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CLOUD SEEDING - THE UTAH EXPERIENCE

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Abstract. The first cloud seeding project in Utah began in the early 1950s in the central and southern portion of the state and lasted four years. The project was reactivated in 1973 by the original organizers and has continued to the present. The Utah Cloud Seeding Act was passed in 1973 by the Utah Legislature. This law provides for licensing cloud seeding operators and permitting cloud seeding projects by the Utah Division of Water Resources. The act states that for water right purposes all water derived from cloud seeding will be treated as though it fell naturally. The act also allows for the division to sponsor and/or cost-share in cloud seeding projects. Since 1976, the state through the division and Board of Water Resources has cost-shared with local entities for cloud seeding projects. In the 1970s, cloud seeding projects expanded to cover most of the state. The majority of projects were for wintertime snow pack augmentation, but a summertime hail suppression/rainfall augmentation project operated for six years in Northern Utah. The state participated in the NOAA Cooperative Weather Modification Research Project from 1981 to 1996. Wintertime snow pack augmentation projects continue to operate in Utah.

1. THE EARLY YEARS

Utah is the second driest state in the nation. It is not surprising, therefore, that a group of counties in Central and Southern Utah sponsored a cloud seeding project within a few years after the discovery of modern cloud seeding principles in the late 1940s, as did many other groups in the western and mid-western states.

A project began in April 1951 and operated until May 1955. The project used ground generators that burned coke impregnated with silver iodide and was operated by the Water Resources Development Corporation of Denver, Colorado. The sponsoring entity was the Southern Utah Water Resources Development Corporation.

The University of Utah Meteorology Department (Hales et al., 1955) and the American Institute of Aerological Research (1955) made evaluations of the effects of the cloud seeding. The two evaluations resulted in conflicting results, and the project ended.

The first legislation in Utah concerning weather modification was enacted in 1953. This law required the reporting of weather modification activities in Utah to the Department of Meteorology at the University of Utah.

2. THE BANNER YEARS

The years 1973 through 1981 were historic in shaping Utah's weather modification program. In 1973 some of the original organizers of the 1950s

Central and Southern Utah Project reactivated the program. They lobbied the legislature, which resulted in passage of the 1973 Utah Cloud Seeding Act. They operated the Central and Southern Utah Project for wintertime snow pack augmentation in water years 1974 and 1975. They contracted, using their own funds (county taxes), with North American Weather Consultants to operate the project using ground generators that released silver iodide.

Through their lobbying and promotional efforts, state funding became available beginning in water year 1976. With the state funding and local participation, the winter program was expanded to cover more areas of the state. A summertime hail suppression and precipitation augmentation program was started in the northern portion of the state. State funding for the winter and summer programs was about 70 percent, and local funding was the remaining 30 percent.

With greatly increased interest in weather modification and the Cloud Seeding Act of 1973, the Division of Water Resources responded with a public involvement program. A Weather Modification Newsletter, published several times a year, began in 1975 and was distributed until 1980. Five annual one-day cloud seeding seminars were held, and the proceedings were published beginning in 1974. In 1975 the Division of Water Resources created a Technical Advisory Committee made up of university and government scientists, television weathermen, legislators, government agencies involved in water resources, and water users. The committee was realigned in 1977 into two separate committees. One

was called the Program Advisory Committee, comprised of water users and government agencies having stewardship over water resources. The other was the Technical Advisory Committee, composed of meteorologists, statisticians and scientists with expertise relating to program design, evaluation and research. Both committees functioned until 1983 and provided valuable input to the Division of Water Resources. Some cloud seeding research and evaluation began with state funding at Utah State University in the late 1970s. The NOAA/Utah Cooperative Research Program was in the planning stage in the late 1970s, and funding began in 1981.

The state experienced an economic downturn in the early 1980s. State funding for cloud seeding was greatly reduced and the summer project did not survive. The winter programs continued with eventually a much larger portion of the funding from the local sponsors. These nine years--1973 through 1981--were the heydays for cloud seeding in Utah.

3. 1973 CLOUD SEEDING ACT

The following is a summary of the 1973 Utah Cloud Seeding Act:

(1) *Authority:* The state of Utah through the Division of Water Resources shall be the only entity, private or public, that shall have authority to authorize, sponsor, and/or develop cloud seeding projects within the state of Utah.

(2) *Ownership of Water:* All water derived as a result of cloud seeding shall be considered as a part of Utah's basic water supply the same as all natural precipitation water supplies have been heretofore, and all statutory provisions that apply to water from natural precipitation shall also apply to water derived from cloud seeding.

(3) *Record-Keeping:* Repealed the 1953 law on record-keeping and required the Division of Water Resources to establish criteria for reporting data and record-keeping.

(4) *Rules and Regulations:* Any individual or organization that would like to become a cloud seeding contractor in the state of Utah shall register with the Division of Water Resources. As a part of the registration, the applicant shall meet qualifications established by the Division of Water Resources and submit proof of financial responsibility.

(5) *Trespass:* The mere dissemination of materials and substances into the atmosphere or causing precipitation pursuant to an authorized cloud

seeding project shall not give rise to any presumption that such use of the atmosphere or lands constitutes trespass or involves and actionable or enjoyable public or private nuisance.

(6) *Interstate Activities:* Cloud seeding in Utah to target an area in an adjoining state is prohibited except upon full compliance of the laws of the target area state, as well as the provisions of this act.

(7) *Exemptions:* Cloud seeding for the suppression of fog at airports and frost prevention measures for the protection of orchards and crops are excluded from the act.

Based on the 1973 Cloud Seeding Act, the Division of Water Resources promulgated rules and regulations relating to cloud seeding in Utah. A license and permit are required for cloud seeding in Utah as well as proof of financial responsibility. Reporting of cloud seeding activities to NOAA as required by federal law is also required by the Division of Water Resources.

4. STATE FUNDING

The 1973 Cloud Seeding Act authorized the Division of Water Resources to sponsor and/or cost-share in cloud seeding projects. The legislature for water year 1976 provided funding for wintertime projects and a summertime project at about 70 percent cost sharing by the state. This level of funding continued through 1981.

Because of the state's economic downturn in the early 1980s, the legislature only provided funding for the winter projects in 1982 and 1983. Without state funding, the summer project ended in 1981.

An extremely wet period occurred statewide in the spring of 1983 and continued into 1984. No cloud seeding activities occurred in water year 1984. The wet conditions continued over most of the state except in extreme Southern Utah (Washington County). The only cloud seeding operation for 1985 through 1987 was in Washington County. There was no state funding for cloud seeding in 1987 because the state was constructing the West Desert Pumping Project to pump water from the Great Salt Lake to reduce flood damage.

The wet period ended in 1987 and the entire state entered into its most critical 10-year dry period. By 1989 most of the state wintertime cloud seeding projects were again operational due to drought conditions. State funding for cloud seeding increased in 1989 and 1990. Beginning with water year 1991,

the legislature authorized the Utah Board of Water Resources to fund (grant) cloud seeding projects up to \$150,000 each year from its Revolving Construction Fund. State cost sharing with these funds has ranged from 31 to 50 percent, depending on total project costs and board policy. Figure 1 shows the state and local funding for cloud seeding since passage of the 1973 Cloud Seeding Act.

5. SUMMER PROJECT

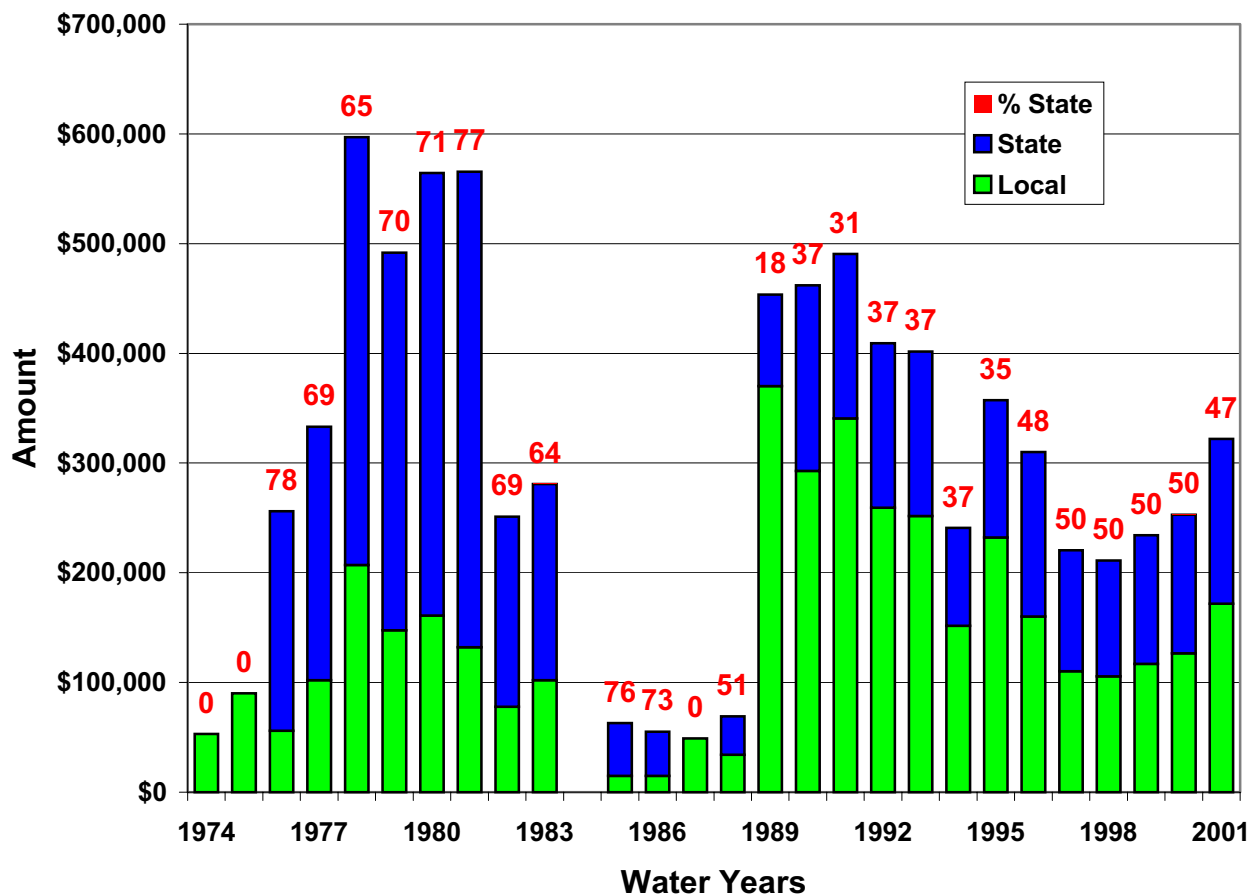
In 1976 Atmospherics Incorporated of Fresno, California, acting as contractor for Box Elder, Cache and Rich counties in Northern Utah (Figure 2), designed and conducted a rain augmentation/hail suppression project. Equipment included a 5.5 cm weather radar system, two cloud seeding aircraft, and five silver iodide ground generators. Operational headquarters were at the Ogden Airport and the radar

system was located on Little Mountain, 15 miles west of Ogden.

The program operated for six consecutive summers (1976-81). Program costs averaged near \$130,000 per year. The state cost-shared with the counties, providing about 70 percent of the project cost. Due to the economic downturn in the state, the legislature did not fund the summer project in 1982 and the project ended. Beginning in water year 1989, Box Elder and Cache counties sponsored a wintertime project that continues today.

During the summer of 1977, a precipitation augmentation project was run statewide from mid-July through September. This was an emergency project funded by the state due to extreme drought conditions.

Figure 1. State and Local Funding for Cloud Seeding



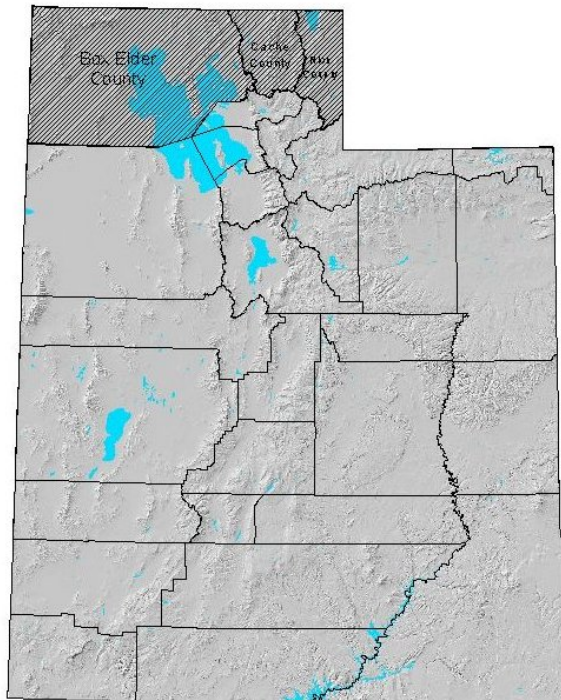


Figure 2. Summer Cloud Seeding Project Area

6. WINTER PROJECTS

A map of the winter projects in Utah for snow pack augmentation since passage of the 1973 Cloud Seeding Act is shown on Figure 3. The map also indicates the currently active projects (2001) as well as inactive projects. The contractor for all of the winter projects is North American Weather Consultants, Inc., of Sandy, Utah. The goal of these projects have primarily been to augment spring and summer streamflow to benefit agriculture interests, although some projects have been conducted to augment municipal water supplies.

6.1 Inactive Projects

There are six inactive project areas. The Ogden River Project Area was cloud seeded in water year 1977 and water years 1991 through 1993. The Wasatch Front Project was operated for 10 years in water year 1977 and water years 1988 through 1996. The Uinta Mountains were cloud seeded in water years 1977 and 1978 and again in 1989. The Carbon County and La Sal Mountains projects were operated in water years 1978 through 1983 and 1990, for a total of seven years. The Abajo (Blue) Mountains Project was operated for 12 years in water years 1976 through 1983 and again in water years 1990 through 1993.

6.2 Active Projects (2001)

There are six active project areas in Utah. Five large-scale project areas using ground based silver iodide generators include: (1) the Central/Southern Utah and the (2) Tooele County Project areas, sponsored by the Utah Water Resources Development Corporation; the (3) West Box Elder and (4) East Box Elder/Cache County Project areas, sponsored by the Bear River Water Conservancy District and Cache County; and the (5) West Uintas Project Area, sponsored by the Weber Basin Water Conservancy District and the Provo River Water Users Association. The total estimated cost for these projects is \$321,900, of which the state will cost share 46.7 percent (\$150,000). Emery Water Conservancy District is operating a small-scale project using liquid propane to seed the Wasatch Plateau above Joes Valley Reservoir. This is a continuation of part of the NOAA/Utah Research Project conducted in the 1990s.

The Central/Southern Utah Project has operated continuously since water year 1974, with the exception of the extreme wet period from 1984-87. The project has 23 seeded seasons. In some of the early years when higher state funding was available, multiple cloud seeding aircraft, weather radar, and rawinsonde operations were used to supplement the ground based silver iodide generator network. The project area currently has 65 cloud seeding generators. Using a target and control regression analysis for December through March precipitation, the Central/Southern Utah Project Area indicates a 14 percent average increase in high elevation target precipitation for this period (Griffith and Solak, 2000a).

Seeding began in the Tooele County Project Area in 1976 and continued through the 1982 water year. Seeding resumed in 1989 through 1992 and again in 1996 to the present. There are 16 seeded seasons. The project area has nine cloud seeding generators. Target and control regression analysis shows a December-March high elevation target precipitation average increase of 19 percent (Griffith and Solak, 2000a).

The East Box Elder/Cache County Project Area has operated 12 years, beginning in 1989. The project area has 22 cloud seeding generators. Target and control regression analysis shows a December-February high elevation target precipitation average increase of 20 percent (Griffith and Solak, 2000b).

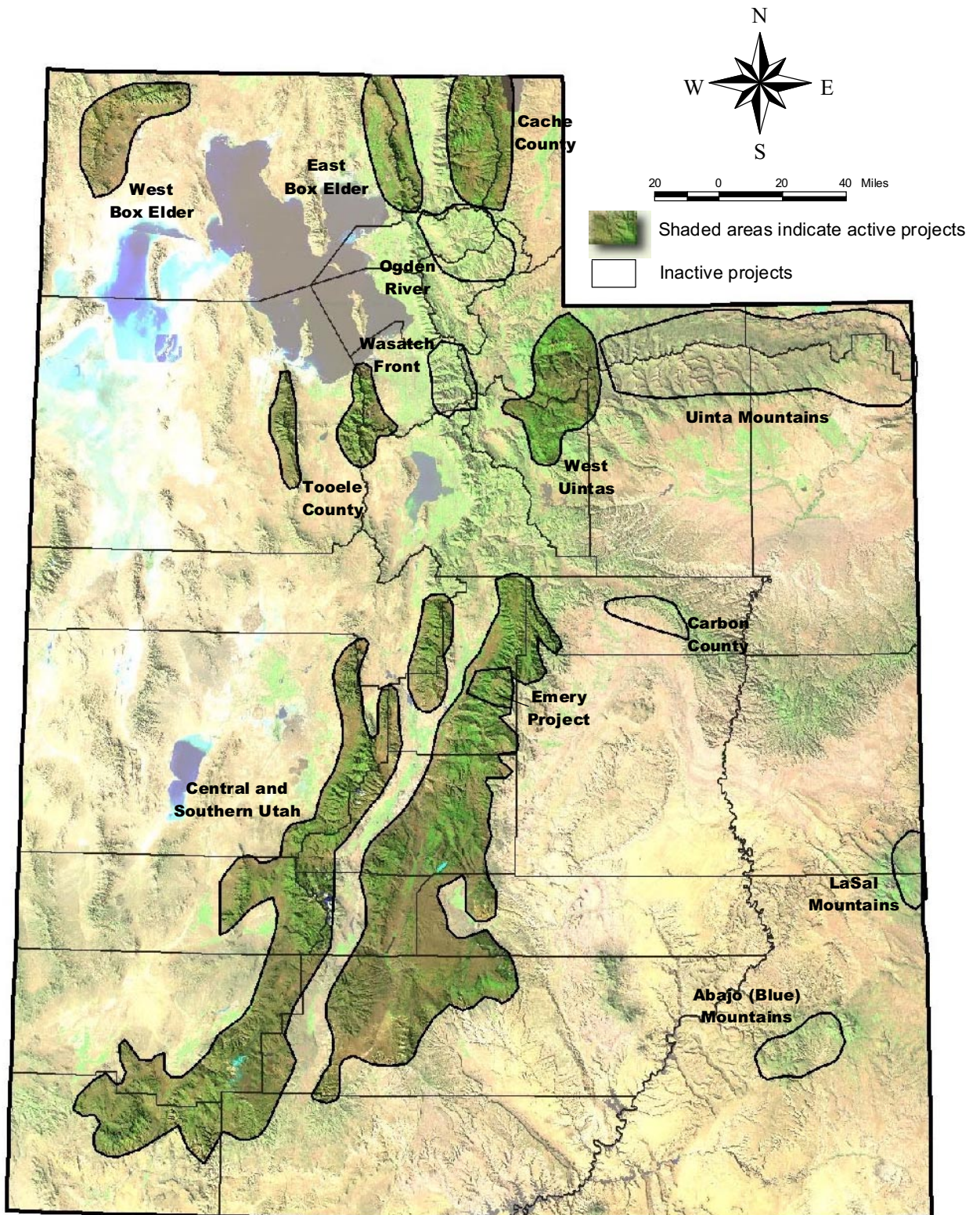


Figure 3. Winter Cloud Seeding Project Areas

The West Box Elder Project Area operated for 10 years from 1989 through 1997, 2000 and 2001. The project area has 12 cloud seeding generators. The target area has no precipitation gages; however, there are two snow courses. A target and control regression analysis shows an April 1 snow water content average increase of 18 percent (Griffith and Solak, 2000b). The target and control regression analysis for the non-seeded years of 1998 and 1999 shows no seeding effects; i.e., the regression equation accurately predicted the target April 1 snow water content even though increases of 26 percent and 13 percent continued in Cache County, which was seeded these two years.

The West Uintas Project Area operated for six years from 1989 through 1993 and during 1995. It is being operated again this year. The project area has 14 cloud seeding generators. Target and control regression analysis shows a December-March high elevation target precipitation average increase of 8 percent (Thompson, et al., 1995). Table 1 below shows a summary of the current cloud seeding project areas.

A study by the Division of Water Resources (Stauffer and Williams, 2000) estimated the average annual increase in runoff due to cloud seeding to be about 250,000 acre-feet (13.0 percent) for the project areas seeded during the 1999-2000 season. The study estimated the cost of water developed from cloud seeding in Utah to be about one dollar per acre-foot.

7. RESEARCH

In the late 1970s, the state funded research at Utah State University for expanding knowledge on winter orographic storms and ways to expand precipitation efficiency as well as evaluating winter cloud seeding projects. In the early 1980s, federal

funds from the NOAA research project contributed to this research at Utah State University. The U. S. Bureau of Reclamation sponsored some ecological impact studies of snow pack augmentation in the Uinta Mountains of Utah during the years 1976 to 1980 (Harper, 1981).

In 1976 Congress passed the National Weather Modification Act (P. L. 94-490) that directed the Secretary of Commerce to conduct a comprehensive study of the state of scientific knowledge concerning weather modification. The secretary appointed a Weather Modification Advisory Board to make the study. The board suggested a local-state-federal funding program for operation/research projects. Federal funding was obtained by the continuing lobbying efforts of all the states and their congressional delegations. Project administration was carried out by NOAA. North Dakota and Utah were the first states participating in the program. Other states joining the program were Nevada, Illinois, Arizona and Texas. The program ran from 1981 through 1996, during which time approximately \$30 million of federal funds was appropriated. Approximately \$6.7 million was spent on the Utah program.

The objectives of the NOAA/Utah Program were to determine the following: (1) Spatial and temporal distribution of super cooled liquid water (SLW) in clouds over mountains, (2) precipitation trajectories within the clouds, and (3) transport and delivery of seeding material from ground-based generators sited upwind of the mountains to clouds passing over the mountains. Field research was conducted in 1981, 1983, 1985, 1987, 1989, 1990, 1991, 1994, 1995 and 1996. The projects prior to 1990 were conducted in the Tushar Mountains near Beaver in Southern Utah. The field projects in the 1990s were carried out on the Wasatch Plateau near Manti in Central Utah. In the latter years, experimentation with both liquid

TABLE 1
SUMMARY OF THE CURRENT CLOUD SEEDING
PROJECT AREAS

Project Area	Number of Cloud Seeding Generators 2000-01 Season	Prior Seeded Seasons	Precipitation Increase During Seeding Period
Central/Southern Utah	65	23	14%
Tooele County	8	16	19%
East Box Elder/Cache County	22	12	20%
West Box Elder County	12	10	18%*
West Uintas	14	6	8%

*Based on April 1 snow water content.

propane and silver iodide was conducted at high altitude remote sites. Emery Water Conservancy District has continued to operate three remote high altitude liquid propane seeders as an operational project on the Wasatch Plateau.

These 16 years of research have increased the general knowledge of winter snow pack augmentation through weather modification. It has partially answered some of the questions concerning the objectives of the Utah/NOAA program. Field observations over the Tusher Mountains and Wasatch Plateau showed SLW exists during portions of winter storms near the windward slopes and tops of mountain barriers. Measurements showed valley-released silver iodide is transported to mountain tops. However, further research experiments are needed to determine (1) the conditions required for the presence of abundant SLW and (2) the amount and effectiveness of the silver iodide at different temperatures of the SLW. The termination of the NOAA/state program in 1996 effectively ended federal funding for weather modification research in the United States. There continues to be a need for improving the efficiencies and the evaluation of operational programs. This can be accomplished through local, state and federal cooperative research programs. A new federal funding program is needed.

8. THE FUTURE

Predicting the future of cloud seeding in Utah is about as accurate as a long-range weather forecast. The Central and Southern Utah Project has been the mainstay of cloud seeding projects in Utah. The project has operated since 1974 and is expected to continue into the future, The Northern Utah Project has been operating continuously since 1989, and it appears it will also continue into the future. Several of the other projects in the state come and go depending on wet and dry cycles, reservoir storage and local politics. State funding appears to be stable at \$150,000 per year from the Utah Board of Water Resources Revolving Construction Fund. Cloud seeding appears to be well and healthy in Utah.

9. ACKNOWLEDGMENTS

Alan Frandson of Centerfield was the leading pioneer for the water users in promoting and organizing cloud seeding in Central and Southern Utah. He was followed by Robert Nielson of Lynndyl. Reese Warburton of Grouse Creek was a leader in organizing the Northern Utah Summer Project.

Those in the commercial weather modification field having major influence in Utah were Keith Brown, Don Griffith, Thomas Henderson and John Thompson. Division of Water Resources personnel that have had significant influence on the cloud seeding program are Larry Anderson, Paul Gillette, Robert King, Dan Lawrence, Robert Murdock, Clark Ogden, Barry Saunders, Norman Stauffer, Paul Summers and Clint Warby.

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