

Results of the ECUA Beulah Constant Rate Aquifer Test Sand-and-Gravel Aquifer, Escambia County Florida

December 2001

Christopher J. Richards
Northwest Florida Water Management District

INTRODUCTION

Escambia County Utilities Authority (ECUA) provides water and wastewater services for most of southern Escambia County. In 1995, ECUA provided 87 percent of public supply withdrawals for the county. ECUA's average daily withdrawal for 1995 totaled approximately 33 Mgal/d. The ECUA and other water utilities throughout Escambia County rely exclusively on the Sand-and-Gravel Aquifer for potable water supply.

In order to provide for increasing potable water demands, ECUA constructed a test well near the Beulah Community (Figure 1). The Beulah Test Well was completed during the summer of 2001. During construction of the test well, staff at the Northwest Florida Water Management District (District) identified two existing ground water monitoring wells in the vicinity of the test well. These monitoring wells were completed in the same zone of the Sand-and-Gravel Aquifer as the test well. The presence of these monitor wells in the vicinity of the test well provided an opportunity to obtain valuable hydraulic information regarding the Sand-and-Gravel Aquifer.

With the cooperation of ECUA staff, District personnel recorded water levels in the two nearby monitor wells, while ECUA pumped the Beulah Test Well. The purpose of this effort was to establish values of aquifer transmissivity, storativity, leakance and perhaps anisotropy. These values could then be used to aid in the assessment of local ground water availability. They could also be used to further validate the existing Escambia County ground water flow and contaminant transport model (Roaza et al. 1991, 1993). The flow and transport model was developed by the District in 1993, in cooperation with ECUA and other water supply utilities in Escambia County.

HYDROGEOLOGY

The Sand-and-Gravel Aquifer consists primarily of fine to medium quartz sand interbedded with varying amounts of clay. Throughout much of southern Escambia County, the Sand-and-Gravel Aquifer can be subdivided into three distinct zones based on hydraulic characteristics. The Surficial Zone is the uppermost portion of the Sand-and-Gravel Aquifer and consists of moderately well-sorted, medium sand. Ground water within this zone typically exists under unconfined conditions. Underlying the Surficial Zone is the Low Permeability Zone which consists of poorly sorted sand and clay. The permeability of the Low Permeability Zone is less than that of the overlying and underlying portions of the aquifer. It forms a leaky confining unit which serves to restrict the vertical movement of water within the aquifer. The lowermost zone within the aquifer is referred to as the Main Producing Zone. This unit consists of moderate to well-sorted medium sand with minor amounts of interbedded clay. This is the most productive unit in the Sand-and-Gravel Aquifer and is the unit tapped by the major supply wells. Underlying the Sand-and-Gravel Aquifer is the Intermediate System which is a regionally extensive confining unit.

Natural gamma ray and normal electric logs run were run on the ECUA Beulah Test Well boring and are shown in Figure 2. The logs show the base of the Sand-and-Gravel Aquifer at 365 ft below land surface datum (lsd). At the Beulah test site the Main Producing Zone is approximately 220 ft thick, extending from 145 ft to 365 ft below lsd. The Low Permeability Zone consists of the sandy clay interval from 119 ft to 145 ft below lsd. The Surficial Zone comprises the saturated sediments above the Low Permeability Zone. The total depth of the test boring and geophysical log data are 435 ft. The elevation of the well site is approximately 118 ft above mean sea level (msl).

AQUIFER TEST

ECUA completed a 10-inch diameter test well in the lower half of the Main Producing Zone. The test well was screened from 285 ft to 365 ft below lsd. Static water level was 86 ft below lsd just prior to the start of the test. Two observation wells were also available for the test. The NFWFMD Beulah Fire Department well is a 2-inch diameter monitor well constructed by the District in 1984. It is screened from 145 ft to 155 ft below lsd and is located 440 feet from the ECUA test well. Static water level for this well was 86.42 ft below lsd just prior to the start of the test. The second observation well, USGS 032-724-1A, was constructed in 1959. It is a 4-inch diameter well screened from 165 ft to 170 ft below lsd and is located 3,666 feet west of the ECUA Beulah Test well. Static water level in the USGS monitor well was 95.95 ft below lsd just prior to the test.

Land surface elevations for the ECUA Beulah Test well and the NFWFMD Beulah Fire Dept well are very similar. Based on a USGS 1:24,000 scale topographic map, the elevations are estimated to be 118 ft and 117 ft respectively. The land surface elevation at the USGS monitor well is 123.43 ft as surveyed by the USGS. The location of all three wells and the radial distances between the wells are based on differentially corrected GPS. Figure 2 shows the relative radial distance and screened intervals for these wells.

The aquifer performance test was initiated on November 5, 2001. ECUA's contractor (Layne-Central) monitored discharge and maintained a constant rate of 1,999 gal/min for the duration of the test. Layne-Central personnel also measured drawdown in the test well using an air line. District personnel measured the water levels in the two observation wells using steel tapes.

Ground water was discharged to a borrow pit approximately 450 ft north of the ECUA test well. The duration of the constant discharge test was 69 hours (4,140 minutes). At the conclusion of the test the ECUA test well showed 87 ft of drawdown. Drawdown in the NFWFMD Beulah Fire Dept well was 8.92 ft and drawdown in the USGS well was 3.10 ft.

TEST ANALYSIS

The aquifer test data were analyzed using AquiferWin32 propriety software which was developed by Environmental Simulations, Inc. Drawdown data from the observation wells were compared to a variety of type curves generated by analytical models which were reasonably consistent with the test procedures and the conceptualization of the Sand-and-Gravel Aquifer as a leaky confined aquifer. 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 USGS observation well was analyzed using the Hantush (1964) analytical model. The Hantush (1964) solution simulates the response to pumping an aquifer overlain by a leaky confining unit which is in turn overlain by a constant head source bed. The model also incorporates the effect of partially

penetrating wells and various vertical to horizontal anisotropy ratios (K_z/K_r). 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

This analytical model is consistent with the conceptualization of the Sand-and-Gravel Aquifer as a leaky confined aquifer and is consistent with the wells and procedures utilized in the test. Figure 3 shows the Hantush (1964) type curve which best represents the drawdown response of the aquifer as recorded in the USGS observation well. Due to the relatively large radial distance of the USGS observation well as compared to the thickness and anisotropy of the aquifer, the type curve was insensitive to the affect of partial penetration. Type curves for various anisotropy ratios are indistinguishable from each other, therefore the anisotropy ratio could not be determined from the response of this well. Based on the response of the USGS observation wells, the following hydraulic parameters were estimated:

Transmissivity (ft^2/d)	9,100
Storativity (dimensionless)	0.0013
r/B (dimensionless)	0.8
Aquitard leakance (k'/b') (1/d)	0.00043

Assuming the thickness of the Main Producing Zone is 220 ft, the horizontal hydraulic conductivity is 41 ft/d.

The response of the NFWMD Beulah Fire Dept well was compared to Hantush (1964) type curves. Hantush (1964) type curves were generated for a variety of r/B values (where B is the leakage factor) and anisotropy ratios. The response of the well to pumping did not compare favorably to the type curves generated by the Hantush (1964) model. The well response was also compared to type curves generated by the Hantush (1960) analytical model. Hantush (1960) assumes fully penetrating wells, constant head source bed and incorporates storage in the confining unit. This method is generally applicable to early time data only. The well response did not compare favorably to Hantush (1960) type curves.

The response of the Main Producing Zone to pumping can generally be analyzed and predicted using leaky aquifer analytical models. The observed response of the NFWMD Beulah Fire Dept well does not appear consistent with the types of analytical models considered, therefore, no estimates of hydraulic properties were derived from the response of this well. Based on the observed response of the NFWMD observation well, the assumptions on which the above analytical models are based appear to have been violated. This could be the result of faulty conceptualization of the Sand-and-Gravel Aquifer, local heterogeneity within the aquifer or attempting to analyze drawdown data which is not representative of the aquifer unit which was pumped. The most likely explanation is either the observation well (drawdown data) is not representative of the aquifer's response, or local heterogeneities are present. In this case there is evidence the well may not be representative of the aquifer when a local stress is applied. The depth of the screened interval (145 ft to 155 ft below lsd) is considered to be the top of the Main Producing Zone, however, the geophysical logs and the drillers lithologic log show this well to be in a somewhat clayey transition zone just above the cleaner, most-productive sands in which the ECUA test well is completed. The response of this observation well may actually be representative of drawdown within the overlying semiconfining unit.

CONCLUSIONS

The response of the USGS observation well to pumping was analyzed and provided estimates of transmissivity ($9,100 \text{ ft}^2/\text{d}$), storativity (0.0013) and r/B (0.8). Based on these estimates, the leakance of the Low Permeability Zone (semi-confining unit) of the Sand-and-Gravel aquifer was calculated and estimated to be 0.00043 1/d . These estimates of hydraulic properties are within the range of expected values. In addition, the results of the aquifer performance test further validate the calibration of the Escambia County ground water flow and contaminant transport model. The estimates of the hydraulic properties compare favorably with hydraulic properties assigned to the ground water model in the vicinity of the Beulah Community.

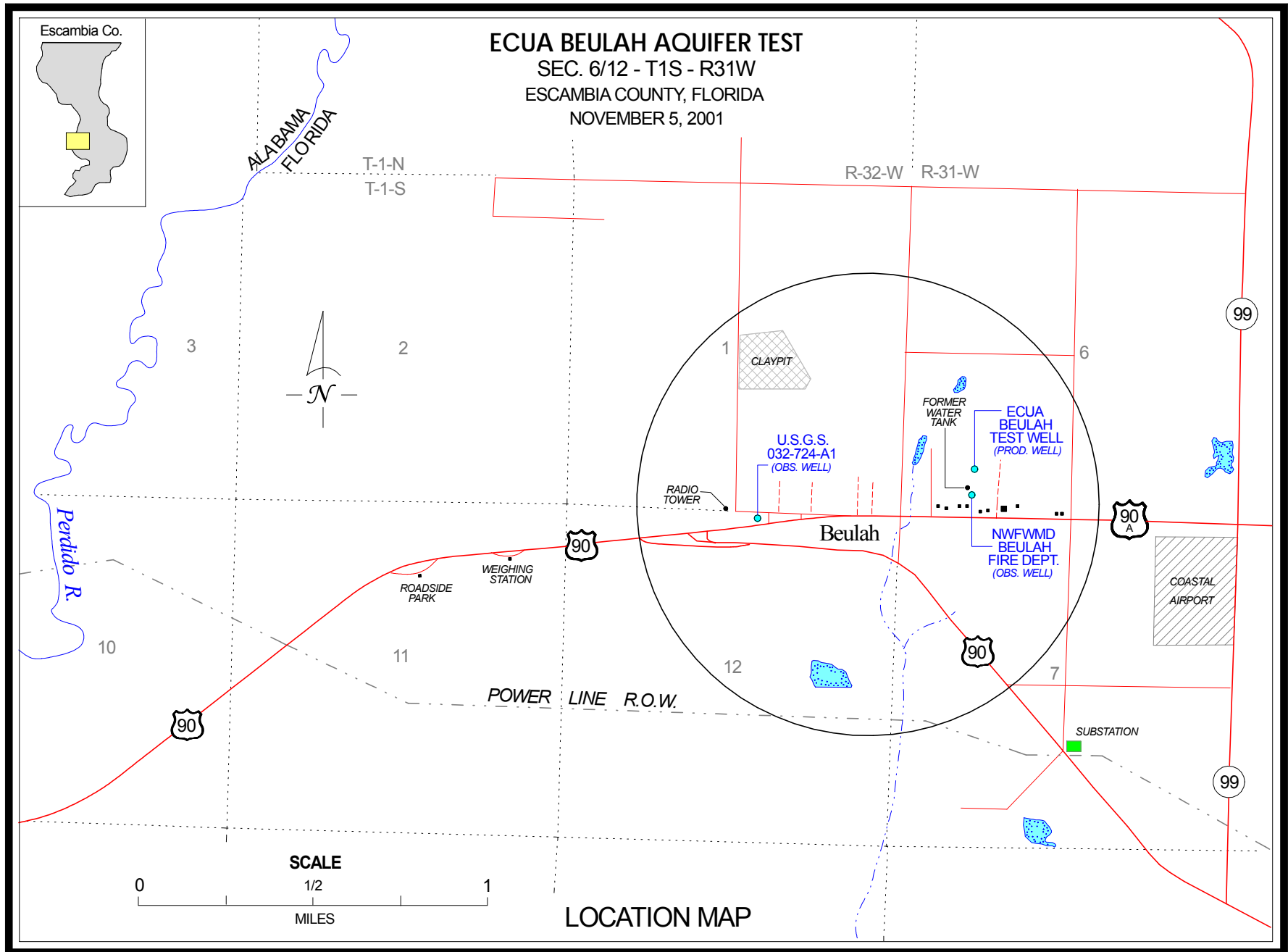


FIGURE 1. MAP SHOWING THE LOCATION OF WELLS USED IN THE AQUIFER PERFORMANCE TEST.

ECUA BEULAH AQUIFER TEST
SEC 6 - T1S - R31W
ESCAMBIA COUNTY, FLORIDA
NOVEMBER 5, 2001

ECUA
 BEULAH
 TEST WELL
 NWF ID 7981
 (PROD. WELL)

NWFWMD
 BEULAH
 FIRE DEPT.
 NWF ID 3484
 (OBS. WELL)

U.S.G.S.
 032-724-A1
 NWF ID 3473
 (OBS. WELL)

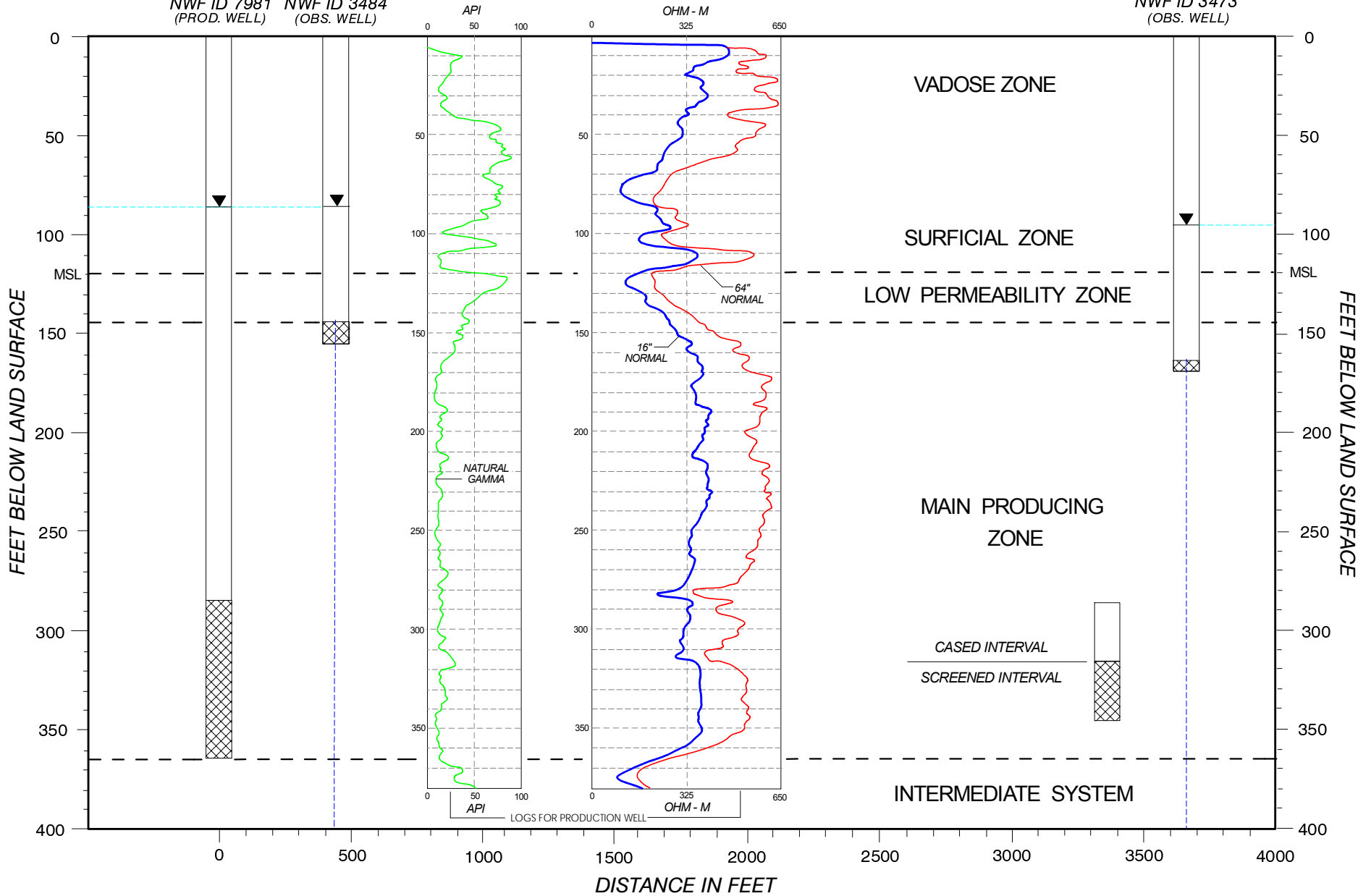


FIGURE 2. WELL CONSTRUCTION AND GENERALIZED HYDROSTRATIGRAPHY AT THE AQUIFER TEST SITE.

ECUA Beulah Test

Hantush, 1964 (Leaky Confined Partial Penetration)

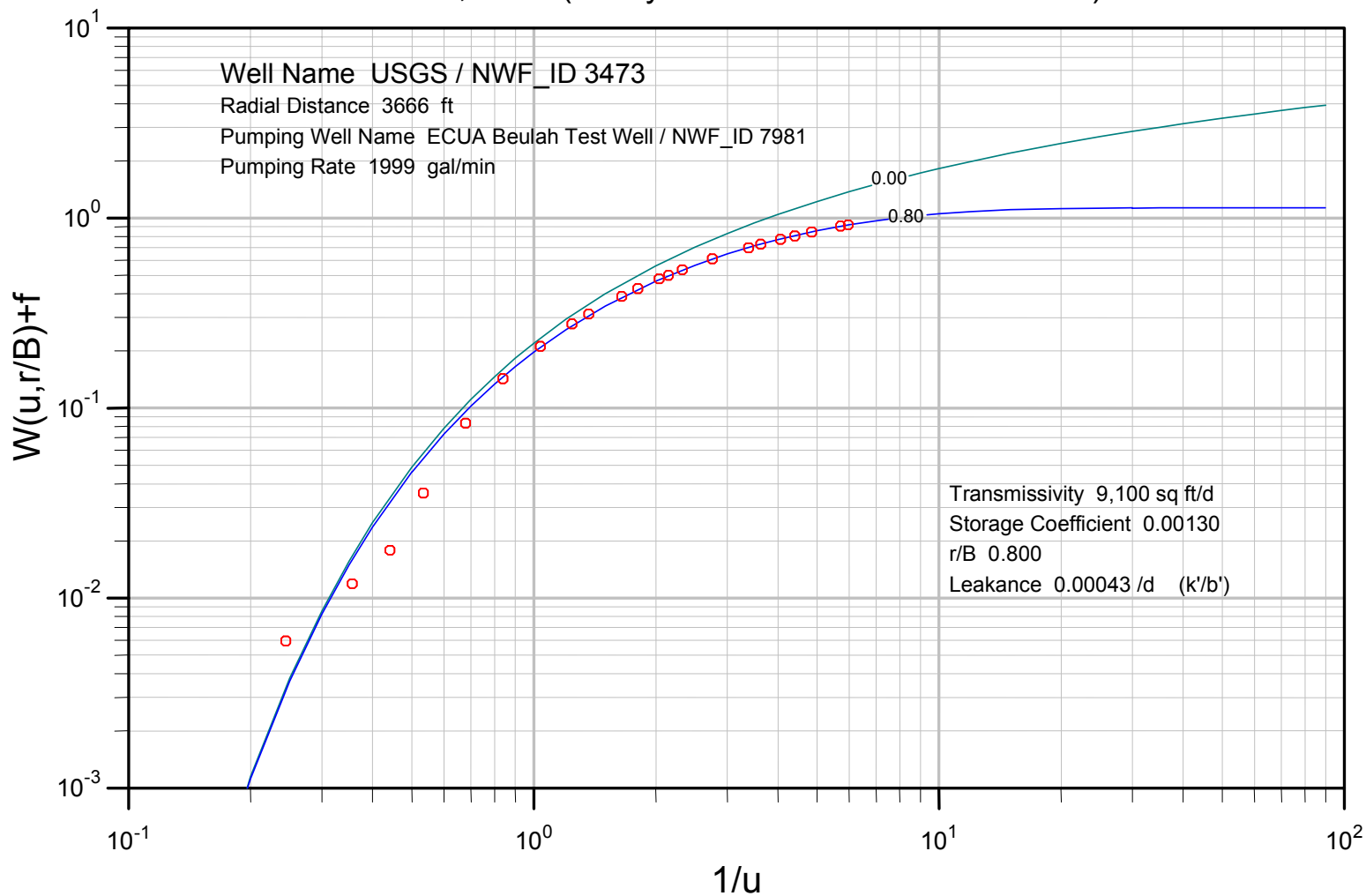


FIGURE 3. AQUIFER RESPONSE AND TYPE CURVE FOR THE USGS OBSERVATION WELL.

Beulah Fire Department / NWF_ID 3484

time (min)	drawdown
3	0.01
4	0.05
5	0.11
6	0.17
7	0.23
8	0.29
9	0.35
10	0.41
11	0.46
12	0.51
13	0.57
14	0.62
15	0.65
16	0.71
17	0.76
18	0.80
19	0.85
20	0.89
21	0.93
22	0.96
24	1.05
26	1.13
28	1.19
30	1.26
32	1.33
34	1.39
36	1.46
38	1.52
40	1.57
42	1.63
44	1.69
46	1.74
48	1.79
50	1.84
52	1.89
54	1.94
56	1.98
58	2.03
60	2.08

time (min)	drawdown
65	2.18
70	2.30
75	2.38
80	2.52
85.5	2.58
90	2.65
95.25	2.74
100	2.81
105	2.87
110	2.98
128.5	3.22
142	3.41
160	3.60
180.5	3.82
200	4.00
215	4.08
230	4.24
255	4.44
287	4.66
342	5.02
399	5.28
479	5.63
588	6.02
727	6.41
866	6.71
966	6.91
1088	7.12
1259	7.36
1415	7.53
1498	7.62
1611	7.74
1915	8.00
2348	8.29
2510	8.38
2807	8.50
3044	8.60
3350	8.72
3946	8.92

USGS / NWF_ID 3473

time (min)	drawdown
168	0.02
245	0.04
304	0.06
367	0.12
467	0.28
577	0.48
715	0.71
855	0.93
940	1.05
1134	1.30
1244	1.43
1404	1.61
1480	1.68
1600	1.80
1900	2.05
2335	2.35
2498	2.45
2796	2.60
3035	2.71
3340	2.84
3937	3.05
4110	3.10

ECUA Beulah Test Well / NWF_ID 7981
data collected by Layne Central using an airline and orifice

time (min)	drawdown	gal/min
1	60	1,999
2	63	1,999
3	65	1,999
4	66	1,999
5	67	1,999
7	69	1,999
9	70	1,999
11	71	1,999
13	71	1,999
15	72	1,999
20	72	1,999
25	73	1,999
30	73	1,999
35	74	1,999
40	75	1,999
45	75	1,999
60	75	1,999
75	75	1,999
90	76	1,999
105	76	1,999
130	77	1,999
160	77	1,999
190	77	1,999
220	78	1,999
250	78	1,999
280	78	1,999
310	79	1,999
340	79	1,999
370	79	1,999
400	79	1,999
430	79	1,999
460	79	1,999
490	79	1,999
520	79	1,999
550	79	1,999
580	79	1,999
600	79	1,999
640	79	1,999
670	79	1,999
700	79	1,999
730	79	1,999
760	79	1,999

time (min)	drawdown	gal/min
790	79	1,999
820	79	1,999
850	79	1,999
880	80	1,999
910	80	1,999
940	80	1,999
970	80	1,999
1000	80	1,999
1060	81	1,999
1120	82	1,999
1180	83	1,999
1240	83	1,999
1300	85	1,999
1360	85	1,999
1420	85	1,999
1480	84	1,999
1540	83	1,999
1600	83	1,999
1660	83	1,999
1720	82	1,999
1780	82	1,999
1840	82	1,999
1900	82	1,999
1960	82	1,999
2020	82	1,999
2080	82	1,999
2140	82	1,999
2200	82	1,999
2260	82	1,999
2320	82	1,999
2380	82	1,999
2440	82	1,999
2500	82	1,999
2560	83	1,999
2620	85	1,999
2680	86	1,999
2740	86	1,999
2800	87	1,999
2860	87	1,999
2920	87	1,999
2980	85	1,999
3040	84	1,999

time (min)	drawdown	gal/min
3100	83	1,999
3160	83	1,999
3220	83	1,999
3280	83	1,999
3340	83	1,999
3400	83	1,999
3460	83	1,999
3520	83	1,999
3580	83	1,999
3640	82	1,999
3700	82	1,999
3760	82	1,999
3820	82	1,999
3880	83	1,999
3940	83	1,999
4000	84	1,999
4060	85	1,999
4120	86	1,999
4140	87	1,999



**NWFWMD Well Inventory Database System
Site Schedule**

Printed: November 7, 2002 10:46

SITE_SCHEDULE

Site Id **303208087241101** Site Type **G** NWF ID **3473**
 Well Name **USGS 032-724-1A** State ID
 Owner **USGS**
 Contact Person Phone
 Street
 City **TALLAHASSEE** State **FL** Zip County **Escambia**
 Latitude **303208.872** Longitude **872418.579** Datum **WGS84** Loc Method **Global Positioning Satellite (GPS)**
 Land Net **S012T01SR32W** Loc Accuracy **0.3 < 3 meters** Loc Source **NWFWMD**
 Elevation **123.43** Datum **NGVD29** Method **Survey**
 Accuracy **< 0.1 feet** Source **Other Government**
 Location Map **SEMINOLE (ALA-FL)** GW Region **Western Panhandle Embayment Region**

Site Use **Monitor / OBS** Water Use

Depth Of Well **170** Depth Of Casing **165**
 MP Distance From LSD **2.9** Diameter **4**
 Construction Data Source **Other Government** Casing Material **Galvanized Steel**
 Finish **Screen** Driller License Number **9038**
 Date of Construction **23/06/1959** Construction Method
 Screen Length **5**
 Screened Intervals **165 / 170**

Water Level **-93.4** Measure Date **08/07/1959**
 WL Source **Other Government** WL Method **Steel Tape**

Hydrogeologic Units **Main Producing Zone (S&G)**

Lift **No Pump** Power
 Horsepower Pump Intake
 Normal Yield Spcap Discharge
 Spcap Source Spcap Discharge Method
 Spcap Static Level Spcap Pumping Level
 Spcap Drawdown Hours Pumped
 Spcap

Field Water Quality Date of Sample **25/06/1959**
 Temperature **22** pH
 Specific Conductance Chloride **8**

Consumptive Use Permit Construction Permit
 FL Geological Survey # **W 5009** Abandonment Permit
 DEP Public Supply #
 Project #'s **74 32 33 36 40 5 42 46 47**
 Geophysical Log # **172** Depth Logged **649**
 Available LOG Data **Gamma Neutron Driller Electric**

Visited By **BARRACLOUG** Date Visited **05/12/1966**
 Data Entered By **C_RICHARDS** Date Entered **22/04/1991**
 Last Updated By **C_RICHARDS** Last Updated **19/12/2001**
 Ambient Network **WL**

Remarks: **MP described as-Plug hole @ T.O. steel casing ; LSD-to-MP =+2.90 ft. MP = TOP OF STEEL PLUG = 126.33;(c.richards,dec 19,2001; lsd elevation surveyed by USGS = 123.43,ngvd 1929)**



**NFWFMD Well Inventory Database System
Site Schedule**

Printed: November 7, 2002 10:46

SITE_SCHEDULE

Site Id **303212087234001** Site Type **G** NWF ID **3484**
 Well Name **BEULAH FIRE DEPT** State ID **AAA6725**
 Owner **NFWFMD**
 Contact Person _____ Phone **850-487-1770**
 Street **RT 1 BOX 3100**
 City **HAVANA** State **FL** Zip **32333** County **Escambia**
 Latitude **303212.822** Longitude **872338.776** Datum **NAD83** Loc Method **Global Positioning Satellite (GPS)**
 Land Net **DCCS006T01SR31W** Loc Accuracy **0.3 < 3 meters** Loc Source **NFWFMD**
 Elevation **117** Datum **NGVD29** Method **Topo Map**
 Accuracy **>= 5 feet** Source **NFWFMD**
 Location Map **SEMINOLE** GW Region **Western Panhandle Embayment Region**

Site Use **Monitor / OBS** Water Use **Monitor**

Depth Of Well **155** Depth Of Casing **145**
 MP Distance From LSD **-.27** Diameter **2**
 Construction Data Source **NFWFMD** Casing Material **PVC**
 Finish **Screen** Driller License Number **2126**
 Date of Construction **03/12/1983** Construction Method **Hydraulic Rotary**
 Screen Length **10**
 Screened Intervals **145 / 155**

Water Level **-77.7** Measure Date **15/08/1984**
 WL Source **NFWFMD** WL Method **Steel Tape**

Hydrogeologic Units **Main Producing Zone (S&G)**

Lift **No Pump** Power _____
 Horsepower _____ Pump Intake _____
 Normal Yield _____ Spcap Discharge _____
 Spcap Source _____ Spcap Discharge Method _____
 Spcap Static Level _____ Spcap Pumping Level _____
 Spcap Drawdown _____ Hours Pumped _____
 Spcap _____

Field Water Quality Date of Sample _____
 Temperature _____ pH _____
 Specific Conductance _____ Chloride _____

Consumptive Use Permit _____ Construction Permit **T198400556**
 FL Geological Survey # _____ Abandonment Permit _____
 DEP Public Supply # _____
 Project #'s **74 3 4 7 21 36 40 42 46**
 Geophysical Log # **40** Depth Logged **395**
 Available LOG Data **Electric Geologist Gamma Neutron**

Visited By **WILKINS** Date Visited **20/12/1983**
 Data Entered By **B_WILLIAMS** Date Entered **21/09/1990**
 Last Updated By **C_RICHARDS** Last Updated **19/11/2001**
 Ambient Network **UN ABK**

Remarks: **K-58, GPS DATA ENTERED 2/95 FOR AMBIENT PROGRAM; MP=T.O. 2" PVC CSG.=116.74 ; T.O. 3" STEEL PROTECTIVE CSG.= 116.71 Unique well Id tagged 6/96 entered by DAH.**



**NWFWMD Well Inventory Database System
Site Schedule**

Printed: November 7, 2002 10:46

SITE_SCHEDULE

Site Id **303218087233901** Site Type **G** NWF ID **7981**
 Well Name **ECUA BEULAH TEST** State ID
 Owner **ECUA**
 Contact Person Phone
 Street
 City State Zip County **Escambia**
 Latitude **303217.088** Longitude **872337.728** Datum **NAD83** Loc Method **Global Positioning Satellite (GPS)**
 Land Net **CCS006T01SR31W** Loc Accuracy **0.3 < 3 meters** Loc Source **NWFWMD**
 Elevation **118** Datum **NGVD29** Method **Topo Map**
 Accuracy **1 < 5 feet** Source **NWFWMD**
 Location Map **SEMINOLE** GW Region **Western Panhandle Embayment Region**

Site Use Test	Water Use Test
Depth Of Well 365	Depth Of Casing 285
MP Distance From LSD 2	Diameter 10
Construction Data Source Driller	Casing Material Steel
Finish Screen	Driller License Number 2459
Date of Construction 21/06/2001	Construction Method Hydraulic Rotary
Screen Length 80	
Screened Intervals 285 / 365	

Water Level -86	Measure Date 05/11/2001
WL Source Driller	WL Method Airline

Hydrogeologic Units **Main Producing Zone (S&G)**

Lift Submersible	Power Electric
Horsepower 150	Pump Intake
Normal Yield	Spcap Discharge 1999
Spcap Source Driller	Spcap Discharge Method Orifice
Spcap Static Level -86	Spcap Pumping Level -173
Spcap Drawdown 87	Hours Pumped 69
Spcap 22.98	

Field Water Quality	Date of Sample
Temperature	pH
Specific Conductance	Chloride

Consumptive Use Permit	Construction Permit T200102049
FL Geological Survey #	Abandonment Permit
DEP Public Supply #	
Project #'s	
Geophysical Log # 247	Depth Logged 435
Available LOG Data Gamma SP Electric	

Visited By C_RICHARDS	Date Visited 05/11/2001
Data Entered By J_GODIN	Date Entered 02/11/2001
Last Updated By C_RICHARDS	Last Updated 18/12/2001
Ambient Network	

Remarks: (c.richards,nov 8, 2001) temp test well for ecua;;; (edit by TRP,) airline length = 183 ft for temporary test well.