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Standard Guide for Documenting a Groundwater Modeling Code[1]

This standard is issued under the fixed designation D6171; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers suggested components of the documentation of a groundwater modeling code. Documentation of a groundwater modeling code consists of textual and graphical information recorded during its design, development, and maintenance regarding its capabilities, development history, theoretical foundation, operation, and verification. It is the principal instrument for those involved in its development and use, such as code development and maintenance staff, network managers, code users, and project managers, to communicate regarding all aspects of the software.

1.2 This guide presents the major steps in preparing the documentation of a groundwater modeling code. It discusses the various documentation audiences and addresses the role of printed documentation versus documentation in electronic form.

1.3 This guide is one of a series of guides on groundwater modeling codes and their applications, such as Guides D5447, D5490, D5609, D5610, D5611, and D5718.

1.4 This guide is not intended to be all inclusive. If offers a series of options and considerations, but does not specify a course of action. Documenting certain codes may require supplemental information or replacement of documentation sections by more appropriate elements. This guide should not be used as a sole criterion or basis of comparison, and does not replace or relieve professional judgement in preparing or evaluating documentation of groundwater modeling software.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.*

1.6 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This guide cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D5447 Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem

D5490 Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information

D5609 Guide for Defining Boundary Conditions in Ground-Water Flow Modeling

D5610 Guide for Defining Initial Conditions in Ground-Water Flow Modeling

D5611 Guide for Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application

D5718 Guide for Documenting a Ground-Water Flow Model Application

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *computer code (computer program)*—the assembly of numerical techniques, bookkeeping, and control language that represents the model from acceptance of input data and instructions to delivery of output.

3.1.2 *functionality*—of a groundwater modeling code, the set of functions and features the code offers the user in terms of model framework geometry, simulated processes, boundary conditions, and analytical and operational capabilities.

3.1.3 *groundwater modeling code*—the non-parameterized computer code used in groundwater modeling to represent a

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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non-unique, simplified mathematical description of the physical framework, geometry, active processes, and boundary conditions present in a reference subsurface hydrologic system.

3.2 For definitions of other terms used in this guide, see Terminology D653.

4. Significance and Use

4.1 Groundwater modeling has become an important methodology in support of the planning and decision-making processes involved in groundwater management. Groundwater models provide an analytical framework for obtaining an understanding of the mechanisms and controls of groundwater systems and the processes that influence their quality, especially those caused by human intervention in such systems. Increasingly, models are an integral part of water resources assessment, protection, and restoration studies and provide essential and cost-effective support for planning and screening of alternative policies, regulations, and engineering designs affecting groundwater (**1**).[3]

4.2 Successful groundwater management requires that decisions be based on the use of technically and scientifically sound methods for data collection, information processing, and interpretation, and that these methods are properly integrated. As computer codes are essential building blocks of modeling-based management, it is crucial that before such codes are used as planning and decision-making tools, their performance characteristics are established and their theoretical foundation, capabilities, and use documented.

4.3 Good code documentation ensures scientific rigor and implementational quality in the development of a code (**2**). Complete and well-written documentation shortens the learning curve for new users, provides answers to questions from project managers, and supports efficient code selection. Well-structured and indexed documentation provides rapid answers for initiated users. This guide is intended to encourage comprehensive and consistent documentation of a groundwater modeling code.

4.4 Earlier surveys of computer models and assessment of specific models indicate that the documents that are supposed to describe and explain these models and their use are lacking in detail, inconsistent in their contents, incomplete with respect to user instructions, inefficient with respect to indexing and structure, and often difficult to obtain (**3**). This still applies to the documentation of many of the groundwater modeling programs recently released or frequently used (**4**).

5. Code Development Process in Groundwater Modeling

5.1 In groundwater modeling, code development consists of the following: definition of design criteria and determining applicable software standards and practices; the development of algorithms and program structure; computer programming; preparation of documentation; code testing; and independent review of scientific principles, mathematical framework, software, and documentation (**1, 4**).

5.2 The development of a specific groundwater modeling code may be part of a research or development project, based on an existing mathematical model, or derived from an existing set of modeling codes.

5.3 Code testing is an integral part of code development. During the programming phase, testing is focused on individual algorithms, subroutines, functions, and other program elements. At the end of the initial programming phase, the code is extensively tested.

5.4 The preparation of the program documentation starts at the beginning of the code development process and is integral to all stages of code development. Specifically, documentation of theoretical foundation, code design, capabilities and program structure are best prepared and evaluated during the design and programming phases of the project. Documentation regarding the operation and performance of the code are best prepared before and during initial testing by code developers.

5.5 The final step in code development is independent review and testing.

6. Code Documentation Requirements

6.1 Following are the main purposes of software documentation (**3**): to record technical information that enables system and program changes to be made quickly and effectively; to assist the (potential) users in understanding what the program is about and what it can do, so that they can determine whether it serves their needs; to enable code users to effectively apply the program to their project(s); to facilitate auditing and verification of program operations, that is, code evaluation; to enable programmers and system analysts, other than software originators, to work on the programs; to provide software development managers with information to review at significant developmental milestones so that they may determine that project requirements have been met and that resources should continue to be expended; to reduce the disruptive effects of personnel turnover during development and use of the software; and to facilitate understanding among developers, users and project managers by providing information about maintenance (that is, required software modifications), training, and operation of the software.

6.2 Documentation of a groundwater modeling code may be comprised of several elements such as internal or published reports, published articles, textbooks, electronic texts, and software help systems. If a program's documentation consists of more than one such element, it is recommended to include a section referencing all elements that constitutes the code's documentation.

6.3 Documentation of a groundwater modeling code should be informative, well-structured (that is, specific topics are easy to find), and well-written (that is, topics are easy to understand).

6.4 Documentation of a groundwater modeling code should include sections on the following(**5**): development purpose; theoretical framework; mathematical/logic methods and computer algorithms employed; model construction and site-specific data required to control the code; analysis of the

[3] The boldface number given in parentheses refers to a list of references at the end of the text.

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