Aquifer-Test Report for Test Well MX-CE-VF-2

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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 MX-CE-VF-2 was one of the wells selected by the USGS for reevaluation. Transmissivity near well MX-CE-VF-2 has been estimated to be 2,900 ft^2/d by Belcher and Elliott (2001, Appendix A, Hydraulic-Properties Database, Worksheet UCA&LCA), from an aquifer test conducted on February 6, 1986 (Berger and others, 1988, pg. 47-55). 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

On February 6, 1986, the USGS began a single-well aquifer test on well MX-CE-VF-2 which lasted approximately 14 hours (Berger and others, 1988, p. 47-52). Well MX- CE-VF-2 is located in the Coyote Spring Valley area of southeastern Nevada (fig. 1) and is completed in the Paleozoic carbonate rock aquifer. The aquifer pumping test data was published in Berger and others, (1988, p. 47-55).

Berger and others, (1988, p. 47) reported that prior to the February 6, 1986, aquifer test, the well was developed initially during 1981 by bailing 25 bails per day for 5.5 days (16.5 gallons per bail). For the aquifer test a 20-horsepower, 6-inch-diameter submersible pump with a 3-inch-diameter discharge pipe was used. The pump intake was set at 707 feet below land surface and the discharge was piped 80 feet away from the site. The well was pumped at approximately 77 gallons per minute during the duration (14 hours) of the test. No adjustments to the drawdown data due to barometric, tidal, or temperature effects were made.

WELL LOCATION

Well MX-CE-VF-2 is located at 36 ◦ 52' 27" N.; 114 ◦ 55' 44" W., in the Coyote Spring Valley, Lincoln County, adjacent to U.S. Highway 93, approximately 4 miles north of the intersection of U.S. Highway 93 and State Route 168. The well site is east of Pahranagat Wash in Coyote Spring Valley (fig. 1).

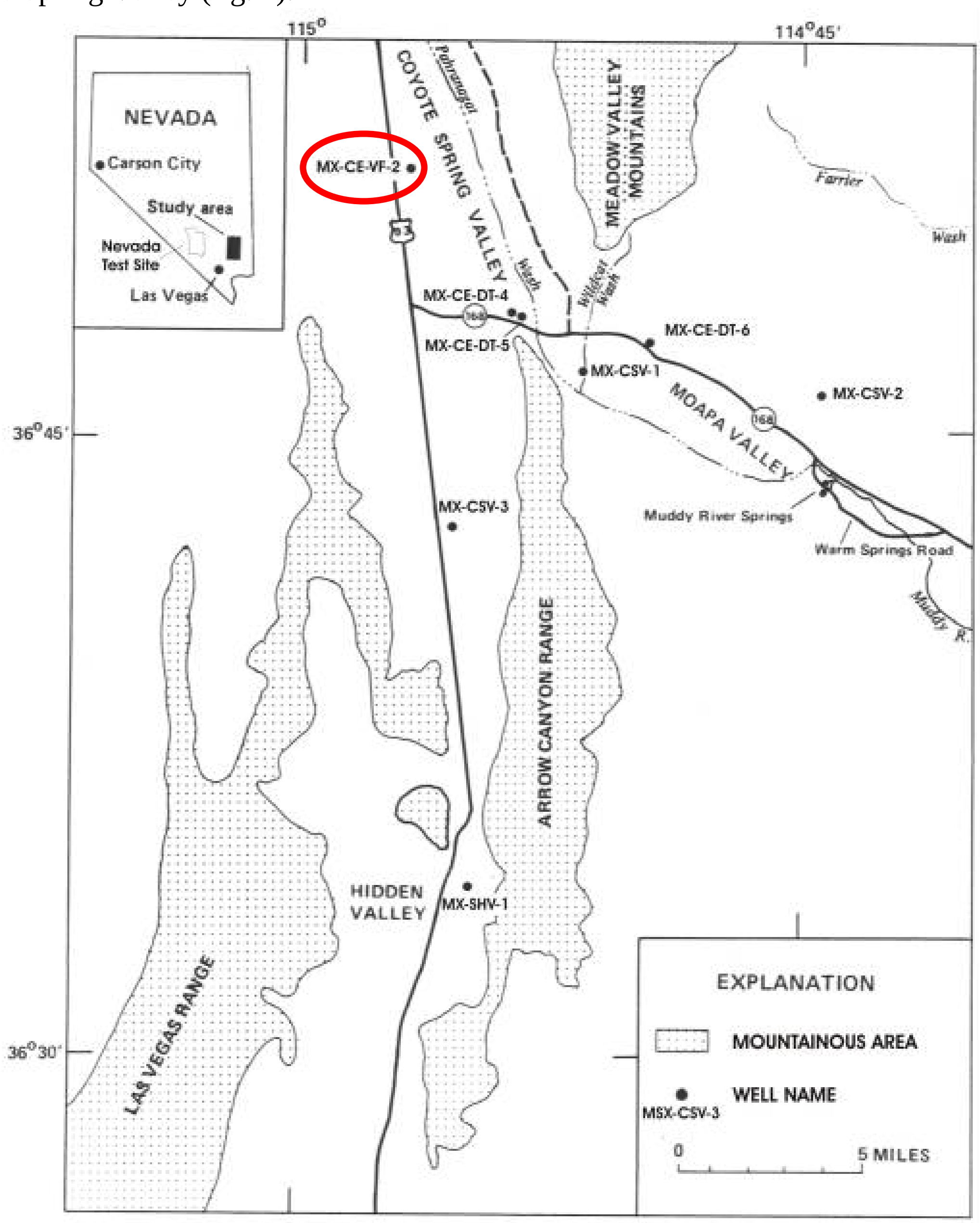

Figure 1 Location of well MX-CE-VF-2.

CONSTRUCTION

Well MX-CE-VF-2 was drilled as a test well for a hydrologic investigation for the U.S. Air Force. Drilling began on December 15, 1980, and was completed before April 1981, (exact date not known) (Berger and others, 1988, p. 47). The reported total depth of the well is 1,221 feet below land surface. The well is cased from 0 to 860 feet below land surface with 10-inch steel casing, and open hole from 860 to 1,221 feet below land surface with a 9.88-inch diameter borehole (Berger and others, 1988, pg 5, table 2). The saturated thickness of aquifer tested is approximately 361 feet (fig. 2).

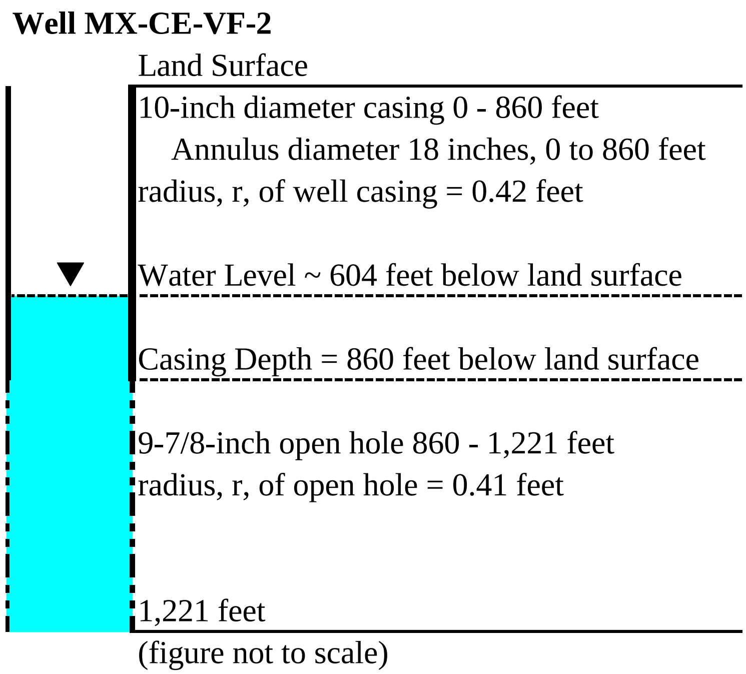

Figure 2 Construction of well MX-CE-VF-2.

HYDROGEOLOGIC CHARACTERISTICS

The saturated zone in the well is completed in alluvium and Paleozoic carbonate rock. The carbonate rock is a dolomitic limestone, gray, fine-grained, and a limey shale, gray to light gray (Berger and others, 1988, p. 48, fig. 48) (table 1).

Table 1 Rock type in well MX-CE-VF-2 from 0 to 1,221 feet below land surface

Depth interval, in feet below land surface [1/]	**Lithology**
0 - 37	Alluvium, sand (50 percent), gravel (50 percent)
37 - 79	Alluvium, clay (65 percent), sand (35 percent)
79 - 100	Alluvium, gravel (70 percent), sand (30 percent)
100 - 178	Sand
178 - 307	Sandy clay, clay (65 percent), sand (35 percent)
307 - 582	Sand
582 - 841	Alluvium, clay (65 percent), sand (25 percent), gravel (10 percent)
841 - 990	Dolomitic limestone
990 - 1,159	Limey shale
1,159 - 1,221	Dolomitic limestone

[1/] Depth interval interpolated from Berger and others (1988, p. 48, fig. 24).

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 3,100 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.

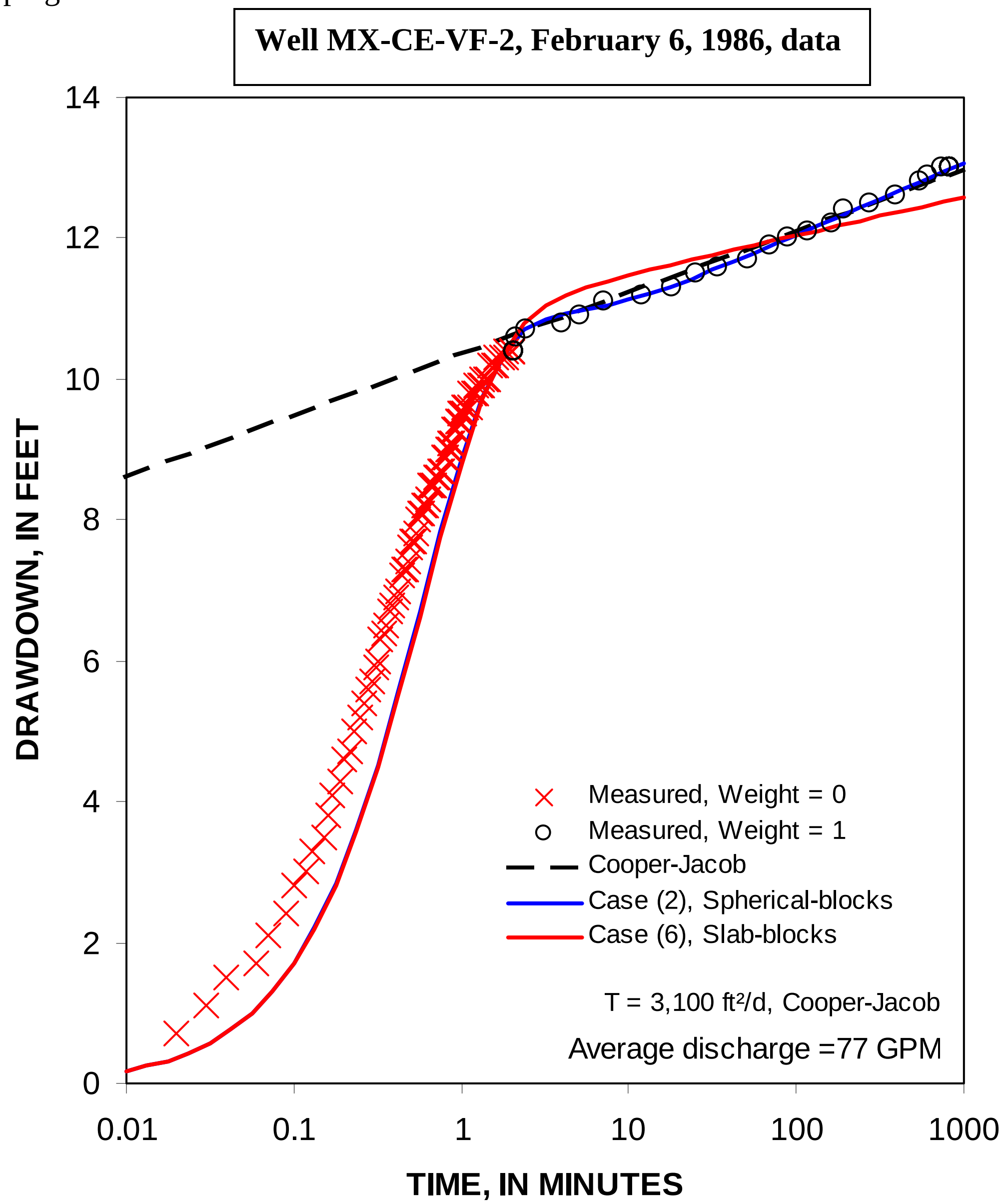

Figure 3 Measured, straight-line approximation, case (2) simulated, and case (6) simulated drawdowns for February 6, 1986, aquifer test conducted at well MX-CE-VF-2.

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.

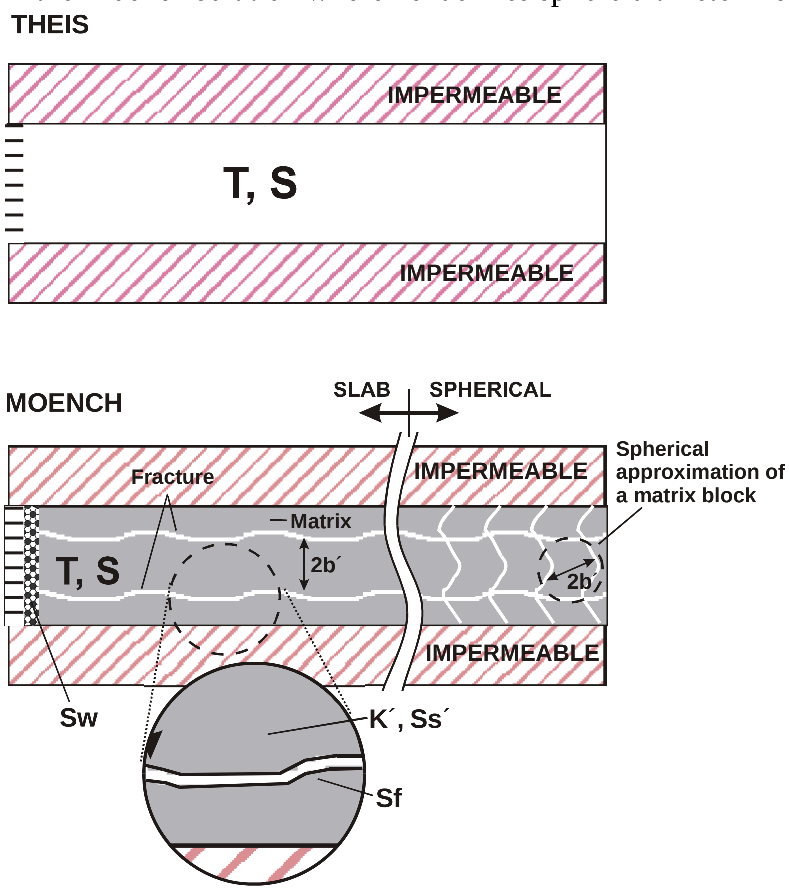

Figure 4 Schematic diagrams of Theis and Moench aquifers.

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 the dolomitic limestone that well MX-CE-VF-2 is completed in 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 suggest interbeds which could be 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 MX-CE-VF-2 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 minute of pumping. Drawdowns from the first minute 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. Because only 361 feet of saturated aquifer were tested, matrix blocks were assumed to have half the thickness (180-ft) of the aquifer tested 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 2 and case 6 had RMS errors of 0.10 to 0.22 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 MX-CE-VF-2.

[Aquifer thickness is 361 feet. A total of 45 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]	180 [a]	180 [a]	180 [a]	180 [a]	180 [a]	10 [a]
K, ft/d	8.71	7.47	11.91	7.75	10.90	13.83	8.59 [a]	8.59 [a]
Ss, 1/ft	8.8E-07	1.0E-08	1.4E-08	1.0E-08	1.0E-08	7.5E-06	1.0E-08	1.0E-08
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	1.6E-04
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]	1.7E-07	1.3E-07
Sw	8.5	6.3	11.8	5.3	9.8	18.3	7.1	7.0
Sf	0.0	44.6	100.0	0.5	100.0	100.0	0.1	0.5
T, ft^2/d	**3,100**	**2,700**	**4,300**	**2,800**	**3,900**	**5,000**	**3,100 [a]**	**3,100 [a]**
S	3.E-04	4.E-06	5.E-06	4.E-06	4.E-06	3.E-03	4.E-06	4.E-06
RMS error, ft	0.19	0.10	0.19	0.13	0.18	0.22	0.13	0.12

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

[a] Values were specified.

CONCLUSIONS

Transmissivity could be reliably estimated around well MX-CE-VF-2 with either Cooper-Jacob or a Moench solution from aquifer-test results. Estimate of transmissivity determined for this report using the Cooper-Jacob solution, 3,100 ft^2/d , was not significantly different from those determined by the Moench solution. Using the Moench solution, transmissivities of 2,700 to 5,000 ft^2/d were estimated, Cases 1- 6. If Case 6 was eliminated, then transmissivities estimates ranged from 2,700 to 4,300 ft^2/d, Cases 1 – 5. The best estimate of transmissivity around well MX-CSV-2 is considered to be 3,100 ft^2/d. This best estimate of transmissivity will be biased above the actual value if the test was of insufficient duration to reach the final limb of a dual-porosity response.

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.

REFERENCES

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APPENDIX A –TIME/WATER LEVEL/DRAWDOWN RECORDS

Well MX-CE-VF-2, February 6, 1986, time/drawdown data.

Source of data, (Berger and others, 1988, pg. 51, 52, table 12), exact time pump on not in literature.

Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet

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Source of data, (Berger and others, 1988, pg. 51, 52, table 12), exact time pump on not in literature.

Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
02/06/86	604.30	0.00	0.00
02/06/86	605.00	0.02	0.70
02/06/86	605.40	0.03	1.10
02/06/86	605.80	0.04	1.50
02/06/86	606.00	0.06	1.70
02/06/86	606.40	0.07	2.10
02/06/86	606.70	0.09	2.40
02/06/86	607.10	0.10	2.80
02/06/86	607.30	0.12	3.00
02/06/86	607.60	0.13	3.30
02/06/86	607.80	0.15	3.50
02/06/86	608.10	0.16	3.80
02/06/86	608.40	0.17	4.10
02/06/86	608.60	0.19	4.30
02/06/86	608.90	0.20	4.60
02/06/86	609.00	0.22	4.70
02/06/86	609.30	0.23	5.00
02/06/86	609.50	0.25	5.20
02/06/86	609.70	0.26	5.40
02/06/86	609.90	0.28	5.60
02/06/86	610.00	0.29	5.70
02/06/86	610.20	0.31	5.90
02/06/86	610.30	0.32	6.00
02/06/86	610.60	0.33	6.30
02/06/86	610.70	0.35	6.40
02/06/86	610.80	0.36	6.50
02/06/86	611.00	0.38	6.70
02/06/86	611.10	0.39	6.80
02/06/86	611.20	0.41	6.90
02/06/86	611.30	0.42	7.00
02/06/86	611.50	0.44	7.20
02/06/86	611.60	0.45	7.30
02/06/86	611.60	0.47	7.30
02/06/86	611.70	0.48	7.40
02/06/86	611.90	0.50	7.60
02/06/86	612.00	0.51	7.70
02/06/86	612.00	0.52	7.70
02/06/86	612.10	0.54	7.80
02/06/86	612.30	0.55	8.00

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Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
02/06/86	612.40	0.57	8.10
02/06/86	612.40	0.58	8.10
02/06/86	612.50	0.60	8.20
02/06/86	612.50	0.61	8.20
02/06/86	612.60	0.63	8.30
02/06/86	612.60	0.64	8.30
02/06/86	612.80	0.66	8.50
02/06/86	612.80	0.67	8.50
02/06/86	612.80	0.69	8.50
02/06/86	612.90	0.70	8.60
02/06/86	612.90	0.71	8.60
02/06/86	612.90	0.73	8.60
02/06/86	613.00	0.74	8.70
02/06/86	613.00	0.76	8.70
02/06/86	613.00	0.77	8.70
02/06/86	613.20	0.79	8.90
02/06/86	613.20	0.80	8.90
02/06/86	613.20	0.82	8.90
02/06/86	613.30	0.83	9.00
02/06/86	613.30	0.85	9.00
02/06/86	613.40	0.86	9.10
02/06/86	613.40	0.88	9.10
02/06/86	613.40	0.89	9.10
02/06/86	613.60	0.90	9.30
02/06/86	613.60	0.92	9.30
02/06/86	613.60	0.93	9.30
02/06/86	613.70	0.95	9.40
02/06/86	613.70	0.96	9.40
02/06/86	613.70	0.98	9.40
02/06/86	613.80	0.99	9.50
02/06/86	613.80	1.01	9.50
02/06/86	613.80	1.02	9.50
02/06/86	613.80	1.04	9.50
02/06/86	613.90	1.05	9.60
02/06/86	613.90	1.08	9.60
02/06/86	613.90	1.12	9.60
02/06/86	614.10	1.14	9.80
02/06/86	614.10	1.18	9.80
02/06/86	614.10	1.21	9.80

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Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
02/06/86	614.20	1.23	9.90
02/06/86	614.20	1.28	9.90
02/06/86	614.20	1.33	9.90
02/06/86	614.30	1.34	10.00
02/06/86	614.30	1.40	10.00
02/06/86	614.30	1.46	10.00
02/06/86	614.50	1.47	10.20
02/06/86	614.50	1.55	10.20
02/06/86	614.50	1.62	10.20
02/06/86	614.60	1.63	10.30
02/06/86	614.60	1.75	10.30
02/06/86	614.60	1.85	10.30
02/06/86	614.70	1.87	10.40
02/06/86	614.70	2.00	10.40
02/06/86	614.70	2.09	10.40
02/06/86	614.90	2.10	10.60
02/06/86	615.00	2.42	10.70
02/06/86	615.10	3.99	10.80
02/06/86	615.20	5.05	10.90
02/06/86	615.40	7.07	11.10
02/06/86	615.50	12.03	11.20
02/06/86	615.60	18.01	11.30
02/06/86	615.80	25.03	11.50
02/06/86	615.90	34.04	11.60
02/06/86	616.00	52.03	11.70
02/06/86	616.20	70.05	11.90
02/06/86	616.30	89.07	12.00
02/06/86	616.40	118.01	12.10
02/06/86	616.50	163.06	12.20
02/06/86	616.70	190.08	12.40
02/06/86	616.80	272.04	12.50
02/06/86	616.90	390.03	12.60
02/06/86	617.10	545.05	12.80
02/06/86	617.20	616.07	12.90
02/06/86	617.30	741.00	13.00
02/06/86	617.30	819.00	13.00