



## North American Interstate Weather Modification Council

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### Colorado River Basin Weather Modification Programs Potential Water Yield and Cost Estimates

#### Summary

- There is significant evidence that winter weather modification can increase snowpack by 10%.
- Between 867,000 and 1.8 million acre-feet (AF) is a reasonable estimate of the amount of water that cloud seeding could develop in the Colorado River Basin.
- Costs for existing projects range between \$6-12 per AF and costs for new projects are projected to be approximately \$20 per AF.
- Estimates of benefit/cost ratios for winter operational programs are favorable.
- Additional research would answer questions such as how to measure the impacts of seeding on a seasonal basis, how cloud seeding activity and effectiveness differs from basin to basin based on more detailed hydrologic modeling, and which basins contribute the most flow of the Colorado River.

#### Estimates of Potential Yield

Table 1 presents the results of four studies which estimate the amount of water that could potentially be made available by winter precipitation augmentation of all desirable areas in the Colorado River Basin:

**Table 1. Water yield estimates from cloud seeding in the Colorado River Basin**

Study	Timeframe of Study	Water Yield (AF)
Bureau of Reclamation (Grant 1969)	1967-68	1,870,000
Stanford Research Institute (Weisbecker 1974)	1971-72	1,150,000
North American Weather Consultants, Twelve Basin Study (Elliott et al. 1973)	1972-73	903,000 - 1,315,000
Bureau of Reclamation (Hunter et al. 2005)	2004-05	867,170*

\*April 1 snowpack for an average year yield. This is a conservative estimate based on more stringent selection criteria of high elevation mountain ranges used to specify potential new target areas.

Assuming the generally accepted increase in precipitation of 10%, the range between 867,000 and 1.8 million AF is a reasonable estimate of the amount of water that cloud seeding could develop in the Colorado River Basin. Policy Statements from the World Meteorological Society and the Weather Modification Association state that 10% increases can be achieved in well designed and executed weather modification program.

## **Estimates of Cost**

Costs for all operating and new cloud seeding projects generally would be less than \$20 per AF. Costs for operating projects in Nevada are estimated to be \$6-15 per AF, and \$10 per AF for Utah and Colorado. The California Department of Water Resources has estimated that seeding to produce 300,000-400,000 AF of potential new supply in California would cost \$19 per AF (CDWR, 2004).

Costs in a report focused on expanding weather modification operations in the states of Arizona, Colorado, Utah, and Wyoming are provided in two categories: 1) implementing new programs in areas identified with good potential; and 2) improvements to existing programs. These costs include design studies, capital, operations, and an evaluation component. In the interest of brevity few cost assumptions are listed here. Improving the existing programs in all of the desirable areas in the Colorado River Basin would provide over 576,000 AF and would cost \$2.12 million. Implementing new programs in these same areas would generate over 804,000 AF and cost \$4.85 million (Griffith and Solak, 2006). Comparing these costs to the total estimated additional streamflow that might be produced in the four states on an annual basis indicates that the estimated cost of producing 1.38 million AF would be \$6.97 million. This yields an estimated cost of \$5 per AF.

A recent study of various augmentation supply options for the Colorado River, prepared by the Southern Nevada Water Authority found that up to 1,350,000 AF could be developed at a conservative cost of \$20-30 per acre-foot (SNWA, 2008).

## **Benefit/Cost Ratios**

An update to a publication of the American Society of Civil Engineers (ASCE, 1995) published in 2006 recommends a ratio of approximately 5 to 1 to consider a program feasible. Estimates of benefit/cost ratios of winter operational programs have been cited in the literature. Henderson (2003) examined six long-term programs being conducted in California. He estimated benefit/cost ratios, primarily driven by the value of additional hydroelectric energy (the primary benefit) due to enhanced streamflows, to range from 13 to 1 to 61 to 1 for increases of 2-9% in additional runoff. The additional streamflow (a secondary benefit) could also be used for irrigated agriculture or municipal and industrial purposes. The estimated average cost of producing a 6% increase in streamflow was \$3 per AF for these six programs.

Benefit/cost ratios on a four-season program conducted on the upper Boise River drainage of west central Idaho yielded an estimated benefit/cost ratio of over 9 to 1, associated with an estimated average increase of 12% in snow water content (Griffith and Solak, 2002). This was based upon enhanced hydroelectric generation; the value of the additional water for downstream uses was not included in the calculation. The estimated average cost of producing the additional streamflow was less than \$1 per AF for the four seasons.

A feasibility/design study was performed for the Wyoming Water Development Commission (WMI, 2005). This study estimated the amount and value of water that might be produced from a winter cloud seeding program in the Wind River, Medicine Bow and Sierra Madre Ranges of Wyoming. The calculation of the amount of water was driven by an assumed 10% increase in precipitation and a resultant 8% increase in runoff. A range of estimated benefit/cost ratios of over 2 to 1 to over 4 to 1 were the result using different assumptions. The associated estimated cost of producing the additional runoff was less than \$8 per AF.

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