Computer Modeling of Water Distribution Systems

AWWA MANUAL M32

Third Edition

American Water Works Association

Manual of Water Supply Practices — M32, Third Edition

Computer Modeling of Water Distribution Systems

AWWA Publications Manager: Gay Porter De Nileon

Project Manager/Copy Editor: Melissa Valentine

Production Editor: Cheryl Armstrong

Manuals Coordinator: Molly Beach

Library of Congress Cataloging-in-Publication Data

Printed in the United States of America
American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235-3098
ISBN 978-1-58321-***-*

Printed on recycled paper

Contents

Figures

This page intentionally blank.

Tables

Foreword

The Engineering Modeling and Applications Committee's (EMAC) mission is to assemble and disseminate information on the use of modeling, GIS, and data management in the design, analysis, operation, and protection of water system infrastructure. The committee was formed in 1982 as the Computer Assisted Design of Water Systems Committee and was renamed the Engineering Computer Applications Committee and eventually to its current name. The Committee consists of volunteers, a liaison from the Engineering and Construction Division, and an AWWA staff advisor. The committee develops programs for the Annual Conference and specialty conferences, manuals, and other documents.

The purpose of the M32 maunal is to share collective expertise on distribution system modeling so that it is better understood and applied more effectively to benefit water utilities and water customers everywhere. The manual is intended to be a basic level or primer reference manual to provide new to intermediate modelers with a basic foundation for water distribution system modeling. The manual is intended to take users through the modeling process from model development through calibration to system analysis. The manual has in-depth discussion on:

- Model Construction and Development,
- Field Data Collection and Testing,
- Model Calibration,
- Steady State Analysis,
- Extended Period Simulation,
- Water Quality Analysis,
- Transient Analysis, and
- Tank Mixing Analysis

M32 is designed to help modelers use water models as effective tools to plan, design, operate, and improve water quality within their water distribution systems.

There have been many advancements in the computer modeling field and, together with emerging issues of the water industry, the main goal of the M32 manual update is to focus on key areas that face today's modeler and utility. Key objectives of the update have been to:

- Reorganize the manual for better flow,
- Change the manual to address recent changes in the water modeling industry, and
- Expand the manual to include key topics more relevant to today's modelers.

Chapters are organized as follows:

Chapter	**Title**
1	Introduction
2	Building and Preparing the Model
3	Hydraulic Tests and Measures

4 Hydraulic Calibration (New)

5 Steady State Simulation

6 Extended Period Simulation

7 Water Quality Modeling

8 Transient Analysis (New)

9 Tank Mixing and Water Age (New)

The Committee is responsible for updating the M32 manual and individuals on this committee have dedicated their time and energy to update the manual to better support the water industry.

Acknowledgments

The Engineering Modeling Applications Committee acknowledges these individuals for their persistence and dedication as standing subcommittee members:

Chair—Larado Robinson, P.E., Draper Aden Associates, Blacksburg, VA
Jerry A. Edwards, P.E., IDModeling, Inc., Kansas City, Mo.
Lindle D. Willnow, P.E., AECOM, Wakefield, Mass.

Authors

Chapter 1 Introduction
Sharavan V. Govindan, Bentley Systems Inc., Exton, Pa.
J. Erick Heath, P.E., Innovyze, Arcadia, Calif.

Chapter 2 Building and Preparing the Model
Dave A. Harrington, IDModeling, Inc., Seattle, Wash.
Paul M. Hauffen, IDModeling, Inc., Arcadia, Calif.
Jerry A. Edwards, P.E., IDModeling, Inc., Kansas City, Mo.
Rajan Ray, Innovyze, Wakefield, R.I.
Patrick B. Moore, P.E., Bohannan Huston, Albuquerque, N.Mex.
Nicole M. Rice, Innovyze, Broomfield, Colo.

Chapter 3 Hydraulic Tests and Measures
Megan G. Roberts, P.E., Hazen and Sawyer, P.C., Greensboro, N.C.
Larado M. Robinson, P.E., Draper Aden Associates, Blacksburg, Va.

Chapter 4 Hydraulic Calibration
Jerry A. Edwards, P.E., IDModeling Inc., Kansas City, Mo.
Nass Diallo, P.E., Las Vegas Valley Water District, Las Vegas, Nev.

Chapter 5 Steady State Simulation
Scott A. Cole, P.E., Freese and Nichols, Inc., Fort Worth, Texas
Jared D. Heller, P.E., Moorhead Public Service, Moorhead, Minn.
Thomas J. Welle, P.E., Apex Engineering Group, Inc., Fargo, N.D.
Larado M. Robinson. P.E., Draper Aden Associates, Blacksburg, Va.

C**hapter 6** Extended Period Stimulation
Lindle D. Willnow, P.E., AECOM, Wakefield, Mass.

Chapter 7 Water Quality Modeling
Walter M. Grayman, P.E, Ph.D., W. M. Grayman Consulting Engineer, Cincinnati, Ohio
Lindle D. Willnow, P.E., AECOM, Wakefield, Mass.
Jerry A. Edwards, P.E., IDModeling Inc., Kansas City, Mo.

Chapter 8 Transient Analysis
Paul F. Boulos, Ph.D., Hon.D.WRE, F.ASCE, Innovyze, Broomfield, Colo.
Delbert G. Skip Martin, P.E., CH2M Hill, Corvallis, Oreg.

Chapter 9 Tank Mixing and Water Age

Ferdous Mahmood, P.E., Malcolm Pirnie / ARCADIS-US, Dallas, Texas
Walter M. Grayman, P.E, Ph.D., W. M. Grayman Consulting Engineer, Cincinnati, Ohio

The authors would like to acknowledge the following individuals who provided editorial and technical comments and/or contributed in other ways:

Xuehua Bai,, P.E., Farnsworth Group, Inc., Denver, Colo.
Marie-Claude Besner, Ph.D., Ecole Polytechnique de Montreal, Montreal, Quebec, Canada
Linda K. Bevis, P.E., San Antonio Water System, San Antonio, Texas
Gregory A. Brazeau, P.E., Draper Aden Associates, Blacksburg, Va.
Thomas W. Haster, P.E., Freese and Nichols, Inc., Fort Worth, Texas
Laura B. Jacobsen, P.E., Las Vegas Valley Water District, Las Vegas, Nev.
Nabin Khanal, P.E., Malcolm Pirnie / ARCADIS-US, Arlington, Va.
Kathleen M. Khyle Price, P.E., San Antonio Water System, San Antonio, Texas
Christopher M. Parrish, P.E., American Water, St. Louis, Mo.
Vasuthevan Ravisangar, Ph.D., P.E., CDM, Atlanta, Ga.
John E. Richardson, P.E., Ph.D., ARCADIS-US, Blue Hill, Maine
Larado M. Robinson, P.E., Draper Aden Associates, Blacksburg, VA.
Vanessa L. Speight, Ph.D., P.E., Latis Associates, Arlington, Va.
Arnie Strasser, P.E., Denver Water, Denver, Colo.
Thomas M. Walski, Ph.D., P.E., Bentley Systems, Inc., Nanticoke, Pa.
Z. Michael Wang, Ph.D., P.E., Hazen and Sawyer, P.C., Raleigh, N.C.
Lindle D. Willnow, P.E., AECOM, Wakefield, Mass.
Don J. Wood, Ph.D., Hon.D.WRE, University of Kentucky, Lexington, Ky.

The following individuals provided peer review of the entire manual. Their knowledge and efforts are gratefully appreciated:

Antony M. Green, C.Eng, C.WEM, GL Industrial Services, Loughborough, U.K.
Frank Kurtz, P.E., American Water Works Association, Denver, Colo.
Saša Tomiç P.E., Ph.D., HDR Engineering, Inc., Manhattan, N.Y.
Thomas M. Walski, Ph.D., P.E., Bentley Systems, Inc., Nanticoke, Pa.
Z. Michael Wang, Ph.D., P.E., Hazen and Sawyer, P.C., Raleigh, N.C.

This manual was reviewed and approved by the Engineering Modeling Applications Committee which included the following personnel at the time of approval:

Elio F. Arniella P.E, Halcrow Inc, Marietta, Ga.
Xuehua Bai,, P.E., Farnsworth Group, Inc., Denver, Colo.
Paul F. Boulos, Ph.D., Innovyze, Broomfield, Colo.
Michael T. Brown P.E, Gannett Fleming, Inc, Harrisburg, Pa.
Scott A. Cole, P.E., Freese and Nichols, Inc., Fort Worth, Texas
Daniel Creegan, Anchorage, Alaska
Nass Diallo, P.E, Las Vegas Valley Water District, Las Vegas, Nev.
Antony M. Green, C.Eng, GL Industrial Services, Loughborough, U.K.
Gary Griffiths, Bentley Systems Inc., Exton, Pa.
Eleni Hailu, Los Angeles County Waterworks, Alhambra, CA
Dave A. Harrington, IDModeling, Inc., Seattle, Wash.
Thomas W. Haster, P.E., Freese and Nichols, Inc., Fort Worth, Texas
Jared D. Heller, P.E., Moorhead Public Service, Moorhead, Minn.
Paul Hlavinka, Gaithersburg, Md.
Paul H. Hsiung, Innovyze, Shawnee Mission, Kans.
Laura B. Jacobsen, P.E., Las Vegas Valley Water District, Las Vegas, Nev.
Joel G. Johnson, P.E., GL Noble Denton, Houston, Texas
Pranam Joshi, NJBSOFT LLC, Phoenix, Ariz.
Jonathan C. Keck Ph.D., California Water Service Company, San Jose, Calif.
Carrie L. Knatz, Camp Dresser & McKee, Inc., Carlsbad, Calif.

Douglas J. Lane, MWH, Bellevue, Wash.
Kevin T. Laptos, P.E., Black & Veatch Corporation, Charlotte, N.C.
Foster McMasters, P.E., AECOM, Cleveland, Ohio
Tina Murphy, P.E., HNTB Corporation, Indianapolis, Ind.
Patrick F. Parault, P.E., Malcolm Pirnie, Long Island City, NY
Christopher M. Parrish, P.E., American Water, St. Louis, Mo.
Larado M. Robinson, P.E., Draper Aden Associates, Blacksburg, Va.
Adam Rose, P.E., PMP, Alan Plummer Associates, Inc., Fort Worth, Texas
Jeffrey Eric Rosenlund, HKM Engineering, Sheridan, WY
Michael Rosh, Bentley Systems, Inc., Sayre, Pa.
Thomas E. Waters Jr., O'Brien and Gere Louisville, Ky.
Paul West, Newfields, Atlanta, Ga.
Dr. Jian Yang, American Water, Voorhees, N.J.

This manual was also reviewed and approved by the Engineering and Construction Division which included the following personnel at the time of approval:

Mike Elliott, Stearns & Wheler GHD, Cazenovia, NY
Gary L. Hoffman, ARCADIS-US, Cleveland, Ohio
Richard C. Hope, AECOM, Stevens Point, Wisc.
Laura B. Jacobsen, P.E., Las Vegas Valley Water District, Las Vegas, Nev.
David S. Koch, Black & Veatch, Grand Rapids, Mich.
Marlay B. Price, Gannett Fleming, Inc., Versailles, Ohio
Michael Stuhr, Portland Water Bureau, Portland, Oreg.
Ian P.D. Wright P.E., Associated Engineering of Canada, Calgary, Alberta, Canada

This page intentionally blank.