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About this draft: This is a working draft. It is incomplete. The chapter contains placeholders for some figures and tables. Much of the data is missing. Full discussion of some topics may be incomplete. This is the second of several drafts to be circulated in 2008 before the public review draft is distributed in December.

Subgroup: Increase Water Supply

Chapter # Precipitation Enhancement

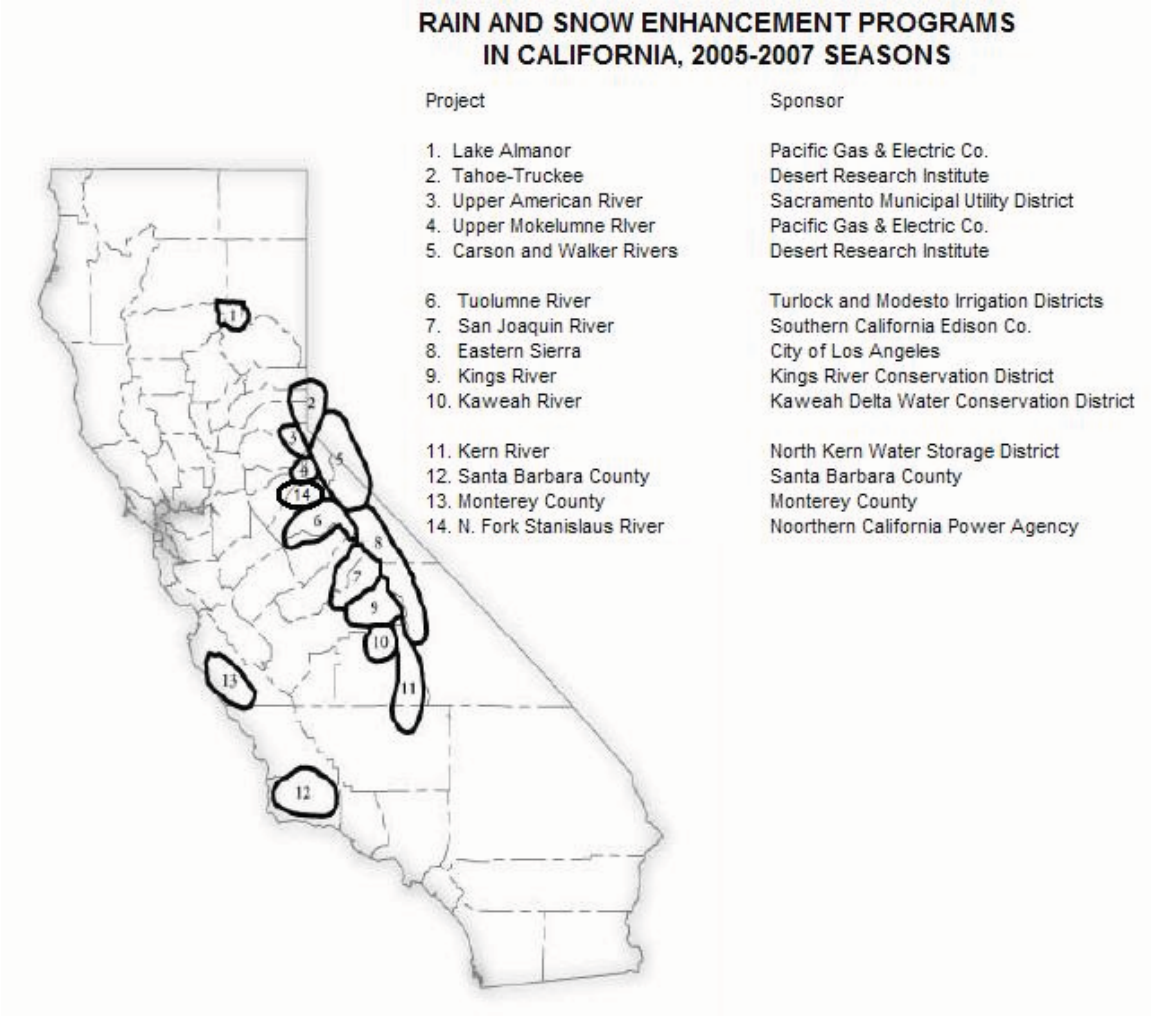
Precipitation enhancement, commonly called "cloud seeding," artificially stimulates clouds to produce more rainfall or snowfall than they would naturally. Cloud seeding injects special substances into the clouds that enable snowflakes and raindrops to form more easily.

Precipitation Enhancement in California

Precipitation enhancement is the one form of weather modification done in California; hail suppression (reducing the formation of large, damaging hailstones) and fog dispersal (when fog is below freezing temperature) projects are conducted in other states.

Winter orographic cloud seeding has been practiced in California since the early 1950s. Most of the projects are along the central and southern Sierra Nevada with some in the Coast Ranges. The projects generally use silver iodide as the active seeding agent, supplemented by dry ice if aerial seeding is done. Silver iodide can be applied from ground generators or from airplanes. Occasionally other agents, such as liquid propane, have been used. In recent years, some projects have been trying hygroscopic materials (substances that take up water from the air) as supplemental seeding agents. Figure ___-1 shows rain and snow enhancement programs which had operated at some time during the 2005-2007 seasons. (Most are long term projects and were operated in all of the three years. A few, such as Monterey County, only ran in one or two seasons.) Historically the number of operating projects has increased during droughts, up to 20 in 1991, but have leveled off at about a dozen in the more normal years. Most of the projects suspend operations during the very wet years once enough snow has accumulated to meet their water needs.

Figure x-1 Rain and snow enhancement programs in California, 2005-2007 seasons



Policy statements by both the American Meteorological Society and the World Meteorological Organization support the effectiveness of winter orographic cloud seeding projects. The American Society of Civil Engineers has also shown interest with its Policy Statement No. 275 on Atmospheric Water Management in 2003 and a report, ASCE/EWRI 42-04, "Standard Practice for the Design and Operation of Precipitation Enhancement Projects in 2004. This standards document was followed by a second edition of ASCE Manual No. 81, "Guidelines for Cloud Seeding to Augment Precipitation," published in 2006.

Since 2005, there have been several developments in weather modification. First a new long term project has been added on the North Fork of the Stanislaus River sponsored by the Northern California Power Authority. Its primary purpose is production of more hydroelectric power.

Pacific Gas and Electric Company is now planning a new project on the Pit and McCloud Rivers in Northern California on the headwaters of Shasta Lake. Since seeding opportunities tend to be greater as one moves north into colder winter weather and more frequent storms, this will likely be a fairly productive program. The plan is to increase precipitation recharge of the large volcanic aquifers which feed the Pit and McCloud Rivers year round and thereby increase hydroelectric power production. An added benefit would be water supply in the upper Sacramento River system at Shasta Reservoir. Projected yields, according to the Company, could average 250,000 AF per year, or about a 9 percent increase in runoff. The company plans to start seeding operations in the 2008-2009 water year.

The third area is the Colorado River basin, where a lengthy drought has caused the seven states to look at all potential options. The best hope of augmenting Colorado River water supply is wintertime cloud seeding in the headwater states of Colorado, Utah, and Wyoming. There are already many seeding programs in place. However, the basin states have agreed to work together in a program for implementing new programs and to designate new areas for seeding and possibly longer seasons of operation for existing projects. There were 15 projects operating in the upper Colorado River region; there may be a potential for up to 15 more in the basin, including 4 in Arizona. From a 2006 study by North American Weather Consultants, the combined potential yield of the new programs could be 800,000 AF per year on average. This is based on a 10 percent increase in precipitation. Additional amounts could be obtained by augmenting the existing programs. As a starter, the Lower Basin states added about $ 410,000 in the three years from 2006 through 2008 for Upper Basin cloud seeding efforts to enhance and extend the operating season.

It is obvious that much more research in weather modification is desirable. The kind needed and the equipment needed are beyond the ability and funding of independent project sponsors, although much can be gained from piggybacking research onto existing programs. To this end, legislation was introduced in the 110th Congress by Senator Hutchinson of Texas and Congressman Mark Udall of Colorado for weather modification research and to increase the effectiveness of existing programs through applied research.

In California, proposals have been made to the CEC's Public Interest Energy Research program for additional research into cloud seeding to evaluate the effectiveness of existing programs in the State and optimize their effectiveness. This approach would survey the latest scientific advances in cloud physics, remote sensing, atmospheric science, seeding technologies and evaluating strategies and recommend the best course of action to maximize the contribution of operational cloud seeding programs to the State's water and energy supplies. Some study could also be made on the potential effect of global warming and atmospheric pollution on seeding practices and capabilities.

Benefits of Precipitation Enhancement

In California, all precipitation enhancement projects are intended to increase water supply or hydroelectric power. The amounts of water produced are difficult to determine, but estimates range from a 2 to 15 percent increase in annual precipitation or runoff. A National Research Council (NRC) 2003 report on weather modification had limited material on winter orographic cloud seeding, such as practiced in California and other western states. However, the report did seem to concur that there is considerable evidence that winter orographic weather modification does work, possibly up to a 10 percent increase. A detailed study by the Utah Department of Natural Resources in 2005 (updating a 2000 study through the 2004 season—all dry years—and expanding the area of projects) showed an average increase in April 1 snowpack water content ranging from 2 to 18 percent from a group of projects which had been operating from 2 (High Uintas) to 27 (Central/Southern Utah) years. The overall estimated annual runoff increase for the State was about 230,000 acre-feet, or 7 percent for the study area. Actual increases in annual runoff are probably less in California than in Utah. A conservative estimate made for Bulletin 160-05 by DWR staff is that the combined California precipitation enhancement projects generate 300,000 to 400,000 acre-feet annually, which would be an average of about a 4 percent increase in runoff.

Although the planned Pit River project would occupy one of the most favorable areas for cloud seeding, another 200,000 to 300,000 AF per year may be available. Many of the best prospects are in other parts of the Sacramento River basin, in watersheds that are not seeded now. The Lahontan regions are already well covered by cloud seeding projects, except for the Susan River. With the exception of the upper Trinity River watershed, and perhaps the Russian River, there is little new potential in the North Coast region because not much extra rainfall could be captured due to limited storage capacity. There is also potential to increase water production by more effective seeding operations in existing projects. Precipitation enhancement should not be viewed as a remedy for drought. Cloud seeding opportunities are generally fewer in dry years. It works better in combination with surface or groundwater storage to increase average supplies. In the very wet years, when sponsors already have enough water, cloud seeding operations are usually suspended.

Potential Costs of Precipitation Enhancement

Costs for cloud seeding generally would be less than $20 per acre-foot per year. State law says that water gained from cloud seeding is treated the same as natural supply in regard to water rights.

It is estimated that about $3 to 4 million is being spent now on yearly operations. Realizing the additional 200,000 to 300,000 acre-feet of potential new supply (beyond the planned Pit-McCloud project) could require an initial investment of around $ 7 million for planning, reports, and initial equipment, plus around $ 4 million in annual operations costs. Over the next 25 years, that would add up to $ 107 million, which would be nearly $ 20 per acre-foot. (Note—This cost estimate is preliminary and may be adjusted in the next revision.)

Major Issues Facing Precipitation Enhancement

Reliable Data

No complete and rigorous comprehensive study has been made of all California Precipitation enhancement projects. Art of the reason is the difficulty in locating unaffected control basins. Some studies of individual projects have been made in the past years on certain projects, such as the Kings River, which have shown increases in water.

Photo: Ground-based seeder/PG&E

Operational Precision

It is difficult to target seeding materials to the right place in the clouds at the right time. There is an incomplete understanding of how effective operators are in their targeting practices. Chemical tracer experiments have provided support for targeting practices. New seeding agents, transport and diffusion studies with some of the new atmospheric measuring tools like some currently being employed by the NOAA hydrometeorological test bed experiments would be helpful.

Concern over Potential Impacts

Questions about potential unintended impacts from precipitation enhancement have been raised and addressed over the years. Common concerns relate to downwind effects (enhancing precipitation in one area at the expense of those downwind), long term toxic effects of sliver, and added snow removal costs in mountain counties. The U.S. Bureau of Reclamation did extensive studies on these issues. The finding are reported in its Project Skywater programmatic environmental statement in 1977 and its Sierra Cooperative Pilot Project EIS in 1981. The available evidence does not show that seeding clouds with silver iodide causes a decrease in downwind precipitation; in fact, at times some of the increase of the target area may extend up to 100 miles downwind (Ref. 1981 SCPP EIS). The potential for eventual toxic effects of silver has not been shown to be a problem. Silver and silver compounds have a rather low order of toxicity. According to the Bureau of Reclamation, the small amounts used in cloud seeding do not compare to industry emissions of 100 times as much into the atmosphere in many parts of the country or individual exposure from tooth fillings. Watershed concentrations would be extremely low because only small amounts of seeding agent are used. Accumulations in the soil, vegetation and surface runoff have not been large enough to measure above natural background. A 2004 study done for Snowy Hydro Limited in Australia has confirmed the earlier findings cited above. In regard to snow removal, little direct relationship to increased costs was found for small incremental changes in storm size because the amount of equipment and manpower to maintain the roadway is essentially unchanged. That is, the effort is practically the same to clear a road of 5.5 inches compared to 5 inches.

Some recent silver accumulation testing by PG & E on the Mokelumne River and Lake Almanor watersheds was reported on at the 2007 annual meeting of the Weather Modification Association. Both watersheds have been seeded for more than 50 years.

Sampling at Upper Blue Lake and Salt Springs Reservoir showed very low to non-detectible concentrations in water and sediment. Similar results were found at Lake Almanor in testing water, sediment and fish samples during the 2000 to 2003 period.

Amounts were far below any toxic levels and there was little to suggest bio-accumulation. Therefore, continued operations should not result in any significant chronic effect on sensitive aquatic organisms.

All operating projects have suspension criteria designed to stop cloud seeding any time there is flood threat. Moreover, the type of storms that produce large floods are naturally quite efficient in processing moisture into rain anyway. In such conditions, seeding is unlikely to make a difference.

Funding

Little federal research funding for weather modification has been available in the past 15 years. The Bureau of Reclamation had some funding in 2002 and 2003 in the Weather Damage Mitigation program. Desert Research Institute of Nevada did obtain a grant of $318,000 from this source early in 2003 to evaluate its seeding in the eastern Sierra.

As noted earlier, bills have been introduced in the 110th Congress which would reestablish federal support for more weather modification research, some which provide research support on existing operating projects. This legislation is supported by the Western States Water Council, the seven Colorado River Basin states, the Colorado River Board of California and others. These bills, S.1807 (Hutchinson) and H.R. 3445 (Udall) will probably be combined and represent the best chance in years for federal cloud seeding research.

Inadvertent Weather Modification

There is evidence that human activities such as biomass burning, transportation, and agricultural and industrial activities modify local and sometimes regional weather. The effects of aerosols on clouds and precipitation are complex. Recent studies by Ramanathan and Rosenfeld suggest suppressed precipitation formation in affected clouds due to pollution and dust. Some aerosols can enhance precipitation and some, especially the very fine aerosols in diesel smoke, can reduce precipitation. Much more research is needed to evaluate the air pollution effects on precipitation processes and the amount of impact as well as possible effects on cloud seeding programs. IT is possible that some of the California cloud seeding projects have offset a potential loss in precipitation from air pollution, which may have obscured a more positive signal from the weather modification projects. Research work in Israel has demonstrated such effects.

Recommendations to Increase Precipitation Enhancement

1. The State should support the continuation of current projects as well as the development of new projects and help in seeking research funds for both old and new projects

2. DWR should collect base data and project sponsor evaluations of existing California and other western states precipitation enhancement projects, independently analyze them, and perform research on the effectiveness of this technology to supplement water supplies while minimizing negative impacts.

3. DWR should support efforts to investigate the potential to augment Colorado River supply by cloud seeding, in cooperation with the Colorado River Board, the other Colorado River Basin Sates, the U.S. Bureau of Reclamation, and Metropolitan Water District of Southern California.

4. DWR should support research on cloud physics and cloud modeling being done by the National Oceanic and Atmospheric Administration labs and academic institutions. With improvement, these models may become tools to further verify and test the effectiveness of cloud seeding activities.

5. The State should support research on potential new seeding agents, particularly ones which would work at higher temperatures. Global warming may limit the effectiveness of silver iodide, the most commonly used agent, which requires cloud temperatures well below freezing, around -5^{o} C, to be effective.

6. DWR should support efforts by California weather modification project sponsors, such as that proposed in 2002-03 by Santa Barbara County Water Agency, to obtain federal research funds for local research experiments built upon their operating cloud seeding projects.

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