Appendix A

Groundwater Evaluation to Support the Reservation Rule for the Caloosahatchee River C-43 West Basin Storage Reservoir Project

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Purpose

The purpose of the document is to briefly describe the geologic and hydrogeologic framework at the C-43 West Basin Storage Reservoir (WBSR or reservoir) site and analyze the potential for groundwater use impacts on the water being stored and reserved from consumptive use. An aerial photograph of the C-43 proposed WSBR site is attached as Plate 1.

Geologic Framework

The elevation of the site is approximately +20 to +21 feet North American Vertical Datum of 1988 (NAVD). The water surface elevation in the reservoir will be +42 feet at "normal pool" (NAVD), with the average depth ranging from +17-19 feet. The description of the subsurface, based on 92 core borings on-site, is as follows:

- Pliocene and Pleistocene-Holocene age: Subsurface lithology from land surface to approximately 20 feet below land surface (bls) includes clean sands, clayey sands and a minor sequence of limestone just beneath the clean sands to a depth of 20 to 25 feet.
- Miocene-age: The Hawthorn Group extends to approximately 500 feet bls and is divided into an upper clastic sequence and a lower carbonate sequence. At the site the upper unit consists of a clayey sand layer ranging from 20 to 80 feet thick which overlays siliciclastic sands, sandstones and clayey sands that make up the upper Peace River Formation.

Plate 2 shows two cross-sections illustrating core boring results striking east-west along the northern and southern boundaries of the reservoir.

A portion of the geologic log, from ground surface to a depth of 180 feet bls of the Caloosahatchee Aquifer Storage and Recovery (ASR) Test Core conducted at the site, is included in Attachment A. The geologic log indicates clays, limestone, and shell beds from 50 feet bls to 90 feet bls which appear to occur as a stringer at the western boundary of the site and is not noted in any other cores.

Hydrogeology

Three major freshwater aquifers provide the majority of groundwater in Hendry County. The water table (WTA) and the lower Tamiami (LTA, not present at this site) aquifers are part of the surficial aquifer system and the sandstone aquifer (SA, the primary groundwater source in the area) is in the intermediate aquifer system. There is also minor use of the brackish mid-Hawthorn aquifer (MHA), also within the intermediate aquifer system, and the Floridan aquifer system (FAS). Plate 3 shows the location of aquifer performance tests in the area and the associated aquifer characteristics.

Surficial Aquifer System

- According to SFWMD Technical Publication 90-04, hydraulic conductivity of the surficial aquifer is 100 ft/day with an aquifer thickness of approximately 20 feet, (transmissivity of 2,000 ft^2/day). Due to its thinness and low hydraulic conductivity, this aquifer is not widely used as a source of groundwater in the area of the C-43 WBSR. Therefore, for the purpose of this evaluation, groundwater withdrawals from the Surficial Aquifer System are considered to have no impact on the stored surface water of the proposed C-43 WBSR.

Intermediate Aquifer System

- Sandstone aquifer: According to two local pump tests, documented in SFWMD Technical Publication 88-12, transmissivity ranges from 14,000 to 70,000 gpd/ft (1,870 to 9,358 ft^2/day) in the project area. Transmissivity ranges from 10,000 to 240,000 gpd/ft (1,400 to 32,000 ft^2/day) where the aquifer occurs in Lee, Hendry and Collier counties, depending on if both the clastic and carbonate portions of the aquifer occur. Local values of storage are 0.0002 to .00004 and leakance is approximately 0.0002 gpd/ft^2. The Sandstone aquifer is the principle source of fresh groundwater in the area and is the focus of the model evaluation described below.

- The mid and lower Hawthorn aquifers supply groundwater to the area, however, these aquifers occur at great depth, are separated from the surface by a semi-confining lithology, and the aquifers are generally low yield and saline. Therefore for the purpose of this evaluation groundwater withdrawals from these aquifers are considered to have no impact on the stored surface water of the proposed C-43 WBSR.

Water Use Impact Assessment

Please refer to Plate 4 for the location of water use permits and permitted facilities.

Existing Onsite Water Use

- Surface water pump facilities:
    - 26-00082-W Labelle Private Drainage District. Townsend Canal, Header Canal
    - 26-00106-W DUDA Labelle Farm.

Existing Offsite Water Use

- Surface water pump facilities:
    - 26-00022-W – Banana Branch Groves, C-43, Banana Branch
    - 26-00076-W – Murphy Groves, Townsend Canal
    - 26-00957-W – Murphys Landing, Townsend Canal
- Well facilities:
    - 26-00022-W – Banana Branch Groves, 1 MHA well, 3,800’ north
    - 26-00082-W – LaBelle Private DD, 10 LHA wells, 1,100’ east

- 26-00265-W – Bob Paul, 14 LHA, 5 SA wells (freeze protection, backup),
- 26-00399-W – B&W Growers, 7 SA wells
- 26-00498-W – Sun Belt Citrus Nursery, 1 SA well, 550' west
- 26-00573-W – Daniels Farm, 1 WTA well, 2,700' north
- 26-00659-W – Shults Commercial, 2 Surficial aquifer, 2,900 north
- 26-00739-W – Smith PWS, 1 SA well, 3.000' north
- 26-00741-W – Zarecky PWS, 1 SA well, 2,300' north
- 26-00789-W – Glen Acres Storage, 1 SA well, 2,100' north
- 26-00739-W – David Smith, 1 SA well, 2,300' north
- 26-00741-W – Zarecky, 1 SA well, 2,400' north
- 26-00789-W – Glenn Acres Storage, 1 SA well, 2,500' north
- 26-00840-W – Gator Golf Cars, 1 SA well, 2,600' north
- 26-00874-W – Riverbend Resort, 4 SA wells, 4,000' north
- 26-00941-W - Hendry County EOC, 2 SA wells, 2,000' north
- 26-00946-W – LaBelle Farms, 1 Surficial well, 1 mile south
- 26-01014-W –River Landings, 2 SA wells, 3,500' north
- 26-01027-W - Domingo Rios Salinas, 1 SA well, 2,500' north
- 26-01144-W – Oak Creek Hammock (GP), 2 SA wells, 1,800' west
- 26-01162-W – '4825 SR80', 1 SA well, 2,600' north
- 36-01134-W – Le Hi Tree Farm, 1 SA well, 2,700' west
- 36-01498-W – Brett's Back Forty, 1 SA well, 4,000' west
- 36-02141-W – Roberge Farms, 7 Surficial, 1 LHA well, 1.3 miles west

Surface water bodies can receive recharge from groundwater if they are connected to the water table. This is not the case with the C-43 WBSR because the above ground design places the reservoir bottom above the prevailing water table. In addition, an impermeable clay wall to the top of the clay in the formation is also proposed in the design to separate the C-43 WBSR from the water table aquifer around the site. Seepage studies at test cells with and without the barrier indicate that the barrier design significantly reduced the seepage losses by 76 percent. Any existing or future withdrawals from adjacent surface water bodies connected to the water table aquifer would not affect the water in the reservoir because of this proposed physical barrier (clay wall).

A series of monitor wells were installed to a depth above, within, and below the clays both near the test cells and around the perimeter of the WBSR to get background water levels for the seepage analysis. In the year of data collection, the wells below the clay layer (Sandstone aquifer wells) had water levels that appeared to be independent of surface water levels in the test cells (Plate 5). Fluctuations in water levels in the Sandstone aquifer were related to regional and seasonal weather and recharge. Water levels in the Sandstone aquifer immediately below the test cells were consistent with those observed in background piezometers located at the C-43 WBSR boundary.

Groundwater withdrawals from the Lower Tamiami, Sandstone and mid-Hawthorn aquifers are subject to existing rules [Prevention and Recovery Strategies in 40E-8.421(4) Florida Administrative Code and Section 3.2.4 of the Basis of Review for Water

Use Applications] which restrict those permitted withdrawals so that the potentiometric head within each aquifer cannot be lowered to less than 20 feet above the top of the uppermost geologic strata of the aquifer during a 1-in-10 year drought. For example, in the vicinity of the WBSR, the top of the Peace River Formation (Sandstone aquifer) is identified as 40 feet below land surface (-19 feet NAVD). Therefore, drawdown would be limited to 20 feet above this, or 20 feet below land surface (+1 feet NAVD). During the test cell seepage monitoring in 2006, water levels in the Sandstone aquifer fluctuated between +15 feet NAVD and +7 feet NAVD (Plate 5). Long term monitor data from Sandstone aquifer wells HE-557 (north of reservoir), HE-559 and HE-560 (south boundary of reservoir) documents water levels of +13 feet NGVD at the south end of the reservoir and +6 feet NGVD at the north end (location on Plate 4 and data on Plate 6). Any new user on the north side of the reservoir (near HE-557) would have to demonstrate that their withdrawals do not have additional drawdowns of more than 5 feet at a distance of 50 feet from the withdrawal point. To the south of the reservoir the drawdown limit is approximately 13 additional feet at a distance of 50 feet from the withdrawal point. Based on model results, withdrawals to the north would be limited to approximately 100,000 gallons per day and to 500,000 gallons per day to the south.

Groundwater Modeling

The groundwater model for Hendry County, documented in SFWMD Technical Publication 90-04, was used to assess impacts due to withdrawals from the Sandstone aquifer. The model cell size in the vicinity of the reservoir was reduced from one mile down to 660 feet. A simulated sandstone aquifer well and also a string of four wells at withdrawal rates of 0.1 million gallons per day (MGD) and 0.5 MGD were used to evaluate the potential drawdown in the water table aquifer, layer 1, and the semi-confined Sandstone aquifer, layer 3. Pumping was simulated under steady-state conditions. Results indicated no drawdown in layer 1. Table 1 summarizes the drawdown in layer 3.

TABLE 1
C-43 WEST BASIN STORAGE RESERVOIR
MODEL OUTPUT SUMMARY

PUMPING RATE (MGD)	DRAWDOWN IN LAYER 3 (Sandstone aquifer) (FEET)	DRAWDOWN IN LAYER 1 (Water Table) (FEET)
0.1 (1 well)	1.2	0
0.1 each (4 wells)	5	0
0.5 (1 well)	11	0
0.5 each (4 wells)	31	0

Potential Water Losses

Vertical and horizontal seepage can occur from the reservoir through the bottom and sides of the above ground impoundment prior to slurry wall installation. Dipping, semi-confining lithologic layers are present under the site beginning at depths ranging from 20 to 30 feet below land surface in the water table aquifer and at greater depths between additional water producing zones in the Peace River Formation. Based on the site hydrogeologic framework, impacts causing minor loss of water from the proposed storage reservoir are possible from nearby water table aquifer groundwater withdrawals. However, due to the reservoir design with a slurry wall and the low yield of the aquifer in the area, significant withdrawals are not possible and minor withdrawals would have no impacts. As shown on Plate 3, there are very few permits in the area withdrawing from the water table aquifer or surficial aquifer system. Wells withdrawing from the Sandstone aquifer are the primary groundwater source in the area and are the water use with the least potential for impacts to the reservoir due to overlying semi-confining lithology. Groundwater modeling of potentially permittable Sandstone aquifer withdrawals predicted no losses from the reservoir.

Conclusions:

Groundwater modeling was used to evaluate the potential impacts of groundwater use near the proposed WBSR by simulating withdrawals from specific depths and volumes in a three dimensional, multi-layered framework. The impact at the simulated ground surface, under the reservoir, is calculated by the amount of water removed from the model cells under the reservoir and by predicted drawdown of water levels beneath the reservoir. Using this methodology, the model did not predict any water loss or predict any drawdown in layer 1 of the model under the reservoir due to Sandstone aquifer withdrawals. The reservoir design, which includes a slurry wall, and the low yield of the water table aquifer in the area prevents seepage due to water table aquifer withdrawals. Therefore, groundwater withdrawals adjacent to the reservoir are not expected to remove significant volumes of reservoir water via seepage and do not need to be restricted or regulated as part of this reservation rule.

References

Dunkleberger Engineering &Testing, July 2007, *C-43 WBSR Test cell Pilot Project Seepage Monitoring.*

Dunkleberger Engineering &Testing, July 30, 2007, *Technical Memorandum C-43 Test Cell Project Drawdown Test*.

GCME, Inc., July 2007, *C-43 West Basin Storage Reservoir Test Cell Pilot Project Settlement Plate Monitoring.*

Missimer, T.M and Scott, T.M, 2001, Florida Geological Society Special Publication 49, *Geology and Hydrology of Lee County, Florida*

Murray Consultants, Inc. Appendix "C", January 8, 2007, *Impact Analysis Port Labelle Utility SFWMD CUP #26-00096-W Hendry County, Florida.*

South Florida Water Management District Technical Publication 88-12, September 1988, *Ground Water Resource Assessment of Hendry County, Florida.*

South Florida Water Management District Technical Publication 90-04, October 1990, *A Three Dimensional Finite Difference Ground Water Flow Model OF Hendry County.*

South Florida Water Management District, *Berry Grove Test Core Well CCBRY-1 Caloosahatchee River ASR Well Completion Report.*

U.S. Army Corps of Engineers and South Florida Water Management District, November 2010, *Central and Southern Florida Project Caloosahatchee River (C-43) West Basin Storage Reservoir Volume 4 – Appendix A - Engineering*

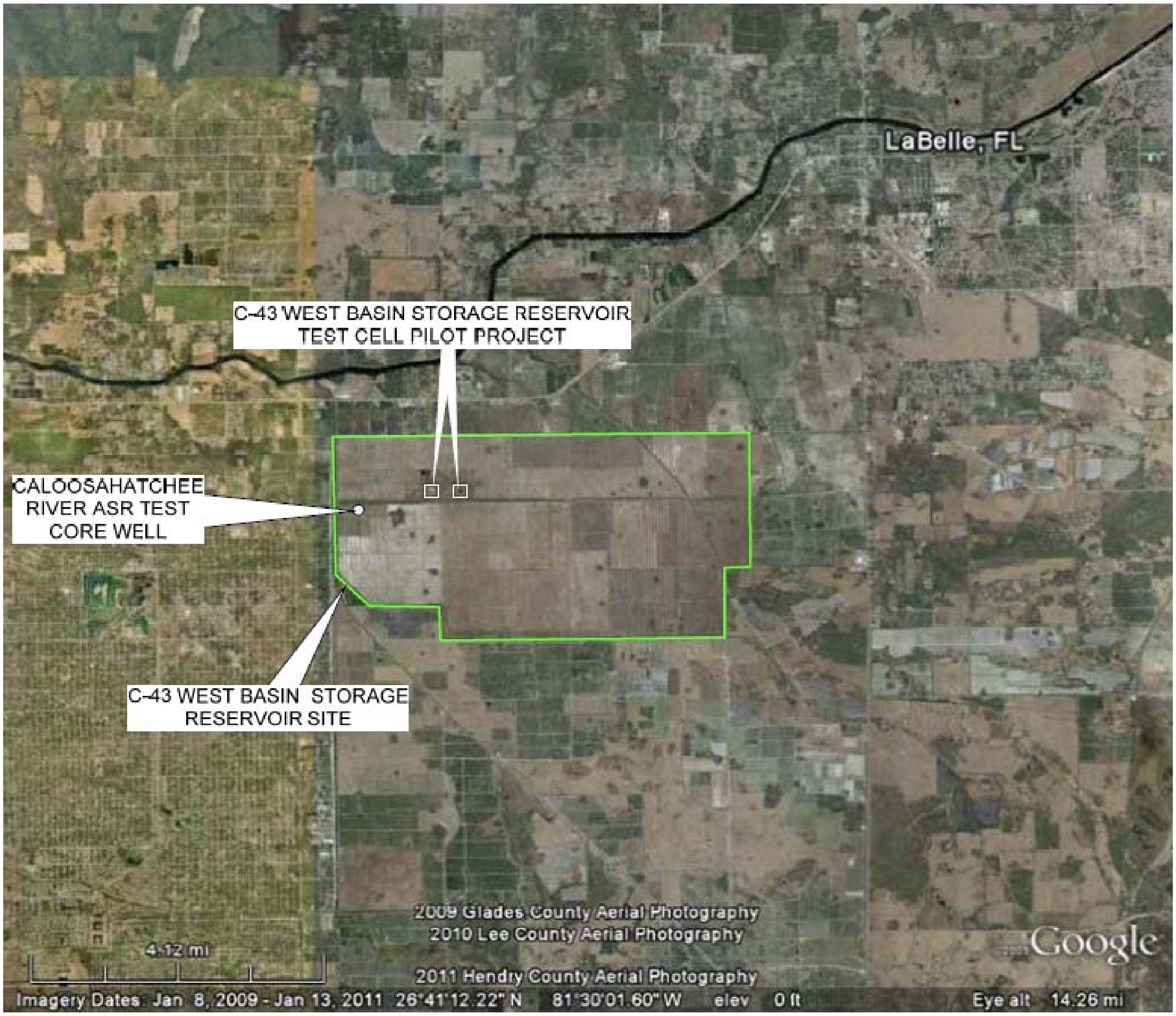
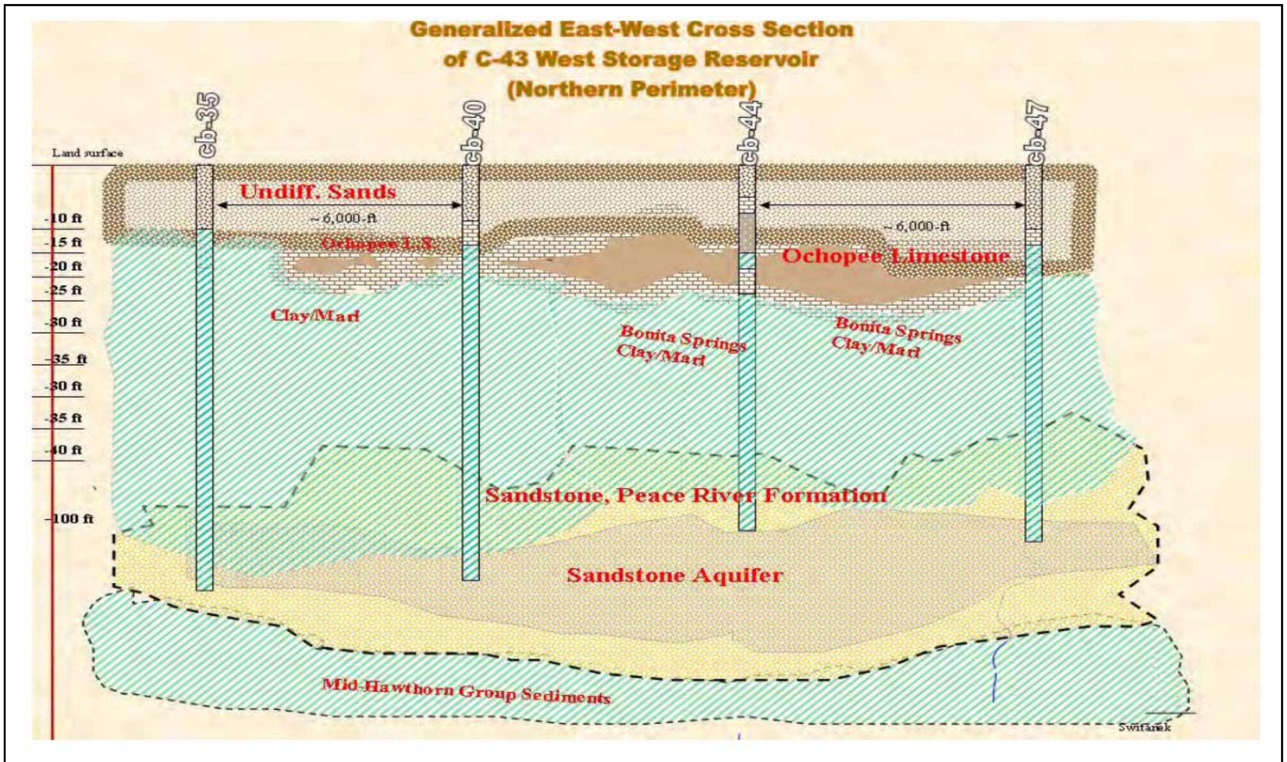


PLATE 1
SITE LOCATION


Generalized East-West Cross Section
of C-43 West Storage Reservoir
(Northern Perimeter)
cb-35
cb-40
cb-44
cb-47
Land surface
Undiff. Sands
~ 6,000-ft
~ 6,000-ft
Ochopee L.S.
Ochopee Limestone
Clay/Marl
Bonita Springs
Clay/Marl
Bonita Springs
Clay/Marl
Sandstone, Peace River Formation
Sandstone Aquifer
Mid-Hawthorn Group Sediments
Switanek

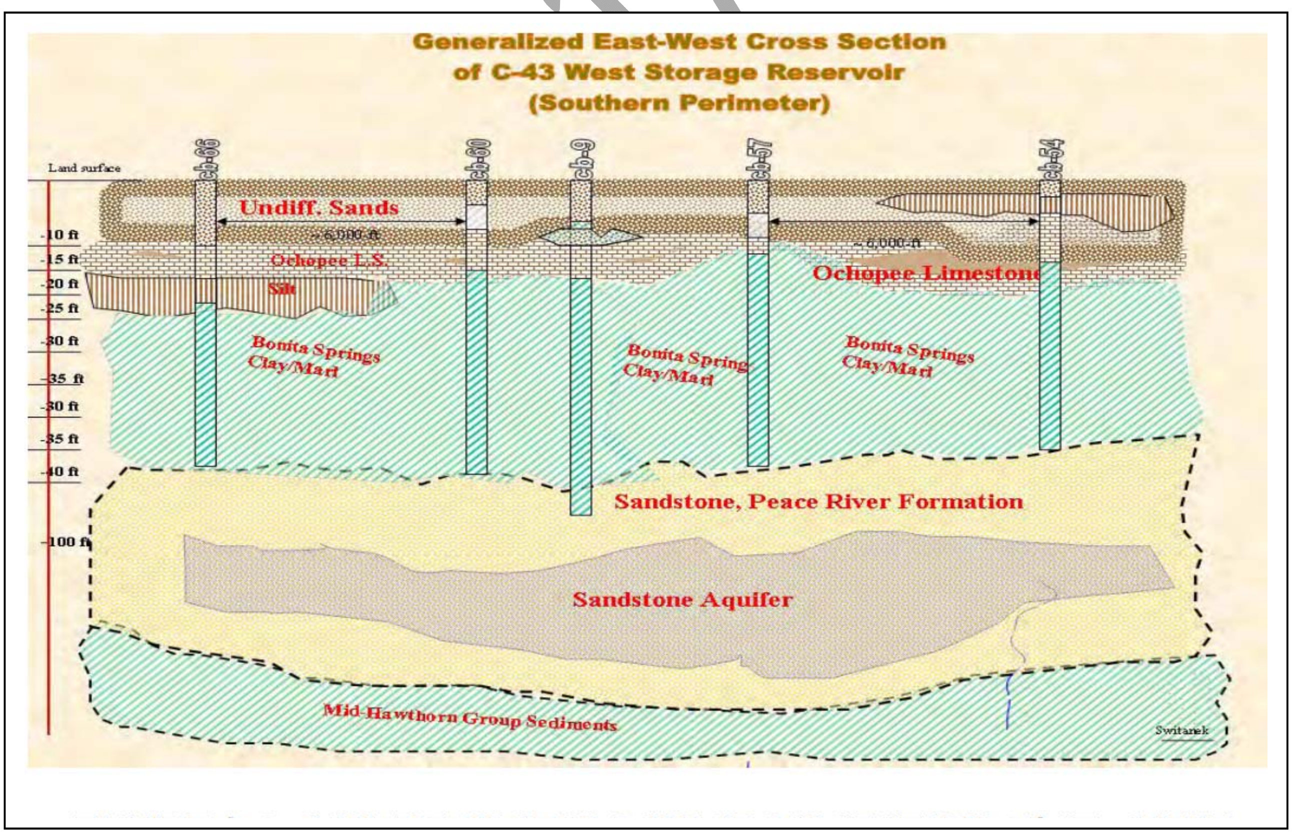

Generalized East-West Cross Section
of C-43 West Storage Reservoir
(Southern Perimeter)
cb-66
cb-60
cb-9
cb-57
cb-54
Land surface
Undiff. Sands
~ 6,000-ft
~ 6,000-ft
Ochopee L.S.
Silt
Ochopee Limestone
Bonita Springs
Clay/Marl
Bonita Spring
Clay/Marl
Bonita Springs
Clay/Marl
Sandstone, Peace River Formation
Sandstone Aquifer
Mid-Hawthorn Group Sediments
Switanek

PLATE 2

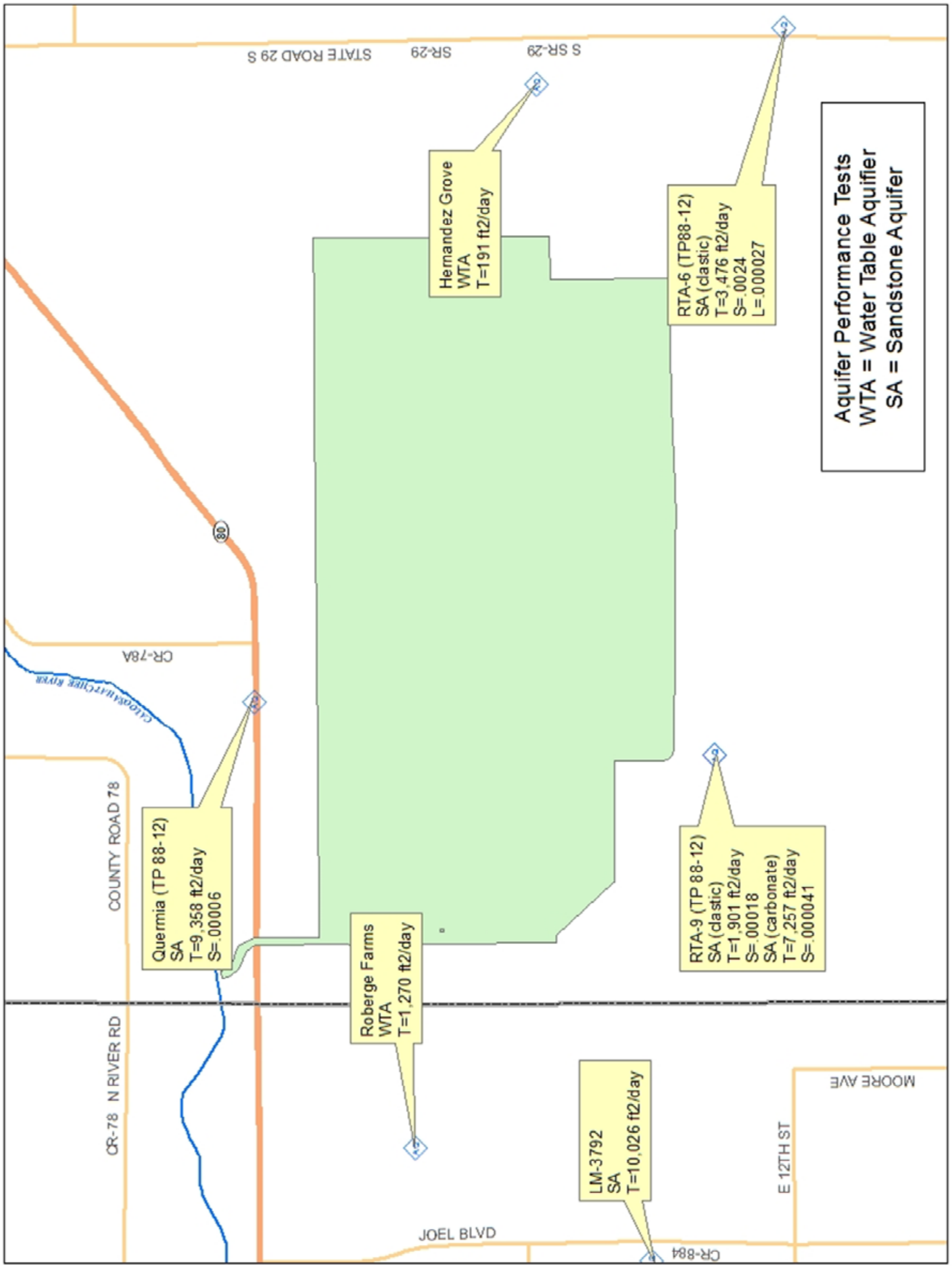

STATE ROAD 29 S
SR-29
S SR-29
Hernandez Grove
WTA
T=191 ft2/day
RTA-6 (TP88-12)
SA (clastic)
T=3,476 ft2/day
S=.0024
L=.000027
Aquifer Performance Tests
WTA = Water Table Aquifer
SA = Sandstone Aquifer
80
CR-78A
COUNTY ROAD 78
Quermia (TP 88-12)
SA
T=9,358 ft2/day
S=.00006
Roberge Farms
WTA
T=1,270 ft2/day
RTA-9 (TP 88-12)
SA (clastic)
T=1,901 ft2/day
S=.00018
SA (carbonate)
T=7,257 ft2/day
S=.000041
CR-78 N RIVER RD
LM-3792
SA
T=10,026 ft2/day
E 12TH ST
MOORE AVE
JOEL BLVD
CR-884

PLATE 3

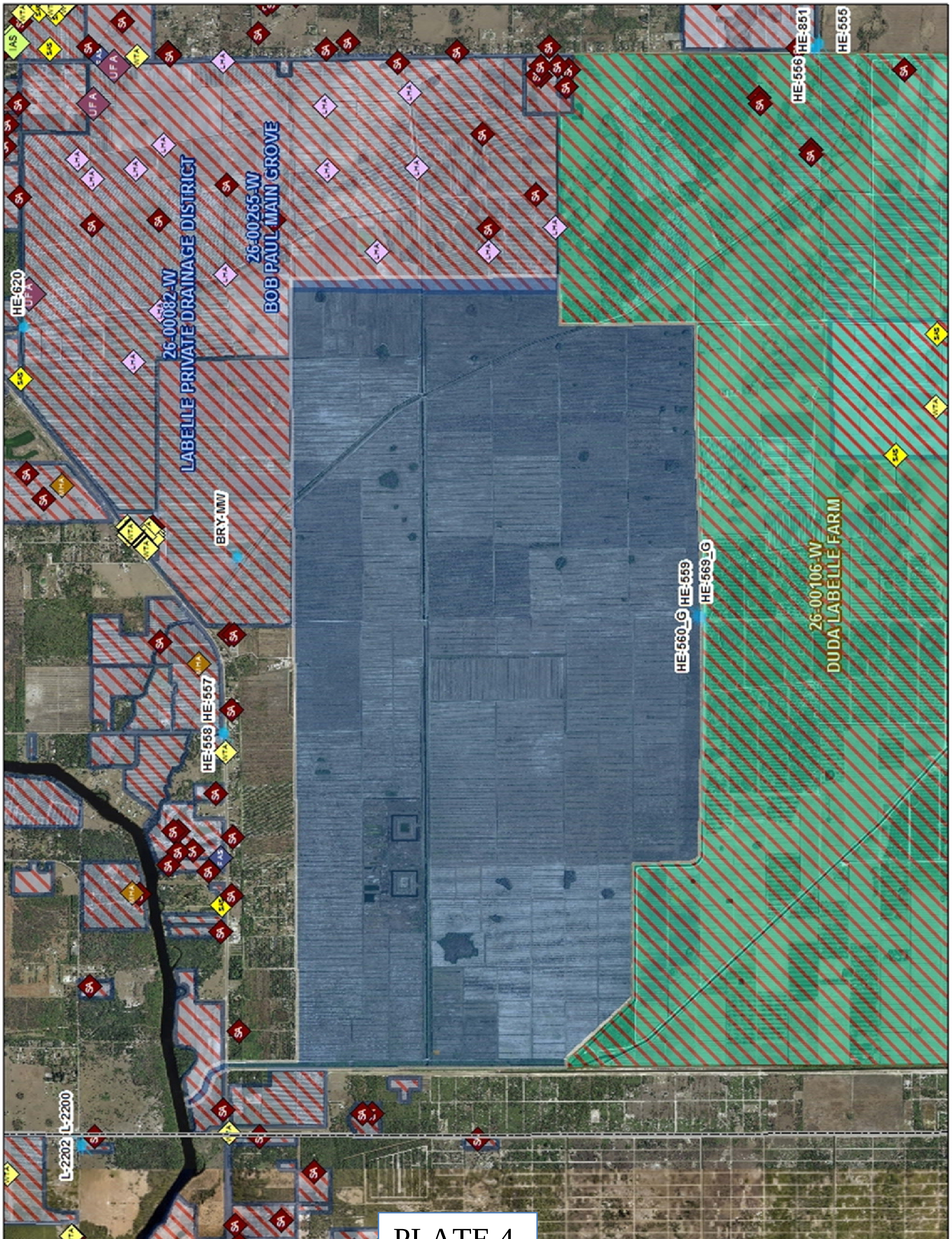
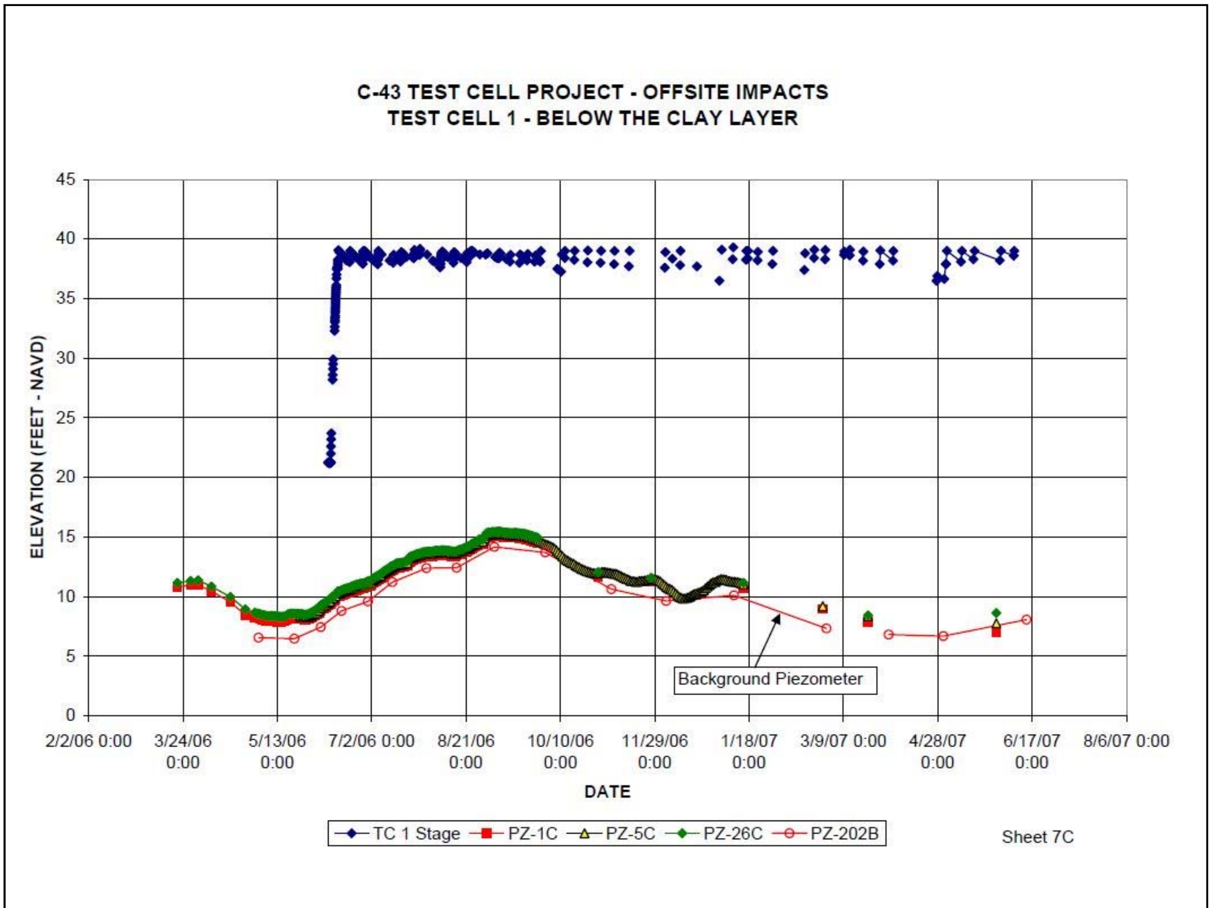

26-00082-W
LABELLE PRIVATE DRAINAGE DISTRICT
26-00265-W
BOB PAUL MAIN GROVE
26-00106-W
DUDA LABELLE FARM
HE-620
BRY-MW
HE-557
HE-558
HE-559
HE-569_G
HE-560_G
HE-556
HE-851
HE-555
L-2200
L-2202

PLATE 4


C-43 TEST CELL PROJECT - OFFSITE IMPACTS
TEST CELL 1 - BELOW THE CLAY LAYER
ELEVATION (FEET - NAVD)
Background Piezometer
DATE
TC 1 Stage
PZ-1C
PZ-5C
PZ-26C
PZ-202B
Sheet 7C

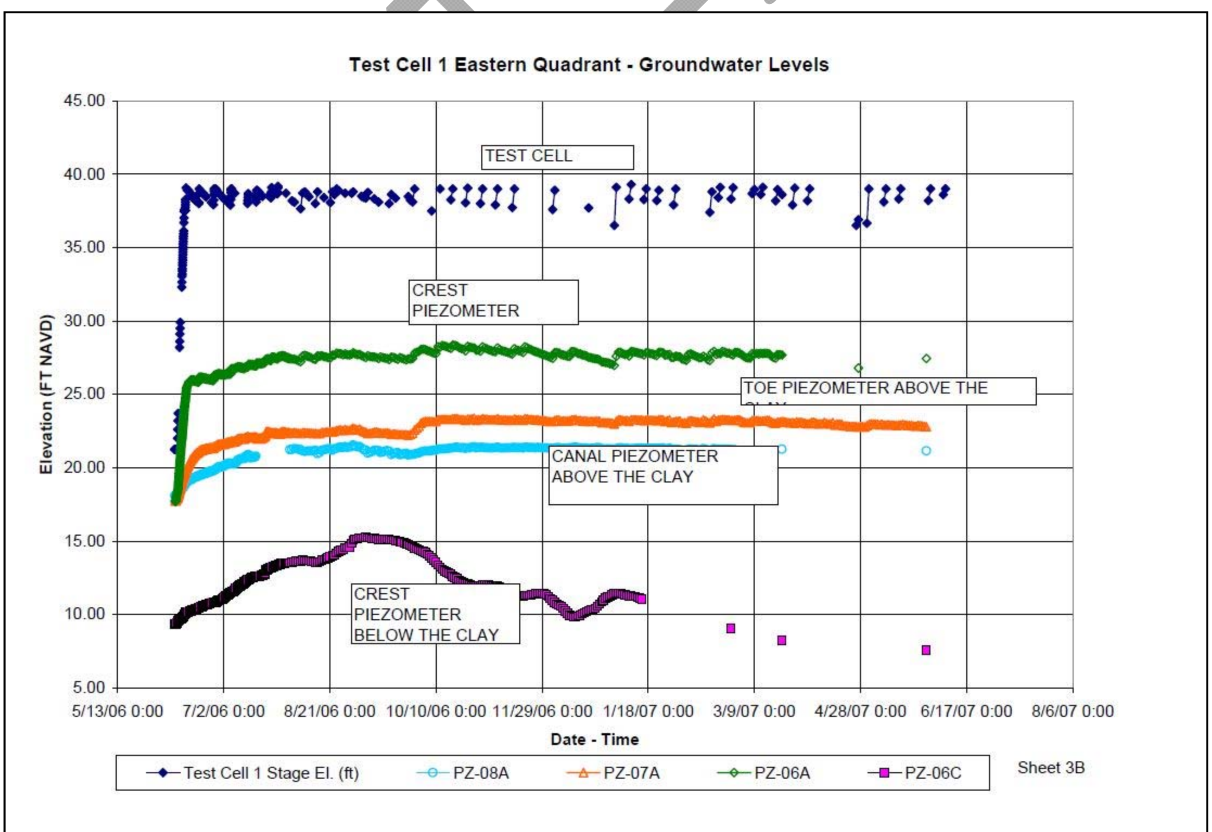

Test Cell 1 Eastern Quadrant - Groundwater Levels
Elevation (FT NAVD)
TEST CELL
CREST PIEZOMETER
TOE PIEZOMETER ABOVE THE
CANAL PIEZOMETER ABOVE THE CLAY
CREST PIEZOMETER BELOW THE CLAY
Date - Time
Test Cell 1 Stage El. (ft)
PZ-08A
PZ-07A
PZ-06A
PZ-06C
Sheet 3B

PLATE 5

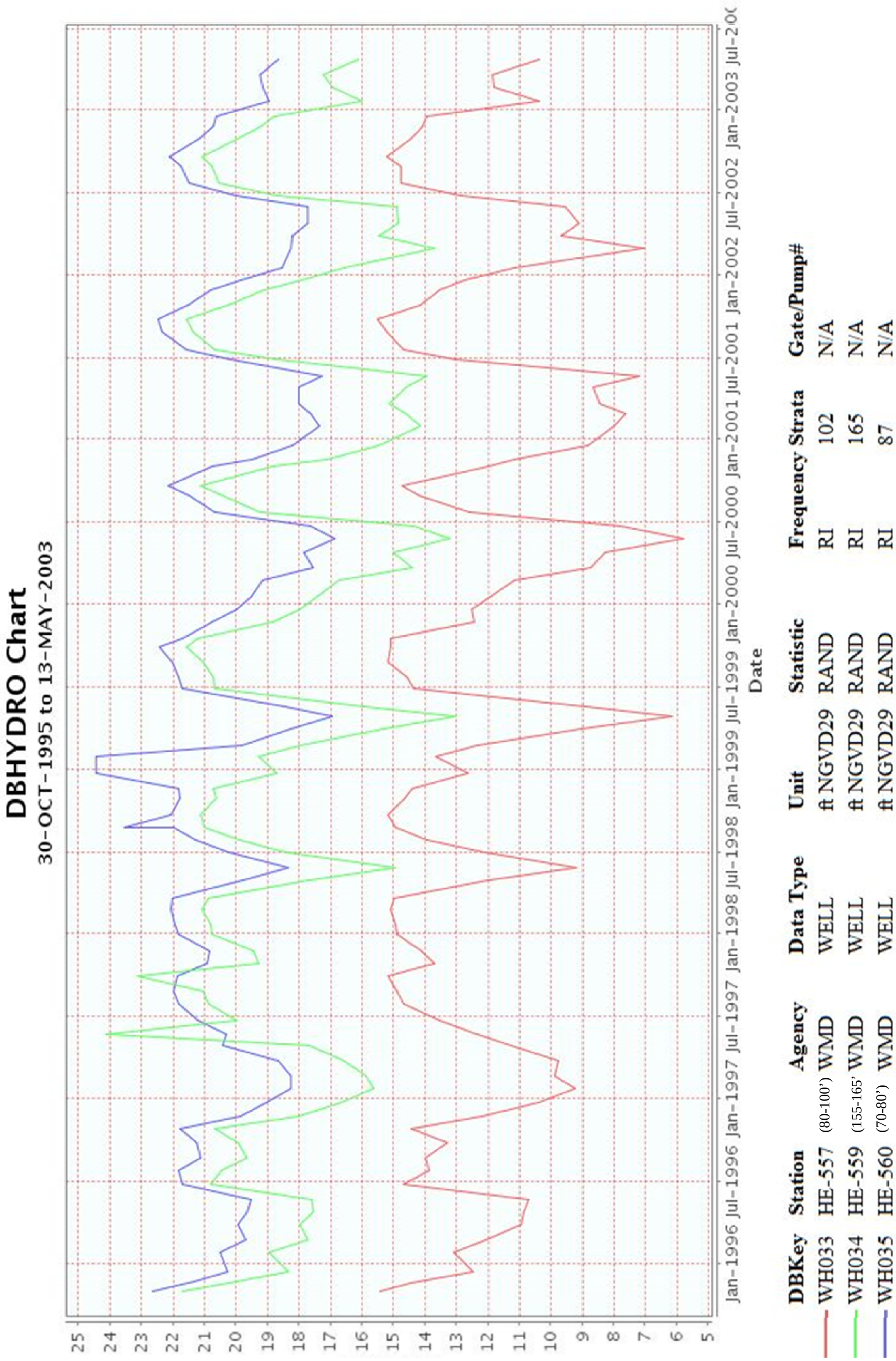

DBHYDRO Chart
30-OCT-1995 to 13-MAY-2003
Date
DBKey Station Agency Data Type Unit Statistic Frequency Strata Gate/Pump#
WH033 HE-557 (80-100') WMD WELL ft NGVD29 RAND RI 102 N/A
WH034 HE-559 (155-165') WMD WELL ft NGVD29 RAND RI 165 N/A
WH035 HE-560 (70-80') WMD WELL ft NGVD29 RAND RI 87 N/A

PLATE 6

ATTACHMENT 1

Geologist's Log
Caloosahatchee Aquifer Storage (ASR) Test Core

Depth	Lithology
0-1.5	Sand, dark yellowish orange (10YR 6/6), clayey fine quartz, silty, fair porosity, fair to poor apparent permeability
1.5-12	Limestone, very pale orange (10YR 8/2), wackestone, moderately well indurated, silty, good to fair moldic porosity, fair apparent permeability
12-22	Clay, greenish gray (5GY 6/1), fine quartz sand, soft to firm, silty, phosphatic (very fine to coarse), poor apparent permeability
22-38	Clay, greenish gray (5GY 6/1), fine quartz sand, firm to stiff, silty, sticky, variably finely phosphatic, poor apparent permeability
38-40	Limestone, yellowish gray (5Y 7/2), wackestone, fine to coarse quartz sand, moderately well indurated, good to fair moldic porosity, fair to poor apparent permeability
40-48	Clay, light gray (N7), fine quartz sand, soft to firm, finely phosphatic, common medium-coarse to pebble-sized quartz and phosphate, poor apparent permeability
48-65	Shell bed (whole and fragments, incl. Mollusks and Gastropods), yellowish gray (5Y 8/1), with thin interbeds of clay as above, common fine quartz sand, excellent porosity and excellent apparent permeability in the shell beds
65-90.5	Shell bed (whole and fragments, incl. Mollusks and Gastropods), yellowish gray (5Y 8/1), abundant fine to very coarse quartz and phosphate sand, rare pebble-sized quartz, excellent porosity, excellent apparent permeability
90.5-100.5	Sand, light gray (N7), medium to very coarse quartz, poorly sorted, sub-rounded, abundant medium to very coarse phosphate, excellent porosity, excellent apparent permeability
100.5-112	Sand, light gray (N7), quartz, medium to very coarse, poorly sorted,sub-rounded, common coarse to very coarse phosphate, occasional shell fragments, excellent porosity, excellent permeability
112-113	Limestone, yellowish gray (5Y 8/1), packstone, well indurated, sparry, fine quartz sandy, finely phosphatic, poor porosity, poor apparent permeability
113-115	Sand, light gray (N7), quartz, medium coarse to pebble-sized, poorly sorted, sub-rounded, common coarse to very coarse phosphate, excellent porosity, excellent permeability
115-126	Clay, greenish gray (5GY 6/1), soft, fine quartz sand, silty, finely

	phosphatic, poor porosity, poor apparent permeability
126-135	Limestone, yellowish gray (5Y 8/1), packstone, sparry, well indurated, very hard, fine quartz sand, finely phosphatic, fair moldic porosity, fair to poor apparent permeability, loss of circulation at approximately 134 feet bls
135-151	No recovery
151-157	Limestone, yellowish gray (5Y 7/2), fossil packstone, moderately indurated, common shell inclusions in rock (mollusks and gastropods), rare very fine phosphate, good moldic and interparticle porosity, fair apparent permeability
157-160	Clay, light greenish gray (5GY 8/1), fine quartz sand, soft, marly, finely phosphatic, common shell fragments, poor apparent permeability
160-170	Sand, yellowish gray (5Y 8/1), medium to coarse quartz, sub-rounded, abundant fine to medium coarse phosphate, excellent interparticle porosity, excellent apparent permeability
170-180	Clay, greenish gray (5GY 6/1), very fine quartz sand, soft, silty, finely phosphatic, abundant shell fragments, poor apparent permeability
180-185	No recovery