Upper Colorado Basin

Technical Feasibility

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Cloud seeding is one of several options under consideration by the Colorado River Basin states for augmenting water supplies in the basin. How much "new" water could it provide? In spring 2006, the Upper Colorado River Commission contracted North American Weather Consultants Inc. to evaluate the current status of cloud seeding and the feasibility of using the method to enhance streamflow in the Colorado River region.

A 2005 report by the Bureau of Reclamation (Hunter et al., 2005) identified areas within Arizona, Colorado, Utah, and Wyoming where new operational winter cloud seeding programs could be developed and existing programs enhanced to provide additional runoff in the Colorado River Basin (see figure and table). Criteria for new programs included elevation above 9,000 feet, a mountain barrier at least three miles wide west to east, and location largely or wholly outside any designated wilderness areas. Operational programs with a straightforward goal of increasing streamflow are distinguished from more costly research programs that seek to advance knowledge.

How Much Water? At What Cost?

Carefully designed and conducted winter orographic seeding programs are considered the most physically and economically feasible and are generally estimated to achieve 5 to 15 percent increases in precipitation. Streamflow model simulations were performed for Colorado, Utah, and Wyoming by the National Weather Service's Colorado Basin River Forecast Center. The center predicted that an average increase of 650,500 acre-feet of runoff into Lake Powell for April through December could be gained from the proposed new cloud-seeding programs, assuming a 10 percent increase in October through March precipitation. Another 576,500 acre-feet of additional runoff was projected by augmenting existing programs for the same period and under the same conditions. With an additional 154,000 acre-feet of annual runoff that could come from new seeding programs in Arizona, the total estimated average potential for additional runoff in the Colorado River Basin is nearly 1.4 million acre-feet per year.

Developing new operational programs and augmenting existing ones in the four Upper Basin states has a preliminary cost estimate of around $7 million annually, at an average cost of $5 per acre foot. Fifteen percent of the total estimated

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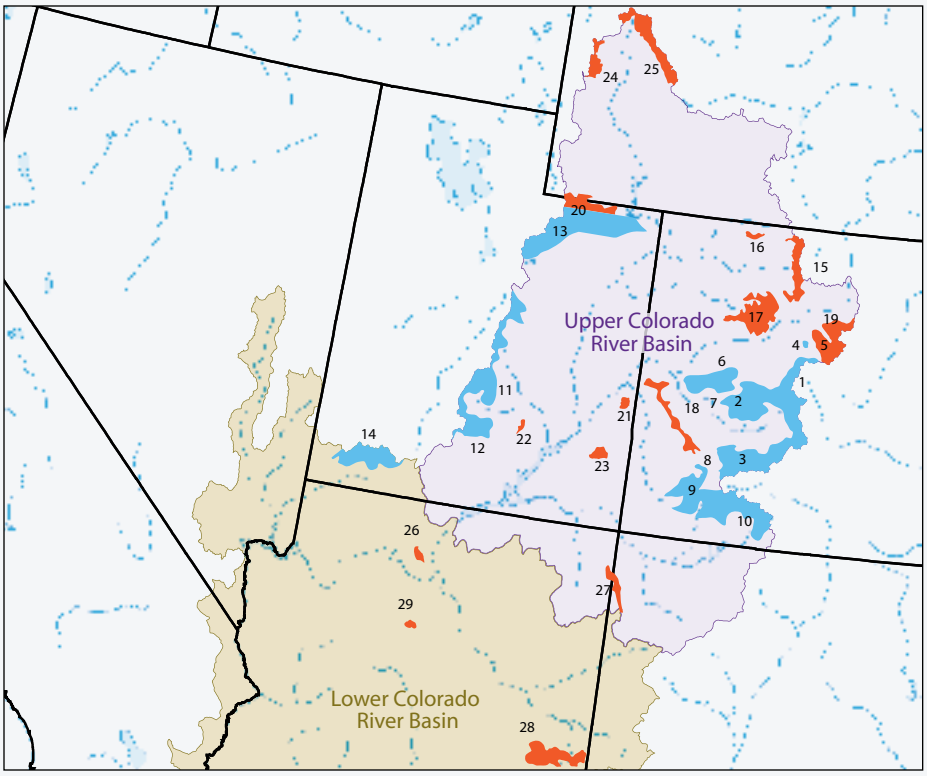

Existing (operational) cloud seeding target areas (blue) and potential target areas (red), indexed to the tables below (modified from Hunter, 2006; reprinted with permission from the Journal of Weather Modification*).*

Existing Target Areas	
Colorado	Utah
1. Upper Arkansas *	11. Fishlake Mtns. *
2. Gunnison North	12. Boulder Mtn. *
3. Gunnison South	13. Uinta Mtns. South
4.Vail	14. Dixie Natl. Forest *
5.Beaver Creek	
6. Grand Mesa North	
7. Grand Mesa South	
8. San Miguel Mtns.	
9. Western San Juans	
10. Eastern San Juans	

Potential Target Areas	
Colorado	Utah
15. Park Range	20. Uinta Mtns. North Slope
16. Elkhead Mts.	21. La Sal Mts.
17. White R. Plateau	22. Mt. Ellen
18. Uncompahgre Plateau	23. Abajo Pk.
19. Central Rockies	
Wyoming	**Arizona**
24. Wyoming Range	26. Kaibab N.F.
25. Wind River Mtns.West	27. Chuska Mts.(AZ/NM)
	28. White Mts.
	29. San Francisco Peaks

** Portion of area outside Colorado River Basin*

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have significant, active, winter cloud-seeding programs. In some cases these efforts have been going on for over 30 years. Current annual expenditures for Upper Basin operational cloud-seeding programs have reached approximately $2.6 million. These operations have benefited not only specific Upper Basin states but also the entire basin.

Lower Basin states are now collectively attempting to add funding to Upper Basin cloud-seeding efforts to enhance and extend existing programs. During water year 2007, an estimated $270,000 will be added by the Lower Basin for these efforts. In general, Upper Basin states have expressed a willingness to consider additional funding to enhance and extend existing efforts, provided weather modification is adequately controlled and monitored to ensure that no Upper Basin state or local interests are harmed, such as from impacts from operations in above-average years.

The Effectiveness Debate

The scientific community is currently debating the effectiveness of winter cloud-seeding programs. Uncertainty arises primarily from the difficulty of statistically demonstrating and predicting precise amounts of increased snowpack from a certain level of effort. Some scientific organizations have decided not to support the idea that cloud seeding will increase water supplies unless there are direct, measured, and statistically verified increases over natural events. For many practical reasons, this is a difficult fact to tease out of the data. However, many scientific organizations do conclude there is increased precipitation from cloud seeding when it is properly conducted. A significant preponderance of indirect statistical information implies that snowfall and runoff will increase under proper conditions. Existing seeding operators have gained sufficient data from their efforts to allow confidence that cloud seeding is effective and justifies continued funding. Most professional cloud seeding organizations now believe that the effectiveness of these programs is in the range of a 5 to 15 percent increase in precipitation over the target areas.

Results of a winter cloud seeding preliminary feasibility study funded by the Upper Basin and conducted by Don A. Griffith of North American Weather Consultants Inc. (see page 19) agreed with this predicted increase in snowpack over selected target areas from properly designed and conducted cloud-seeding efforts. Estimates of the amount of additional water that might be generated from all cloud-seeding efforts in the basin ranged from about 600,000 acre-feet to 1.6 million acre-feet per year during average weather conditions. During drought, less additional water would be generated from seeding, so it is important to seed during wetter times and store additional water in reservoirs. A portion of these predicted increases is already contributed from existing operations, but a very significant additional amount was predicted to be gained from new efforts. The cost of developing this water was estimated to range from $4.50 to $11.50 per acre-foot. These costs are extremely low compared to any other feasible means to augment the flow of the river. Although scientific debate about the exact amount of increase generated from cloud seeding remains, the result would be the most cost-effective water that can be developed, even if estimates are off by an order of magnitude.

With proper design, controls, safeguards and monitoring, the Upper Basin states will likely consider additional cloud seeding. However, because of the difficulty in quantifying the specific effect of cloud seeding, any water generated will be considered "system water" and not specifically allocated to any state or entity. The water may be used by any state, but only within that state's Compact apportionment and consistent with state water law. Just as a high tide floats all boats, increased runoff will benefit all states, primarily through increased reservoir storage that will help the states get through periods of drought.

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cost is designated for effectiveness evaluations, including statistical studies and physical measurements such as the detection of silver in snow.

Ways to Proceed

Design studies are recommended to customize new operational winter cloud-seeding programs in the four states according to site-specific factors such as climatology, topography, the presence and frequency of seedable conditions, social considerations, and existing state regulations. Existing programs could be enhanced by new or supplemental seeding equipment or by extending the operational periods.

Federal funding should be sought to support research programs, which could be piggybacked onto operational programs, to evaluate the effectiveness of various types of seeding and impacts on streamflow. The basin states should also coordinate among themselves to share costs and administration of both new and existing programs.

Because they do not require large permanent infrastructure, cloud-seeding programs can be relatively quickly implemented, suspended, or terminated. Routine, year-after-year cloud-seeding programs could help stabilize and bolster water supplies, even though the total volume of increase will vary over wet and dry years. Establishing routine programs is recommended because predicting a wet or dry year in advance is difficult, conditions can change mid-season, additional wet-year precipitation can be stored for use during dry periods, and commitment to a long-term program helps provide stability and acceptance by funding agencies and the public.

The complete report is available at www.nawcinc.com/Colorado%20River%20Seeding.pdf. Contact Don Griffith at dgriffith@nawcinc.com.

References

Hunter, S.M., 2006. Potential water augmentation from cloud seeding in the Colorado River Basin, J. Weather Modification, 38, 51-57.

Hunter, S.M., S. Meyer, and R. Aman, 2005. Water augmentation from cloud seeding in the Colorado River Basin, Bureau of Reclamation Technical Service Center, 9p.