

Chapter 1 Introduction

1-1. Purpose

This manual provides guidance to Corps of Engineers (CE) personnel who are responsible for monitoring and analyzing embankment dams and levees.

1-2. Applicability

This manual applies to HQUSACE elements, major subordinate commands (MSC), districts, laboratories, and field operating activities (FOA) involved with planning, design, construction, installation, monitoring, analysis, and maintenance of instrumentations systems in Corps of Engineers embankment dams and levees.

1-3. References

a. A variety of sources was used to compile the information presented herein, including publications of professional societies, and guidance from consultants and from that developed by the Corps of Engineers and other federal agencies. References specifically applicable to chapter topics are included in that respective chapter text. A listing of all references is included as Appendix A.

b. Permission to use copyrighted material was obtained. The following sources are acknowledged.

(1) Figures 2-2, 2-3, 4-1 through 4-12, 4-16 through 4-26, 6-1, B-5, and B-6, Tables 4-1 through 4-4 and 9-1, a portion of the text in Chapter 4, and the lists in Sections 6-7*c* and 6-12 were obtained from the following source:

Dunncliff, John. 1988. *Geotechnical Instrumentation for Monitoring Field Performance*. Copyright ©1988 by John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.

(2) Figure 2-4 was obtained from the following source:

This manual supersedes EM 1110-2-1908 Part 1 dated 31 Aug 1971 and Part 2 dated 19 Nov 1976.

Terzaghi, K., and Peck, R. B. 1967. *Soil Mechanics in Engineering Practice*. 2nd. Copyright © 1967 by John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.

(3) Figure 4-31 was obtained from the following source:

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(4) Figures B-1, B-2, B-3, B-4, B-8, and B-9 were obtained from the following source:

Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. 1989. Reprinted by permission of the National Ground Water Association.

(5) Figure B-7 was obtained from the following source:

Driscoll, Fletcher G. 1986. *Groundwater and Wells*. 2nd. Copyright © Johnson Division, SES, Inc. Reprinted by permission of Wheelabrator/ Johnson Screens.

(6) Tables 3-1 and 3-2 were obtained from the following source:

Dunncliff, John. 1990. *Twenty-Five Steps to Successful Performance Monitoring of Dams*. Volume 9, Number 4. *Hydro Review*. Copyright, HCI Publications, 1990. Reprinted by permission of HCI Publications.

1-4. Focus

This revision focuses on issues that are of current concern in the Corps' mission of dam safety which includes monitoring embankment dams and levees. Design and construction of new projects have been decreasing. The majority of Corps dams have been instrumented, and the basic instrumentation concepts for monitoring seepage, pressure, and movement have been emphasized over the years in several CE regulations, directives, and programs. Geotechnical personnel are generally familiar with the behavior of instrument systems for which they are responsible. The current challenge for personnel responsible for embankment dam and levee safety is increased, and

continuous attention must be paid to operation and maintenance of existing embankment structures and instrument systems. Therefore, a significant amount of engineering judgment must be applied to major rehabilitation, assessment of system performance, replacement, maintenance, and other situations that have become unique to each embankment structure and instrument system. This manual provides information and guidance that is needed for modifying existing systems as well as for new system installation for new construction.

1-5. Approach

Every instrument system is unique and a significant amount of engineering judgment must be applied to each. It is not possible to provide blanket instructions and/or specific procedures that are universally applicable to every situation that may be encountered. Therefore, this manual emphasizes the use of judgment rather than providing a recipe to follow. Whether analyzing data to determine the competency of a sensor, planning a new system for a rehabilitation project, or selecting a sensor for retrofitting a system with automation, responsible personnel must take the initiative to observe the conditions that require attention, to recognize the need for some action to be taken, to apply available information and properly assess what action is appropriate, and, finally, to follow through with implementing the efforts that are necessary.

1-6. Scope

The manual addresses all aspects of instrumentation including the traditional methods of monitoring, the important geotechnical concepts that must be understood, and the growing concerns of rehabilitation, replacement, and maintenance. New initiatives such as automation are also addressed. The manual also addresses features that influence the performance of embankment dams and levees. Therefore, information presented can be applied to abutments, foundations, and the reservoir rim. Instrumentation of concrete and steel structures is not addressed. Refer to EM 1110-2-4300 and TR REMR-CS-5 for guidance for these features. Instrumentation for research and investigative purposes also is not specifically included.

1-7. Format of the Manual

The manual begins with a description of geotechnical aspects of embankment dams and levees, and briefly discusses important concepts of applying instrumentation. This is followed by addressing various methods of monitoring, the potential for automation, and the installation

that is appropriate. The last portion of the manual addresses operation and maintenance issues including data management and analysis, maintenance, and continual reassessment over the life of the project. For quick reference, a summary of each successive chapter follows:

a. Chapter 2 - Behavior of Embankments and Abutments. The chapter begins by discussing the geotechnical aspects of soil behavior, including soil structure, the presence and buildup of pressures and stresses, and the effects of them on the embankment materials. It also identifies specific mechanisms that are inherent to embankment dam performance and that are key to accessing behavior. This chapter contains fundamental information which is essential to understanding the parameters that are monitored and the environment in which instruments perform.

b. Chapter 3 - Instrumentation Concepts, Objectives, and System Design Considerations. This chapter builds on geotechnical knowledge, identifies parameters in embankment structures that may require monitoring, and offers an approach to planning and designing systems to achieve that purpose. It includes important characteristics of instrument systems that must be considered and recommendations for designing them such that all critical aspects of the process are addressed. The suggested qualifications of the personnel that are responsible for implementing various related instrumentation tasks are also presented.

c. Chapter 4 - Summary of Measurement Methods. The most commonly used devices and technologies for embankment monitoring are discussed. The performance characteristics are described as well as the preferred uses and applications. This information is needed for the selection of appropriate sensors for various applications.

d. Chapter 5 - Automation Considerations. Current guidance for automating new or existing systems is given in this chapter. Automation presents an increasingly viable alternative to traditional manual instrument systems. Certain characteristics of automation, however, are unique and require special attention. Information in this chapter should be kept in mind as other instrumentation aspects (e.g., data analysis, installation, sensor selection, and maintenance) in other chapters are discussed.

e. Chapter 6 - Installation. This chapter discusses several issues that are critical to obtaining reliable and functional instrument systems including contractor qualifications, quality control, instrument protection,

acceptance tests, drilling methods, placement of sensors, seals, and filters, and documentation.

f. Chapter 7 - Data Management, Analysis, and Reporting. This chapter stresses the importance of acquiring valid and complete field information, and the thorough interpretation and meaningful presentation of the data. Other related topics include data validity, selection of scales for plotting, and use of data to prompt the maintenance of instruments. It also contains valuable suggestions for various ways of analyzing raw as well as processed data and managing computerized databases.

g. Chapter 8 - Instrument Maintenance. Testing and calibration of components are critical to instrument performance and data validity. Chapter 8 suggests specific basic attention that is required for portable, retrievable, and embedded components of the instrument system. Historical documentation, maintenance programs, as well as instruments that require more than the basic maintenance of portable, retrievable, and embedded components are also discussed.

h. Chapter 9 - Continual Reassessment for Long-Term Monitoring. The performance of embankment dams and levees must continue for the life of the project. Therefore, comprehensive programs must be established to assure continued attention in the overall context of the behavior of the embankment structures. Changes in performance with time, remedial modifications to the structure in the course of useful life, and the inevitable damage or loss of operating instruments requires significant judgment regarding abandonment, rehabilitation, replacement, or upgrade of instruments. This chapter addresses these issues.

1-8. Use of the Manual

There are three primary uses of this manual: planning and design of instrument systems, continuous use of instrument systems, and making decisions regarding the

modification or replacement of instrument systems. Planners and designers are reminded of theoretical and practical concepts and are assisted with acquiring a reliable and appropriate system. Personnel responsible for the use of the systems are provided guidance regarding data retrieval, analysis, and maintenance. Dams and levees, and associated instrument systems, require increased attention with age and use. Practical approaches to modification and replacement are provided.

1-9. Implementation of an Instrumentation Program

An instrumentation program is a comprehensive approach that assures that all aspects of instrumentation from planning and design through maintenance and rehabilitation are commensurate with the overall purpose. An instrumentation program is an important contributing effort to the much larger concept of dam safety. As such, the characteristics of the instrumentation program must be consistent with the other entities of dam safety such as dam safety training, emergency response, periodic inspections, remedial studies, and structure modifications. In the overall context of understanding and responding to the behavior of the dams and levees, particularly with aging structures and increasing maintenance, it is most important to apply the quality and quantity of attention that is required. Qualified personnel, quality equipment, and timely information and assessment must be encouraged and supported. Without this level of attention and commitment, the importance of all entities of dam safety will deteriorate, wasted effort and expense will result, and areas that depend on input from the instrumentation program will also suffer.