HYDRAULIC TESTING AT THE WHITE MESA URANIUM MILL NEAR BLANDING, UTAH DURING JULY 2002

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August 22, 2002

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Environmental Science & Technology

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1. INTRODUCTION

This report describes the methods and presents the results of the interpretation of hydraulic tests conducted at the White Mesa Mill Site during the week of July 8, 2002. Field tests and data collection efforts were conducted by Hydro Geo Chem, Inc. (HGC) with assistance from International Uranium (USA) Corporation (IUSA). Mr. Loren Morton of the Utah Department of Environmental Quality (UDEQ) was on-site during the week of July 8, 2002, and observed some of the testing. The tested wells consisted of permanent perched zone monitoring wells MW-01, MW-03, MW-05, MW-17, MW-18, MW-19, MW-20, and MW-22. Although MW-16 was proposed to be tested in the workplan (HGC, 2002) this well was not tested because it was dry. Figure 1 is a map showing the locations of the wells. The tested wells provide good areal coverage over the site.

The proposed testing detailed in the workplan (HGC, 2002) included a pumping/recovery test at each well using IUSA's portable piston pump and a system that would continuously recirculate most of the pumped water back into the well to achieve very low net discharge rates. This method was to be employed in an attempt to limit the rate of drawdown in the wells, which are all completed in the low permeability perched zone at the site. The perched zone is hosted by the Burro Canyon sandstone and underlain by the Brushy Basin member of the Morrison Formation. Because the procedure to achieve very low discharge rates did not work well in practice, slug tests were instead

conducted at all wells except MW-01, where a pumping/recovery test was performed at a relatively high average pumping rate of approximately 1.5 gpm. All tests yielded easily interpretable data.

2. DATA COLLECTION METHODS

Water level data during all tests were collected using a GeoKon data logger and submersible pressure transducer. When possible, data were also collected by hand using a hand-held electric water level meter. In all tests, the static water level was first measured using the electric water level meter. Water level readings were recorded at approximately 5-second intervals using the data logger, and periodically by hand using the electric water level meter. Hand measurements were taken more rapidly at first (several per minute), then more slowly as water level changes occurred more slowly. These data were used as a backup to and check on the automatically logged data. Water level measurements by hand were not collected at MW-03, or during the early portion of the test at MW-05 (as discussed in Section 2.1).

Methods specific to the performance of slug tests at MW-03, MW-05, MW-17, MW-18, MW-19, MW-20, and MW-22 are described in Section 2.1. Methods specific to the performance of the pumping/recovery test at MW-01 are described in Section 2.2.

2.1 Slug Tests

Slug tests were performed using "slugs" made of Schedule 80 PVC pipe filled with clean pea gravel and capped to form a watertight seal. An approximately 2-inch ID, 3-foot long "slug" was used in all 4-inch diameter wells (all wells except MW-03), and an approximately 1¼-inch ID, 4-foot

long "slug" was used in MW-03, which has a casing diameter of approximately 3 inches. Based on measurement of the slug outer dimensions (including endcaps), the larger diameter "slug" displaced approximately 0.75 gallons, and the smaller diameter "slug" approximately 0.47 gallons. (Note that Schedule 80 PVC has a rather larger outer diameter than inner diameter.)

In conducting the slug tests, the pressure transducer was lowered to a depth approximately 10 feet or more below the static water level and pressure readings were allowed to stabilize prior to beginning each test. Once pressure readings had stabilized, the "slug" was lowered to just above the static water level, the electric water level meter probe was lowered (when possible) to just above the static water level, then the slug was lowered as smoothly as possible into the water within a few seconds.

Because the electric water level meter probe could not be lowered into the well casing to a depth just above the static water level due to the presence of the slug waiting to be lowered into the water column, hand measurements of water levels were not collected during the test at MW-03 or during the early portion of the test at MW-05.

2.2 Pumping/Recovery Test

Water level data were also collected using the data logger and pressure transducer at MW-01 during the pumping/recovery test. The pressure transducer was lowered to a depth of approximately

105 feet below the top of the casing (ft btoc) after the pump had been lowered to approximately 110 ft btoc. IUSA's portable piston pump was used. Once pressure readings had stabilized, the test began. Attempts to achieve a smooth net discharge rate using the proposed low net discharge methodology (HGC, 2002) were unsuccessful and, after approximately 1½ liters of water were removed, the test was stopped, the well allowed to recover for approximately 20 minutes, then pumped at approximately 1.5 gallons per minute (gpm) until water levels had dropped approximately 23 feet, which occurred in less than 5½ minutes. Twenty-three feet of drawdown represented approximately 58% of the initial water column in the well (and approximately 58% of the initial saturated thickness) and brought the water levels approximately 3 feet below the top of the well screen. The recovery of water levels was then measured using the data logger and by hand using the electric water level meter. The pressure transducer and logger were removed after approximately 3 hours, but the pump assembly was allowed to remain in the well until the following day. Prior to removing the pump, a final water level was obtained to complete the test. Water levels had only recovered approximately 80% at the time the final reading was taken the following day.

3. DATA ANALYSIS

Data were analyzed using WHIP (HGC, 1988), a well hydraulics interpretation program developed and marketed by HGC, and using AQTESOLV (HydroSOLVE, 2000), a program developed and marketed by HydroSOLVE, Inc. Both are commercially available packages. In preparing the data for analysis, the total number of records was reduced. In general, all data collected in the first 30 seconds to 1 minute were used, then every 2nd, then 3rd, then 4th, etc., record was retained for analysis. The last data point for the MW-01 test, and the last 6 data points for the MW-05 test were collected by hand using the electric water level meter. Drawdowns (or displacements) were calculated based on the last water level recorded immediately prior to the start of each test.

The "homogenous aquifer" solution was used in analyzing all the tests by WHIP. This solution assumes a fully penetrating well and accounts for well bore storage and any leakage or skin effects. In analyzing slug tests, WHIP treats the introduction of a slug as a high pumping (or injection) rate over a short period of time. The introduction of the slug was assumed to occur over a 5-second interval. This provided a numerically stable solution for all the analyses. To achieve a conservatively high estimate of permeability, in all cases in which the well was partially penetrating (static water levels were above the effective screened interval), the effective top of the water bearing zone was assumed to be no shallower than the top of the effective screened interval. The base of the water bearing zone was always assumed to coincide with the Brushy Basin contact.

In each case, WHIP was allowed to optimize for Transmissivity (T), storage coefficient (S), and effective casing radius (R_e). The effective casing radius is affected by both the casing diameter and borehole diameter, and the presence or absence of a filter pack. The pumping/recovery test at MW-01 was also analyzed using the confined and unconfined Moench solutions (Moench, 1985 and Moench, 1997), available in AQTESOLV. The confined Moench solution ("leaky" solution) is similar to the "homogenous aquifer" solution used in WHIP. The AQTESOLV Moench solution was also used to analyze the MW-19 slug test data for comparison to the WHIP results.

All slug tests were also analyzed using the KGS solution (Hyder 1994) and the Bouwer-Rice solutions (Bouwer and Rice, 1976) available in AQTESOLV. Confined and unconfined versions of the solutions were used in some cases for comparison. Well construction parameters were based on available well construction diagrams. When filter pack porosities were required by the analytical method, a porosity of 30% was assumed when a filter pack was present, and a porosity of 99% for an open annular space (as specified at MW-03 and MW-05). In each case, the software was at least initially allowed to optimize for the best fit to the data. Because the Bouwer-Rice solution is only valid for data that forms a straight line on a log of displacement versus time plot, fits were obtained only for straight-line portions of the data. Also, in using Bouwer-Rice, the correction for a partially submerged well screen was used at MW-03 and MW-05 because the initial water levels were below the top of the screen in these wells. Whether or not this was also appropriate at MW-20 and MW-22 is uncertain, because although the initial water level was above the top of the screen, it was below

the bore annular seal. Solutions were therefore obtained with and without the correction at these locations.

In all cases except when using the Moench, KGS, and Bouwer-Rice unconfined solutions, the effective water bearing zone thickness was taken to be the interval between the static water level and the Brushy Basin formation contact, or, if static water levels were above the well bore annular seal, the depth of the base of the bore seal was assumed to be the top of the water bearing zone. In using the unconfined solutions, which account for partial penetration, the effective water bearing zone was assumed to extend from the static water level to the Brushy Basin contact.

The effective screen length was assumed to extend from the Brushy Basin contact to the base of the bore seal (Fetter, 2001). This is appropriate, because in a low permeability formation, the annular space between the bore seal and the top of the screen does not significantly limit horizontal flow from the formation into the borehole and thence into the well casing, even if a filter pack is present. Although water entering the borehole below the seal but above the screen cannot enter the screen directly via a horizontal pathway, it can flow vertically downward within the filter pack in the annular space to the screen. Because the filter pack has a high permeability relative to the formation, it does not provide a significant barrier to flow. In cases where the well screen was only partially submerged, the screen was treated as fully penetrating.

All solutions used in the analyses assume a homogenous aquifer of uniform thickness and infinite areal extent, and an initially horizontal potentiometric surface. The Moench solutions, the homogenous aquifer solution in WHIP, and the KGS solution assume unsteady flow, and the Bouwer-Rice solution assumes steady flow to (or from) the well. When using the Moench leaky aquifer (confined) solution and the WHIP "homogenous aquifer" solution, leakage was assumed to be zero. When using the Moench unconfined solution, delayed yield was assumed to be insignificant. This was appropriate because no evidence for delayed yield was present at MW-01 and it is generally not a factor when analyzing slug tests.

4. RESULTS

The results of the analyses are summarized in Table 1 and the well construction parameters, based on the available well construction diagrams, in Table 2. Plots of the fits obtained to the measured data using WHIP are provided in Figures 2 through 11. Plots of the fits obtained using AQTESOLV are provided in Appendix A. Note that in the plots of the WHIP slug test analyses, drawdowns are negative indicating a rise in water levels due to introduction of the slug.

As shown in Table 1, permeability estimates range between approximately 4×10^{-7} and 5×10^{-4} centimeters per second (cm/s), similar to estimates by previous investigators at the site. Furthermore, similar permeabilities are obtained using the various solution methods except that a much lower permeability was obtained at MW-03 using the KGS solution compared to the other solution methods. A reasonable fit to the data at MW-20 using KGS could not be obtained. A noticeable break in slope occurs in the late-time MW-05 data, and a Bouwer–Rice fit to the late time data yields approximately an order of magnitude lower permeability than the fit to the early time data. The permeability estimate obtained using WHIP at MW-05 was between the early and late time Bouwer-Rice estimates. Possible well skin effects were noted at MW-18 and MW-19 (using WHIP), and solutions both with and without a skin were obtained. When assuming a skin at MW-18, a storage coefficient that is more consistent with an unconfined formation is obtained, however, a poorer fit to the data was obtained when assuming a skin (compare Figures 6 and 7).

At MW-19, both confined and unconfined Moench, KGS, and Bouwer-Rice solution methods were used for comparison. As shown in Table 1, similar permeabilities are obtained when assuming either confined or unconfined conditions. In using the KGS solution to analyze the data at MW-19, the first data point was ignored, otherwise a reasonable fit to the data could not be achieved. The first data point may be anomalous, most likely due to a too rapid initial drop of the slug in the well.

Data collected by hand using the electric water level meter at MW-05, MW-17, MW-18, MW-19, MW-20, and MW-22 were independently analyzed using AQTESOLV. WHIP was also used to analyze the hand-collected recovery data at MW-01. The results of these analyses are provided in Appendix B. Table 3 is a comparison of the permeability results obtained by analyzing the hand-collected data with those listed in Table 1. As indicated, very similar permeabilities were obtained when analyzing the hand-collected data. Although the automatically logged data are considered more reliable, the analyses of the hand-collected data provide an independent check of the automatically logged data, and increase the confidence that can be placed in the results of the analyses.

5. CONCLUSIONS

The results of hydraulic testing of monitoring wells MW-01, MW-03, MW-05, MW-17, MW-18, MW-19, MW-20, and MW-22 during the week of July 8, 2002, indicate that average permeabilities in the perched water zone range from approximately 8×10^{-7} to 5×10^{-4} cm/s (disregarding the value of 4×10^{-7} cm/s obtained using the KGS solution at MW-03 as anomalously low). This range is similar to the results obtained by previous investigators at the site. Similar results were obtained in the present investigation by using 4 different solution methods to analyze the data and using two different sets of data (automatically logged and hand-collected data).

6. REFERENCES

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TABLES

TABLE 1
Hydraulic Test Analysis Results

Well	Interpretation Method	Type	T (ft^2/day)	K (cm/sec)	S	b (ft)	Skin	Effective Bore Radius R_e (ft)	Time Interval	Bower-Rice Partially Submerged Screen Correction
MW-01	WHIP	pump/recovery	0.043	7.7×10^{-7}	0.0082	20	none	0.12	--	--
	AQTESOLV (Moench, Leaky)	pump/recovery	0.043	7.7×10^{-7}	0.0082	20	none	0.12	--	--
	AQTESOLV (Moench, Unconfined)	pump/recovery	0.098	8.9×10^{-7}	0.01	40	none	0.12	--	--
MW-03	WHIP	slug	0.631	4.3×10^{-5}	0.01	5.2	none	0.32	--	--
	AQTESOLV (KGS, Unconfined)	slug	--	4.0×10^{-7}	0.098 (1.92×10^{-2}/ft)	5.2	--	--	--	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	1.5×10^{-5}	--	5.2	--	--	middle to late	Yes
MW-05	WHIP	slug	0.309	1.1×10^{-5}	0.1	10	none	0.245	--	--
	AQTESOLV (KGS, Unconfined)	slug	--	3.5×10^{-6}	0.044 (4.4×10^{-3}/ft)	10	--	--	--	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	3.9×10^{-6}	--	10	--	--	late	Yes
	AQTESOLV (Bouwer-Rice, unconfined)	slug	--	2.4×10^{-5}	--	10	--	--	early	Yes
MW-17	WHIP	slug	1.47	2.9×10^{-5}	0.01	18	none	0.168	--	--
	AQTESOLV (KGS, Unconfined)	slug	--	2.6×10^{-5}	0.0031 (1.71×10^{-4}/ft)	18	--	--	--	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	2.7×10^{-5}	--	18	--	--	--	No
MW-18	WHIP	slug	55.5	4.4×10^{-4}	2.2×10^{-5}	45	none	0.16	--	--
	WHIP	slug	66	5.3×10^{-4}	0.02	45	6.54	0.167	--	--
	AQTESOLV (KGS, Unconfined)	slug	--	2.9×10^{-4}	2.7×10^{-5} (4.6×10^{-7}/ft)	58	--	--	--	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	2.4×10^{-4}	--	58	--	--	--	No

TABLE 1
Hydraulic Test Analysis Results

Well	Interpretation Method	Type	T (ft^2/day)	K (cm/sec)	S	b (ft)	Skin	Effective Bore Radius R_e (ft)	Time Interval	Bower-Rice Partially Submerged Screen Correction
MW-19	WHIP	slug	0.929	7.1×10^{-6}	0.032	47	none	0.154	--	--
	WHIP	slug	2.24	1.7×10^{-5}	0.027	47	2.24	0.167	--	--
	AQTESOLV (Moench, Leaky)	slug	2.21	1.7×10^{-5}	0.027	47	2.24	0.165	--	--
	AQTESOLV (KGS, Unconfined)	slug	--	1.7×10^{-5}	1.2×10^{-4} (1.44×10^{-6}/ft)	80	none	--	--	--
	AQTESOLV (KGS, Confined)	slug	--	1.6×10^{-5}	1.5×10^{-4} (3.24×10^{-6}/ft)	47	none	--	--	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	1.3×10^{-5}	--	80	--	--	--	No
	AQTESOLV (Bouwer-Rice, Confined)	slug	--	1.2×10^{-5}	--	47	--	--	--	No
MW-20	WHIP	slug	0.276	8.2×10^{-6}	0.02	12	none	0.213	middle to late	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	9.3×10^{-6}	--	12	--	--	middle to late	Yes
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	5.9×10^{-6}	--	12	--	--	middle to late	No
MW-22	WHIP	slug	0.603	4.2×10^{-6}	0.014	51	none	0.183	--	--
	AQTESOLV (KGS, Unconfined)	slug	--	1.0×10^{-6}	0.10 (0.002/ft)	51	--	--	--	--
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	7.9×10^{-6}	--	51	--	--	--	Yes
	AQTESOLV (Bouwer-Rice, Unconfined)	slug	--	4.4×10^{-6}	--	51	--	--	--	No

Note:

b = effective aquifer thickness

TABLE 2
Well Construction Parameters

Well	Approximate Depth to Top of Screen (feet)	Approximate Depth of Base of Screen (feet)	Approximate Depth to Base of Bore Annular Seal (feet)	Approximate Depth to Brushy Basin (feet)	Depth to Water[1] (feet bls)	Approximate Casing Diameter (inches)	Approximate Bore Diameter (inches)	Effective Screen Length (feet)	Filter Pack (yes/no)
MW-01	92	112	92?	112	71.6	3	7.875	20	No
MW-03	67	87	67	87 [2]	81.8	3	7.875	20	No
MW-05	95.5	133.5	93.5	118	107.8	4	6.5	25	No
MW-17	90	100	86	104	83.8	4	7.875	18	Yes
MW-18	103	133	94	139	81.2	4	7.875	45	Yes
MW-19	100	130	95	142	61.8	4	7.875	47	Yes
MW-20	80	90	73	90	78.1	4	7.875	17	Yes
MW-22	80	120	68	120	69.2	4	7.875	51	Yes

Notes:

[1] *Depth to water was at time of test.*

[2] *Brushy Basin contact assumed to be at base of screened interval at MW-03.*

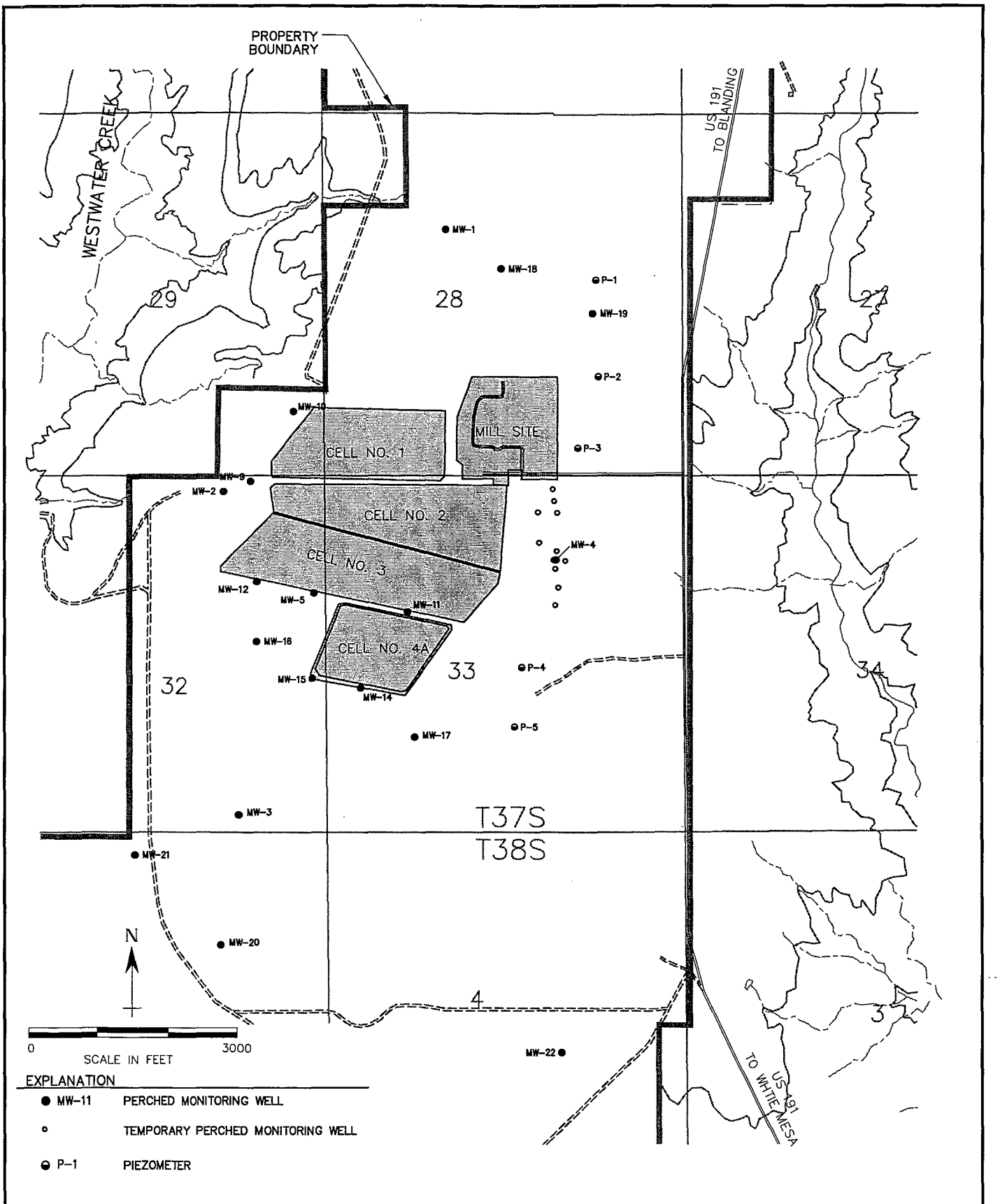
Effective screen length = distance from bore annular seal to Brushy Basin contact

TABLE 3
Comparison of Analyses Using Automatically-Logged Data to Analyses Using Data Collected by Hand

Well	Interpretation Method	K (cm/sec)	Hand Collected Data K (cm/s)	Time Interval
MW-01	WHIP	7.7×10^{-7}	7.7×10^{-7}	--
	AQTESOLV (Moench, Leaky)	7.7×10^{-7}	7.7×10^{-7}	--
MW-05	AQTESOLV (KGS, Unconfined)	3.5×10^{-6}	3.2×10^{-6}	--
	AQTESOLV (Bouwer-Rice, Unconfined)	3.9×10^{-6}	4.3×10^{-6}	Late
	AQTESOLV (Bouwer-Rice, unconfined)	2.4×10^{-5}	1.8×10^{-5}	Early
MW-17	AQTESOLV (KGS, Unconfined)	2.6×10^{-5}	2.2×10^{-5}	--
	AQTESOLV (Bouwer-Rice, Unconfined)	2.7×10^{-5}	3.0×10^{-5}	--
MW-18	AQTESOLV (KGS, Unconfined)	2.9×10^{-4}	3.2×10^{-4}	--
	AQTESOLV (Bouwer-Rice, Unconfined)	2.4×10^{-4}	2.5×10^{-4}	--
MW-19	AQTESOLV (KGS, Unconfined)	1.7×10^{-5}	1.2×10^{-5}	--
	AQTESOLV (Bouwer-Rice, Unconfined)	1.3×10^{-5}	1.5×10^{-5}	--
MW-20	*AQTESOLV (Bouwer-Rice, Unconfined)	5.9×10^{-6}	2.5×10^{-6}	--
MW-22	AQTESOLV (KGS, Unconfined)	1.0×10^{-6}	9.0×10^{-7}	--
	*AQTESOLV (Bouwer-Rice, Unconfined)	4.4×10^{-6}	3.4×10^{-6}	--

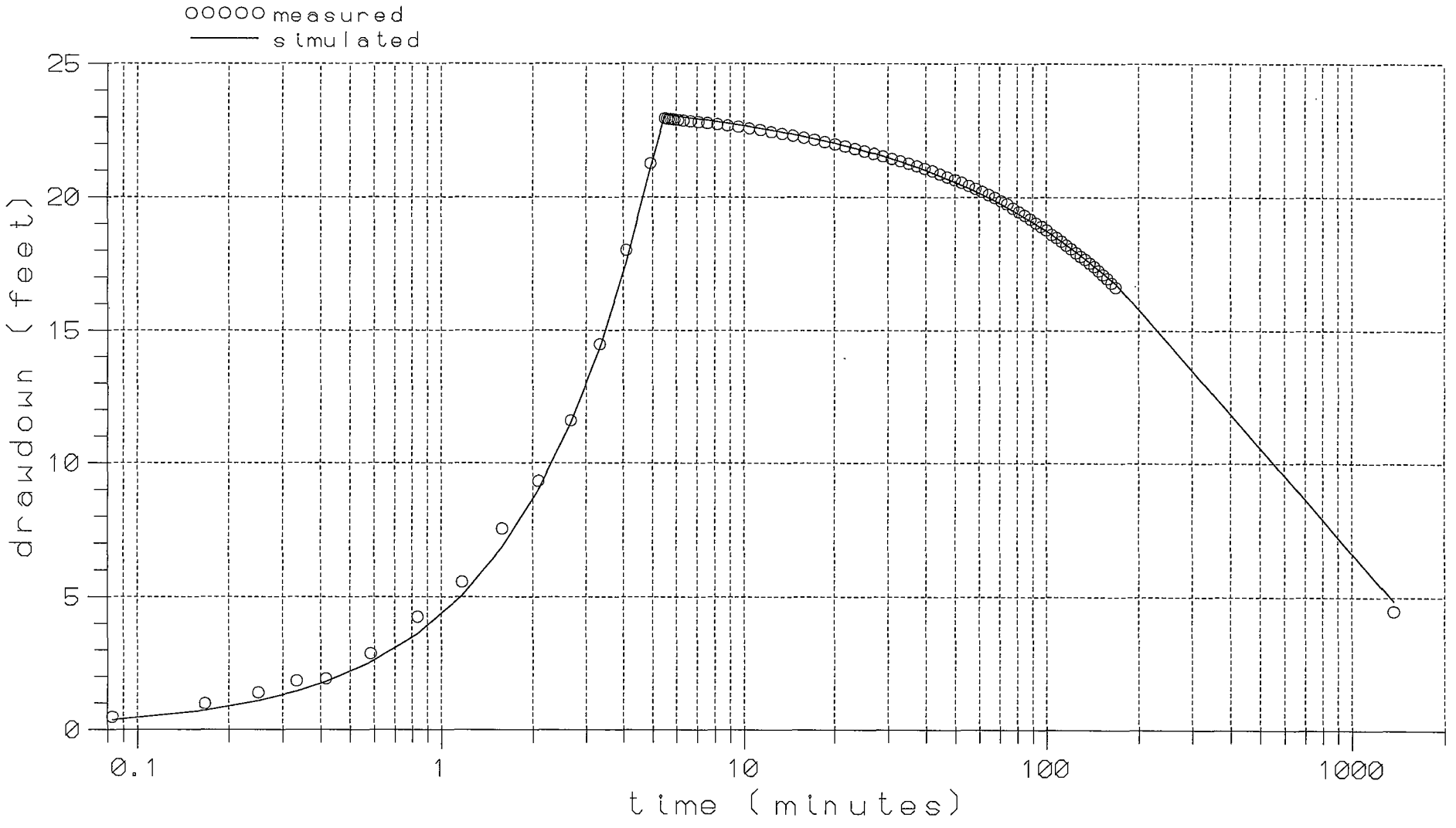
Note:
** Partially submerged screen correction not applied.*

FIGURES



WELL LOCATIONS

Approved	Date	Revised	Date	Reference:	FIG.
SS	5/17/02			71800065	1



TEST RESULTS

T= 0.043 ft2/day
S= 0.0082
Re= 0.12 ft
K= 7.7e-7 cm/sec
(assuming b=20 ft)

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MW-01 PUMP TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
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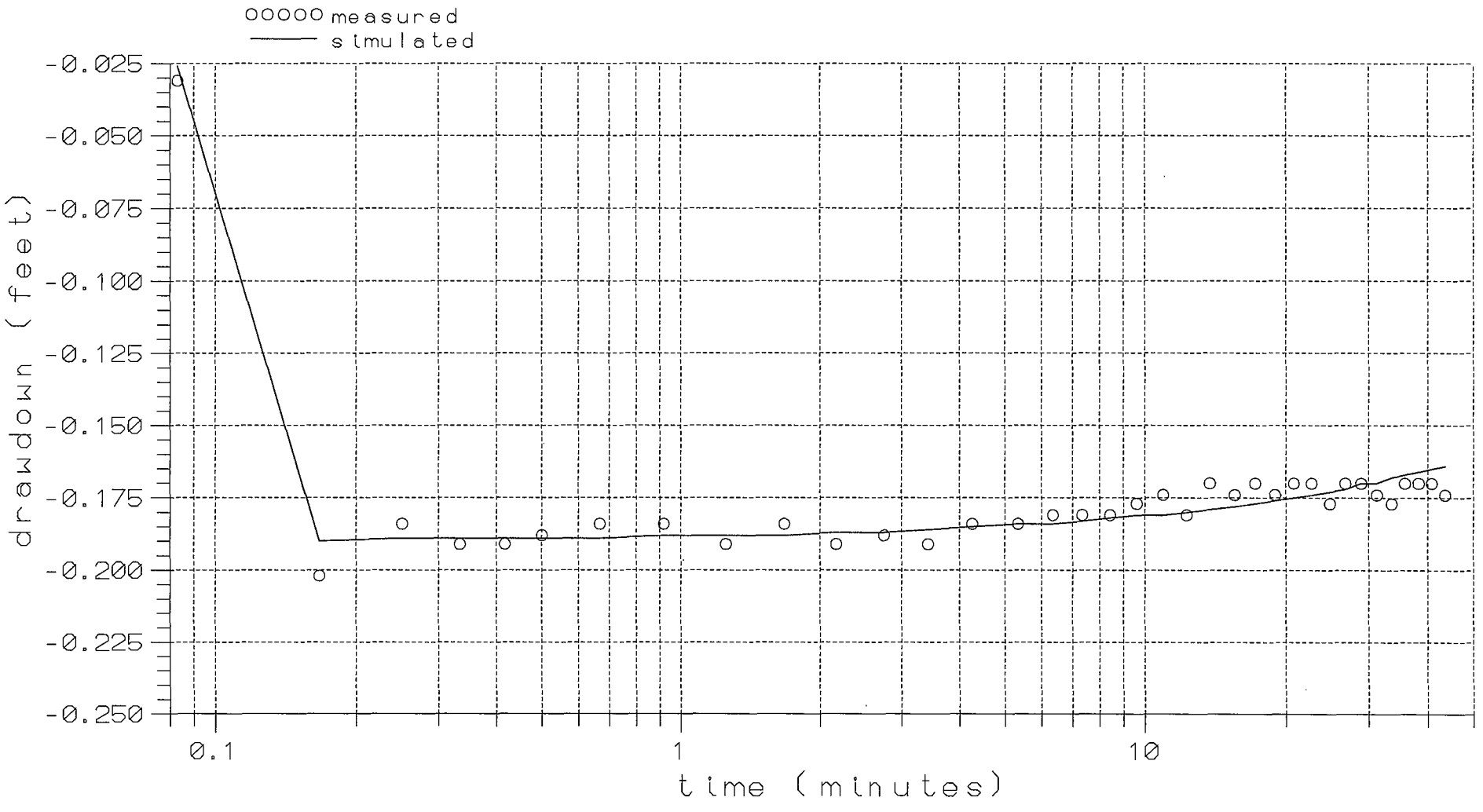


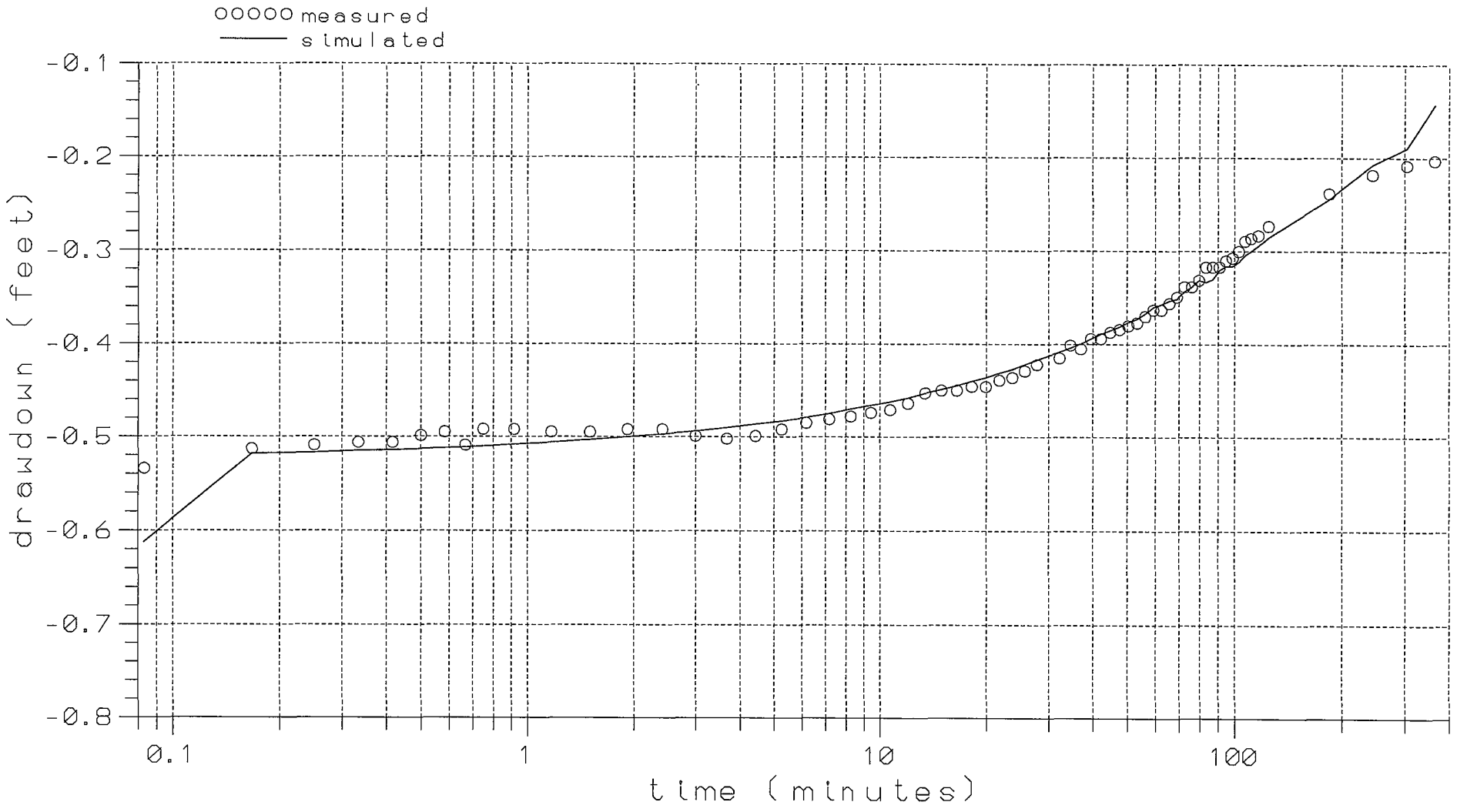
TEST RESULTS

T= 0.631 ft2/day
S= 0.01
Re=0.323 ft
K= 4.3E-5 cm/sec
(assuming b= 5.2 ft)

HYDRO GEO CHEM, INC.

MW-03 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
		h:/718000/hydtst02/whip	3



TEST RESULTS

T= 0.309 ft2/day
S= 0.100
Re=0.245 ft
K= 1.1e-5 cm/sec
(assuming b= 10 ft)

HYDRO GEO CHEM, INC.

MW-05 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
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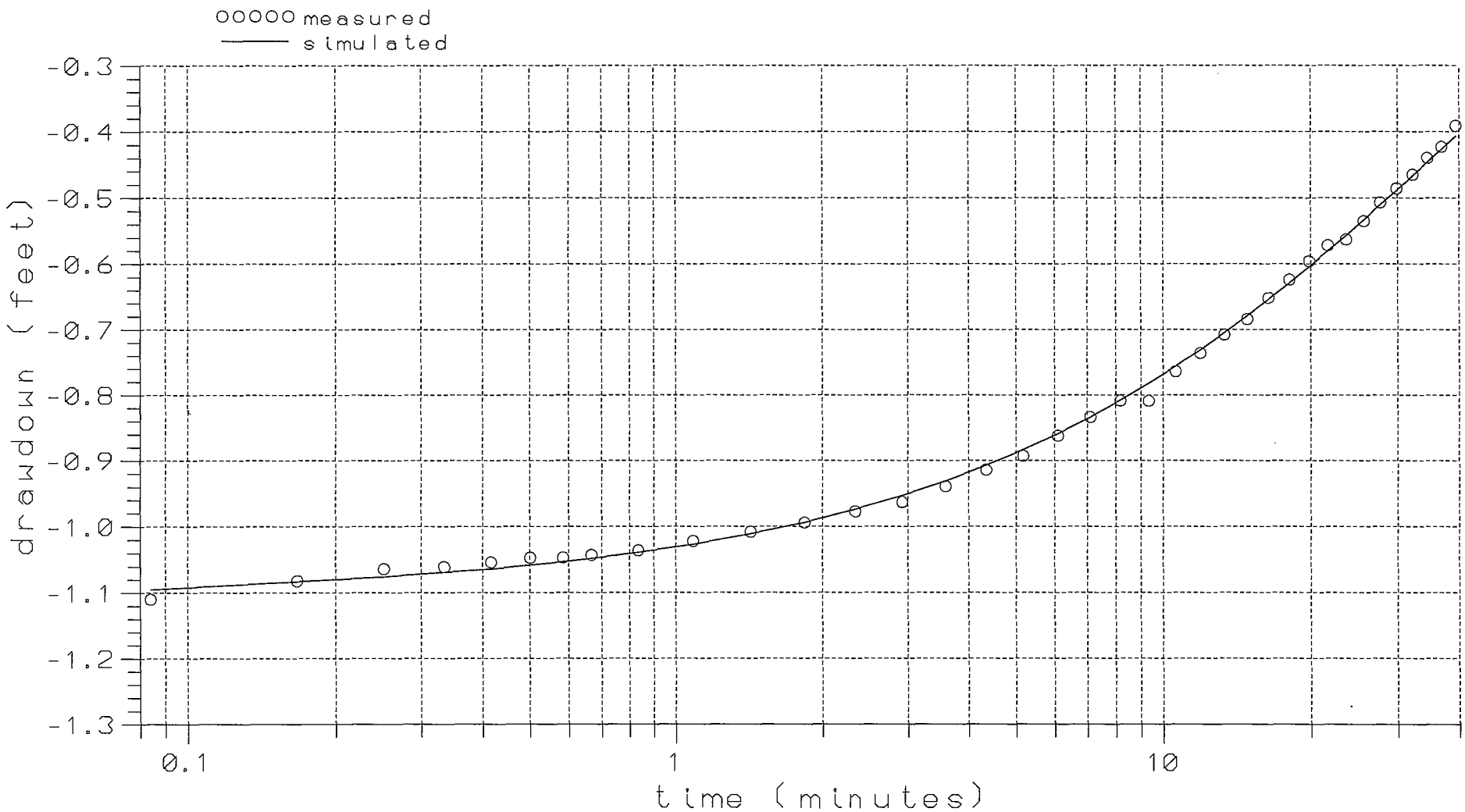

TEST RESULTS

T= 1.47 ft2/day
S= 0.01
Re= 0.168 ft
K= 2.9e-5 cm/sec
(assuming b= 18 ft)

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MW-17 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
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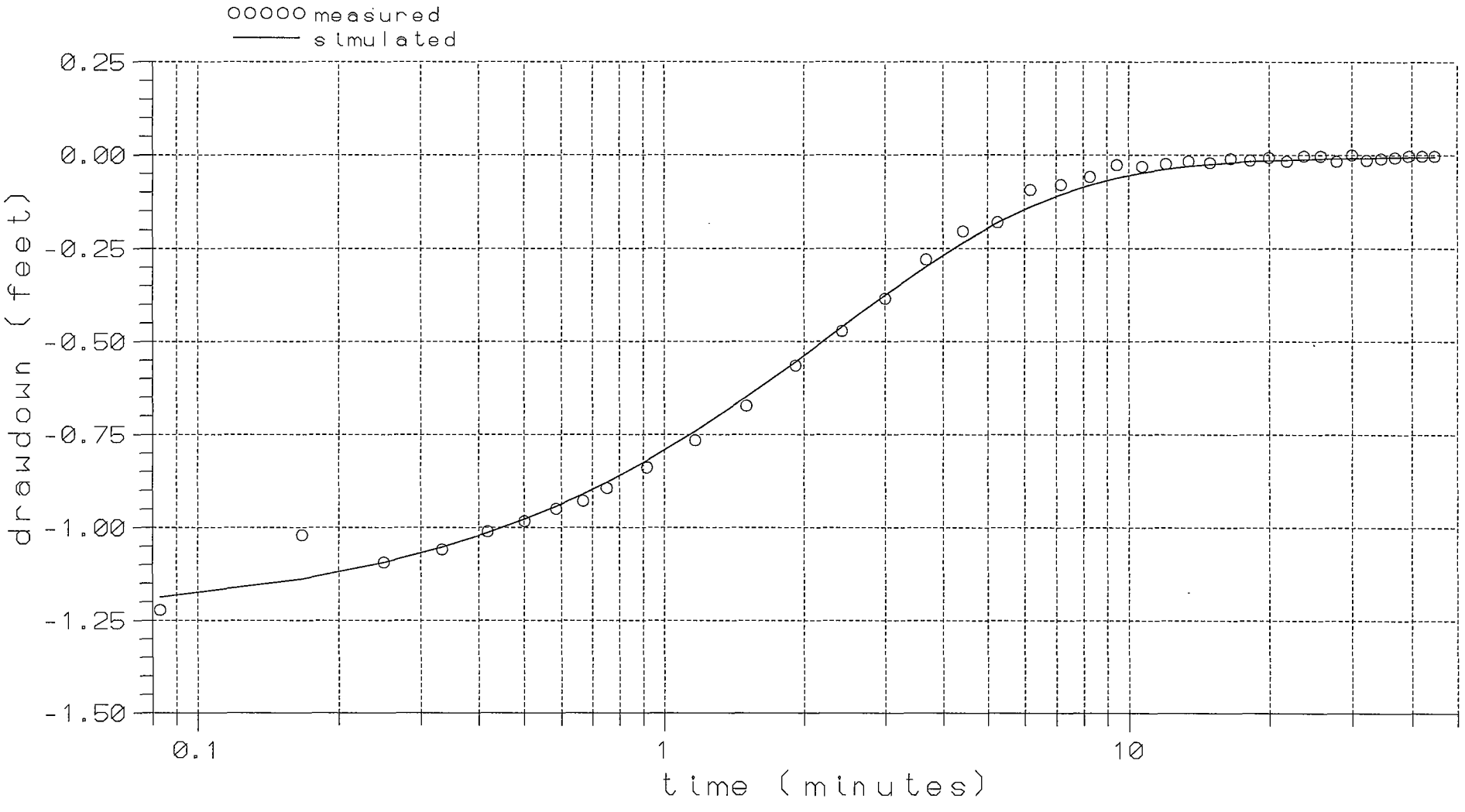

TEST RESULTS

T= 55.5 ft2/day
S= 2.23e-5
Re= 0.160 ft
K= 4.4e-4 cm/sec
(assuming b= 45 ft)

HYDRO GEO CHEM, INC.

MW-18 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
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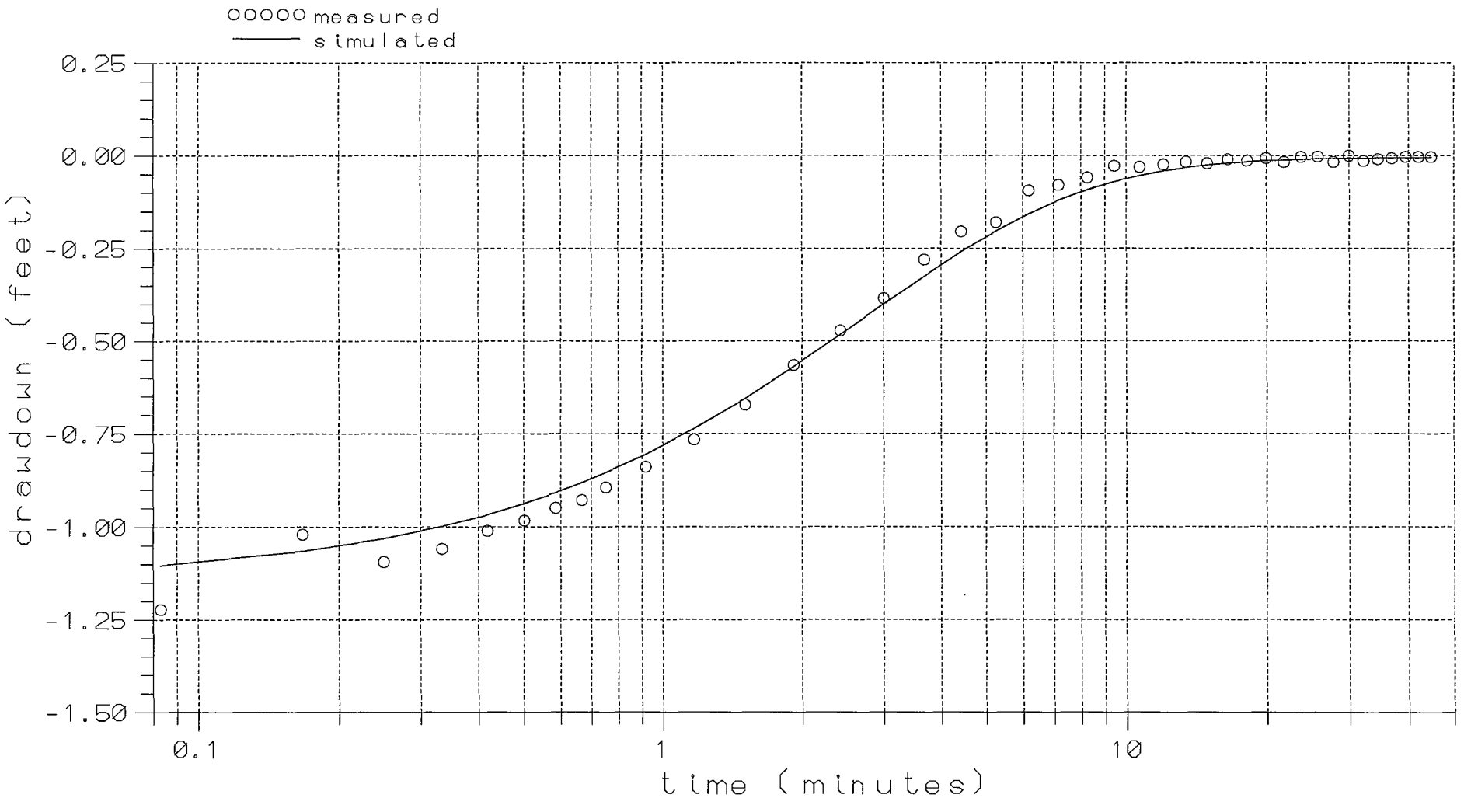


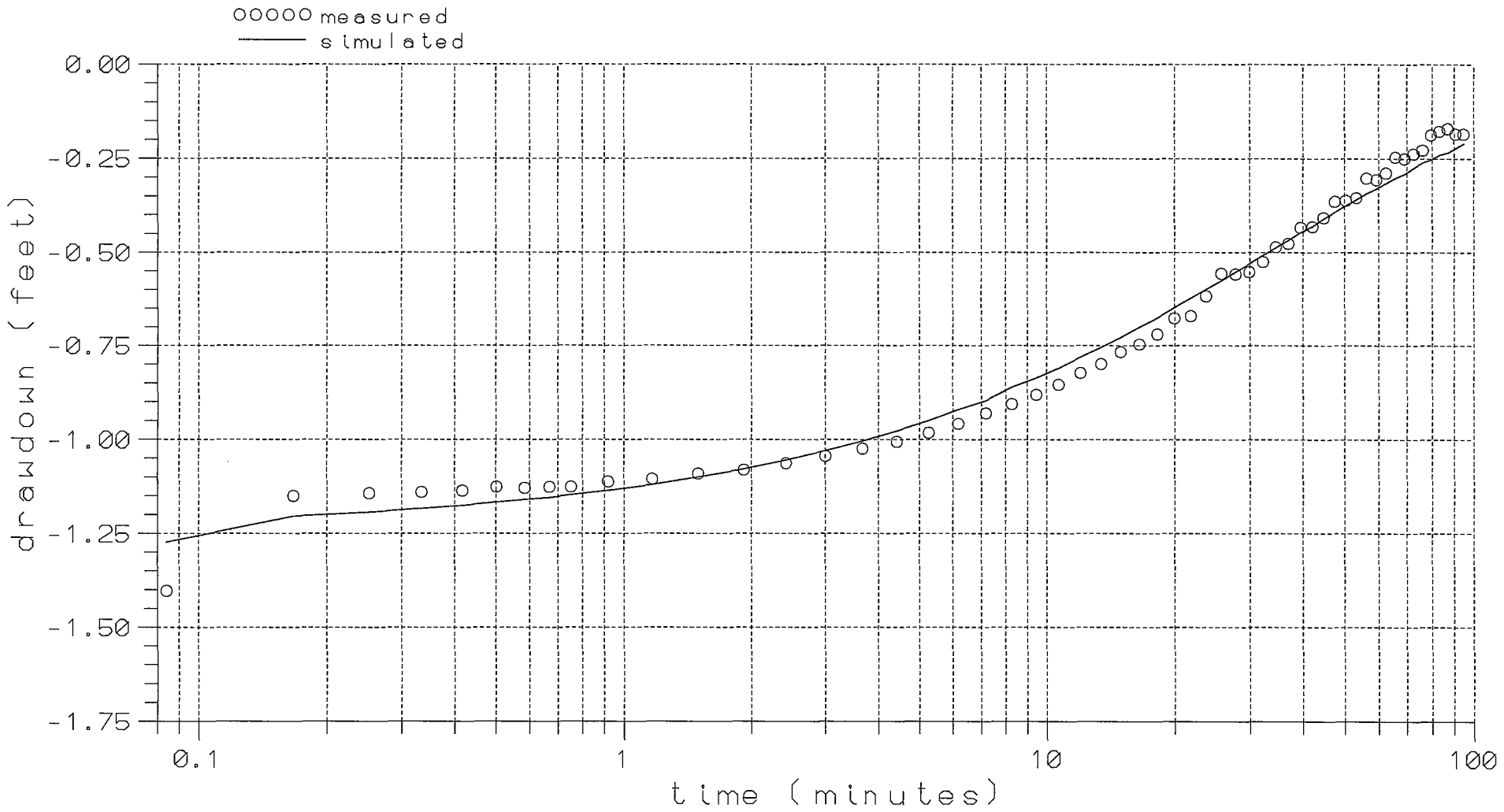
TEST RESULTS

T= 66.0 ft2/day
S= 0.02
Re= 0.167 ft
SKIN= 6.54
K= 5.2e-4 cm/sec
(assuming b= 45 ft)

HYDRO GEO CHEM, INC.

MW-18 SLUG TEST RESULTS
(with skin)
(interpretation using WHIP)

Approved	Date	Reference	Figure
		h:/718000/hydtst02/whip	7



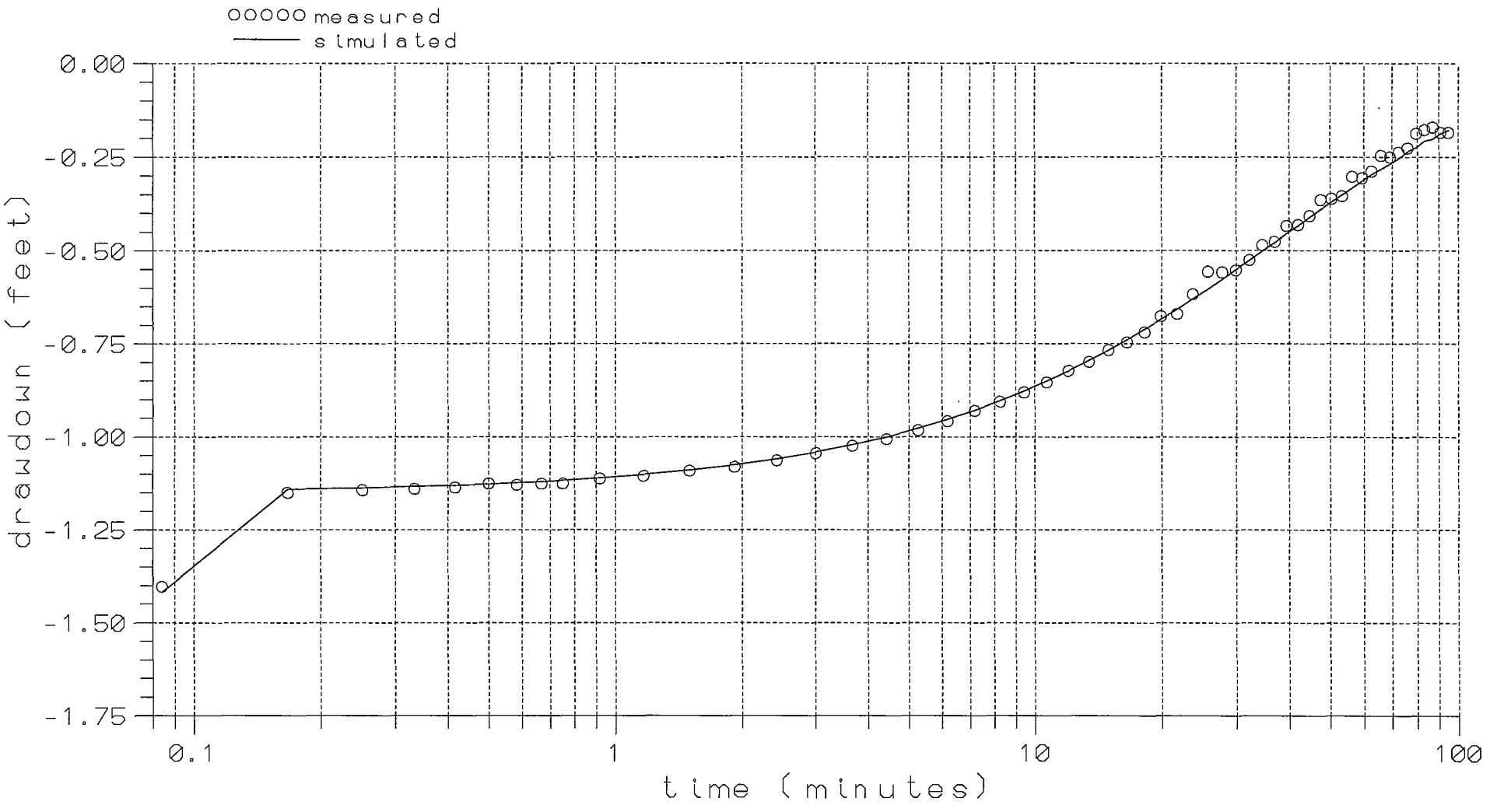
TEST RESULTS

T= 0.929 ft2/day
S= 0.032
Re= 0.154 ft
K= 7.1e-6 cm/sec
(assuming b= 47 ft)

HYDRO GEO CHEM, INC.

MW-19 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
		h:/718000/hydtst02/whip	8



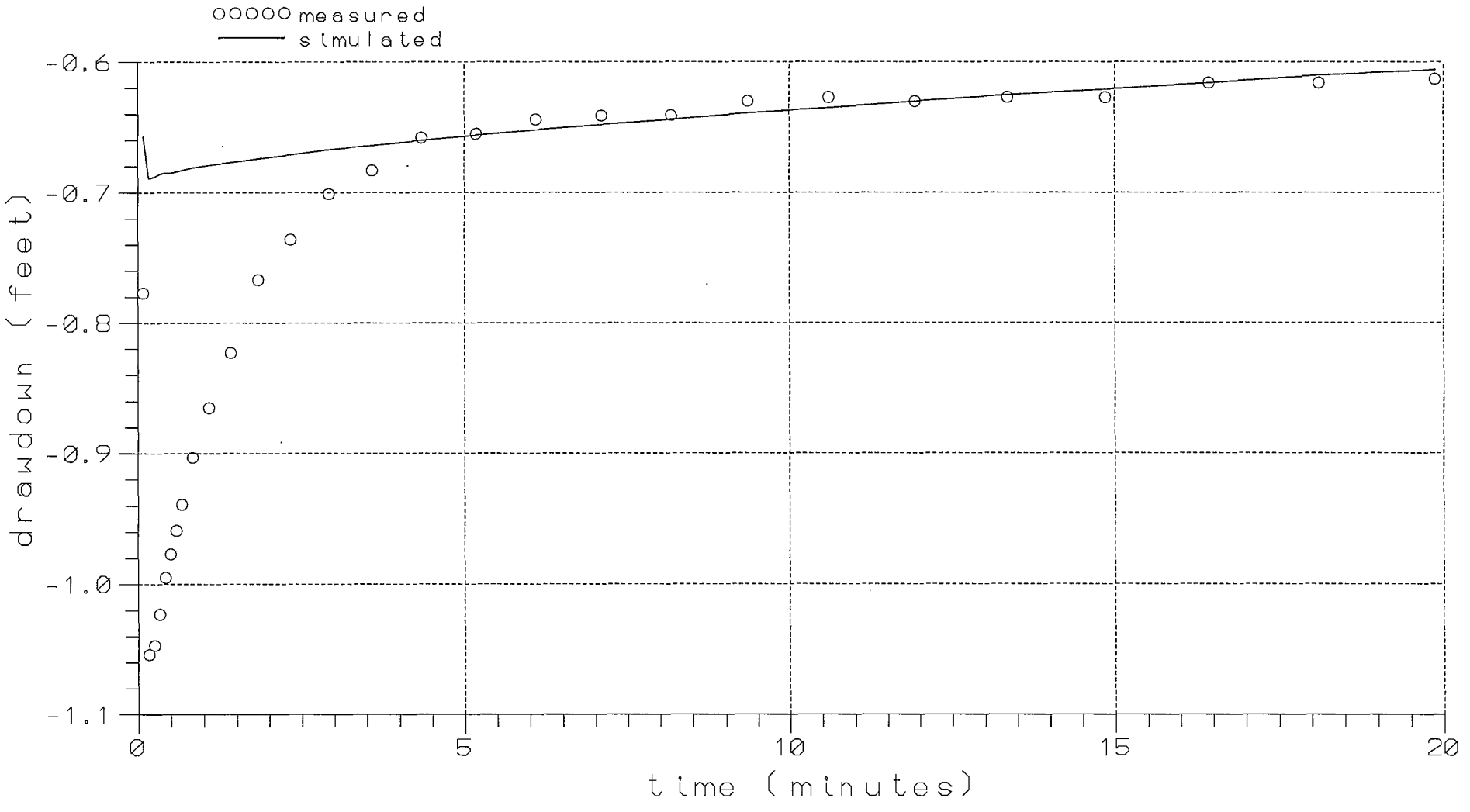
TEST RESULTS

T= 2.24 ft2/day
S= 0.0273
Re= 0.167 ft
SKIN= 2.24
K= 1.64e-5 cm/sec
(assuming b= 47 ft)

HYDRO GEO CHEM, INC.

MW-19 SLUG TEST RESULTS
(with skin)
(interpretation using WHIP)

Approved	Date	Reference	Figure
		h:/718000/hydtst02/whip	9



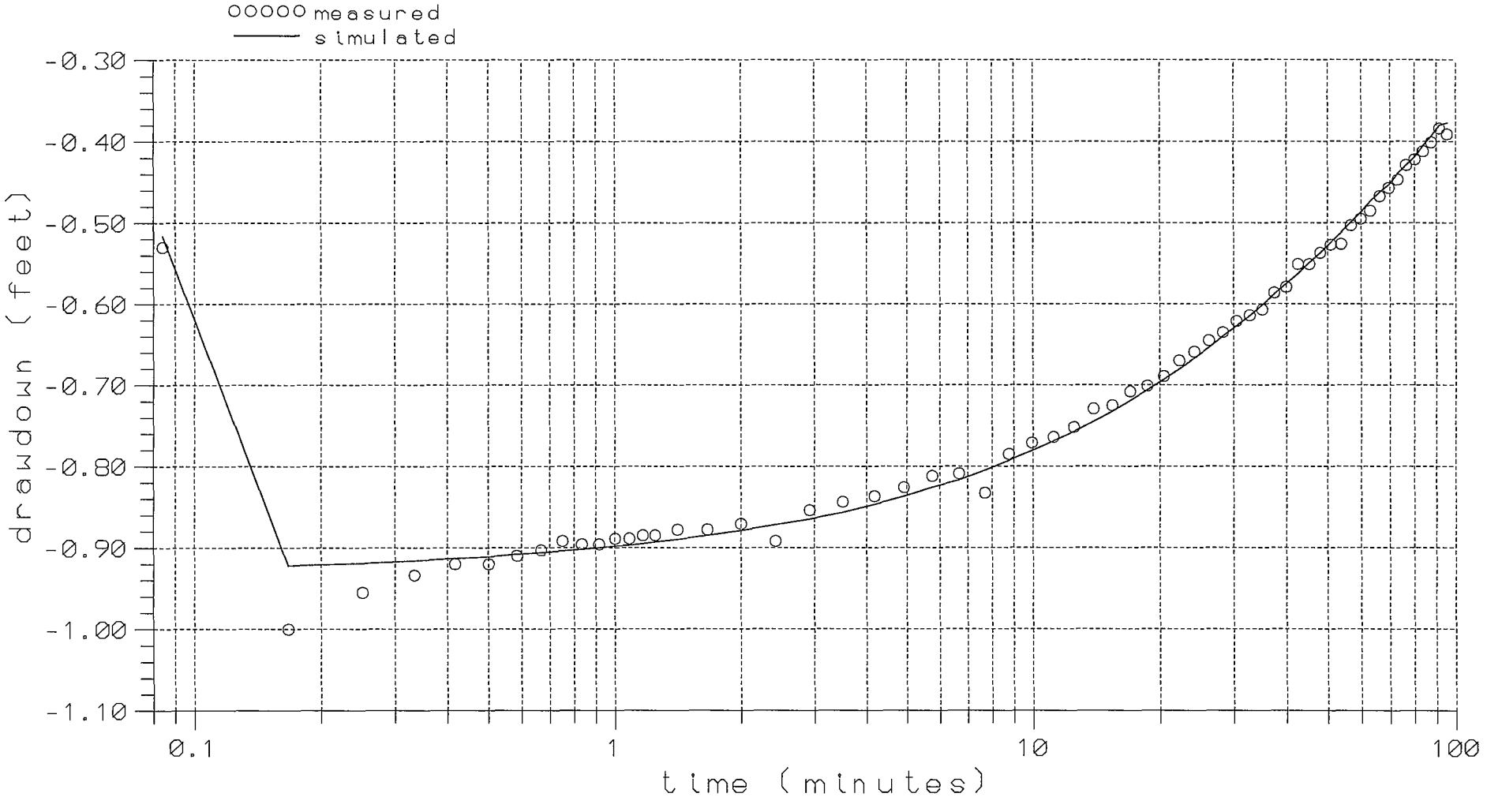
TEST RESULTS

T= 0.276 ft2/day
S= 0.02
Re= 0.213 ft
K= 8.2e-6 cm/sec
(assuming b= 12 ft)

HYDRO GEO CHEM, INC.

MW-20 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
		h:/718000/hydtst02/whip	10



TEST RESULTS

T= 0.603 ft2/day
S= 0.014
Re= 0.183 ft
K= 4.2e-6 cm/sec
(assuming b= 51 ft)

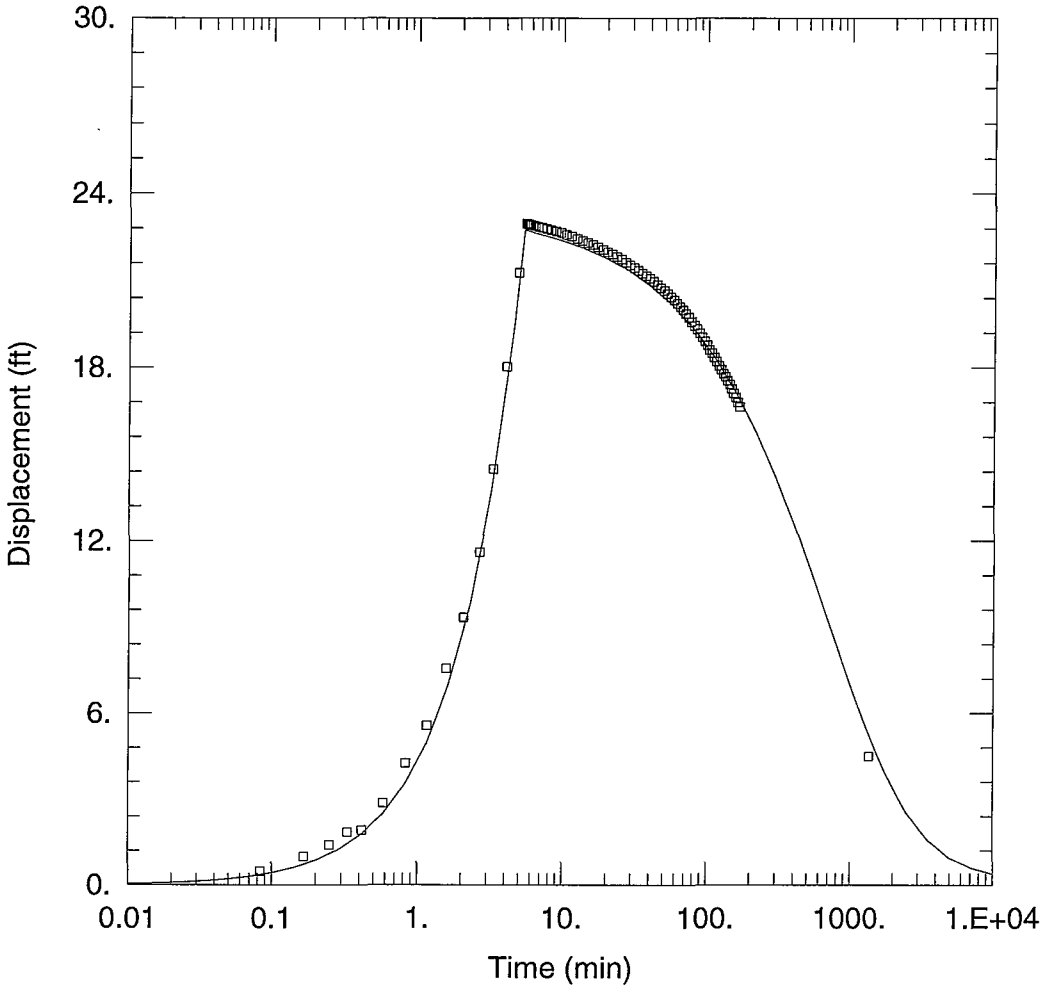
HYDRO GEO CHEM, INC.

MW-22 SLUG TEST RESULTS
(interpretation using WHIP)

Approved	Date	Reference	Figure
		h:/718000/hydtst02/whip	11

APPENDIX A

RESULTS OF AQTESOLV ANALYSES OF AUTOMATICALLY LOGGED DATA



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw01p.aqt
Date: 08/16/02 Time: 13:50:47

PROJECT INFORMATION

Client: iuc
Test Well: mw01

AQUIFER DATA

Saturated Thickness: 20. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
mw01	0	0

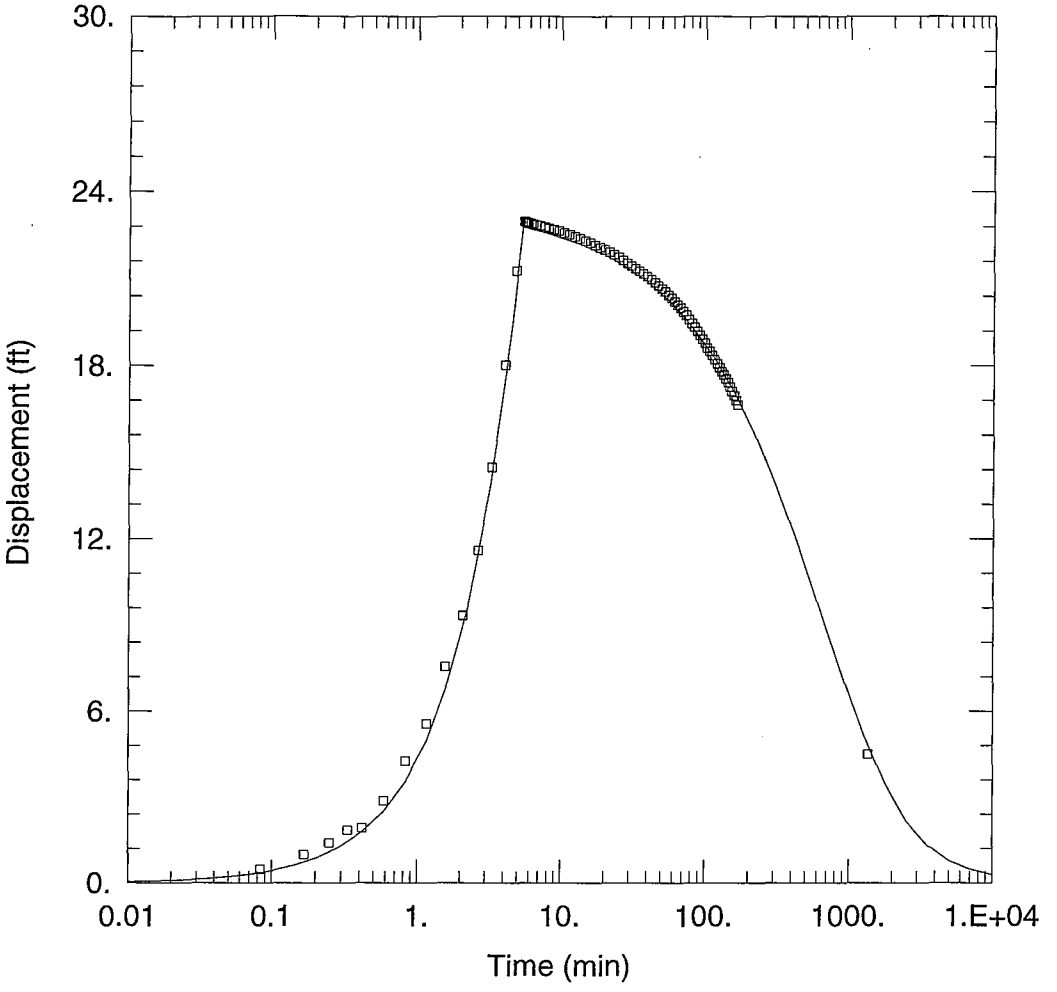
Observation Wells

Well Name	X (ft)	Y (ft)
▫ mw01	0	0

SOLUTION

Aquifer Model: Leaky Solution Method: Moench (Case 2)

T = 0.0432 ft^2/day S = 0.008
r/B = 1.E-09 ß = 1.E-05
Sw = 0. Rw = 0.12 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw01unc.aqt
Date: 08/21/02 Time: 15:57:46

PROJECT INFORMATION

Client: iuc
Test Well: mw01

AQUIFER DATA

Saturated Thickness: 40. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
mw01	0	0

Observation Wells

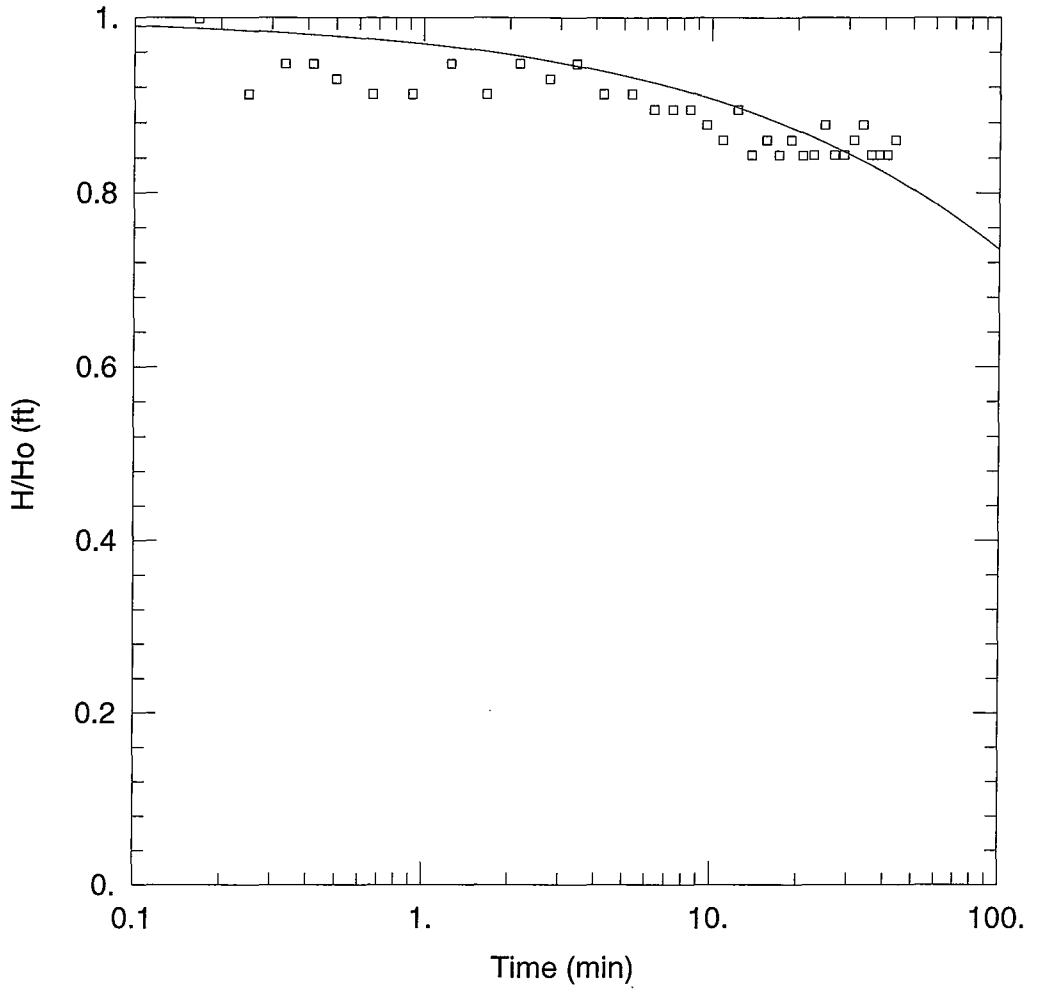
Well Name	X (ft)	Y (ft)
▫ mw01	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Moench

T = 0.09783 ft^2/day
Sy = 0.001
Sw = 0.
alpha = 1.E+30 min^{-1}

S = 0.01
β = 1.E-05
Rw = 0.12 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw03.aqt
Date: 08/16/02 Time: 13:53:03

PROJECT INFORMATION

Client: iuc
Test Well: mw03

AQUIFER DATA

Saturated Thickness: 5.2 ft

WELL DATA (mw03)

Initial Displacement: 0.202 ft
Wellbore Radius: 0.33 ft
Screen Length: 5.2 ft
Gravel Pack Porosity: 0.99

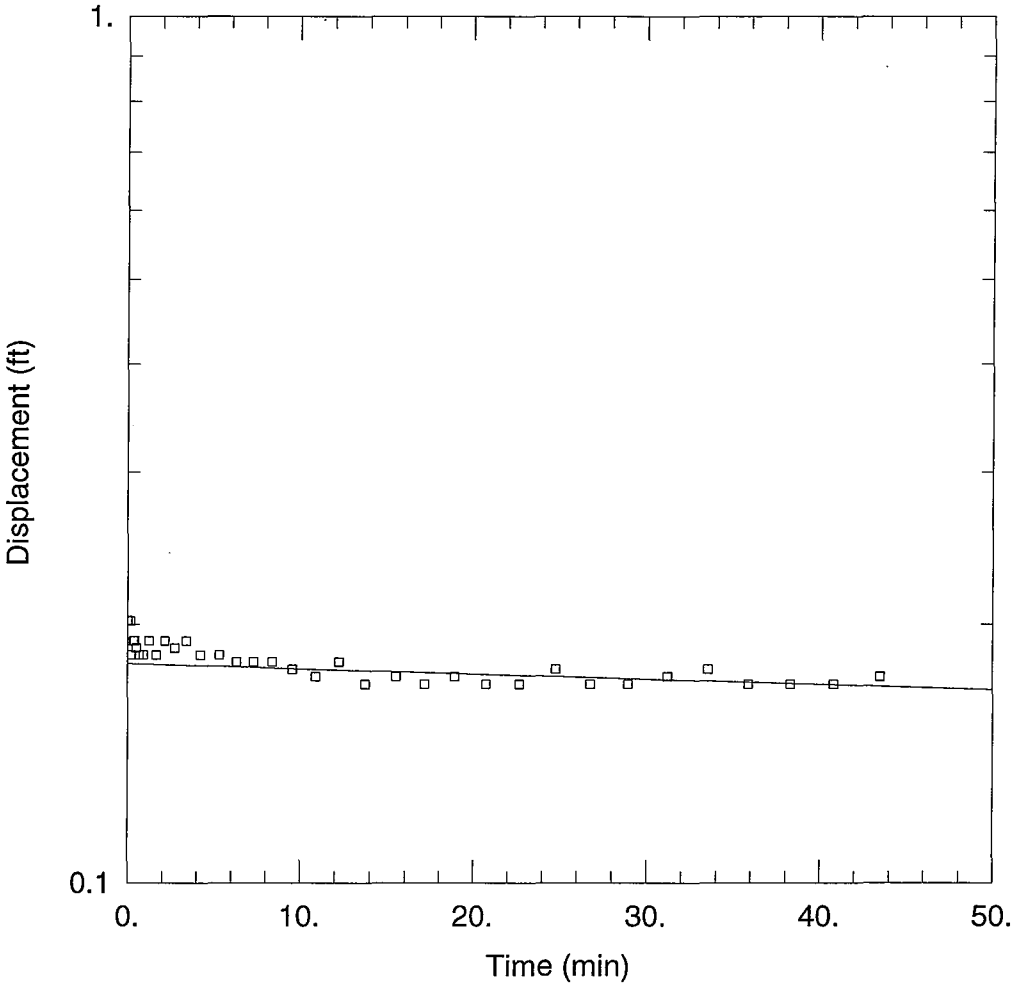
Casing Radius: 0.125 ft
Well Skin Radius: 0.33 ft
Total Well Penetration Depth: 5.2 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 4.042E-07 cm/sec
Kz/Kr = 1.

Ss = 0.01923 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw03br.aqt
Date: 08/16/02 Time: 13:53:37

PROJECT INFORMATION

Client: iuc
Test Well: mw03

AQUIFER DATA

Saturated Thickness: 5.2 ft
Anisotropy Ratio (Kz/Kr): 1.

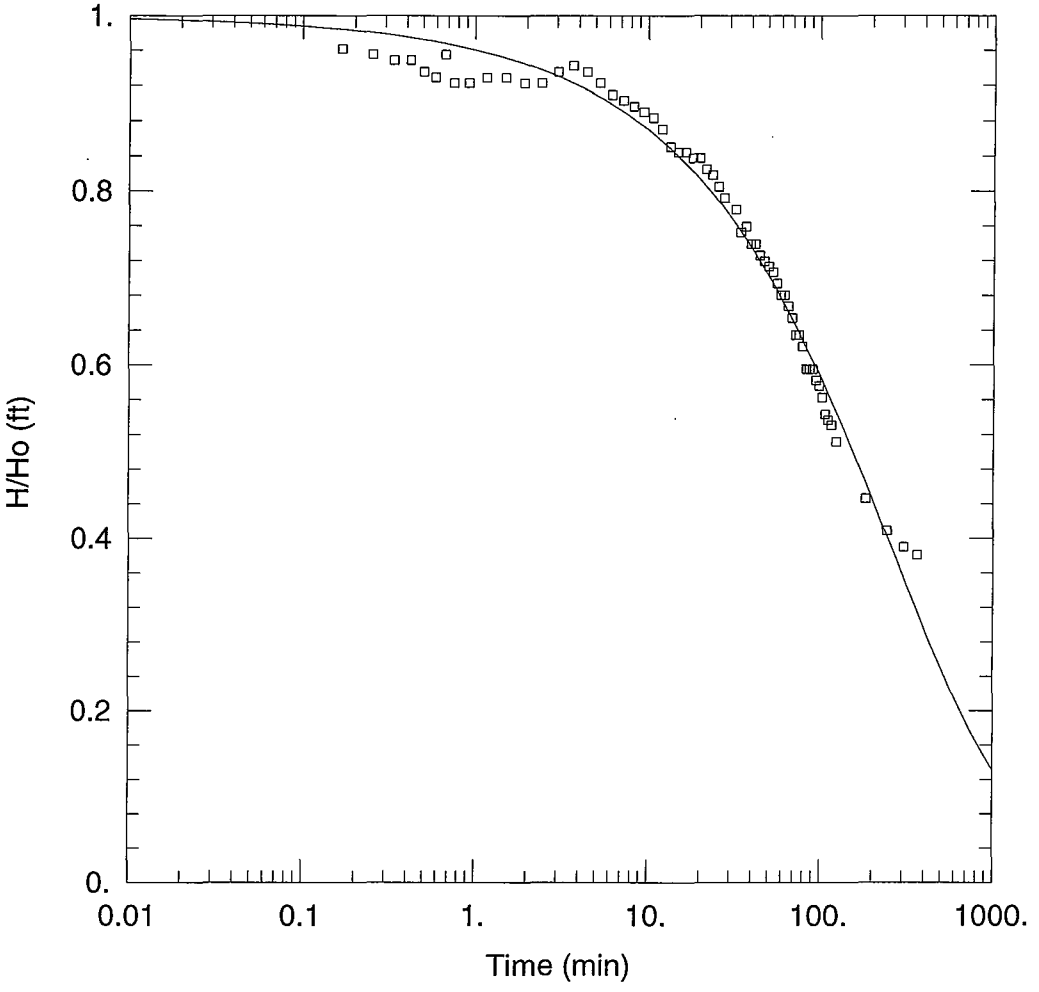
WELL DATA (mw03)

Initial Displacement: 0.202 ft
Wellbore Radius: 0.33 ft
Screen Length: 5.2 ft
Gravel Pack Porosity: 0.99
Casing Radius: 0.125 ft
Well Skin Radius: 0.33 ft
Total Well Penetration Depth: 5.2 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.478E-05 cm/sec
y0 = 0.18 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw05.aqt
Date: 08/16/02 Time: 13:54:26

PROJECT INFORMATION

Client: iuc
Test Well: mw05

AQUIFER DATA

Saturated Thickness: 10. ft

WELL DATA (mw05)

Initial Displacement: 0.533 ft
Wellbore Radius: 0.27 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.99

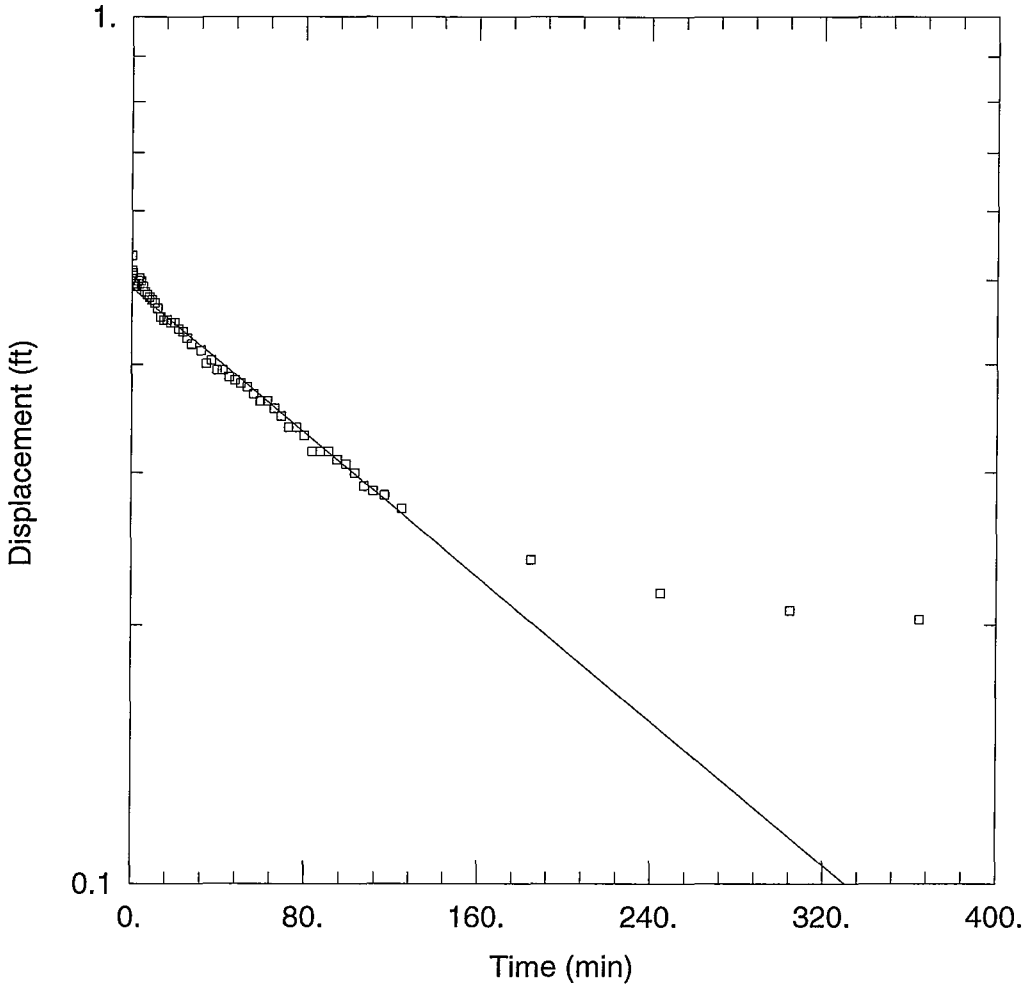
Casing Radius: 0.167 ft
Well Skin Radius: 0.27 ft
Total Well Penetration Depth: 10. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 3.454E-06 cm/sec
Kz/Kr = 1.

Ss = 0.004419 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw05bret.aqt
Date: 08/16/02 Time: 13:56:44

PROJECT INFORMATION

Client: iuc
Test Well: mw05

AQUIFER DATA

Saturated Thickness: 10. ft
Anisotropy Ratio (Kz/Kr): 1.

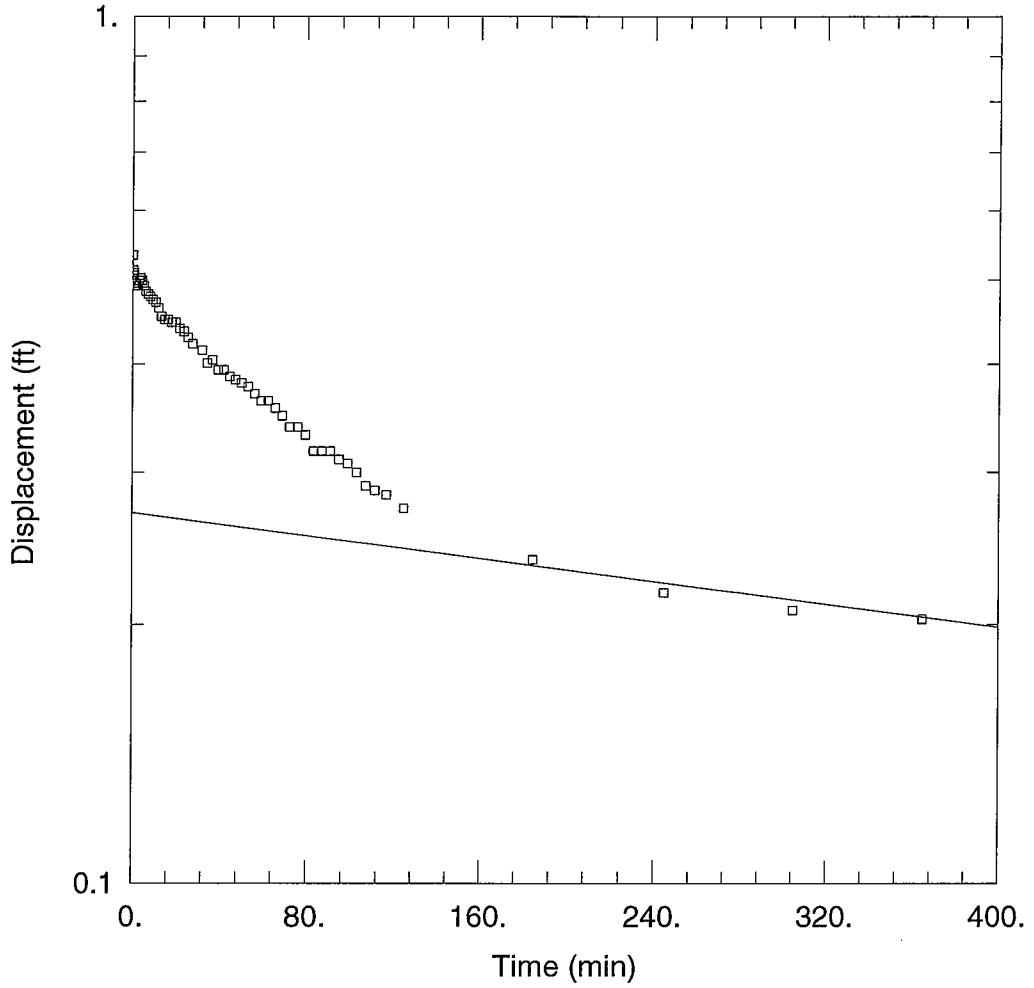
WELL DATA (mw05)

Initial Displacement: 0.533 ft
Wellbore Radius: 0.27 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.99
Casing Radius: 0.167 ft
Well Skin Radius: 0.27 ft
Total Well Penetration Depth: 10. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.434E-05 cm/sec
y0 = 0.4904 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw05brlt.aqt
Date: 08/16/02 Time: 13:57:16

PROJECT INFORMATION

Client: iuc
Test Well: mw05

AQUIFER DATA

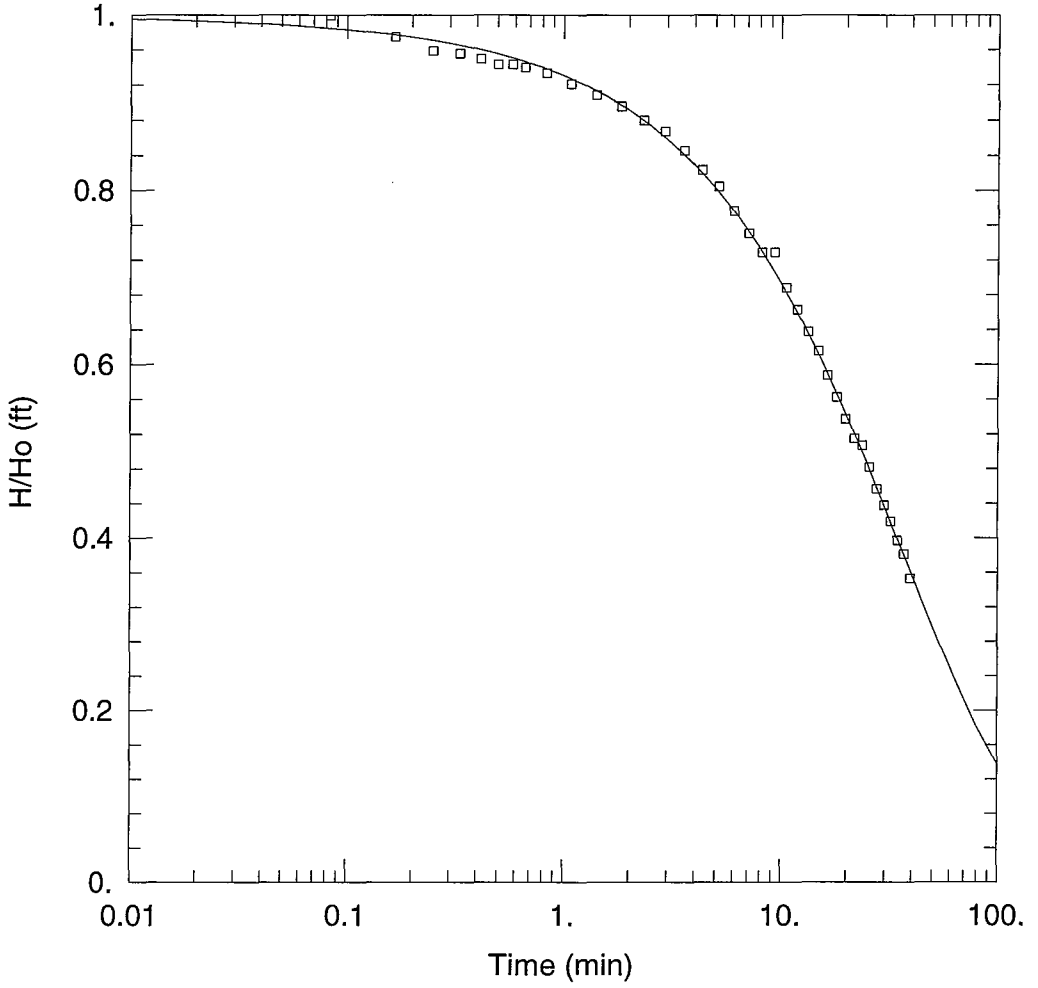
Saturated Thickness: 10. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (mw05)

Initial Displacement: 0.533 ft
Wellbore Radius: 0.27 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.99
Casing Radius: 0.167 ft
Well Skin Radius: 0.27 ft
Total Well Penetration Depth: 10. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.857E-06 cm/sec
y0 = 0.2695 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw17.aqt
Date: 08/16/02 Time: 13:58:02

PROJECT INFORMATION

Client: iuc
Test Well: mw17

AQUIFER DATA

Saturated Thickness: 18. ft

WELL DATA (mw17)

Initial Displacement: 1.11 ft
Wellbore Radius: 0.328 ft
Screen Length: 18. ft
Gravel Pack Porosity: 0.3

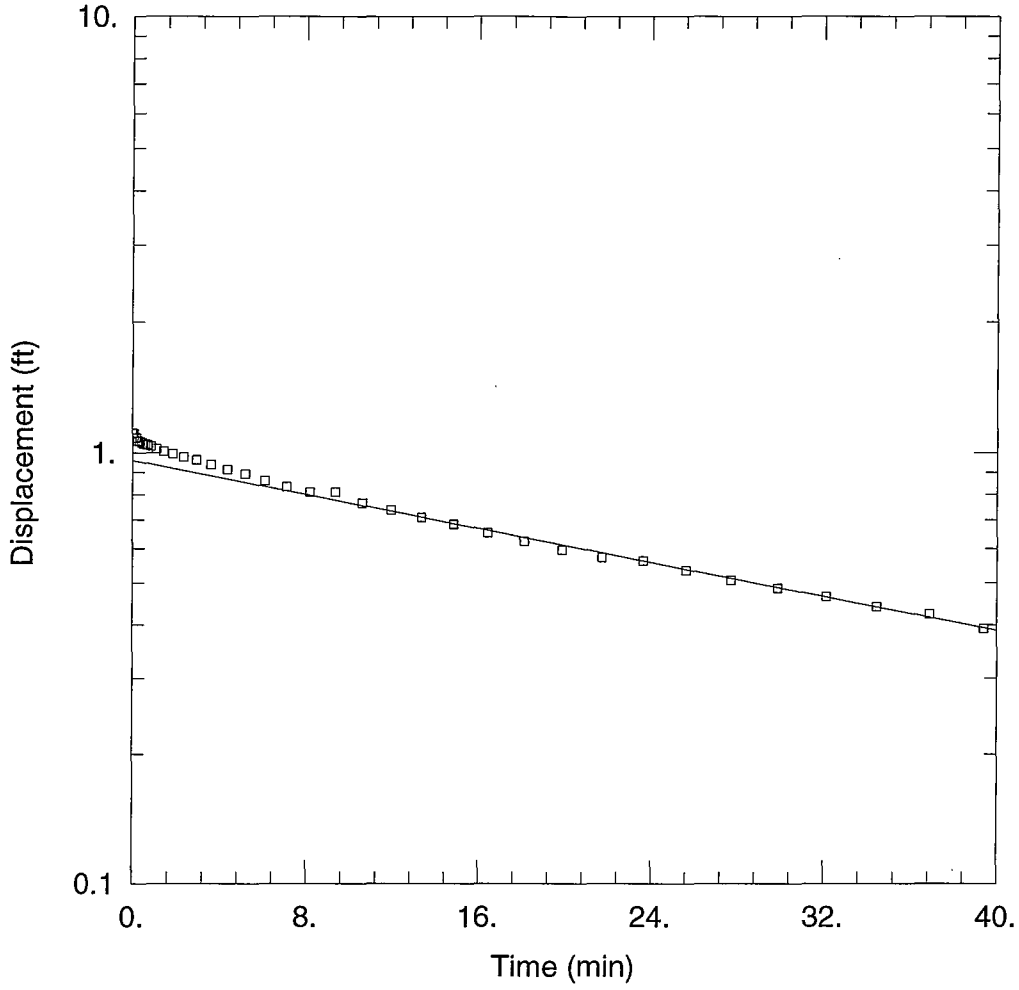
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 18. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 2.563E-05 cm/sec
Kz/Kr = 1.

Ss = 0.0001706 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw17br.aqt
Date: 08/16/02 Time: 14:04:08

PROJECT INFORMATION

Client: iuc
Test Well: mw17

AQUIFER DATA

Saturated Thickness: 18. ft
Anisotropy Ratio (Kz/Kr): 1.

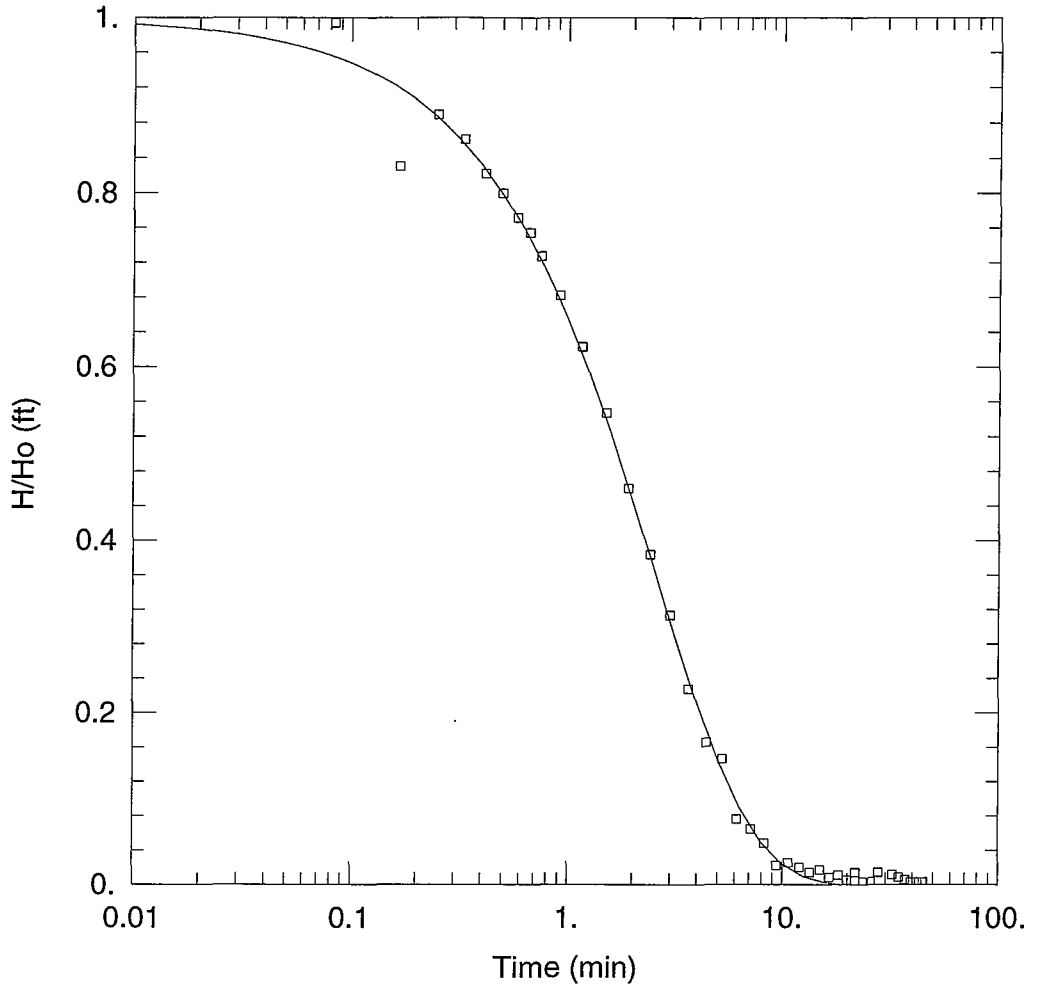
WELL DATA (mw17)

Initial Displacement: 1.11 ft
Wellbore Radius: 0.328 ft
Screen Length: 18. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 18. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.731E-05 cm/sec
y0 = 0.959 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw18.aqt
Date: 08/22/02 Time: 12:36:33

PROJECT INFORMATION

Client: iuc
Test Well: mw18

AQUIFER DATA

Saturated Thickness: 58. ft

WELL DATA (mw18)

Initial Displacement: 1.23 ft
Wellbore Radius: 0.328 ft
Screen Length: 45. ft
Gravel Pack Porosity: 0.3

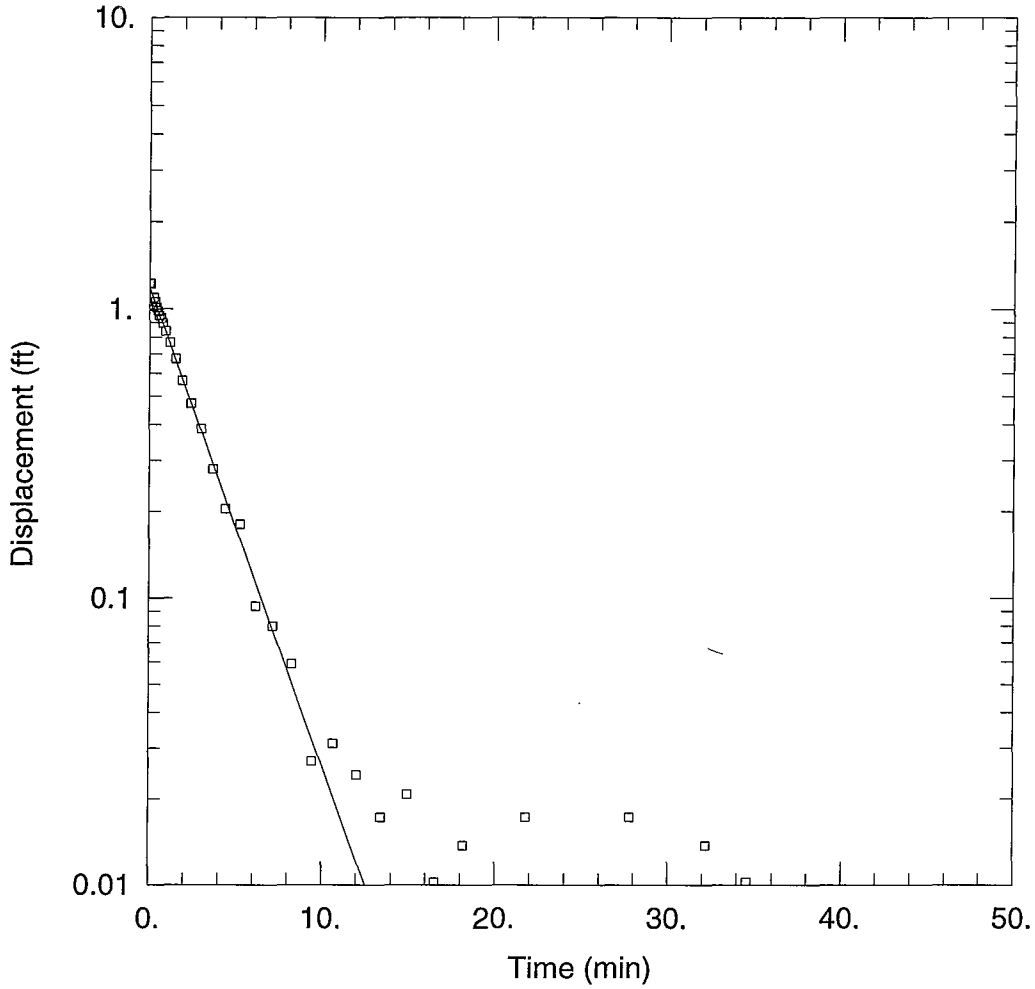
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 58. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 0.0002892 cm/sec
Kz/Kr = 1.

Ss = 4.573E-07 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw18br.aqt
Date: 08/22/02 Time: 12:38:01

PROJECT INFORMATION

Client: iuc
Test Well: mw18

AQUIFER DATA

Saturated Thickness: 58. ft
Anisotropy Ratio (Kz/Kr): 1.

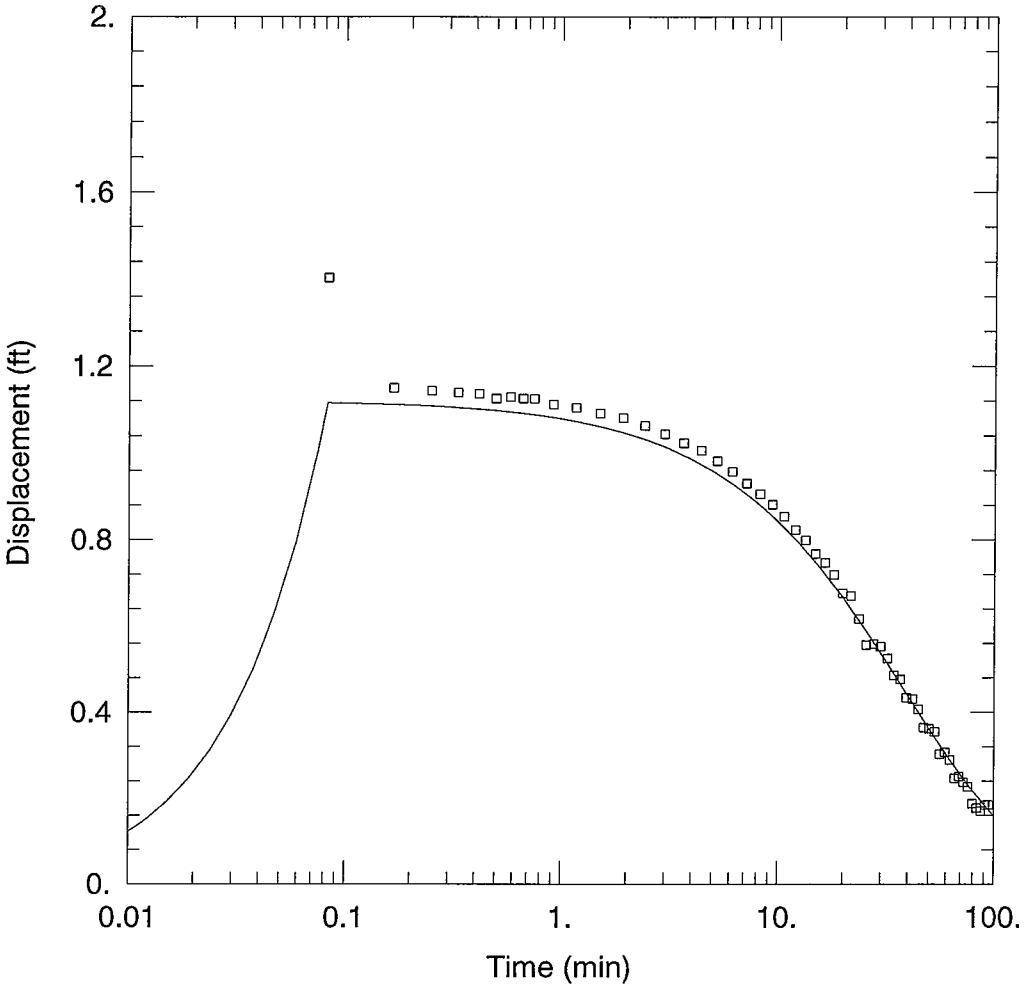
WELL DATA (mw18)

Initial Displacement: 1.23 ft
Wellbore Radius: 0.328 ft
Screen Length: 45. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 58. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0002382 cm/sec
y0 = 1.191 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw19p.aqt
Date: 08/16/02 Time: 14:15:27

PROJECT INFORMATION

Client: iuc
Test Well: mw19p

AQUIFER DATA

Saturated Thickness: 48. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
mw19p	0	0

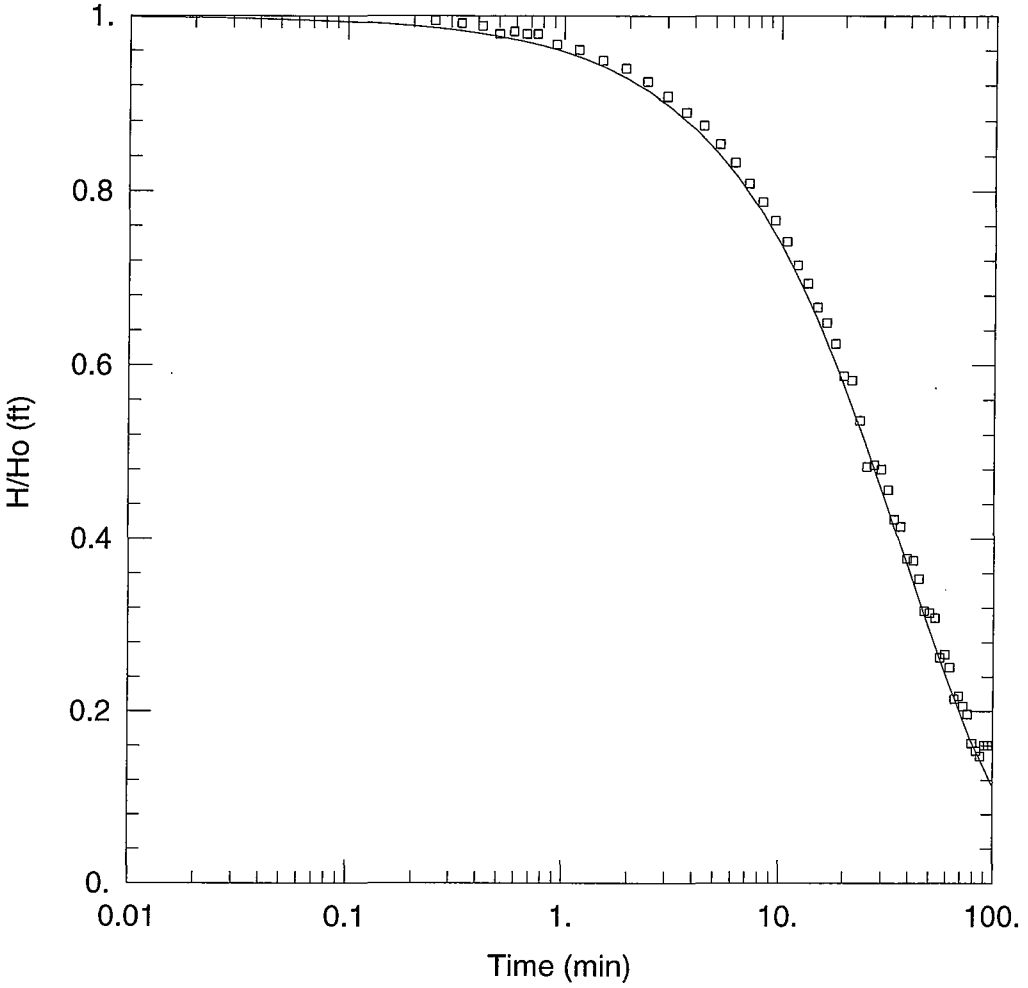
Observation Wells

Well Name	X (ft)	Y (ft)
▫ mw19p	0	0

SOLUTION

Aquifer Model: Leaky Solution Method: Moench (Case 2)

T = 2.215 ft^2/day S = 0.0273
r/B = 1.E-09 ß = 1.005E-05
Sw = 2.24 Rw = 0.165 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw19.aqt
Date: 08/16/02 Time: 14:11:14

PROJECT INFORMATION

Client: iuc
Test Well: mw19

AQUIFER DATA

Saturated Thickness: 80. ft

WELL DATA (mw19)

Initial Displacement: 1.15 ft
Wellbore Radius: 0.328 ft
Screen Length: 47. ft
Gravel Pack Porosity: 0.3

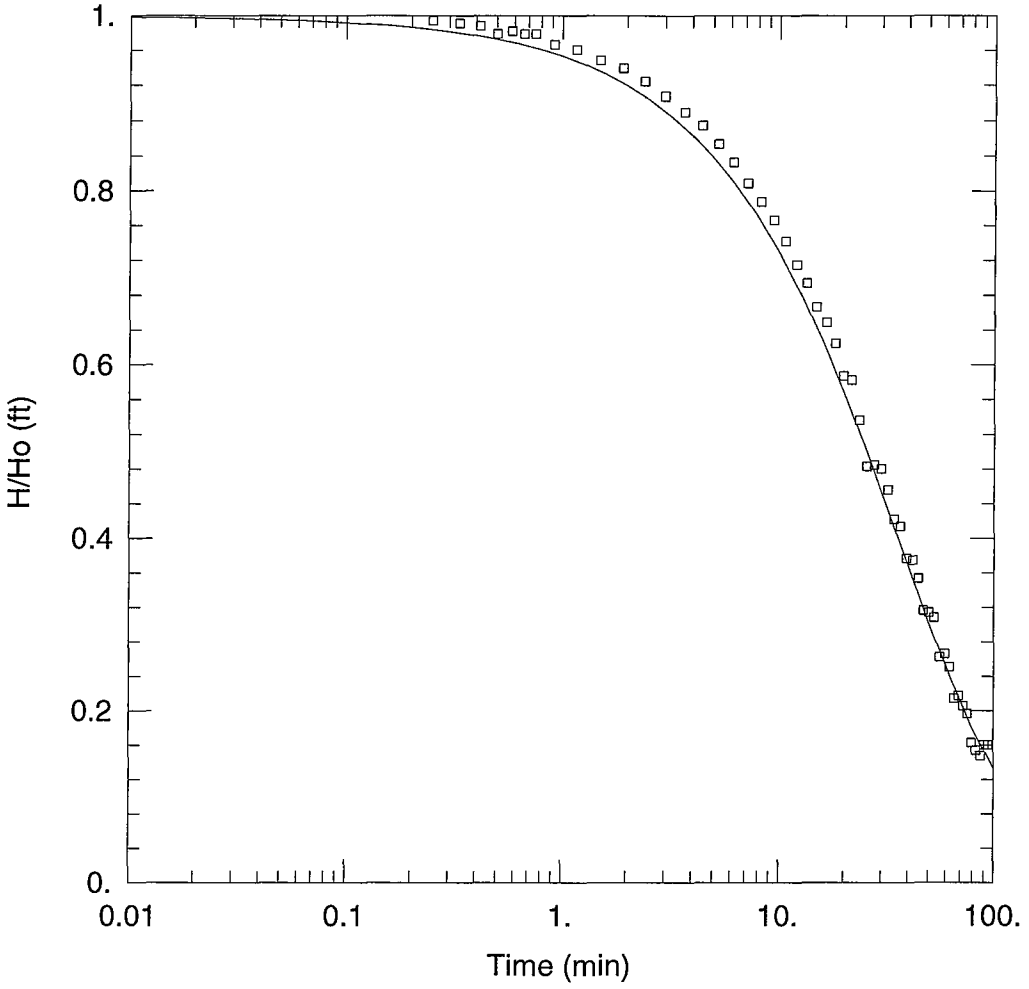
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 80. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 1.693E-05 cm/sec
Kz/Kr = 1.

Ss = 1.444E-06 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw19c.aqt
Date: 08/16/02 Time: 14:14:38

PROJECT INFORMATION

Client: iuc
Test Well: mw19

AQUIFER DATA

Saturated Thickness: 48. ft

WELL DATA (mw19)

Initial Displacement: 1.15 ft
Wellbore Radius: 0.328 ft
Screen Length: 47. ft
Gravel Pack Porosity: 0.3

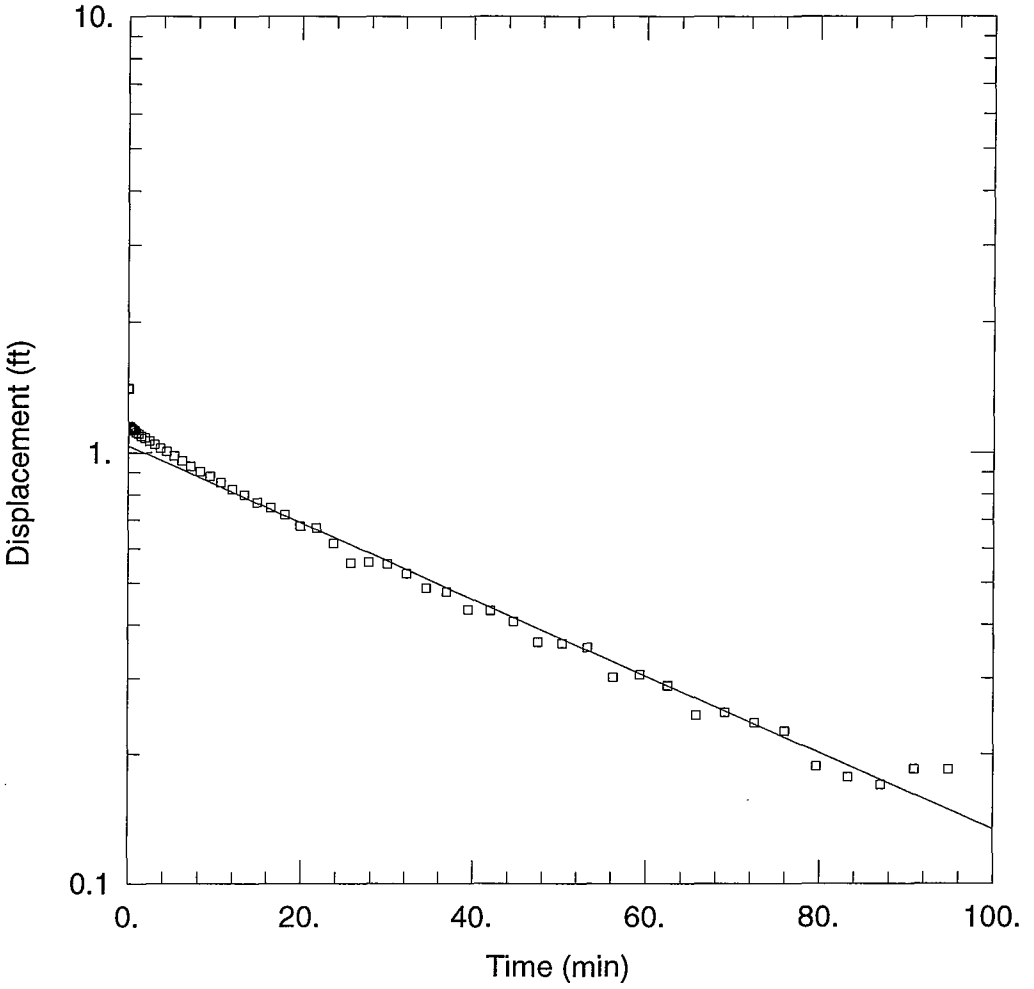
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 47. ft

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 1.628E-05 cm/sec
Kz/Kr = 1.

Ss = 3.236E-06 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw19br.aqt
Date: 08/21/02 Time: 15:18:51

PROJECT INFORMATION

Client: iuc
Test Well: mw19

AQUIFER DATA

Saturated Thickness: 80. ft
Anisotropy Ratio (Kz/Kr): 1.

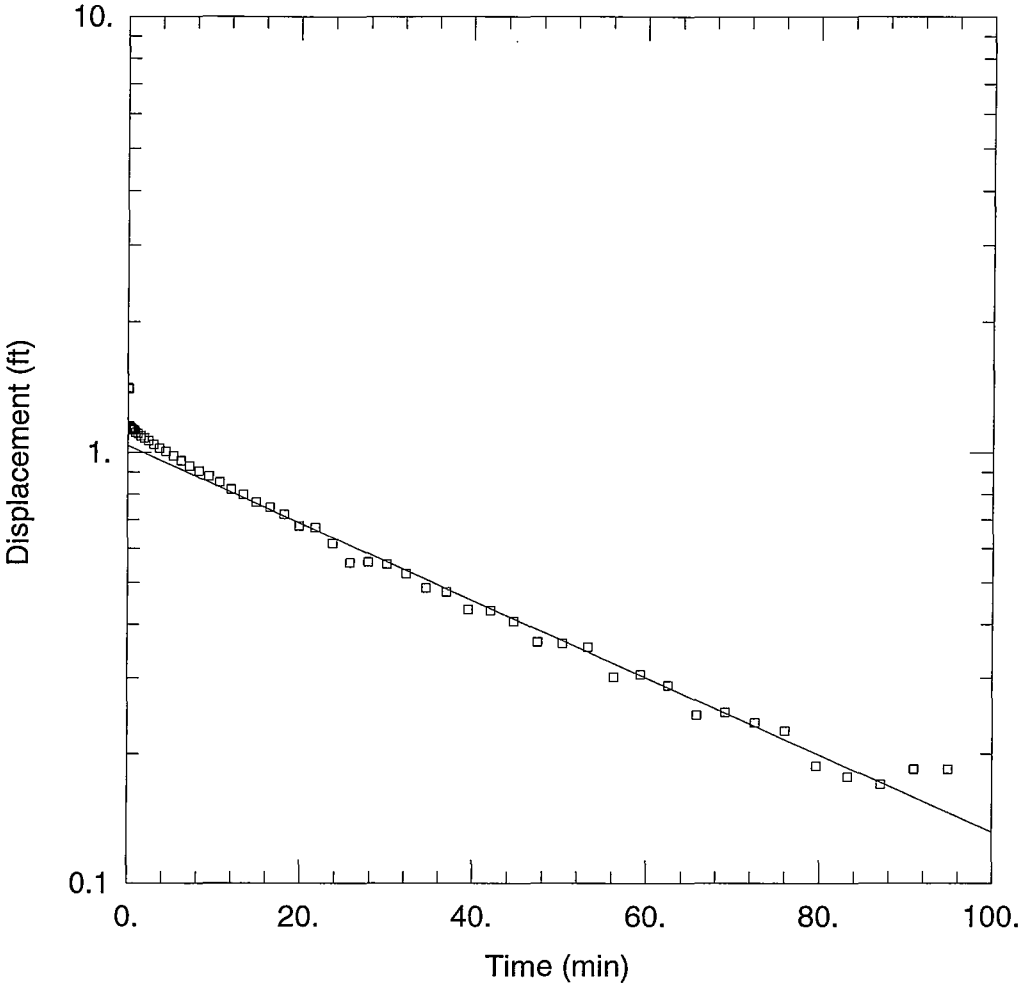
WELL DATA (mw19)

Initial Displacement: 1.41 ft
Wellbore Radius: 0.328 ft
Screen Length: 47. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 80. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.291E-05 cm/sec
y0 = 1.038 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw19brc.aqt
Date: 08/16/02 Time: 14:12:47

PROJECT INFORMATION

Client: iuc
Test Well: mw19

AQUIFER DATA

Saturated Thickness: 47. ft
Anisotropy Ratio (Kz/Kr): 1.

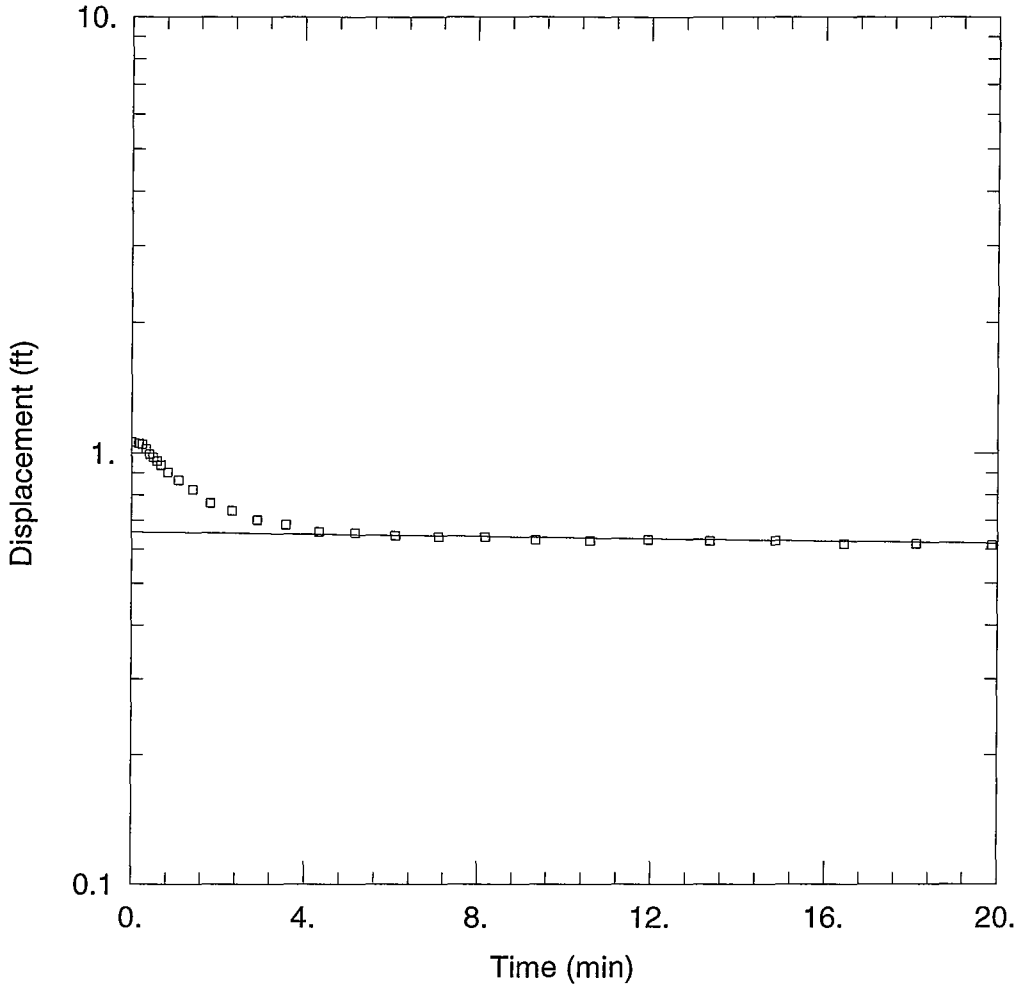
WELL DATA (mw19)

Initial Displacement: 1.41 ft
Wellbore Radius: 0.328 ft
Screen Length: 47. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 47. ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 1.195E-05 cm/sec
y0 = 1.038 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw20br.aqt
Date: 08/16/02 Time: 14:17:53

PROJECT INFORMATION

(with correction for partially submerged screen)

Client: iuc
Test Well: mw20

AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

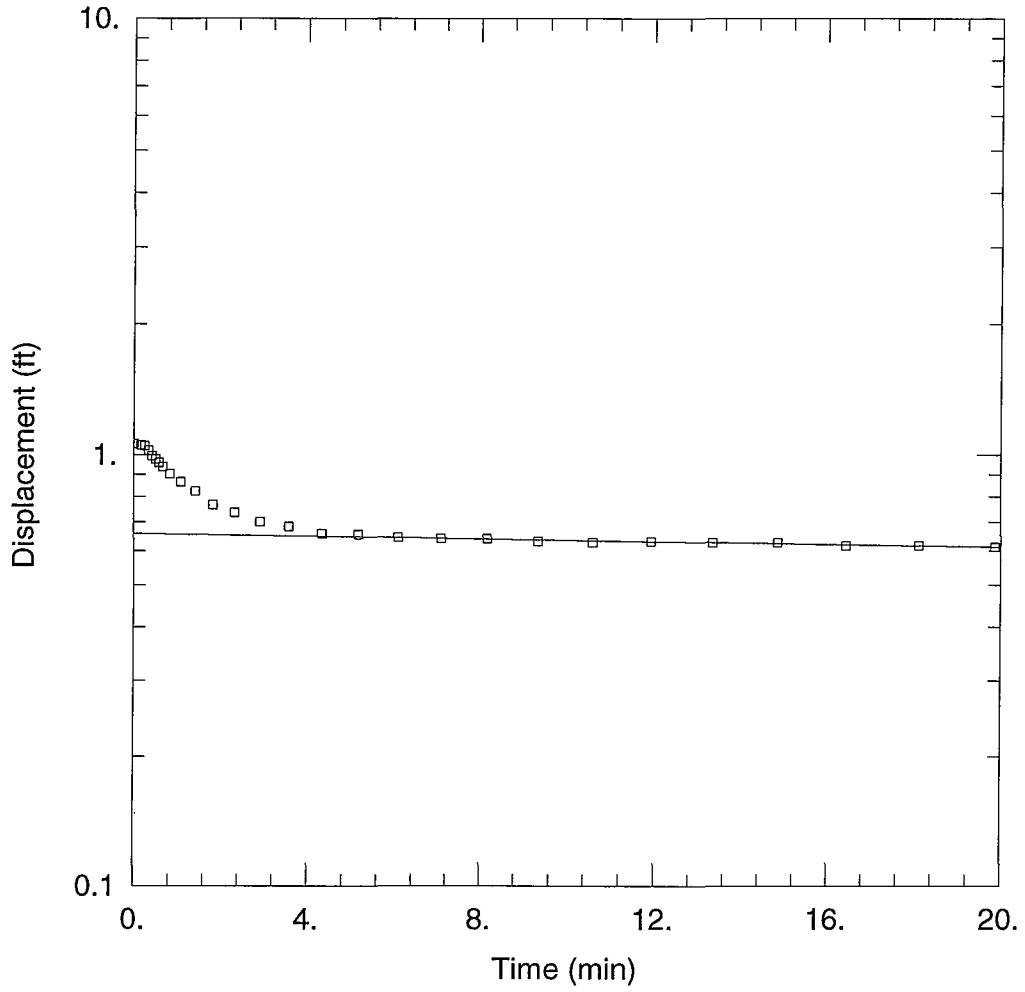
WELL DATA (mw20)

Initial Displacement: 1.06 ft
Wellbore Radius: 0.328 ft
Screen Length: 12. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 12. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 9.31E-06 cm/sec
y0 = 0.6583 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw20brnc.aqt
Date: 08/16/02 Time: 14:18:29

PROJECT INFORMATION

Client: iuc
Test Well: mw20

AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

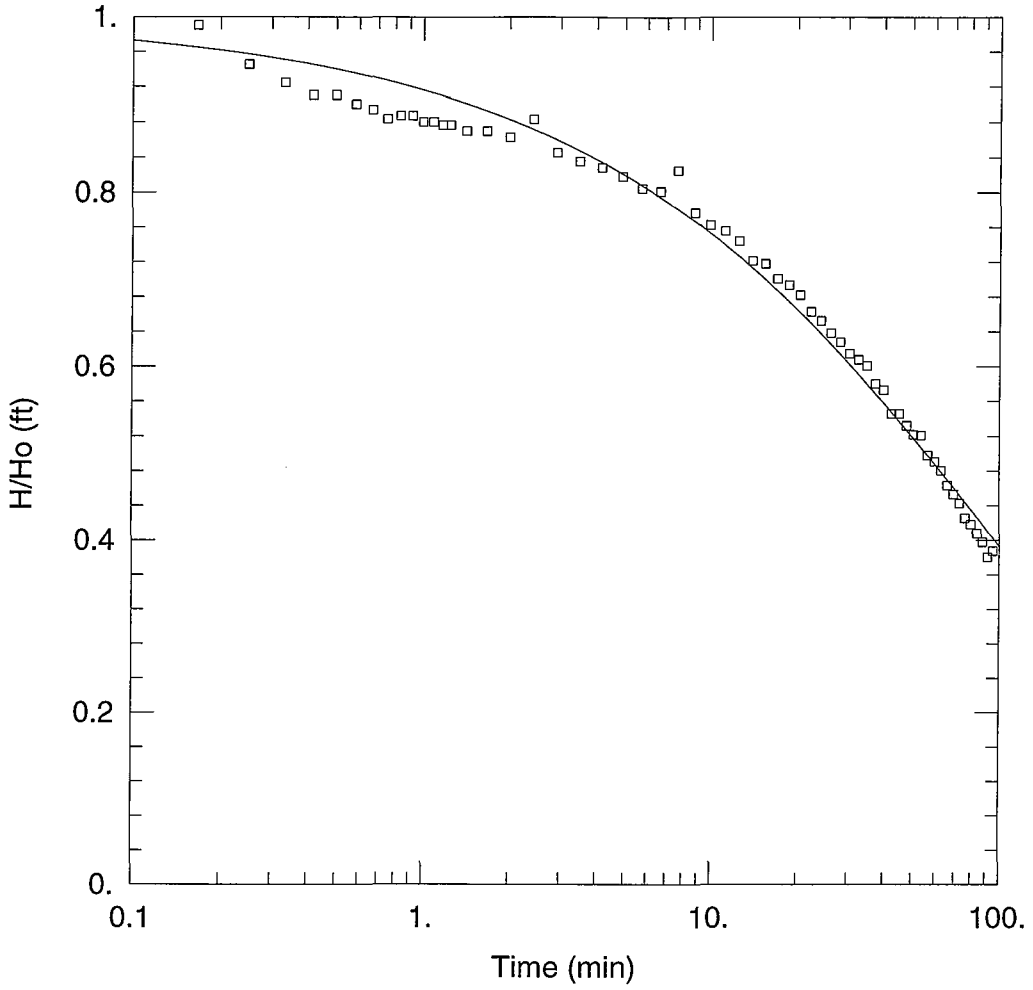
WELL DATA (mw20)

Initial Displacement: 1.06 ft
Wellbore Radius: 0.328 ft
Screen Length: 12. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 12. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 5.874E-06 cm/sec
y0 = 0.6583 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw22.aqt
Date: 08/16/02 Time: 14:19:33

PROJECT INFORMATION

Client: iuc
Test Well: mw22

AQUIFER DATA

Saturated Thickness: 51. ft

WELL DATA (mw22)

Initial Displacement: 1.01 ft
Wellbore Radius: 0.328 ft
Screen Length: 51. ft
Gravel Pack Porosity: 0.3

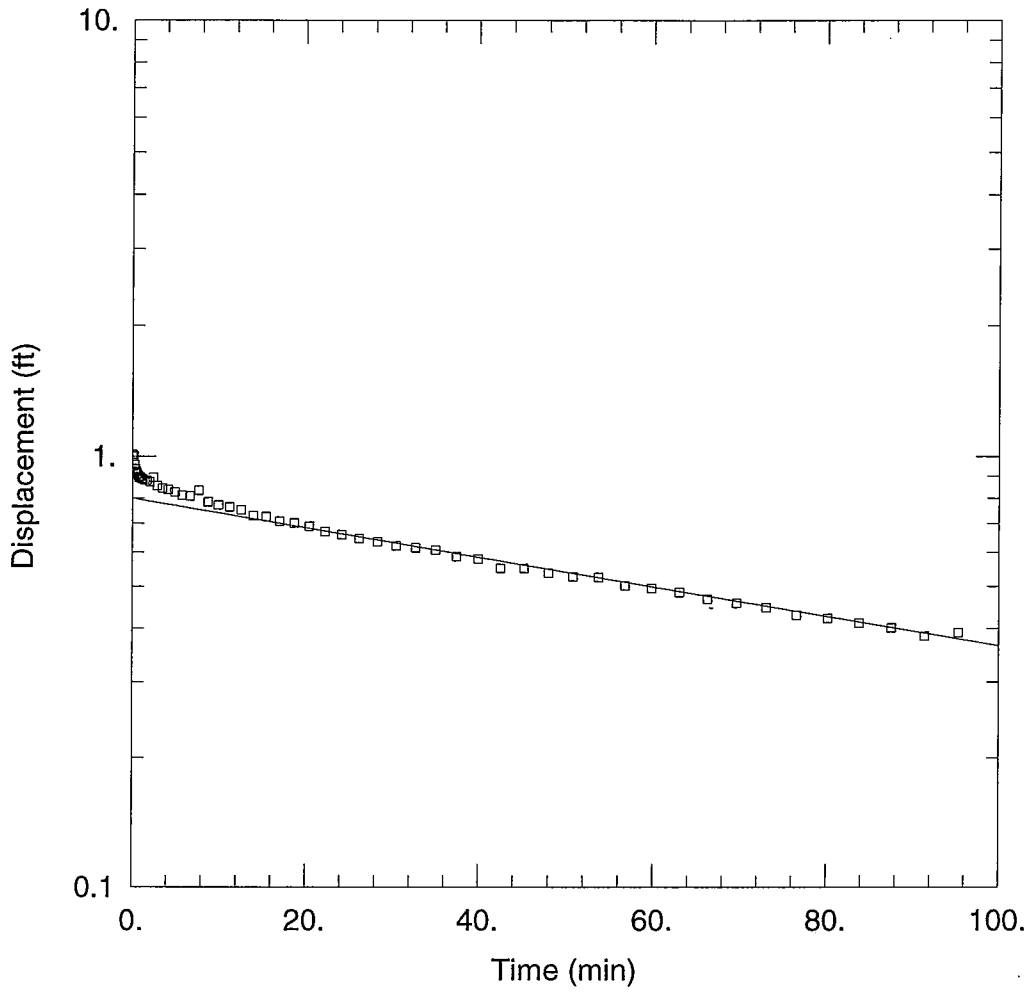
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 51. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 1.04E-06 cm/sec
Kz/Kr = 1.

Ss = 0.001939 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw22br.aqt
Date: 08/16/02 Time: 14:20:18

PROJECT INFORMATION

(with correction for partially submerged screen)

Client: iuc
Test Well: mw22

AQUIFER DATA

Saturated Thickness: 51. ft
Anisotropy Ratio (Kz/Kr): 1.

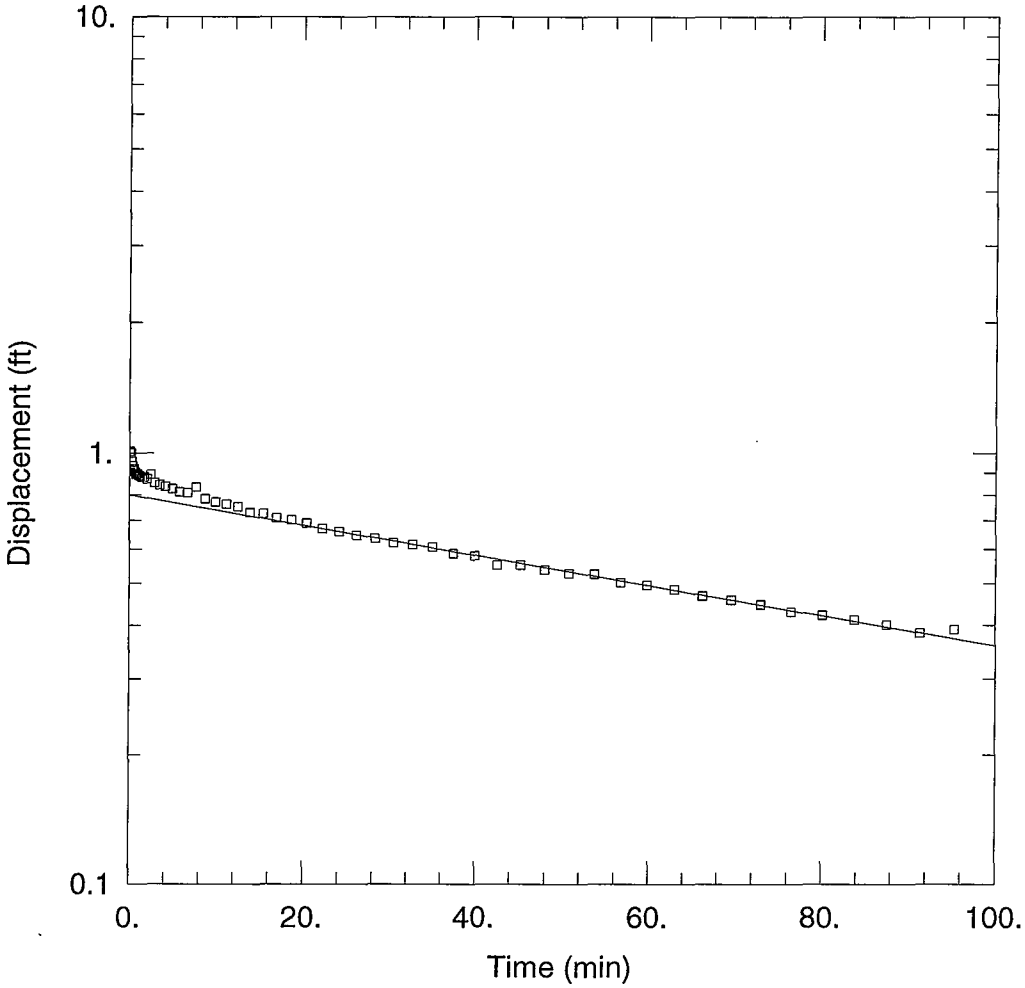
WELL DATA (mw22)

Initial Displacement: 1.01 ft
Wellbore Radius: 0.328 ft
Screen Length: 51. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 51. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 7.919E-06 cm/sec
y0 = 0.8 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesolv\mw22brnc.aqt
Date: 08/16/02 Time: 14:26:59

PROJECT INFORMATION

Client: iuc
Test Well: mw22

AQUIFER DATA

Saturated Thickness: 51. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (mw22)

Initial Displacement: 1.01 ft
Wellbore Radius: 0.328 ft
Screen Length: 51. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 51. ft

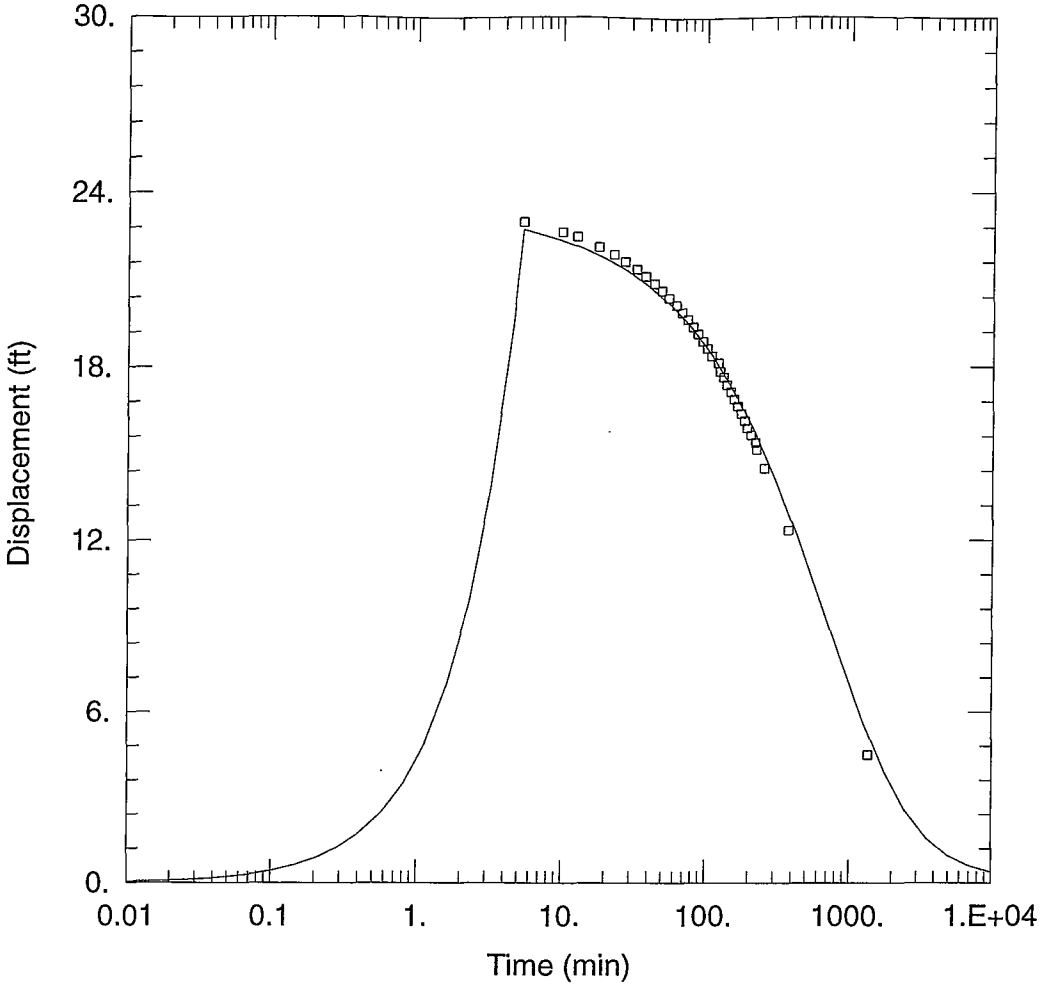
SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 4.352E-06 cm/sec
y0 = 0.8 ft

APPENDIX B

RESULTS OF ANALYSES OF HAND-COLLECTED DATA



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw01hp.aqt
Date: 08/22/02 Time: 12:07:59

PROJECT INFORMATION

Client: iuc
Test Well: mw01

AQUIFER DATA

Saturated Thickness: 20. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
mw01	0	0

Observation Wells

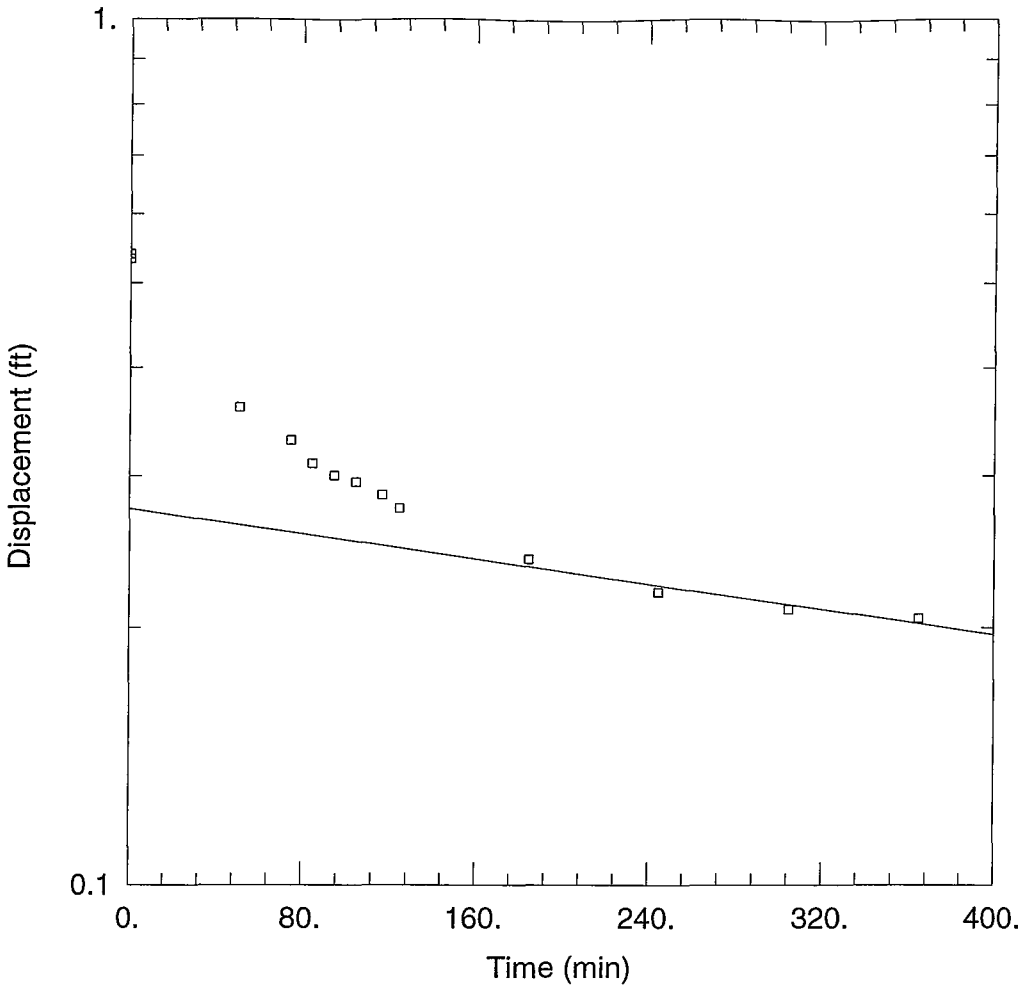
Well Name	X (ft)	Y (ft)
▫ mw01	0	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 2)

T = 0.0432 ft^2/day
r/B = 1.E-09
Sw = 0.

S = 0.008
ß = 1.E-05
Rw = 0.12 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw05hbr.aqt
Date: 08/21/02 Time: 14:25:04

PROJECT INFORMATION

Client: iuc
Test Well: mw05h

AQUIFER DATA

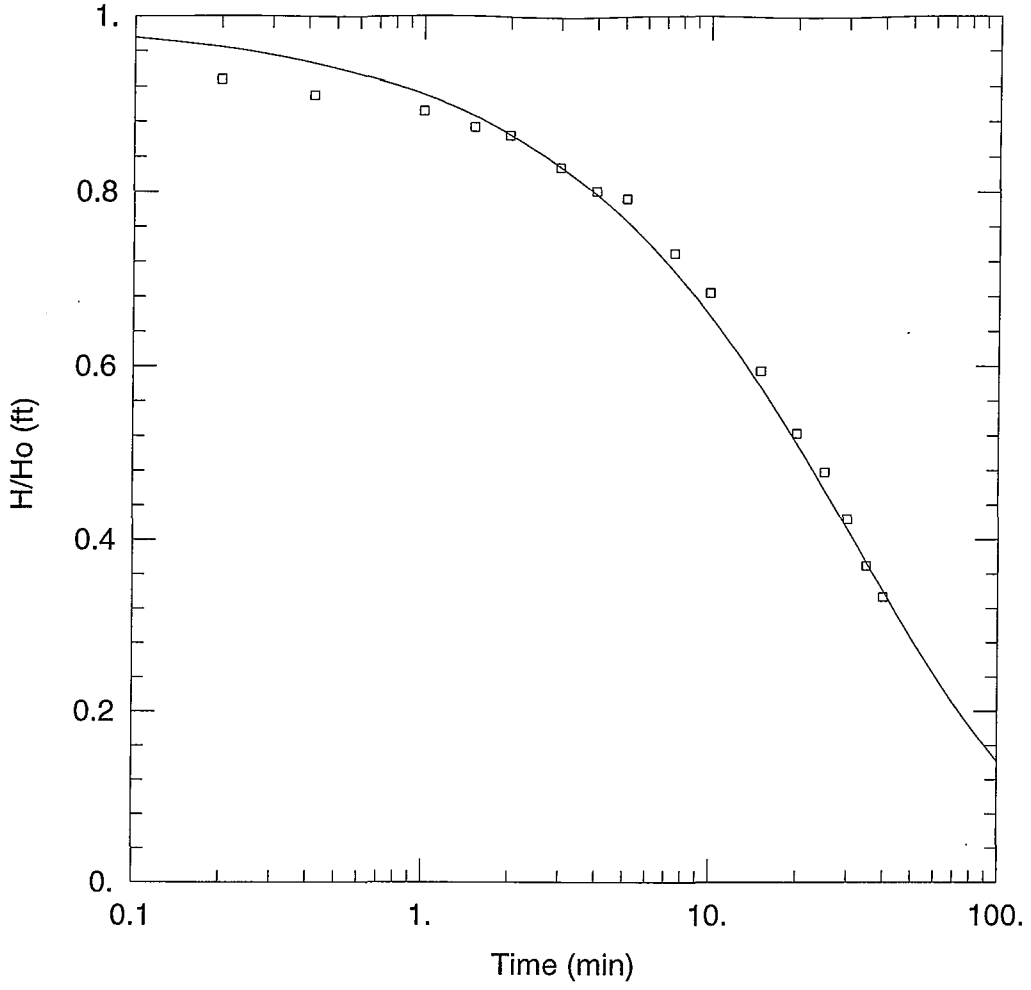
Saturated Thickness: 10. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (mw05h)

Initial Displacement: 0.533 ft
Wellbore Radius: 0.27 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.99
Casing Radius: 0.167 ft
Well Skin Radius: 0.27 ft
Total Well Penetration Depth: 10. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 4.26E-06 cm/sec
y0 = 0.275 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw17h.aqt
Date: 08/21/02 Time: 14:25:33

PROJECT INFORMATION

Client: iuc
Test Well: mw17h

AQUIFER DATA

Saturated Thickness: 18. ft

WELL DATA (mw17h)

Initial Displacement: 1.11 ft
Wellbore Radius: 0.328 ft
Screen Length: 18. ft
Gravel Pack Porosity: 0.3

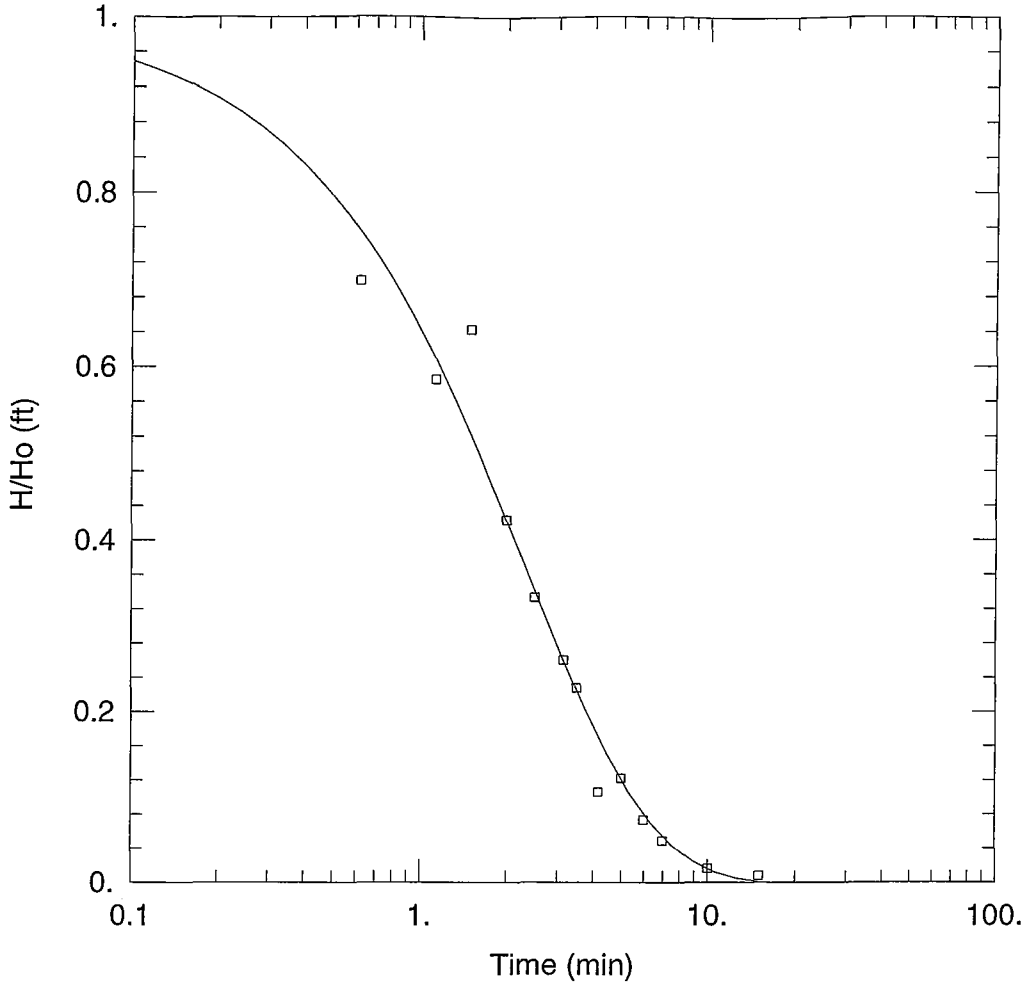
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 18. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 2.242E-05 cm/sec
Kz/Kr = 1.

Ss = 0.0004757 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw18h.aqt
Date: 08/22/02 Time: 08:47:30

PROJECT INFORMATION

Client: iuc
Test Well: mw18

AQUIFER DATA

Saturated Thickness: 58. ft

WELL DATA (mw18)

Initial Displacement: 1.23 ft
Wellbore Radius: 0.328 ft
Screen Length: 45. ft
Gravel Pack Porosity: 0.3

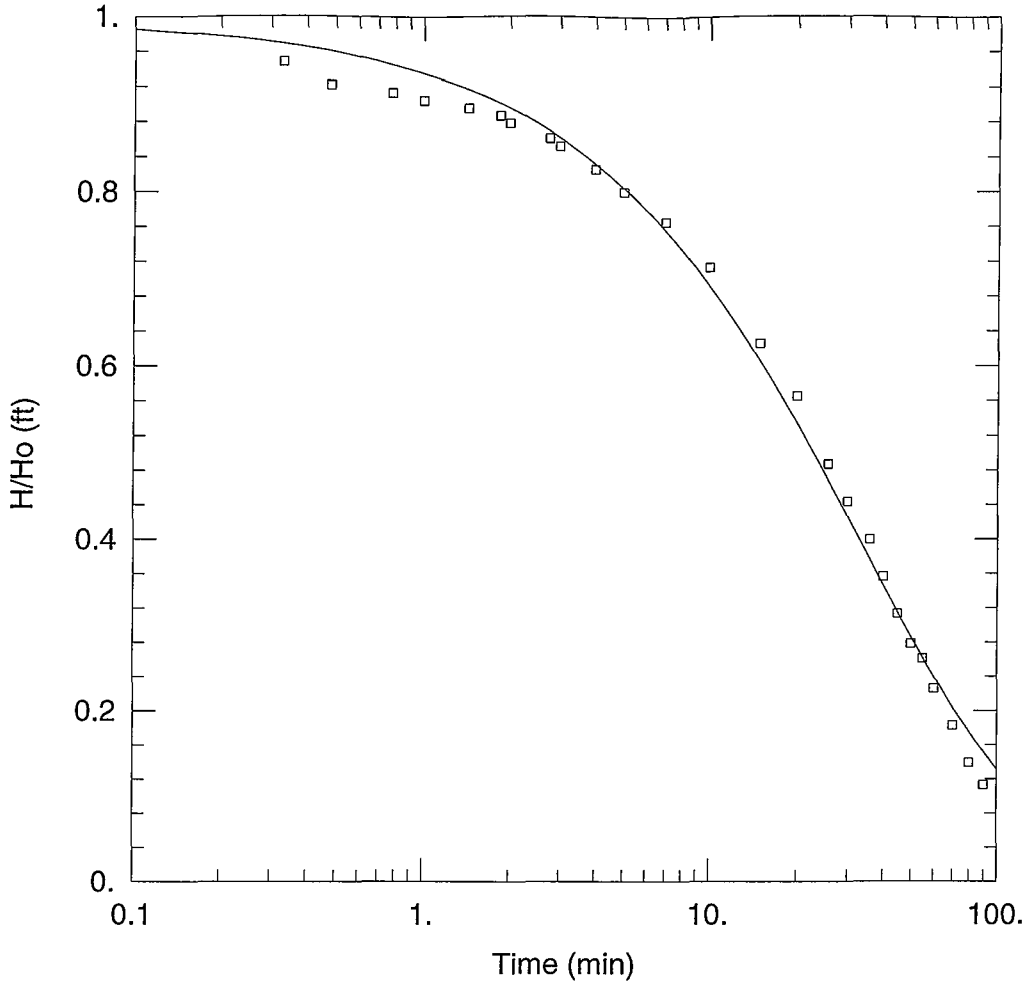
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 58. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 0.0003155 cm/sec
Kz/Kr = 1.

Ss = 1.813E-07 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw19h.aqt
Date: 08/21/02 Time: 15:30:35

PROJECT INFORMATION

Client: iuc
Test Well: mw19h

AQUIFER DATA

Saturated Thickness: 80. ft

WELL DATA (mw19h)

Initial Displacement: 1.15 ft
Wellbore Radius: 0.328 ft
Screen Length: 47. ft
Gravel Pack Porosity: 0.3

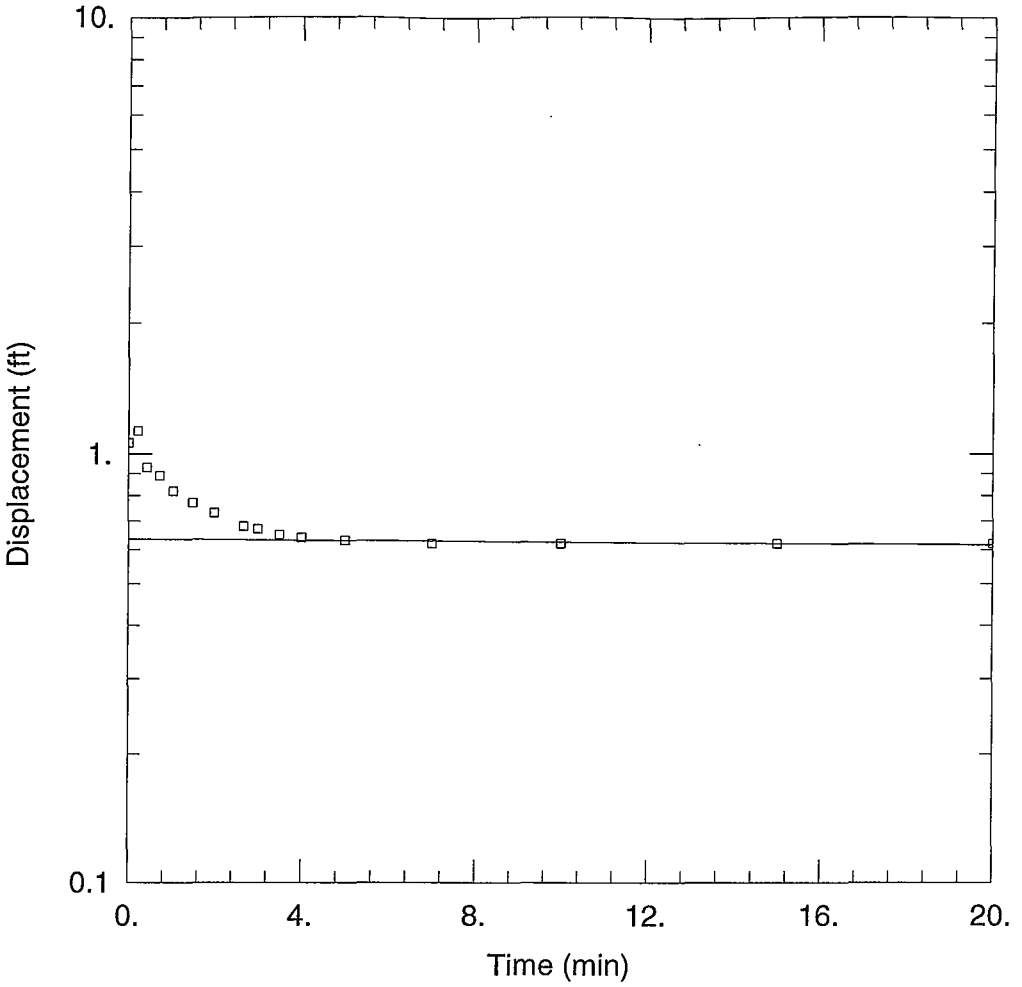
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 80. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 1.241E-05 cm/sec
Kz/Kr = 1.

Ss = 3.282E-05 ft^{-1}



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw20hbrn.aqt
Date: 08/21/02 Time: 14:27:19

PROJECT INFORMATION

Client: iuc
Test Well: mw20h

AQUIFER DATA

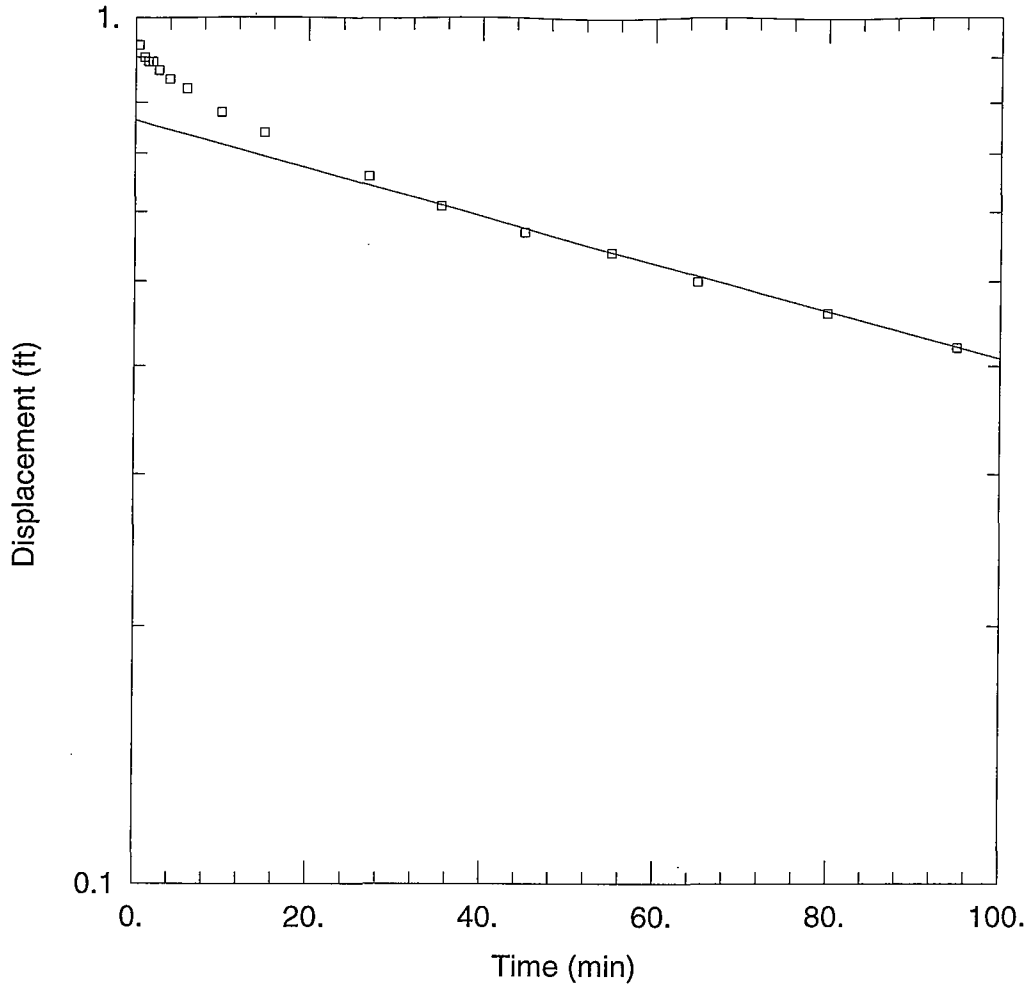
Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (mw20h)

Initial Displacement: 1.06 ft
Wellbore Radius: 0.328 ft
Screen Length: 12. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 12. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.49E-06 cm/sec
y0 = 0.6347 ft



WELL TEST ANALYSIS

Data Set: H:\718000\hydtst02\aqtesol2\mw22hbrn.aqt
Date: 08/21/02 Time: 14:27:59

PROJECT INFORMATION

Client: iuc
Test Well: mw22h

AQUIFER DATA

Saturated Thickness: 51. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (mw22h)

Initial Displacement: 1.01 ft
Wellbore Radius: 0.328 ft
Screen Length: 51. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.328 ft
Total Well Penetration Depth: 51. ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.408E-06 cm/sec
y0 = 0.764 ft