WATERWAY ENGINEERING

OTTO FRANZIUS

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A TEXT AND HANDBOOK TREATING OF THE DESIGN, CONSTRUCTION, AND MAINTENANCE OF NAVIGABLE WATERWAYS

BY

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TRANSLATOR'S PREFACE

ALTHOUGH no political barriers are recognized in the engineering sciences, there are real or fancied obstacles which prevent the dissemination of knowledge to the busy designing engineer. One of the common barriers involves the differences in language. Every generation finds each outstanding civilized nation producing a number of individuals who might be called geniuses; and for the most part, the thought of these men is directed along the great scientific and social problems of the nation. Hence, the genius of one country may follow along entirely different lines of endeavor from that of another. America's expansive territory and its business enterprise made paramount the development of transportation and communication, resulting in a communication network far surpassing all others of the world. Until quite recently, however, this country has been comparatively little concerned with river regulation problems and in providing transportation facilities over its huge unimproved system of natural waterways; their rectification and regulation were considered unnecessary. The public now recognizes a great natural resource in its undeveloped system of water routes. As an indirect consequence thereof, many ingenious methods of regulation have of late been developed in America. This country is now on the threshold of what promises to be the greatest era of river regulation in history.

Europe, because of the density of its population, was forced to consider the matter of river regulation seriously several decades ago. Thus Germany began a systematic scheme of river improvement about the middle of the past century and has all but completed this work; she is now concerned chiefly with the maintenance of river control structures and in providing artificial connecting canals to link together the already improved natural system of waterways. It is only reasonable, therefore, to presume that a definite technique of river regulation has been evolved and that the methods used abroad are bound to include valuable suggestions for the American engineer. There is no intention or desire on the part of the writer to transplant German methods of river regulation in America, but rather to disseminate some of the knowledge of over a century's accumulation in a country where the improvement of waterways has been a paramount issue.

John R. Freeman, a foremost American hydraulic engineer, in consequence of his broad acquaintance and frequent contact with foreign engineers, recognized the great value that might accrue to the profession by an exchange of thought. In his visits abroad he found that the application of experimental hydraulics to practical design had produced astounding results in facilitating and bettering the designs of hydraulic structures. With the desire of effecting this exchange of thought of Americans with foreign hydraulic engineers, he presented funds to three leading engineering societies (American Society of Civil Engineers, American Society of Mechanical Engineers, and Boston Society of Civil Engineers), the interest on which is to provide young hydraulic engineers with scholarship stipends for study and research abroad, and foster the diffusion of foreign knowledge of hydraulics in this country. Besides these funds, Dr. Freeman provided additional financial support to accelerate the realization of his plan of returning something for the advancement of the profession (hydraulic engineering) of which he was a member. The translation of this treatise from the German was thus conceived by Mr. Freeman and undertaken by the writer with the hope of bringing to light otherwise more or less inaccessible information concerning foreign practice in the design, construction, and maintenance of navigable waterways.

There are a number of excellent German books on applied hydraulics; this one was chosen largely because of its recent date of publication and the scope of its subject matter. It is to be hoped that other notable foreign writings in hydraulics will be published in English so as to be readily accessible to American hydraulic engineers.

An earnest effort has been made in the translation to retain the original viewpoint of the author. As is to be expected in any subject which borders on both art and science, diversities of opinion are bound to exist. All German hydraulic engineers do not agree with the author in all matters presented in this book; nor is it to be expected that all Americans in the profession will agree with him verbatim. This should not detract from the treatise; it is simply inherent in the subject. In places where it was deemed especially advisable the writer has provided explanatory notes calling attention to characteristic individualities.

Although the entire book of over eight hundred pages was translated into English and edited, after careful consideration of the subject matter it was decided to print only those parts which provide information not readily accessible to American engineers. In this way it was possible to present the salient information at a reasonable cost of publication, and lower selling price of the book, and at the same time avoid further duplication of material available in American treatises. The omissions in all cases consisted of entire chapters, including Parts I, II, VII, VIII, and XI. Part I of the German edition, entitled "Shipping — Its Nature and Its Significance," contains nothing new or unavailable to American engineers. Part II, entitled "Water," treats of the general field of hydrology — a subject that already has been well developed in such books as "Hydrology" by D. W. Mead, "Elements of Hydrology" by A. F. Meyer, and "Stream Gaging" by W. A. Liddell. Part VII, "Dams," contains material which has been well treated in "The Design and Construction of Dams" by Edward Wegman. The subject matter of Part VIII, "Water Power Plants," is covered quite thoroughly by "Water Power Engineering" by D. W. Mead, "Water Power Engineering" by H. K. Barrows, and similar treatises. Part XI, entitled "Ports," is well treated by such books as "Port Development" and "Ports and Terminal Facilities," both by R. S. MacElwee.

The elimination of these chapters from the English edition does not greatly affect the unity or coherence of the subject matter inasmuch as virtually nothing has been omitted from the original treatment which concerns the construction and improvement of navigable waterways, with the exception of the development of port facilities. The latter forms an independent subject in itself.

The writer wishes to express his gratitude to all who have had a part in assisting with the presentation of this book in the English. He is especially indebted to the late Dr. John R. Freeman who, as founder of a group of fellowships for the study of hydraulic practice abroad, made it possible for the writer to spend two years in Europe where he could become familiar with foreign practice and German technical terms in hydraulic engineering, thus facilitating translation of the treatise; also for Mr. Freeman's complete financial support and sustained personal interest in this undertaking. The writer also wishes to express his appreciation to Mr. J. Rhyne Killian, Jr., Editor of the *Technology Review*, for his work in reviewing the entire treatise and for his valuable suggestions, constructive criticism, and close coöperation with the writer in the production of the English edition of this book.

L. G. S.

Minneapolis, Minn.

AUTHOR'S PREFACE

THIS treatise is intended to provide the designing and construction engineer with a condensed presentation of present-day knowledge of waterway engineering. It is not a book on transportation but rather one on that phase of hydraulics which serves transportation. The book is intended to be scientific, not in the sense that all theories are presented, but rather in the sense that the plausibility of various statements is critically analyzed. Antiquated methods have not been entirely disregarded because, according to experience, the antiquated methods of today may frequently be re-evaluated by ingenious changes. The older procedures, however, have been treated very lightly and in some cases have only been mentioned. The sources of information from which further data may be obtained have been indicated by footnotes. Inasmuch as the treatise is intended particularly for practical purposes, the development of the theories has been confined to a minimum space. It seemed more useful to present the theory in a condensed but well-analyzed form than to give extended developments thereof. In many cases new presentations or conceptions have been discussed. Thus, for example, the tables of water velocities have been presented in a different way than has been customary heretofore; methods of computation for shore walls, locks, lock gates, etc., were presented in a newer form.

The treatise is limited to the subject matter of waterway engineering, a profession which I have pursued in practice for twenty-five years and as a teacher for thirteen years. The treatment of questions of land reclamation as related to hydraulics has been avoided as far as possible. Discussion of the occurrence and movement of water has been condensed, the necessary practical information being emphasized. The book is not intended as a treatise for advanced training, but rather as an aid to the scientifically minded, practical engineer. In order to save space and maintain a systematic presentation, it was necessary to treat the more theoretical questions as a group; thus, for example, all questions concerning the occurrence and movement of water, regardless of whether river or ocean was concerned, were treated together. Locks of all types, canals, harbors, etc., have been discussed in individual sections, but have not been segregated according to divisions of river works, sea works, etc.

In the presentation of this treatise I especially acknowledge the valuable coöperation of my former assistant, Dr.-Ing. F. Collorio, and my

present assistant, Dipl.-Ing. Heinze. The former prepared most of the drawings, numerical tables, part of the data; the latter read proof with particular care. Furthermore, my assistant, Dr.-Ing. A. Streck, contributed materially to the book. All of these men have also aided greatly by a critical examination of the subject matter. Many firms and engineers have provided me with valuable drawings and discussions. Thanks are again expressed to all of these at this time. I want to especially acknowledge the coöperation of the publisher [of the German edition], Julius Springer, and thank him for his fine make-up of this book.

O. Franzius.

Hanover, September 1927.

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WATERWAY ENGINEERING

PART ONE — RIVER CONTROL

A. GENERAL

TWO entirely different problems must be dealt with in river control. One consists in attaining a good discharge, in which detritus movement is of interest only insofar as it affects the water movement. This condition must be brought about in cases where the combined interests of agriculture, power development, and city planning are of prime importance, but where large depth for navigation is unimportant.

The second problem is that of developing the greatest possible uniform depth in rivers, and necessitates a well-regulated detritus movement especially at LW and MW stages. For this purpose the scouring capacity of the river is extremely important, the movement of the water being of interest only insofar as it is the cause of scouring capacity. We are not concerned with a uniform movement of water but with equalization of detritus movement. Because of the lack of uniformity in various river sections, this *is possible only with variation of water movement,* and, therefore, with corresponding variation in the gradient. The development of uniform detritus movement is particularly important in streams where depth is the chief characteristic of the river; that is, in navigable streams.

Every natural river forms bends. Erosion takes place at the concave side of the bend. At the convex side, sand banks form because of the low scouring force. Submerged bar formations occur in the transitions. There is a medium scouring force at transitions, but it is usually too small to keep the channel deep enough for navigation. In order to effect uniform transportation of sediment the shoals must be deepened at the cost of the depth of the pools; that is, the depth must be made uniform. *The best solution is not obtained by making the gradient uniform, as is frequently still attempted, but by balancing the available scouring forces.* One adjustment, however, must be made in the water movement. This concerns the distribution of velocity in bends. The velocity must be lessened in the deep part of the pool and increased in the remainder of the section.

It can be demonstrated that the transporting force corresponds to the expression[1] $S = atJ$. The scouring force possesses a similar value. In spite of the fact that especially great depths occur at the pools, nature has taken care that the value of S does not become too large, the gradients at bends always being flatter than at transitions. Nevertheless, because of the great depths at bends, the scouring force there is usually much greater than at transitions. If the depth at the transitions could be mechanically increased, the scouring capacity would be augmented, but such a procedure would be of no avail since subsequent HW would again leave shoals. Furthermore, rapid improvement for navigation cannot be accomplished by dredging the sills.

Even good dredging does not alter the requirement that the river must be forced to scour out the shoals of its own accord. This is best accomplished by increasing the gradient over the shoals. Even a small diminution of the gradient in the pools, which are very long, makes possible a substantial increase in gradient at the transitions, because the steep gradient over the shoal begins only a comparatively short distance above the actual shoal crest, just as in the case of weirs. Toward the upstream side, the level of the backwater is affected far up the bend; downstream the steep gradient quickly adjusts itself to the flatter gradient of the following bend. Stretches having a flat gradient are thus very long, while the steep stretches over the shoals are comparatively short. In large rivers with excessive width, the width of the transitions should be narrowed down more substantially than has been done heretofore.

Just as detritus movement is dependent upon the kinetic energy of the water $mv^2/2$, resistance to navigation is likewise dependent upon this value. Doubtless an increase in velocity at individual short stretches causes very slight inconvenience which is acceptable to steamship operators if the usable depth of the stream at LW stages can thereby be increased. It is not even necessary to increase the power of the towboats to cope with the increase in gradient at the shoals. The towboats will simply travel somewhat slower at these locations in the case of properly regulated streams, but will be able to travel more rapidly in the bends because here the velocity of flow will be diminished. The total consumption of towing energy for propelling the ship, to be sure, will be slightly raised because of the increased irregularity in velocity of the water; the value of the stream for transportation, on the other hand, will become much greater since considerably heavier loading can be handled than could be otherwise.

[1] In this equation, when expressed in English units, S is the transporting force in pounds per square foot, J is the slope of the water surface, t the depth of the stream in feet, and a the weight of water in pounds per cubic foot.