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Stability Design of Grass-Lined Open Channels

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ABSTRACT

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This handbook presents the state of the art in grass-lined channel design. It is intended primarily for use by engineers and technicians directly involved in planning, designing, or maintaining open channels where vegetation can be used as a lining for erosion protection. Each of the six chapters is a complete discussion, with reference to other chapters as appropriate. Nomographs and calculator/computer programs are included as design aids. Only those design conditions that have implications unique to the use of grass as a channel lining are discussed in detail, and the design aids focus on stability design under steady, uniform flow conditions.

KEYWORDS: grass linings, open channel hydraulics, agricultural waterways, lined channels erosion

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PREFACE

Grass linings have been widely used for agricultural waterways for many years. The U.S. Department of Agriculture's Soil Conservation Service (USDA, SCS) developed an empirical permissible velocity procedure for the design of these waterways that was published in revised form in 1954 as SCS TP-61 (SCS 1954). This publication has been the basis for most grass-lined channel design since that time.

In the late 1970's, renewed interest in grass linings for use in floodways, urban drainageways, and reservoir emergency spillways led to a reanalysis of the available data and a better understanding of the interaction of the flow with a vegetated boundary. The effective stress design approach resulting from this reanalysis, although still semiempirical, improved the separation of independent variables in the design relations. Combining this approach with appropriate soil erodibility relations results in improved design procedures which are more flexible than the permissible velocity based procedures and which are consistent with current nonvegetated channel design practices.

This handbook presents the state-of-the-art in grassed waterway design. Only those design conditions which have implications unique to the use of grass as a channel lining are discussed in detail. Relations routinely applied to rigid boundary or unlined channels are presented with little or no comment, because we assume that an individual wishing to use the material in this handbook will already be familiar with the basic principles of open channel hydraulics. Dimensionally dependent relations are presented in English units only; a metric-unit version may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Since the design relations and examples are presented in the general context of steady uniform flow, additional references will be needed for hydraulically complex conditions. An attractive point of effective stress analysis, however, is that more hydraulically complex conditions may be approached the same for lined and unlined channels. Procedures based on conservation of momentum or energy should use the appropriate coefficients as discussed herein.

This handbook is intended for use primarily by engineers and technicians in planning, designing, or maintaining open channels where vegetation can be used as a lining for erosion protection. Because not all users will wish to study the entire text in detail, each of the six chapters is presented as a complete discussion, with reference made to other chapters as appropriate. Figures and tables are cross-referenced rather than repeated.

Chapter 1 discusses the theory and logic underlying the effective stress approach to the design of vegetated channels. Limitations of the approach are also discussed. The contents of this chapter should be understood by engineers faced with unusual design conditions and/or those conditions which may not be well represented in the data base.

Chapter 2 addresses the essential agronomic considerations in selecting, establishing, and maintaining grass channel linings. This chapter is intended as a first reference when considering grass as a channel lining. In many instances, it will be desirable to consult a qualified agronomist familiar with local conditions before finalizing a design.

Chapter 3 will be used routinely to estimate design parameters after soil and cover types have been identified. Although the design aids presented in this chapter may be used in "cookbook" fashion, an understanding of the flow behavior as discussed in chapter 1 is desirable. It is in the estimation of these parameters that engineering judgment enters the design process. For properly maintained channels, designs based on direct use of the tables and graphs provided in these chapters will usually result in conservative designs. Rational modification of the estimated values based on a knowledge of local conditions and an understanding of the flow-boundary interaction will, therefore, have the potential of decreasing costs.

The numerical effective stress design procedure is presented in chapter 4, along with examples of its application. The procedure may be used directly in hand calculations, but is best suited for programmed calculator or computer application. Programs may be developed directly from the procedure described here, or sample computational routines in chapter 5 may be used.

Chapter 6 consists of a limited set of graphical design aids for rapid estimation of channel stability. Use of these curves requires less initial information than the numerical procedure and does not require the use of a calculator or computer to determine limiting conditions. When both procedures are applied correctly, however, the required channel cross-sectional area associated with the numerical procedure will usually be slightly less than that estimated using the graphical approach.

The numerical expressions and design aids presented in these chapters are directly applicable to open channels lined with a relatively uniform grass cover. When the vegetal cover is very nonuniform, a more detailed flow analysis and/or engineering judgment will usually be required. A thorough understanding of basic hydraulic principles and the concepts discussed in chapter 1 will allow such judgment to be applied rationally.

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