SUPPLEMENTAL

COMMISSION MEMORANDUM NO. 2019.125

DATE: December 17, 2019

TO: SAWPA Commission

SUBJECT: Santa Ana River Watershed Weather Modification for Water Supply Feasibility Study | Award of Contract

PREPARED BY: Mark Norton P.E., Water Resources & Planning Manager

RECOMMENDATION
It is recommended that the SAWPA Commission authorize the General Manager to execute an Agreement for Services and Task Order No. NAWC370-01 with North American Weather Consultants Inc. to conduct a feasibility analyses for a weather modification for water supply program in the Santa Ana River Watershed in an amount to not to exceed $75,000; and, authorize SAWPA invoice each Member Agency $15,000 to cover the cost of conducting this work.

DISCUSSION
On June 4, 2019, SAWPA staff in conjunction with Tom Ryan, Metropolitan Water District of Southern California (MWDSC and/or MWD), provided a presentation to the Commission about weather modification for water supply programs commonly known as cloud seeding programs. Cloud seeding is the process of adding a specific chemical agent into an already existing cloud mass that causes the cloud to thicken and/or water vapor to condense and fall as rain or snow. Cloud seeding programs have proven successful in many locations throughout Northern California and neighboring states; however, the program in Santa Barbara Water District is the only Southern California program in operation at this time. MWDSC has been financing water districts in Colorado and Northern California for several years to increase snowpack in the mountains using these methods. The project benefits MWD's customer water districts and neighboring states who also draw from the Colorado River, and who also contribute money to the project.

After the June 4, 2019, Commission meeting, SAWPA approached the SAWPA member agency GMs to determine if there was interest in conducting a feasibility study for potential weather modification for water supply in the Santa Ana River Watershed. The GMs were supportive and felt such a feasibility study could be a good first step for possible regional implementation and funding of such a program using DWR Proposition 1 Integrated Regional Water Management (IRWM) grant funding under Round 2 anticipated in the FY 20-21 timeframe. Further, the potential benefits of increased precipitation in the watershed, 5-15% on average, could have significant benefit to local ski resorts, forest fire suppression, downstream stormwater recharge, and replenishment of natural lakes like Lake Elsinore which is very dependent on storm flow.

On August 6, 2019, the SAWPA Commission supported SAWPA staff issuing a Request for Proposals (RFP) for a feasibility study to conduct the Santa Ana River Watershed Weather Augmentation Study. Tom Ryan of MWDSC was contacted by staff for a list of firms who provide such services and staff received a list of four firms who have expertise in conducting such studies. Additionally, SAWPA staff found four additional firms who also had expertise in conducting such studies. The RFP was sent to each of these firms and posted on the SAWPA website. In response to the RFP, two proposals were received by SAWPA for consideration. They are listed as follows:

North American Weather Consultants Inc.	$75,000
RHS Consulting LTD.	$102,098

Based on feedback of Tom Ryan, MWDSC and a review committee composed of representatives from SBVMWD, WMWD and OCWD and SAWPA, the consultant firm, North American Weather Consultants Inc. is recommended to conduct this work based on their expertise, local experience and knowledge and lower costs.

Funding for the feasibility study was not budgeted since it was not considered at the time of the FYE 2019/2020 budget. Several potential local partners such as ski resorts, downstream lake operators, US Forest Service and groundwater recharging agencies were contacted to determine interest in this feasibility study. Feedback for this outreach is still ongoing and forthcoming. At this time in order to expedite the study work and avoid delays which may disqualify the quotes provided, it is recommended that each SAWPA member agency contribute $15,000/each for their support of this work and a contract be executed with the recommended firm.

Another option for funding of the feasibility study is to pull funding from carryover reserves from Fund 370-01 Basin Planning General in which approximately $163,000 remains. Staff believes that outside funding support is the preferred option to ensure the reserves under Fund 370-01 are set aside for more urgent regional water resource planning needs should they arise.

CRITICAL SUCCESS FACTORS

OWOW

- Data and information needed for decision-making is available to all.

RESOURCE IMPACTS
The feasibility study is not included in the SAWPA FYE 2019/2020 Budget. If supported, each member agency would be invoiced $15,000 to conduct this work.

Attachments:
1. PowerPoint Presentation
2. August 6, 2019, Commission Memorandum No. 2019.84
3. Request for Proposals (RFP), issued October 1, 2019
4. **Task Order No. NAWC370-01 (including submitted proposal) REVISED**
5. General Services Agreement

SANTA ANA WATERSHED PROJECT AUTHORITY
TASK ORDER NO. NAWC370-01

CONSULTANT:	North American Weather Consultants, Inc. 8180 S. Highland Drive, Suite B-2 Sandy, UT 84093	**VENDOR NO.** 2260
COST:	$75,000.00	
PAYMENT:	Upon Proper Invoice	
REQUESTED BY:	Mark Norton, Water Resources & Planning Manager	December 17, 2019

FINANCE: ____
Karen Williams, CFO Date

FINANCING SOURCE:	Acct. Coding	370-01-60121-01
	Acct. Description	General Consulting

COMMISSION AUTHORIZATION REQUIRED FOR THIS TASK ORDER: YES (X) NO ( )
Authorization: December 17, 2019; CM#2019.125

This Task Order is issued upon approval and acceptance by the Santa Ana Watershed Project Authority (SAWPA) and North American Weather Consultant, Inc. (Consultant) pursuant to the Agreement for Services between SAWPA and Consultant, entered into on December 17, 2019, and expiring December 31, 2020.

I. PROJECT NAME OR DESCRIPTION
Weather Modification Feasibility Study for the Santa Ana River Watershed

II. SCOPE OF WORK / TASKS TO BE PERFORMED
Consultant shall provide all labor, materials, and equipment for conducting a feasibility/design study of a weather modification or cloud seeding program to increase precipitation and snowpack in the Santa Ana River Watershed, as thoroughly described in Attachment A.

Please also refer to Appendix X for acceptable formats, also found at www.sawpa.org/html/e_req.htm

III. PERFORMANCE TIME FRAME
Consultant shall begin work January 1, 2020 and shall complete performance of such services by **December 31, 2020.**

IV. SAWPA LIAISON
Mark Norton shall serve as liaison between SAWPA and Consultant.

V. COMPENSATION
For all services rendered by Consultant pursuant to this Task Order, Consultant shall receive a total not-to-exceed sum of **$75,000.00** including travel expenses. Payment for such services shall be made monthly upon receipt of timely and proper invoices from Consultant, as required by the above-mentioned Agreement. Each such invoice shall be provided to SAWPA by Consultant within 15 days after the end of the month in which the services were performed.

VI. CONTRACT DOCUMENTS PRECEDENCE

In the event of a conflict in terms between and among the contract documents herein, the document item highest in precedence shall control. The precedence shall be:

- **a.** The Agreement for Services by Independent Consultant/Contractor.
- **b.** The Task Order or Orders issued pursuant to the Agreement, in numerical order.
- **c.** Exhibits attached to each Task Order, which may describe, among other things, the Scope of Work and compensation therefore.
- **d.** Specifications incorporated by reference.
- **e.** Drawings incorporated by reference.

In witness whereof, the parties have executed this Task Order on the date indicated below.

SANTA ANA WATERSHED PROJECT AUTHORITY

____
Richard E. Haller, P.E., General Manager Date

NORTH AMERICAN WEATHER CONSULTANTS, INC.

____ ______________________
(Signature) Date Print/Type Name and Title

Appendix X: Electronic Deliverables

X.1 PRODUCTS

All products identified as deliverables under this Contract/Task Order/Work Order (including, but not limited to documents, data analyses, databases, maps, graphics, images, design drawings, and Geographic Information System [GIS] data) will be provided to SAWPA in electronic format in accordance with the project delivery schedule.

Unless specified elsewhere in the Contract/Task Order/Work Order, SAWPA will have no license restrictions, and may use the electronic files/data for purposes it deems appropriate.

X.2 FORMATS

All deliveries will be provided in native (editable) formats. Additional non-native formats (e.g., Adobe Acrobat) will also be provided as described below.

SAWPA's standard data file formats are:

- Documents (including Desktop Publishing)
  - Microsoft Word 2010 or later
- Tables/Spreadsheets
  - Microsoft Excel 2010 or later
- Presentations
  - Microsoft PowerPoint 2010 or later
- Databases
  - Microsoft Access 2010 or later
  - Microsoft SQL Server 2008 or later
- Project Schedules
  - Microsoft Project 2010 or later
- Computer Aided Drafting (CAD) - Design Drawings, etc.
  - AutoDesk AutoCAD 2016 or later
- Graphics/Images
  - Adobe Illustrator CS5 or later
  - Adobe Photoshop CS5
  - Microsoft Visio 2010 or later
  - Standard JPG format
  - TIF 4 format
- Web Information
  - HTML
  - Adobe Acrobat XI or later Portable Document Format (PDF)
- GIS Data
  - File Geodatabase
  - GIS Shapefiles
  - Data in ODBC-compatible format, preferably one of the following
    - Microsoft Access (for relational data)
    - Microsoft SQL Server (for more complex relational data)
  - GIS Applications to be fully compatible with ArcGIS 10.x or later
  - See Section X.3 for specifications
- Field mapping (GPS data)
  - Mapping formats to be one of the following
    - Trimble Pathfinder-compatible files
    - GIS format files listed above
- Analytical Data Formats
  - Standard Electronic Data Deliverable (EDD) formats as used by certified laboratories

- Applications
    - Specifications to any applications (specialized software, scripts, code, Plug-Ins, etc.) required as part of the Contract/Task Order/Work Order will be detailed in the body of Statement of Work.

X.3 SPECIFICATIONS (GIS AND RELATED DATA)

In general, data provided to SAWPA for use in SAWPA's GIS will be fully compatible with SAWPA's GIS. Therefore, the following specifications will be followed:

- All data will be provided in Universal Transverse Mercator (UTM), Zone 11 meters, North American Datum (NAD) of 1983
- All vector data will be provided in shape file or file geodatabase format
- All rrid data will be provided in ESRI GRID, ESRI TIN, or US Geological Survey DEM format
- All image data (e.g., satellite imagery/aerial photos) will be provided in formats that are fully compatible with ESRI ArcGIS 10.X at no cost for plug-ins, Extensions, or other software tools
- All database information tied to the GIS will be fully compatible/functional with SAWPA's GIS with no additional software requirements
- All data will have sufficient metadata to identify as a minimum
    - Data description
    - Data sources
    - Data creator
    - Data creation date
    - Data accuracy.
- Metadata formats will be in ESRI Catalog format, based on accepted metadata standards (e.g., the Federal Geographic Data Committee, the CADD/GIS Technology Center's Spatial Data Standards, or other recognized standards format). Documents associated with metadata will identify the format/standards being used.

X.4 DELIVERY OF ELECTRONIC FILES

For each delivery specified, and for each version specified (e.g., Draft and Final Reports; 35%, 60%, 90%, 100%, and As-Built Design Drawings), the Consultant will provide electronic copies of the files in addition to any specified hard copies on the same schedule, unless otherwise specified in the schedule of deliverables. Delivery of electronic files does not substitute for required delivery of hard copies, unless approved in writing by SAWPA's Project Manager.

Review Files. In addition to native file format deliveries, Contractor will provide ALL report, map, graphic, and drawing deliverables in Adobe Acrobat PDF files. The PDF files will faithfully represent the completed hard copy document in terms of color pages, page sizes, etc. These files will be fully integrated files in proper page order, with graphics, tables, attachments, etc. inserted in their proper location in the document (or connected using the Link function). PDF files exceeding 10 pages in length will use internal hyperlinks (in Table of Contents) and/or use Acrobat's Bookmark features to enable easy navigation throughout the file. PDF files will be ready for posting to SAWPA's web site (if deemed appropriate) or distributed for review as part of a technical/peer/management review process.

Media. Delivery method for formal contract deliverables will be specified and approved by SAWPA's Project Manager, but will be one of the following (in general order of preference):

- Via email to SAWPA's Project Manager (for deliverables less than 15 MB, or time critical)
- USB Flash Drive
- Posted to Consultant's FTP or Dropbox

X.5 EXCEPTIONS

Exceptions to these formats may be allowed in some cases. All exceptions will be approved within the body of the Contract/Task Order/Work Order or in writing by the Project Manager AND the Information Systems/Data Management Manager.

Answers to Questions on North American Weather Consultants (NAWC) Proposa1 #19-447 entitled "Proposal to Conduct a Cloud Seeding Feasibility/Design Study for the Santa Ana River Watershed, California"

Work Schedule

There are five tasks to be completed contained in the Request For Proposals (RFP):

1. Collection of Data
2. Selection of Target Areas
3. Development of Program Design and Seeding Increase Estimates
4. Perform a Benefit/Cost Analysis
5. Delivery of Final Report

The RFP indicates an estimated start date of contractor work on January 2, 2019 and a completion date in the fall of 2020. The completion of Tasks 2 through 5 are dependent upon the acceptance of a Memorandum prepared in Task 1 leading the SAWPA to decide to whether to proceed with Tasks 2-5.

An approximate schedule for completion of these Tasks is as follows (all 2020 dates):

- Task 1: January 2nd to February 15th
- Task 2: March 1st to April 15th (note, this March 1st date allows the SAWPA 2 weeks to determine whether to proceed with Tasks 2-5)
- Task 3: Apr. 15th to Jun. 15th
- Task 4: Jun. 15th to Aug. 1st
- Task 5: Aug. 1st to Oct. 31st (note allows 4 weeks for SAWPA to review draft report then have NAWC incorporate comments into the final report)

Costs

The following explanation is contained in our proposal, which was an exception taken regarding the language in the RFP:

"NAWC requests a fixed cost instead of a cost reimbursable contract. A fixed cost would be established for each of the five tasks. **All previous NAWC feasibility/design contracts, including those in California, have been conducted on a fixed cost basis.** NAWC does not require our employees to submit time cards. We expend whatever personnel time is needed in order to deliver an acceptable product. We use this same fixed price approach in the conduct of all of our operational cloud seeding programs, with the exception of a cost reimbursable section in our contracts that is used to charge our clients for seeding material usage and flight hours, which are entirely a function of the weather conditions". So unfortunately the answer is no to your request for detailed costs per staff and hourly rates.

Yes, the $75,000 is an all-inclusive number. There are no upfront costs. The proposed payment schedule, as contained in our proposal, is as follows:

Fixed Costs

•	Task 1, Collection of Data.	$15,000
•	Task 2, Selection of Target Areas.	$15,000
•	Task 3, Development of Program Design and Seeding Increase Estimates.	$20,000
•	Task 4, Perform a Benefit/Cost Analysis.	$15,000
•	Task 5, Delivery of Final Report	$10,000
	Total	$75,000

These costs would be invoiced after the completion of each task.

Note: NAWC assumes that if chosen to conduct this feasibility/design study that this would not preclude NAWC from being able to bid on any follow on work (e.g., preparation of a Mitigated Negative Declaration or implementation of an operational cloud seeding program).

Don Griffith, North American Weather Consultants
November 22, 2019

PROPOSAL TO CONDUCT A WEATHER MODIFICATION FEASIBILITY/DESIGN STUDY FOR THE SANTA ANA RIVER WATERSHED, CALIFORNIA

Prepared for

Santa Ana Watershed Project Authority

by

North American Weather Consultants, Inc.
8180 South Highland Dr., Suite B-2
Sandy, Utah 84093

Proposal No. 19-447

October 2019

TABLE OF CONTENTS

Proposal to Conduct a Cloud Seeding Feasibility/Design Study for the Santa Ana River Watershed, California

1.0 Introduction

North American Weather Consultants (NAWC), with headquarters in Sandy, Utah, received a Request For Proposals (RFP) to conduct a weather modification feasibility study for the Santa Ana watershed located in southern California. This RFP was issued by the Santa Ana Watershed Project Authority (SAWPA) on October 1, 2019 with the title Weather Modification Program. "The primary objective of the study is to determine the feasibility of a weather modification or cloud seeding program to increase precipitation and snowpack in the Santa Ana River Watershed".

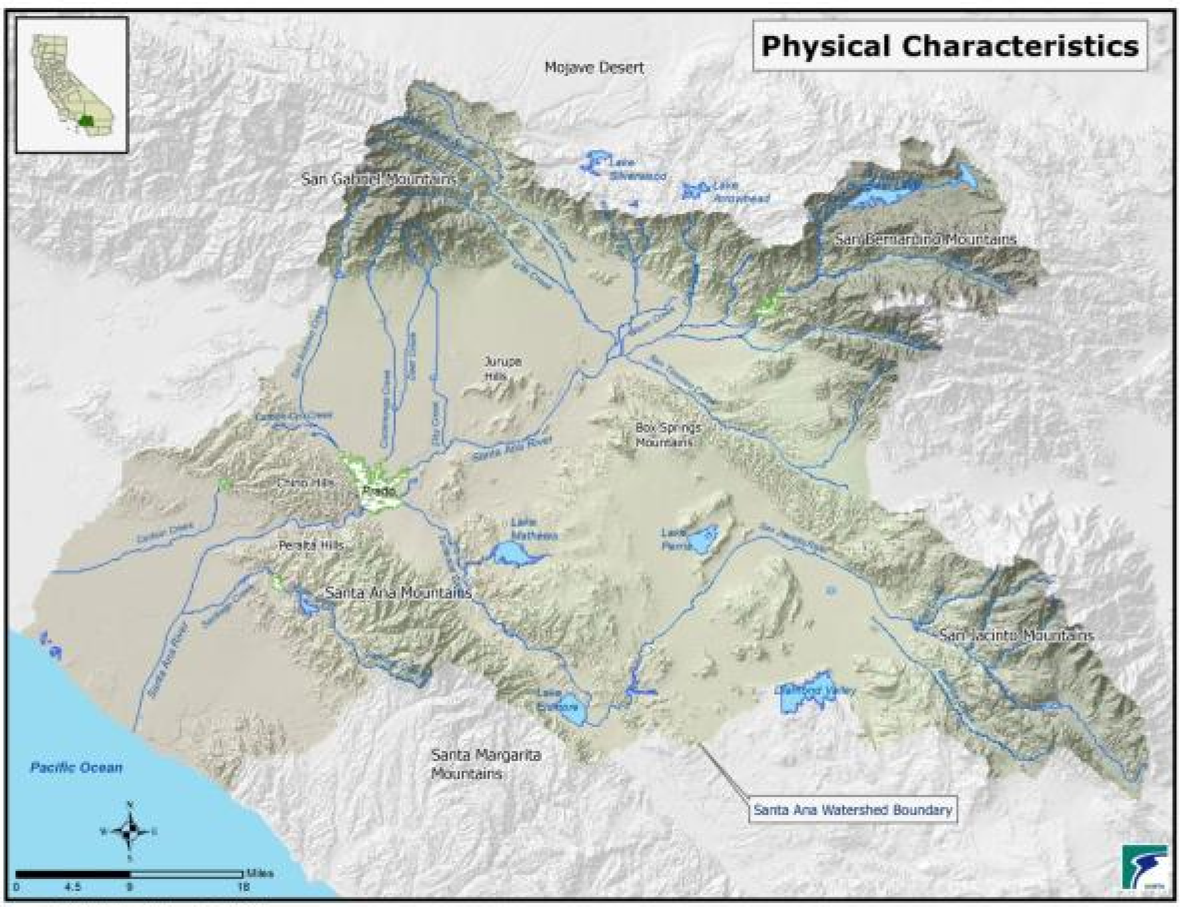
There are five tasks to be completed in this study:

- Task 1, Collection of Data.
- Task 2, Selection of Target Areas.
- Task 3, Development of Program Design and Seeding Increase Estimates.
- Task 4, Perform a Benefit/Cost Analysis.
- Task 5, Delivery of Final Report

These tasks will be discussed separately in the following sections but will be preceded by a background on North American Weather Consultants and our perspective on responding to this RFP. A brief description on the theory of cloud seeding principles will also be provided. Figure 1 from the RFP depicts the area of interest.

2.0 NAWC Background and Relevant Experience

NAWC has a President/Treasurer and a Vice-President/Secretary that are also owners of the firm. NAWC was incorporated in the State of Utah as an S Corp on August 11, 1999. NAWC was a publically owned company from 1990-1999 but a private firm from 1950 to 1990 with offices in Santa Barbara, California from 1951 through 1980 then in Salt Lake city from 1980 to the present. NAWC was one of the first firms to design, conduct and evaluate winter cloud seeding programs in the western U.S. following discoveries in the late 1940's that indicated some types of clouds could be seeded to potentially increase precipitation. One such long-term program began in 1951 in the Sierra Nevada of California. NAWC proceeded to establish additional operational programs and was involved in a number of research programs from the 1950's to the present day. Operational programs are conducted to increase precipitation. Research programs are conducted to gain further insights into cloud physics processes, the impacts of seeding on these processes, and attempts to quantify increases in precipitation often relying upon randomized seeding of seedable storms. Randomized studies involve seeding of approximately half of the seedable events and leaving the other half unseeded, to allow comparisons between seeded and unseeded precipitation. Since 1951 NAWC has conducted hundreds of successful operational winter cloud seeding programs in the western United States, a list of which is provided in Appendix A. This involves developing a customized design for each program, conscientious conduct of seeding operations and publishing annual reports on each program. For most programs, NAWC develops a historical target/control evaluation which is used to estimate the potential increases in precipitation. NAWC also frequently prepares technical papers for publications in technical journals describing some of these programs (e.g., Griffith, et al, 2013: Griffith, et al, 2017). Table 1 summarizes NAWC's history in weather modification.



P:\projects\OWOW2\PhysicalMap.mxd SW-2197

Figure 1 Santa Ana Watershed

Table 1
NAWC Weather Modification History

- Incorporated in 1950, NAWC has more than 66 years of continuous involvement in weather modification. We are, indeed, the longest-standing private weather modification company in the world.

- NAWC was founded as a weather modification company. Weather modification has always been NAWC's primary specialty.

- NAWC is recognized internationally as a leader in the weather modification field, in research and operations.

- NAWC received the American Meteorological Society's prestigious "Award for Outstanding Services to Meteorology by a Corporation" in 1970 for its pioneering the practice of private meteorology in the United States.

- NAWC has conducted weather modification projects and provided consulting services in many areas outside the United States, including Europe, South America, Central America, Asia and the Middle East.

- Our weather modification activities and contributions are well known, through our hundreds of publications, reports and conference presentations.

- Our extensive client list includes hydroelectric utilities, government agencies, water districts, municipalities, universities and private entities.

- NAWC's client satisfaction rating is consistently very high, due to NAWC's ongoing commitment to carefully determining and then fully addressing each client's specific needs. We always tailor our services/project to our clients' interests and circumstances.

- NAWC offers weather modification services, ranging from feasibility studies, designing programs, reviews of existing projects, evaluations of results of cloud seeding and the conduct of operational programs.

NAWC personnel that would be involved with study would include Don Griffith, David Yorty, Stephanie Beall and Todd Flanagan. Don Griffith will be program manager and David Yorty will serve as an alternate. Don Griffith, David Yorty and Todd Flanagan are WMA Certified Managers and Operators. Stephanie Beall is a WMA Certified Operator. Mr. Griffith is also an American Meteorological Society Certified Consulting Meteorologist. All four have extensive experience in the design, conduct and evaluation of winter precipitation augmentation programs. Mr. Flanagan has operated a NAWC winter cloud seeding programs in the Kings River

Basin east of Fresno and Ms. Beall has operated a NAWC winter cloud seeding program for a number of years in Santa Barbara County. Mr. Yorty has assisted Mr. Griffith in the performance of a number of cloud seeding feasibility/design studies. Mr. Flanagan and Ms. Beall have also assisted on these feasibility/design studies. Appendix B provides resumes of these four individuals.

NAWC was involved in the conduct of a research weather modification program in the 1950's known as Santa Barbara I. NAWC was also involved in a research weather modification program from 1967-1973 known as Santa Barbara II (Griffith et al., 2005). This second research program has served as the foundation for the design and conduct of operational cloud seeding programs conducted within Santa Barbara County by NAWC, beginning in 1981. NAWC published a journal paper containing an evaluation of this program through 2009 that indicated increases in winter season precipitation of 9% to 21% (Griffith et al., 2015).

NAWC has performed a number of winter cloud seeding feasibility/design programs. These studies have complied with ASCE Standards and Guidelines for the performance of such studies. NAWC has recently performed three winter California cloud seeding feasibility/design studies: 1) Santa Barbara County Water Agency, Upper Cuyama River drainage 2) San Luis Obispo County (Lopez Lake and Salinas Reservoir drainages) and 3) Monterey County (Nacimiento and San Antonio Reservoir drainages). A variety of topics may be considered in such studies including:

- Review and Summary of Previous Research
- Climatology of the Target Area
- Development of Preliminary Design
- Establishment of Operational Criteria
- Environmental Consequences and Legal Implications
- Permitting and Reporting
- Evaluation Methodology
- Potential Benefits
- Cost Estimates
- Preliminary Benefit/Cost Analysis

NAWC has published several technical papers based upon the final reports completed for these programs. Table 2 provides a listing of NAWC previously completed cloud seeding feasibility/design studies.

NAWC has conducted winter cloud seeding programs targeting the San Gabriel Mountains of Southern California located north of the city of Los Angeles for numerous previous winter seasons dating back to the 1950's (1959-1973, 1991-1993, 1997-2001 and 2016 seasons. Of potential historical interest, NAWC conducted a ground-based winter cloud seeding for the Santa Ana River Basin from 1956-1960. These programs have used ground-based seeding sites. The most recent program conducted during the 2015-2016 winter season used some ground-based flare trees, which are the same ground-based seeding systems used for NAWC's long-term cloud seeding program for Santa Barbara County. These programs were conducted for the Los Angeles County Department of Public Works (LACDPW) and part of the target area for these programs is likely to be one of the target areas for the Santa Ana program. NAWC also was contracted by the LACDPW to prepare a Mitigated Negative Declaration following CEQA guidelines. This could be important in the future should the SAWPA decide to implement a Santa Ana River Watershed winter program. If so, an MND would need to be prepared for this program.

Table 2 Previous NAWC Cloud Seeding Feasibility/Design Studies

Location	Sponsor	Completion Date	Publication[1]
Salt River/Wyoming Range SW Wyoming	**Wyoming Water Development Commission**	**2006**	**Griffith, et al, 2007**
Upper Colorado River	**Upper Colorado River Commission**	**2006**	**Griffith and Solak, 2006**
Eastern Snake River Basin, Idaho	**Idaho Water Resources Board**	**2008**	**Griffith, et al, 2010**
Big and Little Wood River Basins, Idaho Central Idaho	**Idaho Water Resources Board**	**2009**	**Griffith and Yorty, 2009**
Upper Boise River Basin, W. Idaho	**Idaho Water Resources Board**	**2009**	**Griffith, et al, 2012**
Upper Cuyama River Basin, SW California	**Santa Barbara County Water Agency,**	**2016**	**Griffith, et al, 2016**

	California		
Wyoming Range Level II, Phase II Study	**National Center for Atmospheric Research/Wyoming Water Development Commission**	**2016**	**Tessendorf, et al, 2016**
Abajo and La Sal Mountains, SE Utah	**Utah Division of Water Resources**	**2017**	**Griffith, et al, 2017**
Lake Lopez and Salinas Reservoir Drainages, SW California	**San Luis Obispo Flood Control and Water Conservation District**	**2017**	**Griffith, et al, 2017**
San Antonio and Nacimiento Drainages, SW California	**Monterey County Water Resources Agency, SW California**	**2017**	**Griffith, et al, 2017**
Upper Yadkin River Basin, North Carolina	**Cube Hydro**	**2019**	**Griffith, et al, 2019**

3.0 Theory Of Cloud Seeding For Precipitation Augmentation

Clouds form when temperatures in the atmosphere reach saturation, that is, a relative humidity of 100%. This saturated condition causes water vapor to condense around a nucleus forming a cloud droplet. These nuclei, which may be small particles like salts formed through evaporation off the oceans, are known as "cloud condensation nuclei." Clouds can be composed of water droplets, ice crystals or a combination of the two. Clouds that are entirely warmer than freezing are sometimes referred to as "warm clouds." Likewise, clouds that are colder than freezing are sometimes referred to as "cold clouds." Cold clouds may have cloud bases that are warmer than freezing. Precipitation can occur naturally from both types of clouds.

In warm clouds, cloud droplets that survive long enough and especially when cloud drops are of different sizes, may result in cloud water droplets colliding and growing. They may attain sufficient sizes to precipitate as rain. This process is known as "collision/coalescence." This process is especially important in tropical clouds but can also occur in more temperate climates.

In cold regions (< 0°C) of clouds, cloud water droplets may not freeze. The reason for this is the purity of the cloud water droplets. In a laboratory environment, pure water droplets can remain unfrozen down to a temperature of -39°C. Natural impurities in the atmosphere can cause cloud droplets that are colder than freezing (usually referred to as supercooled) to freeze. These supercooled cloud droplets are what causes icing to occur on aircraft. The natural impurities often consist of tiny soil particles or bacteria. These impurities are referred as "freezing nuclei." A supercooled cloud droplet can be frozen when it collides with one of these natural freezing nuclei thus forming an ice crystal. This process is known as "contact nucleation." A water droplet may also be formed on a freezing nucleus, which has hygroscopic (water attracting) characteristics. This same nucleus can then cause the water droplet to freeze at temperatures less than about -5°C forming an ice crystal. This process is known as "condensation/freezing." Once an ice crystal is formed within a cloud it will grow as cloud droplets around it evaporate and add their mass to the ice crystal, eventually forming a snowflake (diffusional growth). Ice crystals can also gain mass as they fall and accrete surrounding supercooled cloud droplets, a process known as "riming." These snowflakes may fall to ground as snow if temperatures at the surface are ~ 0°C or colder. They may reach the surface as rain if surface temperatures are warmer than freezing.

Research conducted in the late 1940's demonstrated that tiny particles of silver iodide could mimic the natural process and serve as freezing nuclei at temperatures colder than about -5°C. In fact, these silver iodide particles were shown to be much more active at temperatures of ~ -5° to -15°C than the natural freezing nuclei found in the atmosphere. As a consequence, most of man's modern day attempts to modify clouds to produce more precipitation (or reduce hail sizes) have used silver iodide as a seeding agent. These programs are conducted to affect cloud regions that are -5°C or colder (e.g., "cold clouds") and are sometimes called "cold cloud" or "glaciogenic" seeding programs. Glaciogenic cloud seeding can be conducted in summertime clouds by seeding clouds whose tops pass through the -5°C level, and in winter stratiform clouds that reach at least the -5°C level.

There has been some research and operational programs designed to increase precipitation from "warm clouds." The seeding agents used in these programs are hygroscopic (water-attracting) particles which are typically some kind of salt (e.g., calcium chloride). These salt particles can form additional cloud droplets, which may add to the precipitation reaching the ground. This seeding technique, which is sometimes referred to as "warm cloud" or "hygroscopic" seeding can also modify the warm portion of clouds which may then grow vertically to reach temperatures colder than freezing. A research program conducted in South Africa targeting these types of clouds indicated that such seeding did increase the amount of rainfall from the seeded clouds.

In summary, most present-day cloud seeding programs introduce a seeding agent, such as microscopic sized silver iodide particles, into clouds whose temperatures are colder than freezing. These silver iodide particles can cause condensation, forming cloud droplets that subsequently freeze or cause naturally occurring cloud droplets to freeze, forming ice crystals. These ice crystals can grow to snowflake sizes falling to the ground as snow or as rain depending on the surface temperature profile.

4.0 Data Collection and Potential Target Climatology

NAWC will perform a literature search on any relevant climatology information available for the potential Santa Ana River Watershed target areas. NAWC proposes to expend considerable time in developing climatological information for the proposed target areas. This will involve the analyses of a variety of data sources in order to develop climatologies of relevance to cloud seeding activities. Sources of relevant data will include twice-daily upper-air rawinsonde (balloon borne temperature, dew point and wind) observations from San Diego and Vandenberg AFB, National Weather Service (NWS) daily and hourly precipitation observations, hourly weather observations, visual and infrared satellite observations and NWS Next Generation Radar (NEXRAD) information from the Los Angeles and Santa Ana Mountains sites.

Site-specific climatologies will be developed with the goal of assessing the seeding potential of the potential Santa Ana River Watershed target areas. Most existing climatological information is not directly related to assessing cloud seeding potential. Items of interest in assessing cloud seeding potential include low-level atmospheric stability, low and mid-level wind flow, cloud top temperatures, height of the -5° C level, etc. The -5C level is often around 10,000 feet elevation in winter storms but varies considerably. Relationships between precipitation amounts and elevation will be examined. Seeding potential is typically greater in elevated mountainous areas. These areas also typically have favorable seeding conditions during some storm periods due to what is known as the <u>orographic effect</u> in which low-level air masses are forced over mountain barriers due to the winds that accompany winter storms. The orographic effect produces higher precipitation over the mountains than that observed in surrounding lower elevation areas. This will likely help focus the selection on which areas are recommended as target areas. The above discussion explains why almost all previous and current winter cloud seeding programs in the western United States have mountain barriers as their target areas and why they are often referred to as orographic cloud seeding programs.

This is also logical from another perspective, in that the majority of streamflow in the western U.S. originates from such mountain barriers.

These climatologies will be derived through an evaluation of storm frequencies and characteristics, temperatures, precipitation characteristics, prevailing winds, surface observations, barriers, etc. Monthly climatologies of precipitation occurrence in the Santa Ana River Watershed target areas will be developed. This information along with other more detailed information described below and the periods when additional water is valuable to the SAWPA will be used to determine the months in which a cloud seeding project could be conducted.

Storm frequencies will be developed for storms that produce ranges of precipitation (e.g. 0.50 - 1.0 inches, 1.0 -2.0 inches per 24-hour periods, etc.). The prevailing winds at various levels (e.g. 4500 feet, 10,000 feet, 18,000 feet, etc.) as determined from upper-air weather balloon observations for each range of precipitation amounts will be determined. This information will be useful in later considerations of targeting of seeding materials. National Weather Service (NWS) upper-air observations are available twice per day from San Diego and Vandenberg AFB, which should be representative of meteorological parameters of interest over the proposed target areas. The frequency of occurrence of low-level atmospheric inversions will be documented utilizing historical information from these two sounding sites. Those inversions whose bases are warmer than –5° C are of special interest since silver iodide seeding material released under such inversions is likely to be trapped and would not produce a seeding effect since the warmest activation temperature of silver iodide is –5° C. This may be a consideration in the possible use and siting of ground-based cloud seeding nuclei generators during the winter season. The height of the -5° C level will be documented since this is the activation temperature threshold of silver iodide, a frequently used seeding material. Often, cloud seeding flights are conducted at this level during winter and summer cloud seeding programs. The above information will be presented in monthly as well as seasonal formats. Monthly information may be useful in later studies concerned with the design of a project.

The above information will be used to document the frequency of "seedable" storm conditions. Past research has shown that not all storm periods are seedable. As explained in section 3.0, the primary determination of whether clouds are seedable using silver iodide as the seeding agent (the most commonly used seeding agent) is whether there are supercooled (colder than freezing) cloud droplets present in clouds. There are other considerations of whether storm periods are seedable. For example, if ground-based sites generators are to be used then wind directions need to be considered since generators will be required at proper locations upwind of the target area in order to produce a seeding effect in the target area. Also, any low-level atmospheric inversions in the atmosphere that may restrict the movement of the seeding material from the ground to the -5° C level should be taken into account. In addition, some past research has shown that deep storms with cold cloud tops normally do not contain any significant amounts of supercooled liquid water cloud droplets. NAWC has developed some general criteria that can be used to determine whether a storm period appears to be seedable. These criteria are provided in Table 3.

Table 3
NAWC Winter Orographic Cloud Seeding Criteria

- Cloud bases are below the mountain barrier crest.
- Low-level wind directions and speeds would favor the movement of the silver iodide particles from their release points to the intended target area.
- No low-level atmospheric inversions or stable layers that would significantly restrict the vertical movement of the silver iodide particles from the surface to at least the -5°C (23°F) level or colder.
- Temperature at mountain barrier crest height expected to be -5°C (23°F) or colder.
- Temperature at the 700mb level (approximately 10,000 feet) expected to be warmer than -15°C (5°F).
- Cloud top temperatures ≥ -25°C (-13°F).

Obviously, some of these criteria only apply to ground based seeding modes. Seeding from aircraft is not subject to all of the above limitations. These criteria will be used to establish one estimate of the frequency of seedable events in each of the potential target areas.

Another major consideration when determining storm seedability will be the frequency of "convection bands" in these areas. A winter weather modification research program was conducted in Santa Barbara County in the period from 1967 through 1973 (Brown et al., 1974). This program was funded by the Naval Weapons Center at China Lake, California and conducted by North American Weather Consultants. The design of this program was based upon the work conducted in the 1960's which identified "convection bands" as the primary target of opportunity for winter cloud seeding precipitation augmentation activities in the County. This research program and subsequent adaptation in the conduct of operational cloud seeding programs in Santa Barbara County is described in Griffith, et al, 2005. The research program was known as Santa Barbara II phases I and II. Phase I consisted of the release of significant amounts of silver iodide from a ground location near 1,200 m MSL located in the Santa Ynez Mountains north of Santa Barbara. A similar experiment, phase II, employed an aircraft to release silver iodide generated by high output (silver iodide - acetone wing tip nuclei generators) into the "convection bands" as they approached western coastline of Santa Barbara

County. Figure 2 is a NEXRAD radar depiction of a convection band observed last winter season over Santa Barbara County.

Detailed analysis of the potential impacts of the seeding were performed in the Santa Barbara County studies. The results were strongly positive, indicating up to 50% statistically significant increases in seeded convection band precipitation downwind of the seeding locations from both ground and airborne seeding (Phases I and II). A more recent report (Solak, et al, 1996) provided a more precise quantification of the optimal seeding increases that might be expected at Juncal and Gibraltar Dams (i.e., 18-22%) from seeding convection bands. A recent evaluation of the estimated seeding impacts from the long-term (1981 through 2011 winter seasons) Santa Barbara operational cloud seeding program produced estimates of average seasonal increases in precipitation of 9% to 21% (Griffith, et al, 2015).

The climatological analysis of the seeding potential in the Santa Ana River Watershed target areas will therefore include consideration of the frequency and characteristics of convection bands impacting these areas.

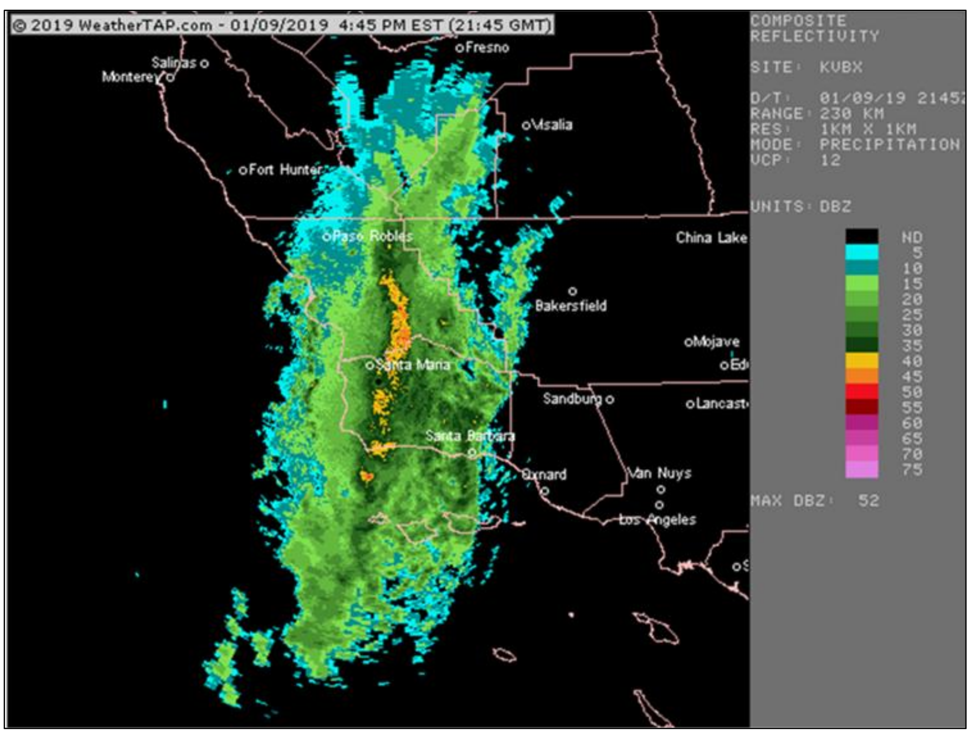


Figure 2 Composite Radar Image from January 9, 2019 at 1345 PST

Information from the above analyses will be used to recommend **potential locations** of ground-based seeding sites, including a discussion of the possible types of ground-based seeding nuclei generators that might be deployed at these sites. Aircraft seeding feasibility and possible flight path locations will be considered under Task 2. **NAWC does not propose to select specific site locations which would require site visits and establishing whether access to these sites can be approved by the various owners of these properties.** NAWC suggests that these specific site locations be selected by the Contractor selected to implement this program, should this study determine that a program is feasible and a decision be made to move forward by the SAWPA. assuming this study determines that a project appears feasible. The timing between the submission of a final study report and the implementation of a program could be a few years, for various reasons. A Mitigated Negative Declaration would need to be drafted, opened for comment, then approved by the SAWPA Board of Directors. During this time, the availability of specific site locations may change. The specification of potential locations should be adequate to establish whether the proposed program is technically feasible as defined by the ASCE.

NAWC will also examine existing hydrologic records, primarily steam gauge data, to determine the contributions of streamflow from different potential Santa Ana River Watershed target areas. This information along with the meteorologically oriented analyses described above will assist NAWC in recommending and prioritizing target areas under Task 2.

NAWC will attempt to "collect cost data from similar weather modification programs in other watersheds". Such information from other agencies may be considered proprietary. NAWC has or is conducting similar programs in other parts of southern California and can ask these clients if relevant cost information may be shared. Otherwise, NAWC can provide cost estimates to conduct a program according to our design established under Tasks 3 and 4.

A memorandum will be prepared that "describes the climatology of the Santa Ana River Watershed and whether weather modification to increase seasonal precipitation appears feasible and deserves further study". Such a determination would need to be considered preliminary since work to be performed in later tasks would provide more factual information related to the feasibility of a program. NAWC personnel have participated in the preparation of recent American Society of Civil Engineers (ASCE) Standards and Documents on cloud seeding. The "Guidelines for Cloud Seeding to Augment Precipitation, Third Edition" (ASCE 2016) describe procedures to determine whether a proposed cloud seeding appears feasible. NAWC would apply these procedures in later tasks to answer this feasibility question.

5.0 Selection of Target Areas

As discussed under Task 1, NAWC proposes to recommend the most suitable Santa Ana River Watershed target areas based upon prevailing storm wind directions during seedable storms. It is likely that NAWC's recommended locations will focus on wind directions during convection band passages and also on streamflow that is generated from the various potential target areas. This approach is suggested in b. under the Task 2 description from the RFP which brings in consideration of hydrologic data. For example, assuming similar frequencies of seedable conditions in several potential target areas and similar increases from seeding, then the target watersheds with the highest average runoff should receive priority. In other words, the same percentage increase applied to different areas will result in higher yields for target areas with the highest natural runoff. Consequently, NAWC believes that this task needs to be conducted in tandem with Task 3.

NAWC will utilize in-house personnel to perform this and other tasks in this study. NAWC has four WMA Certified Managers one of which is also an AMS Certified Consulting Meteorologist.

NAWC proposes that one of its meteorologists visit the identified target areas to conduct on-site surveys of potential ground sites. The assistance of SAWPA personnel in these site surveys would be very useful. For example, are there secured debris basin locations that might serve as good ground generator locations? NAWC used this approach in selecting sites for our 2015-2016 seeding program conducted for the San Gabriel Mountains under contract to the Los Angeles County Department of Public Works (LACDPW). As mentioned previously, some of these same sites may be useful in the conduct of a Santa Ana River Watershed program with approval from the LACDPW.

NAWC will investigate the predicted seeding plume transport from potential ground generator locations under prevailing wind directions. This could include winds during various storm situations (e.g. pre-frontal, frontal and post-frontal). The typical wind directions with frontal passages in southern California include pre-frontal winds from the southwest, transitioning to westerly in the cold frontal zone, with northwesterly post-frontal winds.

NAWC intends to use a National Weather Service model known as HYSPLIT to provide some predicted plume transports. The HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model is intended for use in computing simple air parcel trajectories to complex dispersion and deposition simulations and was developed as a joint effort between NOAA and Australia's Bureau of Meteorology. NAWC has used this model routinely for the past several winter seasons in the conduct of its operational cloud seeding programs. It can be run in real-time for input to decision making regarding which seeding sites may be useful in a given storm situation, or archived data may be used to predict seeding plume dispersion for previous historical storm events. Figure 3 provides an example of a model simulation from a seeded storm during last winter's seeding program in Santa Barbara County.

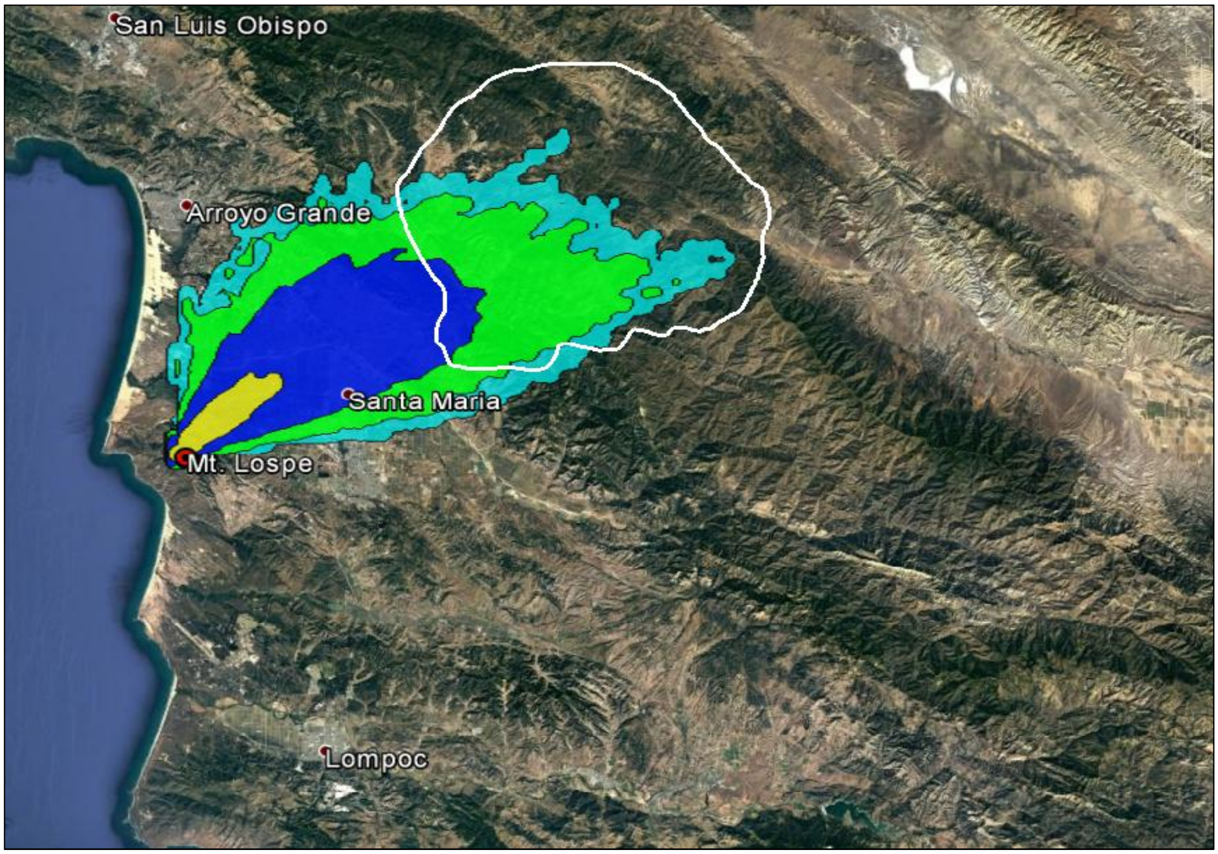


Figure 3 HYSPLIT Model Output for Seeding Operations on March 20, 2019

The HYSPLIT model can also be used to simulate seeding plume transport from aerial releases. The targeting of seeding effects to impact intended target areas using seeding aircraft is somewhat simpler than that from ground-based sites for a variety of reasons (some of which will be discussed in Task 3).

A report will be prepared describing the results of the work conducted under this task that will address the information requested in the RFP.

6.0 Development of Program Design and Seeding Increases Estimates

The ASCE Guidelines 2016 Manual contains the following statement regarding feasibility studies; *"When possible, the feasibility study for a program should draw significantly from previous research and well-conducted operational programs that are similar in nature to the proposed program".* In NAWC's opinion, in the context of the proposed work for the Santa Ana River Watershed, it is fortunate that the Santa Barbara II research program was conducted in as similar environment as the proposed Santa Ana River Watershed program. As discussed previously, this research program yielded very positive results and NAWC has applied the basic components of the design of this program in the conduct of operational winter cloud seeding programs for Santa Barbara County since 1981. The components of the design of the operational program have evolved over time to the present. The results from the operational program have been positive with calculated increases of target area precipitation from 9% to 21% (Griffith et al., 2015). This evolved design can be used to develop a robust design for the Santa Ana River Watershed program, which can include consideration of both ground-based sites and airborne seeding. Potential ground generator locations and potential flight paths (if airborne seeding is deemed feasible) will be documented in a report prepared for this task. **The design will include consideration of a number of factors, including personnel, organizational structure, operations center location and equipment, communications, weather data, predictive models, means for real-time recognition of seedable situations, how seeding is to be performed in varying situations, operations plans, cloud seeding suspension criteria, permits, reports, potential means to evaluate the effectiveness of the seeding, etc.** A design for the Santa Ana River Watershed program is expected to be similar to one developed for San Luis Obispo County (Griffith et al., 2019). Although not mentioned in the RFP, NAWC could prepare a summary of potential environmental impacts of the cloud seeding program with relevant references.

Average estimates will be made of the potential increases in precipitation due to seeding. Such estimates may include precipitation increases and increases in snow water content in higher target area locations. Estimates will then be made of potential increases in runoff. NAWC has routinely performed both types of estimations for other NAWC operational programs or feasibility studies. We typically use an historical target/control evaluation technique where precipitation in upwind control areas is correlated with proposed target area precipitation prior to any seeding being conducted. These evaluations are normally based on linear or multiple linear regression equations. These equations, based on non-seeded seasonal periods, can then be used during seeding periods to estimate the amount of natural precipitation that would be expected in the target area(s). These estimates are then compared to the actual precipitation during the seeded periods (see Griffith et al., 2009).

Thus, the development of regression equations would provide an evaluation technique that could be used in future years (if a seeding program is implemented) to estimate the effectiveness of seeding.

For estimates of increased runoff in feasibility studies, correlations may be established between seasonal precipitation or April 1st snow water contents for not seeded seasons with the most representative seasonal or entire water year streamflow totals. These correlations are also in the form of regression equations. An average amount of precipitation is calculated for the proposed period of seeding (e.g. November through March) or for April 1st snow water content. These amounts are then increased by the estimated percentage increases in order to estimate the potential increases in runoff (see Griffith et al., 2019).

The report prepared for this task will include the results of these analyses. These results would also be needed in the next task in order to estimate the potential Benefit/Cost ratio or ratios (next task).

7.0 Perform a Benefit/Cost Analysis

The ASCE "Guidelines for Cloud Seeding to Augment Precipitation" published in 2016 will be followed in the performance of this task. **The publication states in part: "Before a cloud seeding program is implemented, a feasibility study, as described in Section 6.3, should be conducted to assess the probability pf the program being successful".** The following is also quoted from this publication:

Feasibility Study Considerations

The term "feasibility study" refers to the examination of the local climate and cloud characteristics, to determine whether or not cloud seeding technology has a reasonable expectation of increasing precipitation. The term "program assessment" refers to the evaluation of the program itself when it is actually conducted.

The feasibility of a program depends largely upon two factors. First, is there a scientific basis for the work proposed that could yield the desired additional precipitation? This is discussed in detail in Section 4. Secondly, even if such a basis exists, is the cost of implementing a program based on the known science affordable? The latter depends heavily upon the combination of available financial resources and the expected return in additional water, in other words, the benefit/cost ratio.

When possible, the feasibility study for a program should draw significantly from previous research and well-conducted operational programs that are similar in nature to the proposed program (e.g., similar topography, similar precipitation occurrences, etc.). Percentage increases obtained from such programs can be used in the development of benefit/cost analysis for the proposed program (See Section 2.4).

Feasibility Study Objectives (Program Scope)

The primary purpose of the feasibility study is to answer two questions. First, does it appear that a cloud seeding program could be implemented in the intended target area that would be successful in achieving the stated objectives of the program? Examples include the increase of high elevation snowpack or the increase of summer rainfall directly on croplands. Secondly, is the proposed program design expected to produce a positive benefit/cost ratio? The answers to these two questions will determine whether the proposed program appears to be technically and economically feasible.

Answering the first question involves assessing whether or not the climate and cloud characteristics of the region in interest will normally produce sufficient numbers of clouds amenable to effective treatment. In "normal" seasons there must be enough suitable clouds to make a program worthwhile. That number depends upon the increase in precipitation likely to be obtained from each event, and on the value of the additional water thus reaching the surface. Background climatological studies of the weather typical of the intended target area(s) can help address these questions. In addition, the clouds must be treatable, that is, there must be a means of consistently treating the cloud volumes with enough seeding agent(s) to achieve the desired effects. Contributing factors include how seeding agents are transported and dispersed by the airflow and/or convection relative to the locations of the seedable clouds. For orographic seeding, the transport and dispersion are primarily studied relative to the terrain. For airborne seeding, the location(s) of aircraft base(s), the aircraft performance, and the locations climatologically favored for the development of suitable clouds are the primary considerations.

The feasibility study should also address other potential concerns, e.g., the environmental effects of seeding agents such as silver iodide (AgI), and the possibility of measurable downwind effects. References to all relevant research should be summarized for the benefit of the potential program sponsors, and the public. Numerous studies have shown repeatedly that adverse environmental effects are unlikely even with long-term programs.

To prepare a benefit/cost analysis, NAWC would first need to make estimates of the costs associated with different seeding modes and different target areas. NAWC would then need estimates from the SAWPA of the value of streamflow at various stream gauge measurement points or calculated streamflows that the SAWPA may be able to provide. The desired values would be expressed in dollars per acre-foot. NAWC would then multiply these values by the estimated average of runoff increases from Task 3, then divide by the estimated program costs to derive benefit/cost estimates. NAWC will provide a second California benefit/cost analysis method for comparison.

The ASCE Guidelines (2016) suggest a benefit/cost ratio of 5/1 for a proposed cloud seeding program to be considered economically feasible. According to this publication, a proposed program must be considered to be both technically and economically feasible in order to be considered feasible. NAWC will adhere to this definition in ultimately determining whether the proposed Santa Ana River Watershed program is feasible. NAWC has applied these same criteria in the performance of other feasibility/design studies.

8.0 Final Report

Quoting from the RFP, "A draft version of the Report shall be provided to SAWPA, allowing four weeks to review the draft and return comments. All comments shall be incorporated, finalized, and delivered to SAWPA within three weeks for approval". NAWC will follow these procedures. The final report will summarize the work conducted under the previous four tasks.

Exceptions

NAWC does not propose to select specific site locations which would require site visits and establishing whether access to these sites can be approved by the various owners of these properties. NAWC suggests that these specific site locations be established by the Contractor selected to implement this program should the decision be made to move forward by the SAWPA assuming this study determines that a project appears feasible. The timing between the submission of a final study report and the implementation of a program could be a few years for, among other reasons, a Mitigated Negative Declaration would need to be drafted, opened for comment, then approved by the SAWPA Board of Directors. During this time, the availability of specific site locations may change. The specification of potential locations should be adequate to establish whether the proposed program is technically feasible as defined by the ASCE.

NAWC requests a fixed cost instead of a cost reimbursable contract. A fixed cost would be established for each of the five tasks. **All previous NAWC feasibility/design contracts, including those in California, have been conducted on a fixed cost basis.** NAWC does not require our employees to submit time cards. We expend whatever personnel time is needed in order to deliver an acceptable product. We use this same fixed price approach in the conduct of all of our operational cloud seeding programs, with the exception of a cost reimbursable section in our contracts that is used to charge our clients for seeding material usage and flight hours, which are entirely a function of the weather conditions.

NAWC does not agree with sections 4.05, 11.06, X.3 in the sample contract.

Fixed Costs

J	Task 1, Collection of Data.	$15,000
J	Task 2, Selection of Target Areas.	$15,000
J	Task 3, Development of Program Design and Seeding Increase Estimates.	$20,000
J	Task 4, Perform a Benefit/Cost Analysis.	$15,000
J	Task 5, Delivery of Final Report	$10,000
	Total	$75,000

References

ASCE, 2016: Guidelines for Cloud Seeding to Augment Precipitation. ASCE Manual 81, 3rd Edition, Reston, VA.

ASCE, 2017: Standard Practice for the Design, Conduct and Evaluation of Operational Precipitation Enhancement Projects. ANSI/ASCE/EWRI 42-17, Reston, VA.

Brown, K.J., R.D. Elliott, J.R. Thompson, P. St. Amand and S.D. Elliott, Jr., 1974: The seeding of convective bands. AMS Preprints 4th Conf. on Weather Modification, Nov. 18-21, 1974, Ft. Lauderdale, FL.

Griffith, D.A., M.E. Solak, R.B. Almy and D. Gibbs, 2005: The Santa Barbara Cloud Seeding Project in Coastal Southern California, Summary of Results and Their Implications. WMA, Journal of Weather Modification, Vol. 37, pp. 21-27.

Griffith, D.A., M.E. Solak, D.P. Yorty and B. Brinkman, 2007: A Level II Weather Modification Feasibility Study for Winter Snowpack Augmentation in the Salt River and Wyoming Ranges in Wyoming, Weather Modification Association's *Journal of Weather Modification,* Vol. 39, p. 76-82.

Griffith, D.A., M.E. Solak and D.P. Yorty, 2009: 30+ Winter Seasons of Operational Cloud Seeding in Utah. WMA, J. of Wea. Modif., Vol. 41, pp. 23-37.

Griffith, D.A., M.E. Solak and D.P. Yorty, 2010: Summary of a Weather Modification Feasibility Study for Winter Snowpack Augmentation in the Eastern Snake River Basin, Weather Modification Association's *Journal of Weather Modification,* Vol. 42, p. 115-123.

Griffith, D.A., D.P. Yorty and M.E. Solak 2012: Summary of a Weather Modification Feasibility/Design Study for Winter Snowpack Augmentation in the Upper Boise River Basin, Idaho. Weather Modification Association's *Journal of Weather Modification,* Vol. 44, p. 30-47

Griffith, D.A., D.P. Yorty and S.D. Beall, 2015: Target/Control Analyses for Santa Barbara County's Operational Winter Cloud Seeding Program. WMA, Journal of Weather Modification, Vol. 47, pp. 10-25.

Griffith, D.A., D.P. Yorty, T.R. Flanagan and S.D. Beall, 2017: A Feasibility/Design Study for a Winter Cloud Seeding Program for the Abajo and La Sal Ranges, Utah. Weather Modification Association's *Journal of Weather Modification,* Vol. 49, p. 13-21

Griffith, D.A., D.P. Yorty, S.D. Beall and T.R. Flanagan, 2019: Results from a Winter Cloud

Seeding Feasibility/Design Study Conducted for the Lopez Lake and Salinas Reservoir Drainage Basins in Southern San Luis Obispo County, California. Weather Modification Association's *Journal of Weather Modification,* Vol. 51, p. 1-9.

APPENDIX A: NORTH AMERICAN WEATHER CONSULTANTS OPERATIONAL CLOUD SEEDING PROGRAMS

Partial Listing

Project Area: Gunnison County, Colorado
Sponsor: Gunnison County
Technique: Ground based silver iodide seeding
Time Period: 2003-present
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: Little Cottonwood Canyon, Utah
Sponsor: Alta and Snowbird Ski Areas
Technique: Ground based silver iodide seeding
Time Period: 1996 - present
Goal: Enhanced winter snowfall for skiing

Project Area: Abajo Mountains of southeastern Utah
Sponsor: San Juan County Water Conservancy District
Technique: Ground based silver iodide seeding
Time Period: 2012-2013
Goal: Enhanced winter precipitation for water supplies

Project Area: Wellsville and Wasatch Mountains of Northern Utah
Sponsor: Utah Division of Water Resources and Cache County
Technique: Ground based silver iodide seeding
Time Period: 1997 - 2000, 2002-present
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: Upper Ogden River and Lost Creek Watersheds, Utah
Sponsor: Weber Basin Water Conservancy District and Utah Division of Water Resources
Technique: Ground based and airborne silver iodide seeding
Time Period: 1991 - 1993
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: Upper San Joaquin River Drainage, Southern Sierra Nevada of California
Sponsor: Southern California Edison Company
Technique: Ground based and airborne silver iodide seeding with radar surveillance
Time Period: 1951 - 1987 and 1990 - 1992
Goal: Enhanced winter and summer precipitation for hydroelectric power production

Project Area: Mountain Watersheds in Central and Southern Utah
Sponsor: Utah Water Resources Development Corporation Utah Division of Water Resources, 13 Utah Counties
Technique: Airborne and ground based silver iodide seeding
Time Period: 1973 - 1983, 1987, 1988-present
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: Bear Lake Drainage, Smith & Thomas Forks, Southwestern Wyoming and Southeastern Idaho
Sponsor: Utah Power and Light Company
Technique: Ground based silver iodide seeding
Time Period: 1954 - 1970; 1979 - 1982, 1989 - 1990
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: Santa Barbara County, California
Sponsor: Santa Barbara County Water Agency
Technique: Ground based and airborne silver iodide seeding with radar surveillance; ground-based flare seeding
Time Period: 1950-1953; 1955; 1956-1960; 1978; 1982 – 1997 2002-2007; 2008 - present
Goal: Enhanced winter precipitation for municipal and agricultural water supplies

Project Area: Grouse Creek, Raft River, Wellsville and Wasatch Mountains of Northern Utah
Sponsor: Utah Water Resources Development Corporation,Utah Division of Water Resources, and Cache and Box Elder Counties
Technique: Ground based silver iodide seeding
Time Period: 1989 - 1997, 2001-present
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: Provo and Weber River Drainages in Western Uinta Mountains of Utah
Sponsor: Utah Water Resources Development Corporation Utah Division of Water Resources, Provo River Water Users Association and Weber Basin Water Conservancy District
Technique: Ground based silver iodide seeding
Time Period: 1989 - 1995, 2000-present
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: Wasatch Mountains in Eastern Salt Lake County, Utah
Sponsor: Utah Water Resources Development Corporation Utah Division of Water Resources; Salt Lake City Water Division; and Alta, Brighton, and Snowbird Ski Areas
Technique: Ground based silver iodide seeding
Time Period: 1989 - 1996
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Upper Kings River Drainage in the Southern Sierra Nevada of California**
Sponsor: Kings River Conservation District and Kings River Water Users Association
Technique: Airborne and ground based silver iodide seeding with radar surveillance
Time Period: 1989 – 1993, 2007-present
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Upper Feather River Drainage in the Northern Sierra Nevada of California**
Sponsor: California Department of Water Resources
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1989
Goal: Enhanced winter precipitation for municipal and irrigation water supplies

Project Area: **Grand Mesa and West Elk Mountains of Western Colorado**
Sponsor: Grand Mesa Water Users Association
Technique: Ground based silver iodide seeding
Time Period: 1990 - 1991
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **San Gabriel Mountains, California**
Sponsor: Los Angeles County Flood Control District
Technique: Ground based silver iodide seeding
Time Period: 1959 - 1973, 1991 - 1993, 1997-2001, 2015-2016.
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Bannock, Portneuf and Bear River Mountain Ranges of Southeastern Idaho**
Sponsor: Bear River RC&D and Bannock, Bear Lake, Caribou, Franklin, and Oneida Counties
Technique: Ground based silver iodide seeding
Time Period: 1988 - 1989, 1992, 1993
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Uinta Mountains of Northeastern Utah**
Sponsor: Uinta County, Duchesne County and Utah Division of Water Resources
Technique: Airborne and ground based silver iodide seeding
Time Period: 1977, 1989, 2003-present
Goal: Increased winter spring, and summer precipitation for irrigation water supplies

Project Area: **Boise River Drainage, Idaho**
Sponsor: Boise Project Board of Control
Technique: Ground based silver iodide seeding
Time Period: 1992 - 1996, 2002-2005, 2007-2009; 2010-2011; 2013-2014
Goal: Enhanced winter precipitation for irrigation water supplies and hydroelectric power production

Project Area: **Willow Creek Drainage, Colorado**
Sponsor: Northern Colorado Water Conservancy District
Technique: Ground based silver iodide seeding
Time Period: 1992 - 1995
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Higher Elevation Watersheds of Nine Eastern Idaho Counties and One Western Wyoming County**
Sponsor: High Country RC&D
Technique: Ground based silver iodide seeding
Time Period: 1993, 1995
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Santa Clara County, California**
Sponsor: Santa Clara Valley Water District
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1992
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Mornos River Drainage, Greece**
Sponsor: Greater Athens Water Authority
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1992, 1993
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Chixoy River Drainage, Guatemala, C. A.**
Sponsor: Empresa Electrica and Instituto Nacional de Electrificacion
Technique: Airborne and ground based silver iodide seeding with radar surveillance
Time Period: 1991, 1992, 1994
Goal: Enhanced summer precipitation for hydroelectric power production

Project Area: **El Cajon Drainage Basins, Honduras, C. A.**
Sponsor: Empresa Nacional De Energia Electrica
Technique: Airborne and ground based silver iodide seeding with radar surveillance
Time Period: 1993, 1994, 1995, 1997
Goal: Enhanced summer precipitation for hydroelectric power production

Project Area: **Tsengwen Dam Drainage, Taiwan**
Sponsor: Taiwan Central Weather Bureau
Technique: Ground based silver iodide seeding
Time Period: 1992, 1994
Goal: Enhanced summer precipitation for irrigation water supplies

Project Area: **West Central Texas Near San Angelo**
Sponsor: City of San Angelo, Texas
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1985, 1986, 1987, 1988
Goal: Enhanced summer precipitation for municipal water supplies

Project Area: **Edwards Plateau Northwest of San Antonio**
Sponsor: Edwards Underground Water District, San Antonio, Texas
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1985, 1986
Goal: Enhanced summer precipitation for municipal water supplies

Project Area: **South Central Texas North of Corpus Christi**
Sponsor: City of Corpus Christi, Texas
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1985
Goal: Enhanced summer precipitation for municipal water supplies

Project Area: **Pine Valley Mountains in Southwestern Utah**
Sponsor: Washington County Water Conservancy District and Utah Division of Water Resources
Technique: Ground based silver iodide seeding
Time Period: 1985-1987
Goal: Enhanced winter precipitation for municipal and irrigation water supplies

Project Area: **Southern Delaware**
Sponsor: Delaware Department of Agriculture
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1985
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Abu Dhabi, United Arab Emirates**
Sponsor: Abu Dhabi Municipality
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1982
Goal: Enhanced winter precipitation for agricultural water Supplies

Project Area: **Catalina Island, California** Sponsor: Southern California Edison, Co. Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1977 - 1978
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Bulloch County, Eastern Georgia**
Sponsor: Drought Relief Fund
Technique: Airborne silver iodide seeding with radar Surveillance
Time Period: 1977
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Southern Georgia**
Sponsor: Southern Georgia Rain Gain
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1977
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Burke County, Eastern Georgia**
Sponsor: Burke County
Technique: Airborne silver iodide seeding with radar surveillance
Time Period: 1977
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Polk County, Oregon**
Sponsor: Polk County
Technique: Airborne dry ice seeding
Time Period: 1977
Goal: Enhanced winter precipitation for agricultural water supplies

Project Area: **Deschutes River Drainage, Central Oregon**
Sponsor: Portland General Electric Company
Technique: Ground based silver iodide seeding
Time Period: 1964-1965; 1974-1976
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Chelan Lake Drainage, Central Washington**
Sponsor: Chelan Public Utility District
Technique: Airborne dry ice seeding
Time Period: 1976 - 1977
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Baker River Drainage, Northern Washington**
Sponsor: Puget Power Company
Technique: Airborne dry ice seeding
Time Period: 1976 -1977
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Skagit River Drainage, Northern Washington**
Sponsor: Seattle City Light Company
Technique: Airborne dry ice seeding
Time Period: 1976 - 1977
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Lake Spalding Drainage, in the Northern Sierra Nevada of California**
Sponsor: Pacific Gas and Electric Company
Technique: Airborne silver iodide seeding
Time Period: 1976 - 1977
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Heritage and Mona Reservoir Areas, Central Jamaica**
Sponsor: Kingston Water Commission
Technique: Airborne silver iodide seeding
Time Period: 1976
Goal: Enhanced summer precipitation for municipal water supplies

Project Area: **Port of Ensenada, Mexico**
Sponsor: Insisa
Technique: Ground based silver iodide seeding
Time Period: 1970 - 1976
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Northwestern South Dakota**
Sponsor: South Dakota Weather Control Commission
Technique: Airborne silver iodide seeding
Time Period: 1975
Goal: Enhanced summer precipitation and hail suppression for agricultural crops

Project Area: **Coeur D'Alene Lake Watershed, Northern Idaho**
Sponsor: Washington Water and Power Company
Technique: Ground based silver iodide seeding
Time Period: 1950-1951; 1952-1960; 1966-1971; 1973-1974
Goal: Enhanced fall - early winter precipitation for hydroelectric power production

Project Area: **Hungry Horse Reservoir Area, Northwestern Montana**
Sponsor: Bonneville Power and Light Company
Technique: Ground based silver iodide seeding
Time Period: 1966 - 1971
Goal: Enhanced winter precipitation for hydroelectric power generation

Project Area: **San Benito County, California**
Sponsor: San Benito County
Technique: Ground based silver iodide seeding
Time Period: 1964 - 1966
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Owyhee Reservoir, Southwestern Idaho**
Sponsor: Board of Control - Owyhee Project
Technique: Ground based silver iodide seeding
Time Period: 1954-1956; 1959-1962
Goal: Enhanced winter precipitation for irrigation water supplies

Project Area: **Ventura County, California**
Sponsor: Ventura County
Technique: Ground based silver iodide seeding
Time Period: 1957 - 1960
Goal: Enhanced winter precipitation for irrigation and municipal water supplies

Project Area: **Santa Ana River Basin, California**
Sponsor: Santa Ana River Weather Corporation
Technique: Ground based silver iodide seeding
Time Period: 1956 - 1960
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Lake Almanor Drainage, in the Northern Sierra Nevada of California**
Sponsor: Pacific Gas and Electric Company
Technique: Ground based silver iodide seeding
Time Period: 1952 - 1960
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Mokelumne & Stanislaus Rivers, in the Central Sierra Nevada of California**
Sponsor: Pacific Gas and Electric Company
Technique: Ground based silver iodide seeding
Time Period: 1952 - 1960
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Campbell River Drainage, British Columbia**

Project Area: **Southern Cascades, Oregon**
Sponsor: California-Oregon Power Company
Technique: Ground based silver iodide seeding
Time Period: 1951 - 1960
Goal Period: Enhanced winter precipitation for hydroelectric power production

Project Area: **Crane Valley in the Central Sierra Nevada of California**
Sponsor: Pacific Gas and Electric Company
Technique: Ground based silver iodide seeding
Time Period: 1954 - 1959
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **San Diego County, California**
Sponsor: San Diego County Weather Corporation
Technique: Ground based silver iodide seeding
Time Period: 1950-1951; 1956-1957
Goal: Enhanced winter precipitation for municipal water supplies

Project Area: **Ocean Falls, British Columbia**
Sponsor: Crown-Zellerbach Paper Company
Technique: Ground based silver iodide seeding
Time Period: 1955 - 1957
Goal: Enhanced winter precipitation for hydroelectric power production

Project Area: **Decatur and Clarke Counties, Iowa**
Sponsor: The Decatur County Weather Modification Association
Technique: Ground based silver iodide seeding
Time Period: 1957
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Greene, Boone and Story Counties, Iowa**
Sponsor: Central Iowa Modification Association
Technique: Ground based silver iodide seeding
Time Period: 1957
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Dallas County, Iowa**
Sponsor: Dallas County Weather Modification Group
Technique: Ground based silver iodide seeding
Time Period: 1957
Goal: Enhanced summer precipitation for agricultural water supplies

Project Area: **Southeastern Idaho**
Sponsor: Salmon River Canal Company, Oakley Canal Company, Cedar Mesa Reservoir and Canal Company
Technique: Ground based silver iodide seeding
Time Period: 1953 - 1955
Goal: Enhanced winter precipitation for irrigation water supplies

Sponsor:	British Columbia Hydro Company
Technique:	Ground based silver iodide seeding
Time Period:	1954 - 1960
Goal:	Enhanced winter precipitation for hydroelectric power production

APPENDIX B: Resumes

DON A. GRIFFITH, CCM

EDUCATION

B.S., Meteorology, University of Utah, Salt Lake City, Utah, 1967
Mathematics, Westmont College, Santa Barbara, California, 1967
B.S., Industrial Construction and Management, Colorado State University, 1963

TECHNICAL SPECIALTIES

Mr. Griffith has 48 years of experience in meteorology. Some of Mr. Griffith's technical specialties include:

- Research in Weather Modification
- Design, Operation, and Evaluation of Operational Weather Modification Programs
- Synoptic Weather Forecasting
- Climatological Studies
- Design, Operation, and Evaluation of Atmospheric Tracer Programs
- Applied Meteorological Applications
- Probable Maximum Precipitation Site-Specific Studies
- Forensic Meteorology

REPRESENTATIVE EXPERIENCE

Mr. Griffith is currently serving as President of North American Weather Consultants (NAWC), located in Salt Lake City, Utah. NAWC provides meteorological consulting services in applied meteorology, climatological studies, forensic meteorology, weather forecasting, probable maximum precipitation studies, and weather modification. He is responsible for the overall management and supervision of NAWC and the technical direction and supervision of NAWC's weather modification activities. Mr. Griffith has directed these weather modification activities since 1977. Activities encompass participation in field research programs in weather modification and the design, conduct, and evaluation of operational cloud seeding programs. Programs are conducted in the western United States and a number of foreign countries.

Mr. Griffith has authored or co-authored 41 journal articles and over 190 technical reports. He has presented over 90 technical presentations at a variety of professional conferences.

PROFESSIONAL AFFILIATIONS

American Meteorological Society, Professional Member
- Past Member, Committee on Planned and Inadvertent Weather Modification
- Certified Consulting Meteorologist, Applied Meteorology
- Member, Committee on Planned and Inadvertent Weather Modification

American Society of Civil Engineers, Affiliate Member
- Member, Standards Committee on Atmospheric Water Management
- Past Chairman, Weather Modification Committee

Past Chairman, Weather and Climate Change Committee
Past Member, Weather and Climate Change Committee
Past Member, Research and Education Committee

Weather Modification Association, Certified Manager and Operator

President, 1976-77, 2008-2009, 2011-2012
Member, Editorial Board
Past Member, Standard and Ethics Committee
Past Member, Publications Committee
Past Chairman, Certification Committee
Chairman, Awards Committee

WORK HISTORY

President
North American Weather Consultants
Utah
1999 - Present

Senior Vice President/General Manager
TRC North American Weather Consultants
Utah
1994 - 1999

Senior Vice President/Research Meteorologist
North American Weather Consultants/TRC Environmental Corporation
Utah 1992 - 1994

Senior Vice President/Research Meteorologist
North American Weather Consultants
Utah and California
1973 - 1992

Meteorologist/Assistant Director, Atmospheric Water Resources Research
Fresno State College Foundation, California
1968 - 1973

Meteorologist
Booz-Allen Applied Research, Inc., California
1967 - 1968

Weather Officer
United States Air Force, California and Vietnam
1964 - 1967

AWARDS

Air Force Commendation Medal, 1967
Environmental & Water Resources Institute, Standards Development C/CE-4 Award
Listed in Strathmore's Who's Who, 2002
Thunderbird Award, Weather Modification Association, 1993

SELECTED PUBLICATIONS

Griffith, D.A. D.P. Yorty, T.R. Flanagan and S.D. Beall, 2017: Feasibility/Design Study for a Winter Cloud Seeding Program for the Abajo and La Sal Mountain Ranges, Utah. WMA *Journal of Weather Modification,* Vol. 49**,** p. 15-23.

Langerud, D., C.J. Keyes, Jr., T.P. DeFelice and D.A. Griffith, 2017: Standard Practice for the Design, Conduct and Evaluation of Operational Precipitation Enhancement Projects. ANSI/ASCE/EWRI 42-17. 50 p.

Keyes, C.G., Jr., B.A. Boe, G.W. Bomar, T.P. DeFelice, D.A. Griffith and D.W. Langerud, 2016: Guidelines for Cloud Seeding to Augment Precipitation. ASCE Manuals and Reports on Engineering Practice No. 81, third edition, 197 p.

Tessendorf, S., R. Rasmussen, D. Breed, L. Xue, C. Weeks, K. Ikeda, D. Axisa, D. Griffith, D. Yorty, S. Ward and R. Erickson, 2016: Weather Modification Feasibility- Wyoming Range Level II Phase II Study. National Center for Atmospheric Research report to Wyoming Water Development Commission, 217 p.

Griffith, D.A., S.M. Ward and D.P. Yorty, 2016: Analysis of Ice Detector Observations at Mount Crested Butte, Colorado during the 2014-2015 Winter Season. WMA *Journal of Weather Modification,* Vol. 48**,** p. 8-23.

Griffith, D.A., D. P. Yorty and S. D. Beall, 2015: Target/Control Analyses for Santa Barbara County's Operational Winter Cloud Seeding Program.WMA Journal of Weather Modification, Vol. 47, pp. 10-25.

Griffith, D.A. and D.P. Yorty, 2014: A Brief History of Evaluations Performed on the Operational Kings River Winter Orographic Cloud Seeding Program. WMA *Journal of Weather Modification,* Vol. 46**,** pp. 29-36.

DeFelice, T.P., J. Golden, D. Griffith, W. Woodley, D. Rosenfeld, D. Breed, M. Solak and M. Solak, 2014: Extra Area Effects of Cloud Seeding - An Updated Assessment. Atmospheric Research, pp. 193-203.

Griffith, D. A., D.P. Yorty, W. Weston and M.E. Solak, 2013: Winter "Cloud Seeding Windows" and Potential Influences of Targeted Mountain Barriers. WMA Journal of Weather Modification, Vol. 45, pp. 44-58.

Yorty, D.P. W. Weston, M.E. Solak and D.A. Griffith, 2013: Low-Level Stability during Winter Storms in the Uinta Basin of Utah : Potential Impacts on Ground-Based Cloud Seeding. WMA Journal of Weather Modification, Vol. 45, pp. 14-23.

Griffith, D. A., D.P. Yorty and M.E. Solak, 2012: Summary of a Weather Modification Feasibility/Design Study for Winter Snowpack Augmentation in the Upper Boise River Basin, Idaho. WMA Journal of Weather Modification, Vol. 44, pp. 30-47.

Yorty, D., T.W. Weston, M.E. Solak and D. A. Griffith, 2012: Low-Level Atmospheric Stability during Icing Periods in Utah and Implications for Winter Ground-Based Cloud Seeding. WMA Journal of Weather Modification, Vol.44, pp. 48-68.

Griffith, D. A., D.P. Yorty and M.E. Solak, 2011: A Winter Operational Cloud Seeding Program: Upper Gunnison River Basin, Colorado. WMA Journal of Weather Modification, **43**, pp. 29-43.

Griffith, D.A., M.E. Solak, and D. P. Yorty, 2010: Summary of a Weather Modification Feasibility Study for Winter Snowpack Augmentation in the Eastern Snake River Basin, Idaho. WMA Journal of Weather Modification, Vol. 42, pp. 115-123.

Griffith, D.A., D. P. Yorty, and M.E. Solak, 2010: Reply to Silverman's Comments on WMA Journal Paper Entitled "30+ Winter Seasons of Operational Cloud Seeding in Utah", WMA Journal of Weather Modification, Vol. 42, pp. 137-147.

Griffith, D.A., D. P. Yorty, and M.E. Solak, 2010: Comments on Silverman's Paper published in the WMA 2009 Journal of Weather Modification Entitled "An Independent Statistical Evaluation of the Vail Operational Cloud Seeding Program", WMA Journal of Weather Modification, Vol. 42, pp. 148-154.

Griffith, D.A., M.E. Solak, and D. P. Yorty, 2009: 30+ Winter Seasons of Operational Cloud Seeding in Utah. WMA Journal of Weather Modification, Vol. 41, pp. 23-37.

Griffith, D.A., M.E. Solak, D. P. Yorty and B. Brinkman, 2007: A Level II Weather Modification Feasibility Study for Winter Snowpack Augmentation in the Salt River and Wyoming Ranges in Wyoming. WMA Journal of Weather Modification, Vol. 39, pp. 76-83.

Griffith, D. A. and M .E. Solak, 2007: Cloud Seeding in the Upper Colorado Basin; Technical Feasibility. Southwest Hydrology, March/April. pp. 19, 32.

Griffith, D.A., M.E. Solak, 2006: The Potential Use of Cloud Seeding Programs to Augment the Flow of the Colorado River. North American Weather Consultants White Paper prepared for the Upper Colorado River Commission, 49 p.

Keyes, C.G., Jr., B.A. Boe, G.W. Bomar, R.R. Czys, T.P. DeFelice, D.A. Griffith, 2006: Guidelines for Cloud Seeding to Augment Precipitation. ASCE Manuals and Reports on Engineering Practice No. 81, second edition, 181 p.

Griffith, D.A., M.E. Solak, and D.P. Yorty, 2005: Is Air Pollution Impacting Winter Orographic Precipitation in Utah? WMA Journal of Weather Modification, Vol. 37, pp. 14-20.

Solak, M.E., D.P. Yorty and D.A. Griffith, 2005: Observations of Rime Icing in the Wasatch Mountains of Utah: Implications for Winter Season Cloud Seeding. WMA Journal of Weather Modification, Vol. 37, pp. 28-34.

Griffith, D.A., M.E. Solak, R.B. Almy and D. Gibbs, 2005: The Santa Barbara Cloud Seeding Project in Coastal Southern California, Summary of Results and Their Implications. WMA Journal of Weather Modification, Vol. 37, pp. 21-27.

Griffith, D.A., et al, 2004: Standard Practice for the Design and Operation of Precipitation Enhancement Projects. ASCE/EWRI Standard # 42-04, American Society of Civil Engineers, 63p.

Griffith, D.A. and M.E. Solak, 2004: Reply to a Paper Entitled Reexamination of Historical Regression Analysis Applied to a Recent Idaho Cloud Seeding Project, WMA Journal of Weather Modification, Vol. 36, pp. 15-22.

Solak, M.E., D.P. Yorty and D.A. Griffith, 2003: Estimations of Downwind Cloud Seeding Effects in Utah. WMA Journal of Weather Modification, Vol. 35, pp. 52-58.

Griffith, D.A. and M.E. Solak, 2002: Economic Feasibility Assessment of Winter Cloud Seeding in the Boise River Drainage, Idaho. WMA Journal of Weather Modification, Vol. 34, pp. 39-46.

Griffith, D.A., 2002: Alternative: Increase Precipitation, Runoff and Infiltration through Cloud Seeding. White Paper prepared for inclusion in a Jemez y Sangre Water Plan for Daniel B. Stephens and Associates, Albuquerque, New Mexico.

Griffith, D. A., J. R. Thompson, D. A. Risch, and M. E. Solak, 1997: An Update on a Winter Cloud Seeding Program in Utah. WMA Journal of Weather Modification, Vol. 29, No. 1, pp. 95-99.

Keyes, C. G, R. D. Elliott, R. F. Reinking, R. J. Davis, L. O. Grant, and D. A. Griffith, 1995: Guidelines for Cloud Seeding to Augment Precipitation. American Society of Civil Engineers Manual of Professional Practice No. 81.

Ming-Sen Lin, J., P. T. Chiou, D. A. Griffith, G. W. Wilkerson, M. E. Solak, 1995: Cloud Seeding and Atmospheric Tracer Program Conducted in the Tsengwen Reservoir Area of Taiwan During the 1992 Mei-Yu Season. WMA Journal of Weather Modification, Vol. 27, No. 1, pp. 94-98.

Griffith, D. A., 1993: Planting the Seeds for Increased Water Availability for Hydro. Hydro Review, Vol, XII, No. 5, pp. 122-129.

Griffith, D. A., G. W. Wilkerson, W. J. Hauze, and D. A. Risch, 1992: Observations of Ground Released Sulfur Hexafluoride Gas Plumes in Two Utah Winter Storms. WMA Journal of Weather Modification, Vol. 24, No. 1, pp. 49-65.

Griffith, D. A., J. R. Thompson, and D. A. Risch, 1991: A Winter Cloud Seeding Program in Utah. WMA Journal of Weather Modification, Vol. 23, No. 1, pp. 27-34.

Griffith, D. A., G. W. Wilkerson, and D. A. Risch, 1990: Airborne observations of a summertime, ground-based tracer gas release. WMA Journal of Weather Modification, Vol. 22, No. 1., pp. 43-48.

Swart, H. R., D. A. Griffith, and E. B. Jones, 1987: Feather River Basin cloud seeding feasibility. WMA Journal of Weather Modification, Vol. 19, No. 1, pp 73-76.

Griffith, D. A., 1987: Three rainfall augmentation programs in Texas. WMA Journal of Weather Modification, Vol. 19, No. 1, pp 25-29.

Stith, J. L., D. A. Griffith, R. Lynn Rose, J. A. Flueck, J. R. Miller Jr., and P. L. Smith, 1986: Aircraft observations of transport and diffusion in cumulus clouds. Journal of Climate and Applied Meteorology, Vol. 25, No. 12, pp 1959-1970.

Griffith, D. A., 1984: Selected analysis of a Utah/NOAA Cooperative Research Program conducted in Utah during the 1982-83 winter season. WMA Journal of Weather Modification, Vol. 16, No. 1, pp 34-39.

Summers, P. L., R. D. Elliott, O. H. Foehner, R. J. Davis, L. O. Grant, D. A. Griffith, and C. G. Keyes, Jr., 1983: Guidelines for cloud seeding to augment precipitation. ASCE Journal of Irrigation and Drainage Engineering, Vol. 109, No., 1, March 1983.

Griffith, D. A., J. R. Thompson, and R. W. Shaffer, 1983: Winter orographic cloud seeding northeast of Bear Lake, Utah. WMA Journal of Weather Modification, Vol. 15 No. 1, pp. 23-27.

Sutherland, J. L., J. R. Thompson, D. A. Griffith, and B. Kunkel, 1982: Seeding tests on supercooled stratus using vertical fall pyrotechnics. AMS Journal of Applied Meteorology, Vol. 21, pp. 248-251.

Griffith, D. A., 1982: Emergency cloud seeding in Georgia, Summer, 1977. WMA Journal of Weather Modification, Vol. 14, Number 1, pp. 43-46.

Thompson, J. R. and D. A. Griffith, 1981: Seven years of weather modification in central and southern Utah. WMA Journal of Weather Modification, Vol. 13, No. 1, pp 141-149.

Griffith, D. A., and K. J. Brown, 1975: An operational drought relief program conducted in Jamaica during the summer of 1975. WMA Journal of Weather Modification, Vol. 8, Number 2, pp. 115-125.

Griffith, D. A., G. L. Smith, D. E. Lehrman, and J. R. Vowell, 1971: Analysis of four winter storms. WMA Journal of Weather Modification, Vol. 3, Number 1, p. 223-234.

David Yorty

EDUCATION

M.S., Meteorology, University of Utah, 2001
B.S., Meteorology, University of Utah, 1999

WEATHER MODIFICATION AND FORECASTING EXPERIENCE AND SKILL

Φ Forecasting and meteorological support for weather modification programs in Idaho, Utah, Colorado, and California, 2001-2012
Φ Daily and medium range forecasts for Sacramento Municipal Utility District in California, 2004-present
Φ Good understanding of synoptic and mesoscale meteorology
Φ General knowledge of meteorological processes in a variety of latitudes and climate zones

REPRESENTATIVE EXPERIENCE

David Yorty is currently a Staff Meteorologist for North American Weather Consultants (NAWC) in Salt Lake City, Utah. NAWC provides meteorological consulting services in applied meteorology, weather forecasting, probable maximum precipitation studies, and weather modification. David conducts real-time weather monitoring and forecasting for weather modification activities, and directs cloud seeding operations. He has experience with this type of monitoring and forecasting over the past 15 years, for cloud seeding programs in Utah, Idaho, California, and Colorado. He also tracks the usage and servicing of a large array of ground-based Cloud Nuclei Generators (CNGs), and participates in data collection and analysis related to the effects of cloud seeding conducted by NAWC.

PROFESSIONAL AFFILIATIONS

American Meteorological Society
Weather Modification Association

RELATED WORK HISTORY

Staff Meteorologist

North American Weather Consultants, Inc.
Sandy, Utah
2001-present

Research Assistant, Meteorology
University of Utah
Salt Lake City, UT
2000-2001

Teaching Assistant, Meteorology
University of Utah
Salt Lake City, UT
1999-2000

RELATED PUBLICATIONS

Griffith, D. A., S. D. Beall, T. R. Flanagan, and D. P. Yorty, 2017: Feasibility/Design Study for a Winter Cloud Seeding Program in the San Antonio and Nacimiento Drainages, California. NAWC report prepared for the Monterey County Water Resources Agency, June 2017.

Griffith, D. A., D. P. Yorty, S. D. Beall and T. R. Flanagan, 2017: Feasibility/Design Study for a Winter Cloud Seeding Program in the Lake Lopez and Salinas Reservoir Drainages, California. NAWC report prepared for the San Luis Obispo County Flood Control and Water Conservation District, March 2017.

Griffith, D.A., S. Ward and D.P. Yorty, 2016: Analysis of Ice Detector Observations at Mount Crested Butte, Colorado during the 2014-2015 Winter Season. J. Wea. Modif, Vol. 48, pp. 8-23.

Griffith, D. A., S. D. Beall and D. P. Yorty, 2016: Feasibility/Design Study for a Winter Cloud Seeding Program in the Upper Cuyama River Drainage, California NAWC report prepared for the Santa Barbara County Water Agency, June 2016.

Griffith, D. A., D. P. Yorty and S. D. Beall, 2015: Target/Control Analyses for Santa Barbara County's Operational Winter Cloud Seeding Program. J. Wea. Modif, Vol. 47, pp. 10-25.

Yorty, D.P. and D. A. Griffith, 2014: A Brief History of Evaluations Performed on the Operational Kings River Winter Orographic Cloud Seeding Program. J. Wea. Modif, Vol. 46, pp. 29-36.

Yorty, D. P., T. W. Weston, M. E. Solak and D. A. Griffith, 2013: Low-Level Stability During Winter Storms in the Uinta Basin of Utah: Potential Impacts on Ground-Based Cloud Seeding. J. Wea. Modif, Vol. 45, pp. 14-23.

Yorty, D. P., T. W. Weston, M. E. Solak and D. A. Griffith, 2012: Low-Level Atmospheric Stability During Icing Periods in Utah, and Implications for Winter Ground-Based Cloud Seeding, J. Wea. Modif, Vol. 44, pp. xx-xx (Publication in Process as of July 2012)

Griffith, D. A., D. P. Yorty, and M. E. Solak, 2011: A Winter Operational Cloud Seeding Program: Upper Gunnison River Basin, Colorado, J. Wea. Modif, Vol. 43, pp. 29-43.

Griffith, D. A., M. E. Solak, and D. P. Yorty, 2010: Summary of a Weather Modification Feasibility Study for Winter Snowpack Augmentation in the Eastern Snake River Basin, Idaho, J. Wea. Modif., Vol. 42, pp. 115-123.

Griffith, D. A., M. E. Solak, D. P. Yorty, and B. Brinkman, 2007: A Level II Weather Modification Feasibility Study for Winter Snowpack Augmentation in the Salt River and Wyoming Ranges in Wyoming, J. of Wea. Modif., Vol. 39, pp. 76-83.

Griffith, D. A., M. E. Solak and D. P. Yorty, 2005: Is Air Pollution Impacting Winter Orographic Precipitation in Utah?, J. of Wea. Modif., Vol. 37, pp. 14-20.

Solak, M.E., D. P. Yorty and D. A. Griffith, 2005: Observation of Rime Icing in the Wasatch Mountains of Utah: Implications for Winter Season Cloud Seeding, J. of Wea. Modif., Vol. 37, pp. 28-34.

Solak, M.E., D. P. Yorty and D.A. Griffith, 2003: Estimations of Downwind Cloud Seeding Effects in Utah, J. of Wea. Modif., Vol. 35, pp. 52-58.

TODD R. FLANAGAN

tflanagan@nawcinc.com

EDUCATION

M.S., Atmospheric Science, Texas Tech University, Lubbock, TX, 1998
B.Sc., Combined Honours Atmospheric Science/Geography, York University, Toronto, ON, Canada, 1994

TECHNICAL SPECIALTIES

Mr. Flanagan has 20 years of experience in meteorology. Some specialties include:

- Synoptic & Mesoscale forecasting for short and medium range
- Tropical/hurricane forecasting
- Daily operation of both summer and winter weather modification programs which included airborne (summer/winter) and ground (winter) seeding operations
- Limited evaluation of operational summer weather modification program
- Some technical writing/editing experience

REPRESENTATIVE EXPERIENCE

Mr. Todd Flanagan is a staff meteorologist for North American Weather Consultants (NAWC) in Sandy, Utah. NAWC provides meteorological consulting services in applied meteorology, weather forecasting, probable maximum precipitation studies, and weather modification. Mr. Flanagan conducts real-time weather monitoring and forecasting for weather modification activities, and has directed cloud seeding operations for some of NAWC's winter seeding programs, including the Kings River Watershed in the Southern Sierra Nevada and SMUD's cloud seeding program for the Upper American River Basin. He participates in data collection and analyses related to the effects of cloud seeding conducted by NAWC. Mr. Flanagan also has extensive experience in the daily directing of summer convective cloud seeding operations.

PROFESSIONAL AFFILIATIONS

American Meteorological Society
Weather Modification Association

- Certified Operator (#80) since 2011
- Certified Manager (#18) since 2017

- President, 2010-2011
- Member, Membership Committee
- Member, Nominating Committee

American Society of Civil Engineers (non-member)

- Secretary, Standards Committee on Atmospheric Water Management

WORK HISTORY

Staff Meteorologist
North American Weather Consultants
Sandy, UT
2016-present

Project Meteorologist (Kings Program – winter only)
North American Weather Consultants
Fresno, CA
2009-2016

Project Meteorologist
South Texas Weather Modification Association
Pleasanton, TX
1998-2015

AWARDS

Weather Modification Field Meteorologist Distinguished Service Award, Weather Modification Association, 2010

PUBLICATIONS

Griffith, D. A., S. D. Beall, T. R. Flanagan, and D. P. Yorty, 2017: Feasibility/Design Study for a Winter Cloud Seeding Program in the San Antonio and Nacimiento Drainages, California. NAWC report prepared for the Monterey County Water Resources Agency, June 2017.

Griffith, D. A., D. P. Yorty, S. D. Beall and T. R. Flanagan, 2017: Feasibility/Design Study for a Winter Cloud Seeding Program in the Lake Lopez and Salinas Reservoir Drainages, California. NAWC report prepared for the San Luis Obispo County Flood Control and Water Conservation District, March 2017.

Flanagan, T.R., Beall, S.D., Rhodes, R.E., Wright, J., and A. Ruiz-Columbié, 2008: A review of the Texas weather modification programs in 2007. *J. Wea. Mod.*, 40, 85-91.

Strautins, A., Flanagan, T., and W.L. Woodley, 1999: Coalescence activity in Texas clouds: The index of coalescence activity and the first echo. *J. Wea. Mod.*, 31, 42-50.

Flanagan, T.R., Peterson, R.E., and D.A. Smith, 1999: Hurricane wind fields derived from WSR-88D. *Preprints, 23rd Conf. On Hurr. & Trop. Meteorology*. Dallas, TX, Amer. Meteor. Soc., 469-470.

Stephanie Beall

2246 E. Karalee Way Sandy, UT
84092

Phone: 210-416-0037 | **Email:** sbeall@nawcinc.com

Professional Summary

Meteorologist with thirteen years of operational forecast experience specializing in weather modification operations. Highly experienced in forecasting for winter time precipitation in California and convective precipitation in Texas. Experience with deep knowledge of synoptic and mesoscale processes associated with mid-latitude cyclones as well as radar meteorology. Highly motivated individual with a willingness to learn new skills in the field of meteorology and beyond.

Meteorological Experience

- Thirteen years' experience in radar meteorology, conducting weather modification operations, forecasting of mid-latitude cyclones and orographically induced precipitation.
- Conducted winter cloud seeding activities for two separate project areas in central and southern California.
- Conducted winter cloud seeding activities for projects in Utah and Colorado.
- Experience in using and interpreting Radiometer data.
- Experience with preforming feasibility studies and statistical analyses pertaining to weather modification operations.
- Proficient in map generation with KMZ and KML files and HYSPLIT modeling.
- Conducted weather modification activities for a five-county target area in southwest Texas. Operations are conducted on a 24/7 basis during the operational period of March to November.
- Daily convective/aviation forecasting for weather modification activities conducted via aircraft methods.
- Daily winter precipitation/aviation forecasting for weather modification activities conducted via aircraft and ground methods.
- Airborne seeding operations include vectoring/directing aircraft around and into weather systems while communicating via radio.
- Issue weekly forecasts for four different newspapers for a five country target area in South Texas.
- Responsible for daily, monthly, and annual technical reports relating to operations.
- Experience using aerosol data to determine what aerosol effects will have on

precipitation processes.
- Experience in developing and conducting feasibility studies for potential seeding programs.

Website Experience

- Developed content and maintained the website for the Weather Modification Association – http://weathermodification.org
- Designed, developed, and maintained the website for the South Central Texas Chapter of the American Meteorological Society – http://sctxamsnwa.net
- Designed, developed, and maintained the website for the Southwest Texas Rain Enhancement Association – http://swtrea.org
- Supervised the redesign of the Weather Modification Association's website

Computer/Programming Skills

- UNIX/LINUX, PC, Mac
- MS Word, Excel, Powerpoint, Frontpage, Publisher
- RAOB Software
- HYSPLIT
- Adobe Dreamweaver, Photoshop
- HTML, PHP, PERL, FORTRAN 90
- ARC GIS, Google Earth Map generator with KMZ layers
- LoggerNet: Flare Firing Software – Campbell Scientific

Technical Writing Experience

- Designed and developed content for a tri-fold brochure containing information about weather modification in the state of Texas to raise awareness of the programs in the state that has been distributed to over 400 people at various technical and trade shows.
- Designed and developed content for a 32-page informational booklet for the Weather Modification Association that will be distributed to water and governmental agencies and the organization's members.
- Developed and designed a newsletter quarterly for local chapter of the American Meteorological Society.
- Developed and designed a newsletter semi-annually for the Weather Modification Association.
- Developed and designed a 50-page training manual for new weather modification meteorologists.
- Secretary/Treasurer for local chapter of the AMS/NWA for three years. Duties include, taking minutes, developing/posting agendas, and in charge of organization's

financials.

Publications

- Don A. Griffith, D.P. Yorty, S.D. Beall, 2015: Target/Control Analyses for Santa Barbara County's Operational Winter Cloud Seeding Program. J. Wea. Mod., 47, 10-25.
- Beall, S. et. al, 2009: Texas weather modification operations in 2008. J. Wea. Mod., 41, 127-134.
- Paper presented at 2013 AMS meeting: Jonathan A. Jennings and T. R. Flanagan, S. D. Beall, J. Wright Puryear, and A. Ruiz Columbie. A 10-year Analysis of Operational Cloud Seeding Conducted by the Texas Weather Modification Association
- Interview on Fox News: "Weather Modification to Ease Texas Drought?" http://www.youtube.com/watch?v=AUF1hwxQaes\

North American Weather Consultants Reports

- Don. A Griffith, D.P. Yorty, S.D Beall, T.R. Flanagan, 2017: Feasibility/Design for a Winter Cloud Seeding Program in the Lake Lopez and Salinas Reservoir Drainages, California – NAWC report No.: WM 16-17
- Don. A Griffith, S.D Beall, T.R Flanagan, D.P Yorty,2017: Feasibility/Design for a Winter Cloud Seeding Program in the San Antonio and Nacimiento Drainages, California – NAWC report No.: WM 17-3
- Stephanie Beall, D.A Griffith: Analysis of the Mt. Crested Butte Ice Detector and Associated Measurements during the 2015-2016 Winter Season, 2016 – NAWC report No.: WM 16-16
- Don. A Griffith, S.D Beall, D.P. Yorty, 2016: Feasibility/Design for a Winter Cloud Seeding Program in the Upper Cuyama River Drainage, California – NAWC report No.: WM 16-8

Work Experience

- **Meteorologist**
  North American Weather Consultants – (October 2014 – Present)
- **Meteorologist, Public Outreach Coordinator**
  Southwest Texas Rain Enhancement Association – (Aug. 2004 –Sept. 2014)
  - Conducted weather modification activities for a five-county target area in

southwest Texas

- o Knowledge of project area and climatology.
- o Daily/convective forecasting for weather modification activities conducted via aircraft methods.
- o Responsible for documentations of weather modification activities and reports to the Wintergarden Groundwater Conservation District, City of Laredo, and Edwards Aquifer Authority of San Antonio, Texas.

Meteorologist

North American Weather Consultants, Inc.– (Dec. 2010 – March 2011; Dec. 2013 – April 2014; Dec. 2014 – April 2015, Nov. 2015-Apr. 2016, November 2016 – April 2017)

- o Conducted weather modification activities for the Twitchell and Santa Ynez watersheds in Santa Barbara County, California. Operations are conducted on a 24/7 basis during the operational period of December to March.
- o Knowledge of project topography, climatology, watersheds, surface hydrology, and ALERT network.
- o Daily convective/aviation forecast for weather modification activities conducted via aircraft and ground methods.
- o Responsible for documentation of weather modification activities and reports to the County of Santa Barbara.
- o Responsible for set-up and take down of field operations office.

Meteorologist

North American Weather Consultants, Inc. – (Nov.2007-Apr. 2008; Nov. 2008 -Apr.2009)

- o Conducted weather modification activities for the Kings River Watershed in the southern Sierra-Nevada Mountains in Central California. Operations are conducted on a 24/7 basis during the operational period of November to April.
- o Daily winter precipitation/aviation forecasting for weather modification activities conducted via aircraft and ground methods.
- o Airborne operations include vectoring/directing aircraft and communicating with via radio.
- o Responsible for monthly reports and presentations to the Kings River Conservation District (KRCD).
- o Responsible for set-up and take down of field operations office.

Certifications

- Weather Modification Association – Certified Weather Modification Operator (Jan. 2011 – Present)

Organizations

- American Meteorological Society
- National Weather Association
- Weather Modification Association –current President
- South Central Texas Chapter of the AMS/NWA – Past Secretary/Treasurer, Webmaster

Education

- Bachelor of Science - Meteorology, University of Oklahoma Norman, OK
  Area of Concentration, Business