fall suggests a lengthening of the summer regime, Dirmeyer said. "In other words, you're getting more summer-like conditions in the spring and in the fall."

From the WKWMP Weekly Newsletter No. 2006-22, September 9 – September 15

Second warmest summer on record

A recent news release from the National Climate Data Center (NCDC) indicates that this summer was the second warmest on record (records began in 1895) with an average June-August temperature of 72.1 degrees F. The warmest summer was during the dust bowl year of 1936 when the average June-August temperature was 72.3 degrees F. When including the earlier months of January-May of 2006, the 2006 January-August temperature was the warmest on record according to the NCDC. The summer temperature article appears on the Internet site: http://www.msnbc.msn.com/id/14849568/

VIII. RESULTS AND CONCLUSIONS

Currently, we can only speculate as to the extent of hail damage sustained to the target area this year. Due to a sharp decline in subscribers for the claim information, the only company that supplied hail claim information had suspended the dissemination of such information in 2004. As a result, we have no information about the extent of hail damage incurred on those who carry crop-hail insurance in Kansas. However, the WKWMP has been working with the National Crop Insurance Services (NCIS) to reestablished the crop-hail insurance data.

Seasonal rainfall in Western Kansas in 2006 was below normal to various degrees for most of the target area. Last year, roughly half of the target area counties fell back into the drought while the other half continued an extended moist period going back to 2004. This year, the area had fallen back into the drought entirely for an extended period, which spreads across at least half the United States. For a second year in a row, August turned out to be the best month for rainfall as significant rains fell over much of western Kansas with 64% of target area counties reporting above average rainfall. Also, for a second year in a row, July turned out to be the driest month for the area with only 18% of target area counties reporting a monthly rain surplus. Of course there were some exceptions to this description at each reporting location, but for most of the target area, this scenario fit the area fairly well.

Based upon precipitation reports from both WKWMP weather observers and the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS), www.cocorahs.org, Haskell County was the only target area county that reported a rainfall surplus for the period May through August with 12.63 inches or 14% above normal for Haskell. Within the target area, the driest areas occurred mainly across the central, northwest and south-central including Greeley, Kearny and Grant. For the period May through August, Grant reported only 6.82 inches or 33% below normal for the county. As of mid October, precipitation has increased a bit due to seasonal weather pattern changes resulting in a decent moisture increase across western Kansas according to drought maps. This year's drought most likely originated during October and November of last year with county precipitation reports starting a long monthly run of below average values persisting through mid summer of this year. Interestingly, every county in Kansas reported zero precipitation for this past February. It's anyone guess as to what next year will hold, but this decade thus far has seen more dry years than wet. The 2006-2007 winter outlook calls for above normal temperatures, although slightly cooler than last winter, and equal chances of being above, normal or below in precipitation for western Kansas.

This year was another below average seeding season with 47 days where seeding for rain optimization and/or hail suppression occurred ranking 2006 the 9th least active season in our 32-year history. Short-tern drought conditions in April, May, June, July and a period of September along with a moderate lack of severe weather contributed to the low number of seeding days this year.

IX. RECOMMENDATIONS

Last year, the recommendations were:

(1) Continue the use of burn-in-place flares (BIP) for the 2006 operational season.
(2) Look into the possibility of modifying our existing BIP flare racks to make the flare holder portion of the rack assembly become interchangeable.

Regarding (1), above: Fortunately, sufficient funding was available in 2006 for the continued use of burn-in-place flares. As has been stated in recent years regarding the use of BIP's, the additional seeding agent output provided by these flares have greatly increased our effectiveness during times when exceedingly large storm complexes with high hail potential are within the target area

Regarding (2), above: Unfortunately, no changes were made to the flare racks during 2006. There was some conversation and theoretical concepts floated by members of the program on possible design changes that might work. But, no physical progress was made to implement the design concepts.

Recommendation #1: Continue the use of burn-in-place flares (BIP) for the 2007 operational season. Although tough financial times still plague our program, efforts should continue to have funding available for BIP flares. The seeding agent output rate of a flare per minute is much higher than the output rate of wing-generators, which are standard on all WKWMP cloud-base aircraft. Basically, an aircraft operating with both wing-generators and BIP's have the same capability as two, or more, seeding aircraft operating with just wing-generators alone.. With reduced numbers of seeding aircraft, BIP's have become extremely useful when our aircraft resources are strained to the limit. Unfortunately, BIP's are expensive and many are required for large storms. There are really only two drawbacks to using BIP flares as a substitution for more aircraft. The first drawback is that even though each plane produces more usable seeding agent per unit time by using a wing-generator and BIP combination, that plane is still limited to seeding only one particular cloud at any one time. Whereas, two planes using only wing-generators can seed two clouds at any moment with an example being that one plane can seed a cloud over Hamilton while the other plane at the same time can work a cloud over Lane. The optimal situation is to have funding available for integrating both more aircraft into seeding operations as well as using BIP's. In 2006, funding allowed for the use of four aircraft with three of those planes using BIP's along with wing-generators. The highly dynamical storm environment of western Kansas often times requires more than four aircraft and the use of BIP flares for almost every seeding operation. The overall cost of outfitting three cloud-base planes with flares is less than the cost of placing only one more cloud-base plane online for operations. Should additional funding become available for putting a fifth plane online for 2007, our program will have to decide if the benefits of outfitting four planes with BIP flares still outweighs the benefits of putting the fifth plane online and discontinuing flare usage.

The second drawback to BIP flares is the time required to reload flares onto the seeding plane during times when that plane must land and quickly reload seeding agent and then launch immediately to continue seeding. Each plane can carry twelve flares. When an aircraft lands to reload these flares, a pilot must first de-install the used flares from the wings and then go about the lengthy task of installing and wiring the new flares onto the aircraft. This process takes a good deal of time and equates to unwelcome extended ground time during those days when a plane must make a quick return to the air for continued seeding. With limited numbers of seeding aircraft available, it is extremely critical that multiple planes be in the air and seeding storms on days when multiple storms are in progress for extended periods. Installing and wiring flares onto an aircraft always takes away from the time that a plane could otherwise be seeding a storm.

Recommendation #2: Further develop and implement a modification to the existing BIP flare racks to make the flare holder portion of the rack assembly become interchangeable. As noted in recommendation #1, a significant portion of time needed to reload seeding agent is due to the lengthy time needed to de-install used flares and then install and wire new flares onto the BIP device. If the flare holder could be detached from the remaining flare rack assembly, then a duplicate of the flare holder could be fabricated and be stored with new flares pre-wired onto the device for use when the plane needs to launch quickly to resume seeding operations. In this instance, the pilot only needs time to detach the holder with the used flares and then attach the spare holder which already has the individual flares installed. As stated last year, a setup like this would probably cut down the ground time needed to reload seeding agent by 90%.

Recommendation #3: We should reconsider the possibility of acquiring the TITAN software system along with the RDAS aircraft tracking system. As mentioned in the recommendations published in 1999 and 2002, TITAN is the acronym for Thunderstorm Identification, Tracking, Analysis and Nowcasting. The TITAN system is coupled with another software system RDAS (Radar Data Acquisition System). Developed by a groups in South Africa and 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 sections 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. TITAN and RDAS systems are currently the standard systems on all weather modification programs around the world

Another powerful tool incorporated into the TITAN and RDAS systems is an aircraft tracking device similar to a "black box". This aircraft tracking technology is relatively new as it was developed roughly six years ago. An electronic specialist from South Africa also developed these black box devices that are installed in the operations office and on seeding aircraft. The tracking system allows the meteorologist to monitor aircraft positions with respect to storm location as well as distance and radial measurements from the radar field office. The information from the tracking system is overlaid directly onto the operational radar computer screen. The tracking systems transmit GPS data, as well as time and place of seeding material release. Weather radar incorporating the TITAN and RDAS systems is the most advanced weather monitoring/aircraft tracking available today for cloud seeding. I personally worked with the TITAN and RDAS systems during my time on one of the Texas projects and strongly recommend upgrading our existing radar to include TITAN, RDAS and aircraft tracking.

Using TITAN on the WKWMP has been resisted in the past because all of the weather modification programs using it were rain optimization programs, which aren't as fast-responding to storms, or mission critical, or lack similar aircraft numbers to make a good comparison. However, the TITAN system has become the sole radar system of almost all weather modification projects operating around the world and modifications have continued on the software making the system superior to other radar programs used for weather modification.

Using TITAN and RDAS on the WKWMP will produce many important benefits:

(1) Increase operational efficiency by greatly increasing our capability to analyze seeding operations in both real-time and during post-analysis.
(2) Allow for quantitative post-analysis of a given storm event.
(3) Provide us with state-of-the-art aircraft tracking capability far superior to our 1950's style IFF system.
(4) Allow us to better demonstrate our seeding efforts to the general public by being able to reproduce the entire seeding event complete with aircraft location/activity, numerical tools evaluating storm structure and storm trends as long as public presentations are done at the radar site.
(5) Provide a complete data set of any storm day that can be utilized for program evaluations and/or research in the future.

In 2002, the total cost to implement both the TITAN and RDAS systems was estimated to be in the neighborhood of $46,800 for outfitting four aircraft. This total breaks down into $6,000 for the RDAS system, $32,000 for all aircraft radios and GPS units and ~$8,800 for an RDAS/TITAN computer and systems configuration. It is certainly safe to assume the price has increased some since then.

One alternative is to consider purchasing the TITAN/RDAS installation for the radar one year and the aircraft tracking systems in another year. In any event, on a long-term basis, we should make plans for future acquisition of the modern systems within the near future. Our current radar software package is antiquated and incompatible with nearly all modern computer operating systems.

X. ACKNOWLEDGEMENTS

The WKWMP has now completed its 32nd year of program operations. As a result of many hours of consultation, hard work, training, previous experience and perseverance, we are confident in our ability to continue aggressive seeding operations in 2007 and beyond with the same aggressive and determined manner as this year's performance.

I would like to thank everyone who provided words of encouragement to the program during this season as it was indeed a tough time going not just for the program but for everyone who depends on the weather. Much appreciation goes out to those who recognize that there are a few days when our planes cannot be everywhere at the same time nor perform at the most effective level when severe storms are almost everywhere clearly outnumbering and overpowering our ability. Thankfully those extreme days occur only a few times a year and although hail damage can be terrible, I don't believe any other program in the United States would be any more successful than ours at combating the shear number of severe storms that occur on those days.

Sincere appreciation is also extended to the program staff: pilots, intern-pilots, assistant meteorologists and stand-in pilots. Periods of extreme dry weather during this season strained many staff members' patience as dry period's mean frustration as well as idle and unwelcome down time for everyone. However, it was always nice to know that when the time came for our services to be called into action, everyone was anxious and ready to go with tremendous enthusiasm.

Much appreciation is in order for David Brenn, Executive Director of the Western Kansas GMD #1 (WKGMD#1). David has been to aggressively pursuing a financial framework that would put this program on strong footing by furthering interest in this program not only at the State level but possibly the insurance companies as well. High level meetings between the WKGMD#1, Kansas Water Office and Kansas insurance companies interested in reducing crop-damaging hail will be held in November in the hope of increased State funding and perhaps funding aid by insurance companies similar to an insurance funded weather modification program in Canada. David's effort along with the tremendous support and dedication of the Board of Directors continues to sustain the WKWMP during difficult times with the result always being a focused and well-administered program.

On behalf of the WKWMP staff, I welcome Jan King, new administrative assistant of WKGMD#1, to the staff and look forward to working with her for years to come.

Lastly, many thanks and best wishes to Neta Wheeler, who retired this year after a long and distinguished career as administrative assistant of WKGMD#1. Neta was wonderful to work with and work for. She was the most personable and cordial administrative assistant I have ever worked with. On behalf of all staff members of the WKWMP, we wish Neta well in her retirement!

Walter Geiger III, WKWMP Program Manager

APPENDIX A

HISTORIC PROGRAM OPERATIONAL ACTIVITY SUMMARY

(SEEDING AND OBSERVATION FLIGHTS)

YEAR	SEED+OBS FLIGHTS (hours)	SEEDING TIME (hours)	SEEDING AGENTS CONSUMED			NO. AIRCRAFT ASSIGNED	
			AgI (gms)	CO2 (kg)	LCO2 (kg)	BASE	TOP
1975	281	178	63,310	N/A	N/A	4	0
1976	415	236	84,603	N/A	N/A	3	0
1977	263	147	47,850	N/A	N/A	4	0
1978	427	262	112,332	N/A	N/A	1	2
1979	318	205	100,311	N/A	N/A	1	2
1980	282	142	67,175	N/A	N/A	1	2
1981	264	142	69,793	N/A	N/A	1	2
1982	240	160	33,279	1,078	N/A	2	1
1983	205	112	15,706	759	N/A	2	1
1984	251	166	26,346	1,059	N/A	3	1
1985	235	154	42,851	786	N/A	3	1
1986	723	319	64,388	2,150	N/A	3	1
1987	761	362	68,049	N/A	N/A	4	0
1988	521	250	42,432	1,710	N/A	3	1
1989	579	265	52,902	1,310	N/A	3	1
1990	640	331	58,798	2,531	N/A	3	1
1991	942	433	78,718	3,900	N/A	3	1
1992	731	374	72,180	2,648	N/A	4	1
1993	747	262	55,845	3,159	N/A	4	1
1994	938	375	77,226	3,020	N/A	4	1
1995	868	356	75,970	2,622	N/A	4	1
1996	1,542	705	151,002	3,509	N/A	5	1
1997	2,224	864	204,906	3,488	N/A	8	1
1998	1,552	1,322	167,752	3,159	N/A	8	1
1999	1,552	1,107	136,443	3,165	N/A	8	1
2000	1,037	1,146	117,369	2,089	N/A	7	1
2001	1,067	722	119,176	1,740	N/A	5	1
2002	483	312	58,590	1,431	N/A	3	1
2003	466	421	68,807	1,430	349	3	1
2004	413	263	60,860	945	N/A	3	1
2005	513	319	77,288	1,663	N/A	3	1
2006	497	270	64,563	1,802	N/A	3	1
TOTALS 31 years	21,977 hours	12,681 hours	2,536,820 grams AgI	51,153 Kg CO2	349 Kg LCO2		

APPENDIX B

HISTORIC MONTHLY NUMBER OF SEEDING DAYS FOR HAIL SUPPRESSION AND/OR RAIN OPTIMIZATION

YEAR	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR SUM	MAY-AUG TOTAL	NUMBER OF COUNTIES	NUMBER OF AIRCRAFT	SEASON DATES
1975		3	13	12	16	12	2	58	53	12	4	4/01 - 9/15
1976		7	8	9	11	10	6	51	38	12	3	4/01 - 9/15
1977		4	17	6	14	13	4	58	50	14	4	4/01 - 9/15
1978		3	11	14	14	14	1	57	53	14	3	4/01 - 9/15
1979			11	15	18	16		60	60	15	3	5/01 - 8/31
1980			6	12	14	8		40	40	14	3	5/01 - 8/31
1981			14	8	14	9		45	45	14	3	5/01 - 8/31
1982			18	7	11	9		45	45	12	3	5/01 - 8/31
1983			9	15	12	10		46	46	12	3	5/01 - 8/31
1984		0	4	16	12	18	2	52	50	13	4	4/15 - 9/15
1985		6	9	10	15	10	3	53	44	13	3	4/15 - 9/15
1986		1	10	21	14	16	4	66	61	11	3	4/15 - 9/15
1987	1	1	19	14	9	10	8	62	52	10	4	3/15 - 9/30
1988		2	14	16	17	9	0	58	56	10	4	4/15 - 9/15
1989			11	12	11	16	2	52	50	11	4	5/01 - 9/15
1990			8	12	16	11		47	47	11	4	5/01 - 8/31
1991			14	19	14	14	5	66	61	12	4	5/01 - 9/15
1992			11	16	16	11	4	58	54	13	5	5/01 - 9/15
1993			10	14	17	13	1	55	54	13	5	5/01 - 9/15
1994			12	11	13	12	1	49	48	13	5	5/01 - 9/15
1995			11	12	16	12	4	55	51	13	5	5/01 - 9/15
1996		1	11	23	19	16	6	76	69	14	6	4/15 - 9/30
1997		1	12	20	18	17	6	74	67	16	9	4/23 - 9/21
1998		0	15	10	25	16	2	68	66	16	9	4/22 - 9/21
1999		1	12	20	17	10	8	68	59	16	9	4/20 - 9/20
2000		3	3	12	18	12	2	50	45	16	8	4/20 - 9/20
2001		4	9	10	18	11	9	61	48	14	6	4/20 - 9/20
2002		1	6	13	7	15	1	43	41	14	4	4/22 - 9/20
2003		2	7	14	11	8	3	45	40	11	4	4/21 - 9/19
2004		2	11	9	11	6	1	40	37	10	4	4/19 - 9/17
2005		1	5	11	9	8	4	38	33	11	4	4/18 - 9/16
2006		3	8	10	9	14	3	47	41	11	4	4/17 - 9/22
TOTAL	1	46	339	423	456	386	92	1743	1604			

AVERAGE NUMBER OF SEEDING DAYS PER MONTH - ALL YEARS:

MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2.3	10.6	13.2	14.3	12.1	3.5

4 MONTHS MAY - AUG = 50.2 Days
ALL SEASON AVERAGE = 57.0 Days

MAXIMUM NUMBER OF SEEDING DAYS PER MONTH - ALL YEARS:

MAR	APR	MAY	JUN	JUL	AUG	SEP
1	7	19	23	25	18	9

MAXIMUM DAYS FOR ANY SEASON = 75 DAYS (1996)
MAXIMUM DAYS FOR ANY MAY - AUG = 69 DAYS (1996)

MINIMUM NUMBER OF SEEDING DAYS PER MONTH - ALL YEARS:

MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0	3	6	7	6	0

MINIMUM DAYS FOR ANY SEASON = 38 DAYS (2005)
MINIMUM DAYS FOR ANY MAY - AUG = 33 DAYS (2005)

APPENDIX C

HISTORIC WKWMP COUNTY PARTICIPATION

1975 - 2006

WESTERN AND SOUTHWESTERN KANSAS

COUNTY	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
WALLACE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
GREELEY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
WICHITA	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SCOTT	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LANE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HAMILTON	X	X	X	X	X	X	X											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
KEARNY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FINNEY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GOVE																											X	X				
GRAY	X	X	X	X	X	X	X									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HODGEMAN			X	X	X			X	X	X	X																					
STANTON	X	X	X	X	X	X	X	X		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GRANT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HASKELL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FORD			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
SEWARD					X	X	X	X	X	X	X	X																				
STEVENS						X																X						X				
TOTALS	12	12	14	14	15	14	14	12	12	13	13	11	10	10	11	11	12	13	13	13	13	14	13	13	13	13	14	14	11	10	11	11

Note: 1975 - 1996 Wallace County participation was limited to WKGMD #1 boundaries

NORTHWEST KANSAS PARTICIPATION

		97	98	99	00	01	02	03	04	05	06
SHERMAN		X	X	X	X						
THOMAS		X	X	X	X						
SHERIDAN		X	X	X	X						
CHEYENNE	(PARTIAL)	X	X	X							
RAWLINS	(PARTIAL)	X	X	X							
DECATUR	(PARTIAL)	X	X	X							
LOGAN	(PARTIAL)	X	X	X	X						
GOVE	(PARTIAL)	X	X	X	X						
GRAHAM	(PARTIAL)	X	X	X	X						
	TOTALS:	9	9	9	6	0	0	0	0	0	0

EASTERN COLORADO DEMONSTRATION AREA PARTICIPATION

		97	98	99	00	01	02	03	04	05	06
YUMA		X	X	X							
KIT CARSON			X								
CHEYENNE			X	X	X	X					
	TOTALS:	1	3	2	1	1	0	0	0	0	0

NOAA FORM 17-4A
(4-31)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Form Approved OMB No. 0648-0025
Expires 12/31//2007

INTERIM ACTIVITY REPORTS AND FINAL REPORT

This report is required by Public Law 92-205; 85 Stat. 735; 145 U.S.C. 330b. Knowing and wilful violation of any rule adopted under the authority of Section 2 of Public Law 92-205 shall subject the person violating such rule to a fine of not more than $10,000, upon conviction thereof.

NOAA FILE NUMBER
06-1330

[ ] INTERIM REPORT [X] FINAL REPORT

Complete in accordance with instructions on reverse and forward one copy to:
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
1315 East-West Highway SSMC-3 Room 11216
Silver Spring, MD 20910

REPORTING PERIOD
FROM 04/17/06 TO 09/22/06

MONTH	(a) NUMBER OF MODIFICATION DAYS	(b) NUMBER OF MODIFICATION DAYS PER MAJOR PURPOSE: INCREASE PRECIPITATION	ALLEVIATE: HAIL	ALLEVIATE: FOG	OTHER	(c) HOURS OF APPARATUS OPERATION BY TYPE: AIRBORNE (hrs)	GROUND	(d) TYPE AND AMOUNT OF AGENT USED: SILVER IODIDE (gms)	CARBON DIOXIDE (kg)	UREA	SODIUM CHLORIDE	OTHER
JANUARY												
FEBRUARY												
MARCH												
APRIL	3	1	2			6.1		1491	19.0			1 RS3 (80gms)
MAY	8	2	7			53.8		12104	475.5			84 RS3 (80gms)
JUNE	10	4	10			95.3		23024	581.2			126 RS3 (80gms)
JULY	9	8	8			35.1		8152	369.8			48 RS3 (80gms)
AUGUST	14	8	11			58.4		14255	241.2			49 RS3 (80gms)
SEPTEMBER	3	0	3			21.0		5141	115.9			
OCTOBER												
NOVEMBER												
DECEMBER												
TOTAL	47	23	41			269.7		64167	1802.6			308 RS3 (80gms)
TOTALS FOR FINAL REPORT	47	23	41			269.7		64167	1802.6			308 RS3 (80gms)

DATE ON WHICH FINAL WEATHER MODIFICATION ACTIVITY OCCURRED *(For Final Report only.)*
09/15/06

CERTIFICATION: I certify that all statements in this report on this weather modification project are complete and correct to the best of my knowledge and are made in good faith.

NAME OF REPORTING PERSON
Walter Eugene Geiger III

AFFILIATION
estern Kansas Groundwater Mgmt. Dist. #1

SIGNATURE

STREET ADDRESS
. Highway 94

OFFICIAL TITLE
Program Manager

CITY
Scott City

STATE
KS

ZIP CODE
67871

DATE
10/15/06