AVAILABILITY OF GROUND WATER FROM THE SAND-AND-GRAVEL AQUIFER IN COASTAL OKALOOSA COUNTY, FLORIDA

Water Resources Technical File Report 04-01

Thomas R. Pratt
Florida Registered
Professional Geologist
No. 159
August 30, 2004

Prepared by:

Kevin L. DeFosset
The Northwest Florida Water Management District

August 2004

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

For additional information, write or call:

Northwest Florida Water Management District
81 Water Management Drive
Havana, Florida 32333
(850) 539-5999

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Purpose and Scope

The Northwest Florida Water Management District prepared a "Regional Water Supply Plan for Santa Rosa, Okaloosa, and Walton Counties" in response to requirements of the Florida Water Resources Act, Chapter 373, F.S. The 'Regional Water Supply Plan' (RWSP) is intended to assist the counties of Water Supply Planning Region II in recognizing and addressing current and future water resource issues through 2020. A recommendation of the RWSP is evaluation of the potential for the coastal sand-and-gravel aquifer in the southern part of the region to serve as a supplemental water resource for the region. The development of this source would serve to alleviate withdraws from the Floridan Aquifer.

This report is an evaluation of the potential for a portion of the coastal sand-and-gravel aquifer in southern Okaloosa County to serve as a supplemental source of water for the region. Previous efforts (Hayes and Barr, 1983; Barr, Maristany, and Kwader, 1981) in the area are refined and supported by additional data included in this evaluation. The analysis is based on a compilation of existing data documenting the general hydraulic properties of the aquifer, current pumpage, and water quality. Analysis of the data shows that the aquifer could potentially function as a water resource.

Study Area

The approximately 100 mi^2 area of interest in southern Okaloosa County is bounded on the north and west by Eglin Air Force Base and Hurlburt Field respectively. The Gulf of Mexico and Choctawhatchee Bay serve as the southern and eastern boundaries. The low-lying topography, flatwoods, swamps, bayous, and dune structures characterize the area as part of the Coastal Lowlands physiographic division. Elevations in the area range from sea level to 100 ft above sea level.

The study area comprises one of the main population centers in the panhandle, as represented by Fort Walton Beach and its surrounding communities. Land use (Figure 1) is primarily residential with the area to the north (Eglin Air Force Base) being forested. Commercial, industrial, and waste related activities exist and require consideration that will be discussed below.

Hydrogeology

The general hydrostratigraphy of the sand-and-gravel aquifer in the study area features fine to coarse grained quartz sand with varying percentages of silt and clay. Thorough discussions of the hydrostratigraphy of the sand-and-gravel aquifer exist if more detail is desired. Specific to the study area, aquifer thickness (Figure 2) from land surface to the top of the intermediate system (Figure 3) ranges from 75 to 150 ft. Concordant with the thickness trend of the sand-and-gravel aquifer across the panhandle, the aquifer is most thick in the western part of the study area. Due to the complex local and regional arrangement of the aquifer components, division of the aquifer into multiple permeability zones is not a consistent characteristic in this area.

According to a recent potentiometric surface map (Figure 4), rain water recharging the aquifer travels from the north-northwest to the south-southeast. Based on current water levels, the saturated thickness of the aquifer ranges between 50 and 125 ft. Extended periods of drought or above average precipitation would cause the saturated thickness to vary over time. Area wetlands and streams likely serve as initial discharge points for ground water flowing from the north-

northwest. Ground water flowing deeper in the aquifer, or water recharging the aquifer in the southern portion of the study area, discharges to Choctawhatchee Bay and the Gulf of Mexico.

AQUIFER HYDRAULIC PROPERTIES

Pump Tests

Results from three multi-well and five single-well sand-and-gravel aquifer pump tests (Table 1) previously conducted in the study area are available to characterize the hydraulic properties of the aquifer. All but one of the tests were located (Figure 5) in the western portion of the study area. Although the lack of testing in the eastern portion of the study area neglects the hydraulic properties of the aquifer underlying that area, production likely would be from the western portion of the study area where the thickness of the sand-and-gravel aquifer is greatest.

Hayes and Barr (1983) performed two multi-well aquifer pump tests. Test data were analyzed using a method applicable to leaky confined aquifers developed by Hantush and Jacob (1955) and modified by Cooper (1963). Hayes and Barr concluded that the storativity and leakance values obtained from the analyses justified treating the basal sand-and-gravel aquifer as a leaky confined aquifer.

The test at Site 1 included a production well and two observation wells, each constructed with 40 feet of screen set in the basal portion of the aquifer (main-producing zone). The observation wells were located approximately 75 and 150 feet from the production well, which was pumped at a rate of 382 gal/min. A third well, also located approximately 150 feet from the production well, was screened in the surficial zone and showed no effects from pumping the main-producing zone. The test at Site 2 included a production well and one observation well located 51 feet from the production well. Each well was constructed with 20 feet of screen set in the main-producing zone. The production well was pumped at a rate of 48 gal/min.

Okaloosa County performed a 72-hour multi-well aquifer pump test at the Wright Landfill (Site 3) northwest of Fort Walton Beach. Test data were analyzed by the Northwest Florida Water Management District utilizing AquiferWin32 software and are included in Appendix A. The Neuman (1972) analytical method was used which addresses unconfined aquifers with fully-penetrating wells. The test included a production well and three observation wells. Two of the observation wells were located 30 and 100 feet from the production well. Because a basal main-producing zone was not well defined, the wells were screened through the entire saturated thickness of the aquifer. The third observation well, located 30 feet from the production well, was partially penetrating, screened into the upper, surficial zone of the aquifer. The pumping rate varied throughout the test, but averaged 155 gal/min.

Hayes and Barr (1983) conducted four single-well pump tests of the main-producing zone. Each well was constructed with 20 feet of screen and pumped at a rate of approximately 50 gal/min. Jacob's (1950) straight-line method was used to calculate transmissivities ranging between 400 ft^2/d to 2,000 ft^2/d. Although the authors note the shortcomings of results from single-well pump tests, they note their utility in showing the relative variations in transmissivity within the main-producing zone.

A single-well 24-hour pump test was performed at Hurlburt Field by consultants to the USAF. The production well was constructed with 80 feet of screen and pumped at 300 gal/min. Driscoll's empirical solution was used by the consultant to estimate a transmissivity based on the specific capacity (8.1 gal/min/ft). Data from this test were also analyzed by the Northwest Florida Water Management District using AquiferWin32 software and Cooper and Jacob's (1946) straight-line method. Both analytical methods produced similar transmissivity values.

Table 1.—Results of sand-and-gravel aquifer pump tests performed in study area.

Test Site	NWFWMD Well ID	T (ft^2/d)	S	Sy	K'/b'	Analytical Method
1*	2857	6200	$1.4x10^{-4}$		$1x10^{-2}$	Hantush & Jacob (1955)
	2858	5400	$4.5x10^{-4}$		$1x10^{-2}$	Hantush & Jacob (1955)
2*	2876	1500	$1.9x10^{-4}$		$2x10^{-2}$	Hantush & Jacob (1955)
3	8584	3600	$1x10^{-3}$	0.2		Neuman (1972)
	8585	3500	$8x10^{-4}$	0.12		Neuman (1972)
4*	1965	400				Jacob (1950) Straight-Line
5*	2133	2000				Jacob (1950) Straight-Line
6*	2507	1100				Jacob (1950) Straight-Line
7*	2760	700				Jacob (1950) Straight-Line
8	7976	2300	$4x10^{-4}$			Cooper and Jacob (1946) Straight-Line

* Hayes and Barr (1983)

Specific Capacity and Potential Yield

Specific capacity tests for wells constructed in the main-producing zone of the sand-and-gravel aquifer have been conducted at fourteen sites (Figure 6) in the study area. From these specific capacities and the available drawdown, estimated potential yields were calculated (Table 2). Barr, Maristany, and Kwader (1981) conducted twelve of these tests and concluded that the wells with the greatest potential yield are those wells six inches or greater located north-northwest of Fort Walton Beach. Based on data given in Table 2, 4-inch diameter wells seem to have a tendency to underestimate specific capacity, and hence, potential yield.

Two additional tests were included in this evaluation. Data from the pumping wells utilized for the Wright Landfill test (Site 3) and the Hurlburt Field test (Site 8) described above were used to calculate a specific capacity and potential yield. As with the other test wells that produced favorable potential yields (greater than 200-300 gal/min), both wells were six inches or greater in diameter. The landfill is located northwest of Ft. Walton Beach. Hurlburt Field is located directly west of Fort Walton Beach.

Table 2.—Specific capacities and potential yields from main-producing zone wells.

Test Site	NWFWMD Well ID	Diameter (inches)	Well Discharge (gal/min)	Drawdown (ft)	Specific Capacity (gal/min/ft)	Maximum Available Drawdown (ft)	Estimated Potential Yield (gal/min)
1*	2857	4	50	8	6.2	52	320
2*	2856	6	200	16	12	50	600
3	3034	6	155	8.3	18.7	40	750
4*	1965	4	49	36.4	1.3	80	100
5*	2133	4	50	18.5	2.7	76	200
6*	2507	4	52	12.2	4.3	36	160
7*	2760	4	53	17.8	3	67	200
8	7976	8	300	37.2	8.1	49	400
9*	2172	4	48	23.8	2	65	130
10*	2470	4	50	14	3.6	44	160
11*	2773	10	350	24	15	24	360
12*	2793	10	350	30	12	19	230
13*	2821	10	350	22	16	24	380
14*	2833	10	350	20	18	24	430

Values for estimated potential yield rounded.
***** Hayes and Barr (1983).

CURRENT GROUND WATER USE

Ground water withdrawn from the sand-and-gravel aquifer in the study area originates from both deep and shallow depths. The arrangement of the sands and the corresponding hydraulic properties in the deeper reaches allow for greater production from this part of the aquifer. Although the aquifer in the study area is not consistently divided into three permeability zones, the deeper portions of the aquifer are referred to as the main-producing zone.

The shallower depths tend to support smaller diameter wells for irrigation at residences and small-scale commercial operations. Due to the lack of mandatory pumpage reporting for smaller users, the quantity of water pumped from these shallower depths is not available.

Larger diameter wells (6-inches or greater) that support larger scale production are typically constructed in the main-producing zone. Current usage (Table 3) for water pumped from this zone is represented by irrigation needs for golf courses, recreational fields, and landscaping. Reported pumpage from the main-producing zone of the sand-and-gravel for 2002 averaged approximately 0.868 Mgal/d.

Table 3.—2002 pumpage totals reported under consumptive use permitting requirements.

USER	JAN	FEB	MAR	APR	MAY	JUN		
Shalimar Point Golf & Country	6.641	6.476	11.92	17.363	28.785	28.668		
EAFB Hurlburt Field	6.403	5.286	6.662	7.456	9.646	8.879		
Choctawhatchee High School	0.45	0.372	0.618	0.495	1.233	2.178		
City of Fort Walton Beach Golf Course	0.082	0.683	1.551	0.541	1.118	1.079		
Okaloosa Walton Community College	0	0	0.183	0.386	0.787	0.777		
Monthly Total (Mgal)	**13.576**	**12.817**	**20.934**	**26.241**	**41.569**	**41.581**		
Daily Average (Mgal/d)	**0.438**	**0.458**	**0.675**	**0.875**	**1.341**	**1.386**		
USER	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**TOTAL**	**Mgal/d**
Shalimar Point Golf & Country	28.045	27.868	23.772	12.43	0	0.486	**192.5**	**0.527**
EAFB Hurlburt Field	8.758	8.411	8.482	7.488	6.944	6.449	**90.8**	**0.249**
Choctawhatchee High School	2.658	3.603	2.883	2.451	0.876	0.432	**18.3**	**0.050**
City of Fort Walton Beach Golf Course	1.632	1.508	0.836	1.15	0.104	1.771	**12.1**	**0.033**
Okaloosa Walton Community College	0.393	0.332	0.25	0.001	0.025	0.065	**3.2**	**0.009**
Monthly Total (Mgal)	**41.486**	**41.722**	**36.223**	**23.52**	**7.949**	**9.203**	**317**	**0.868**
Daily Average (Mgal/d)	**1.338**	**1.346**	**1.207**	**0.759**	**0.265**	**0.297**	**0.868**	

Numbers are in millions of gallons.

WATER QUALITY

Available water quality data for the sand-and-gravel aquifer in the study area is not extensive. The collection of water quality data has focused primarily on the Floridan Aquifer due to the area's traditional dependence on this ground water resource. Water quality data assembled for this sand-and-gravel aquifer assessment originates from historical USGS data and water-resource investigations. The data represent samples taken over 40 years with most of the samples from the 1960s and 1970s. Additional water quality data is available through the Florida Department of Environmental Protection (FDEP) collected to satisfy compliance monitoring for environmental assessment and remediation.

Existing data suggest that parameters with the greatest potential to exceed drinking water standards are pH and iron. Chloride and manganese also show instances of elevated levels but they seem to occur less frequently than elevated iron and low pH. Low pH and high iron and manganese levels reflect background conditions within the sand-and-gravel aquifer. Elevated chloride levels were found in water samples taken from shallow wells constructed on Cinco and Poquito bayous and reflect naturally-occurring conditions in near proximity to saline surface water bodies. Aggressive pumping in near proximity to the lengthy coastline can result in elevated chloride levels through induced salt water intrusion.

Due to the lack of use of the sand-and-gravel aquifer as a potable supply, there is little data available for those parameters sampled under FDEP drinking water permitting programs. These include primary standards, secondary standards, Groups I, II and III unregulated compounds, radiologicals and trihalomethanes. In 2000, the City of Fort Walton Beach conducted a sampling program for primary standards (inorganics, VOCs, radiologicals, and pesticides/PCBs), secondary standards, Groups I, II and III unregulated compounds, bromacil, and hexazinone (Fabre Engineering, Inc., 2000). The sampled wells were FWB golf course irrigation wells A (NWF_ID 2821) and D (NWF_ID 2773). Bromacil and hexazinone are herbicides that might reasonably be expected to have been used on a golf course. Results are summarized below.

	Well A	Well D
Primary inorganics	below MCL, NO_3—4.14 mg/L	below MCL
Pesticide/PCB	below MDL	below MDL
VOC	below MDL	below MDL
Secondary	Fe—1.6 mg/L, MCL exceedance	Fe—1.1 mg/L, pH—6.1
Group I unregulated	below MDL	below MDL
Group II unregulated	below MDL	below MDL
Group III unregulated	below MDL	below MDL
Hexazinone	below MDL	below MDL
Bromacil	below MDL	no analytical data reported

These results illustrate water quality problems typically encountered with the sand-and-gravel aquifer; high iron, low pH, and elevated nitrate concentrations. Iron is commonly found at naturally-occurring concentrations that exceed the secondary drinking water standard of 0.3 mg/L. An adequate test well drilling program is necessary to ascertain iron concentrations at any given site. Utilities typically try to avoid having to treat for iron removal because of the expense. The usual means of dealing with iron is avoidance of sites with demonstrated high iron concentrations in ground water. Low pH is common in the sand-and-gravel aquifer. In Escambia County, pH below the secondary standard of 6.5 SU is near universal. Typically, pH is treated at the wellhead. Treatment is relatively inexpensive. Elevated nitrate concentrations are a concern in suburbanized areas such as Fort Walton and environs. Nitrogen can be contributed to ground water by various human activities including spray field wastewater disposal and use of inorganic fertilizers on lawns. In the absence of anthropogenic inputs, nitrogen concentrations in ground water are quite low. At present, there is not sufficient data to characterize either the spatial distribution of nitrogen in ground water or the frequency at which the primary drinking water standard (10 mg/L) is exceeded. Treatment for nitrate in excess of 10 mg/L is expensive.

Data with which to assess the frequency of occurrence of organic contamination of the sand-and-gravel aquifer is also very limited. Based on experience in Escambia County, the three most likely encountered organic contaminants are tetrachloroethylene, BTEX and MTBE. Tetrachloroethylene is typically encountered down gradient from dry cleaning facilities where it was inadvertently released to the environment. Although an inventory of dry cleaning facilities in the Fort Walton Beach area was beyond the scope of this effort, they do exist and some of them have, undoubtedly, over the years leaked, contaminating the sand-and-gravel aquifer. BTEX is one or more of the following, benzene, toluene, ethylbenzene or xylene. These compounds are four of the most frequently detected gasoline components in ground water. Leaking underground gasoline storage tanks are the source of this class of contaminants. An inventory of leaking underground storage tanks was beyond the scope of this work, but they do exist in the area. MTBE is a gasoline additive also commonly detected in ground water.

Fort Walton Beach lacks the intensive commercial and industrial land use present in southern Escambia County which has resulted in extensive ground water contamination. In spite of this, sources (dry cleaners and gas stations) which account for significant histories of ground water contamination elsewhere are present at densities similar to other areas. It should reasonably be expected that contaminants associated with these types of facilities are in sand-and-gravel aquifer ground water in Fort Walton Beach and environs. Documenting the extent of this contamination is beyond the scope of this work. Expanded use of the sand-and-gravel aquifer will result in a greater likelihood of encountering these contaminants in ground water. Utilities should plan on eventually being required to treat for organic contaminants if they use the sand-and-gravel aquifer at enough different points or for a long enough period of time.

SAND-AND-GRAVEL AQUIFER DEVELOPMENT POTENTIAL

Barr, Maristany, and Kwader (1981) and Hayes and Barr (1983) conclude that the coastal sand-and-gravel aquifer in western Okaloosa County could serve as a ground water resource. Data gathered since those earlier assessments support this conclusion. The data suggest that, in general, wells constructed in portions of the main-producing zone with transmissivities greater than 2,000 ft^2/d and storage coefficients greater than 10^{-4} should be expected to produce specific capacities greater than 6 gal/min/ft and yields greater than 200-300 gal/min.

A previous attempt was made to determine the potential drawdown from sand-and-gravel production. Barr, Maristany, and Kwader (1981) prepared a calibrated digital flow model of the aquifer. The model was used to simulate a well field containing 17 wells located north of Fort Walton Beach, on Eglin AFB. The model simulated the sand-and-gravel aquifer as an unconfined aquifer, and included a specific yield term of 0.2. Recharge was estimated at 18-inches per year. At the end of a 10-year transient simulation period producing at 5 Mgal/d, predicted drawdowns were on the order of 50 feet within 1.5 miles of the well field and 10 to 20 feet within 7.5 miles of the well field. Drawdowns of this magnitude would result in water levels standing at or below sea level over much of the Fort Walton Beach area. For sand-and-gravel production to be sustainable, this degree of drawdown is not recommended.

For the current assessment, the program DRAWDOWN was used to construct distance-drawdown curves resulting from pumping a single 300,000 gal/d (300 gal/min and 1,000 min/day) well for 1, 3, 10, and 30 days. Transmissivities of 2,000 ft^2/d and 4,000 ft^2/d were modeled. After 30 days of pumping, drawdown one mile from the production well was 7.5 feet ($T=2{,}000\ ft^2/d$) and 3 feet ($T=4{,}000\ ft^2/d$). DRAWDOWN implements a solution to the Theis equation, which conceptualizes the pumped aquifer as confined. Although a more thorough assessment of predicted drawdown was outside the scope of this current assessment, drawdown of this order is considered acceptable.

Because the study area is largely developed, one potential model for sand-and-gravel aquifer utilization would be to co-locate wells at sites of existing utility-owned Floridan Aquifer wells. The City of Fort Walton Beach operates seven Floridan wells and Okaloosa County Water and Sewer operates five Floridan wells in areas where the underlying sand-and-gravel aquifer possesses hydraulic characteristics conducive to potential development (Figure 7). These twelve sites offer the advantages of current utility land ownership, proximity to the existing distribution system and potentially, a footprint of sufficient size to accommodate any required treatment facilities.

The following steps are recommended in order to evaluate sites for potential sand-and-gravel aquifer production:

1. The twelve Floridan production well sites shown in Figure 7 should be visited to determine if adequate space exists for installation of a sand-and-gravel production well and any potentially requisite water treatment facilities.

2. At sites with adequate space, a sand-and-gravel test well six inches in diameter (or slightly greater) should be drilled. Tests performed in this area on wells six inches and greater appear to produce more dependable hydraulic parameter estimates. Information contained in this report may be utilized to design the test well drilling program. The goal of drilling a test well should be to determine both the quality and yield of the sand-and-gravel aquifer at the site of interest. In order to make the best determination, well screens should be gravel packed.

3. A 24-hour specific capacity test should be performed on all test well sites. Tests performed at pumping rates of 300-400 gal/m that produce specific capacities greater than 6-8 gal/min/ft should be considered the minimum for further evaluation as potential production well sites.

4. Water quality samples should be taken during the aquifer test for analysis of FDEP drinking water standards.

5. Test sites that produce favorable specific capacities and water quality should be considered as locations for sand-and-gravel production wells.

It should be noted that when considering the twelve sites, water levels above sea level and saturated thicknesses (Table 4) are greatest at the central and southwest locations of potential sites. Therefore from this perspective, Fort Walton Beach wells 3, 8, 9, and 11 and Okaloosa County wells 4, 6, 9, and 10 would be recommended sites. At all locations, low pH and elevated iron concentrations are the immediate concerns relative to water quality. However, salt water intrusion and current and past land uses discussed above both in the vicinity and upgradient of these sites need to be considered when addressing issues of current and future water quality.

Table 4. —Water levels and saturated thicknesses at locations considered for sand-and-gravel aquifer production.

Well	Elevation of the Intermediate System (ft. msl)	Water Level Elevation (ft. msl)	Saturated Thickness (ft.)
FWB #8	-115	12	127
FWB #9	-110	17	127
OCWS-9	-107	19	126
FWB #3	-110	10	120
FWB #11	-100	20	120
OCWS-6	-70	25	95
OCWS-10	-70	25	95
OCWS-4	-70	22	92
OCWS-8	-60	10	70
FWB #6	-60	10	70
FWB #7	-60	10	70
FWB #10	-47	20	67

CONCLUSIONS

Ultimately, total daily sand-and-gravel aquifer production will depend on the number of Floridan production well (or other) sites suitable for development. Although twelve potential Floridan Aquifer production well sites exist, it is expected that not more than six of these would be suitable for concurrent sand-and-gravel aquifer production. Assuming six sites are developed at production rates between 300,000-400,000 gal/d, 1.8-2.4 Mgal/d of additional production capacity should be available from the sand-and-gravel aquifer within the environs of Ft. Walton Beach.

REFERENCES

Barr, D.E., Maristany, A. and Kwader, T., 1981, Water Resources of Southern Okaloosa and Walton Counties, Northwest Florida – Summary of Investigation: Northwest Florida Water Management District, Water Resources Assessment 81-1, 41 p.

Fabre Engineering, Inc., 2000, Evaluation of the Sand-and-Gravel Aquifer at the Fort Walton Beach Municipal Golf Course, Project No. 98004-4.

Hayes, L.R. and Barr, D.E., 1983, Hydrology of the Sand-and-Gravel Aquifer, Southern Okaloosa and Walton Counties: U.S. Geological Survey, Water-Resources Investigations Report 82-4110, 43 p.

APPENDIX A
FIGURES

FIGURE 1

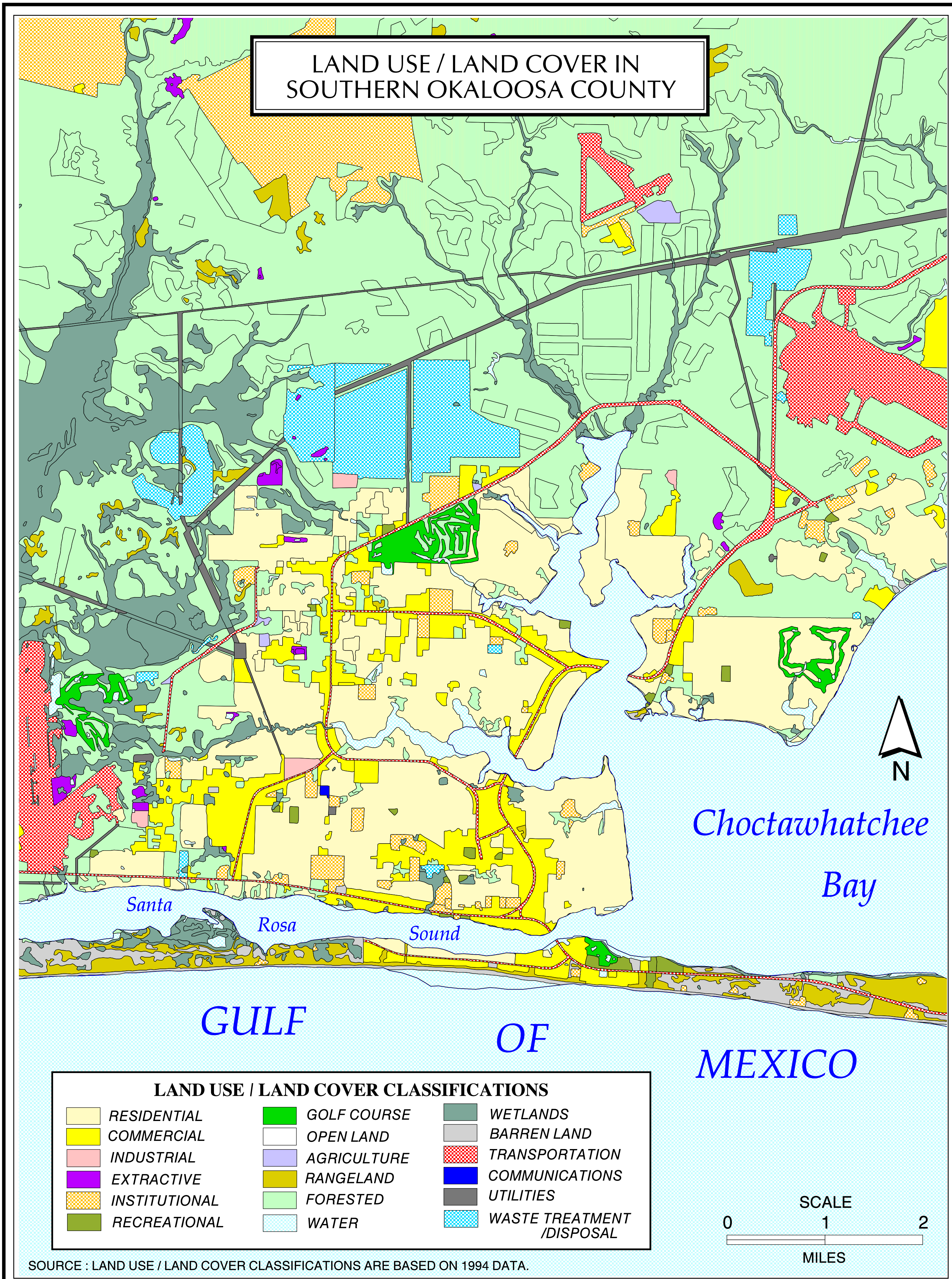

LAND USE / LAND COVER IN
SOUTHERN OKALOOSA COUNTY
Choctawhatchee
Bay
Santa
Rosa
Sound
GULF
OF
MEXICO
N
LAND USE / LAND COVER CLASSIFICATIONS
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
EXTRACTIVE
INSTITUTIONAL
RECREATIONAL
GOLF COURSE
OPEN LAND
AGRICULTURE
RANGELAND
FORESTED
WATER
WETLANDS
BARREN LAND
TRANSPORTATION
COMMUNICATIONS
UTILITIES
WASTE TREATMENT /DISPOSAL
SCALE
0
1
2
MILES
SOURCE : LAND USE / LAND COVER CLASSIFICATIONS ARE BASED ON 1994 DATA.

FIGURE 2

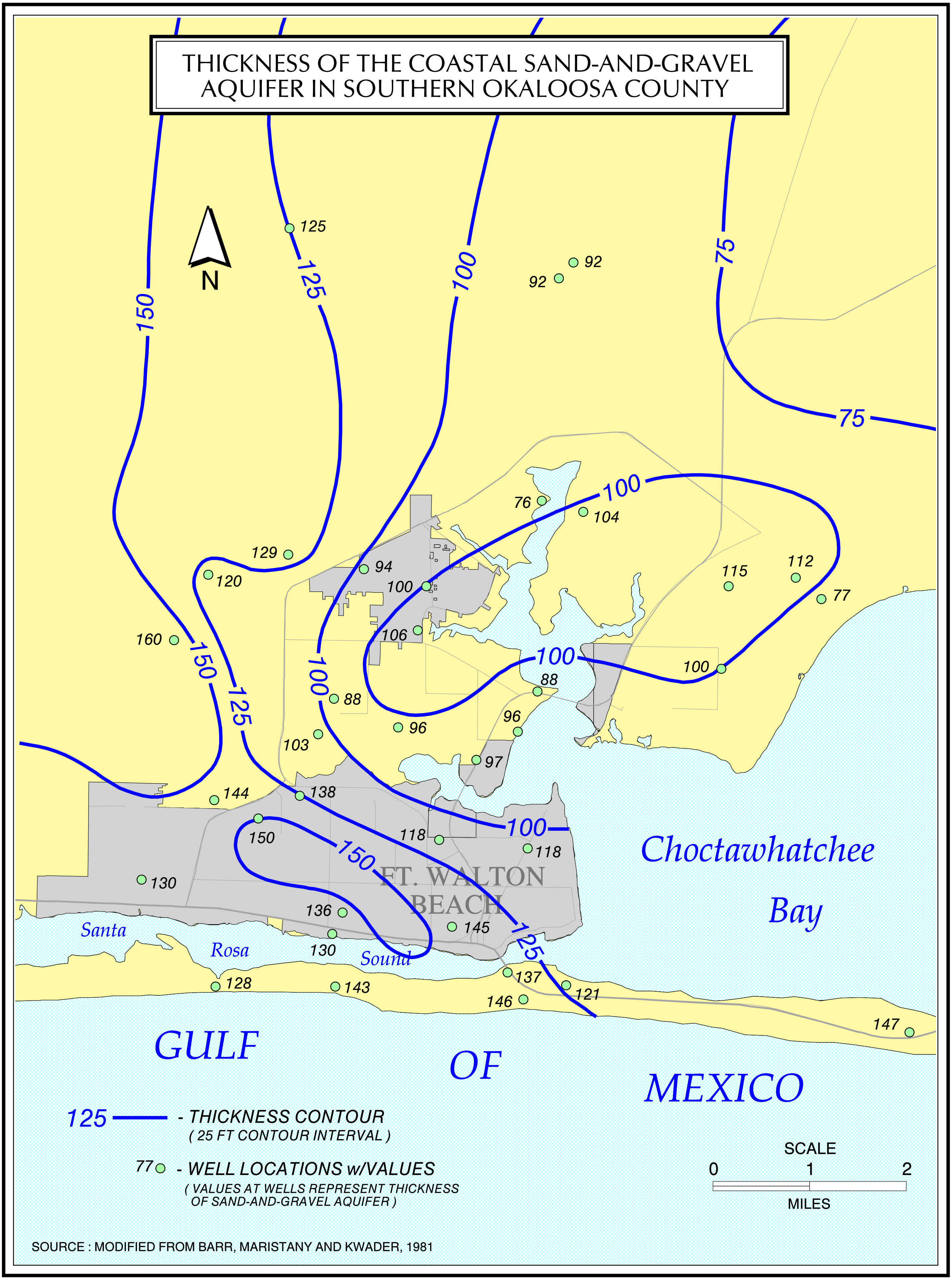
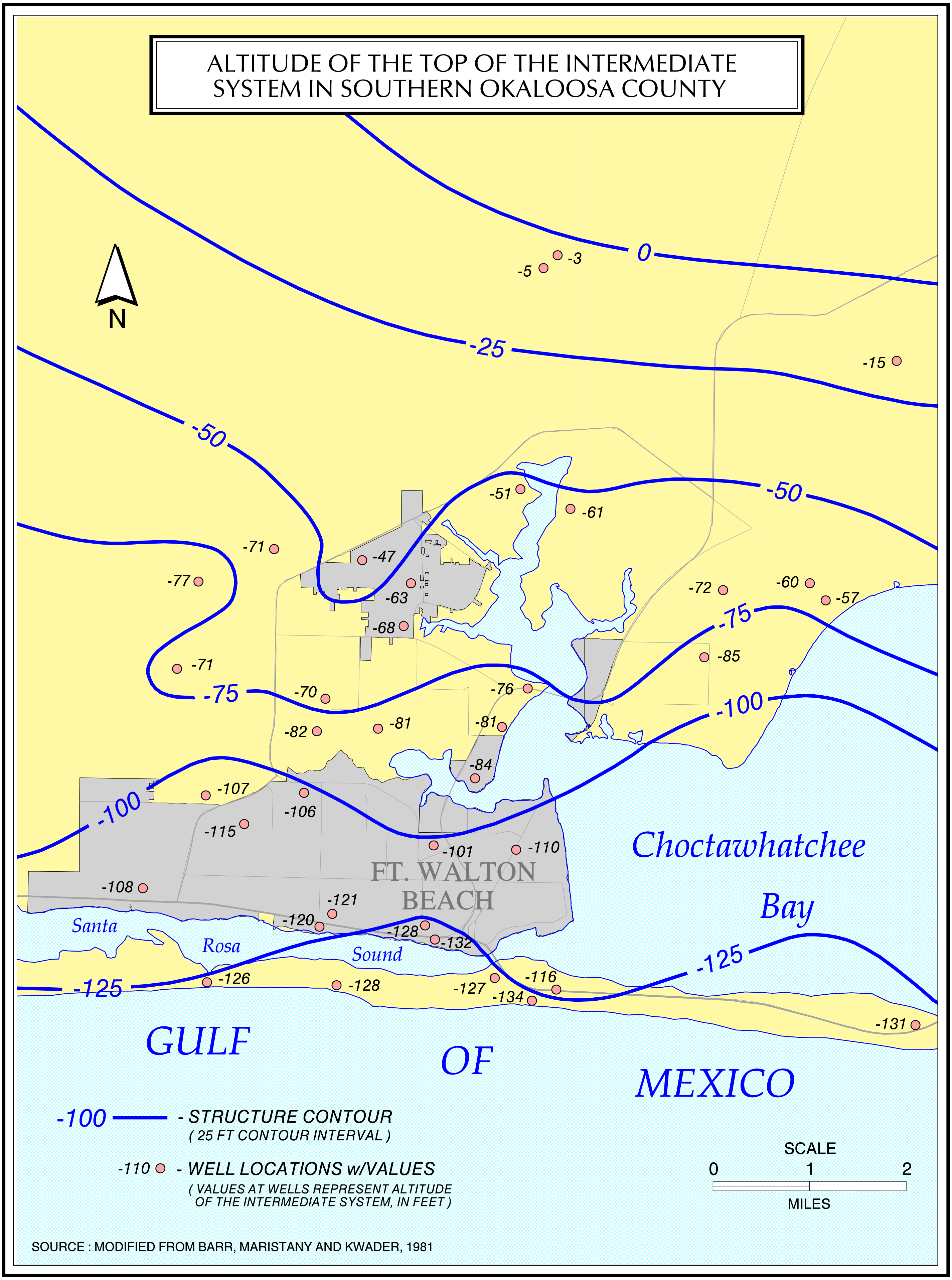
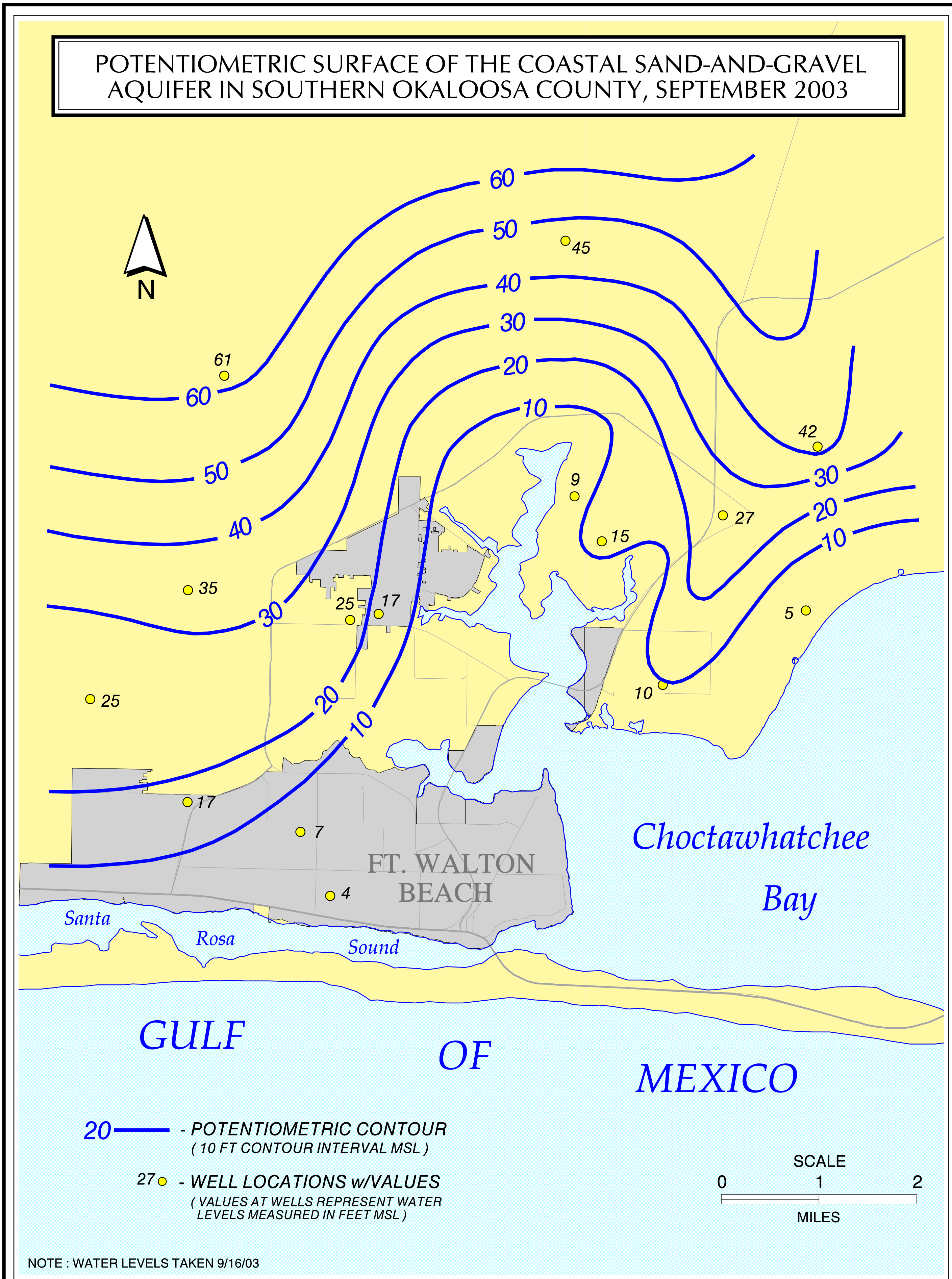

THICKNESS OF THE COASTAL SAND-AND-GRAVEL AQUIFER IN SOUTHERN OKALOOSA COUNTY
N
150
125
100
75
125
92
92
129
120
94
100
76
104
115
112
77
160
106
100
88
100
88
96
103
96
97
144
138
150
118
118
130
FT. WALTON BEACH
136
145
130
128
143
137
146
121
147
Santa
Rosa
Sound
Choctawhatchee
Bay
GULF
OF
MEXICO
125 - THICKNESS CONTOUR
(25 FT CONTOUR INTERVAL)
77 - WELL LOCATIONS w/VALUES
(VALUES AT WELLS REPRESENT THICKNESS OF SAND-AND-GRAVEL AQUIFER)
SCALE
0
1
2
MILES
SOURCE : MODIFIED FROM BARR, MARISTANY AND KWADER, 1981

FIGURE 3



ALTITUDE OF THE TOP OF THE INTERMEDIATE
SYSTEM IN SOUTHERN OKALOOSA COUNTY
N
0
-25
-50
-75
-100
-125
-3
-5
-15
-51
-61
-71
-47
-77
-63
-68
-72
-60
-57
-85
-71
-70
-76
-82
-81
-81
-84
-107
-106
-115
-101
-110
-108
-121
-120
-128
-132
-126
-128
-127
-116
-134
-131
FT. WALTON
BEACH
Choctawhatchee
Bay
Santa
Rosa
Sound
GULF
OF
MEXICO
-100 - STRUCTURE CONTOUR
(25 FT CONTOUR INTERVAL)
-110 - WELL LOCATIONS w/VALUES
(VALUES AT WELLS REPRESENT ALTITUDE
OF THE INTERMEDIATE SYSTEM, IN FEET)
SCALE
0
1
2
MILES
SOURCE : MODIFIED FROM BARR, MARISTANY AND KWADER, 1981

FIGURE 4



POTENTIOMETRIC SURFACE OF THE COASTAL SAND-AND-GRAVEL AQUIFER IN SOUTHERN OKALOOSA COUNTY, SEPTEMBER 2003
N
60
50
40
30
20
10
61
45
42
9
27
15
35
25
17
5
10
25
17
7
4
FT. WALTON BEACH
Choctawhatchee Bay
Santa Rosa Sound
GULF OF MEXICO
20 - POTENTIOMETRIC CONTOUR
(10 FT CONTOUR INTERVAL MSL)
27 - WELL LOCATIONS w/VALUES
(VALUES AT WELLS REPRESENT WATER LEVELS MEASURED IN FEET MSL)
SCALE
0
1
2
MILES
NOTE : WATER LEVELS TAKEN 9/16/03

FIGURE 5

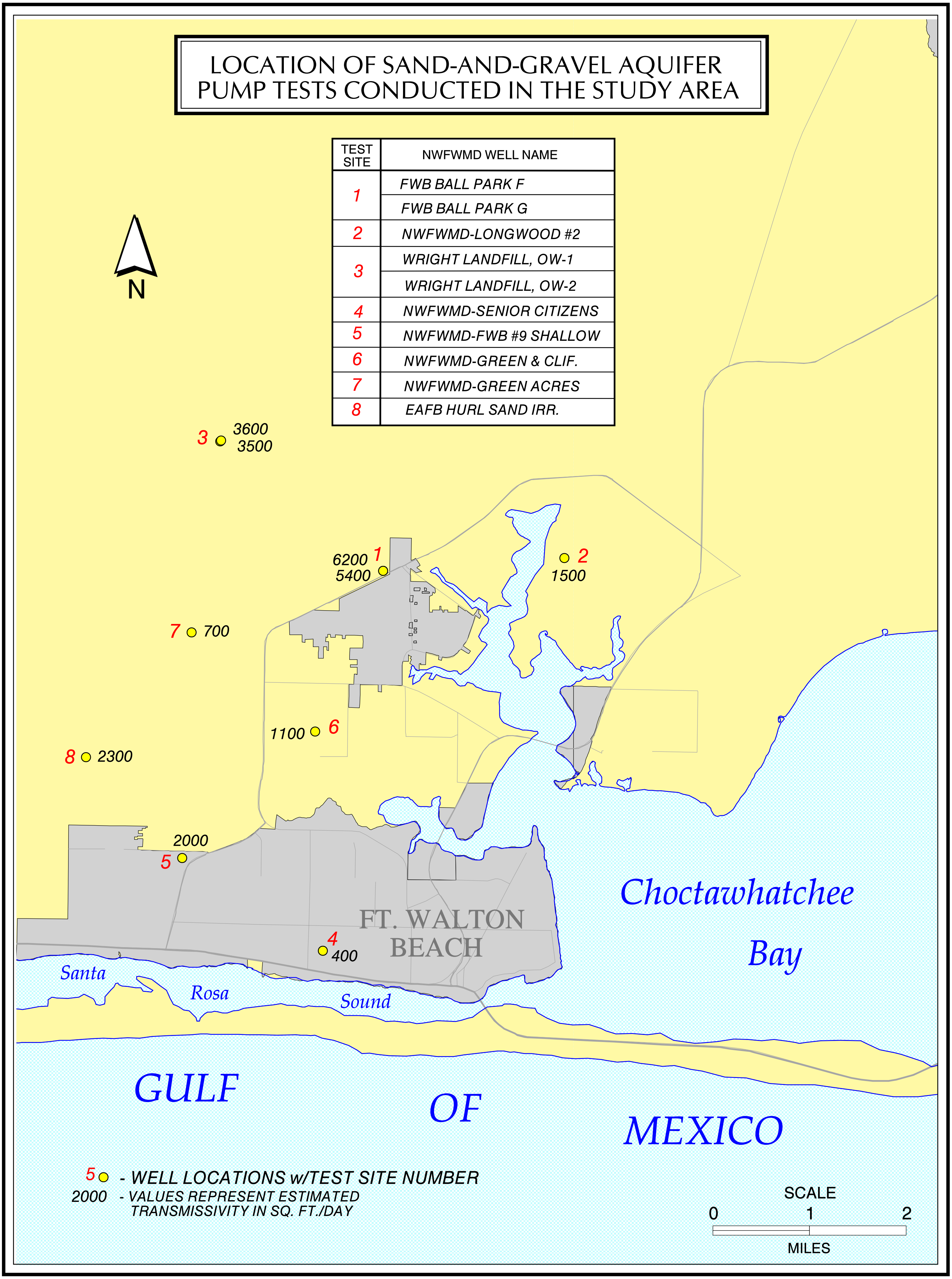

LOCATION OF SAND-AND-GRAVEL AQUIFER
PUMP TESTS CONDUCTED IN THE STUDY AREA
TEST SITE
NWFWMD WELL NAME
1
FWB BALL PARK F
FWB BALL PARK G
2
NWFWMD-LONGWOOD #2
3
WRIGHT LANDFILL, OW-1
WRIGHT LANDFILL, OW-2
4
NWFWMD-SENIOR CITIZENS
5
NWFWMD-FWB #9 SHALLOW
6
NWFWMD-GREEN & CLIF.
7
NWFWMD-GREEN ACRES
8
EAFB HURL SAND IRR.
N
3 3600 3500
1 6200 5400
2 1500
7 700
6 1100
8 2300
5 2000
4 400
FT. WALTON BEACH
Santa Rosa Sound
Choctawhatchee Bay
GULF OF MEXICO
5 - WELL LOCATIONS w/TEST SITE NUMBER
2000 - VALUES REPRESENT ESTIMATED TRANSMISSIVITY IN SQ. FT./DAY
SCALE
0
1
2
MILES

FIGURE 6

LOCATION OF SPECIFIC CAPACITY TESTS CONDUCTED IN THE STUDY AREA

TEST SITE	NWFWMD WELL NAME	TEST SITE	NWFWMD WELL NAME
1	FWB BALL PARK F	8	EAFB HURL SAND IRR.
2	FWB BALL PARK 11	9	NWFWMD-BEAL CEM S&G
3	WRIGHT LANDFILL, P1	10	NWFWMD-SHALIMAR
4	NWFWMD-SENIOR CITIZENS	11	FWB IRRIGATION D
5	NWFWMD-FWB #9 SHALLOW	12	FWB IRRIGATION C
6	NWFWMD-GREEN & CLIF.	13	FWB IRRIGATION A
7	NWFWMD-GREEN ACRES	14	FWB IRRIGATION B

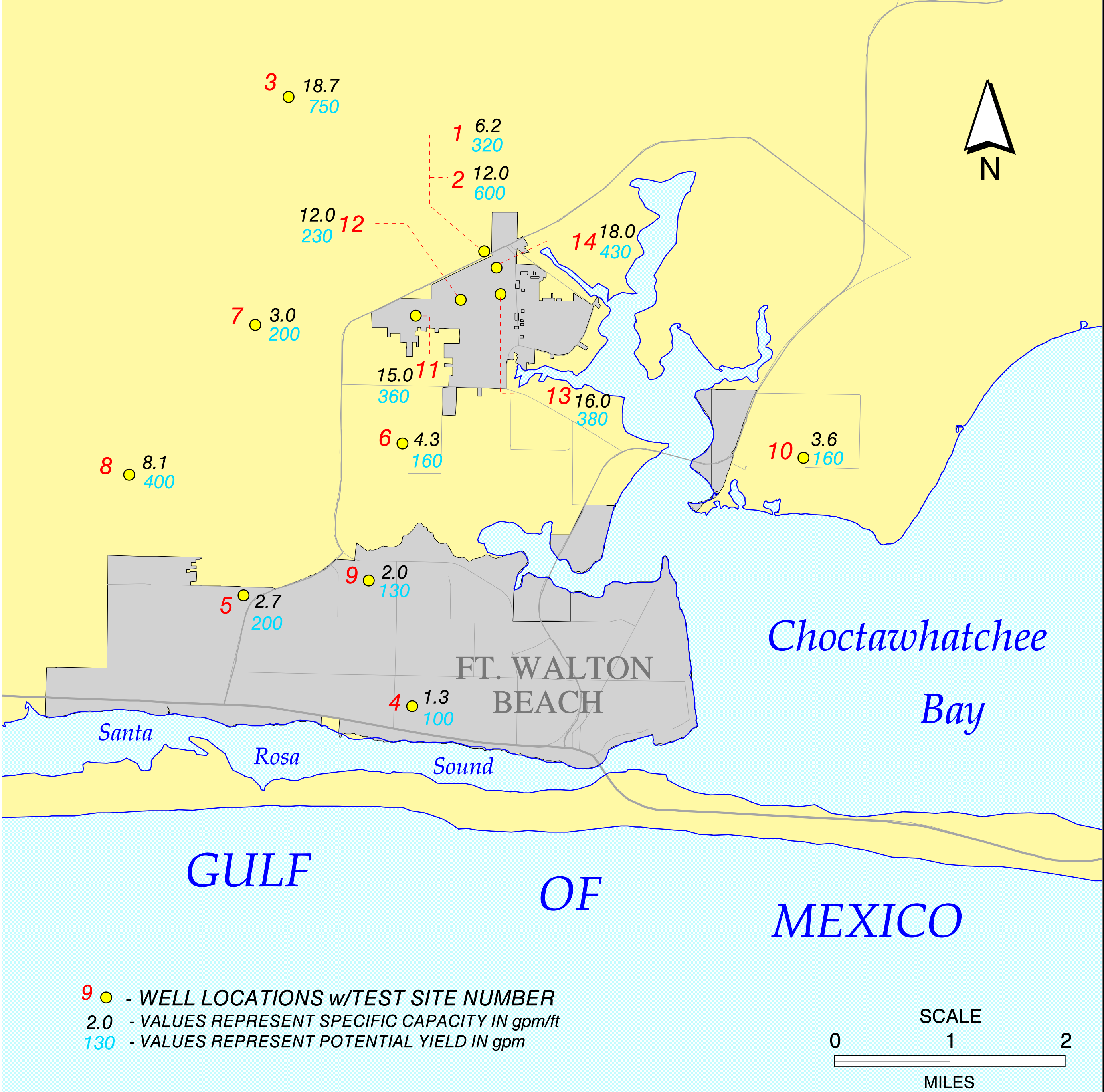
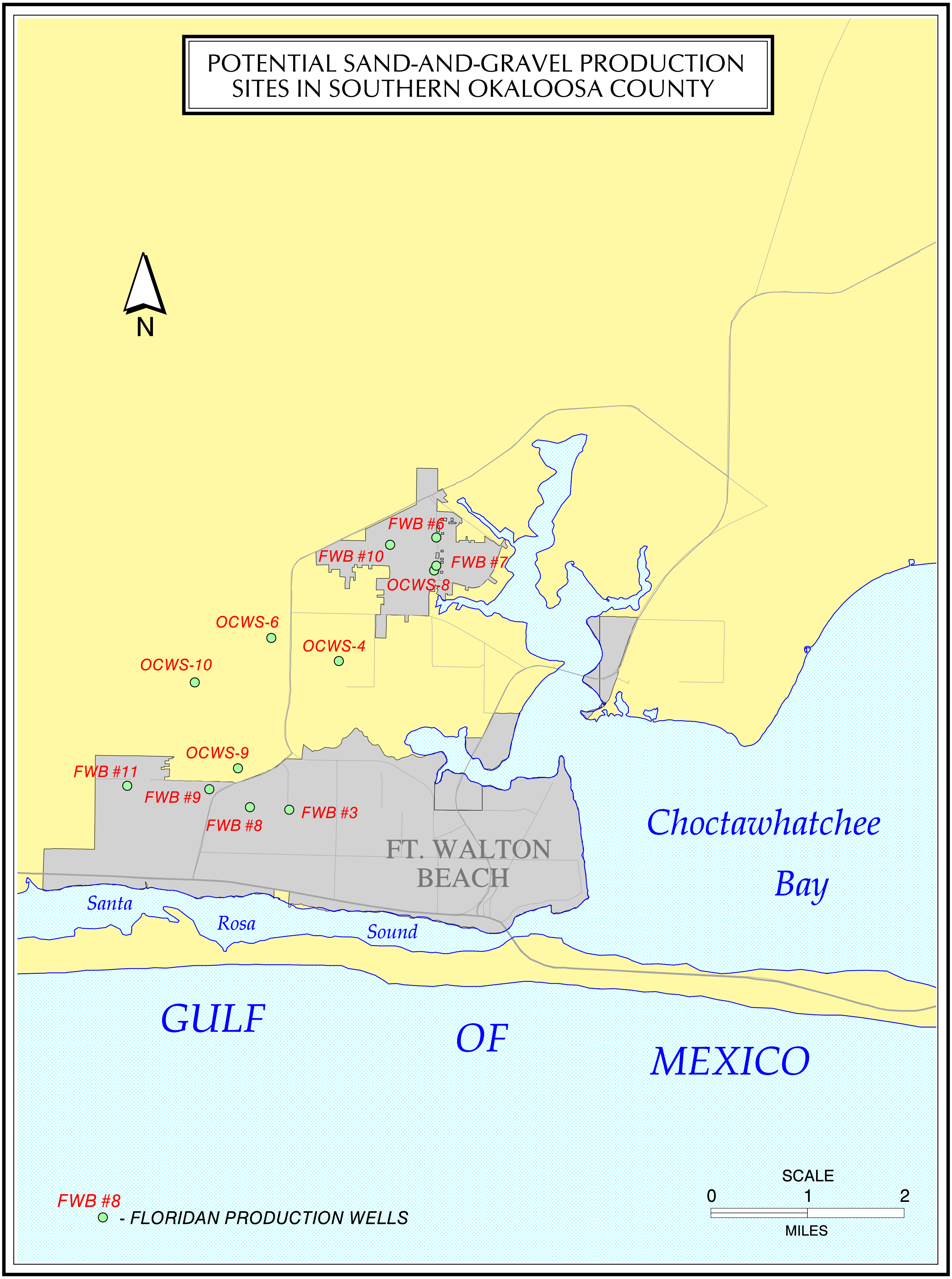


FIGURE 7


POTENTIAL SAND-AND-GRAVEL PRODUCTION
SITES IN SOUTHERN OKALOOSA COUNTY
N
FWB #6
FWB #10
FWB #7
OCWS-8
OCWS-6
OCWS-4
OCWS-10
OCWS-9
FWB #11
FWB #9
FWB #8
FWB #3
FT. WALTON
BEACH
Choctawhatchee
Bay
Santa
Rosa
Sound
GULF
OF
MEXICO
FWB #8
- FLORIDAN PRODUCTION WELLS
SCALE
0
1
2
MILES

APPENDIX B
WRIGHT LANDFILL MULTI-WELL AQUIFER TEST

ANALYSIS OF A SAND-AND-GRAVEL AQUIFER PUMP TEST
WRIGHT LANDFILL, OKALOOSA COUNTY, FLORIDA

January 2003

Kevin L. DeFosset
Christopher J. Richards

INTRODUCTION

To assist remediation activities addressing ground water contamination, Okaloosa County conducted a pump test at Wright Landfill on July 9-12, 1990. The 72-hour test was carried out in the northwest corner of the property (Section 22, Township 1S, Range 24W) and consisted of a pumping well and three observation wells. Analysis of the test data determined the hydraulic properties in that portion of the Sand-and-Gravel Aquifer.

This report provides a format to bring together information relevant to the aquifer test. Analysis of the test data by NWFWMD allows for an independent assessment of the hydraulic properties of the Sand-and-Gravel Aquifer underlying the site. Combined with results from similar tests implemented at other sites, these properties provide a basis for decisions related to the availability and management of the ground water resource of the Sand-and-Gravel Aquifer in the area.

HYDROGEOLOGY

The Sand-and-Gravel Aquifer is composed of fine to coarse grained sands with varying percentages of clay. The aquifer thickens across the panhandle from east to west with thicknesses of 100 to 150 ft in the vicinity of the landfill. The sands overlie a sequence of predominately fine-grained sediments representing the Intermediate System. Underlying the Intermediate System is the Floridan Aquifer. The confining nature of the Intermediate System serves to restrict the exchange of water between the Sand-and-Gravel Aquifer and the Floridan Aquifer.

Rainfall is the sole source of recharge to the Sand-and-Gravel Aquifer. Due to the complex arrangement of the sands and the varying percentages of clay, the quantity of recharge to and rate of horizontal and vertical movement through the aquifer can be highly variable. Water that does recharge the system eventually discharges to surface water bodies such as streams, wetlands, or bays.

Okaloosa County prepared a detailed lithologic log of the site based on split spoon samples taken from a test bore every 5 ft from 0 to 92 ft below land surface (bls). From 92 to 115 ft, no change in lithology was noted. Below is a simplified version of the lithologic log prepared by Okaloosa County. There was no dramatic change in the composition of the samples from 0 to 86 ft. Below 86 ft, the change in lithology was interpreted by the county to be the top of the Pensacola Clay, signifying the transition from the Sand-and-Gravel Aquifer to the Intermediate System.

LITHOLOGIC DESCRIPTION

0-67 ft	Quartz sand, fine-very coarse grained, predominately medium grained, very slightly-slightly silty, moderately-well sorted, subrounded-well rounded grains, yellowish tan-yellowish brown top 12 ft changing to brown below, small blebs orange clay 25-27 ft, 2 inch seam of iron cementation in sample of 45-47 ft.

67-77 ft	Quartz sand, very fine-coarse grained, predominately very fine-fine grained, slightly silty and clayey, poorly-moderately sorted, subangular-well rounded grains.
77-86 ft	Quartz sand, fine-very coarse grained, predominately medium grained, slightly silty and clayey, moderately-well sorted, subrounded-rounded grains.
86-115 ft	Quartz sand, fine-granule size grains, predominately medium grained, poorly-moderately sorted, subrounded-well rounded grains, shell fragments, green, silty, slightly clayey, becomes more consolidated with depth, interpreted to be the top of the Pensacola Clay.

AQUIFER TEST

The aquifer test included a fully-penetrating production well, two fully-penetrating observation wells and a partially-penetrating observation well. The 6-inch production well (P-1) was constructed in the initial test boring. The NWFWMD ran gamma log and electric logs on the test boring prior to completion. These logs do not indicate the presence of any significant semi-confining layer within the Sand and-Gravel Aquifer at the site. The production well was completed at a depth of 89 ft bls with 80 ft of screen extending from 9 ft to 89 ft. The static water level prior to the aquifer test was 10.02 ft bls (60.08 ft NGVD).

The three observation wells were all 2-inch diameter. Observation Well 1 (OW-1) was located 30 ft northeast of P-1. It was a fully-penetrating well completed at a depth of 76 ft bls with 70 ft of screen extending from 6 ft to 76 ft. Observation Well 2 (OW-2) was located 100 ft northeast of P-1. It was a fully-penetrating well completed at a depth of 86 ft with 80 ft of screen extending from 6 ft to 86 ft. Observation Well 3 (OW-3) was located 30 ft southwest of P-1. It was a partially-penetrating well completed at a depth of 24 ft with 10 ft of screen extending from 14 ft to 24 ft.

A 78-minute pre-test was completed on June 14, 1990 during the development of P-1. A pumping rate of approximately 164 gallons per minute (gal/min) produced a drawdown in OW-1 and OW-2 of 2.92 ft and 1.69 ft respectively. The actual test was initiated July 9, 1990. Prior to the aquifer test, the static water levels in OW-1, OW-2, and OW-3 were 9.56 ft bls (60.24 ft NGVD), 7.93 ft bls (60.47 ft NGVD), and 10.21 ft bls (60.29 ft NGVD) respectively. During the test, the pumping rate was calculated to vary between 116.2 and 217.5 gal/min with an average rate of 155 gal/min. Between minutes 3,801 and 3,854, the pump was stopped in order to repair a fan belt. Due to potential complications the malfunction could cause in interpreting the trend of observed water levels, data gathered after 3,801 minutes was not used in the analysis presented here. Because the number of water level measurements made between minute 3,801 and the conclusion of the test were so few, the exclusion of this data is not believed to impact the analysis. At the conclusion of the test on July 12, 1990, the water level had drawn down 4.12 ft in OW-1, 2.81 ft in OW-2, and 2.29 ft in OW-3.

TEST ANALYSIS

Analysis of the test data was performed using AquiferWin32 software. AquiferWin32 is proprietary software produced by Environmental Simulations, Inc. The Neuman (1972) analytical solution was used to analyze the test data for wells OW-1 and OW-2. The method is intended to simulate the response of an unconfined aquifer with fully-penetrating wells to pumping. It has the added advantage of being able to accommodate the variable pumping rate that existed during the aquifer test. Assumptions inherent to the solution are as follows:

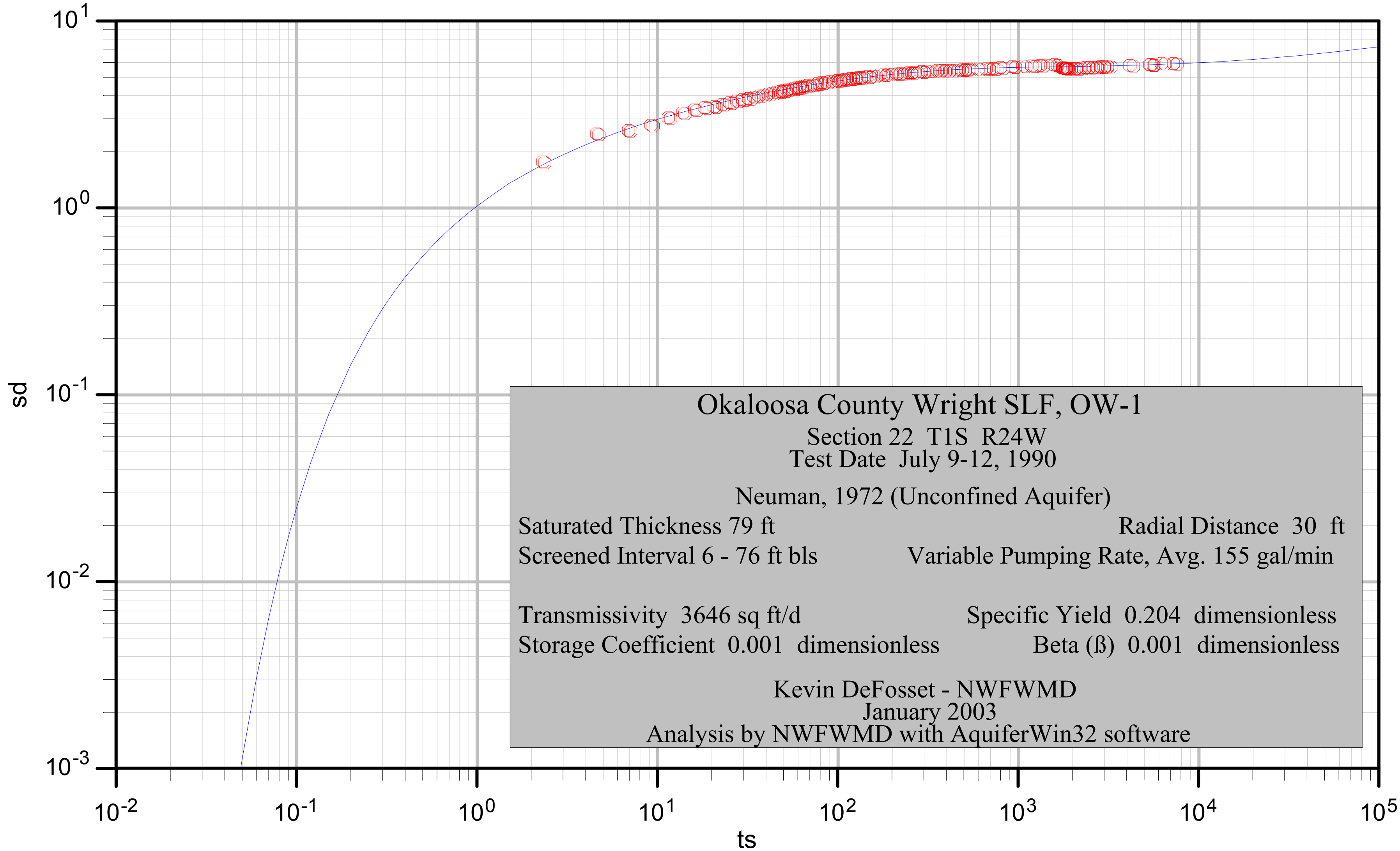
1. The aquifer has an infinite areal extent.
2. The aquifer is homogeneous and of uniform thickness over the area influenced by the test.
3. Prior to pumping, the water table is horizontal over the area influenced by the test.
4. The aquifer is isotropic or anisotropic.
5. The flow to the well is in an unsteady state.
6. The influence of the unsaturated zone upon the drawdown in the aquifer is negligible.
7. Due to the small diameter of the wells, storage in them can be neglected.

Considering a saturated thickness of 79 ft and distances from the pumping well of 30 ft for OW-1 and OW-3 and 100 ft for OW-2, the following hydraulic properties were obtained from analysis of the test results:

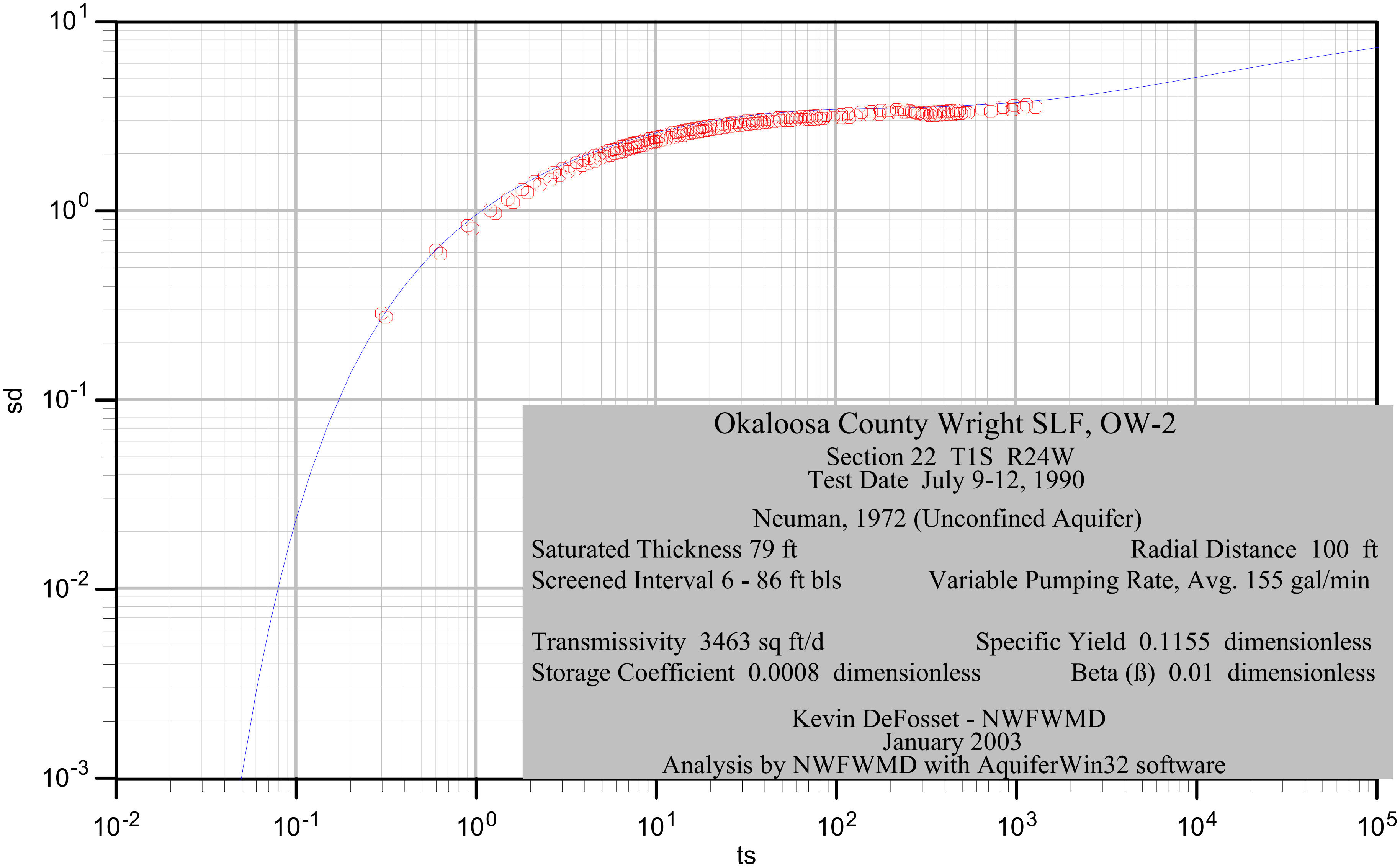
Hydraulic Parameter	**OW-1**	**OW-2**	**OW-3**
Saturated Thickness (ft)	79	79	79
Radial distance from P-1 (ft)	30	100	30
Transmissivity (sq ft/d)	3,600 (rounded)	3,500 (rounded)	4,700 (rounded)
Storage Coefficient (dimensionless)	0.001	0.0008	0.006
Specific Yield (dimensionless)	0.20 (rounded)	0.12 (rounded)	0.23 (rounded)
Beta (dimensionless)	0.001	0.01	0.05
Kz/Kr (dimensionless)			0.05

Neuman (1974) was used to analyze the test data for well OW-3. The solution addresses the response of an unconfined aquifer with partially-penetrating wells to pumping. Assumptions inherent to this method are similar to those of Neuman (1972). A reasonable type curve match was achieved. Also, the hydraulic parameters calculated appear to reasonably agree with those from OW-1 which is located the same distance from P-1. However, it is acknowledged that the drawdown data are less than ideal and therefore, the results from OW-3 should be viewed with caution.

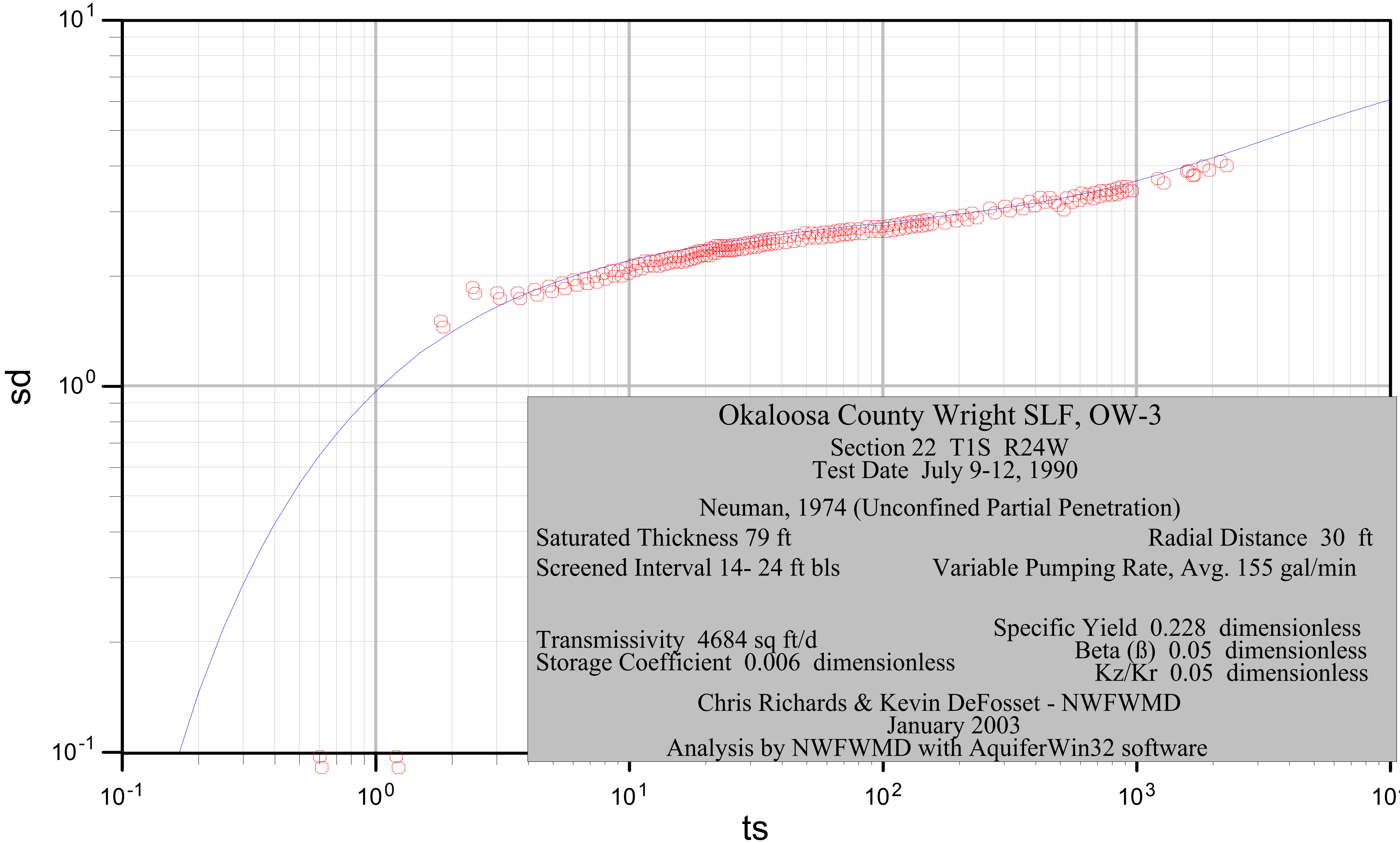
OKALOOSA CO. WRIGHT SLF SAND-AND-GRAVEL AQUIFER TEST, OW-1



OKALOOSA CO. WRIGHT SLF SAND-AND-GRAVEL AQUIFER TEST, OW-2



OKALOOSA CO. WRIGHT SLF SAND-AND-GRAVEL AQUIFER TEST, OW-3



SAND-AND-GRAVEL AQUIFER PUMP TEST
Wright Landfill, Okaloosa County, Florida

Test date: July 9-12, 1990	Test conducted by: Okaloosa County/ B.C.M. Engineers, Inc.
Production well: P-1	Observation wells: OW-1, OW-2, OW-3
Tested aquifer: Sand and Gravel	Production rate: Variable; 155 gal/min average
Test duration: 72 hrs.	Data type: Drawdown

ELAPSED TIME (min)	OW-1 DRAWDOWN (ft)	ELAPSED TIME (min)	OW-1 DRAWDOWN (ft)
1	1.13	36	3
2	1.6	38	3.02
3	1.67	40	3.05
4	1.78	42	3.06
5	1.95	44	3.08
6	2.07	46	3.1
7	2.15	48	3.12
8	2.21	50	3.14
9	2.24	52	3.15
10	2.3	54	3.17
11	2.35	56	3.18
12	2.4	58	3.19
13	2.44	60	3.2
14	2.47	65	3.23
15	2.52	70	3.25
16	2.55	75	3.29
17	2.58	80	3.3
18	2.61	85	3.33
19	2.64	90	3.33
20	2.67	95	3.34
21	2.69	100	3.36
22	2.72	105	3.37
23	2.75	110	3.39
24	2.77	115	3.39
25	2.79	120	3.41
26	2.82	130	3.43
27	2.83	140	3.45
28	2.86	150	3.45
29	2.88	160	3.49
30	2.9	170	3.48
32	2.92	180	3.49
34	2.96	190	3.49

ELAPSED TIME (min)	OW-1 DRAWDOWN (ft)
200	3.49
210	3.5
220	3.51
230	3.52
240	3.525
270	3.535
300	3.555
330	3.56
360	3.605
420	3.64
480	3.67
540	3.68
600	3.7
660	3.71
720	3.73
780	3.63
800	3.58
802	3.58
804	3.58
806	3.58
808	3.58
813	3.58
823	3.57
827	3.565
835	3.56
840	3.565
900	3.56
960	3.555
1020	3.575
1080	3.605
1140	3.6
1200	3.61
1260	3.61
1320	3.635
1380	3.65
1440	3.65
1920	3.69
2483	3.725
2520	3.73
2880	3.79
3360	3.78

ELAPSED TIME (min)	OW-2 DRAWDOWN (ft)	ELAPSED TIME (min)	OW-2 DRAWDOWN (ft)
1	0.2	54	1.92
2	0.43	56	1.93
3	0.58	58	1.94
4	0.7	60	1.96
5	0.8	65	1.98
6	0.9	70	2
7	0.99	75	2.02
8	1.05	80	2.04
9	1.11	85	2.05
10	1.16	90	2.07
11	1.2	95	2.08
12	1.25	100	2.1
13	1.29	105	2.1
14	1.32	110	2.12
15	1.36	115	2.13
16	1.39	120	2.14
17	1.42	130	2.15
18	1.45	140	2.18
19	1.47	150	2.19
20	1.49	160	2.19
21	1.52	170	2.2
22	1.54	180	2.21
23	1.56	190	2.21
24	1.58	200	2.22
25	1.6	210	2.22
26	1.61	220	2.23
27	1.63	230	2.24
28	1.65	240	2.25
29	1.66	270	2.26
30	1.68	300	2.27
32	1.71	330	2.28
34	1.73	360	2.31
36	1.76	425	2.35
38	1.78	482	2.37
40	1.81	542	2.4
42	1.82	603	2.41
44	1.84	663	2.43
46	1.86	722	2.44
48	1.88	782	2.39
50	1.89	830	2.36
52	1.9	842	2.35

ELAPSED TIME (min)	OW-2 DRAWDOWN (ft)
901	2.34
961	2.34
1021	2.35
1082	2.37
1142	2.38
1201	2.38
1262	2.4
1322	2.4
1381	2.42
1441	2.42
1918	2.46
2486	2.51
2523	2.51
2881	2.57
3361	2.59

ELAPSED TIME (min)	OW-3 DRAWDOWN (ft)	ELAPSED TIME (min)	OW-3 DRAWDOWN (ft)
1	0.05	24	1.16
2	0.05	25	1.16
3	0.77	26	1.16
4	0.95	27	1.17
5	0.92	28	1.18
6	0.92	29	1.19
7	0.94	30	1.2
8	0.96	31	1.21
9	0.98	32	1.21
10	1	33	1.21
11	1.01	34	1.23
12	1.02	35	1.23
13	1.04	36	1.25
14	1.06	37	1.25
15	1.06	38	1.25
16	1.08	39	1.25
17	1.1	40	1.25
18	1.11	41	1.25
19	1.13	42	1.26
20	1.13	44	1.26
21	1.13	46	1.27
22	1.14	48	1.28
23	1.15	50	1.28

ELAPSED TIME (min)	OW-3 DRAWDOWN (ft)	ELAPSED TIME (min)	OW-3 DRAWDOWN (ft)
52	1.29	963	1.76
54	1.3	1024	1.75
56	1.3	1084	1.77
58	1.31	1144	1.79
60	1.31	1203	1.79
65	1.32	1263	1.8
70	1.33	1323	1.82
75	1.34	1383	1.84
80	1.36	1442	1.84
85	1.36	1916	1.93
90	1.36	2489	2.02
95	1.37	2525	2.03
100	1.37	2883	2.09
105	1.38	3371	2.15
110	1.39		
115	1.39		
120	1.4		
130	1.4		
140	1.42		
150	1.42		
160	1.42		
170	1.43		
180	1.44		
190	1.45		
200	1.46		
210	1.47		
220	1.47		
230	1.48		
240	1.49		
270	1.5		
300	1.52		
330	1.53		
360	1.55		
423	1.6		
484	1.62		
544	1.64		
605	1.67		
665	1.71		
724	1.71		
784	1.63		
845	1.71		
903	1.73		

ELAPSED TIME (min)	PUMPING RATE (gpm)	ELAPSED TIME (min)	PUMPING RATE (gpm)
5	160	1860	151.7
7	160	1920	143.3
8	157	1980	170
10	156	2040	160
14	150	2100	126.7
20	156	2160	153.3
30	160	2220	170
35	170	2280	156.7
43	150	2340	148.3
55	156	2400	160
60	156	2460	138.3
90	157.4	2501	150
180	217.5	2527	153.8
240	156.7	2580	150.9
270	136.7	2640	156.7
300	180	2700	151.7
360	156.7	2760	153.3
420	161.7	2820	158.3
480	156.7	2880	150
540	156.7	2940	150
600	163.3	3000	155
660	156.7	3060	151.7
720	158.3	3120	151.7
780	156.7	3180	153.3
817	116.2	3240	153.3
840	208.7	3300	156.7
900	155	3360	138.3
960	148.3	3420	180
1020	155	3480	143.3
1080	153.3	3540	153.3
1140	155	3600	136.7
1200	151.7	3660	148.3
1260	151.7	3720	170
1320	155	3780	135
1380	153.3		
1440	153.3		
1500	155		
1560	155		
1620	153.3		
1680	155		
1740	155		
1800	153.3		