U.S. Department of the Interior
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Water-Resources Investigations Report 01-4210

Prepared in cooperation with the
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U.S. DEPARTMENT OF ENERGY
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Hydraulic-Property Estimates for Use With a Transient Ground-Water Flow Model of the Death Valley Regional Ground-Water Flow System, Nevada and California

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drawdown or recovery data plotted as a function of log time the values of transmissivity and storativity can be determined (Cooper and Jacob, 1946).

In bailing tests, water is bailed repeatedly for an extended period, but some recovery of water level in well occurs as the bailer is brought to the surface, emptied, and then returned to the test interval. The average withdrawal rate, which is the total volume of water removed divided by the time that the well was bailed, does not account for drainage back to the well between bailing runs or variations in the rate of bailing. In most bailing tests, residual drawdown from bailing can be analyzed using the recovery method of Theis (1935).

In swabbing tests, a mechanical device is lowered into the well to displace water. After repeated runs, the average withdrawal rate is calculated in the same way that the average bailing rate is calculated. Residual drawdown is then analyzed using the recovery method of Theis (1935).

In slug tests, a known volume of water either is instantaneously removed from or is injected into a well, and the time history of water-level recovery to the static water level is monitored. Cooper and others (1967) developed a method for analyzing slug tests, which was later modified by Bredehoeft and Papadopulos (1980). In the solution of Cooper and others (1967), ratios of the water-level drawdown or rise to the static water level (H/H_0) are plotted as a function of log time since the test was initiated. Similar to the other curve-fitting techniques previously described, the data curve is then matched to a dimensionless type curve to obtain values of hydraulic properties.

Drill-stem tests are the standard way in which hydraulic properties of potential oil and gas reservoirs are evaluated by the petroleum industry (Bredehoeft, 1965). This test measures the pressure drop as the formation fluid (such as oil) moves from an isolated section of the borehole into a drill stem lowered into the borehole. In the method of Horner (1951), fluid-pressure recovery during the second shut-in period is plotted as a function of the ratio of the time elapsed during the shut-in period and preceding flow period to the time elapsed during the shut-in period.

Statistical Analyses

Descriptive statistics, including the geometric and arithmetic means, range, and the 95-percent confidence interval (± 1.96 standard deviations from the geometric mean) of the hydraulic conductivity, storage parameters, and anisotropy ratios are reported for each of the HGUs. These parameters will be used to aid in the calibration of the DVRFS transient ground-water flow model. Because hydraulic conductivity tends to be log normally distributed (Neuman, 1982), the geometric mean of the estimates is reported. The arithmetic mean also is reported. Storage parameters tend to be normally distributed (Neuman, 1982) and because of this, the arithmetic mean of the estimates is reported. Values of hydraulic conductivity derived from pumping well data, when an observation well was available, were not used in the statistical calculations to avoid bias from re-sampling the same aquifer test. For similar reasons, slug tests from intervals that overlapped each other, although present in the database (app. A), were not used in the statistical calculations.

Fractured Media and Equivalent Porous Media

Most of the analytical methods used in this work assume that an aquifer is a porous medium. However, the influence of fractures is fundamental to the flow of water in volcanic and carbonate rocks. In order to apply these aquifer-test methods to fractured rocks it is necessary to assume that the rocks are sufficiently homogeneously fractured and interconnected such that the rock being tested can be considered "an equivalent porous medium." The spacing of fractures, as well as their interconnectivity, can affect the results of an aquifer test. In areas where fractures are tightly spaced and interconnected, transmissivities generally are higher than in areas where the fractures are widely spaced and not interconnected. In a study on transmissivity in crystalline rock, slug tests using either porous or fractured media methods, provided estimates of transmissivity within an order of magnitude of each other (Shapiro and Hsieh, 1998). In the cases examined here, the equivalent-porous-medium assumption cannot be ruled out because plots of drawdown or recovery of water levels in wells conform to type curves derived for porous media.

Effects of Test Scale on Determination of Hydraulic Properties

Hydraulic-conductivity and transmissivity estimates are functions of test scale (Dagan, 1986; Neuman, 1990). As media test volume increases, more aquifer heterogeneity is encountered and influences the test results. For example, the potential exists to involve a larger network of fractures in the aquifer response to the imposed stress. In laboratory permeameter tests of core samples for determining rock matrix properties, unfractured core is needed for successful results. Because only matrix rock properties are determined from permeameter tests, the estimates generally are not useful for regional-scale ground-water flow models of fractured-rock aquifer systems. Thus, results for permeameter tests of core samples are not utilized in the descriptive statistical calculations of the hydraulic parameters (with the exception of the clastic confining units). Similarly, slug tests only examine a relatively small amount of aquifer material adjacent to the borehole. Because of this, hydraulic-property estimates from slug tests might not be representative of an entire unit. Single-well aquifer tests (including the pumping or injection well in multiple-well tests) optimally determine hydraulic properties in the near-borehole environment, but the accuracy of these tests can be decreased by inefficient borehole construction, convergence of flow lines and related head losses as water flows into or out of sections of perforated casing, and head loss as water moves between the test-interval depth and the pump-intake depth. As such, for the same set of wells transmissivity estimates derived from single-well tests tend to be less than those of multiple-well tests. Similarly, estimates of storage coefficients from single-hole tests are less reliable than those from multiple-well tests. Multiple-well aquifer tests tend to be more reliable because they manifest the influence of field-scale features, such as faults and fractures, as well as the water-transmitting properties of the rock matrix.

The hydraulic-property estimates presented in this report are based on the results of mostly field-scale tests involving wells. These tests include only a small amount of the volume of aquifer material within an HGU and thus are testing only a very small part of the HGU. The hydraulic-property estimates presented herein are intended to serve only as the basis for constraining flow estimates obtained from the simulation process. The scaling-up of these values for use in calibrating a regional ground-water flow model is problematic and is not explicitly addressed in this report.

General Limitations

General guidelines were used for selecting hydraulic-property data for compilation. These include: (1) the use of published aquifer-test results from wells in the DVRFS area. Selected unpublished data and aquifer-test results were evaluated and analyzed to fill spatial or hydrogeologic data gaps. (2) analyses of aquifer tests using methods appropriate to regional numerical ground-water flow models and (3) analyses for each HGU should be sufficient to provide adequate spatial coverage and statistically describe variance resulting from differences in lithology, fracturing, and faulting. Based on Freund (1992), about 30 samples are a sufficient number to statistically describe parameters. Because wells and boreholes often are installed for purposes other than obtaining hydraulic-property data (such as water supply or monitoring), the above guidelines were not satisfied completely. Selected unpublished DVRFS area aquifer-test results and published data are from hydrologically similar areas.

Analytical methods used to determine the hydraulic-property estimates presented in this report rely on assumptions about the type and configuration of the aquifer. These assumptions are necessary to simplify the flow system so that mathematical equations representing ground-water flow can be solved analytically but result in some uncertainty in the computed hydraulic properties.

Most analytical methods assume that flow to a pumping well is derived from an aquifer of infinite extent. This assumption may not be accurate for many aquifer tests presented in this report because of faults in the study area that may act as either recharge or barrier boundaries.

The most commonly applied analytical methods for pumping tests in the study area, those of Theis (1935) and Cooper and Jacob (1946), assume radial flow to the pumping well under an axisymmetric hydraulic gradient. However, because of media heterogeneities, hydraulic gradients may vary directionally. Differing results in hydraulic-property values obtained from multiple-well aquifer tests involving multiple observation wells may arise as a result of non-radial flow occurring in a part of the flow system monitored by one or more, but not all observation wells. Disregarding a non-uniform hydraulic gradient seemingly would result in inaccurate computations of hydraulic properties, if the solutions of Theis (1935) or Cooper and Jacob (1946) are used. Only a single estimate of transmissivity and storage properties should be reported for these particular tests. To obtain these single results, the average of the property estimates could be used. Because the purpose of this report is to compile and report on estimates of hydraulic properties