Aquifer-Test Report for Test Well UE-19gs

By Robert Graves and Steve Reiner,
U.S. Geological Survey, Water Resources Division, Las Vegas, Nevada

INTRODUCTION

Numerous aquifer tests have been conducted in and around the Nevada Test Site. Many of these tests have been completed in a fracture rock media. Methods used to analyze these aquifer tests have included the Theis and Cooper-Jacob solutions. Although both methods are used to estimate aquifer characteristics in a fracture media, the results may be qualified because both methods were developed for a porous rock media. Recently, GeoTrans Inc., working in cooperation with the U.S. Department of Energy (DOE), evaluated time/drawdown data collected in wells drilled for DOE in the Oasis Valley area (ER-EC wells, completed in fractured volcanic rock) using a fractured-rock, double-porosity model (Moench, 1984). Bill Fryer of GeoTrans Inc., thought that analyzing aquifer-test results from these wells with a dual-porosity solution would yield a better transmissivity estimate in these wells. Subsequently, individuals from GeoTrans Inc. identified approximately 62 wells in the vicinity of the Nevada Test Site with aquifer test data that could potentially be reevaluated with a fractured-rock, double-porosity model. Transmissivity estimates from these aquifer tests will support ground-water flow models being developed for DOE.

The U.S. Geological Survey (USGS) proposed to DOE to work in cooperation with GeoTrans Inc. to review these aquifer tests for the availability of aquifer-test data that might be suitable for reevaluation. During this process well UE-19gs was one of the wells selected by the USGS for reevaluation. Transmissivity in well UE-19gs has been estimated to be 4,000 ft^2/d by Blankennagel and Weir (1973, p. B12, table 3), from an aquifer test conducted on March 26 – 27, 1965. The aquifer-test data from this test were reanalyzed using the Cooper-Jacob solution (Cooper and Jacob, 1946) and Moench's dual-porosity spherical-shaped block and slab-shaped block solutions (Moench, 1984). Transmissivity estimates from each solution were compared.

TEST DESCRIPTION

Well UE-19gs is located in Area 19 of the Nevada Test Site (fig. 1). On March 26, 1965, at 03:36 pm (Pacific Standard Time, PST) the USGS began an aquifer test on well UE-19gs which lasted approximately 24 hours (pump off at 03:36 pm, PST, on March 27, 1965) (Blankennagel and Weir, 1965, p. 14). Average discharge during the test was 185 gallons per minute.

Blankennagel and Weir, (1965, p. 15), in footnote a/, reported that well UE-19gs was developed for approximately 4 hours by pumping the well for 30 minutes and then allowing the well to recover for 15 minutes before pumping again. Following well development and prior to conducting the March 26, 1965, aquifer test, well UE-19gs was pumped for a period of 2 hours and 40 minutes. This period of pumping was spent in an attempt to purge the access line of soap suds which were causing problems in making water-level measurements. Following this pumping period the pump was idle for 2 hours prior to the start of the test. In footnote b/

Blankennagel and Weir, (1965, p. 15) report that there was difficulty in measuring the water level during the aquifer test because the measuring line adhered to the wet access pipe. Line adhesion was a problem intermittently during the test, especially during 80 and 900 minutes of pumping. Complete accuracy of depths measured are somewhat in doubt, however, Blankennagel and Weir (1965, p. 15) indicated that the differences in depth to determine drawdown were usable for hydrologic test analysis. No adjustments to the drawdown data due to barometric or tidal effects were made.

On page 5, Blankennagel and Weir (1965) reported that

> *"Water levels were measured with a deep-well electrical line capable of detecting relative changes in water level as small as 0.02 foot. The static-level measurements have not been corrected to a steel tape secondary standard and should not be used for water-level contouring.*
>
> *A Byron Jackson submersible pump was used in the test on hole UE-19gs. A positive displacement check value was placed immediately above the pump. Discharge measurements were made using Sparling water meters. In most tests the meter accuracy was checked with a 44 gallon oil drum or a 10,000 gallon tank."*

TEST SITE

Well UE-19gs is located at 37 ◦ 18’ 30” N.; 116 ◦ 21’ 53” W., in Area 19 of the Nevada Test Site (fig. 1).

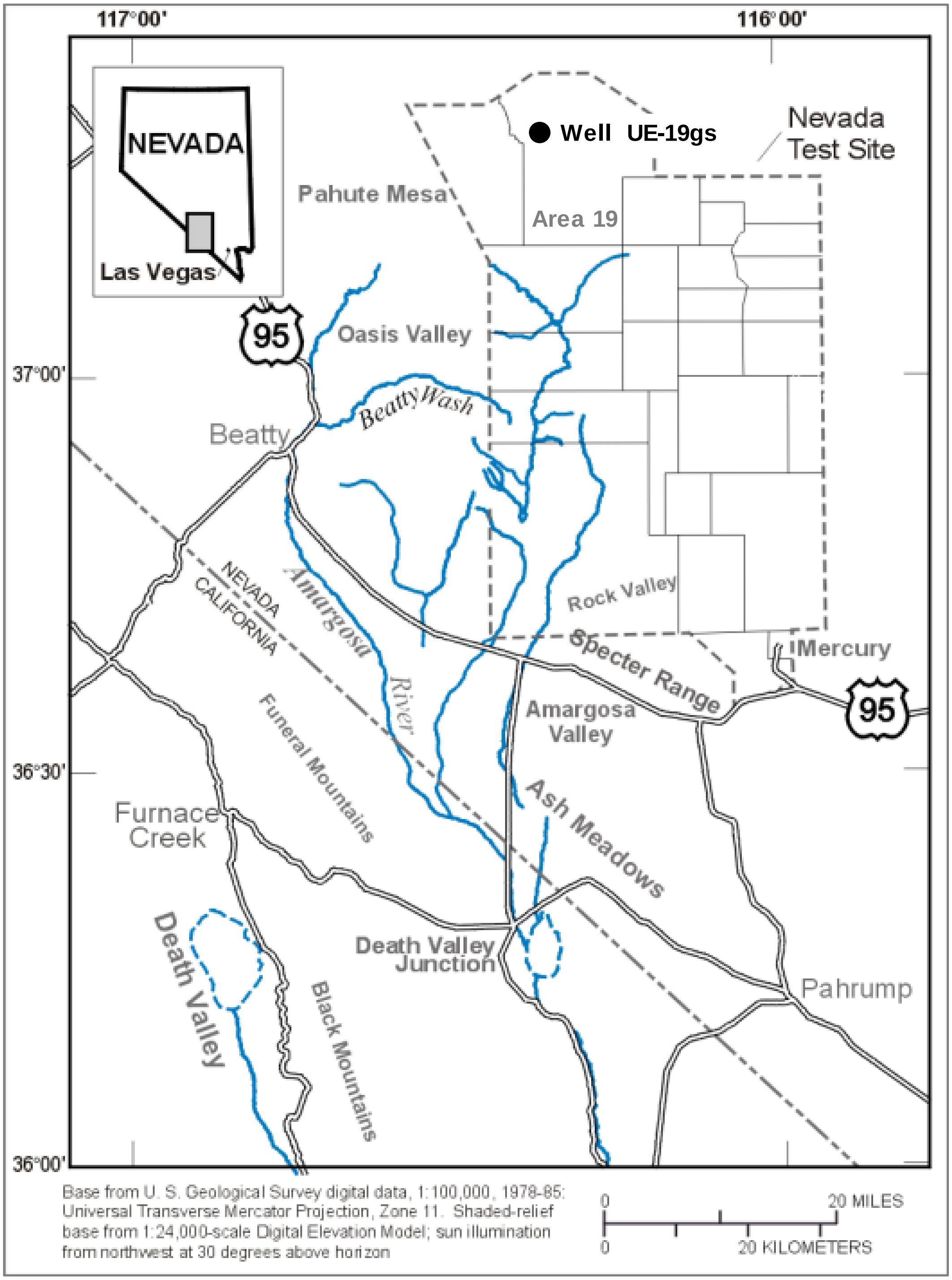

Figure 1 Location of well UE-19gs on the Nevada Test Site.

CONSTRUCTION

Well UE-19gs was drilled in the Pahute Mesa area to collect data for the evaluation of the subsurface geologic and hydrologic environment (Blankennagel and Weir, 1973, p. B1-B2). Well UE-19gs was drilled to a depth of 4,508 feet below land surface and was completed with a 13 3/8-inch outside diameter casing from land surface to 2,650 feet below land surface, and a 9 7/8-inch diameter open hole from 2,650 to 4,508 feet below land surface (fig. 2). Major producing zones were reported to be in interflow zones at approximately 2,940, 3,970 and 4,270 feet below land surface (Blankennagel and Weir, 1965, p. 14). The saturated thickness of aquifer tested is about 1,860 feet (Belcher and Elliott, 2001). Following the March 26 – 27, 1965, aquifer test, well UE-19gs was deepened from 4,508 to 7,506 feet below land surface (not shown in figure 2).

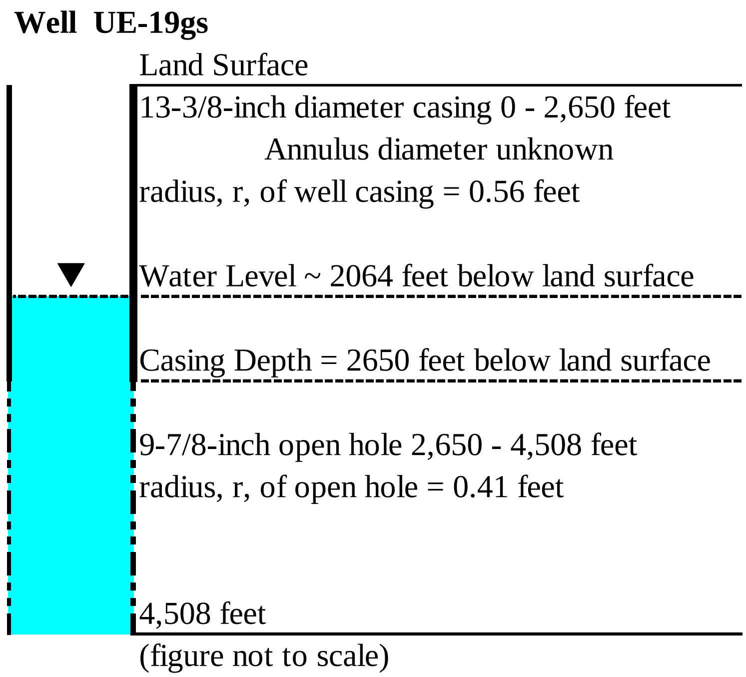

Figure 2 Construction of well UE-19gs at time of March 26-27, 1965, aquifer test.

HYDROGEOLOGIC CHARACTERISTICS

Belcher and Elliott (2001) report well UE-19gs was completed in comendite lava flows, ash-flow tuff, and bedded tuff of the Belted Range Group/Dead Horse Flat Formation. Orkild and Jenkins, (1978, p. 37-38) present a detailed description of rock type and stratigraphic units for well UE-19gs (table 1).

Table 1 Rock type in well UE-19gs from 0 to 4,580 feet below land surface (adapted from Orkild and Jenkins (1978, p. 37-38)

Depth interval, in feet below land surface	Rock type
0 - 180	Partially welded ash-flow tuff
180 - 839	Partially to densely welded ash-flow tuff
839 - 1,480	Vitric to zeolitized bedded tuff
1,480 - 1,770	Partially welded ash-flow tuff
1,770 - 2,020	Zeolitized nonwelded ash-flow tuff and tuffaceous sandstone
2,020 - 2,120	Zeolitized tuffaceous siltstone and reworked pumiceous ash-fall tuff
2,120 - 2,250	Andesitic lava flow
2,250 - 2,680	Zeolitized nonwelded lithic-rich ash-flow tuff
2,680 - 2,920	Rhyolitic lava flow (phenocryst rich)
2,920 - 2,990	Densely welded ash-flow tuff
2,990 - 3,054	Zeolitized nonwelded to partially welded ash-flow tuff
3,054 - 3,075	Zeolitized bedded tuff
3,075 - 3,700	Rhyolitic lava flow (phenocryst rich)
3,700 - 3,760	Zeolitized nonwelded lithic-rich ash-flow tuff
3,760 - 3,770	Rhyolitic lava flow (vitrophyre)
3,770 - 3,955	Rhyolitic lava flow (phenocryst poor)
3,955 - 4,085	Nonwelded to moderately welded ash-flow tuff
4,085 - 4,290	Rhyolitic lava flow
4,290 - 4,310	Zeolitized nonwelded lithic-rich ash-flow tuff
4,310 - 4,580	Partially to moderately welded ash-flow tuff

COOPER-JACOB ANALYSIS

The Cooper-Jacob method (Cooper and Jacob, 1946), commonly referred to as the straight-line method, is a simplification of the Theis (1935) solution for flow to a fully penetrating well in a confined aquifer. Using the Cooper-Jacob method, a transmissivity was estimated to be 2,500 ft^2/d by fitting a straight line to late-time drawdown data (fig. 3).

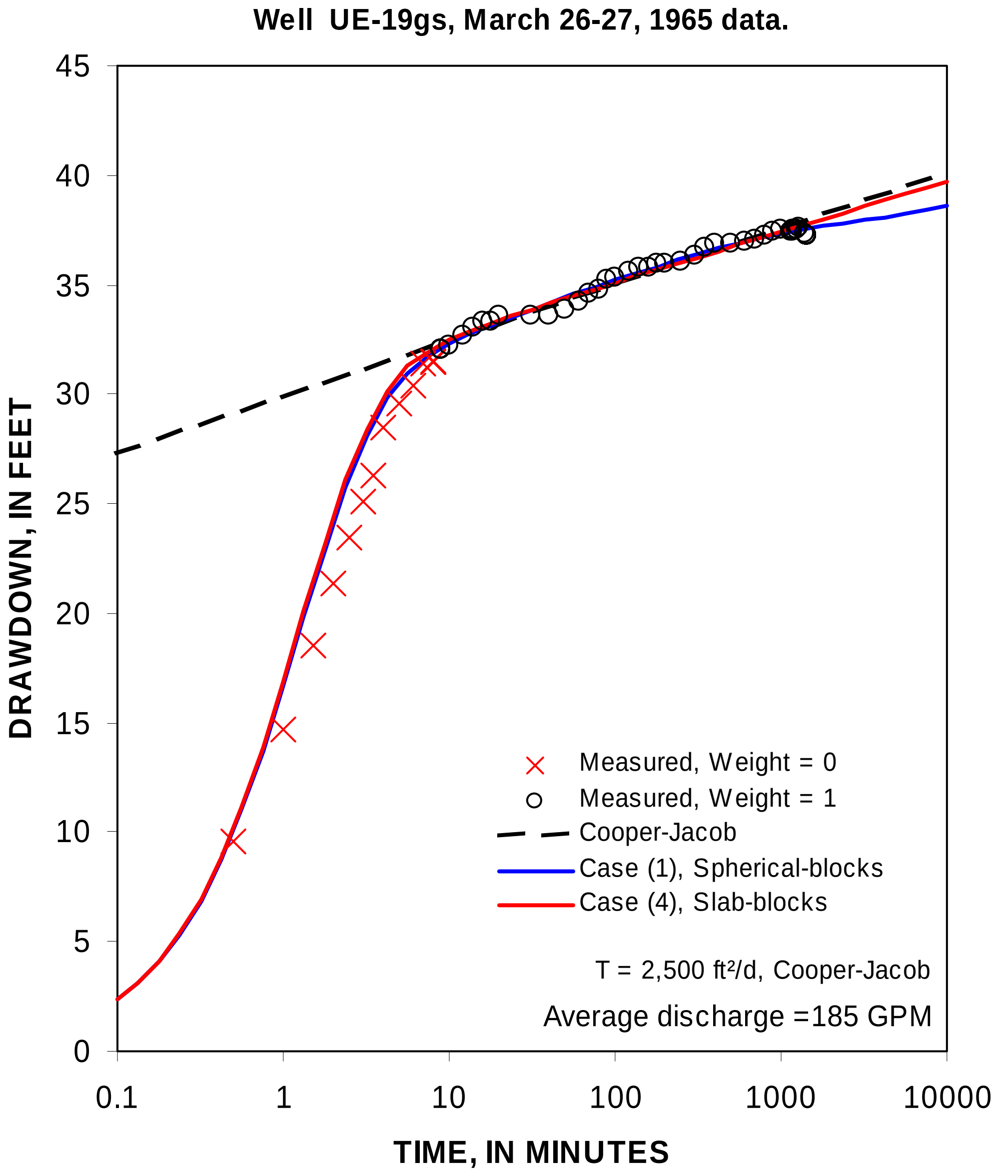

Figure 3 Measured, straight-line approximation, case (1) simulated, and case (4) simulated drawdowns for March 26 – 27, 1965, aquifer test conducted at well UE-19gs.

MOENCH ANALYSIS

General assumptions about aquifer geometry and hydraulic properties are similar for the Theis and Moench solutions. Common assumptions for both solutions are that aquifers are laterally infinite, have homogeneous and isotropic transmissivities, and are bounded by impermeable confining units. Production and observation wells are assumed to be fully penetrating so that all flow is horizontal. Transmissivity (T) and storage (S) are the same parameters in both solutions.

The Theis and Moench solutions differ in how the release of water from storage is simulated. Water is supplied from aquifer and water compressibility in the Theis solution, which is defined by a single parameter (S). Fractures and blocks of unfractured matrix provide two sources of water in the Moench solution. The first source is from fractures, which contribute water from aquifer and water compressibility in direct proportion to drawdown as defined by a single storage term (S). The second source of water is from the blocks of unfractured matrix that can release water at highly variable rates because the blocks are simulated as one-dimensional aquifers. The blocks of unfractured matrix are characterized by four parameters; slab thickness (2b'), (b' in table 2), fracture skin (Sf), matrix hydraulic conductivity (K'), and matrix specific storage (Ss') (fig. 4). The fracture network also can be conceptualized as spheres instead of slabs in the Moench solution where 2b' defines sphere diameter instead of slab thickness.

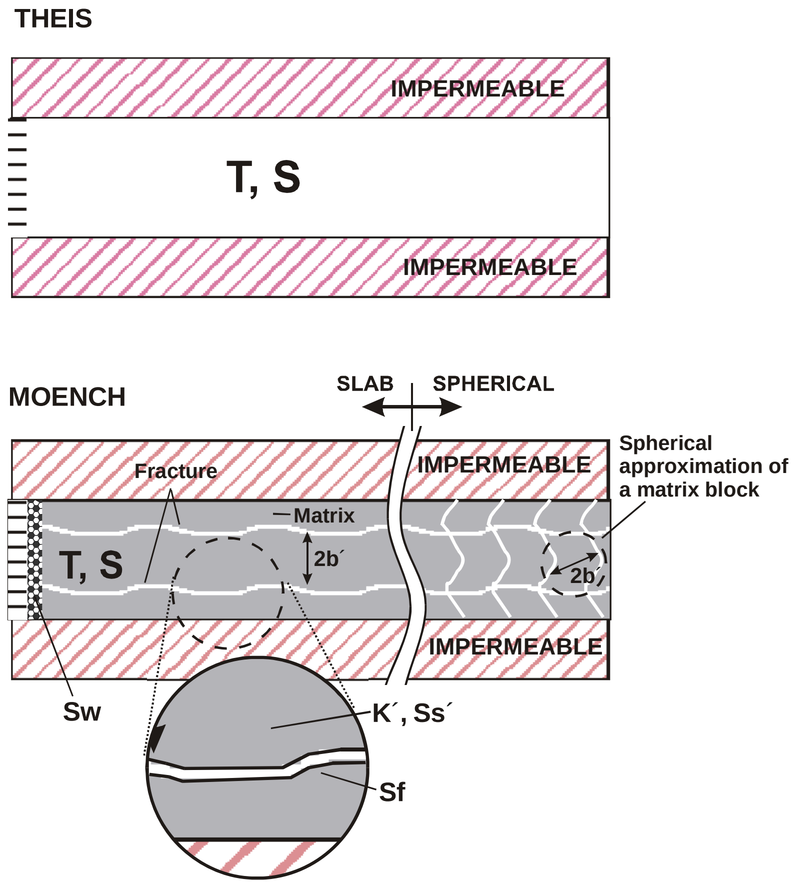

Figure 4 Schematic diagrams of Theis and Moench aquifers.

The range of hydraulic properties that is expected for matrix blocks or slabs is dependent on how the dual-porosity system is conceptualized. Fracture intervals in welded tuffs that are predominantly vertical and recur in intervals of 10 ft or less suggest a spherical approximation of matrix blocks is reasonable. Matrix permeability would be similar to estimates from cores and would have a relatively limited range of expected values if the dual-porosity system were pictured as spheres. Flow logging and packer testing in wells at the Nevada Test Site suggest volcanic interbeds that recur in intervals of 100 to 1,000 ft are the primary permeable zones. This would suggest that the dual-porosity system could be conceptualized as slabs of 100 to 1,000 ft thick. Matrix permeability in the slab conceptualization could be much greater than estimates from cores because the 'matrix' also would be fractured, albeit less well connected than the interbeds.

Multiple conceptualizations of the dual-porosity system around well UE-19gs were tested to determine the uniqueness of hydraulic property estimates. Hydraulic properties were estimated by minimizing the sum-of-squares difference between simulated and observed drawdowns after the first 8 minutes of pumping. Drawdowns from the first 8 minutes of pumping were not used because wellbore storage greatly affected these measurements.

Aquifer geometry was specified and all hydraulic properties except for transmissivity were constrained to reasonable ranges (table 2). Matrix blocks were assumed to have 10-ft diameters for the spherical solutions. Matrix blocks were assumed to have 500-ft thickness for the slab solutions. Matrix specific storage coefficients were limited to range from 10^{-7} to 10^{-5} ft^{-1}. Matrix hydraulic conductivities were limited to range from 10^{-5} to 0.1 ft/d. The skin terms Sf and Sw were estimated, but were constrained to range from 0 to 100.

Estimates of S, b', Sf, K', and Ss' were not unique (table 2). Final estimates of the parameters that were estimated were highly dependent on initial estimates, except for transmissivity. Case 1 and case 4 had RMS errors of 0.21 to 0.26 ft, respectively, which spans the range of RMS errors for all cases that were tested (table 2). Simulated drawdowns from all cases described the observed drawdowns equally well (fig. 3). Although some simulated drawdowns differed significantly for times later than when measurements existed.

Table 2 Parameter estimates and fitting error for multiple Moench solutions to the observed drawdowns in well UE-19gs.

[Aqufer thickness is 1,858 feet. A total of 37 points were used in the analyses. b' is slab thickness or sphere diameter. K is aquifer hydraulic conductivity. Ss is specific storage of fractures. K' is matrix hydraulic conductivity. Sw is wellbore skin. Sf is fracture skin. T is aquifer transmissivity. S is storage coefficient of aquifer. RMS is Root Mean Square.]

Hydraulic Property	**CASE**							
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Slab Geometry[†]	Spherical	Spherical	Slab	Slab	Slab	Slab	Slab	Spherical
Slab, (b'), ft	10 [a]	10 [a]	500 [a]	500 [a]	500 [a]	500 [a]	500 [a]	10 [a]
K, ft/d	1.33	1.56	1.52	1.52	1.32	1.31	1.35 [a]	1.35 [a]
Ss, 1/ft	3.4E-07	2.9E-08	6.8E-07	2.6E-06	1.2E-09	9.8E-07	1.1E-05	7.4E-06
K', ft/d	1.0E-5 [a]	1.0E-1 [a]	1.0E-5 [a]	1.0E-1 [a]	1.0E-5 [a]	1.0E-1 [a]	1.0E-01	7.7E-05
Ss', 1/ft=	2.0E-6 [a]	2.0E-6 [a]	1.0E-7 [a]	1.0E-7 [a]	1.0E-5 [a]	1.0E-5 [a]	1.0E-05	1.0E-05
Sw	7.9	11.2	10.2	10.9	5.0	8.2	9.8	9.6
Sf	3.8	0.0	0.0	0.0	0.1	1.4	0.0	1.2
T, ft^2/d	**2,500**	**2,900**	**2,800**	**2,800**	**2,500**	**2,400**	**2,500 [a]**	**2,500 [a]**
S	6.E-04	5.E-05	1.E-03	5.E-03	2.E-06	2.E-03	2.E-02	1.E-02
RMS error, ft	0.21	0.26	0.25	0.26	0.21	0.21	0.26	0.22

[†] Geometry of matrix in Moench solution which is either slab or sperical.

[a] Values were specified.

CONCLUSIONS

Transmissivity could be reliably estimated around well UE-19gs with either Cooper-Jacob or a Moench solution from aquifer-test results. Estimates of transmissivity determined for this report using the Cooper-Jacob solution were not improved by using the Moench solution. The best estimate of transmissivity is considered to be 2,500 ft^2/d, but reasonable matches between simulated and measured drawdowns were observed for transmissivity estimates that ranged from 2,400 to 2,900 ft^2/d.

Final estimates of parameters b', S, Ss, K', Ss', and Sf were dependent on initial estimates and could not be estimated uniquely. Estimates of matrix hydraulic conductivity (K') and fracture skin (Sf) could range over more than four orders of magnitude for models that matched the observed drawdowns equally well.

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APPENDIX A –TIME/WATER LEVEL/DRAWDOWN RECORDS

Well UE-19gs, March 26-27, 1965, time/drawdown data.
Source of data, (Blankennagel and Weir, 1965, page 14, table 5).

DATE TIME	DEPTH TO WATER, IN FEET	ELAPSED TIME, IN MINUTES	DRAWDOWN, IN FEET
03/26/65 15:36:00	2063.80	0.00	0.00
03/26/65 15:36:30	2073.40	0.50	9.60
03/26/65 15:37:00	2078.50	1.00	14.70
03/26/65 15:37:30	2082.30	1.50	18.50
03/26/65 15:38:00	2085.20	2.00	21.40
03/26/65 15:38:30	2087.30	2.50	23.50
03/26/65 15:39:00	2088.90	3.00	25.10
03/26/65 15:39:30	2090.10	3.50	26.30
03/26/65 15:40:00	2092.30	4.00	28.50
03/26/65 15:41:00	2093.40	5.00	29.60
03/26/65 15:42:00	2094.20	6.00	30.40
03/26/65 15:43:00	2095.20	7.00	31.40
03/26/65 15:44:00	2095.30	8.00	31.50
03/26/65 15:45:00	2095.80	9.00	32.00
03/26/65 15:46:00	2096.00	10.00	32.20
03/26/65 15:48:00	2096.50	12.00	32.70
03/26/65 15:50:00	2096.80	14.00	33.00
03/26/65 15:52:00	2097.10	16.00	33.30
03/26/65 15:54:00	2097.10	18.00	33.30
03/26/65 15:56:00	2097.40	20.00	33.60
03/26/65 16:07:00	2097.40	31.00	33.60
03/26/65 16:16:00	2097.40	40.00	33.60
03/26/65 16:26:00	2097.70	50.00	33.90
03/26/65 16:36:00	2098.00	60.00	34.20
03/26/65 16:46:00	2098.40	70.00	34.60
03/26/65 16:56:00	2098.60	80.00	34.80
03/26/65 17:06:00	2099.00	90.00	35.20
03/26/65 17:16:00	2099.10	100.00	35.30
03/26/65 17:36:00	2099.40	120.00	35.60
03/26/65 17:56:00	2099.60	140.00	35.80
03/26/65 18:16:00	2099.60	160.00	35.80
03/26/65 18:36:00	2099.80	180.00	36.00
03/26/65 18:56:00	2099.80	200.00	36.00
03/26/65 19:46:00	2099.86	250.00	36.06
03/26/65 20:36:00	2100.09	300.00	36.29
03/26/65 21:26:00	2100.45	350.00	36.65
03/26/65 22:16:00	2100.72	400.00	36.92
03/26/65 23:56:00	2100.72	500.00	36.92
03/27/65 01:36:00	2100.75	600.00	36.95
03/27/65 03:16:00	2100.90	700.00	37.10
03/27/65 04:56:00	2101.07	800.00	37.27
03/27/65 06:36:00	2101.20	900.00	37.40
03/27/65 08:16:00	2101.31	1000.00	37.51
03/27/65 11:00:00	2101.24	1164.00	37.44
03/27/65 11:22:00	2101.26	1186.00	37.46
03/27/65 11:32:00	2101.29	1196.00	37.49
03/27/65 12:21:00	2101.31	1245.00	37.51
03/27/65 13:06:00	2101.41	1290.00	37.61
03/27/65 14:51:00	2101.14	1395.00	37.34
03/27/65 15:36:00	2101.01	1440.00	37.21

FIGURES

TABLES

APPENDIX A - TIME/WATER LEVEL/DRAWDOWN RECORDS
Well UE-19gs, March 26-27, 1965, time/drawdown data.

Additional information:

1. Semi-log plot with Cooper-Jacob straight line shown.
2.– 9. Plots for Case 1 – 8 of table 2, with Moench double porosity curves shown.
10. CD