



**Pacific Gas and  
Electric Company**

Applied Technology Services (ATS)  
3400 Crow Canyon Road  
San Ramon, CA 94583

August 13, 2012

Rebecca George Walker, President  
Eagle Lake Guardians  
503-150 Mahogany Way  
Susanville, CA 96130

Dear Ms. Walker:

As communicated in the July 12 letter from Mr. Randal Livingston, PG&E is pleased to have the opportunity to answer your questions regarding our Lake Almanor Cloud Seeding Program. The attached report provides an overview of cloud seeding operations and specifically responds to the inquiry from the Eagle Lake Guardians.

While we have provided some general information about cloud seeding projects in the State of California, the response is specific to PG&E cloud seeding operations. Mr. John Andrews, Chief Flood Hydrology & Water Supply Branch of the California Department of Water Resources may be able to provide you with information pertaining to all cloud seeding operations in California.

If you have any questions once you have reviewed the report, please contact me at 925-866-5956.

Sincerely,

Edward F. McCarthy, CCM  
Supervisor, Meteorology Services  
PG&E

EFM(866-5956):efm  
File No. 460.11-12.5

Attachment

The following summary provides general information about cloud seeding and specific information about the Lake Almanor Cloud Seeding Program in responding to a request for information by Eagle Lake Guardians, Ms. Rebecca Walker's letter of July 12, 2012. This summary section is then followed by the verbatim requests in Ms. Walker's letter and PG&E's response.

## Introduction

Cloud seeding has steadily increased since its discovery early in the 20<sup>th</sup> century. In California, cloud seeding has been implemented since the early 1950s, one of the longest records of seeding in the world. Nationally, cloud seeding is used primarily to augment water supplies for domestic use, for agriculture, and to augment stream flows for hydroelectric generation. Most programs in California have been conducted in winter over the Sierra Nevada, and are intended to augment the snowpack. The additional snowpack melts and runs off, providing water for multiple beneficial uses. As climate change has led to reduced snowpack and other hydrologic impacts, the Intergovernmental Panel on Climate Change and the California Department of Water Resources have embraced cloud seeding as one adaptation technique.

Cloud seeding is being conducted in numerous areas of the western United States in order to augment public water supply, hydro-electric power, increase summer precipitation for agriculture and grazing, aquifer recharge and hail suppression (Figure 1). Winter cloud seeding programs in California began more than 50 years ago and in the last 20-years cloud seeding has been conducted in 11 to 14 watersheds annually (Figure 2). Sponsors of these programs include public water supply agencies, agricultural water agencies and power generation.

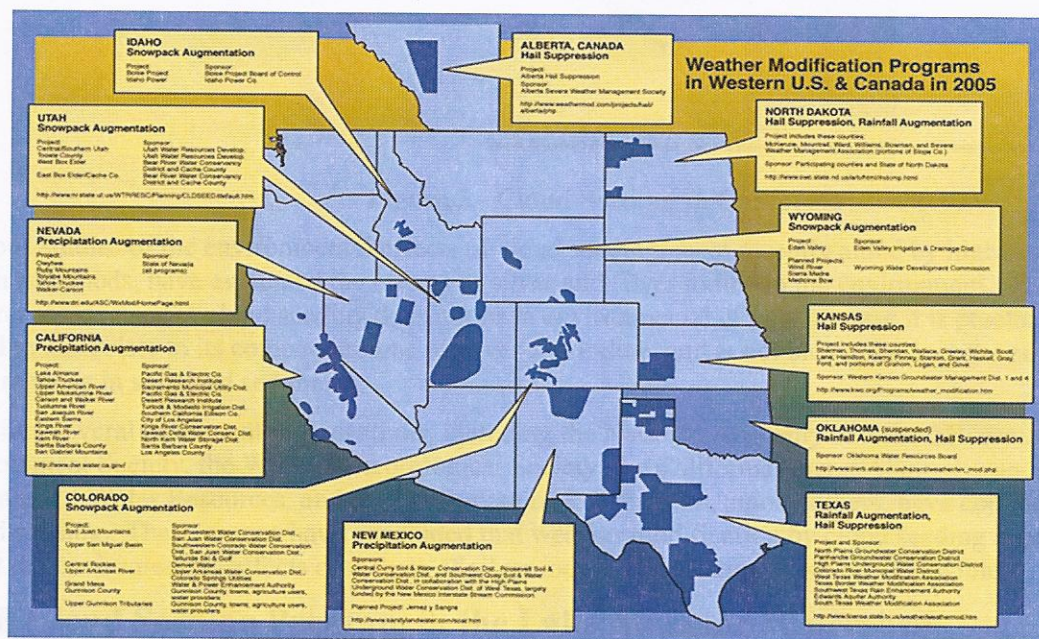


Figure 1 - Cloud Seeding Programs in the US and Canada in 2005





**Figure 2 - Cloud Seeding in California**

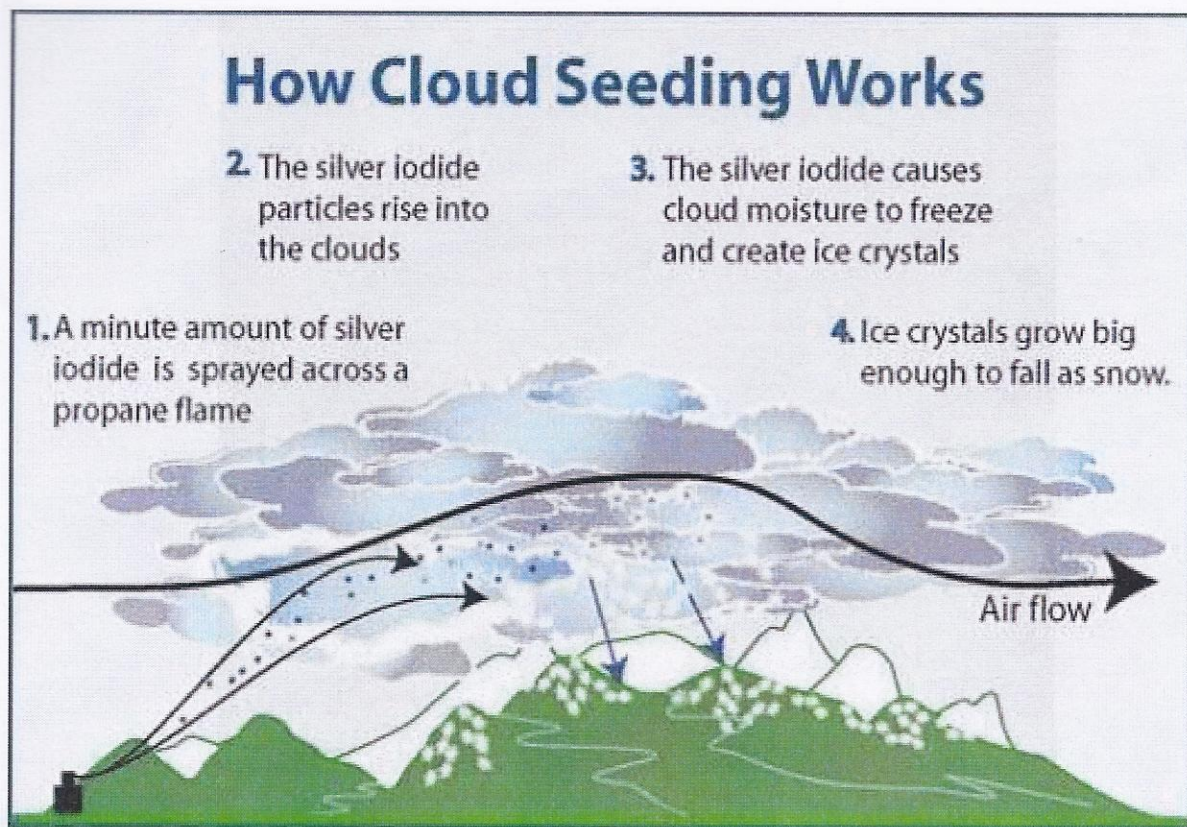
Numerous studies of the environmental effects of cloud seeding, most recently aided by high-resolution analytical chemistry methods, have evaluated the effects of silver and silver iodide in the environment. The studies all conclude that silver iodide used in cloud seeding does not have environmental effects because it is practically insoluble, does not tend to dissociate to its component ions of silver and iodine, and is not bioavailable in the aquatic environment but instead remains in soils and sediments.

In addition, several prominent organizations, including the National Academy of Sciences, the American Meteorological Society, the World Meteorological Society, the California Energy Commission, the California Department of Water Resources, and the US Bureau of Reclamation, among others, have conducted critical reviews of cloud seeding. These groups have concluded that weather modification by cloud seeding is potentially beneficial, and that the environmental effects of the use of silver iodide as a seeding agent are negligible.

### **PG&E Cloud Seeding Program in the Lake Almanor Watershed**

The benefits of PG&E's program in the Lake Almanor watershed include enhancing the winter snowpack, which then enhances stream flows, lake levels, and groundwater levels. PG&E utilizes ground-based seeding during cold winter storms during the months of November through May in the Lake Almanor Watershed. Cloud seeding introduces ice-forming nucleating particles into cloud regions with appropriate conditions and causes super-cooled liquid water droplets to freeze. Once these droplets freeze, the initial ice embryos grow at the expense of the cloud water droplets around them (sublimation) and through contact with these neighboring cloud water droplets (riming). These embryos, if they remain in favorable cloud conditions, will grow into snowflakes, falling to the surface as snow if surface temperatures are below or near freezing, or as raindrops at warmer surface temperatures (Figure 3). This process mimics nature where certain airborne substances, e.g., soil particles have the ability to act as ice-forming nuclei and initiate the freezing process. (Source: North American Weather Consultants, Inc., [www.nawcinc.com](http://www.nawcinc.com)).



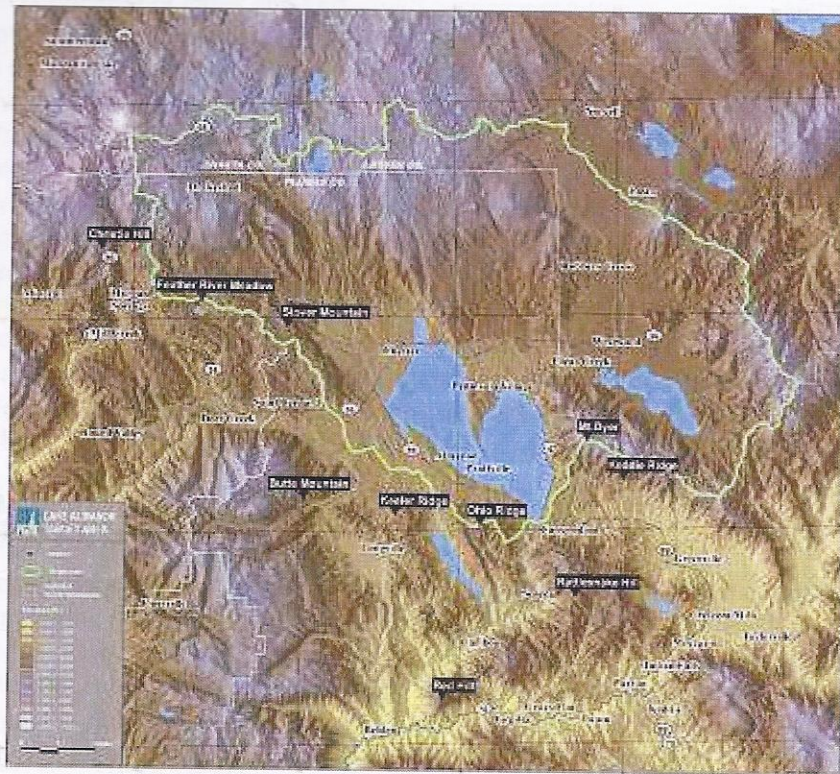


**Figure 3 - How Cloud Seeding Works**

PG&E started cloud seeding in the Lake Almanor watershed in 1953 (59 years ago). PG&E releases the seeding aerosol from 10 ground based burners (aerosol generators) located in the higher terrain south and west of Lake Almanor basin (Figure 4). One of the ground based burners is in Lassen County at Dyer Mountain near the northern end of Keddies Ridge. PG&E has never used aircraft for seeding in the Almanor Basin.

PG&E uses remote-radio controlled ground based cloud seeding burners which release sub-micron sized silver-iodide silver-chloride seeding particles to the atmosphere through a chimney on the burner structure. PG&E meteorologists monitor the weather conditions and forecast conditions over the Lake Almanor region. When weather conditions meet specific criteria, the meteorologist issues seeding orders to local PG&E personnel, who in turn initiate the process using a system control and data acquisition (SCADA) system. The performance of the seeding burner is monitored via SCADA, and the burners also have an automatic shut-down should there be a loss of radio contact.





**Figure 4 - Aerosol Generators (Black Labels) in the Lake Almanor Cloud Seeding Area**

PG&E cloud seeding operations in the Lake Almanor watershed during the last 13 years are summarized in Table 1, including the first and last day of operation for each winter season, the number of days operated, and the amount of silver-iodide seeding agent used in the process. Since there is only one cloud seeding generator in Lassen County at Dyer Mountain, a simple approximation on the number of pounds of cloud seeding material released in Lassen County would be 1/10<sup>th</sup> of the annual total presented for each season in Table 1.

**Table 1 PG&E Lake Almanor Cloud Seeding Summary 2000 – 2012**

Winter Season Nov–May 212 Days	Days Operation	Total Seeder Hours–Sum of Nine Seeders	Silver-Iodide Released (kg)/(lbs)	First Operation	Last Operation	Suspension Periods
2000-01	41	3,796	81.6/180	Nov 13	Apr 21	
2001-02	38	3,220	69.2/152	Nov 12	May 20	
2002-03	44	4,319	91.1/200	Nov 9	May 9	
2003-04	28	2,710	58.2/128	Nov 9	Apr 21	
2004-05	49	3,655	76.2/168	Nov 2	May 9	Jan 7 - 12
2005-06	33	2,822	60.7/133	Nov 3	Mar 28	Mar 28 - on
2006-07	34	2,647	53.4/118	Nov. 26	May 4	
2007-08	38	3,220*	69.2/152	Dec. 6	Apr. 22	
2008-09	39	3,716*	79.9/177	Nov. 3	Apr. 24	
2009-10	34	2,829*	60.8/134	Nov. 17	May 10	
2010-11	16	929*	20.0/47	Nov. 20	Mar. 20	Dec 17 – Dec 21 Dec 24 – Feb 7 Mar 21 - on
2011-12	12	961*	20.7/46.	Jan 19	Apr 12	Nov 1-Dec 31



The cloud seeding burners release hot gases and very small particles at a rate of approximately 21.5 grams/hour during seeding. The hot gases are the result of combustion – burning the combination of propane gas, air and seeding solution (which is 98% acetone). Acetone is used to dissolve the seeding chemicals and is the carrier liquid of these chemicals, via tubing and atomizer, to the propane flames. All of the acetone is consumed in the flames of the burner, and is converted to carbon oxides, nitrogen oxides and water vapor. Each seeding particle released from the burner chimney is made predominantly of silver iodide (64%), with lesser amounts of silver chloride (10%), bismuth oxide (1%), and potassium chloride (25%). In chemistry notation the seeding particles are  $\text{AgI}^{0.8} \text{AgCl}^{0.2} 0.005 \text{Bi}_2\text{O}_3 \text{KCl}$ , and we call this seeding salt – silver iodide. As combustion sources, the total amount of material released from PG&E cloud seeding burners are far below health related limits and do not trigger the need for air quality permits. The seeding particles are typically in a size range of 0.05 to 0.10 microns. At this size they float in the air with the wind and have a negligible settling velocity. They are dispersed by the turbulence of the wind and they rise with the lift of the air that occurs in the mountains during storms. The silver iodide silver chloride bismuth oxide portion of the particle is very insoluble and it acts as an ice nucleus (freezes water) upon contact with super-cooled (sub-freezing) liquid water cloud droplets. The potassium chloride (KCl) portion of the particle is hygroscopic (attracts water) and it is soluble in water.

## Environmental Effects

Silver iodide and the closely-related silver chloroiodide ( $\text{AgI}_{0.8}\text{Cl}_{0.2}$ ) is one of the most common nucleating materials used in cloud seeding, including projects in the Sierra Nevada range in California. Small quantities of the silver chloroiodide are released (usually less than 200 lbs per year), and is dispersed over hundreds of square miles of watershed. The resulting concentrations of the seeding material in the environment are extremely small, typically in the parts per trillion range. Sophisticated collection and analytical chemistry methods are required to detect the seeding material in the environment, requiring capabilities to measure concentration in the sub-part per billion range.

The crystalline structure of silver iodide closely resembles that of ice, and as such, it makes a very effective surrogate for ice as nucleating agents in the cloud. Another reason that silver iodide is so commonly used for cloud seeding is that it is practically insoluble in water. That is, it stays in the solid form rather than dissolving in water. This characteristic is essential to the success of cloud seeding, because if the nucleating agent were to dissolve in water it would no longer be useful as a nucleation site for precipitation. In addition, by remaining in a solid form, the introduced silver iodide does not become biologically available in the environment, and as such does not have an adverse effect to human health and the environment (Williams and Denholm, 2009).

Several multi-year studies, summarized in Cardno ENTRIX 2011, are unanimous in their conclusion that silver iodide used in cloud seeding is practically insoluble, does not tend to dissociate to its component ions of silver and iodine, and is not bioavailable in the aquatic environment but instead remains in soils and sediments.

Cloud seeding aerosol is formed by ground-based burners, as described previously. After leaving the burner, the seeding particles are carried by the wind and rising air currents into the clouds. Some of the seeding particles are swept from the air to the earth surface by existing falling snow particles. However, a portion of the seeding particles enter the cloud. At cloud temperatures below minus 5°C and when super-cooled liquid water is available the seeding particles trigger the formation of ice crystals upon contact with the cloud droplets. The new ice crystal with particle grows in size and falls from the cloud as snow. Release into the atmosphere does not change the physical or chemical properties of the seeding particles. The physical shape changes as the new ice crystals that contain the seeding particles grow by vapor deposition and aggregation to sizes large enough to fall from the clouds to the earth's surface.

Once on the ground, the snow melt water carries the seeding particles to the soil surface where they adhere to the surface dirt particles, decayed plant material and plant life (moss, algae) (Williams and Denholm, 2009; Cardno ENTRIX, 2011). Since the silver iodide is practically insoluble, it does not tend to percolate downward in the soil column. The potassium chloride would be dissolved (ionized) and would chemically combine with other ions in the soil to form solids. Potassium is a plant nutrient and it would likely be absorbed by live plant roots. Previous studies in cloud seeding areas have examined the upper 20 cm (about 8 inches) to find seeding chemical concentrations within the range of background concentrations (Cardno ENTRIX, 2011), and more recent soil studies of cloud seeding areas in Australia have focused on the upper 2 cm (<0.8 inches) of soil with the same results.

During snowmelt, some of the seeding particles are carried in the runoff to surface water courses, (William and Denholm, 2009). The seeding particles that fall upon surface water enters the water as does that which falls upon ice covered surface water upon ice melt. The particles move with the water, and eventually become part of the sediments that collect at the bottom of lakes, stream beds, and rivers. The physical and chemical properties of the insoluble



seeding particles do not change in the water and sediments. The potassium chloride dissolves in water and is subsequently combined with other water chemicals and or becomes nutrients for aquatic plants.

Silver iodide is the chemical species of silver that is most commonly used cloud seeding nuclei, because it is practically insoluble and has a structure that closely mimics that of ice. In contrast, the free silver ion ( $\text{Ag}^+$ ) has been used as a disinfectant. The similarity in nomenclature between silver iodide and free silver ion has led to concerns about the environmental fate of silver iodide particles, but it is important to understand that silver iodide is used in cloud seeding, not silver ions. Silver is not toxic to humans, and it is used for tooth fillings, silverware, and other common consumer items. The drinking water standard, or secondary maximum contaminant level (MCL), was developed to reduce nuisance conditions, and is set at 100  $\mu\text{g/L}$  (micro-gram per liter, or part per billion) dissolved silver. There are no toxicity-based drinking water standards (primary standards) for silver in drinking water set by EPA or California because it is not toxic to humans.

Studies of the free silver ion ( $\text{Ag}^+$ ) have found adverse consequences to plants and other biota, and most ecological guidelines are lower than the drinking water standard. The lowest freshwater aquatic life protection guideline found in the literature, and reported in Cardno ENTRIX 2011, is 1.4 parts per billion. Most studies of silver in the environment have measured total silver, not the concentrations of the individual silver species. Since the free silver ion is the toxic form of silver, these studies overestimate the actual toxicity of silver iodide, which is practically insoluble and so does not produce free silver ions. It is important to note that in discussions of toxicity, concentrations of silver iodide are compared to standards for total silver. This comparison is not meant to imply that total silver (including the free silver ion) and silver iodide are equivalent, because they are not. Rather, the comparison is made to demonstrate that, even if one were to make the assumption that all silver iodide dissociates to silver ion and iodine (which in fact it does not), the concentrations of silver affected by cloud seeding are still less than any drinking water, aquatic life, or terrestrial life standards.

## Water and Sediment Monitoring

PG&E has conducted monitoring studies in the Lake Almanor Basin and the Mokelumne watershed as part of relicensing the hydroelectric projects through the Federal Energy Regulatory Commission. These studies have not identified human health or ecological concerns related to cloud seeding, even using ultra-low laboratory detection limits. The PG&E studies are consistent with and supported by the literature on the environmental effects of cloud seeding using silver iodide (Cardno ENTRIX 2011). As part of the Project Number 2105 Relicensing Settlement Agreement for Lake Almanor and the North Fork Feather River, silver is included as one of the constituents in PG&E's proposed water quality monitoring program. The monitoring is not required as a result of cloud seeding, but is a component of the suite of metals that are included in the water analyses.

PG&E's tests in the Feather River-Lake Almanor between 2000 and 2003 examined total silver (from all sources) in the water and sediments. The 2000-01 tests used a method detection limit of 0.36 parts per billion, and all results were below freshwater aquatic life protection guidelines. In a study conducted in 2002 and 2003, PG&E collected water samples and analyzed them for several constituents, including dissolved silver. The method detection limit used in these studies for water was 0.090 parts per billion. A total of 35 water samples analyzed in these studies had concentrations below method detection limits, one sample showed 0.093 parts per billion. Another showed 0.153 parts per billion and this value is about 10-20 times lower than freshwater aquatic life protection guidelines and 650 times below the secondary maximum contaminant level (SMCL), or drinking water standard, of 100 parts per billion.

PG&E also conducted limited water tests in the Feather River-Lake Almanor during 2012. All samples were determined to be below the method detection limit (0.005 parts per billion) for silver. All data from the 2000 – 2003 and the 2012 tests are presented in Exhibit A.

Cardno ENTRIX 2011 summarizes the evidence-based studies related to cloud seeding and public health correlations; no studies have indicated a correlation between cloud seeding and public health concerns. Measured concentrations are typically many times safer than the drinking water standard.

## Air Quality

Inversions are generally associated with calm, fair weather, with night-time and very early morning hours frequently having a surface base temperature inversion. Also high pressure aloft can be associated with temperature inversions occurring over the Lassen region. PG&E cloud seeding operations are conducted during windy, stormy conditions as low pressure systems and weather fronts move across the area. These windy, stormy conditions are not associated



with inversions, and cloud seeding during these conditions would not concentrate near the ground nor create health problems for the Lassen residents.

Cloud seeding is not directly regulated by the EPA, but PG&E's cloud seeding activity complies with regulatory guidelines for the protection of air quality, water quality, human health, and the environment.

## Summary

PG&E operates a weather modification program (cloud seeding) to augment winter season snowfall in the Lake Almanor Area. The seasonal operation commences on November 1 of each year and typically ends on May 31<sup>st</sup> of the following year; however, in those years with much above normal precipitation accumulating thru the season, the program may be terminated before May 31<sup>st</sup>. Not all winter-season storm systems are seeded; only those systems that meet strict criteria based on moisture, temperature, wind speed, and wind direction. This weather modification program relies strictly on the use of ten ground based seeders, one of which is in Lassen County. PG&E's program conforms to all state and federal regulations.

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