Sacramento Municipal Utility District
El Dorado Cloud Seeding Expansion Project

Final Initial Study and Mitigated Negative Declaration • September 2017
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APPENDIX

Appendix A Stillwater Sciences Study
ACRONYMS AND OTHER ABBREVIATIONS

µg  microgram(s)
ASCE  American Society of Civil Engineers
CEQA  California Environmental Quality Act
CNG  cloud nuclei generator
EPA  U.S. Environmental Protection Agency
ERCS  Energy Resources and Customer Services
IS  initial study
MLD  most likely descendant
MMRP  mitigation monitoring and reporting plan
MND  mitigated negative declaration
NAHC  Native American Heritage Commission
NOAA  National Oceanic and Atmospheric Administration
PRC  Public Resources Code
project or proposed project  El Dorado Cloud Seeding Program Expansion Project
SMUD  Sacramento Municipal Utility District
State CEQA  California Environmental Quality Act Guidelines
Guidelines
UARP  Upper American River Project
Executive Summary

The Sacramento Municipal Utility District (SMUD) is proposing to implement the El Dorado Cloud Seeding Program Expansion Project (project or proposed project), which would expand SMUD’s current cloud seeding target area from 190 square miles to approximately 444 square miles of the Upper American River watershed, primarily in El Dorado County. The expanded target area would be treated with silver iodide nuclei dispersed by remotely controlled or mobile ground-based units, aircraft, and mobile units transported to selected sites. The program is designed to produce localized increases in snowfall and subsequent snowmelt over a larger area of the watershed of SMUD’s Upper American River Project (UARP).

Like SMUD’s current cloud seeding program, the proposed project would focus on the watersheds of Ice House, Union Valley, and Loon Lake reservoirs and their hydropower facilities in El Dorado County. The proposed project would also expand into areas to the south and west to include southern areas of the South Fork American River watershed that drain to Slab Creek Reservoir, where UARP facilities are and will be used to generate hydroelectric power at the Slab Creek and White Rock powerhouses and the future South Fork powerhouse downstream of Slab Creek Dam.

SMUD plans to continue the use of manually operated, ground-based cloud nuclei generators (CNGs). These remotely operated fixed sites would be located on private property, away from publicly accessible areas, and in upwind areas south and west of the target area based on prevailing low-level winds during storm periods. SMUD may also conduct aerial seeding using planes with wings outfitted with brackets to hold multiple silver iodide flares, and may use mobile, manually operated ground-based CNGs instead of or in addition to the other ground-based or aircraft seeding methods.

A combination of SMUD and SMUD contractor staff would manage and operate the cloud seeding operation. For aerial and/or ground seeding, SMUD would arrange a contract with a specialty firm (or firms) that would provide the required personnel and equipment. The meteorologist would select appropriate storms based on data from SMUD’s Fresh Pond meteorological station and the National Weather Service.

The meteorologist would have access to observational tools that are useful in identifying storms potentially amenable to seeding, such as ground-based icing meters and microwave radiometers. He or she would also make decisions regarding ground generators to be operated or seeding tracks to be flown based on a storm’s wind direction, wind speed, and vertical temperature structure, and on atmospheric dispersion models.

The project would use predetermined suspension criteria developed by SMUD and the meteorological consultant to determine when the program should be curtailed or suspended. These criteria are reported to the agencies that oversee cloud seeding programs (e.g., the National Oceanic and Atmospheric Administration [NOAA]) and are designed to minimize unneeded cloud seeding expenditures and reduce the potential for flooding or damage to downstream hydroelectric facilities. Suspension criteria are standard practice in the industry and are recommended by the American Society of Civil Engineers (ASCE 2004, 2016) and other organizations that conduct cloud seeding research and develop more effective techniques and procedures. For example, SMUD routinely evaluates whether the snowpack in the target area has reached a predetermined percentage above normal, or whether unusually heavy
precipitation events might result in snowmelt that could exceed reservoir capacity and cause flooding. Similar criteria would be used to guide the proposed project.

This final initial study/mitigated negative declaration (IS/MND) provides an overview of the environmental review process, including public review of the draft IS/MND, which was available for public and agency comment from May 17 through June 16, 2017. During this period, SMUD held one public workshop and received four comment letters.

SMUD conducted a detailed review of the comments and has prepared the responses presented in Section 2.0 of this document. SMUD has determined that the comments do not warrant changes to the IS and has not identified any new environmental effects or provided substantial project changes needed to reduce effects to below the level of significance. Therefore, the draft IS/MND does not require recirculation per Section 15073.5 of the California Environmental Quality Act Guidelines.

After reviewing the comments and determining that no additional mitigation measures are warranted, SMUD has prepared a mitigation monitoring and reporting plan (MMRP) that includes the mitigation measures outlined in the draft IS/MND. The MMRP is presented in Section 4.0 of this document.

SMUD has determined that although the proposed project could have a significant effect on the environment, a significant effect would not occur because the proposed mitigation measures would reduce the effects of any impacts to below the established thresholds of significance. Therefore, SMUD prepared an MND, and the SMUD Board of Directors will discuss and consider the MND at a board meeting on October 19, 2017.
1.0 INTRODUCTION

1.1 Project Summary
The Sacramento Municipal Utility District (SMUD) is proposing to implement the El Dorado Cloud Seeding Program Expansion Project (project or proposed project), which would expand SMUD’s current cloud seeding area from 190 square miles to approximately 444 square miles of the Upper American River watershed, primarily in El Dorado County. The expanded target area would be treated with silver iodide nuclei dispersed by remotely controlled or mobile ground-based units, aircraft, and mobile units transported to selected sites. The program is designed to produce localized increases in snowfall and subsequent snowmelt over a larger area of the watershed of SMUD’s Upper American River Project (UARP).

Like SMUD’s current cloud seeding program, the proposed project would focus on the watersheds of Ice House, Union Valley, and Loon Lake reservoirs and their hydropower facilities in El Dorado County. The proposed project would also expand into areas to the south and west to include southern areas of the South Fork American River watershed that drain to Slab Creek Reservoir, where UARP facilities are and will be used to generate hydroelectric power at the Slab Creek and White Rock powerhouses and the future South Fork powerhouse downstream of Slab Creek Dam.

1.2 Summary of the Environmental Review Process

1.2.1 Review of the Draft IS/MND
Copies of the draft initial study/mitigated negative declaration (IS/MND) were distributed to the State Clearinghouse of the Governor’s Office of Planning and Research; various SMUD office locations; local libraries in El Dorado, Placer, and Alpine Counties; County Clerk-Recorder offices in El Dorado, Placer, Amador, and Alpine Counties; and relevant resource agencies. In addition, the IS/MND was posted on SMUD.org. Pursuant to California Government Code Section 65091(4), in lieu of mailing notices to property owners in and adjacent to the project area, the notice of intent was published in four newspapers of general circulation within the project area at a size of at least one-eighth page.

The 30-day public review period began on May 17, 2017, and ended on June 16, 2017. SMUD held a public meeting at the Strawberry Lodge in Kyburz on June 1, 2017. Four written comments were received. These four comment letters and SMUD’s responses are presented in Section 2.0 of this document. The comments have not changed the conclusions presented in the draft IS/MND.

1.2.2 Preparation of the Final IS/MND
The comment letters were reviewed and responses were prepared (see Section 2.0). Based on the comments received, no new environmental effects have been identified. SMUD has determined that the comments do not identify any new environmental effects or provide substantial project changes needed to reduce effects to below the level of significance. Therefore, the draft IS/MND does not require recirculation per Section 15073.5 of the California Environmental Quality Act (CEQA) Guidelines (State CEQA Guidelines).
State CEQA Guidelines

Section 15073.5 of the State CEQA Guidelines provides for recirculation of a negative declaration before adoption. Section 15073.5(a) states:

A lead agency is required to recirculate a negative declaration when the document must be substantially revised after public notice of its availability has previously been given pursuant to §15072, but prior to adoption.

According to Section 15073.5(b), a substantial revision is required when:

1. A new, avoidable significant effect is identified and mitigation measures or project revisions must be added in order to reduce the effect to insignificance, or
2. The lead agency determines that the proposed mitigation measures or project revisions will not reduce potential effects to less than significance and new measures or revisions must be required.

SMUD has determined that none of the aforementioned conditions requiring recirculation have been identified and added. Therefore, recirculation of the draft IS/MND is not required and SMUD, as the lead agency, may approve the final IS/MND.

Circumstances under which recirculation is not required include:

1. Mitigation measures are replaced with equal or more effective measures pursuant to §15074.1.
2. New project revisions are added in response to written or verbal comments on the project’s effects identified in the proposed negative declaration which are not new avoidable significant effects.
3. Measures or conditions of project approval are added after circulation of the negative declaration which are not required by CEQA, which do not create new significant environmental effects and are not necessary to mitigate an avoidable significant effect.
4. New information is added to the negative declaration which merely clarifies, amplifies, or makes insignificant modifications to the negative declaration. (State CEQA Guidelines Section 15073.5[c])

SMUD has determined that none of the provisions of Section 15073.5 apply; therefore, recirculation of the draft IS/MND is not required.

1.2.3 SMUD Board Approval Process

The SMUD Board of Directors must adopt the IS/MND and approve the mitigation monitoring and reporting plan (MMRP) (Chapter 4.0) before it can approve the proposed project. The proposed project and pertinent environmental documentation will be formally presented to the
SMUD Board of Directors for information at a meeting of the Energy Resources and Customer Services (ERCS) Committee on October 4, 2017. The SMUD Board of Directors will then discuss and consider the final IS/MND at its next meeting, to be held October 19, 2017. The ERCS Committee and Board of Directors meetings are held at SMUD’s Customer Service Center (6301 S Street, Sacramento, CA 95817-1899) and are open to the public. The public may comment at both meetings.

Once the IS/MND has been adopted, the SMUD Board of Directors may render a decision on project approval or defer such a decision to a later date.

1.3 Mitigation Measures

The proposed project would require two mitigation measures to ensure that the project will not disturb cultural resources. Installing cloud seeding equipment would have minimal ground disturbance; however, clearing space and mounting the equipment on a small new concrete pad could affect previously unidentified cultural resources, resulting in a potentially significant impact. Therefore, SMUD would implement the following mitigation measure:

Cultural Resources

Mitigation Measure CUL-1. Conduct Cultural Resources Survey

Prior to installation of remotely controlled cloud seeding equipment on concrete pads, a qualified archaeologist will survey the proposed installation area. In the event that any prehistoric or historic archaeological features or deposits (including locally darkened soil or “midden” soils that could contain cultural deposits) are discovered, the archaeologist will record the site and work with SMUD to identify an alternate installation location on the property that will avoid impacting cultural resources. The archaeologist will prepare a report according to current professional standards. If the site has no resources, no report will be required.

Implementing Mitigation Measure CUL-1 would reduce potential impacts on historic and archaeological resources to less than significant.

Should the installation of equipment unearth any human remains, particularly remains determined to be Native American in origin, the impact would be potentially significant and SMUD would implement Mitigation Measure CUL-2 as shown below.

Mitigation Measure CUL-2. Implement State and County Requirements for Addressing Discovery of Human Remains and Site Protection.

In accordance with the California Health and Safety and Public Resources Codes and the County General Plan, if human remains are uncovered during ground-disturbing activities, the contractor and/or SMUD will immediately halt potentially damaging excavation in the area of the burial and notify the county coroner and a professional archaeologist to determine the nature of the remains. The coroner is required to examine all discoveries of human remains within 48 hours of receiving notice of a discovery on private or state lands (California Health and Safety Code, Section 7050.5[b]). If the coroner determines that the remains are those of a Native American, he or she must
contact the NAHC [Native American Heritage Commission] by phone within 24 hours of making that determination (California Health and Safety Code, Section 7050[c]). Following the coroner’s findings, the property owner, the contractor or project proponent, an archaeologist, and the NAHC-designated MLD [most likely descendant] will determine the ultimate treatment and disposition of the remains and take appropriate steps to ensure that additional human interments are not disturbed. The responsibilities for acting upon notification of a discovery of Native American human remains are identified in PRC [Public Resources Code] Section 5097.9.

Upon the discovery of Native American remains, SMUD will ensure that the immediate vicinity (according to generally accepted cultural or archaeological standards and practices) is not damaged or disturbed by further development activity until consultation with the MLD has taken place. The MLD will have 48 hours after being granted access to the site to complete a site inspection and make recommendations. A range of possible treatments for the remains may be discussed, including nondestructive removal and analysis, preservation in place, relinquishment of the remains and associated items to the descendants, or other culturally appropriate treatment. PRC Section 5097.9 suggests that the concerned parties may extend discussions beyond the initial 48 hours to allow for the discovery of additional remains. SMUD will employ the following site protection measures:

(1) record the site with the NAHC or the appropriate Information Center,

(2) use an open-space or conservation zoning designation or easement, and

(3) record a document with the county in which the property is located.

If the NAHC is unable to identify a MLD or the MLD fails to make a recommendation within 48 hours after being granted access to the site, SMUD or its authorized representative will rebury the Native American human remains and associated grave goods with appropriate dignity on the property in a location not subject to further subsurface disturbance. SMUD or its authorized representative may also reinter the remains in a location not subject to further disturbance if it rejects the recommendation of the MLD and mediation by the NAHC fails to provide measures acceptable to SMUD.

Implementing Mitigation Measure CUL-2 would reduce the potentially significant impact of the disturbance or discovery of human remains at the project site to *less than significant*. 


## 1.4 Environmental Factors Potentially Affected

Impacts related to the environmental factors below were evaluated using the checklist included in Chapter 3.0 of the draft IS/MND. SMUD determined that the environmental factors checked below would be less than significant with implementation of mitigation measures. It was determined that the unchecked factors would have a less-than-significant impact or no impact.

<table>
<thead>
<tr>
<th>Aesthetics</th>
<th>Agriculture and Forestry Resources</th>
<th>☒ Cultural Resources</th>
<th>☐ Air Quality</th>
<th>☐ Geology and Soils</th>
<th>☐ Greenhouse Gas Emissions</th>
<th>☐ Hazards and Hazardous Materials</th>
<th>☐ Hydrology and Water Quality</th>
<th>☐ Land Use and Planning</th>
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<td>☐ Mineral Resources</td>
<td>☐ Public Services</td>
<td>☐ Noise</td>
<td>☐ Recreation</td>
<td>☐ Population and Housing</td>
<td>☐ Recreation</td>
<td>☐ Public Services</td>
<td>☐ Transportation/Circulation</td>
</tr>
</tbody>
</table>
DETERMINATION: On the basis of this initial evaluation:

☐ I find that the proposed project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

☒ I find that although the proposed project COULD have a significant effect on the environment, there will not be a significant effect in this case because revisions in the proposed project have been made by or agreed to by the proposed project proponent. A MITIGATED NEGATIVE DECLARATION will be prepared.

☐ I find that the proposed project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

☐ I find that the proposed project MAY have a “potentially significant impact” or “potentially significant unless mitigated” impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An ENVIRONMENTAL IMPACT REPORT is required, but it must analyze only the effects that remain to be addressed.

☐ I find that although the proposed project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier EIR or NEGATIVE DECLARATION pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier EIR or NEGATIVE DECLARATION, including revisions or mitigation measures that are imposed upon the proposed project, nothing further is required.

Jerry Park  Sacramento Municipal Utility District
Printed Name  Lead Agency

Signature  Date

September 13, 2017
## 2.0 COMMENTS AND RESPONSES

### Table 2-1. List of Commenters

<table>
<thead>
<tr>
<th>Commenter</th>
<th>Letter Number</th>
<th>Comment Numbers</th>
</tr>
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<tbody>
<tr>
<td>Scott Morgan</td>
<td>1</td>
<td>1-1</td>
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<tr>
<td>Governor’s Office of Planning and Research,</td>
<td></td>
<td></td>
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<tr>
<td>State Clearinghouse</td>
<td></td>
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<tr>
<td>June 16, 2017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molly Kelly</td>
<td>2</td>
<td>2-1 and 2-2</td>
</tr>
<tr>
<td>Resident</td>
<td></td>
<td></td>
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<tr>
<td>June 6, 2017</td>
<td></td>
<td></td>
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<tr>
<td>Daphne Osell</td>
<td>3</td>
<td>3-1 and 3-2</td>
</tr>
<tr>
<td>Strawberry resident</td>
<td></td>
<td></td>
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<td>June 12, 2017</td>
<td></td>
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<tr>
<td>Dona J. Baxter</td>
<td>4</td>
<td>4-1</td>
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<td><em>Tahoe Mountain News</em></td>
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<tr>
<td>June 14, 2017</td>
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</tbody>
</table>
June 16, 2017

Jerry Park  
Sacramento Municipal Utility District  
P.O. Box 15830 MS H201  
Sacramento, CA 95852-1830

Subject: El Dorado Cloud Seeding Program Expansion  
SCH#: 2017052041

Dear Jerry Park:

The State Clearinghouse submitted the above named Mitigated Negative Declaration to selected state agencies for review. The review period closed on June 15, 2017, and no state agencies submitted comments by that date. This letter acknowledges that you have complied with the State Clearinghouse review requirements for draft environmental documents, pursuant to the California Environmental Quality Act.

Please call the State Clearinghouse at (916) 445-0613 if you have any questions regarding the environmental review process. If you have a question about the above-named project, please refer to the ten-digit State Clearinghouse number when contacting this office.

Sincerely,

Scott Morgan  
Director, State Clearinghouse
2.1.1 Response to Scott Morgan, Governor’s Office of Planning and Research, State Clearinghouse

The following section provides SMUD’s response to comments submitted on the draft IS/MND by Scott Morgan, Governor’s Office of Planning and Research, State Clearinghouse, on June 16, 2017.

Response to Comment 1-1

Comment Summary

Mr. Morgan indicates that SMUD has complied with the State Clearinghouse’s review requirements for draft environmental documents.

SMUD Response

SMUD appreciates the State Clearinghouse’s support in distributing the environmental document for review by state agencies. SMUD also appreciates the confirmation that it has complied with State Clearinghouse review requirements.
Jerry Park

From: Molly Kelly <mollykellygallery@gmail.com>
Sent: Tuesday, June 06, 2017 9:03 PM
To: Jerry Park
Subject: Cloud Seeding

...CAUTION EXTERNAL SENDER: Do not open links/attachments if uncertain about the sender...

Dear Sir,

Please consider the fact that a very high percentage of the oak trees fell sick to fungus this year due to the overabundance of rain. The trees dropped all their spring leaves and twigs. They are growing new leaves, but someone who is into forest management should weigh in on the idea of increasing rain.

Also much of the area to be seeded is using well water and some tests should be done on this as well, for the public good.

Thank you for your consideration on these matters that have an immediate effect on us.

Molly Kelly
2.1.2 Response to Molly Kelly

The following section provides SMUD’s response to comments submitted on the draft IS/MND by Molly Kelly on June 6, 2017.

Response to Comment 2-1

Comment Summary

The commenter expresses concern about the number of oak trees affected by fungus because of an overabundance of rain and a concern that cloud seeding could increase the amount of rain.

SMUD Response

During the winter of 2016–2017, the area experienced above-normal precipitation after 4 years of drought, and many trees and other natural resources reacted to these changes. SMUD would conduct cloud seeding only to enhance snowpack; cloud seeding would not occur during extremely wet seasons. The additional precipitation/snowpack caused by cloud seeding would remain within the normal range of precipitation for any given year, and would not result in long-term above-normal precipitation patterns. Therefore, it is unlikely that any reaction of local vegetation could be directly tied to cloud seeding activities. SMUD appreciates the comment and concern.

Response to Comment 2-2

Comment Summary

The commenter expresses concern that the area in which cloud seeding would occur uses well water and that testing should be done.

SMUD Response

Please refer to Appendix A regarding a study commissioned by SMUD to further investigate the potential for toxic effects of silver iodide in response to the commenter’s concerns. Historically, SMUD has measured total and dissolved silver in water samples within the Upper American River watershed at various times. Total silver would include any contributions from silver iodide measurements of total silver, including both dissolved and particulate silver, in all years ranged from <0.008 to 0.86 microgram (µg), which in all cases is below the U.S. Environmental Protection Agency (EPA) secondary drinking water threshold (100 µg dissolved silver) (Stillwater Sciences 2017). Please refer to Appendix A for additional detail on monitoring and the data analyzed by SMUD.
Jerry Park

From: Daphne Osell <osellgirls@gmail.com>
Sent: Monday, June 12, 2017 8:03 AM
To: Jerry Park
Subject: Cloud Seeding on Hwy 50

......CAUTION EXTERNAL SENDER: Do not open links/attachments if uncertain about the sender......

These are public comments for the proposed cloud seeding project. Please enter them into the public record. They have been additionally forwarded to our County Supervisor, Sue Novasel

We live in the community of Strawberry/Twin Bridges, along the Highway 50 corridor. Our community recently attending a meeting with representatives from SMUD about the current plan to expand cloud seeding operations directly over our community.

While this seems like an important project from SMUD to insure additional precipitation for hydroelectric power for the Sacramento basin, a few questions arose which SMUD was unable to answer. We are hoping that as our representative, you will follow up during this comment period and help ensure the safety and support for our community that will be primarily impacted by this project.

Our concerns are as follows:

1. While cloud seeding has gone on since the 1960's, there do not appear to be sufficient studies on the impact of silver iodide which, under the guidelines of the Clean Water Act by the EPA, silver iodide is considered a hazardous substance, a priority pollutant, and as a toxic pollutant.

"The Office of Environment, Health and Safety, UC Berkeley, rates silver iodide as a Class C, non-soluble, inorganic, hazardous chemical that pollutes water and soil.(8) It has been found to be highly toxic to fish, livestock and humans.(6,7,8,9) Numerous medical articles demonstrate that humans absorb silver iodide through the lungs, nose, skin, and GI tract.(7,8,9) Mild toxicity can cause GI irritation, renal and pulmonary lesions, and mild argyria (blue or black discoloration of the skin). Severe toxicity can result in hemorrhagic gastroenteritis, shock, enlarged heart, severe argyria, and death by respiratory depression.(8)"

When this was brought up with the SMUD representatives, including their scientist, they were unaware of the dangers of this substance. The very one they use for cloud seeding. They also do NOT test for this substance or monitor accumulation levels sufficiently. They operate on the assumption that this is not accumulating, or hazardous.

Our suggestion is that they set up regular studies, immediately following seeding events over a large enough area, so that we, as a community, can be assured that our water, soil, and health will not be adversely impacted.
Since we will not personally benefit from this program, and it is happening literally on top of our heads, it seems only fair that these studies are put into place, and reports are shared with our community on an ongoing basis.

We would like your support to ensure that SMUD will indeed conduct regular, ongoing testing for silver iodide accumulations in our community, and provide public reports of their findings.

"In the latest National Resources Commission report into the trial released in 2010, the authors raised concern that there was not enough information on what happened to the cloud seeding agents once they were dispersed. 'Although no adverse environmental effects have been detected to date, it is an important matter for future risk analysis to understand the ultimate fate of these seeding chemicals,' the report said. Dr Faruqi says the program should never have been allowed to move out of the trial phase before answering those concerns...There is nothing to tell us how those chemicals accumulate in the environment...When we don't know longer term impacts we have to take a precautionary approach, not just 10 years. We have to learn our lessons from the past things like DDT, asbestos, CFCs, the impact of these chemicals accumulating became apparent decades after they started being used."  [Source: http://www.smh.com.au/technology/sci-tech/concerns-persist-over-longterm-impact-of-cloud-seeding-in-kosciuszko-20150303-13ij6e.html]

2. When there is additional precipitation, our community is dramatically impacted. This year, with record snowfall, we had no power for 15 out of 30 days. Mud slides and avalanche control isolated us. Children who attend school in South Lake Tahoe, could not attend many days, as the county plows were unable to keep up. Our roads were not plowed for weeks; preventing emergency response, we could not leave our driveways, PG&E could not access lines, and cell towers could not be serviced, leaving us without phone, power, road access or emergency services.

SMUD suggests it is "only" a 3-10% increase, but studies are unclear on this. In addition, just a small increase can have a big impact on our tiny, mountain community. We would like additional resources to be dedicated to county services, particularly road clearing. It is not right or fair for our community to suffer for the benefit of SMUD, when additional forethought could ensure our community is not adversely impacted by this project.

"In the core of the silver iodide plumes, we may see the snowfall rate double or more, according to the model," Geerts says. [Source: http://cen.acs.org/articles/94/22/Docs-cloud-seeding-really-work.html]
2.1.3 Response to Daphne Osell

The following section provides SMUD’s response to comments submitted on the draft IS/MND by Daphne Osell on June 12, 2017.

Response to Comment 3-1

**Comment Summary**

The commenter raises concerns that the potential impacts of silver iodide have not been studied sufficiently and regarding a literature compilation prepared by the University of California, Berkeley, citing studies that found adverse effects. The commenter also raises concerns that SMUD does not conduct testing for silver iodide and suggests that SMUD conduct studies after future seeding events.

**SMUD Response**

Please refer to Appendix A for an additional study on the subject. At the request of SMUD, Stillwater Sciences conducted an independent review of the studies mentioned. Historically, SMUD has measured total and dissolved silver in water samples within the Upper American River watershed at various times. Total silver would include any contributions from silver iodide. Measurements of total silver, including both dissolved and particulate silver, in all years ranged from <0.008 to 0.86 µg, which in all cases is below the EPA secondary drinking water threshold (100 µg dissolved silver) (Stillwater Sciences 2017). Please refer to Appendix A for additional detail on monitoring and the data analyzed by SMUD.

Response to Comment 3-2

**Comment Summary**

The commenter cites examples of the challenges encountered in the community during the heavy snows of winter 2016–2017 and raises concerns about the potential impact of increased snowfall.

**SMUD Response**

Although SMUD estimates that cloud seeding may increase snowfall between 3 and 10 percent, this is the estimated increase over the amount of snowfall that would occur without cloud seeding. This does not mean that cloud seeding would result in a 3–10 percent increase in the snowfall that occurs during winters with heavy snow. In these years, cloud seeding would be suspended before such conditions would occur. The challenges faced by the community during heavy snowfall in winter 2016–2017 (e.g., avalanches, blocked roads, power outages) resulted from a very heavy snowfall that occurred throughout the West and well after SMUD had suspended cloud seeding. Further, as described in the draft IS (Section 3.9, “Hydrology and Water Quality,” pages 104–108), “the project would occur in an area subject to major winter storms including rain, snow, and rain following snow (i.e., rain-on-snow) ... In these years, SMUD would implement the program’s suspension criteria and would curtail cloud seeding ...”
The suspension criteria would minimize the potential for cloud seeding to contribute to heavy snowfall and related subsequent risks from avalanches, erosion, and flooding.

SMUD has conducted cloud seeding in the Sierra Nevada since 1968 and is aware of the concerns regarding the impacts of precipitation enhancement on the local community. However, as described in the draft IS, cloud seeding is designed to increase snowfall and subsequent snowmelt but is curtailed or suspended if the potential exists for hazardous conditions. SMUD has suspended cloud seeding in past years with heavy snowfall and concern about potential avalanches. As described in the draft IS on pages 40–41 (Section 2.6.2, “Operations,” in Chapter 2.0, “Project Description”):

The project would use predetermined suspension criteria developed by SMUD and the meteorological consultant to determine when the program should be curtailed or suspended. These criteria are reported to the agencies that oversee cloud seeding programs (e.g., the National Oceanic and Atmospheric Administration [NOAA; see Section 2.6.4, “Compliance and Reporting”]), and are designed to minimize unneeded cloud seeding expenditures and reduce the potential for flooding or damage to downstream hydroelectric facilities. Suspension criteria are standard practice in the industry and are recommended by the American Society of Civil Engineers (ASCE 2004, 2016) and other organizations that conduct cloud seeding research and develop more effective techniques and procedures. For example, SMUD routinely evaluates whether the snowpack in the target area has reached a predetermined percentage above normal or whether unusually heavy precipitation events might result in snowmelt that could exceed reservoir capacity and result in flooding. Similar criteria would be used to guide the proposed project. Monitoring the snowpack and runoff would allow SMUD to determine whether additional precipitation from cloud seeding could exceed reservoir storage late in the season, or whether an individual storm could result in rain (and not the desired snow) that could require reservoir releases.

SMUD and the program’s meteorological consultant would routinely monitor gauges located throughout the watershed that record precipitation, snowpack water content, and ambient temperature. In addition, the meteorologist would monitor special circumstances such as flood potential based on NWS [National Weather Service] flash-flood warnings, avalanche risk, ongoing search and rescue in the target area, and the potential to produce crop-damaging hail. SMUD also evaluates whether seeding could affect areas that have recently burned or could have unstable soils because of recent seismic events, including recent or potential landslides that could remove vegetation. These suspension criteria are instrumental in controlling program costs and avoiding undue erosion, landslides, mudflows, and/or downstream flooding. SMUD and the meteorologist would jointly make decisions regarding when to invoke the suspension criteria.

SMUD’s current suspension criteria are described in the draft IS and would be evaluated and used to manage the proposed El Dorado Cloud Seeding Program Expansion Project. These include specific numeric criteria for curtailing cloud seeding and the amount of additional snowpack caused by cloud seeding based on projected snowmelt, minimizing the risk of flooding and avalanches, minimizing impacts on any ongoing search-and-rescue missions, and reducing the potential for impacts on crops from hail.
SMUD Cloud Seeding Project Comment Card

Date: 6-14-2017  Name: ICON T. BAXTER
Phone: 530-546-0188  Email: sotabo@adyad.com
Organization: NA
Address: Zip Code:

Comment:
KEEP YOUR CHEMICAL CRAP OUT OF OUR SLEEP, DANCE YOURSELF, NOT ENOUGH RESEARCH DO BY ON SILICIL, WIDDLE WHAT IT DOES TO THE HUMAN BODY WITH REPEATED EXPOSURE.
2.1.4 Response to Dona J. Baxter

The following section provides SMUD’s response to comments submitted on the draft IS/MND by Dona J. Baxter on June 14, 2017.

Response to Comment 4-1

Comment Summary

The commenter expresses concern regarding repeated exposure of humans to silver iodide.

SMUD Response

Please refer to Appendix A regarding a study commissioned by SMUD to further investigate the effects of silver iodide. Historically, SMUD has measured total and dissolved silver in water samples within the Upper American River watershed at various times. Total silver would include any contributions from silver iodide. Measurements of total silver, including both dissolved and particulate silver, in all years ranged from <0.008 to 0.86 µg, which in all cases is below the EPA secondary drinking water threshold (100 µg dissolved silver) (Stillwater Sciences 2017). Please refer to Appendix A for additional detail on monitoring and the data analyzed by SMUD.
3.0 CHANGES TO DRAFT CEQA TEXT

This chapter contains errata to the draft IS/MND. New text is identified by **bold, underlined font**, while deletions are indicated by strikethrough font. Text revisions affecting mitigation measures have been incorporated into the MMRP presented in Chapter 4 of this final IS/MND. Revisions provided in this final IS/MND are intended to highlight minor revisions to the project description.

The change to the project description is minor and does not change the impact conclusions or proposed mitigation initially identified in the IS/MND. Edits to the original text of the IS/MND contained herein do not constitute substantive new information; therefore, the conclusions of the draft IS/MND are not affected by these revisions.

The comments and responses presented in Chapter 2.0 do not warrant changes to the draft IS/MND.

For clarification purposes, SMUD has added a name to Mitigation Measure CUL-1 and changed “would” to “will” in the same measure. These changes are reflected in the MMRP and do not constitute a significant change.

3.1 Changes to the Project Description

The following deletion has been made to Section 2.6.1, “Aerial Cloud Seeding (Aircraft),” of the IS/MND as shown below. Although SMUD does not currently intend to use belly-mounted flares, it would like to have the flexibility to use that method in the future.

“The aircraft used would be based at a commercial airport, most likely in Sacramento (e.g., McClellan, Mather). SMUD would use a contractor to provide cloud seeding services for a set period of time, based on a competitive bid. During recent years, SMUD’s meteorological consultant and cloud seeding crews operated a Cessna 340A seeding aircraft that was based out of McClellan Airfield. The planes would be equipped with wing-mounted flare racks, data logging, and communication systems. Belly-mounted flares are not proposed for future aerial seeding. In addition to flares, SMUD could opt to use silver iodide–acetone solution generators on the program’s aircraft.”
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4.0 MITIGATION MONITORING AND REPORTING PLAN

4.1 Introduction

This MMRP summarizes identified mitigation measures, the implementation schedule, and responsible parties for the proposed project. SMUD will use this MMRP so that identified mitigation measures, adopted as a condition of project approval, are implemented appropriately. This monitoring plan meets the requirements of State CEQA Guidelines Section 14074(d), which mandates preparation of monitoring provisions for the implementation of mitigation assigned as part of project approval or adoption.

4.2 Mitigation Implementation and Monitoring

SMUD will be responsible for monitoring the implementation of mitigation measures designed to minimize impacts of the proposed project. Although SMUD has ultimate responsibility for ensuring implementation, others may be assigned the responsibility of actually implementing the mitigation. SMUD will retain the primary responsibility for ensuring that the proposed project meets the requirements of this MMRP and other permit conditions imposed by participating regulatory agencies.

SMUD will designate specific personnel who will be responsible for monitoring implementation of the mitigation that will occur during equipment installation. The designated personnel will be responsible for submitting documentation and reports to SMUD on a schedule consistent with the mitigation measure and in a manner necessary for demonstrating compliance with mitigation requirements. SMUD will ensure that the designated personnel have the authority to implement the mitigation requirements and are capable of terminating installation activities found to be inconsistent with the mitigation objectives or project approval conditions.

SMUD will be responsible for demonstrating to the appropriate regulatory agency that the project is in compliance with any permit conditions. SMUD also will be responsible for ensuring that its equipment installation personnel understand their responsibilities for adhering to the performance requirements of the MMRP and other contractual requirements for implementing the mitigation measures as part of the project.

In addition to the prescribed mitigation measures, Table 4-1 lists each identified environmental resource being affected, the corresponding monitoring and reporting requirement, and the party responsible for ensuring implementation of the mitigation measure and monitoring effort.

4.3 Mitigation Enforcement

SMUD will be responsible for enforcing mitigation measures. If alternative measures are identified that would be equally effective at mitigating the identified impacts, these alternative measures will not be implemented until agreed on by SMUD.
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<table>
<thead>
<tr>
<th>Checklist Section</th>
<th>Environmental Criteria</th>
<th>Mitigation Measure</th>
<th>Implementation Duration</th>
<th>Monitoring Duration</th>
<th>Responsibility Implementation</th>
<th>Responsibility Monitoring</th>
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</thead>
<tbody>
<tr>
<td>Cultural Resources</td>
<td>b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to Section 15064.5?</td>
<td>Mitigation Measure CUL-1. Conduct Cultural Resources Survey</td>
<td>Construction</td>
<td>Construction</td>
<td>SMUD</td>
<td>SMUD</td>
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<td></td>
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<td>Prior to installation of remotely controlled cloud seeding equipment on concrete pads, a qualified archaeologist will survey the proposed installation area. In the event that any prehistoric or historic archaeological features or deposits (including locally darkened soil or “midden” soils that could contain cultural deposits) are discovered, the archaeologist will record the site and work with SMUD to identify an alternate installation location on the property that will avoid impacting cultural resources. The archaeologist will prepare a report according to current professional standards. If the site has no resources, no report will be required.</td>
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<td>Cultural Resources</td>
<td>d) Disturb any human remains, including those interred outside of formal cemeteries?</td>
<td>Mitigation Measure CUL-2. Implement State and County Requirements for Addressing Discovery of Human Remains and Site Protection.</td>
<td>Preconstruction/Construction</td>
<td>Construction</td>
<td>SMUD</td>
<td>SMUD</td>
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<td>In accordance with the California Health and Safety and Public Resources Codes and the County General Plan, if human remains are uncovered during ground-disturbing activities, the contractor and/or SMUD will immediately halt potentially damaging excavation in the area of the burial and notify the county coroner and a professional archaeologist to determine the nature of the remains. The coroner is required to examine all discoveries of human remains within 48 hours of receiving notice of a discovery on private or state lands (California Health and Safety Code, Section 7050.5[b]). If the coroner determines that the remains are those of a Native American, he or she must contact the NAHC by phone within 24 hours of making that determination (Health and Safety Code, Section 7050[c]). Following the coroner’s findings, the property owner, the contractor or project proponent, an archaeologist, and the NAHC-designated MLD will determine the ultimate treatment and disposition of the remains and take appropriate steps to ensure that additional human interments are not disturbed. The responsibilities for acting upon notification of a discovery of Native American human remains are identified in PRC Section 5097.9.</td>
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<td>Upon the discovery of Native American remains, SMUD will ensure that the immediate vicinity (according to generally accepted cultural or archaeological standards and practices) is not damaged or disturbed by further development activity until consultation with the MLD has taken place. The MLD will have 48 hours after being granted access to the site to complete a site inspection and make recommendations. A range of possible treatments for the remains may be discussed, including nondestructive removal and analysis, preservation in place, relinquishment of the remains and associated items to the descendants, or other culturally appropriate treatment. PRC Section 5097.9 suggests that the concerned parties may extend discussions beyond the initial 48 hours to allow for the discovery of additional remains. SMUD will employ the following site protection measures:</td>
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<td>(1) record the site with the NAHC or the appropriate Information Center,</td>
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<td></td>
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<td>(2) use an open-space or conservation zoning designation or easement, and</td>
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<td>(3) record a document with the county in which the property is located.</td>
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<td></td>
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<td>If the NAHC is unable to identify a MLD or the MLD fails to make a recommendation within 48 hours after being granted access to the site, SMUD or its authorized representative will rebury the Native American human remains and associated grave goods with appropriate dignity on the property in a location not subject to further subsurface disturbance. SMUD or its authorized representative may also reinter the remains in a location not subject to further disturbance if it rejects the recommendation of the MLD and mediation by the NAHC fails to provide measures acceptable to SMUD.</td>
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</table>
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5.0 REPORT PREPARATION

The following people contributed to the preparation of this document.

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Julie Nichols—Technical Editor

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Maia S. Singer, Ph.D.

Scott D. Wilcox
6.0 REFERENCES

ASCE. See American Society of Civil Engineers.


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APPENDIX A:
STILLWATER SCIENCES STUDY
Environmental Effects of Silver Iodide from Cloud Seeding Operations

Sacramento Municipal Utility District

Hydro License Implementation • August 2017
FERC Project No. 2101
Prepared by:
Stillwater Sciences

Nathaniel L. Butler, Ph.D.
Maia S. Singer, Ph.D.
Scott D. Wilcox
EXECUTIVE SUMMARY

SMUD has conducted cloud seeding since 1968 in the South Fork American River watershed upstream of the Upper American River Project (UARP) over a 190-square mile target area, with a currently planned expansion to 444-square miles. Silver iodide (AgI) is a compound of silver used in cloud seeding activities to promote the formation of ice crystals and enhance total snowpack accumulation. Silver iodide is used for cloud seeding because its crystalline structure makes the compound ideally suited for ice formation, it exhibits very low solubility in natural waters (i.e., less than 1 microgram per liter [ug/L]), and it is not bioavailable or toxic to organisms in the environment.

In general, studies of cloud seeding using silver iodide have demonstrated increased total silver concentrations in associated precipitation, but no corresponding, statistically significant systematic increase or accumulation of total silver in freshwater, soil, or in stream, lake, or reservoir sediments in the areas experiencing cloud seeding.

Silver iodide is not typically measured in isolation in the environment, with existing analytical methods relying upon measurements of total silver. Cloud seeding using silver iodide has been found to increase total silver concentrations in precipitation between two and three times on average when compared to unseeded precipitation.

In studies conducted in the California Sierra Nevada, total silver concentrations in snow from areas seeded with silver iodide were typically less than 0.02 ug/L but reached a maximum of approximately 0.115 ug/L. Freshwater total silver concentrations in areas cloud seeded with silver iodide were usually less than analytical detection limits (between 0.0005 and 0.04 ug/L depending on the method used), but they were occasionally measured between 0.09 - 0.74 ug/L in the Feather River-Lake Almanor watershed and less than 0.0005 ug/L on average in the Mokelumne River watershed. In general, total silver concentrations have not been shown to increase above background levels in terrestrial, stream, and lake sediments in areas seeded with silver iodide.

There are no documented environmental hazards associated with silver iodide and to date no studies have identified adverse environmental impacts due to cloud seeding with silver iodide. There are no federal, state, or local regulations establishing acceptable levels of exposure for silver iodide. In natural waters, silver iodide has such extremely low solubility (0.984 ug/L) that it is generally considered to be insoluble and is thus not bioavailable or toxic.

In contrast, there are known environmental hazards and regulations associated with dissolved silver (free silver ion [Ag^+]) because, unlike insoluble silver iodide, dissolved silver is bioavailable and potentially toxic to sensitive organisms. Dissolved silver is a negligible environmental hazard for humans, but federal and state regulations set the maximum contaminant level for dissolved silver in drinking water at 100 ug/L to prevent a cosmetic gray or blue-gray discoloration of skin that may occur from chronic exposure to high levels. Dissolved silver is a potential hazard to aquatic and terrestrial organisms.
at a wide range of concentrations depending on the species, life-stage, and water hardness with 1.2 to 4.9 ug/L lethal to sensitive aquatic organisms. Accordingly, the USEPA has set an acute freshwater criterion or criteria maximum concentration (CMC) for dissolved silver as a function of water hardness with a CMC of 3.2 ug/L at a hardness of 100 mg/L. Lower water hardness results in a lower CMC for silver. There is no chronic freshwater criterion for dissolved silver. Dissolved silver also is an environmental hazard to terrestrial plants and animals, but the concentrations causing adverse effects are much higher than found under typical natural conditions. However, despite the hazards associated with dissolved silver, there is no equivalent hazard with silver iodide because it is insoluble and thus not bioavailable.

Historically, SMUD has measured total and dissolved silver in water samples within the Upper American River watershed at various times. Total silver would include any contributions from silver iodide, while dissolved silver would not include any silver iodide since silver iodide is insoluble in water under natural conditions. Measurements of total silver, including both dissolved and particulate silver, in all years ranged from <0.008 – 0.86 ug/L, which in all cases is below the USEPA secondary drinking water threshold (100 ug/L dissolved silver). Dissolved silver was analyzed in 2004 and ranged from <0.0045 – 0.02 ug/L with the hardness-adjusted freshwater CMC for aquatic biota being exceeded in two reservoir samples and one riverine sample. Total and dissolved silver concentrations in water and fish tissue measured more recently have been consistently at or near the lowest analytical detection limits.

SMUD currently monitors total and dissolved silver in the Upper American River watershed every five years as part of a suite of trace metals. Monitoring is conducted seasonally at 22 sites across seven stream reaches and 20 sites across 11 reservoirs in the watershed, where monitoring sites range in elevation from approximately 500 – 6,500 feet, covering the full elevational extent of SMUD cloud seeding activities. Of the 42 total riverine and reservoir monitoring sites, 23 are located directly within the existing 190-square mile cloud seeding target area, and the remaining sites are located downstream of both the existing and the expanded target area, allowing for an assessment of potential downstream transport of silver. The current trace metals monitoring program would detect long-term seasonal trends in total and dissolved silver concentrations in specific reservoir and river locations within the existing cloud seeding target area, and it would also detect spatial variations in concentrations within this area (e.g., particular locations that may exhibit higher concentrations than others). While the frequency and spatial coverage of the current monitoring program is not able to attribute variations in concentrations of these forms of silver to individual cloud seeding events, it would measure long-term changes in the amount of dissolved (i.e., bioavailable) silver directly within the existing 190-square mile cloud seeding target area, and downstream of both the existing and the expanded target area, which could be compared to long-term trends in SMUD application rates of silver iodide.
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1.0 INTRODUCTION

Cloud seeding with silver iodide (AgI) has been conducted in California for over 50 years with many projects dispersing silver iodide along the central and southern Sierra Nevada to enhance snowpack accumulation (Hunter 2007; DWR 2013, 2016). Silver iodide is used in cloud seeding because it is insoluble, able to be dispersed by ground- or aerial-based methods, and has a crystalline structure similar to ice that promotes the formation of snow from water vapor in the atmosphere. Silver iodide and the impacts of its use in cloud seeding have been frequently studied by industry, government, and academia to quantify its efficacy at increasing snow accumulation as well as its environmental impact. While some studies have directly evaluated silver iodide under laboratory conditions, most studies have focused on field monitoring of total silver concentrations in the environment (see also Section 4.1).

In 2017, the Sacramento Municipal Utility District (SMUD) received questions about the use of silver iodide in cloud seeding during public comments on the proposed expansion of SMUD’s El Dorado Cloud Seeding Program. The objective of this report is to generally address those questions through discussion of the following topics:

- Cloud seeding practices
- Properties of silver and silver iodide
- Silver iodide levels in the environment
- Potential human and environmental hazards of silver and silver iodide
- Relevant regulatory thresholds
- Overview of SMUD’s cloud seeding program

2.0 BACKGROUND

2.1 CLOUD SEEDING

Cloud seeding is the introduction of very small particles into clouds to increase the amount of precipitation the clouds would naturally produce. Clouds are formed when temperatures in the atmosphere reach saturation or a relative humidity of 100 percent, causing water vapor in the air to condense around a particle and form a droplet. Naturally occurring particles, such as dust from wind erosion or salt formed by evaporation from the ocean, are the “cloud condensation nuclei” critical to condensing water vapor in the air into clouds composed of water droplets, ice crystals, or a mixture of both. The two types of cloud formation processes are “warm cloud” and “cold cloud”. Warm cloud formation occurs when cloud temperatures are above freezing and water droplets in the cloud collide until they form droplets with sufficient weight to fall as rain. Cold cloud formation occurs when cloud temperatures are below freezing, such that cloud droplets remain unfrozen as pure water until coming into contact with a particle or ice nuclei that causes the pure water to freeze and form an ice crystal. The ice crystal grows as more water vapor or unfrozen water droplets freeze onto the ice crystal, until it forms a snowflake that falls to the ground as snow or rain (Hunter 2007).
In either warm or cold cloud formation processes, microscopic airborne particles are critical to water droplet or ice crystal formation, which then produces precipitation. In cold cloud formation, particles are especially important for causing ice crystal development and precipitation because pure water droplets do not freeze until well below 32°F (Hunter 2007; SMUD 2017). In some cold storm systems, natural particles in the air are too few to promote ice crystal formation of the pure water droplets, so no precipitation occurs. Cloud seeding introduces a sufficient number of additional small particles to stimulate the formation of water droplets or ice crystals and create precipitation (County of Los Angeles 2015).

The main types of cloud seeding that commonly occur are cold-season orographic cloud seeding, hail and fog reduction cloud seeding, and warm-season convective cloud seeding. As SMUD conducts cold-season orographic cloud seeding with silver iodide, the remainder of this report focuses primarily on the processes involved in this type of cloud seeding. Cold-season orographic cloud seeding relies on cold cloud formation processes. It generally occurs in California when moist air flowing from the Pacific Ocean rises as it reaches the western side of the Sierra Nevada and subsequently cools, causing water vapor to condense into clouds. However, if there are insufficient natural particles in the cloud to cause the pure water to form ice crystals, no precipitation will occur. Artificial particles introduced by ground- or aerial-based cloud seeding methods can provide the additional particles needed to initiate or increase precipitation.

Silver iodide (AgI) is the most common artificial particle used in cloud seeding because it has a crystal structure similar to ice which enables it to easily promote ice crystal formation. Silver iodide is most effective at producing ice crystals when air temperatures are below 23°F (-5°C), so effective cloud seeding with silver iodide would only occur under those conditions. As a cloud seeding agent, silver iodide is released in smoke from ground-based cloud-nuclei generators (CNGs), flare “trees”, or from aerial-based flares mounted to an aircraft that flies through the clouds. Specific details of the methods used to disperse silver iodide in cloud seeding conducted by SMUD are discussed in Section 6.

While cloud seeding has been used for many decades and in numerous locations throughout the western United States, the efficacy of cloud seeding is still debated amongst experts in the field and in the scientific literature. In a 2003 report, the National Academy of Sciences (NAS) notes there is strong evidence that some cloud seeding programs have induced precipitation changes, but more tests of significance and reproducibility are needed to prove cloud seeding increases precipitation. Garstang et al. (2005) and Super and Heimbach (2005) summarize the main viewpoints and evidence of experts related to cloud seeding efficacy. While NAS concludes that there was no convincing scientific proof of the efficacy of weather modification efforts at that time (NAS 2003), multiple studies have been conducted since which indicate that cloud seeding does increase precipitation. For example, using air- and ground-based radar
measurements, Huggins (2007) documents that ice crystal concentrations were over an order of magnitude greater in the seeded cloud zone area than those outside. A five-year experimental program in the Snowy Mountains of southeastern Australia indicates that cloud seeding increased precipitation between 7% and 14% in the targeted area compared to unseeded areas (Manton et al. 2011; Manton and Warren 2011).

Cold season orographic cloud seeding in California has been practiced since the early 1950s and in the last 20 years cloud seeding programs have occurred in 11 to 14 watersheds annually. Cloud seeding is recognized as a precipitation enhancement method by the California Department of Water Resources (DWR 2016) and the California Water Plan Update 2013 (DWR 2013). Most cloud seeding projects in California are located along the central and southern Sierra Nevada and use silver iodide as the active seeding agent (DWR 2016). Cloud seeding projects are required to provide the National Oceanic and Atmospheric Administration (NOAA) with activity reports, detailing the number of days, hours of operation, and amounts of seeding material used. The State of California requires cloud seeding project sponsors to file a notice of intent initially and every five years for continuing projects, record keeping by operators, and annual or biennial reports to DWR. All cloud seeding projects must comply with the California Environmental Quality Act (DWR 2016).

2.2 PROPERTIES OF SILVER AND SILVER IODIDE

Silver is a relatively rare, naturally occurring element with an abundance of approximately 0.07 mg/kg in the earth’s crust. It is found primarily in mineral ores containing other elements. In its elemental state, silver can be found in oxidation states of Ag⁰, Ag¹⁺, Ag²⁺, and Ag³⁺, but only the solid state (Ag⁰), dissolved (Ag⁺), or free silver ion in water (Ag¹⁺) occur under typical environmental conditions (Eisler 1996).

Dissolved silver is the primary form of silver that is an environmental concern because it interferes with biological processes in aquatic organisms (EPA 1980). Dissolved silver is fungicidal, algicidal, and bactericidal at concentrations ranging 10–1,000 ug/L so it is frequently used in medical applications and to sterilize potable water (Williams and Denholm 2009).

Silver also forms compounds with a range of other substances including arsenic, sulfate, bicarbonate, nitrate, iodide, and chloride with each silver compound exhibiting very different properties (Cardno ENTRIX 2011). As noted previously, silver iodide is one of the most common particles used in cloud seeding because the crystalline structure of silver iodide closely resembles ice, making it an effective surrogate for ice as a nucleating agent in clouds (PG&E 2011). The reaction to form silver iodide (AgI) from dissolved silver (Ag⁺) and iodide (I⁻) is expressed as:

$$\text{Ag}^+ (\text{liquid}) + I^- (\text{liquid}) \rightarrow \text{AgI} (\text{solid}) \quad \text{(Equation 1)}$$
2.2.1 Solubility of Silver Compounds

Solubility is the ability of a compound to dissolve in a solvent. In the environment, solubility in water generally controls bioavailability so silver compounds that are not readily soluble (or “insoluble”) in water are of significantly less environmental concern (Karen et al. 1999; Williams and Denholm 2009). Table 1 provides a comparison of the solubility of several silver compounds in water, along with two common substances (table salt, sand/quartz) for comparison. The solubility of silver compounds varies widely, with some silver compounds (e.g., silver nitrate) being very soluble and readily forming dissolved silver ions in water, while other silver compounds (e.g., silver iodide) are very insoluble, producing very few dissolved silver ions when in contact with water. Solubility is also represented by a solubility product or $K_{sp}$. The solubility product for the silver iodide reaction expressed above in Equation 1 is $8.5 \times 10^{-17}$ indicating the reaction is strongly driven toward the solid form. The maximum concentration of dissolved silver that can form in water that is in contact with solid silver iodide at 25°C (standard conditions) is 0.984 ug/L (parts per billion [ppb]) (Stone 2006). Solid silver iodide in water will not form any dissolved silver if the concentration of dissolved silver is 0.984 ug/L or higher (Williams and Denholm 2009).

Table 1. Solubility of Selected Silver Compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Solubility (g/100 mL)</th>
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<tbody>
<tr>
<td></td>
<td>Cold Water</td>
</tr>
<tr>
<td>Sodium chloride (NaCl or table salt)</td>
<td>35.9</td>
</tr>
<tr>
<td>Silver nitrate (AgNO₃)</td>
<td>122</td>
</tr>
<tr>
<td>Silver chloride (AgCl)</td>
<td>0.000089</td>
</tr>
<tr>
<td>Silver iodide (AgI)</td>
<td>Insoluble</td>
</tr>
<tr>
<td>Silver sulfide (Ag₂S)</td>
<td>Insoluble</td>
</tr>
<tr>
<td>Silicon dioxide (SiO₂ or sand/quartz)</td>
<td>Insoluble</td>
</tr>
</tbody>
</table>


Silver iodide is soluble in hydroiodic acid (pH < 3) and ammonia solutions (pH > 10), as well as aqueous solutions of other compounds (e.g., potassium iodide, sodium chloride, potassium cyanide, ammonium hydroxide sodium thiosulfate), and concentrated solutions of compounds such as alkali bromides, chlorides, thiocyanates, thiosulfates, mercuric and silver nitrates (Firsching 1960; Lewis 1997; O’Neil 2001). These solutions can be generated in a laboratory or industrial setting, but they are not present under typical environmental conditions.

The extremely low environmental solubility of silver iodide, along with a crystalline structure closely resembling ice, makes it an ideal particle for cloud seeding. In clouds, silver iodide remains a solid nucleating site as water vapor forms droplets and/or ice crystals around it. On the ground, it does not readily disassociate into biologically available dissolved silver ions (PG&E 2011).
2.2.2 Adsorptivity of Silver and Silver Iodide

In the environment, sorption (the physical and chemical process by which one substance becomes attached to another) is the dominant process controlling silver partitioning in water and its movement in solids and sediments. Silver strongly adsorbs to manganese dioxide, ferric (iron) compounds, and clay minerals commonly present in watershed and forms precipitates with naturally occurring fluorine, chlorine, bromine, and iodine, reducing the concentration of dissolved silver (free silver ions) in water (Eisler 1996). Silver also readily adsorbs to particulate matter, to the extent that only approximately 25 percent of the total silver is estimated to be dissolved as either ion colloids or complexes (Wen et al. 1997; Stone 2006). Silver adsorption to particulate matter in water contributes to silver deposition into sediments when particulate matter settles out of the water column (Eisler 1996). The U.S. Environmental Protection Agency (USEPA) ambient water quality criteria also notes that silver may adsorb to organic material in natural waters and form metal-organic complexes (USEPA 1980). Silver may desorb under reducing conditions in the sediment after which it may either reduce to metallic silver or combine with reduced sulfur to form insoluble silver sulfide (USEPA 1980). The silver iodide compound is not likely to strongly adsorb to surfaces as it is a relatively uncharged, insoluble solid.

3.0 SILVER IODIDE IN THE ENVIRONMENT

3.1 MEASUREMENT OF SILVER IODIDE IN THE ENVIRONMENT

The silver iodide compound is not typically measured in the environment, even during studies focused on evaluating the impacts of using silver iodide in cloud seeding. Readily available analytical techniques measure total silver concentrations, where the latter include all forms of silver in a sample (e.g., dissolved silver ions, silver iodide, other silver complexes). Total silver concentrations are used to estimate silver iodide released from cloud seeding, assuming that other sources of silver in the sample are minimal or constant. Since the total silver concentration includes both the bioavailable dissolved silver that correlates with aquatic toxicity and the insoluble silver iodide particles, measurements of the total silver concentration cannot be directly compared with regulatory thresholds based on dissolved silver concentrations in water.

Total silver is typically measured with a high resolution inductively-coupled plasma mass spectrometer (HP-ICP-MS) (Huggins et al. 2004; Manton et al. 2011; PG&E 2011), but it also can be measured with inductively coupled plasma optical emission spectrometry (ICP-OES) or inductively coupled plasma atomic emission spectrometry (ICP-AES) (Fajardo et al. 2016). Total silver is also measured in soil using soxlet extraction followed by flame atomic absorption spectrometry and in vegetation using acid digestion then electrothermal atomic absorption spectrometry for grass (Tsiouris et al. 2003). USEPA Method 200.8 and Method 6020A detail HP-ICP-MS procedures for ultra-trace sampling and analysis techniques for trace elements like silver (USEPA 1994; USEPA 1998). SMUD currently uses USEPA Method 200.8 HP-ICP-MS with
detection limits of 0.070 ug/L for total silver and 0.15 ug/L for dissolved silver (SMUD 2016).

Measurements of total silver concentrations have been reported for many locations with the total silver concentration varying significantly depending on geology and past land use activities (Strandler and Vonnegut 1972; Eisler 1996; Williams and Denholm 2009; Cardno ENTRIX 2011). Silver measurements before the late 1980s should be treated cautiously because ultra-clean metal sampling procedures to ensure an uncontaminated sample, especially for trace metals like silver, did not begin until after that period. Eisler (1996) and Williams and Denholm (2009) summarize the total silver concentrations measured at locations around the world in air, water, snow, soils, and aquatic sediments from the Concise International Chemical Assessment Document 44 (CICAD 44) and other publications. Eisler (1996) reports total silver concentrations in the air of 1.0 nanograms per cubic meter [ng/m³] in rural areas with cloud seeding using silver iodide and 0.04 – 0.17 ng/m³ in rural areas without cloud seeding (Table 2). Total silver concentrations in air samples taken directly adjacent to a silver iodide ground based cloud-seeding generator are considerably higher (e.g., >10,000 ng/m³) (Eisler 1996).

3.2 SILVER CONCENTRATIONS IN PRECIPITATION

Silver concentrations in precipitation have been regularly monitored in cloud seeding operations (Super and Huggins 1992; Warburton et al. 1995; Eisler 1996; Sanchez et al. 1999; Huggins et al. 2004; Cardno ENTRIX 2011; Manton and Warren 2011). Silver concentrations in snow in seeded regions have been found to be higher than in unseeded regions. In studies of the central Sierra Nevada, the background silver concentration in snow was measured at 0.002 ug/L, while mean total silver concentration in snow after cloud seeding with silver iodide ranged from approximately 0.003 – 0.0894 ug/L (Table 2; Warburton et al. 1995; Huggins et al. 2004). USEPA (1981) concludes in an exposure and risk assessment for silver that the total silver concentrations in precipitation from silver iodide used in cloud seeding are not expected to contribute significant amounts to water.

3.3 SILVER CONCENTRATIONS IN FRESHWATER

Measured silver concentrations in lakes and streams represent a long-term average of silver concentrations from the area upstream of the measurement point, and integrate silver signals from both seeded and unseeded storms. Silver concentrations in freshwater are also reduced by adsorption on vegetation and sediments such that silver concentrations in surface waters tend to decrease with distance from the source of silver (Cooper and Jolly, 1970). Dissolved silver (Ag⁺) has exhibited rapid removal in freshwater environments, with a one to two-week half-life (Wen et al. 2002). Eisler (1996) reports average total silver concentrations of 0.3 ug/L in rivers, 2.6 ug/L in surface waters, and 2.2 ug/L in tap water across a large number of samples. In the California Sierra Nevada, the freshwater total silver concentrations from cloud seeded areas range from less than detection levels to 0.74 ug/L with most measurements within the range of typical freshwater silver concentrations (Table 2).
3.4 SILVER CONCENTRATIONS IN SOIL AND LAKE SEDIMENTS

Studies of silver concentrations in soils and lake sediments in cloud seeded areas document that silver concentrations in seeded areas have not increased above background levels found in non-seeded areas (Table 2). Measurements of total silver concentrations in soil at three different depths report higher surface concentrations, but the differences between the surface and middle layer or the middle and bottom layer were not statistically significant (Tsiouris et al. 2003). While seeded areas were not found to have elevated silver concentrations, a 1975 study found silver concentrations to be higher in the top 2 cm of soil within 50 m of a cloud seeding generator (USEPA 1981). In a study of the Mokelumne River watershed, average silver concentration in sediment samples ranged from 0.35 ug/L in Lower Blue Lake upwind of the cloud seeding area to 1.07 ug/L in Salt Springs Reservoir where runoff from the seeded area flows past (Stone 2006). Cloud seeding with silver iodide was reported to have a negligible enrichment impact on silver concentrations in lake sediments in a remote alpine lake in Australia (Stromsoe et al. 2013).
Table 2. Comparison of Measured Total Silver Concentrations in Seeded Areas with Typical Background Silver Concentrations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Silver Concentration Measured in Silver Iodide Seeded Areas</th>
<th>Source</th>
<th>Typical Background Total Silver Concentration</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIR (ng/m³)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite of U. S. measurements in rural areas</td>
<td>0.1 - 1.0</td>
<td>Eisler 1996</td>
<td>0.04 – 0.17</td>
<td>Eisler 1996</td>
</tr>
<tr>
<td><strong>SNOW PRECIPITATION (ug/L or ppb)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite of U. S. measurements</td>
<td>0.01 – 0.3</td>
<td>Eisler 1996</td>
<td>0 – 0.02</td>
<td>Eisler 1996</td>
</tr>
<tr>
<td>Lake Tahoe-Truckee River</td>
<td>0.003 – 0.022</td>
<td>Warburton et al. 1995</td>
<td>0.002</td>
<td>Warburton et al. 1995</td>
</tr>
<tr>
<td>Lake Almanor</td>
<td>0.004 – 0.02</td>
<td>Warburton et al. 1995</td>
<td>0.002</td>
<td>Warburton et al. 1995</td>
</tr>
<tr>
<td>Lake Tahoe-Truckee River (2003 – 2004)</td>
<td>0.0126 – 0.0894</td>
<td>Huggins et al. 2004</td>
<td>0.002</td>
<td>Warburton et al. 1995</td>
</tr>
<tr>
<td>Snowy Mountains, Australia</td>
<td>0 – 0.055</td>
<td>Manton and Warren 2011</td>
<td>0 – 0.025</td>
<td>Manton and Warren 2011</td>
</tr>
<tr>
<td><strong>FRESHWATER (ug/L or ppb)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feather River – Lake Almanor (2000)</td>
<td>0 - 0.74</td>
<td>PG&amp;E 2011</td>
<td>0.09 – 0.55</td>
<td>USEPA 1980; Eisler 1996</td>
</tr>
<tr>
<td>Feather River – Lake Almanor (2002 – 2003)</td>
<td>0.090 - 0.153</td>
<td>PG&amp;E 2011</td>
<td>0.09 – 0.55</td>
<td>USEPA 1980; Eisler 1996</td>
</tr>
<tr>
<td>Mokelumne watershed</td>
<td>&lt; 0.0005</td>
<td>Stone 2006</td>
<td>0.09 – 0.55</td>
<td>USEPA 1980; Eisler 1996</td>
</tr>
<tr>
<td><strong>SOIL AND LAKE/RESERVOIR SEDIMENT (ug/L or ppb)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>37.2 – 44.5</td>
<td>Tsiouris et al. 2002</td>
<td>30.4 – 56.7</td>
<td>Tsiouris et al. 2002</td>
</tr>
<tr>
<td>Mokelumne watershed</td>
<td>0.35 - 1.07</td>
<td>Stone 2006</td>
<td>n/a</td>
<td>Stone 2006</td>
</tr>
</tbody>
</table>
4.0 ENVIRONMENTAL HAZARDS OF SILVER AND SILVER IODIDE

Studies of the environmental hazards of silver and silver iodide indicate that the toxicity of silver is primarily dependent on the type of silver present in the environment. The toxicity of silver in the environment strongly correlates with dissolved silver ($\text{Ag}^+$) (USEPA 1980, 1981, 1987, 2010a, 2010b; Eisler 1996; Ratte 1999; Williams and Denholm 2009; Cardno ENTRIX 2011; Fajardo et al. 2016). While silver and its compounds, including silver iodide, do not pose a serious health concern to humans (USEPA 1980, 1981, 2010a, 2010b), dissolved silver has been found to impact aquatic organisms, plants, and other biota at a range of concentrations depending on the organism and ambient conditions (Cardno ENTRIX 2011). An exposure and risk assessment for silver details some of the environmental hazards and toxicity of silver on both biota and humans (USEPA 1980, 1981, 1987), while Eisler (1996) provides an extensive list of the threshold silver concentrations at which adverse effects have been found on many species of invertebrates, aquatic organisms, terrestrial plants, and wildlife.

While dissolved silver ($\text{Ag}^+$) is the main form of silver that presents an environmental hazard, silver is typically analyzed and reported as total silver concentration, particularly in studies of silver iodide used in cloud seeding (Section 4.1). However, total silver concentrations overestimate the amount of bioavailable, toxic dissolved silver, particularly if any particulate silver (e.g., silver iodide) is present.

4.1 SILVER

There is a negligible environmental hazard to humans from silver in the environment, with silver impacting human health only at levels far greater than those found in the environment (USEPA 1981; Eisler 1996). Toxicity tests report silver having no effect on humans at concentrations of 200 ug/L. Chronic exposure to high levels of silver over a long time can cause a cosmetic gray or blue-gray discoloration of skin (USEPA 1981).

Dissolved silver is an environmental hazard to aquatic life with concentration of dissolved silver between 1.2 and 4.9 ug/L lethal to sensitive aquatic organisms, with trout experiencing adverse effects at dissolved silver concentrations as low as 0.17 ug/L in lab tests (Eisler 1996; Williams and Denholm 2009). Field measurements often find higher tolerances to silver than laboratory toxicity tests because dissolved silver toxicity is significantly influenced by the presence of other ions found in natural waters (Eisler 1996; Williams and Denholm 2009). Dissolved silver ions are fungicidal, algicidal, and bactericidal at low doses with bactericidal concentrations occurring between 10 – 1000 ug/L (Williams and Denholm 2009).

Dissolved silver has adverse impacts on terrestrial life at much higher concentrations than would be encountered from cloud seeding (Cooper and Jolly 1970; Eisler 1996). Eisler (1996) summarizes the impacts and threshold silver concentrations from a wide range of silver concentrations on tested crops, domestic poultry, livestock, and other small laboratory mammals. Adverse impacts were observed in crops from sprays
containing 9,800 – 100,000 ug/L dissolved silver. Poultry, livestock and small mammals experienced adverse effects after exposure over several months to drinking water with dissolved silver concentrations from 250 ug/L (rabbits) to 1,586,000 ug/L (rats). There were very limited data describing the effects of silver on laboratory poultry and mammalian life, and there were no studies of the potential effects on wildlife.

4.2 SILVER IODIDE

There are no documented environmental hazards associated with the standard silver iodide concentrations used in cloud seeding because it is insoluble and does not have the toxic properties of dissolved silver (Standler and Vonnegut 1972; USEPA 1980, 1981, 2010a, 2010b; Cardno ENTRIX 2011; PG&E 2011; Fajardo et al. 2016). Insoluble silver compounds are virtually non-toxic to terrestrial and aquatic vertebrates (Ratte 1999). USEPA (1981) specifically evaluates the exposure and risk from silver iodide in cloud seeding concluding that it is not likely to result in significant exposure levels for natural populations or microorganisms. Silver iodide in general and specifically as used in cloud seeding also is not a hazard to human health based on the historical medical usage in nasal sprays and tooth fillings and the evaluation of the health of cloud seeding generator operators (Standler and Vonnegut 1972).

Silver iodide used in cloud seeding is not likely to be an environmental hazard to the environment, with laboratory studies reporting no adverse effects on plants (Cooper and Jolly 1970), soil microbial populations (Klein and Molise 1975), methanogenic organisms (Castignetti and Klein 1979), freshwater phytoplankton (Fajardo et al. 2016), or livestock (Younger and Crookshank 1978). While Cooper and Jolly (1970) noted that there was a possibility that silver iodide impacts the growth of algae, fungi, bacteria, and fish in fresh water and recommended further research into the subject, subsequent studies of silver iodide have not documented impacts at concentrations expected from cloud seeding activities.

Silver iodide used in cloud seeding is not considered an environmental hazard by the California Department of Water Resources (DWR 2013, 2016). The California Water Plan Update 2013 concludes silver iodide from cloud seeding should not result in any chronic effect on sensitive aquatic organisms from a review of silver measurements in water, sediment, and fish from areas with cloud seeding (Hunter 2007; DWR 2013, 2016). The U.S. Bureau of Reclamation (USBR) determined the environmental hazard of silver iodide from cloud seeding is insignificant (USBR 1977; Harris 1981; Howell 1977; Hunter 2007).

4.3 DISPERSAL METHODS FOR SILVER IODIDE

There are no documented environmental hazards or risks associated with the dispersal methods for silver iodide assuming reasonable safe handling and operation of the individual components (Standler and Vonnegut 1972; Hunter 2007; PG&E 2011; County of Santa Barbara 2013; DWR 2013, 2016; Reynolds 2015). Cloud seeding disperses silver iodide by either burning a silver iodide solution with propane or burning flares.
containing silver iodide. An analysis by the Northern Sierra Air Quality Management District found burning of the silver iodide solution with propane was a minimal environmental hazard (PG&E 2011). Flares used for cloud seeding are similar to a standard road flare with silver iodide added. The burning of the flares and the compounds released (e.g., silver iodide) are not considered an environmental hazard because the amount of compounds released is less than the irritant level listed in the manufacturer material safety data sheet (MSDS) and the combustion products are generally considered “inert” since they do not readily react with plants or animals (County of Santa Barbara 2013).

5.0 REGULATORY THRESHOLDS FOR SILVER AND SILVER IODIDE

There are no federal or state regulations for silver iodide because it is considered effectively insoluble and not bioavailable in the aquatic environment (Williams and Denholm 2009; Cardno ENTRIX 2011). USEPA does not have an ambient water quality criterion for silver iodide. The existing water quality criterion is based the bioavailable dissolved silver, which correlates with toxicity data (USEPA 1980, 1981, 1987). Cloud seeding with silver iodide is not regulated by the USEPA (PG&E 2011). In California, there are no water quality standards or criteria for silver iodide, and silver iodide is currently not discussed in the Central Valley Regional Water Quality Control Board’s Basin Plan (RWQCB 2016). The Basin Plan does not identify silver iodide from cloud seeding as an activity that can impact water quality and it does not stipulate discharge requirements for silver iodide. In addition, the State of California’s current 303(d) list of impaired water bodies (SWRCB 2017a) does not identify any water bodies in the target area as water quality limited for silver.

5.1 SILVER WATER QUALITY REGULATORY THRESHOLDS

All regulatory water quality standards for silver are focused primarily on the bioavailable dissolved silver with the silver concentration criteria set to protect human health and aquatic life. At the federal level, silver and its compounds are broadly designated as a toxic pollutant because of its impacts to aquatic life and historical usage as a disinfectant (USEPA 1980, 1981). Regulatory thresholds for silver are detailed in Table 3 below. The USEPA establishes both primary maximum contaminant levels (MCLs) and secondary MCLs for many substances. Primary MCLs are enforceable standards to prevent a risk to human health, while secondary MCLs are non-mandatory standards designed to manage aesthetic conditions like taste, color, or odor. There is no risk to human health at secondary MCLs. The USEPA has no primary maximum contaminant level (MCL) for silver in drinking water, but the USEPA secondary MCL for dissolved silver is 100 ug/L in drinking water (USEPA 2010a, 2010b, 2013). Similarly, the California State Water Resources Control Board lists no primarily MCL and sets the secondary MCL for dissolved silver in drinking water as 100 ug/L (SWRCB 2017b). The USEPA guideline for silver in freshwater is 3.2 ug/L with a hardness of 100 mg/L as the acute toxic limit, but there is no chronic guideline value (USEPA 2004, 2017). While not regulatory thresholds, Eisler (1996) proposed total silver concentration criteria for the protection of natural resources and human health based on an exhaustive review
of the ecological and toxicological hazards of silver found in scientific literature and reports.

5.2 SILVER AIR QUALITY REGULATORY THRESHOLDS

Cloud seeding with silver iodide has been evaluated by regulatory agencies that found emissions from the dispersal of silver iodide do not exceed any regulatory thresholds (Williams and Denholm 2009; USEPA 2010b; PG&E 2011). Table 3 summarizes the regulatory thresholds for silver in the air. Silver iodide emitted by ground-based cloud seeding methods was not a concern in an analysis by the Northern Sierra Air Quality Management District (NSAQMD) of the ground-based dispersal of silver iodide (PG&E 2011).

Silver iodide particles produced from burning the silver iodide solution in CNGs or silver iodide flares are approximately 0.1 micrometers [micron or um], but the amount emitted by cloud seeding has been found to be far less than federal and state triggers for permits controlling emissions of 10 micron (PM 10) and 2.5 micron (PM 2.5) sized particles (PG&E 2011). The California ambient air quality standards for PM 10 is 50 ug/m³ per 24 hours and the annual arithmetic mean is 20 ug/m³, while for PM 2.5 the annual arithmetic mean is 12 ug/m³. The national ambient air quality primary standards for PM 10 is 150 ug/m³ per 24 hours while for PM 2.5 is 35 ug/m³ per 24 hours and the annual arithmetic mean is 12 ug/m³ (CARB 2016). The El Dorado County Air Pollution Control District (EDCAPCD) uses the California and national ambient air quality standards for PM 10 and PM 2.5 (EDCAPCD 2002).
Table 3. Silver Regulatory Thresholds.

<table>
<thead>
<tr>
<th>Regulatory Threshold Description</th>
<th>Regulatory Agency</th>
<th>Regulatory Threshold</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRINKING WATER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary maximum contaminant level (MCL)</td>
<td>USEPA, SWRCB</td>
<td>None</td>
<td>USEPA 2013; SWRCB 2017b</td>
</tr>
<tr>
<td>Secondary maximum contaminant level (SMCL)</td>
<td>USEPA, SWRCB</td>
<td>100 ug/L</td>
<td>USEPA 2013; SWRCB 2017b</td>
</tr>
<tr>
<td><strong>FRESHWATER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute toxic limit (Criteria Maximum Concentration [CMC])</td>
<td>USEPA</td>
<td>3.2 ug/L(^{A})</td>
<td>USEPA 2004, 2017</td>
</tr>
<tr>
<td>Chronic toxic limit (Criterion Continuous Concentration [CCC])</td>
<td>USEPA</td>
<td>None</td>
<td>USEPA 2017</td>
</tr>
<tr>
<td><strong>AIR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. workplace airborne limit</td>
<td>NOHSC</td>
<td>0.1 g/m(^3)</td>
<td>NOHSC 1995; Williams and Denholm 2009</td>
</tr>
<tr>
<td>Occupational exposure limit for silver metal, silver compounds, and soluble silver compounds</td>
<td>OSHA</td>
<td>0.01 mg/m(^3)</td>
<td>USEPA 2010a</td>
</tr>
</tbody>
</table>

\(^{A}\) At hardness of 100 mg/L

6.0 SMUD CLOUD SEEDING PROGRAM

6.1 TARGET AREA

SMUD has conducted cloud seeding in the Sierra Nevada since the 1968–1969 rainy season. SMUD cloud seeding typically disperses silver iodide particles from November through April. Cloud seeding has occurred over a 190-square mile target area in the South Fork American River watershed upstream of the UARP, where the latter is operated by SMUD for hydroelectric power generation. SMUD is currently planning to expand its target area to 444-square miles (Figure 1). The target area is located primarily in El Dorado County, California, east of Sacramento County and west of the Tahoe Basin.
Figure 1. Existing and (Proposed) Expanded Cloud Seeding Target Areas (SMUD 2017).
6.2 CLOUD SEEDING METHODS

Historically, SMUD has used standard cloud seeding methods, including aerial-based seeding, whereby silver iodide is released as a fine smoke from flares mounted to an aircraft that flies through the clouds, and ground-based seeding, whereby silver iodide is released from CNGs or flare “trees”. While SMUD has conducted cloud seeding since the 1960s, detailed cloud seeding data is not available prior to 2008. In 2008–2016, SMUD used aerial cloud seeding with aircraft outfitted with silver iodide flares to release silver iodide particles over the target area during selected storms. In the 2016–2017 winter season, SMUD used only ground-based units to disperse silver iodide particles (SMUD 2017). Methods employed by SMUD are described in general terms below.

6.2.1 Aerial-Based Cloud Seeding

Aerial cloud seeding occurs by equipping an aircraft with wing-mounted or underside mounted flare racks containing multiple silver iodide flares. The aircraft are flown along specified cloud seeding tracks as the flares burn to release silver iodide particles in the proper locations to enhance snowfall in the target area. Cloud seeding tracks are developed by a meteorologist and are based on different types of storms and wind speeds (SMUD 2017). Aerial cloud seeding apparatus can also burn a silver iodide solution similar to that used in CNGs to release silver iodide particles from the aircraft. During 2008-2016, cloud seeding aircraft typically were equipped with two wing-mounted flare racks with twelve flares each (24 total) and two belly-mounted flare racks.

6.2.2 Ground-Based Cloud Seeding

SMUD used seven ground-based CNGs in its 2016-2017 program with an additional 10–15 remotely operated, ground-based CNGs planned under the expanded program, for a total of approximately 15–20 stations. The ground-based units were located on private property, away from publicly accessible areas, and upwind south and west of the target area. The planned ground-based units would be installed west of the target area.

CNGs typically burn a silver iodide solution, which includes silver iodide, ammonium iodide, and acetone, in a propane flame. The flame vaporizes the silver iodide to produce microscopic silver iodide crystals that are released in a fine smoke from the CNG. The CNGs are activated when meteorological conditions support uplift of silver iodide from the CNG locations and transport into the target area.

6.3 APPLICATION RATES

SMUD has used varying application rates over the years, seeding in different storms and locations while collecting snowfall and streamflow data to evaluate seeding effectiveness. During drought periods (e.g., 1991–1992), SMUD has intensified cloud seeding activities. SMUD has also suspended cloud seeding activities when hazardous conditions from heavy snowfall or rain occur. Overall application rates between 2008
and 2017 are summarized in Table 4 below. Future aerial cloud seeding by SMUD will have similar application rates per area as the aerial seeding during the 2013–2014 season with the total amount of silver iodide scaled up based on expanding the target area from 190-square miles to 444-square miles (see also Figure 1).

### Table 4. SMUD Cloud Seeding Rate During Water Years 2009−2017.

<table>
<thead>
<tr>
<th>Wet Weather Season</th>
<th>Number of Days of Cloud Seeding</th>
<th>Total Amount of Silver Iodide Used (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008–2009</td>
<td>28</td>
<td>21.1</td>
</tr>
<tr>
<td>2009–2010</td>
<td>27</td>
<td>27.1</td>
</tr>
<tr>
<td>2010–2011</td>
<td>39</td>
<td>37.4</td>
</tr>
<tr>
<td>2011–2012</td>
<td>25</td>
<td>37.3</td>
</tr>
<tr>
<td>2012–2013</td>
<td>17</td>
<td>16.9</td>
</tr>
<tr>
<td>2013–2014</td>
<td>25</td>
<td>64.7</td>
</tr>
<tr>
<td>2014–2015</td>
<td>14</td>
<td>65.0</td>
</tr>
<tr>
<td>2015–2016</td>
<td>21</td>
<td>53.5</td>
</tr>
<tr>
<td>2016–2017¹</td>
<td>20</td>
<td>10.0</td>
</tr>
</tbody>
</table>

¹ Data available through February 2017.

### 6.4 MONITORING

SMUD has monitored silver in water samples and fish tissue at various times over the past several decades. In November 1992, SMUD conducted water quality sampling upstream and downstream of Slab Creek Reservoir to assess the effects of two events which had mobilized reservoir sediments. Results indicated total silver concentrations of 3-4 ug/L (SMUD and PG&E 2005). During relicensing studies in 2002−2004, SMUD collected and analyzed 406 water samples in 12 reservoirs and in 4 river reaches associated with the UARP during the fall turnover, first major rain, spring runoff, summer low flow periods (SMUD and PG&E 2005). Total silver was analyzed in all years and ranged < 0.008 – 0.86 ug/L, all below the USEPA secondary drinking water threshold (100 ug/L). Dissolved silver was analyzed in 2004 and ranged <0.0045 – 0.02 ug/L. In the 2004 samples, two of 69 reservoir samples, collected at Rockbound and Ice House reservoirs, and one of 66 riverine reach samples, collected at the Gerle Creek inflow to Gerle Creek Reservoir, exceeded the hardness-adjusted freshwater Criteria Maximum Concentration (CMC) for aquatic biota (SMUD and PG&E 2005).

In 2016, as part of FERC licensing requirements for the UARP and Chili Bar projects, SMUD conducted metals bioaccumulation monitoring, including total silver, in fish tissue at seven reservoirs in the project area. In August 2016, 108 individual fish across seven species were collected and analyzed in accordance with protocols of the State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP). Results for silver were all non-detect (< 0.003 ug/g wet weight) (SMUD and PG&E 2017; PG&E and SMUD 2017).
SMUD currently monitors metals in the Upper American River watershed every five years as part of FERC licensing requirements. Total and dissolved silver are included in the suite of trace metals monitored at 22 sites across seven stream reaches and at 20 sites across 11 reservoirs in the watershed on a seasonal basis, including spring, summer, fall, and immediately following either the second or third measurable rain event of the fall-winter period. The monitoring sites range in elevation from approximately 500 – 6,500 feet, covering the full elevational extent of SMUD cloud seeding activities. Of the 42 total riverine and reservoir monitoring sites, 23 are located directly within the existing 190-square mile cloud seeding target area, and the remaining sites are located downstream of both the existing and the expanded target area. Preliminary results from spring-time sampling indicate that total silver ranges from < 0.070 ug/L to 1.3 ug/L and dissolved (bioavailable) silver is consistently non-detect (< 0.15 ug/L).

The current trace metals monitoring program would detect long-term seasonal trends in total and dissolved silver concentrations in specific reservoir and river locations within the existing cloud seeding target area, and it would also detect spatial variations in concentrations within this area (e.g., particular locations that may exhibit higher concentrations than others). While the frequency and spatial coverage of the current monitoring program is not able to attribute variations in concentrations of these forms of silver to individual cloud seeding events, it would measure long-term changes in the amount of dissolved (i.e., bioavailable) silver directly within the existing 190-square mile cloud seeding target area, and downstream of both the existing and the expanded target area, which could be compared to long-term trends in SMUD application rates of silver iodide.

7.0 SUMMARY

Studies focused on monitoring the efficacy and environmental impacts of cloud seeding with silver iodide have detected increases in the total silver concentration in precipitation from cloud seeding, but measurements have shown no systematic increase or accumulation of total silver concentrations in freshwater, soil, or stream, lake, or reservoir sediments. Silver iodide may be retained in the upper soil layers, but studies have found no statistically significant trends indicating this.

Silver iodide has no documented environmental hazards and no studies have found any adverse environmental impact from cloud seeding with silver iodide. There are no federal, state, or local regulations of the acceptable levels of exposure for silver iodide because it is generally considered insoluble and not bioavailable to terrestrial or aquatic vertebrates. While silver iodide does not have any environmental hazards or regulations setting exposure levels, there are environmental hazards and regulations associated with dissolved silver because, unlike insoluble silver iodide, dissolved silver is bioavailable and potentially toxic to sensitive organisms. Dissolved silver is generally a negligible environmental hazard for humans, but federal and state regulations set the maximum contaminant level for dissolved silver in drinking water as 100 ug/L to prevent
a cosmetic gray or blue-gray discoloration of skin. Dissolved silver is an environmental hazard to aquatic and terrestrial organisms at a wide range of concentrations depending on the species, life-stage, and water hardness. The USEPA guideline for silver is 3.2 ug/L in freshwater with a hardness of 100 mg/L as the acute toxic limit or criteria maximum concentration (CMC), but there is no chronic criterion. Dissolved silver also is an environmental hazard to terrestrial plants and animals, but the concentrations causing adverse effects are much higher than found under typical natural or cloud seeding conditions.

SMUD has conducted cloud seeding since 1968 in the South Fork American River watershed upstream of the UARP over a 190-square mile target area, with a currently planned expansion to 444-square miles. Historical SMUD measurements of total silver ranged from < 0.008 – 0.86 ug/L, below the USEPA secondary drinking water threshold (100 ug/L). Dissolved silver measured in 2004 ranged from <0.0045 – 0.02 ug/L with the hardness-adjusted freshwater CMC for aquatic biota being exceeded in two reservoir samples and one riverine sample. Total and dissolved silver concentrations in water and fish tissue measured more recently have been consistently near or below analytical detection limits. Total and dissolved silver are currently being monitored in the Upper American River watershed every five years by SMUD at 22 sites across seven stream reaches and at 20 sites across 11 reservoirs, for a total of 42 sites. Existing data indicate low to non-detectable total and dissolved (bioavailable) silver.

The current trace metals monitoring program would detect long-term seasonal trends in total and dissolved silver concentrations in specific reservoir and river locations within the existing cloud seeding target area, and it would also detect spatial variations in concentrations within this area. While the frequency and spatial coverage of the current monitoring program is not able to attribute variations in concentrations of these forms of silver to individual cloud seeding events, it would measure long-term changes in the amount of dissolved (i.e., bioavailable) silver directly within the existing 190-square mile cloud seeding target area, and downstream of both the existing and the expanded target area, which could be compared to long-term trends in SMUD application rates of silver iodide.
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