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Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling[1]

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1. Scope

1.1 This guide covers techniques and procedures used in defining initial conditions for modeling saturated ground-water flow. The specification of initial conditions is an essential part of conceptualizing and modeling ground-water systems.

1.2 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document 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 ASTM standard 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 document 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:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 5447 Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem[3]

D 5609 Guide for Defining Boundary Conditions in Ground-Water Flow Modeling[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *aquifer, confined*—an aquifer bounded above and below by confining beds and in which the static head is above the top of the aquifer.

3.1.2 *conceptual model*—an interpretation or working description of the characteristics of the physical system.

3.1.3 *flux*—the volume of fluid crossing a unit cross-sectional surface area per unit time.

3.1.4 *ground-water flow model*—an application of a mathematical model to represent a ground-water flow system.

3.1.5 *hydraulic conductivity—(field aquifer tests)*, the volume of water at the existing kinematic viscosity that will move in a unit time under unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

3.1.6 *hydrologic condition*—a set of ground-water inflows or outflows, boundary conditions, and hydraulic properties that causes potentiometric heads to adopt a distinct pattern.

3.1.7 *simulation*—one complete execution of the computer program, including input and output.

3.1.8 *transmissivity*—the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer.

3.1.9 *unconfined aquifer*—an aquifer that has a water table.

3.1.10 For definitions of other terms used in this test method, see Terminology D 653.

4. Significance and Use

4.1 Accurate definition of initial hydrologic conditions is an essential part of conceptualizing and modeling transient ground-water flow, because results of a simulation may be heavily dependent upon the initial conditions.

5. Initial Conditions

5.1 Initial hydrologic conditions for a flow system are represented by the head distribution throughout the flow system at some particular time corresponding to the antecedent hydrologic conditions in the aquifer system.[4] The specified heads can be considered reference heads; calculated changes in head through time will be relative to these given heads, and the time represented by these heads becomes the reference time. As a convenience, this reference time is usually specified as zero time or initial time. Time is reckoned from this zero time or initial time. In more formal terms, an initial condition gives head as a function of position at $t = 0$; that is, $h = f(x, y, z; t = 0)$. This notation suggests that, conceptually, initial conditions may be regarded as a boundary condition in time.

6. Procedure

6.1 The following procedures and requirements are proposed for establishing initial conditions at a specified time for

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

[4] Franke, O. L., Reilly, T. E., and Bennett, G. D., "Definition of Boundary and Initial Conditions in the Analysis of Ground-Water Flow Systems—An Introduction," *Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3*, Chapter B5, 1987.

the following conditions of model simulation.

6.1.1 *Defining Steady-State Initial Conditions for a Transient-State Simulation of Head Distribution*—Select field conditions that represent, at least approximately, an equilibrium condition. The steady-state head distribution must be simulated by modeling hydrologic conditions, including boundary conditions[4] that produced the observed distribution of heads. Exact representation of the field prototype flow system is not possible to achieve in practice, but an acceptably close representation may be used as the initial condition (see Guide D 5447).

NOTE 1—The use of model-generated head values for initial conditions for the transient-state simulation assures that the initial heads and the model boundary conditions and hydrologic parameters are consistent. If the field-measured head values were used as initial conditions, the model response in the early time steps would reflect not only the model stress under study but the adjustment of model head values to offset the lack of correspondence between model boundary conditions, aquifer hydraulic properties, and the initial head values.

6.1.2 *Defining a Transient-State Initial Condition for a Transient-State Simulation of Absolute Head*—Simulate transient-state absolute heads for field conditions by simulating boundary conditions and hydraulic properties of the flow system. This period of absolute head simulation must be sufficiently long that antecedent stresses, that is, stresses on the system predating the simulation period, are insignificant. The simulation period must be for a sufficiently long antecedent period that transient heads prior to the selected initial time are acceptably close to the field heads. The transient-state head distribution is used as initial conditions for absolute transient head distribution with the new stress imposed.

6.1.3 *Defining the Initial Head for Steady- or Transient-State Simulation of Head Change in Response to a Stress*—Apply the principle of superposition and define the initial head in the flow system as zero. Superposition modeling predicts only the water-level changes related to a specific stress and does not predict absolute heads (heads referenced to a common datum). If superposition is applicable to the problem, absolute heads can be obtained by adding the head change obtained by superposition analysis to field heads. Superposition may be applied only to systems that exhibit a linear response to stress.[5]

7. Report

7.1 Completely document the definition of initial conditions for model simulation. Such documentation will be a part of the overall documentation of the model. Include the following items pertaining to the formulation of initial conditions in the model report:

7.1.1 Describe the natural physical processes operating on the system, and

7.1.2 Describe the simulation of the system processes up to the initial time ($t = 0$) representation of each boundary. Evaluate the sensitivity analysis of the boundaries and state the conditions of stress over which the modeled boundary conditions are appropriate.

8. Keywords

8.1 aquifers; boundary condition; ground water model; transmissivity

[5] Reilly, T. E., Franke, O. L., and Bennett, G. D., *The Principle of Superposition and its Application in Ground-Water Hydraulics*, U.S. Geological Survey, Open-file Report 84-459, 1984.