Aquifer-Test Report for Test Well UE-25 J-13

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INTRODUCTION

Numerous aquifer tests have been conducted in and around the Nevada Test Site. Many of these tests have been completed in a fractured rock medium. 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 fracture media, the results may be qualified because both methods were developed for 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). Based on this evaluation, it was 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. Well UE-25 J-13 was one of the wells selected by the USGS for reevaluation. Transmissivity in well UE-25 J-13 has been estimated to be 1,500 ft^2/d by Belcher and Elliott (2001, Appendix A, Hydraulic-Properties Database, Worksheet Tertiary Volcanics), and 9,000 ft^2/d by Winograd and Thordarson (1975, p. C35, figure 23) from an aquifer test conducted on February 18 – 22, 1964. 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-25 J-13 is located in Area 25 of the Nevada Test Site (fig. 1). On February 18, 1964, at 9:15 am (Pacific Standard Time, PST) the USGS began a single-well aquifer test on well UE-25 J-13 which lasted approximately 96 hours (pump off at 9:20 am, PST, on February 22, 1964) (Winograd, 1965, p. 14). Average discharge during the test was 697 gallons per minute.

Winograd (1965, p. 16) reported in footnote c/ that "Well 6 (UE-25 J-13) was pumped about 15 minutes immediately before start of test in order to adjust discharge rate; the pump has been off at least three days prior to this pumping period. To eliminate possible interference effects from the pumping of well J-12 (UE-25 J-12), the discharge of that well was held at 360 gpm during a 3-day period preceding the pumping of well 6 (UE-25 J-13) and also throughout

the test of well 6 (UE-25 J-13)." In footnote d/ Winograd (1965, p. 16) reported that "Average discharge was 688 gpm [3,750 m^3/day] during first 1,400 minutes of test. At 1,715 minutes, pumping rate was increased to 710-735 gpm [3,870 – 4,006 m^3/day] by unauthorized party; discharge was cut back to 696 gpm [3,794 m^3/day] by 1,960 minutes. During remainder of test the discharge remained between 696 – 700 gpm [3,794 – 3,816 m^3/day]." Because of the change in discharge rates at 1,715 minutes, in this report, time/drawdown data collected after this time were not used to estimate transmissivity. No adjustments to the drawdown data due to barometric, tidal, or temperature effects were made.

On page 5, Winograd (1965) reported that "All water-level measurements presented for test well 6 (J-13) were reported from a specified measuring point. Measurements pertaining to well construction are corrected to land surface datum. 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. Reda oil-well submersible pumps were used in all tests. In each test a positive displacement check value was place in the discharge line immediately above the pump. A second check value was usually placed several hundred feet above the pump. Discharge measurements were made using Sparling water meters."

TEST SITE

Well UE-25 J-13 is located at 36 ◦ 48’ 29” N.; 116 ◦ 23’ 41” W., in Area 25 of the Nevada Test Site (fig. 1).

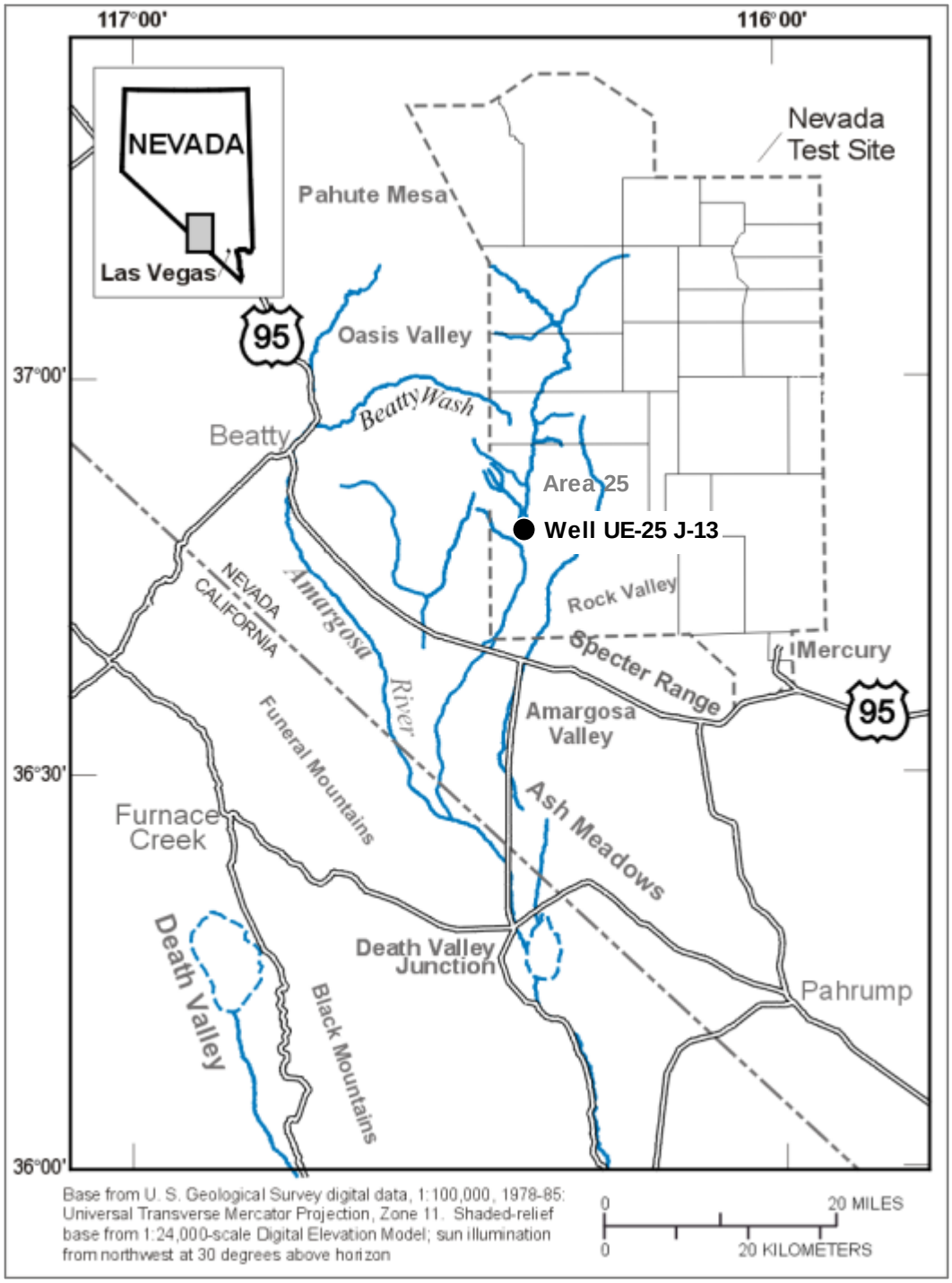

Figure 1 Location of well UE-25 J-13 on the Nevada Test Site.

CONSTRUCTION

Well UE-25 J-13 was drilled as a production well for water supply on the Nevada Test Site. The well was drilled to a depth of 3,488 feet [1,063 meters]. Drill start date was September 1962 and completion date January 1963. The borehole was completed from 0 – 1,301 feet with a 13-3/8 inch diameter casing; from 1,301 – 1,546 feet with an 11-6/8 inch diameter casing; and from 1,484 – 3,385 feet with a 5-4/8 inch diameter casing. The casing is perforated from 996 to 3,385 feet below land surface (Winograd, 1965, p. 14).

Well UE-25 J-13

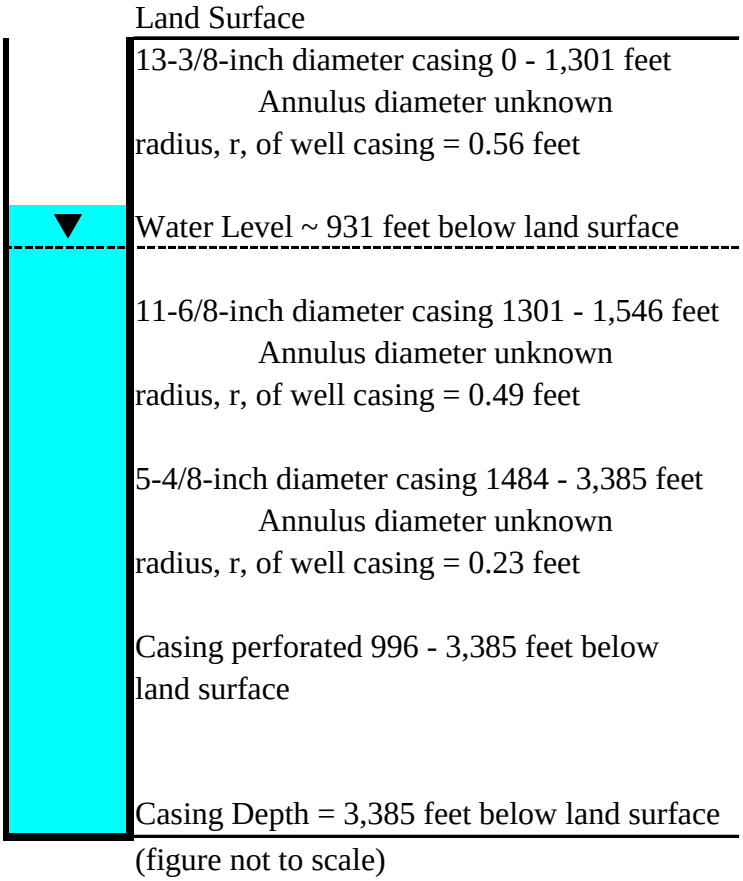

Figure 2 Construction of well UE-25 J-13.

HYDROGEOLOGIC CHARACTERISTICS

Savard (2001, p. 72) reported well UE-25 J-13 was completed in the Topopah Spring Tuff of the Paintbrush group; the Tram Tuff of the Crater Flat Group; and upper part of the Lithic Ridge 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 4,700 ft^2/d by fitting a straight line to late-time drawdown data (fig. 3). Lohman (1979, p. 22) states that the Cooper-Jacob method is only valid when the well function of u is less than or equal to 0.01 (u = r2 S/4 T t, where r = distance to observation well, S = aquifer storage, T = aquifer transmissivity and t = time of pumpage). Assuming an r of 1 foot and S of 0.001, the criteria of a value of u less than or equal to 0.01 was met after the first second of pumping.

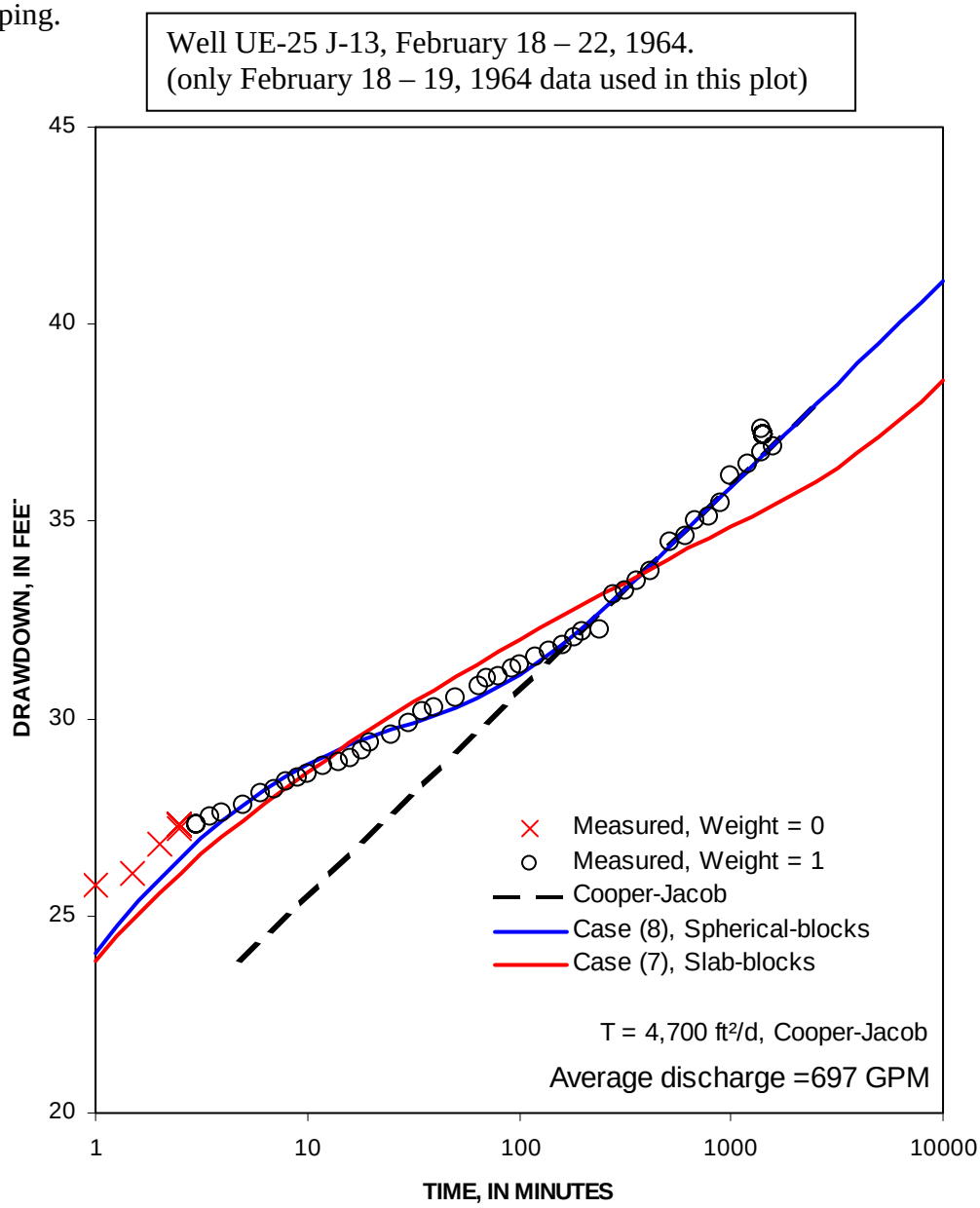

Figure 3 Measured, straight-line approximation, case (8) simulated, and case (7) simulated drawdowns for February 18 – 22, 1964, aquifer test conducted at well UE-25 J-13.

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.

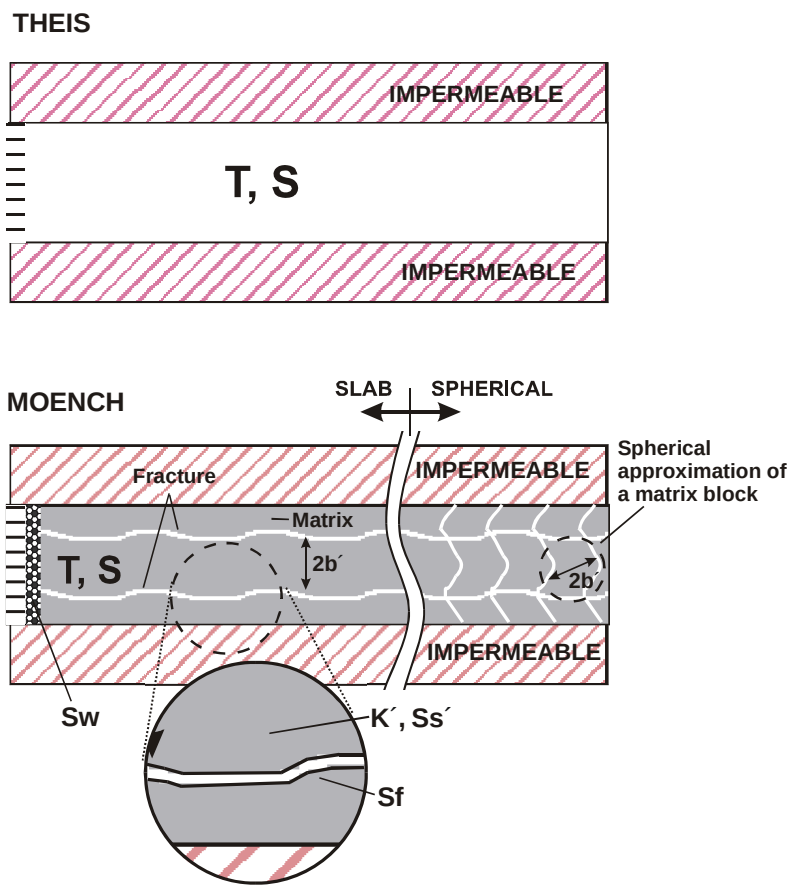

Figure 4 Schematic diagrams of Theis and Moench aquifers.

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-25 J-13 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 8 and case 7 had RMS errors of 0.21 to 0.65 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 1 Parameter estimates and fitting error for multiple Moench solutions to the observed drawdowns in well UE-25 J-13.

[Aquifer thickness is 2,389 feet. A total of 43 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	2.04	2.46	3.05	2.38	3.07	1.93	1.97 [a]	1.97 [a]
Ss, 1/ft	8.6E-08	4.6E-07	4.6E-06	1.8E-08	9.1E-06	2.6E-07	2.8E-07	1.3E-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	1.0E-01
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]	8.0E-06	9.9E-09
Sw	0.0	1.8	4.3	0.0	4.7	0.0	0.1	0.8
Sf	0.0	100.0	0.0	0.2	99.9	0.0	0.0	80.5
T, ft^2/d	**4,900**	**5,900**	**7,300**	**5,700**	**7,300**	**4,600**	**4,700 [a]**	**4,700 [a]**
S	2.E-04	1.E-03	1.E-02	4.E-05	2.E-02	6.E-04	7.E-04	3.E-03
RMS error, ft	0.43	0.30	0.49	0.23	0.49	0.64	0.65	0.21

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

[a] Values were specified.

CONCLUSIONS

Transmissivity could be reasonable estimated around well UE-25 J-13 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 significantly different from those determined by the Moench solution. The best estimate of transmissivity is considered to be 4,700 ft^2/d, but reasonable matches using the Moench solution (Cases 1, 2, 4, and 6) between simulated and measured drawdowns were observed for transmissivity estimates that ranged from 4,600 to 5,900 ft^2/d.

Due to the reported change in pumping rates at 1,715 minutes of pumping, drawdown data after 1,600 minutes of pumpage was not used in this report to estimate transmissivity. The values of transmissivity reported in this report are higher than the 1,500 ft^2/d reported by Belcher and Elliott (2001, Appendix A, Hydraulic-Properties Database, Worksheet Tertiary Volcanics), and lower than the 9,000 ft^2/d reported by Winograd and Thordarson (1975, p. C35, figure 23). This difference in transmissivity could be due to the limb of the drawdown curve used to estimate transmissivity. The value reported by Winograd and Thordarson is high because the first limb of the drawdown curve was used to estimate transmissivity, versus the second limb used for this report. If the change in pump rates at 1,715 minutes had not occurred and the third limb of the drawdown curve could be confidently identified, then the final value of transmissivity for this well could be lower than the 4,700 ft^2/d reported in this report.

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-25 J-13, February 18 - 22, 1964, time/drawdown data. Source of data, (Winograd, 1965, page 14, table I). Data after 1,600 minutes not used in this report to analyze drawdown. Appendix begins on next page.

DATE TIME	DEPTH TO WATER, IN FEET	ELAPSED TIME, IN MINUTES	DRAWDOWN, IN FEET
02/18/64 09:15:00	930.70	0.00	0.00
02/18/64 09:16:00	956.50	1.00	25.80
02/18/64 09:16:30	956.80	1.50	26.10
02/18/64 09:17:00	957.50	2.00	26.80
02/18/64 09:17:30	957.90	2.50	27.20
02/18/64 09:18:00	958.00	3.00	27.30
02/18/64 09:18:30	958.20	3.50	27.50
02/18/64 09:19:00	958.30	4.00	27.60
02/18/64 09:20:00	958.50	5.00	27.80
02/18/64 09:21:00	958.80	6.00	28.10
02/18/64 09:22:00	958.90	7.00	28.20
02/18/64 09:23:00	959.10	8.00	28.40
02/18/64 09:24:00	959.20	9.00	28.50
02/18/64 09:25:00	959.30	10.00	28.60
02/18/64 09:27:00	959.50	12.00	28.80
02/18/64 09:29:00	959.60	14.00	28.90
02/18/64 09:31:00	959.70	16.00	29.00
02/18/64 09:33:00	959.90	18.00	29.20
02/18/64 09:35:00	960.10	20.00	29.40
02/18/64 09:40:00	960.30	25.00	29.60
02/18/64 09:45:00	960.60	30.00	29.90
02/18/64 09:50:00	960.90	35.00	30.20
02/18/64 09:55:00	961.00	40.00	30.30
02/18/64 10:05:00	961.20	50.00	30.50
02/18/64 10:20:00	961.50	65.00	30.80
02/18/64 10:25:00	961.70	70.00	31.00
02/18/64 10:35:00	961.79	80.00	31.09
02/18/64 10:47:00	961.96	92.00	31.26
02/18/64 10:55:00	962.06	100.00	31.36
02/18/64 11:15:00	962.28	120.00	31.58
02/18/64 11:35:00	962.42	140.00	31.72
02/18/64 11:55:00	962.55	160.00	31.85
02/18/64 12:18:00	962.74	183.00	32.04
02/18/64 12:35:00	962.88	200.00	32.18
02/18/64 13:15:00	962.97	240.00	32.27
02/18/64 13:55:00	963.83	280.00	33.13
02/18/64 14:35:00	963.95	320.00	33.25
02/18/64 15:15:00	964.17	360.00	33.47
02/18/64 16:15:00	964.44	420.00	33.74
02/18/64 17:50:00	965.20	515.00	34.50
02/18/64 19:30:00	965.31	615.00	34.61
02/18/64 20:40:00	965.70	685.00	35.00

DATE TIME	DEPTH TO WATER, IN FEET	ELAPSED TIME, IN MINUTES	DRAWDOWN, IN FEET
02/18/64 22:20:00	965.84	785.00	35.14
02/19/64 00:15:00	966.14	900.00	35.44
02/19/64 01:55:00	966.84	1000.00	36.14
02/19/64 05:15:00	967.14	1200.00	36.44
02/19/64 08:35:00	967.43	1400.00	36.73
02/19/64 11:55:00	967.60	1600.00	36.90
02/19/64 15:30:00	969.74	1815.00	39.04
02/19/64 15:50:00	968.51	1835.00	37.81
02/19/64 16:18:00	968.51	1863.00	37.81
02/19/64 17:35:00	968.51	1940.00	37.81
02/19/64 22:40:00	969.50	2245.00	38.80
02/20/64 02:05:00	969.73	2450.00	39.03
02/20/64 07:15:00	970.25	2760.00	39.55
02/20/64 09:15:00	969.98	2880.00	39.28
02/20/64 09:40:00	970.88	2905.00	40.18
02/20/64 11:15:00	970.88	3000.00	40.18
02/20/64 14:45:00	970.91	3210.00	40.21
02/20/64 17:15:00	971.30	3360.00	40.60
02/20/64 23:35:00	971.88	3740.00	41.18
02/21/64 06:05:00	972.30	4130.00	41.60
02/21/64 09:15:00	972.18	4320.00	41.48
02/21/64 12:15:00	972.70	4500.00	42.00
02/21/64 16:30:00	972.65	4755.00	41.95
02/21/64 20:35:00	973.17	5000.00	42.47
02/22/64 04:55:00	973.80	5500.00	43.10
02/22/64 07:45:00	973.46	5670.00	42.76
02/22/64 09:20:00	970.42	5765.00	39.72