Results of the Milton T-Field Aquifer Test
Sand-and-Gravel Aquifer, Santa Rosa County Florida

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INTRODUCTION

In 1978 as part of the Evaluation of Industrial Water Availability Study (NWFWMD Water Resources Assessment 80-1) aquifer testing was performed to determine the hydraulic properties of the Sand-and-Gravel Aquifer in the vicinity of Milton, Florida (Figure 1). The aquifer test was performed at the Milton T-Field Airport located in section 31, township 2N, range 27W. The District undertook this work with the aid of a three year grant from the Coastal Plains Regional Commission. A limited summary of the results of the test were published in the report cited above.

The purpose of this report is to provide additional documentation regarding the aquifer test, provide greater detail regarding the analysis and allow for distribution of the results. This type of information is especially important at this time of increasing water supply demands in northwest Florida. Aquifer testing provides the most realistic assessment of the hydraulic properties of the aquifer, and, forms the basis for determining the availability of ground water and the impact of withdrawals on existing users and the environment.

HYDROGEOLOGY

The Sand-and-Gravel Aquifer consists primarily of fine to medium sand interbedded with varying amounts of clay. Due to the complex nature of the sediments, the lithology is highly variable both horizontally and vertically. The Sand-and-Gravel Aquifer includes the saturated sediments situated between the water table and the underlying, regionally extensive confining unit referred to as the Intermediate System. Beneath the Intermediate System lies the Upper Floridan Aquifer.

The Sand-and-Gravel Aquifer is highly productive in the Milton area and serves as the primary source of ground water. Although the Upper Floridan Aquifer is utilized in the eastern and the southeastern portion of Santa Rosa County, the Upper Floridan Aquifer is not used in the vicinity of Milton. In southwest Santa Rosa County ground water within the Upper Floridan Aquifer exceeds allowable concentrations for potable water supply.

Recharge to the Sand-and-Gravel Aquifer originates as rainfall. That portion of rainfall which percolates through the unsaturated sediments serves to recharge the Sand-and-Gravel Aquifer. Given the very sandy nature of the soils near Milton, rainfall readily recharges the Sand-and-Gravel Aquifer. Ground water flow within the Sand-and-Gravel Aquifer is primarily lateral, and generally flows toward and discharges to nearby surface water features such as perennial streams, wetlands or coastal bays. Due to the thick confining unit between the Sand-and-Gravel Aquifer and the Upper Floridan Aquifer very little exchange of ground water occurs between these aquifers.

A test boring drilled to 230 ft at the aquifer test site indicates the base of the aquifer occurs at approximately 213 ft below land surface (lsd). Cutting descriptions and natural gamma and normal electric logs are available for this boring. Given the site elevation of 85 ft, the bottom of the Sand-and-Gravel occurs at 128 ft below mean sea level (msl). The normal electric log shows the water table to occur at approximately 65 ft below lsd which results in a saturated thickness of 148 ft.

The following lithologic log was prepared by the District based on cuttings collected from the test boring.

Depth	Thickness	Description
0 – 53 ft	53 ft	Sand, medium to coarse; yellow and red clay near top of unit, clay becomes white near base; coarser and with white feldspar below 30 ft.
53 – 70 ft	17 ft	Sand, as above, but medium to medium-coarse, with a little muscovite.
70 – 85 ft	15 ft	Sand, coarse to very coarse and pebbly, also white clay.
85 – 135 ft	50 ft	Sand, medium to coarse, sub-angular, with white and red clay; few coarse grains.
135 – 225 ft	90 ft	Sand, as above, generally coarser and cleaner.
225 – 230 ft	5 ft	Sand, loose, medium to medium-coarse, sub-angular, with muscovite flake and phosphate grains; gray clay.

The lithologic log shows the Sand-and-Gravel Aquifer at the test site to consists primarily of sand with only minor amounts of clay. Consistent with the lithologic log, the natural gamma log indicates an increase in clay content between 80 and 113 ft below lsd. However, both the lithologic log and the normal electric log of this test hole indicate only a minor increase in clay content in this interval. Apparent resistivity of this interval exceeds 300 ohms meter^2/meter (ohm meters) and indicates the lithology of this interval to be primarily sand. The normal electric log exhibits resistivities ranging between 300 ohm meters and 600 ohm meters throughout the Sand-and-Gravel Aquifer indicating the lack of a significant semi-confining unit within the aquifer at this site.

AQUIFER TEST

One six-inch production well and two four-inch observations wells were constructed at the aquifer test site. Figure 2 shows a cross-sectional view of the test site. The production well was completed at a depth of 170 ft below lsd. PVC well screen with a slot size of 0.015 inch was installed and gravel packed from 130 ft to 170 ft with casing extending from 130 ft to land surface.

Observation Well No.1 (OBS-1) was located 75 ft south of the production well. It was completed to a depth of 140 ft. Well screen with a slot size of 0.010 inch was installed and gravel packed from 120 to 140 ft below lsd. Observation Well No.2 (OBS-2) was located 150 ft east of the production well. It was completed to a depth of 190 ft. Well screen with a slot size of 0.010 inch was installed and gravel packed from 170 to 190 ft below lsd. OBS-2 was completed within the test boring which was drilled to a depth of 230 ft. The screen portion of all three wells was thoroughly developed.

A turbine pump was installed in the production well and the observation wells were equipped with digital water level recorders. A preliminary test was conducted on November 14, 1978 and indicated a drawdown of 22 ft in the production well while discharging 230 gal/min. The actual test began on November 16, 1978 and was run for 45 hours. Discharge was held constant at 230 gal/min during the test.

The static water level in all wells was approximately 65 ft below lsd or about 20 ft above mean sea level (msl). At the conclusion of the test, drawdown measured in the production well was 22 ft, drawdown in OBS-1 was 1.68 ft and drawdown in OBS-2 totaled 1.72 ft. Actual measured drawdown for the two observation wells is included in the appendix.

TEST ANALYSIS

The aquifer test data were analyzed in September 1998 utilizing AquiferWin32 software. AquiferWin32 software is propriety software produced by Environmental Simulations, Inc. The data were analyzed using both the Hantush (1964) and Neuman (1974) analytical models. Type curves were generated by the software and manually matched to the observed drawdown data. Type curves were generated for numerous combinations of parameters in order to assess and obtain the combination of parameters which provided the best match with the observed data.

The Hantush (1964) solution essentially simulates response to pumping of an aquifer overlain by a leaky confining unit which is in turn overlain by a constant head source bed. This model incorporates aquifer vertical to horizontal anisotropy (K_z/K_r) and the effects of partially penetrating wells. In addition the model assumes:

- -well discharge is constant
- -well is of infinitesimal diameter
- -no release of water from storage in the confining bed
- -flow of water through the confining unit is vertical
- -the initial potentiometric surface of the aquifer and the water table are horizontal and extend infinitely in the radial direction

Figures 3 and 4 show the Hantush type curves which best represent the aquifer plotted with the observed data where:

$$u = \frac{r^2 S}{4K_r bt} \quad \text{and} \quad W(u,r/B) + f \quad \text{is the well function where}$$

B is the leakage factor = $\sqrt{\frac{Tb'}{k'}}$ and

f is the partial penetration function.

The terms are defined as:

b	= aquifer thickness (ft)
b’	= aquitard thickness (ft)
K_r	= horizontal hydraulic conductivity of the aquifer (ft/d)
K_z	= vertical hydraulic conductivity of the aquifer (ft/d)
k’	= vertical hydraulic conductivity of the aquitard (ft/d)
r	= radial distance from the pumping well to the observation well (ft)
S	= aquifer storativity (dimensionless)
t	= time (d)
T	= aquifer transmissivity (ft^2/d)

In applying the Hantush model, the aquifer thickness and transmissivity refer to the 100 ft thick main sand found between 113 ft and 213 ft. The somewhat clayey interval present between 80 and 113 ft represents the leaky confining unit and the saturated interval between 65 ft and 80 ft represents the constant head source bed. Data analysis using the Hantush (1964) model results in the following hydraulic properties for these units:

Hydraulic Property	OBS-1	OBS-2
K_z/K_r (dimensionless)	0.18	0.10
r/B (dimensionless)	0.17	0.20
T of 100 ft thick zone (ft^2/d)	9,500	7,500
S of 100 ft thick zone (dimensionless)	0.0028	0.0001
k’/b’ (1/d)	0.049	0.021
K_r (aquifer ft/d)	95	75
K_z (aquifer ft/d)	17	7.5
k’ (aquitard ft/d)	1.62	0.69

Applying the average horizontal hydraulic conductivity of the main sand unit (85 ft/d) to the 115 ft of clean, saturated sand (main sand and source bed), and, applying a horizontal hydraulic conductivity of 12 (based on a K_z/K_r anisotropy of 0.10 and k’ of 1.2 ft/d) to the 33 ft thick leaky confining unit, shows the transmissivity of the full thickness of the aquifer to be approximately 10,200 ft^2/d.

The Neuman (1974) model simulates an unconfined, anisotropic aquifer and partially penetrating wells. This model assumes:

-well discharge is constant
-well is of infinitesimal diameter

-the aquifer is bounded below by an aquiclude
-the aquifer is homogeneous and anisotropic
-the aquifer is compressible and instantaneously releases water from storage (specific storage S_s) and, as the water table drops, water is released from storage due to gravity drainage of the effective pore space (specific yield S_y)
-the initial water table is horizontal and extends infinitely in the radial direction
-drawdown is small compared to the saturated aquifer thickness

Figures 5 and 6 show the Neuman type curves which best represent the aquifer plotted with the observed data where:

ts = $\frac{Tt}{S_s b r^2}$ for early time data and = $\frac{Tt}{S_y r^2}$ for late time data

and

sd is the well function which incorporates t_s, b, s and correction for partial penetration where $b = \frac{K_z r^2}{K_r b^2}$ and $s = \frac{S_s b}{S_y}$

The terms are defined as:

b	= aquifer thickness or saturated interval prior to pumping (ft)
K_r	= horizontal hydraulic conductivity of the aquifer (ft/d)
K_z	= vertical hydraulic conductivity of the aquifer (ft/d)
r	= radial distance from the pumping well to the observation well (ft)
S	= aquifer storativity (dimensionless)
S_s	= aquifer specific storage (1/ft)
S_y	= aquifer specific yield (dimensionless)
t	= time (d)
T	= aquifer transmissivity (ft^2/d)

Application of the Neuman solution assumes the aquifer is unconfined. The transmissivity, aquifer storage and anisotrophy derived by the analysis are reflective of the entire 148 ft thick saturated interval. Analyzing the data using the Neuman solution results in the following hydraulic parameters for the Sand-and-Gravel Aquifer.

Hydraulic Property	OBS-1	OBS-2
K_z/K_r (dimensionless)	0.15	0.09
b (dimensionless)	0.038	0.09
T of entire saturated interval (ft^2/d)	14,100	11,500
S (dimensionless)	0.0037	0.0001
S_y (dimensionless)	0.1	0.02
K_r (aquifer ft/d)	95	78
K_z (aquifer ft/d)	14.3	7.0

The Neuman model, as applied in this analysis, has been shown (Chen et al., 1998) to underestimate the specific yield (S_y) and that appears to be the case in this analysis. The specific yield of the Sand-and-Gravel is expected to be somewhat greater than 0.15.

Both the Hantush leaky confined and the Neuman unconfined models provide similar results regarding the hydraulic conductivity of the aquifer. The differing response of, and results derived from, the two observation wells is presumably due to heterogeniety of the aquifer. Review of the geophysical and lithological logs indicate the Hantush leaky confined model to be more appropriate for this site. The average values for the two observation wells obtained from the Hantush analysis provides a reasonable estimate of the hydraulic properties at this site. These values are also consistent with the initial analysis performed by the District in 1978.

REFERENCES

Chen, X., and Ayres, J. F., 1998. Aquifer Properties Determined from Two Analytical Solutions. Ground Water Journal, September-October 1998, pages 783 to 791.

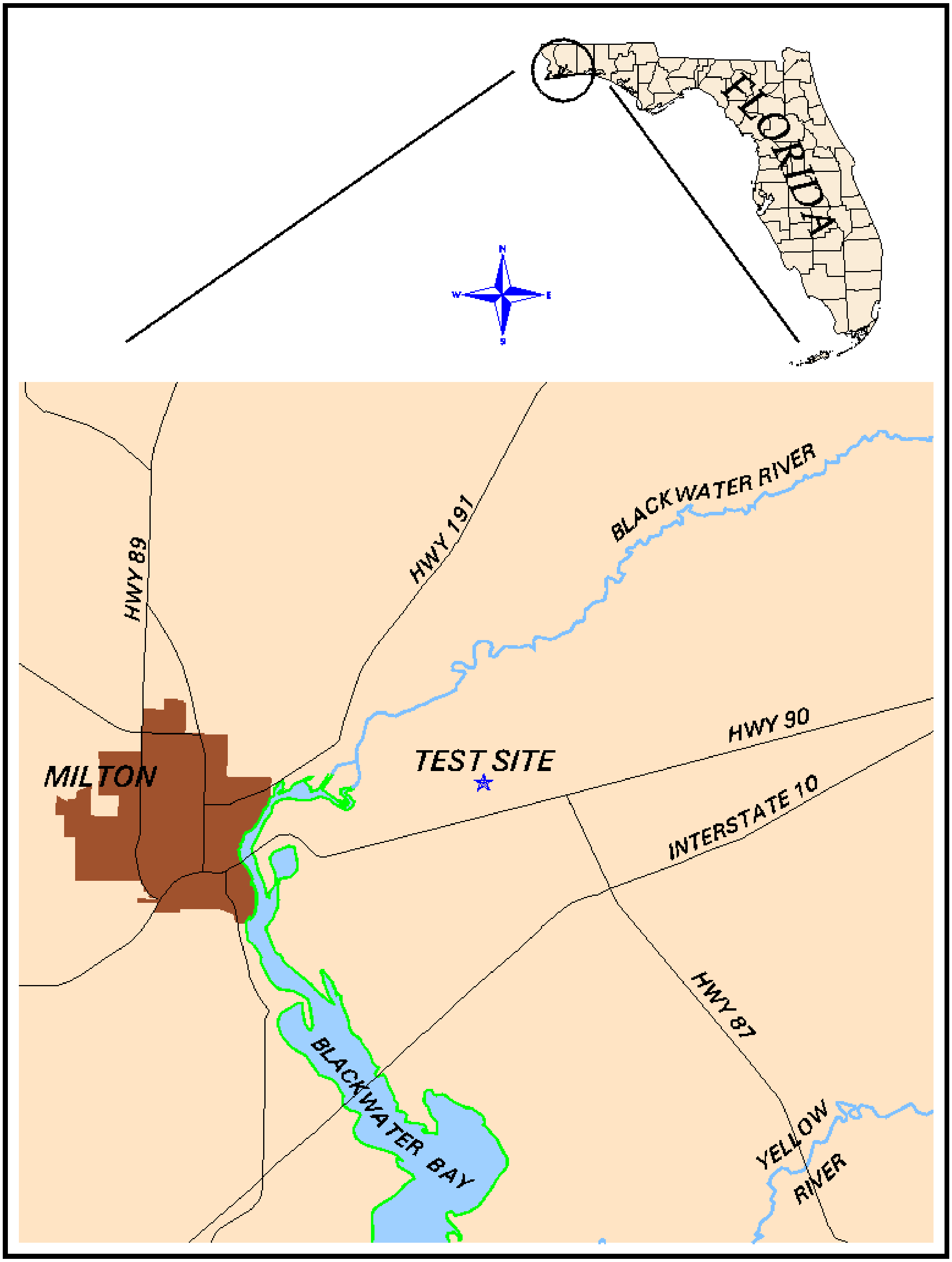

Figure 1. Location of Aquifer Test Site.

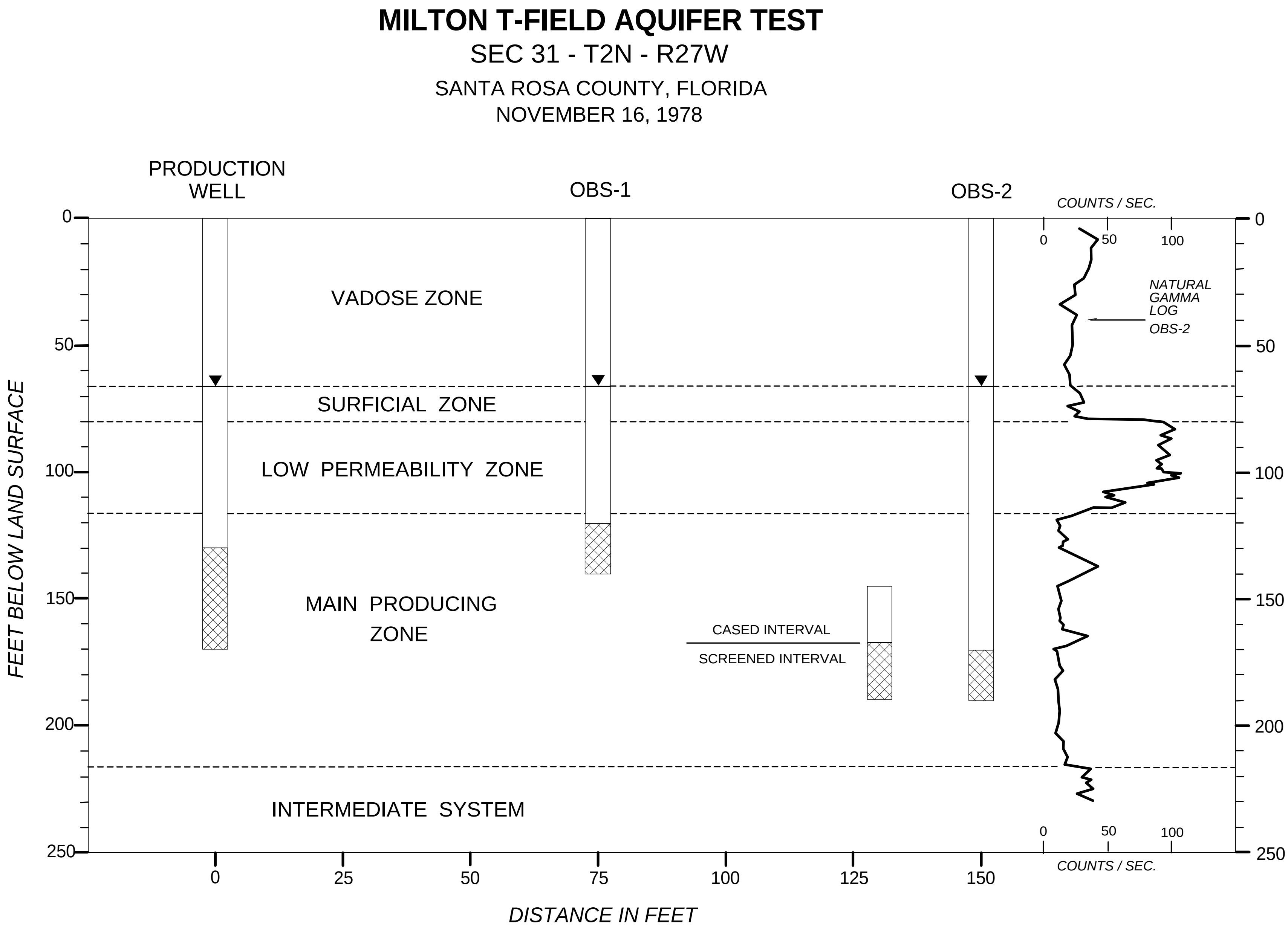

Figure 2. Well Construction and Generalized Hydrostratigraphy at the Aquifer Test Site.

Milton T-Field Aquifer Test, Observation Well No. 1.

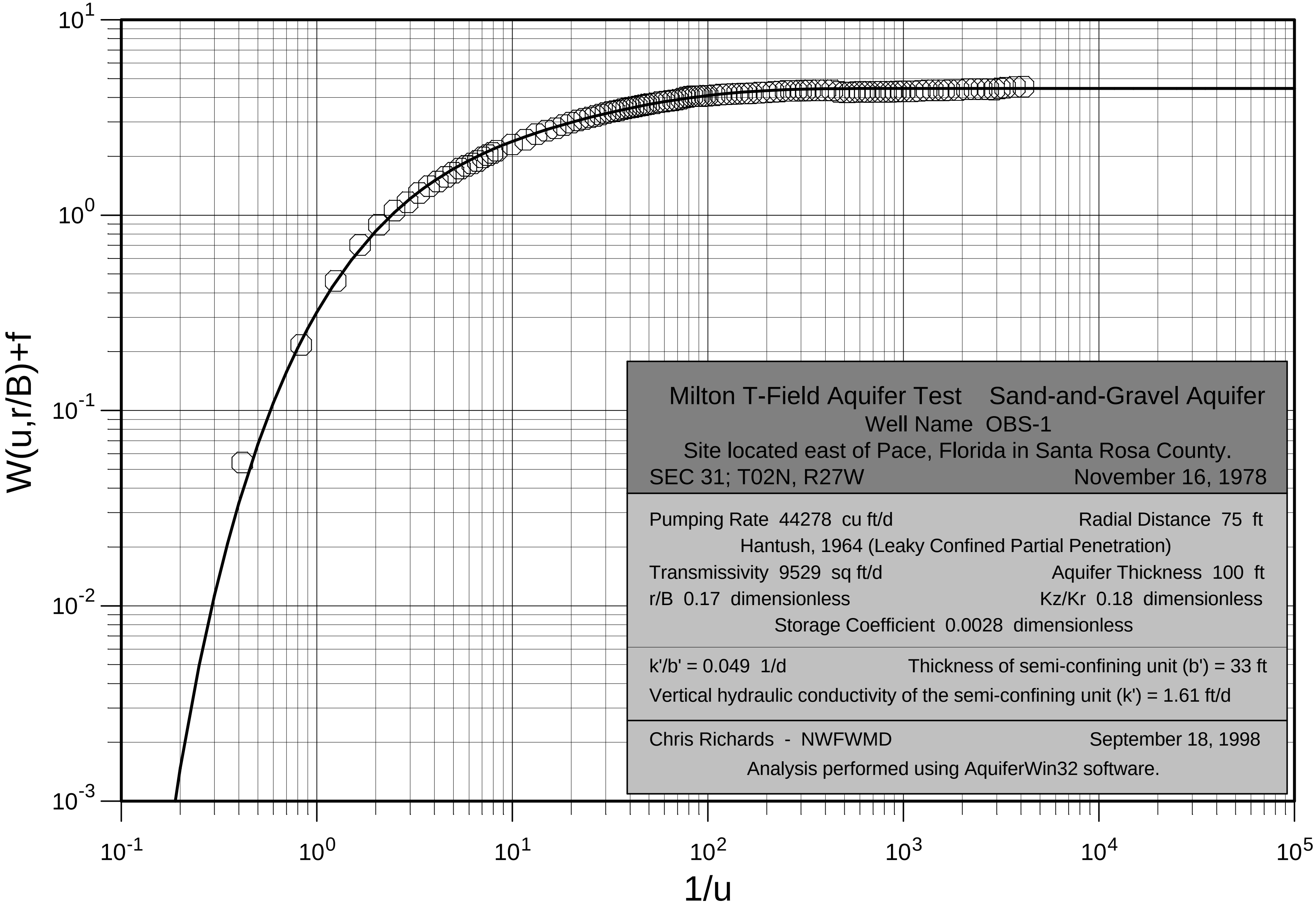

Figure 3. Analysis of Observation Well No. 1 Assuming Leaky Confined Conditions.

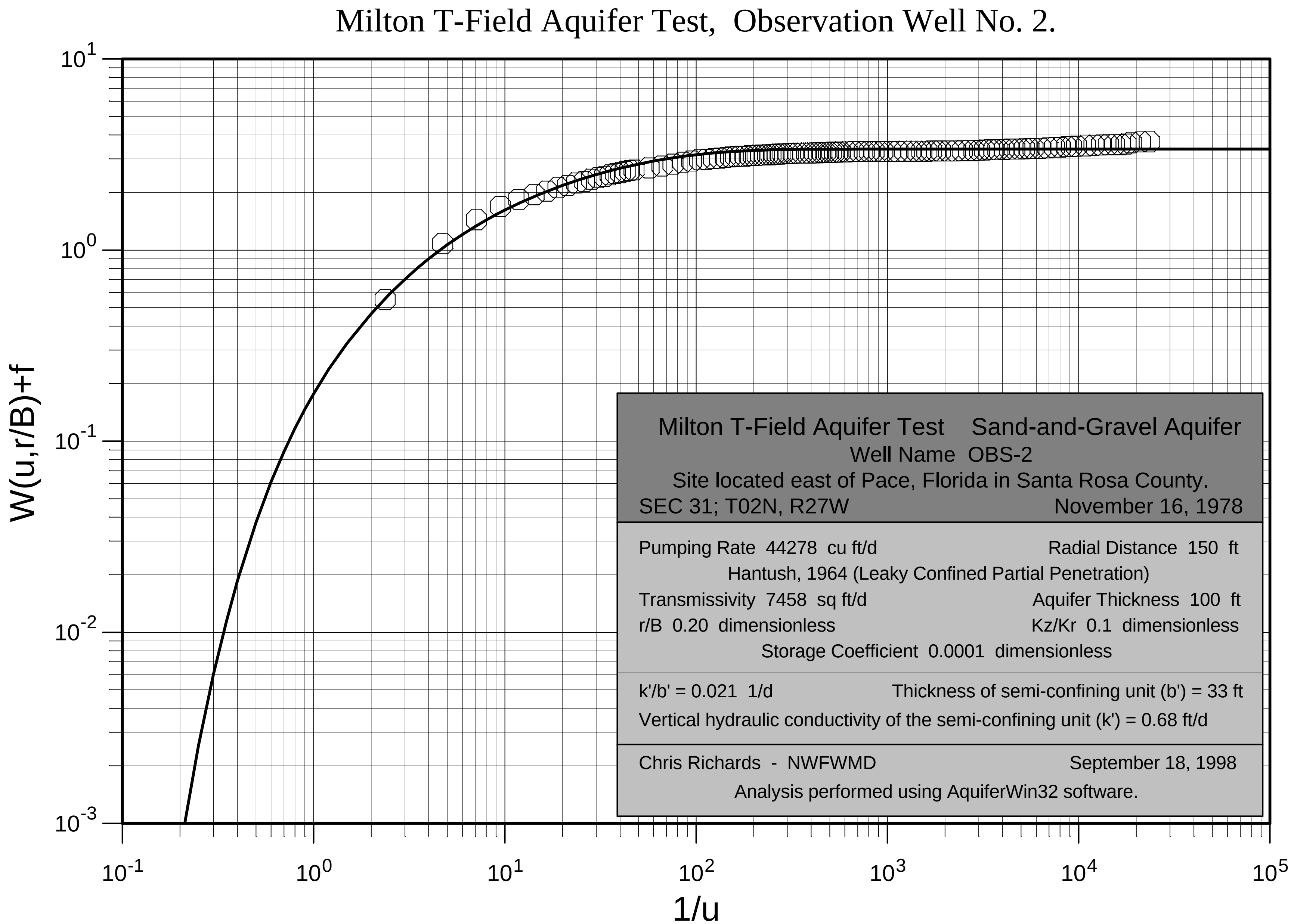

Figure 4. Analysis of Observation Well No. 2 Assuming Leaky Confined conditions.

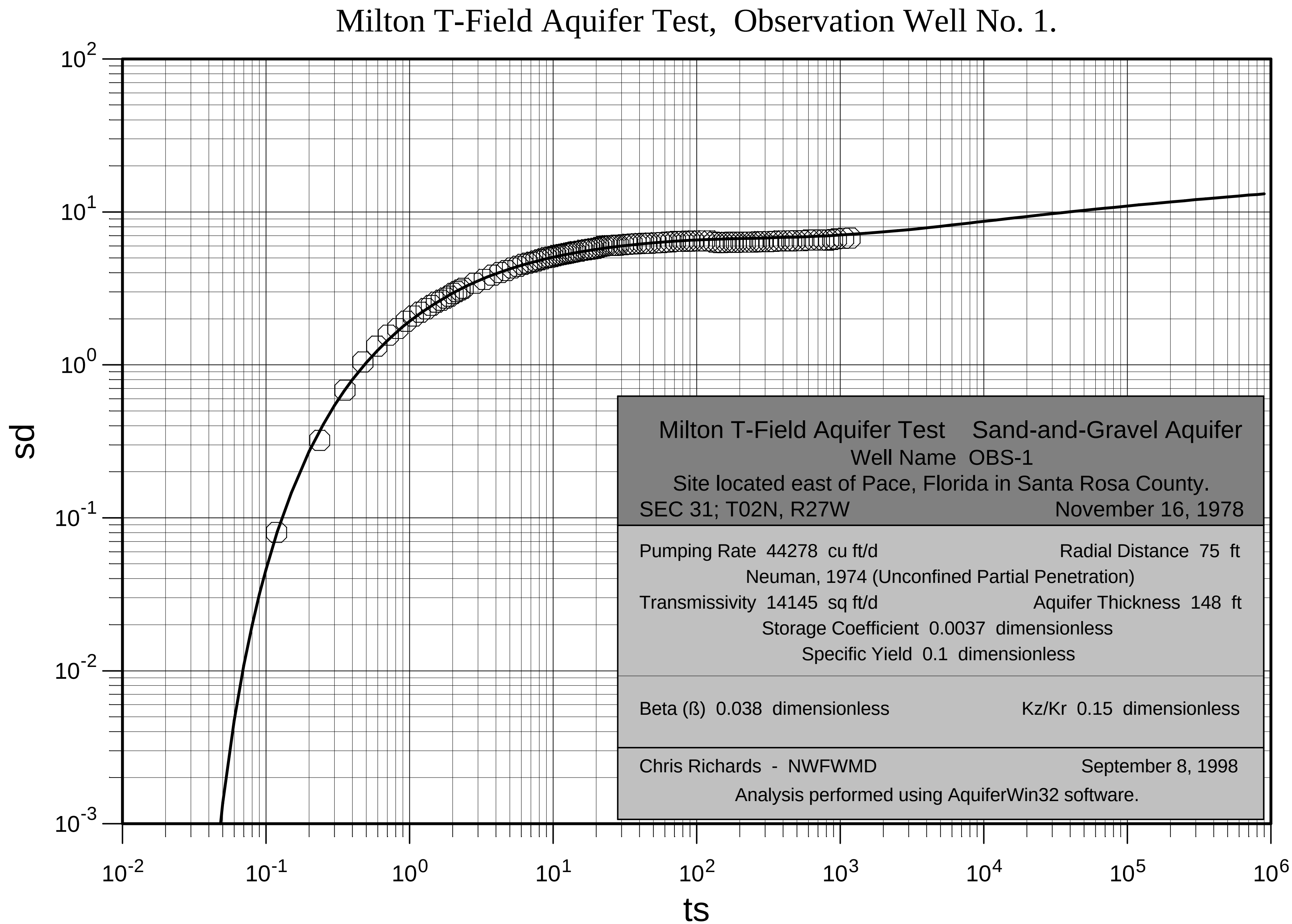

Figure 5. Analysis of Observation Well No. 1 Assuming Unconfined Conditions.

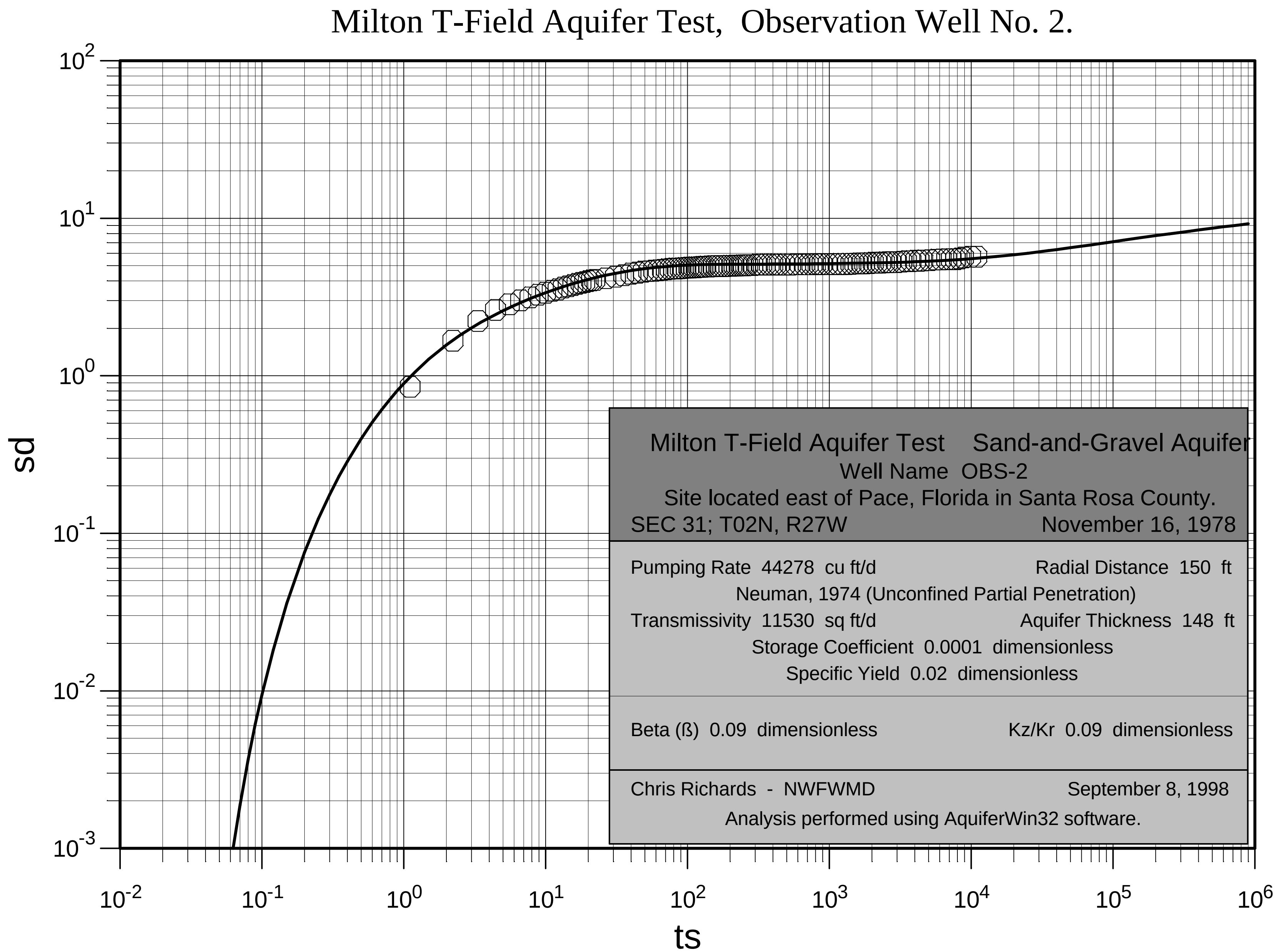

Figure 6. Analysis of Observation Well No. 2 Assuming Unconfined Conditions.

APPENDIX

DRAWDOWN DATA FOR OBSERVATION WELL NO. 1

Elapsed Time (Minutes)	*Drawdown (Feet)*
0.25	0.02
0.5	0.18
0.75	0.17
1	0.26
1.25	0.33
1.5	0.39
1.75	0.43
2	0.48
2.25	0.52
2.5	0.55
2.75	0.58
3	0.61
3.25	0.64
3.5	0.66
3.75	0.68
4	0.7
4.25	0.73
4.5	0.75
4.75	0.77
5	0.79
6	0.85
7	0.9
8	0.96
9	1
10	1.03
11	1.07
12	1.1
13	1.13
14	1.15
15	1.17
16	1.19
17	1.21
18	1.23
19	1.25
20	1.26
21	1.27
22	1.29
23	1.3
24	1.31
25	1.32
26	1.33
27	1.34
28	1.35
29	1.36
30	1.37
32	1.38

Elapsed Time (Minutes)	*Drawdown (Feet)*
34	1.4
36	1.41
38	1.42
40	1.43
42	1.44
44	1.46
46	1.48
48	1.49
50	1.5
52	1.5
54	1.5
56	1.5
58	1.51
60	1.51
65	1.52
70	1.53
75	1.535
80	1.54
85	1.545
90	1.55
95	1.55
100	1.555
110	1.565
120	1.57
130	1.58
140	1.585
150	1.6
160	1.6
170	1.6
180	1.605
190	1.605
200	1.61
220	1.61
240	1.61
260	1.61
280	1.58
300	1.57
320	1.57
340	1.575
360	1.58
380	1.58
400	1.575
430	1.58
460	1.58
490	1.58
520	1.58

Elapsed Time (Minutes)	*Drawdown (Feet)*
550	1.585
580	1.59
610	1.59
670	1.59
730	1.6
790	1.61
850	1.61
910	1.61
970	1.61
1030	1.615
1150	1.615
1270	1.63
1390	1.63
1510	1.63
1630	1.63
1750	1.625
1870	1.645
1990	1.66
2230	1.675
2470	1.68

DRAWDOWN DATA FOR OBSERVATION WELL NO. 2

Elapsed Time (Minutes)	*Drawdown (Feet)*
0.25	0.26
0.5	0.51
0.75	0.68
1	0.8
1.25	0.87
1.5	0.92
1.75	0.96
2	1
2.25	1.03
2.5	1.06
2.75	1.08
3	1.11
3.25	1.13
3.5	1.15
3.75	1.17
4	1.19
4.25	1.2
4.5	1.22
4.75	1.23
5	1.24
6	1.27
7	1.3
8	1.33
9	1.36
10	1.38
11	1.4
12	1.41
13	1.42
14	1.43
15	1.44
16	1.45
17	1.46
18	1.465
19	1.465
20	1.47
21	1.475
22	1.48
23	1.485
24	1.485
25	1.49
26	1.49
27	1.495
28	1.5
29	1.5
30	1.505
32	1.51

Elapsed Time (Minutes)	*Drawdown (Feet)*
34	1.515
36	1.52
38	1.52
40	1.52
42	1.52
44	1.525
46	1.525
48	1.53
50	1.53
52	1.53
54	1.535
56	1.535
58	1.535
60	1.54
65	1.54
70	1.55
75	1.55
80	1.55
85	1.55
90	1.55
95	1.55
100	1.55
110	1.55
120	1.55
130	1.555
140	1.555
150	1.555
160	1.555
170	1.555
180	1.56
190	1.56
200	1.56
220	1.56
240	1.56
260	1.565
280	1.565
300	1.565
320	1.57
340	1.575
360	1.58
380	1.58
400	1.58
430	1.585
460	1.595
490	1.595
520	1.595

Elapsed Time (Minutes)	*Drawdown (Feet)*
550	1.6
580	1.605
610	1.61
670	1.61
730	1.62
790	1.63
850	1.63
910	1.64
970	1.64
1030	1.65
1150	1.655
1270	1.67
1390	1.675
1510	1.68
1630	1.68
1750	1.68
1870	1.695
1990	1.72
2230	1.74
2470	1.74