REVISED THIRD EDITION

Pumping Station Design

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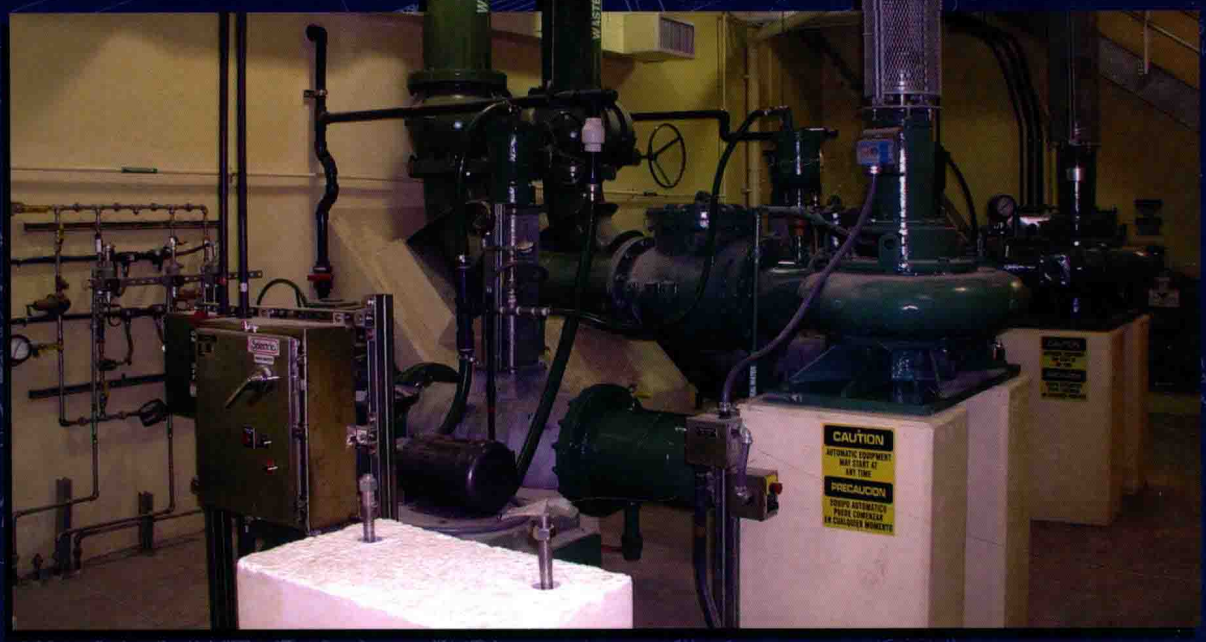

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Pumping Station Design
Revised Third Edition

To the Memory of

Mary Clement Sanks

June 11, 1920–October 24, 1994

Musician of impressive accomplishments, organizer and director of the Annual Chamber Music Festival (1971–1994) for nearly 200 players from North America and Europe, inspiring teacher, enthusiastic chamber music player, and indefatigable worker. On the piano, she could switch keys or leave out a beat or a phrase to match others' mistakes so smoothly that the audience was unaware of a mishap. Generosity, kindliness, compassion, and service to others characterized her life. She once taught a university course for two students after hours for no compensation. A gentle, unassuming lady, she was loved by all who knew her.

Without her patient typing throughout many revisions for seven years, *Pumping Station Design* could not have been written at all. She was also our ultimate authority on grammar and clarity. If she, a non-engineer, could not understand something, it was recast until she could. She had much to do with the book's quality and readability. It is altogether fitting that our profession should know how much it owes to this one dynamic, dedicated musician.

Special Preface to the Third Edition of Pumping Station Design

Robert ("Bob") Sanks was the spark plug behind the projects (a series of individual papers by various authors, a symposium at Montana State University, and the publication of the proceedings from that symposium) that ultimately culminated in writing of a book, *Pumping Station Design*, an award-winning text that has received a seemingly continuous string of accolades since it was first published in 1989. The first edition was followed by an updated version in 1998. In 2000, Bob and I met to review the contents of the second edition and discuss the production of this, the third edition, because advances in technology and the advent of more meaningful standards for pumping applications demanded that a new version must be produced. Bob insisted that I should take on the mantel of Editor-in-Chief to ensure continuity for a future fourth edition. I am still in active practice and very busy, but I somewhat reluctantly agreed, with the understanding that Bob would assist me in interfacing with the other editors, authors, and contributors, as well as liaising with the publisher and copywriters. As this is written, the third edition project is advancing to a close. As in the past, we have managed to weather several crises, including massive rewrites, misplaced artwork, last minute changes, and scrambled text. Through it all, Bob has done the lion's share of the work, with only a few executive decisions left to me. We have somehow managed to come close to most of our deadlines and suffered only a few progress reversals. During the more than five years required to produce the copy for this edition, Bob was the one that questioned, cajoled, harassed, hassled, and corrected the participants (there are many) in this endeavor to ensure that the high level of quality in previous editions has been maintained. The other editors, authors, and contributors can justifiably be proud of this final product. I firmly believe this third edition will measure up to the high standard Bob set with the first edition. The fact is, however, that while my name appears as Editor-in-Chief in the title, it is only because of Bob's tireless efforts that this edition came into being. He deserves the credit, and we all owe him a great debt of gratitude for his tireless efforts.

Garr M. Jones

Special Preface to the Revised Third Edition of Pumping Station Design

Upon publication of the third edition of *Pumping Station Design*, the Board of Editors undertook a thorough review of the entire book to make certain that its quality and usability equaled those of previous editions. Some errors were found and parts required rearrangement for readability. Working with the publisher, the needed corrections were made to this revised edition. The Board of Editors wishes to express its gratitude to Elsevier for its cooperation in helping us to meet our objectives for this revised version of the third edition.

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Bayard E. Bosserman II
Mission Viejo, California
Robert L. Sanks
Bozeman, Montana
George Tchobanoglous
Davis, California
May, 2008

Preface to the First Edition

This book, *Pumping Station Design*, is unique in the following ways. It was written by consultants for consultants so as to be of the greatest practical use for designers. Each author is an expert whose writing is based mostly on personal experience. Little of it was obtained from, or based on, the existing literature. To make the book more usable and understandable, over 370 illustrations are included together with 59 design examples. Most design examples and all formulas are given in both SI and U.S. customary units. The book is complete enough for the novice and advanced enough to be useful to experienced designers and to those who direct or may be associated with design (such as utility managers, city engineers, or equipment suppliers). It is the only text available that deals comprehensively with the entire subject of how to design pumping stations. Finally, the book is unique in the number and expertise of its authors and contributors and in the meticulous care exercised during the seven years of its preparation (as described in the following paragraphs) to make it as easy to read as possible.

The first eleven chapters contain the fundamentals essential for effective design and include hydraulics, piping, water hammer, electricity, and theory and descriptions of pumps. The middle third is devoted to system design, including pump and driver selection and general piping layouts for water, wastewater, and sludge pumping. The last ten chapters contain supporting disciplines and subjects such as instrumentation and design, heating and ventilating, noise and vibration, comparisons of types of pumping stations and pumps, blunder avoidance, contract documents, detailing, and cost analyses. The appendices contain useful physical data, lists of codes and specifications, design checks, start-up checks, and addresses of all publishers given in the references. The tables of flow and headloss in pipes are compiled in a useful form not heretofore published. All of the work is extensively cross-referenced.

Perhaps never before has such a large, talented group of professionals been gathered to produce a book. The 132 expert contributors to this text provide broad and encompassing viewpoints gained from an aggregate of 20 centuries of practical experience. Each author was selected on the basis of specialized knowledge, past performance, experience, and commitment to the profession. Each produced one or more chapters (or parts thereof) based on detailed outlines suggested by the editorial board and improved by author and board as the rest of the book was developed. The other contributors, also selected on the basis of experience and competence, helped in the peer reviews and by supplying information.

Typically, I rewrote (or at least heavily edited) each chapter to conform to a uniform style and then sent it to from three to seven peer reviewers whose collected comments would be rephrased and given to the author with my own comments added. Following the author's reply, a second rough draft would be prepared and sent to author and reviewers. The returned comments would be recast into a third draft and again sent to the author. The fourth draft, usually called "final draft one," was sent to the co-editors. George Tchobanoglous checked every chapter for construction, clarity, and style. Garr M. Jones checked every chapter for practicality and good design practice. The other co-editors reviewed selected chapters for completeness and accuracy. Improvements, integration with other chapters, and nuances of wording often required as many as four subsequent "final drafts" until the chapter satisfied author, reviewers, and editors—a process that has taken seven years. As the book neared completion, new material was added and various subjects were

sometimes shuffled between chapters for more logical presentation and cross-referencing. Alterations and improvements were continued through February 1989. Some idea of the effort taken can be appreciated by realizing that over 50,000 pages of review drafts have been distilled into this book. The result is considered to represent the state of the art (as of early 1989)—practical, authoritative, and essentially timeless. Consulting firms will find that this book can sharply reduce the time for an inexperienced engineer to become a competent pumping station designer. Project leaders will find the comprehensiveness, the checklists, and the list of blunders to be of great help. Utility managers will discover that selective reading of a few chapters will provide insights for directives that can produce better pumping stations for lower overall costs of construction, maintenance, and repair.

The work on this book was begun with a conference on pumping station design and a detailed proceedings outline, which served as a first approximation for the textbook to follow. Proceedings authors were selected on the basis of their experience records and were assigned chapters (or sections thereof) in strict adherence to the outline. The resulting *Proceedings,* published in 1981 in 4 volumes (1576 pages), are still available and valuable as an adjunct tools for design *[out of print in 1996 but still available through interlibrary loan from Montana State University—Ed.]*. Although the purpose of the conference was to make this new material immediately available to the profession, it also enabled us to find a group of experts and to gather resources for this book.

What prompted this project was the lack of a complete textbook about pumping station design in the United States (or in the English language insofar as we knew.) Of course, there were many books about pumps and pumping machinery and a few short manuals for designing pumping stations but there was no comprehensive, authoritative text or reference book dealing specifically with the design of all phases of water and wastewater pumping stations. Indeed, the literature about pumping station design has been fragmented, often superficial, sometimes wrong, and generally incomplete. One expert stated that 95 percent of all pumping stations he has seen contain serious design mistakes and that they occur in every category; if so there was a need for a book written by practicing engineers for consultants and others involved in decision making. Knowledge about the subject has been largely confined to consulting engineers, a few large public utilities and to equipment manufactures, so the overall purpose of this project was to gather, codify, and preserve the knowledge (much of which has never been printed) for the benefit of the public and the profession.

Carl W. Reh was the first co-editor appointed and, until his death in 1983, my chief proponent and supporter. The other co-editors, George Tchobanoglous, Donald Newton, B. E. Bosserman II, and Garr M. Jones (in order of appointment) have made this work possible. As technical advisor, Earle C. Smith provided much invaluable guidance and critiqued a large part of the work. All the authors and contributors have given a great deal of time to the project with no thought of reward beyond a desire to be of service to the profession.

Several consulting firms made extraordinary contributions of time, effort, and finances to the project, as follows: Greeley and Hansen Engineers, Chicago—six authors, including one editor, wrote four chapters, a part of another, and two appendices; Brown and Caldwell Consultants, Walnut Creek, California—three authors, including one editor, wrote six chapters and one appendix; Boyle Engineering Corporation, Newport Beach and Bakersfield, California—two authors, including one editor, produced five chapters and one appendix. Several firms, listed in Chapter 29, contributed cost data, an onerous task. Sincere appreciation is extended to all for this help, and, indeed, the engineering profession is indebted to all the contributing firms and personnel.

Mary C. Sanks patiently typed draft after draft and checked grammar, readability, punctuation, and spelling, and she assisted with galley and page proofs. Edimir Rocumback, student in architecture, drafted most of the figures. The entire project was made possible by the financial support of Montana State University. Officers directly involved included Theodore T. Williams, formerly Head, Department of Civil Engineering and Engineering Mechanics; Byron J. Bennett, formerly Dean, College of Engineering; and Lawrence T. Kain, formerly Administrator of Grants and Contracts.

Robert L. Sanks
Bozeman, Montana
March 1989

Preface to the Second Edition

The reception of the first edition of this work by the engineering profession has indeed been gratifying. It seems to have become the standard reference for pumping station designers, and many have said it is the only reference they constantly use. In 1989, it received the "Excellence" award from the Professional and Scholarly Publishing Division of the Association of American Publishers. Each year a single engineering book is awarded this signal honor—a sort of Pulitzer Prize for engineering.

Matching that high standard with this second edition has been a challenge. Fortunately, most of the coeditors of the first edition again gave generously of their time, knowledge, and experience. Timothy Thor took the previous draftsman's place with equal artistry. Several experienced and competent authors and contributors joined the group to fill the omissions in the first edition. The absence of Mary Sanks to type and polish the manuscript left a gap that slowed the work and increased its difficulty.

This second edition is an improvement over the previous one in two major ways. First, every chapter has been examined and revised in some degree to reflect the best modern practice. Some changes are subtle—a word here and there, but many chapters were extensively rewritten. Second, a number of subjects, missing in the first edition, have been added. These include: (1) interviews with operators and supervisors of 15 utilities (that together manage 2700 pumping stations) to discover how to make operation better and maintenance easier and less expensive; (2) guidelines for troubleshooting existing vibration problems; (3) a straightforward explanation of how to avoid vibration problems in new stations; (4) objective, site-specific considerations in recommending whether large submersible pumps should be located in wet wells or dry pits; (5) directions for easily removing large submersible pumps from wet wells; (6) a comparison of life-cycle costs of constant-speed and variable-speed pumping stations; and (7) advice to utilities on how to choose a consulting engineering firm.

The eighth difference between the two editions is the addition of guidelines and worked examples for the design of modern pump intake basins for small to large pumping stations—especially self-cleaning basins for wastewater. In the first edition, wet wells for solids-bearing waters were limited to the few examples of Seattle Metro—now King County (Washington) Department of Metropolitan Services—pumping stations presented in Chapter 17. Other literature contained little of significance about this important subject, so a four-year period of development and research was immediately begun to improve the self-cleaning properties of the trench-type wet well and to develop guidelines for design. As a result, the self-cleaning properties were enhanced manyfold (as much as 50 or more), and the trench-type wet well, previously limited to variable-speed pumping, was adapted to constant-speed pumping—essentially made possible by the use of the sloping approach pipe described in Chapter 12. The inclusion of the results of this research and development is the most important improvement in the second edition.

Although the research was begun for the express purpose of improving this book, it was partly responsible for the appointment of the Committee on Pump Intake Design by the Hydraulic Institute. Following nearly three years of work by the committee, the standards for wet well design were extensively revised, and, at this writing, the draft is being circulated for public review as a step leading to approval by the American National Standards Institute. The trench-type wet well is included in the proposed new standards for both solids-bearing and clean waters. Other types are also allowed if provisions are made

for cleaning those for solids-bearing waters. The new proposed standards are in consonance with the presentations in Chapters 12, 17, 26, and 29. The research has, furthermore, led to the construction of several successful trench-type wet wells, and more are being planned or constructed.

The co-editors join me in hoping that you find the second edition even more useful than the first. Suggestions for further improvements (other topics, elimination of errors, etc.) to make future printings or editions ever more valuable are welcome.

Robert L. Sanks
Bozeman, Montana
January, 1998

Preface to the Third Edition

The third edition of this book has been revised extensively to reflect the many recent advances in equipment, design, and application of pumping systems and equipment. All chapters have been reviewed and revised as appropriate. Some material, representing equipment or technologies now obsolete has been removed and a great deal of new material added. Among other additions, for example, is a means for ensuring the smoothest operation of rotating equipment, greatly increasing the longevity of bearings, and otherwise reducing maintenance given in Section 16-5 and Appendix C, Section 1.05B.

This new edition contains many references to the Hydraulic Institute Standards, which have been improved to a point that they now are extremely valuable to engineers, owners, and to the public at large. Two of the editors served on some of the committees that revised the standards, and the book and standards are fully compatible. The editors believe understanding and appreciating the many Hydraulic Institute's standards is helpful—almost essential—to the design and installation of pumping equipment.

To emphasize the care needed to meet the requirements of the Hydraulic Institute's Intake Design Standard, Chapter 12 has been entirely rewritten. The latest design information for self-cleaning, trench-type wet wells, obtained by extensive model studies made by Professors Emeriti Theodore Williams and Robert Sanks (and verified by others) in the Hydraulic Laboratory of Montana State University is presented and discussed. Complete calculations are given for the designs of trench-type wet wells for variable speed and for constant speed pumps with computer-assisted methods for analyzing flow during the cleaning cycle. Dr. Joel Cahoon, Associate Professor, Montana State University, developed computer programs (**UnifCrit2.2, Approach, and Trench2.0**) that ease the effort associated with designing self-cleaning wet wells. The use of computers for pump selection is presented and illustrated by example. A step-by-step approach to pump selection is given in which current Hydraulic Institute standards are used to aid in identifying the most suitable equipment for the most reliable performance. The chapter also includes extensive material on those installation details that extend service life and minimize maintenance.

Every effort has been made to improve this edition and to make it more user friendly. The editors welcome suggestions from readers for further improvements.

Garr M. Jones
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December, 2004

Acknowledgments

The list of 171 contributors has increased to 183 including several author-experts, namely: Paul Cooper (Chapter 10), Alan Vause (Chapters 13 and 15), James W. Schettler (Chapter 14), Thomas M. Flegal (Chapters 16 and 28 and Appendix C), and Philip Wolstenholme (Chapter 23). The editors are grateful to these and all other contributors. Fairbanks Morse Division of Pentair Pump contributed most of the cost to build the expensive large-scale model of the revised Kirkland Pump Station for the Hydraulic Laboratory at Montana State University. Robert Sanks contributed the rest. Yeomans Chicago Corporation contributed the recirculation pump for the model, and Mountain West Thortex.gave enough Cerami-Tech E.G. to coat the wetted surfaces of the pump for preventing corrosion. The model was constructed by Gordon Williamson and set on a cabinet built by Professor Theodore Lang. Wes Harms, Laboratory Specialist, assisted. The Civil Engineering Department contributed space, cabinets, electricity, water, and other facilities including printing the hard copy of the manuscript for the book.

ITT Flygt contributed an engineer for several days of testing. Arnold Sdano of Fairbanks Morse spent two days helping with other tests on the model. Professor Theodore Williams worked a great many days with Robert Sanks and the model.

Arnold Sdano drew some of the more complex figures. John Clements prepared Figures 12-35 to 12-39. Many people, not always listed as contributors, have been helpful with advice and information. Thank you all for the assistance received.

Robert L. Sanks
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