ASCE STANDARD

ANSI/ASCE/EWRI

42-17

Standard Practice for the Design, Conduct, and Evaluation of Operational Precipitation Enhancement Projects

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

EWRI
ENVIRONMENTAL & WATER RESOURCES INSTITUTE

Approved American National Standard
ANSI

ASCE STANDARD

ANSI/ASCE/EWRI

42-17

Standard Practice for the Design, Conduct, and Evaluation of Operational Precipitation Enhancement Projects

PUBLISHED BY THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Library of Congress Cataloging-in-Publication Data

Names: American Society of Civil Engineers.
Title: Standard practice for the design, conduct, and evaluation of operational precipitation enhancement projects.
Description: Reston, Virginia : American Society of Civil Engineers, 2016. | Series: ASCE standard | Series: ANSI/ASCE/EWRI ; 42-16 | Includes bibliographical references and index.
Identifiers: LCCN 2016019974 | ISBN 9780784414408 (soft cover : alk. paper) | ISBN 9780784479766 (pdf)
Subjects: LCSH: Rain-making–Standards–United States. | Precipitation (Meteorology)–Modification–Standards–United States.
Classification: LCC QC928.6 .O64 2016 | DDC 551.68/77021873–dc23 LC record available at https://lccn.loc.gov/2016019974

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/bookstore | ascelibrary.org

This standard was developed by a consensus standards development process that has been accredited by the American National Standards Institute (ANSI). Accreditation by ANSI, a voluntary accreditation body representing public and private sector standards development organizations in the United States and abroad, signifies that the standards development process used by ASCE has met the ANSI requirements for openness, balance, consensus, and due process.

While ASCE's process is designed to promote standards that reflect a fair and reasoned consensus among all interested participants, while preserving the public health, safety, and welfare that is paramount to its mission, it has not made an independent assessment of and does not warrant the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed herein. ASCE does not intend, nor should anyone interpret, ASCE's standards to replace the sound judgment of a competent professional, having knowledge and experience in the appropriate field(s) of practice, nor to substitute for the standard of care required of such professionals in interpreting and applying the contents of this standard.

ASCE has no authority to enforce compliance with its standards and does not undertake to certify products for compliance or to render any professional services to any person or entity.

ASCE disclaims any and all liability for any personal injury, property damage, financial loss, or other damages of any nature whatsoever, including without limitation any direct, indirect, special, exemplary, or consequential damages, resulting from any person's use of, or reliance on, this standard. Any individual who relies on this standard assumes full responsibility for such use.

Errata: Errata, if any, can be found at http://dx.doi.org/10.1061/9780784414408.

ISBN 978-0-7844-1440-8 (soft cover)
ISBN 978-0-7844-7976-6 (PDF)
Manufactured in the United States of America.

24 23 22 21 20 19 18 17 1 2 3 4 5

ASCE STANDARDS

In 2014, the Board of Direction approved revisions to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by ASCE. All such standards are developed by a consensus standards process managed by the ASCE Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee and reviewing during a public comment period. All standards are updated or reaffirmed by the same process every five to ten years. Requests for formal interpretations shall be processed in accordance with Section 7 of ASCE Rules for Standards Committees, which are available at www.asce.org. Errata, addenda, supplements, and interpretations, if any, for this standard can also be found at www.asce.org.

This standard has been prepared in accordance with recognized engineering principles and should not be used without the user's competent knowledge for a given application. The publication of this standard by ASCE is not intended to warrant that the information contained herein is suitable for any general or specific use, and ASCE takes no position respecting the validity of patent rights. The user is advised that the determination of patent rights or risk of infringement is entirely his or her own responsibility.

A complete list of currently available standards is available in the ASCE Library (http://ascelibrary.org/page/books/s-standards).

This page intentionally left blank

CONTENTS

This page intentionally left blank

PREFACE

Users of ASCE standards may need special knowledge or professional training and experience to apply a standard properly and safely. Those who use ASCE/EWRI Standard 42-17 shall accept full responsibility for its use. Standards shall not preclude professional judgment in situations where they are used.

This standard, ASCE/EWRI 42-17, is a combination of ASCE/EWRI 42-04, *Standard Practice Guideline for the Design and Operation of Precipitation Enhancement Projects,* and the material provided in this revision. ASCE/EWRI 42-17 has been prepared in accordance with the mandatory language for a standard and nonmandatory language in the Commentary portions per the ASCE Standards Writing Manual (http://www.asce.org/uploadedFiles/Technical_Areas/Codes_and_Standards/Content_Pieces/standards-writing-manual.pdf). This standard practice document was revised with recognized, industry best engineering and scientific principles. It shall not be used without the user's competent knowledge of the underlying principles for a given application.

The units used throughout this document are those recommended by the American Meteorological Society (AMS) and the Weather Modification Association (WMA) for their reports and journals. A conversion table (mandatory), as one of the appendixes, shall accommodate references to English common units or other units not necessarily standard to ASCE.

The American Society of Civil Engineers (ASCE) recognizes the work of the Atmospheric Water Management Standards Committee of the Environmental and Water Resources Institute (EWRI). Many individuals contributed materially to this document by their comments, review, illustrations, and photographs.

This page intentionally left blank

ACKNOWLEDGMENTS

The primary initial revision authors of this document included the ASCE/EWRI Atmospheric Water Management Standards Committee (AWM SC) members, Darin Langerud (Past Chair), Conrad G. Keyes, Jr. (Vice Chair), Thomas P. DeFelice (Chair), and the Corresponding Editor of 42-04, Don Griffith.

This page intentionally left blank

CHAPTER 1
INTRODUCTION TO PRECIPITATION ENHANCEMENT PROJECTS

Traditionally, water resources development pertains to building dams and reservoirs, installing pipelines or using concrete to line ditches or canals, or in some way storing or distributing the available water. In many cases, however, there is only one means to increase water supplies, and that is to facilitate the conversion of atmospheric water vapor into precipitation. The latter is known as weather modification or cloud seeding. In many areas of the United States and the world, a need exists for new water supplies. In many of these areas, cloud seeding technology can be useful to augment the available water (Keyes et al. 2006).

Engineers and water planners must realize that both the direct and indirect effects of any contemplated cloud seeding project must be predicted, recognized, and evaluated throughout the entire project. The major parts of the planning and implementation of a cloud seeding project should include the following (Keyes et al. 2006):

- Origin and justification of the overall project.
- An interdisciplinary approach to decision making. Political and institutional aspects may be the most important.
- Feasibility studies that include a clear statement of the planned cloud seeding program. All weather modification plans should be evaluated by weather modification managers who are certified by the Weather Modification Association (WMA).
- Design, operational procedures, and evaluation of a cloud seeding program that should include long-range and short-range aspects in the interpretation of results and the practical significance of the overall findings.
- Project oversight that consists of technical advisory and citizen advisory groups that are involved in the evaluation and a rapid means of communication to avoid potentially hazardous conditions.
- Project management that incorporates a large amount of information dissemination, i.e., weekly and monthly updating of project progress and educational news releases to the public.

1.1 SCOPE OF STANDARD

This book, *Standard Practice for the Design, Conduct, and Evaluation of Operational Precipitation Enhancement Projects*, is intended to provide water resource managers and others with the standard approach for designing, operating, and evaluating precipitation enhancement projects. They typically need to make a decision on the use of cloud seeding to augment available water supplies. ASCE Manual of Practice 81 (Keyes et al. 2006, 2016) contains the information and, in some respects, insights gathered during the course of many design and operational trials of the standard practice for designing, conducting, and evaluating operational precipitation enhancement projects. Mandatory definitions used in this standard appear in Appendix B. Note that Appendix B may also include other definitions that might not be mandatory.

1.2 HISTORICAL PERSPECTIVE

Precipitation enhancement projects have been conducted primarily in regions where *orographic* clouds (those developed by the lifting of moist air as it flows over elevated topography) are common in the cold season, or where warm-season *cumuliform* clouds are generated by vigorous convection, since the mid-1940s (e.g., Schaefer 1946) based on the scientific principles of the precipitation process (e.g., Bergeron 1935; Findeisen 1938). The underlying concept is to treat those storms or portions of storms that are naturally inefficient to make them more efficient through cloud seeding. The first tests of both dry ice and silver iodide (AgI) as cloud seeding materials were carried out during 1946 and 1947 by a General Electric Laboratory group (Schaefer 1946; Vonnegut 1947). As word of the successful 1946 and 1947 first tests spread, it was not long before operational weather modification projects were conducted (e.g., Dennis 1980; Marwitz 1986; Keyes et al. 2016).

1.2.1 Orographic Clouds. Cloud seeding for enhancing winter snowpack in western mountainous areas is considered highly successful since the mid-1980s (e.g., Elliott 1986). The physical understanding and documentation of the chain of events in both natural and artificially stimulated precipitation processes was emphasized through the Sierra Cooperative Pilot Project (SCPP), which used a revolutionary approach to cloud seeding experiments and physical studies (Marwitz 1986). It found that shallow widespread winter orographic cloud systems provided the best potential for precipitation augmentation through cloud seeding operations because their supercooled liquid water is long lasting and distributed over a large area. This provided the rationale to apply cloud seeding technology to the upper elevations of the American River Basin with the aim of producing additional snowfall for spring runoff (Reynolds and Dennis 1986).

Commentary: Other projects or programs have been designed for research and development of precipitation enhancement technology and evaluation techniques (e.g., Kraus and Squires 1947; Battan and Kassander 1960; Simpson et al. 1965; Bowen 1966; Simpson et al. 1967; Smith et al. 1971; Gagin and Neuman 1974, 1981; Smith 1974; Dennis et al. 1975; Braham 1979, 1986; Dennis 1980; Elliott 1986; Mielke et al. 1970, 1971; Cooper and Saunders 1980; Cooper and Marwitz 1980; Gagin et al. 1986; Ben-Zvi and Fanar 1996, 1997; Super and Heimbach 1988; Super et al. 1989; Boe et al. 1992; Long and Huggins 1992;