Designation: D5473/D5473M – 20

Standard Practice for (Analytical Procedures) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer[1]

This standard is issued under the fixed designation D5473/D5473M; 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 practice covers an analytical solution for determining the horizontal and vertical hydraulic conductivity of an aquifer by analysis of the response of water levels in the aquifer to the discharge from a well that partially penetrates the aquifer. This standard uses data derived from Test Method D4050.

1.2 *Limitations*—The limitations of the technique for determination of the horizontal and vertical hydraulic conductivity of aquifers are primarily related to the correspondence between the field situation and the simplifying assumption of this practice.

1.3 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.4.1 The procedures used to specify how data are collected/recorded or calculated, in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design

1.5 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of the practice 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 the 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 he ASTM consensus process.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4050 Test Method for (Field Procedure) for Withdrawal and Injection Well Testing for Determining Hydraulic

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

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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.

*A Summary of Changes section appears at the end of this standard

Properties of Aquifer Systems
D4105/D4105M Practice for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method
D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *observation well*—a well open to all or part of an aquifer.

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

3.3 *Symbols and Dimensions:*

3.3.1 a [nd]—$(K_z/K_r)^{1/2}$.

3.3.2 b [L]—thickness of aquifer.

3.3.3 d [L]—distance from top of aquifer to top of screened interval of control well.

3.3.4 d' [L]—distance from top of aquifer to top of screened interval of observation well.

3.3.5 f_s [nd]—dimensionless drawdown factor.

3.3.6 K[LT^{-1}]—hydraulic conductivity.

3.3.7 K_r [LT^{-1}]—hydraulic conductivity in the plane of the aquifer, radially from the control well.

3.3.8 K_z [LT^{-1}]—hydraulic conductivity normal to the plane of the aquifer.

3.3.9 K_0—modified Bessel function of the second kind and zero order.

3.3.10 l [L]—distance from top of aquifer to bottom of screened interval of control well.

3.3.11 l' [L]—distance from top of aquifer to bottom of screened interval of observation well.

3.3.12 Q [L^3T^{-1}]—discharge.

3.3.13 r [L]—radial distance from control well.

3.3.14 r_c—distance from pumped well at which an observed drawdown deviation, δs, would occur in the equivalent isotropic aquifer.

3.3.15 S [nd]—storage coefficient.

3.3.16 s [L]—drawdown.

3.3.17 S_s[L^{-1}]—specific storage.

3.3.18 T [L^2T^{-1}]—transmissivity.

3.3.19 u [nd]—$(r^2S)/(4\ Tt)$.

3.3.20 $W(u)$ [nd]—an exponential integral known in hydrology as the well function of u.

3.3.21 $W(u, f_s)$—partial-penetration control well function.

3.3.22 δs [L]—drawdown deviation due to partial penetration from that given by equations for purely radial flow.

3.3.23 z [L]—distance from top of aquifer to bottom of piezometer.

4. Summary of Practice

4.1 This practice uses the deviations in drawdown near a partially penetrating control well from those that would occur near a control well fully penetrating the aquifer. These deviations occur when a well partially penetrating the aquifer is pumped because water levels are drawn down more near the level of the screen, and less at levels somewhat above or below the screened interval, than they would be if the pumped well fully penetrated the aquifer. These effects are shown in Fig. 1 by comparing drawdown and flow lines for fully penetrating and partially penetrating control wells in an isotropic aquifer. Drawdown deviations due to partial penetration are amplified when the vertical permeability is less than the horizontal permeability, as often occurs in stratified sediments (**1**).[3] Hantush (**2**) has shown that at a distance, r, from the control well the drawdown deviation due to pumping a partially penetrating well at a constant rate is the same as that at a distance $r(K_z/K_r)^{1/2}$ if the aquifers were transformed into an equivalent isotropic aquifer.

4.2 *Solutions*—Solutions are given by Hantush (**2**) for the drawdown near a partially penetrating control well being pumped at a constant rate and tapping a homogeneous, isotropic artesian aquifer:

$$s = \frac{Q}{4\pi T}\left[W(u)+f_s\right] \quad (1)$$

where:

$$W(u) = \int_u^\infty \frac{e^{-y}}{y}\,dy \quad (2)$$

and f_s is the dimensionless drawdown correction factor. The function $[\ W(u)+f_s]$ in Eq 1 can be referred to as the partial penetration well function.

4.2.1 The dimensionless drawdown correction factor for a piezometer is given by:

$$f_s = f\left(u, \frac{ar}{b}, \frac{l}{b}, \frac{d}{b}, \frac{z}{b}\right) \quad (3)$$

$$= \frac{2b}{\pi(l-d)}\sum_{n=1}^{\infty}\frac{1}{n}\left(\sin\frac{n\pi l}{b} - \sin\frac{n\pi d}{b}\right)\cos\frac{n\pi z}{b}\,W\left(u, \frac{n\pi ar}{b}\right)$$

and the solution for the dimensionless drawdown correction factor for an observation well is given by:

$$f_s = f\left(u, \frac{ar}{b}, \frac{l}{b}, \frac{d}{b}, \frac{l'}{b}, \frac{d'}{b}\right) \quad (4)$$

$$= \frac{2b^2}{\pi^2(l-d)(l'-d')}\sum_{n=1}^{\infty}\frac{1}{n^2}\left(\sin\frac{n\pi l}{b} - \sin\frac{n\pi d}{b}\right)\left(\sin\frac{n\pi l'}{b} - \sin\frac{n\pi d'}{b}\right)W\left(u, \frac{n\pi ar}{b}\right)$$

where:

$$W(m, x) = \int_u^\infty \frac{\exp\left(-y - \frac{x^2}{4y}\right)}{y}\,dy \quad (5)$$

[3] The boldface numbers in parentheses refer to a list of references at the end of the text.