Report as of FY2007 for 2006FL142B: "Measurement of evapotranspiration, recharge, and runoff in a transitional water table environment"

Publications

- Book Chapters:
  - Trout, Ken and Mark Ross, Estimating Evapotranspiration in Urban Environments, Urban Groundwater Management and Sustainability, J.H. Tellam, et al., editors, pgs 157-168, Springer 2006.
- Articles in Refereed Scientific Journals:
  - Shah, N., M. Nachabe, and M.Ross. 2007. Extinction Depth and Evapotranspiration from Ground Water under Selected Land Covers. Ground Water, Paper # GW20060417-0057R, doi: 10.1111/j.1745-6584.2007.00302., published online March 12, 2007, awaiting paper publication, submitted 4/17/2006 Accepted December 2006, In Press.
  - Shah, N., M.Ross. 2006. Variability in Specific Yield for Different Drying and Wetting Conditions. Vadose Zone Journal, In Review.
  - Shah, N., J.Zhang, and M.Ross. 2006. Long Term Air Entrapment Affecting Runoff and Water Table Observations. Water Resources Research, In Review.
  - Zhang, Jing and Mark A. Ross, 2007. Conceptualization of a 2-layer Vadose Zone Model for Surface and Groundwater Interactions, J. Hydrologic Engrg., HE/2005/022952, in press.
  - Nilsson, Kenneth A., Ken Trout and Mark A. Ross, 2006. Analytic Method to Derive Wetland Stage-Storage Relationships Using GIS Areas, J. Hydrologic Engrg., manuscript number HEENG-07-55, In Review.
  - Shah, N., J.Zhang, and M. Ross, 2006. Long Term Air Entrapment Affecting Runoff and Water Table Observations, Water Resources Research, AGU Paper # 2006WR005602, In Review.
- unclassified:
  - Rahgozar, Mandana, Nirjhar Shah, and Mark Allen Ross, 2006. Estimation of Evapotranspiration and Water Budget Components Using Concurrent Soil Moisture and Water Table Monitoring, Journal of Hydrology, paper no. HYDROL5813, In Review.

Report Follows

Measurement of Evapotranspiration, Recharge, and Runoff
in
Transitional Water Table Environments

Year One Progress Report

Prepared by
Center for Modeling Hydrologic and Aquatic Systems
Department of Civil and Environmental Engineering
University of South Florida

Funding Agency

Southwest Florida Water Management District
Brooksville, Florida

March, 2007

Table of Contents

List of Figures

1. Summary of First-Year Progress

The first year of the USF eco-site hydrology study has been completed. The primary objectives of the first year were to: 1) obtain permission to install wells at the USF eco-site; 2) identify potential sites for data collection; 3) install both surficial aquifer and Floridan aquifer monitor wells at the chosen sites; 4) install soil moisture probes at each well site; 5) install pressure transducers in each well and data loggers to record high-resolution measure (at 10-minute intervals) water levels and soil moisture; 6) install an evaporation pan to measure real-time open-pan evaporation rates; 7) install a weather station to continuously monitor atmospheric conditions; and 8) begin collecting all data above plus background topologic and hydro-geologic data to characterize the site. All of these tasks have been completed. The wells were installed by the Southwest Florida Water Management District (SWFWMD) and cores were recovered at each location. All of the data collection equipment was installed by USF personnel and all instrumentation is operational and recording data. Also, a database (Microsoft Access) has been created to organize and facilitate further assessment of the data.

The sites selected for aquifer water level and soil moisture data were chosen by topography and accessibility and so that they would lie on a general down-slope flow path. The sites range from the top of a ridge, approximately at 55 feet in elevation, to a low-lying area near the Hillsborough River at approximately 28 feet elevation. The vegetative cover transitions from a pine forest at the top of the ridge to a predominately palmetto scrub with scattered slash pine trees.

The upper site is characteristic of a deep water table. It is covered by dry very-fine (D_{50} ~ 0.5 mm) dune sand. The predominant vegetative cover is pine and scrub oak forest. The two upper-most shallow wells have not contained water since they were installed. Both of those wells are in a relatively thin unit of very-fine dune sand overlying a thick clay lens. Precipitation has been unusually light this year and the sand unit has remained unsaturated. All other shallow wells have contained water since installation.

A Florida aquifer monitor well was installed next to the upper-most dry surficial well. The purpose of this Floridan well was to evaluate the geologic structure of the ridge, determine if any actual or potential aquifer units exist above the Floridan aquifer and below the surficial, and to obtain measurements of Floridan aquifer water elevations from a second location. No additional aquifer units were located in the unconsolidated sediments above the Floridan limestone. Below the top 14 feet of dune sand were primarily clay and sandy-clay lenses. If a water table forms on the upper portion of the ridge, it will probably be an ephemeral appearance, present only during the wet season and perched above the underlying clay.

The well at the lowest elevation is approximately ¼ mile from the Hillsborough River and is in a high (shallow) water-table environment. A second well, screened from the bottom of the well to the ground surface, was installed approximately 20 feet away. The purpose of the second well is to compare the water levels in a well fully screened to water levels in a monitor well of standard construction where the well screen is present only at the bottom portion of the well. If the water level in a well is influenced by air pressurization due to an infiltrating wetting front, the water level in a cased well should be more responsive than the water level in a fully-screened well where the air pressure inside the well can equilibrate to the air pressure outside of the well.

A Floridan aquifer monitor well was installed next to the ECO-4 surficial aquifer well to measure the head gradient between the surficial and Floridan aquifers. The ECO-4 well was drilled to a depth of 27 feet, where limestone was encountered. No significant clay (confinement) was detected. For the Floridan well installed approximately 18 feet from ECO-4, limestone was encountered at 44 feet with a total depth of 58 feet. Significant clay units were found at 22 and 37 feet bls. Despite the difference in depths to the limestone (and the

difference in clay content) between the two wells, the water elevations in the wells are almost identical. It is believed that both wells reflect the Floridan aquifer water elevations.

Active data collection is now in progress. USF personnel visit the site weekly to download data and maintain the equipment. Water levels in the wells and in the evaporation pan are measured manually and compared to the transducer measurements for validation. Also the total rainfall recorded by the tipping-bucket gauge is compared to a manual gauge.

Data collection will continue this year and slight modifications to the network may be made to utilize new insights gained from the project.

2. Study Area

The study area, shown in Figure 1, was inspected by the faculty, staff and the graduate students involved in the project. A formal request for permission to use the USF Ecological Research Area was sent to the designated authority, Dr. Gordon Fox. The permission and access was granted subject to specific terms and conditions. (Ref. *Appendix A*: Use of USF Eco-site to Establish and Monitor Hydrologic Processes)

A reconnaissance survey was conducted and the instrument installation sites were identified. The sites were identified based on topographic elevation, soil type, and existing vegetation coverage. The selected sites were flagged. These sites were approved by the USF Eco Area committee and were later instrumented (Figure 2).

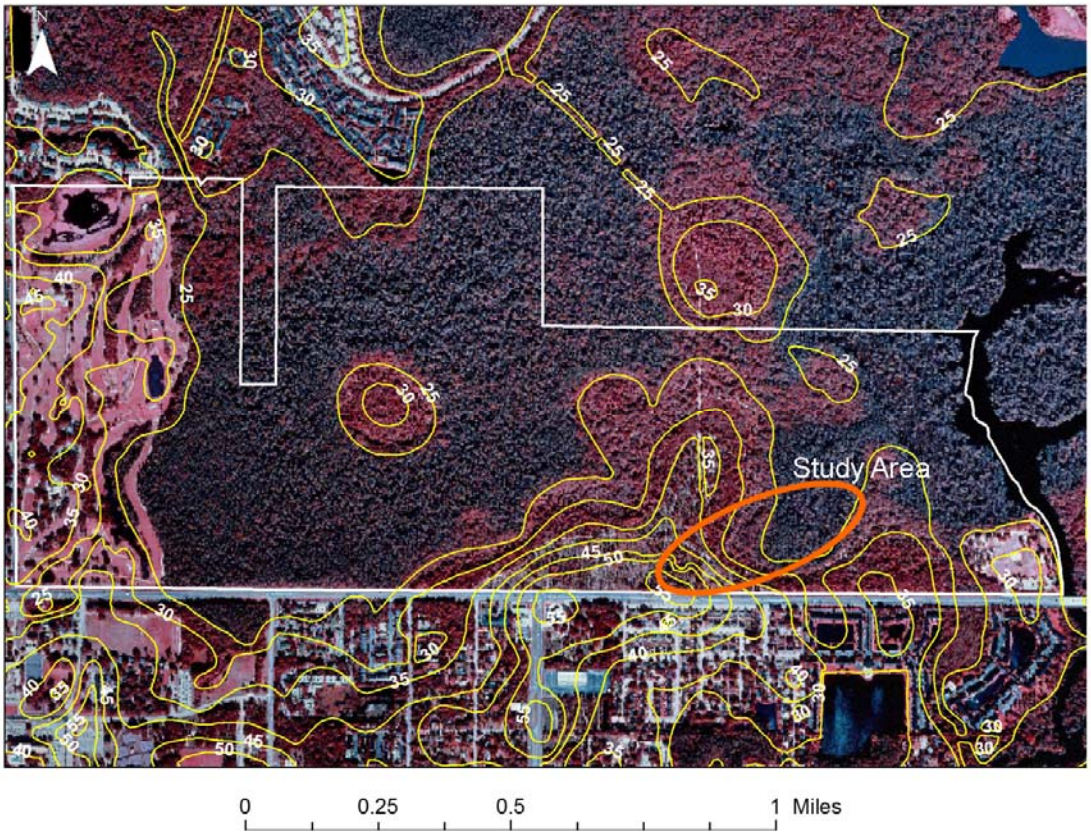

Figure 1. The Orange oval identifies the study area with white line showing the boundary of the USF Eco Area flanked by Fletcher Ave (CR-582A) on the south side. See detailed view in Figure 2.

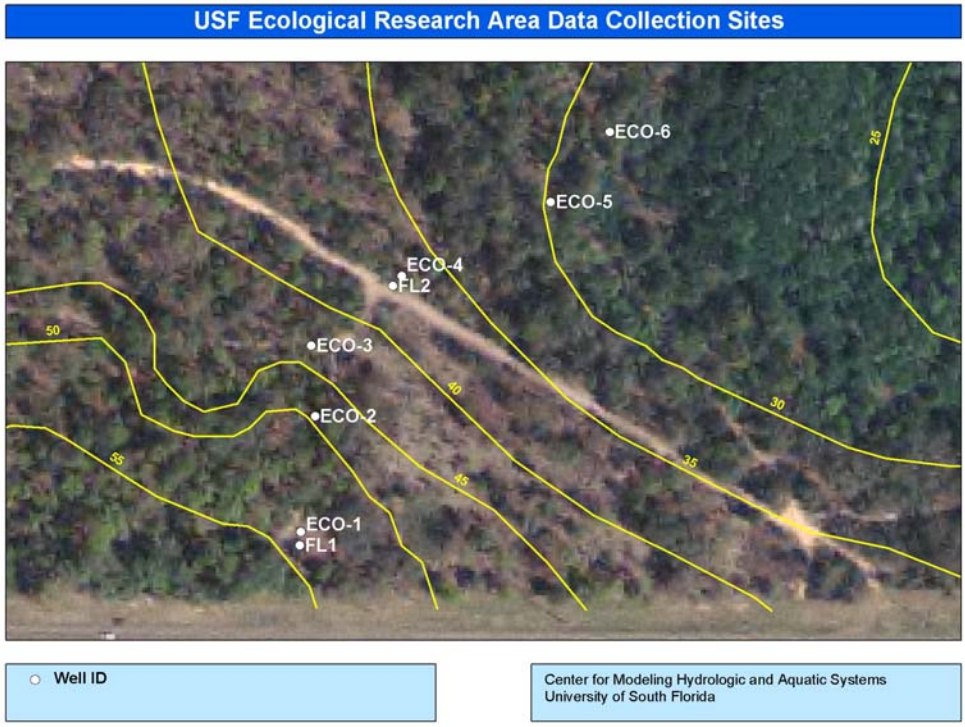

Figure 2. Data collection sites with contour lines showing the land elevation feet above National Geodetic Vertical Datum (NGVD). Floridan wells have an FL prefix.

3. Equipment

3.1 Water-level Monitoring Wells

SWFWMD installed six surficial wells and two Floridan wells at identified sites in the USF Ecological Research Study Area (Figure 2). At the time of well installation, a core was taken and stratigraphic well logs were compiled. Well logs are shown in Tables 1-8 and Cores are shown in Figures 4-16. All wells, with the exception of the most recently installed Floridan well, were then surveyed. Water-level data collection began immediately using Solinst Leveloggers® (Solinst Canada Ltd., Figure 3).

Figure 3. Solinst Levelogger® transducers with built-in data logger.

3.2 Soil Moisture Monitoring

Along with the monitoring wells, EnviroSMART® soil moisture probe (Sentek Pty. Ltd Australia) was installed at the data collection sites to measure water content of the soil profile at high vertical resolution. Figure 4 (a) shows the soil moisture probe with multiple sensors mounted on the rail. Figure 4 (b) shows the soil moisture probe as connected to the Starlogger PRO® (Unidata Ltd., Australia) data logger used to log the water content readings.

(a)

(b)

Figure 4. (a) EnviroSMART soil moisture probe with multiple soil moisture sensors and (b) The probe as installed a with the data logger.

3.3 Weather Monitoring

3.3.1 Weather Station

Campbell ET-106 (Campbell Scientific Inc., Logan, Utah) weather station was installed in the study area. The weather station measures rainfall, wind velocity, solar radiation, temperature and relative humidity (Figure 5).

Figure 5. Campbell Scientific weather station installed in the study area.

3.3.2 Evaporation Pan

A standard USGS Class A evaporation pan was also installed to give a direct measure of the open water evaporation rate. A Geokon Model 4675LV water level monitor (Geokon Inc., Lebanon, New Hampshire) along with Geokon 8001 LC-1 single channel data logger was used to record the fluctuation in the water level in the evaporation pan. The installation of the evaporation pan and water-level monitor beside the weather station is shown in Figure 6.

Figure 6. Class A ET pan with GeoKon water level monitoring device installed next to the weather station.

4. Stratigraphic Logs

Table 1. Stratigraphic well log for ECO-1

Eco-1	
Well Log	6/1/2006
Depth (ft)	Soil Description
0-1	Brown Fine Sand
1-4	Light Brown Fine Sand
4-6	Light Brown-Red Fine Sand
6-10	Very Light Brown Fine Sand
10-12	Very Light Brown Fine Sand
12-12.5	Light Brown Fine Sand
12.5-13.5	Tan Clayey Sand
13.5-16	Gray Clay

Notes:
Total Depth: 16 ft
Screen Length: 5 ft
Screened Interval: 11-16 ft

Figure 7. ECO-1 Core, 0-16 ft.

Table 2. Stratigraphic well log for ECO-2

Eco-2	
Well Log	6/1/2006
Depth (ft)	Soil Description
0-1.5	Light Brown Fine Sand
1.5-6.5	Very Light Brown Very Fine Sand
6.5-10	Very Light Brown Very Fine Sand-almost white
10-10.7	Light Brown Fine Sand
10.7-11.3	Brown Fine Sand (maybe fall)
11.3-13.5	Very Light Brown Very Fine Sand
13.5-14.5	Red-Tan Very Fine Sand
14.5-18	Red Clayey Sand
18-22	Light Brown Sandy Clay

Notes:
Total Depth: 21 ft
Screen Length: 10 ft
Screened Interval: 11-21 ft
Top of screen in Very Light Brown Very Fine Sand

Figure 8. ECO-2 Core, 0-14 ft.

Figure 9. ECO-2 Core, 14-22 ft.

Table 3. Stratigraphic well log for ECO-3

Eco-3	
Well Log	6/1/2006
Depth (ft)	Soil Description
0-4	Brown Fine Sand
4-10	Light Brown Fine Sand
10-19	Light Brown Fine Sand
19-24	Light-Red Clayey Sand, with Red Lenses

Notes:
Total Depth: 22 ft
Screen Length: 10 ft
Screened Interval: 12-22 ft
wet at 14 ft; water table possible at 17 ft

Figure 10. ECO-3 Core, 0-22 ft.

Table 4. Stratigraphic well log for Eco-4

ECO-4	
Well Log	6/2/2006
Depth (ft)	Soil Description
No Core taken	

Notes:
Total Depth: 27 ft
Screen Length: 10 ft
Screened Interval: 17-27 ft
No obvious confining layer observed when well installed
Rock (may be Limestone or Chert) at 27 ft

Table 5. Stratigraphic well log for ECO-5

ECO-5	
Well Log	6/2/2006
Depth (ft)	Soil Description
0-1	Gray Fine-Medium Sand
1-2	Brown Fine-Medium Sand with Organics
2-4	Light Brown Fine Sand
4-5.5	Brown Fine Sand with darker brown Organics
5.5-13	Light Gray Fine Sand
13-13.5	Light Gray to Orange Grading Fine Sand
13.5-14	Orange Clayey Sand
14-19	Light Gray Clayey Sand - Grading to More Clay Content

Notes:
Total Depth: 19 ft
Screen Length: 10 ft
Screened Interval: 9-19 ft

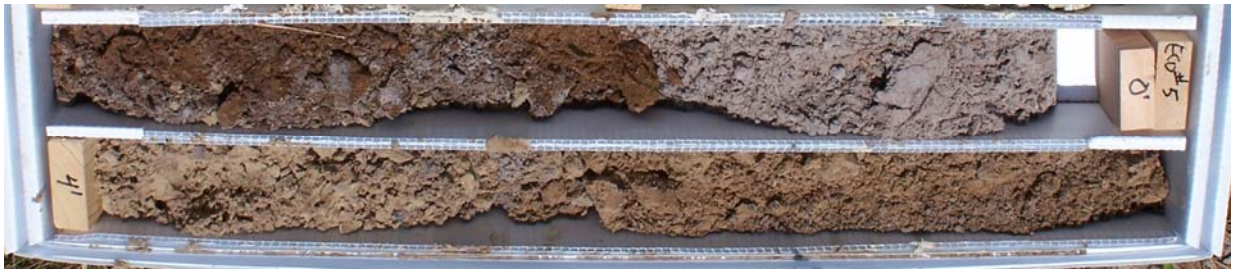

Figure 11. ECO-5 Core, 0-4 ft.

Figure 12. ECO-5 Core, 4-19 ft.

Table 6. Stratigraphic well log for ECO-6

ECO-6	
Well Log	6/5/2006
Depth (ft)	Soil Description
0-2	Dark Brown Medium-Fine Sand
2-9	Light Brown Fine Sand
9-10	Very Light Fine Sand-Clean Quartz, Well Rounded and Sorted

Notes:
Wet at 5 ft
Standing Water inhole at 6 ft below land surface

Figure 13. ECO-6 Core, 0-10 ft.

Table 7. Stratigraphic well log for FL-1 (ECO-8)

Well Log	9/11/2006
Depth (ft)	Soil Description
0-6	Light Red-Brown Fine Sand - Hollow Stem
6-14	Very Light Brown Fine Sand
14-19	Brown Clayey Sand
19-28	Gray Clay - Tight
28-31	Clayey Sand
31-32	Very Light Brown Dry with Small Limestone Nodules
32-33	Red-Brown Clayey Sand - Wet
33-36	Very Light Brown Clayey Sand with Limestone Pieces
36-37	Gray-Brown Sandy Clay
37-38	Blue-Gray Clay with Limestone Pieces
38	Stopped core sampling, began mud drilling; Lost circulation at 40 ft

Notes:
Total Depth: 60 ft
Screen Length: 15 ft
Screened Interval: 45-60 feet

Figure 14. FL-1 Core, 0-40+ ft

Table 8. Stratigraphic well log for FL-2 (ECO-7)

Well Log	6/2/2006
Depth (ft)	Soil Description
0-8	Light Brown Fine Sand-loose
8-12	Very Light Brown Fine Sand-damp
12-13	Very Light Brown Fine Sand-damp
13-21	Light Gray Fine Sand-water table near 16 ft
21-21.5	Reddish Fine Sand
21.5-22	Orange Silty Fine Sand, some clay
22-29.5	Gray Clay with Orange Staining
29.5-30	Orange Clay with weathered Limestone
30-30.5	Gray Clay with Orange Staining
30.5-32	Red-Gray Clay with Limestone nodules
32-33	Orange Wet Sandy Clay with Limestone
33-34	Gray Silty Medium Sand
34-35	Orange-Gray Sandy Clay with Small Chert Fragments
35-36	Gray Sandy Clay
37-37	Wet (sat) Sandy Clay with Limestone Pieces
37-37.8	Orange-Gray Clay with Limestone fragments
37.8-38	Light Gray Limestone Chips
38-40	Tan-Gray Sandy Clay with Limestone
40-42.5	Light Brown Silty Clay with Limestone Pieces
42.5-43.7	Light Tan Silty Clay with Limestone pieces (up to 2.5 inch diameter)
43.7+	Rock at 44 feet; Stopped core sampling, began mud drilling

Notes:
Total Depth: 58 ft
Screen Length: 15 ft
Screened Interval: 43-58 feet
Well drilled into limestone to 64 feet with button bit.
When augers removed, 6 feet of casing pulled out of well.
When pumped, yield from well was good as was water clarity.

Figure 15. FL-2 Core, 0-28 ft.

Figure 16. FL-2 Core, 28-43.7 ft.

5. Data Collection

The data from all the equipment are collected at a 10 minute intervals and stored in a Microsoft-Access database. Figure 17 illustrates data collected at site ECO-5 during a nineteen-day period in December 2006. Soil moisture sensors near the land surface respond rapidly to rainfall event. Deeper sensors respond more slowly, and the deepest sensors show little change during this period. The water table responds to major rainfall events but more slowly.

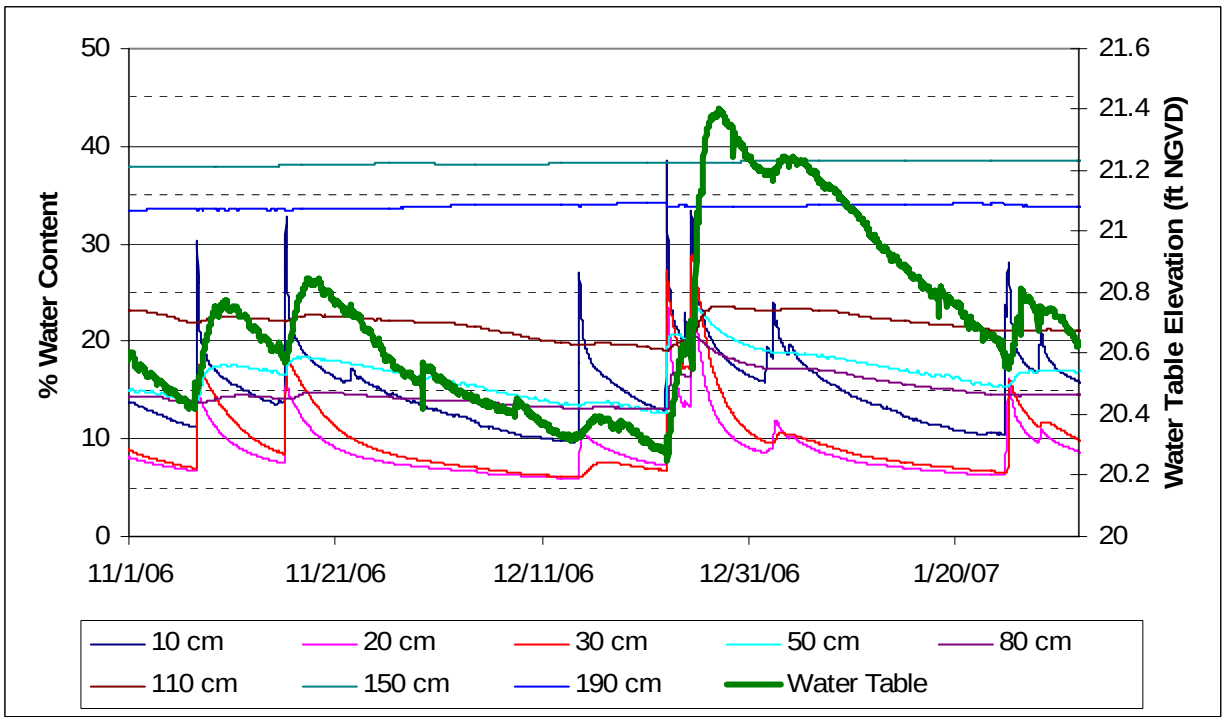

Figure 17. Soil moisture content and water table fluctuations at ECO-05.

5.1 Soil Moisture Data

Soil moisture probes were installed at sites ECO-1 through ECO-6. Each probe has eight moisture sensors at depths below the land surface of 10 cm to 190 cm, except at ECO-6. Site ECO-6 is in a high water-table environment and the deepest moisture sensor at that site is 140 cm. Figures 18-23 show the moisture content at each of the sites through 1/31/2007. In general, shallower sensors respond more quickly to rainfall and subsequent evaporation.

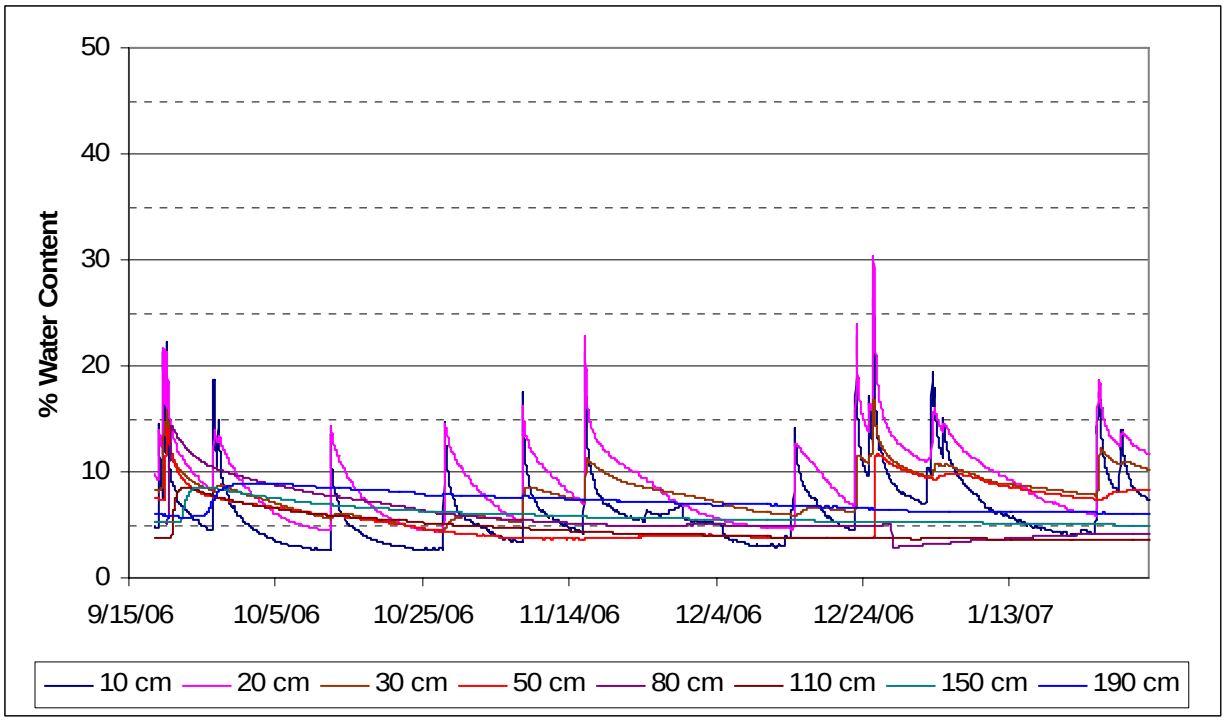

Figure 18. Soil moisture data at ECO-1.

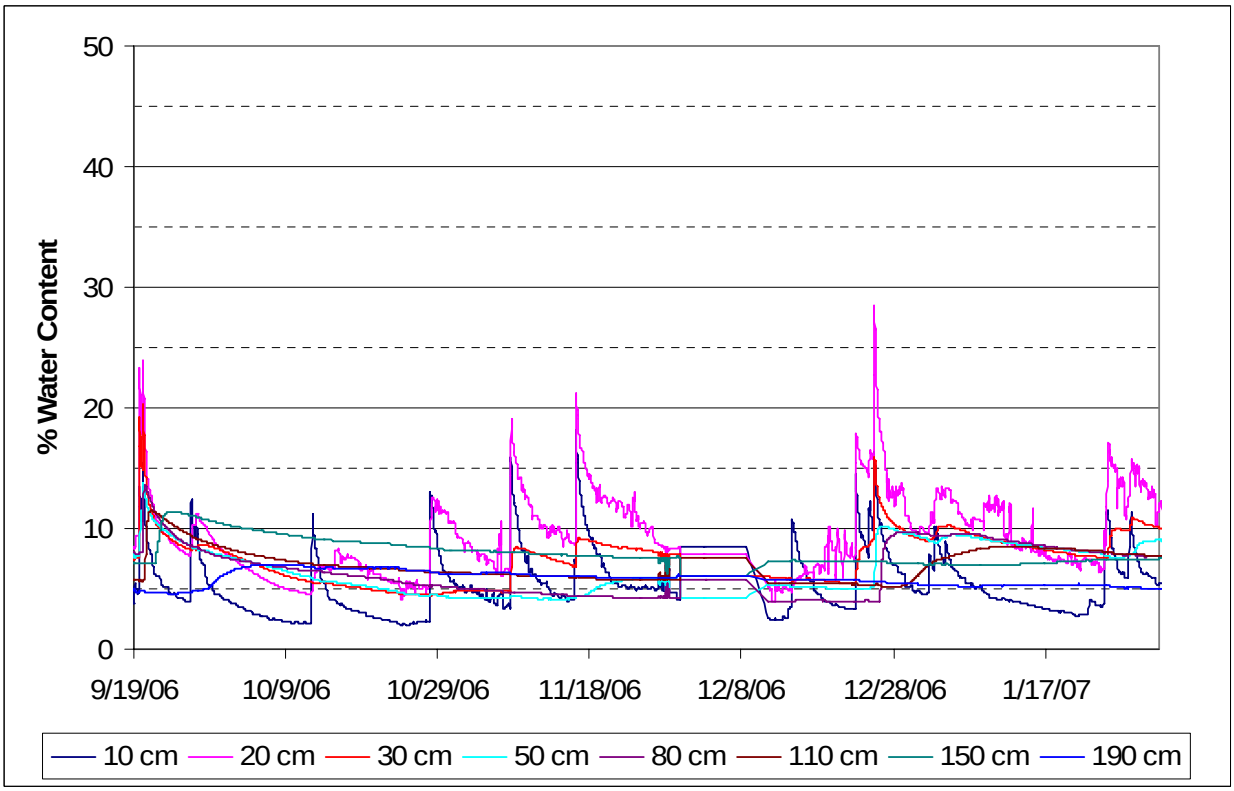

Figure 19. Soil moisture data at ECO-2.

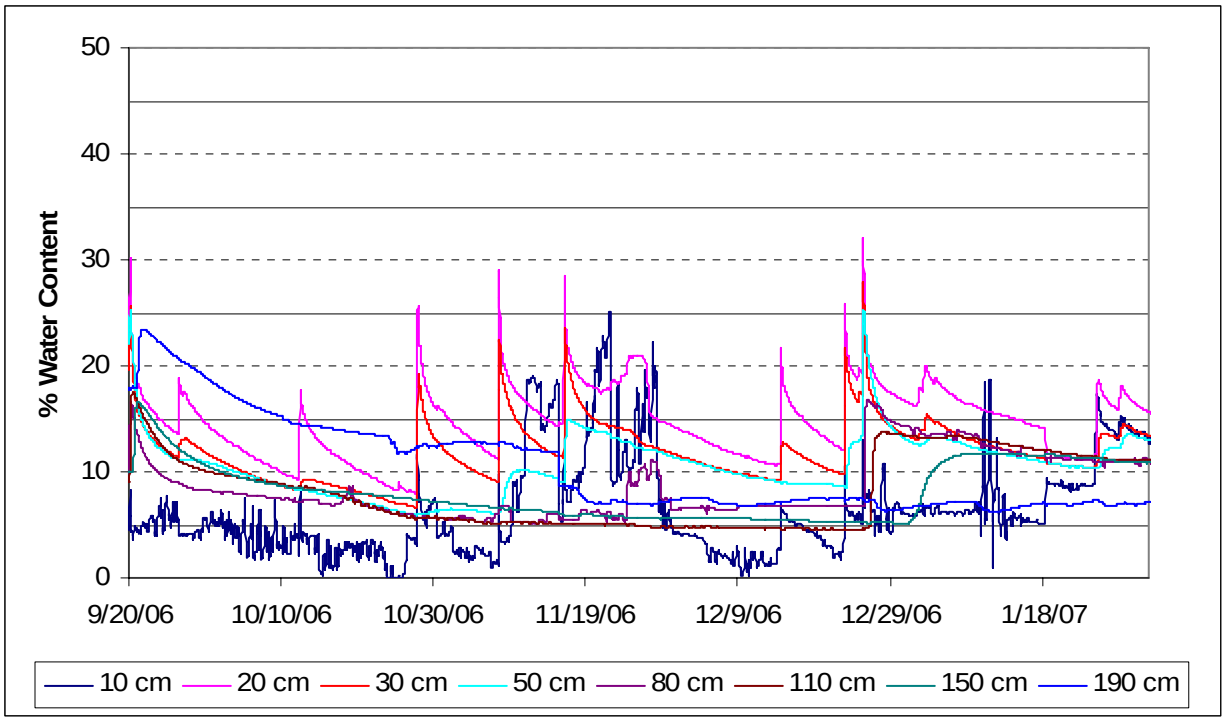

Figure 20. Soil moisture data at ECO-3.

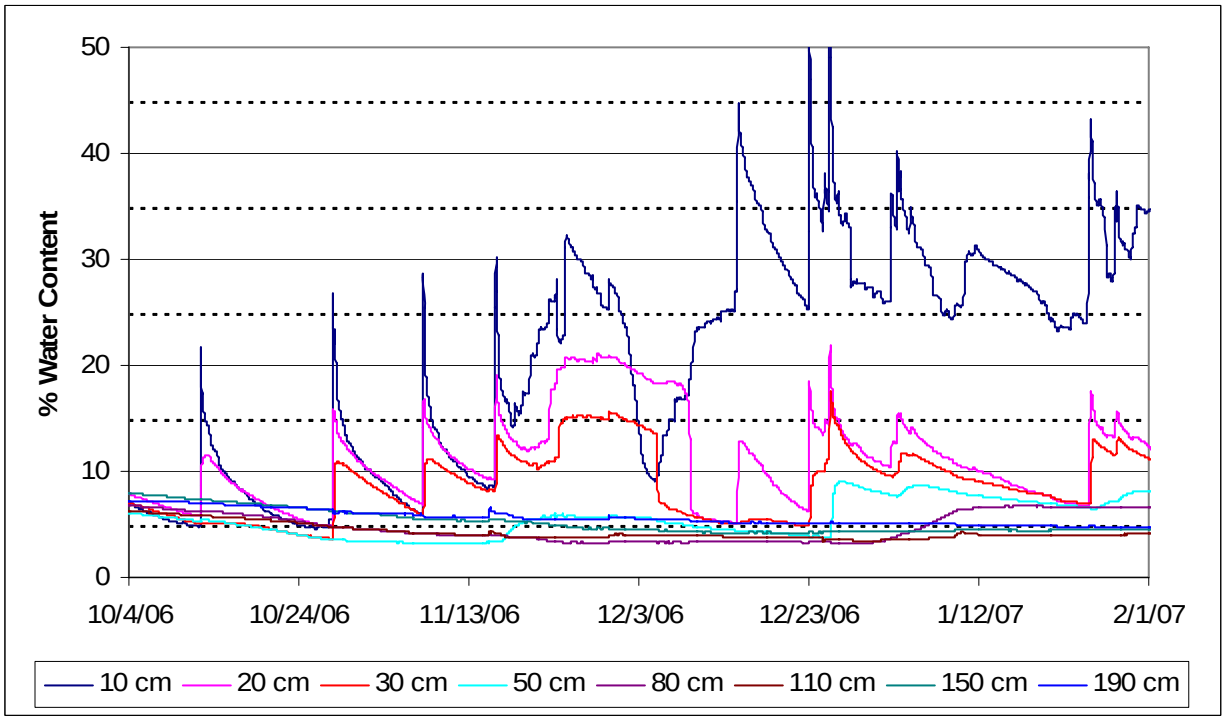

Figure 21. Soil moisture data at ECO-4.

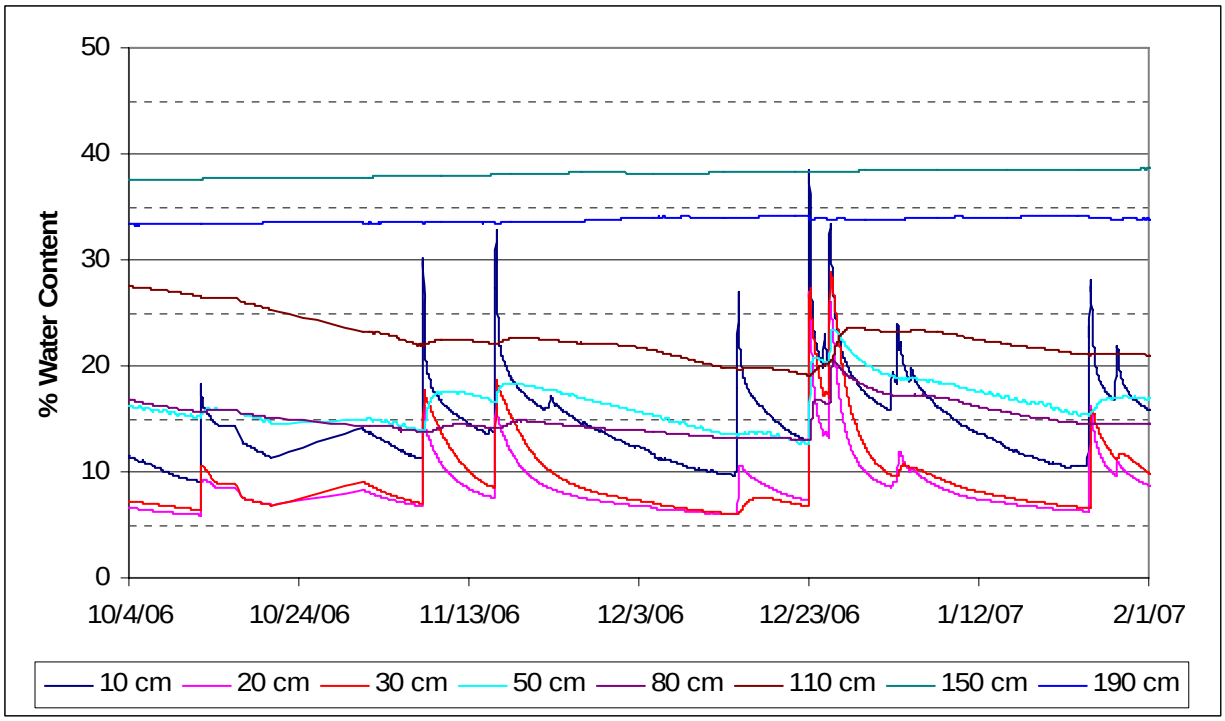

Figure 22. Soil moisture data at ECO-5.

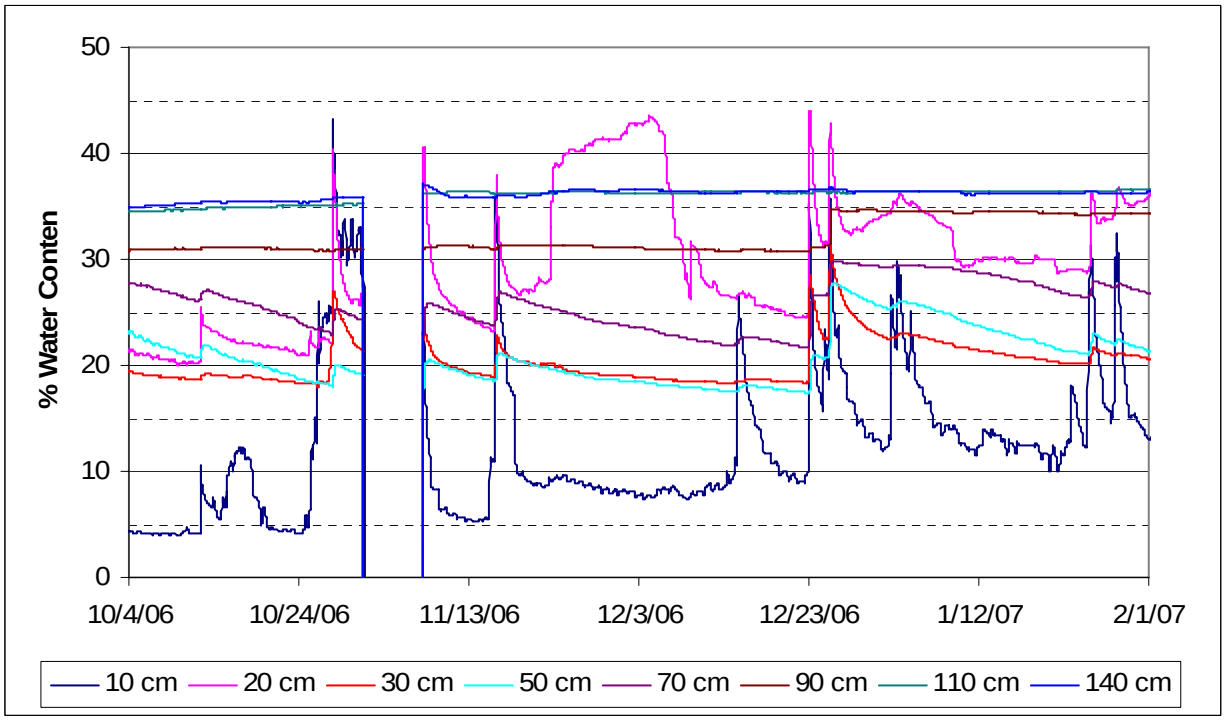

Figure 23. Soil moisture data at ECO-6.

5.2 Water Table Elevations

Pressure transducers were installed in the monitor wells to record ground water levels. ECO-1 and ECO-2 have been dry since they were installed. The wells with the ECO prefix were intended as surficial aquifer monitor wells; they were installed to the first competent clay unit or, in the case of ECO-4, to rock as no clay was encountered. The wells with the FL prefix were installed into the first competent limestone unit which is the Upper Floridan Aquifer. Initially, one Floridan well (FL-2) was installed near ECO-4 to provide head gradient information between the surficial and Floridan aquifers. A second Floridan well (FL-1) was then installed near ECO-1. All the wells except FL-1 have been surveyed and their water levels corrected to NGVD. Figures 24-29 display the continuously recorded water-level elevations (blue line) and the manual measurements (red box) for each of the wells. The water-levels in ECO-3 are the deepest of any of the surficial wells and that well shows very little response to rainfall. The water levels in the Floridan wells exhibit pronounced diurnal fluctuations while the diurnal fluctuations in the surficial wells are less obvious.

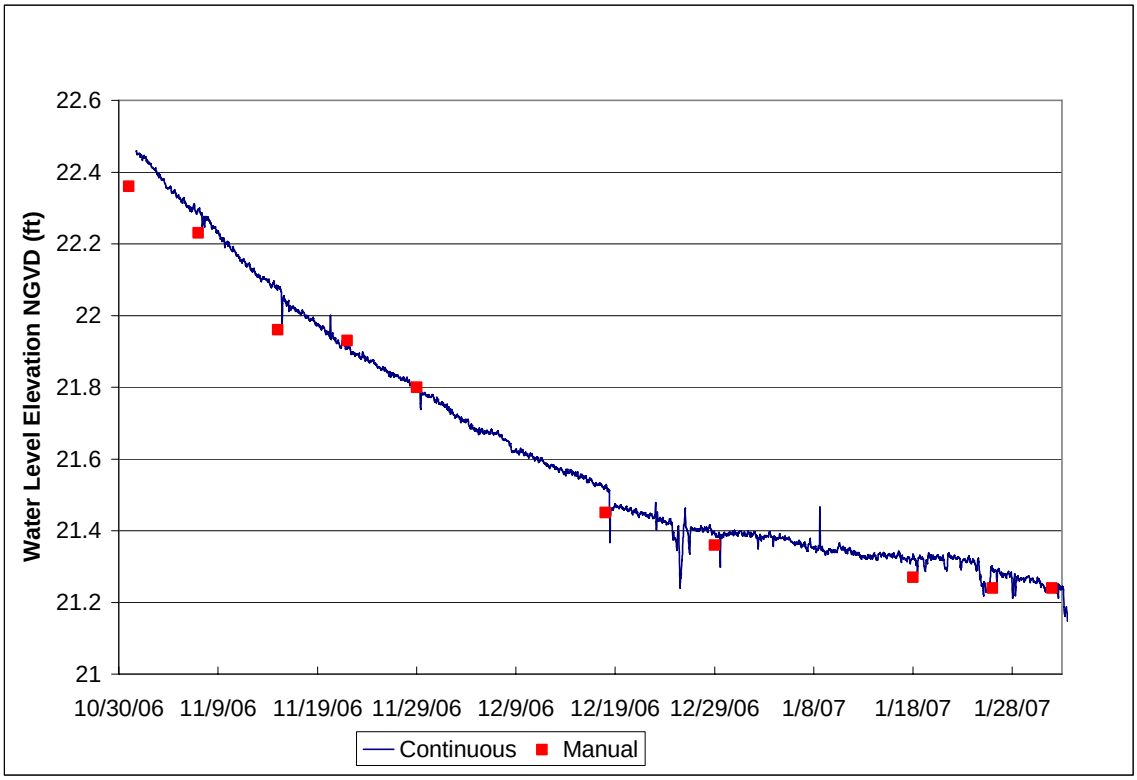

Figure 24. Continuous water-table measurements at ECO-3 with weekly manual measurements.

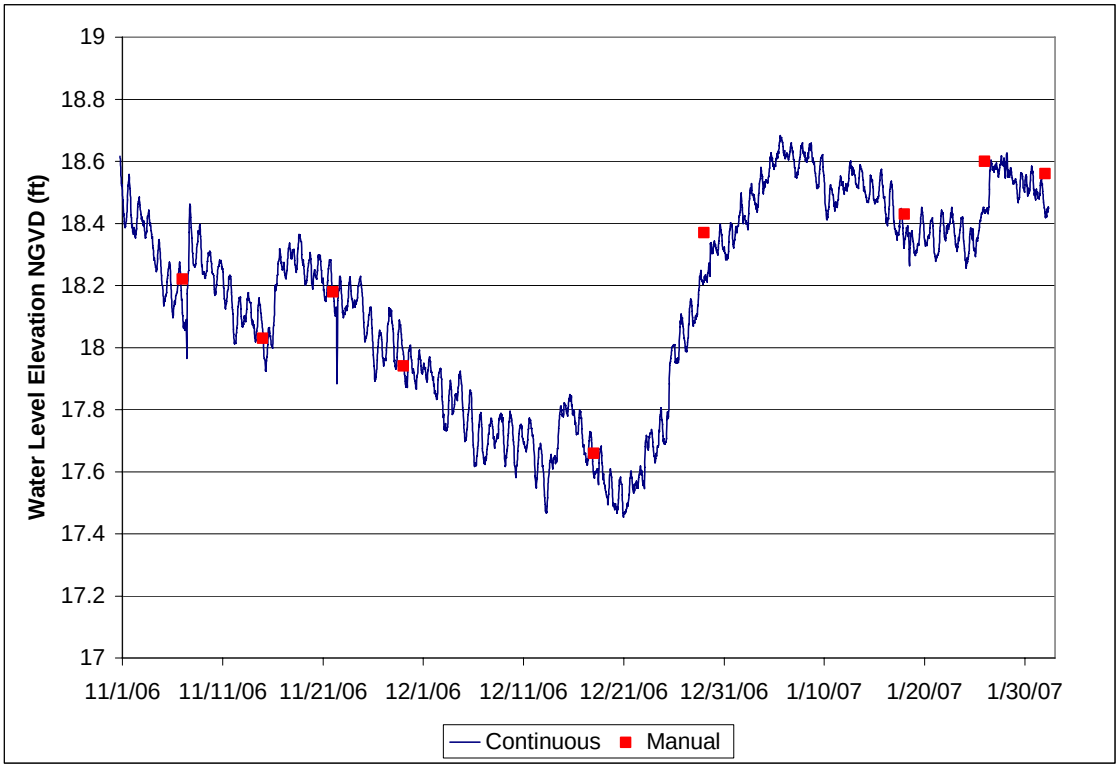

Figure 25. Continuous water-table measurements at ECO-4 with weekly manual measurements.

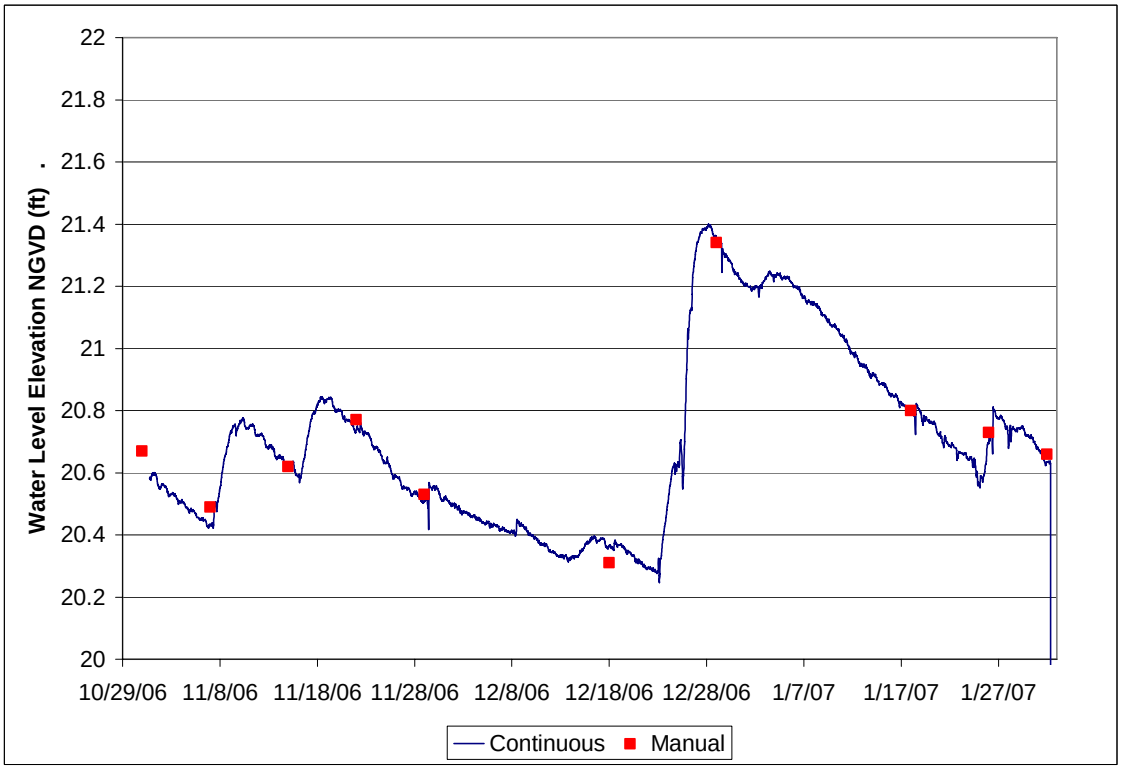

Figure 26. Continuous water-table measurements at ECO-5 with weekly manual measurements.

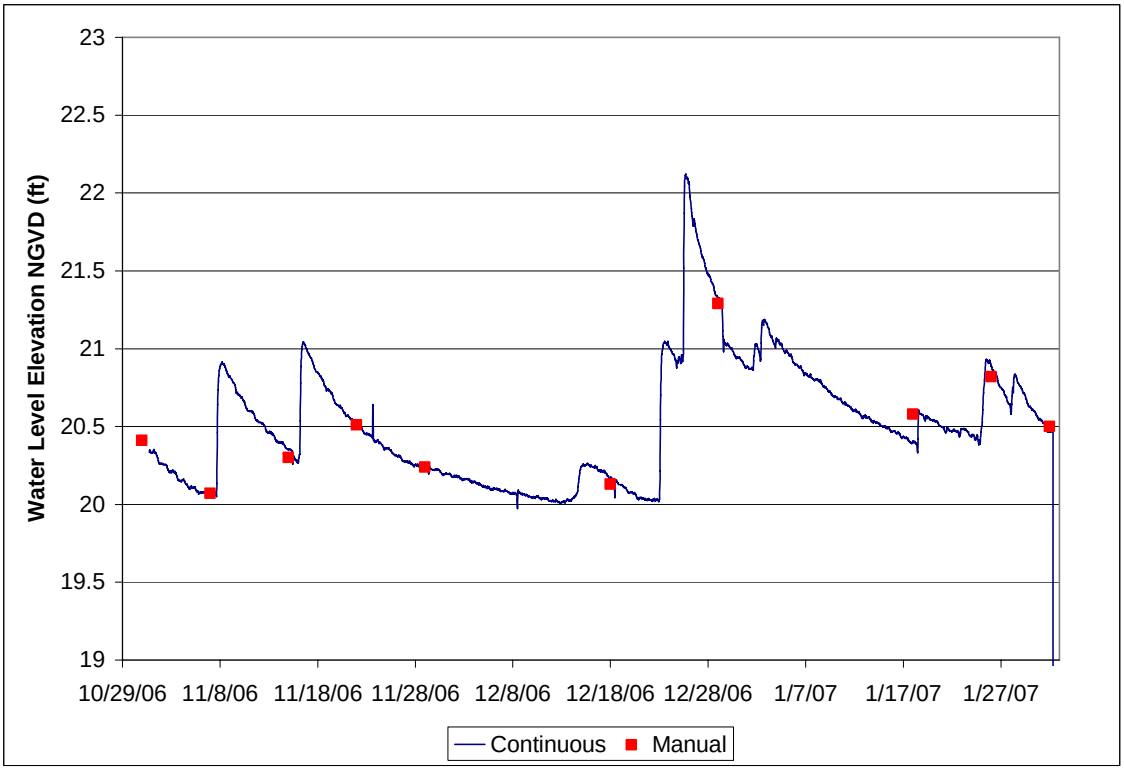

Figure 27. Continuous water-table measurements at ECO-6 with weekly manual measurements.

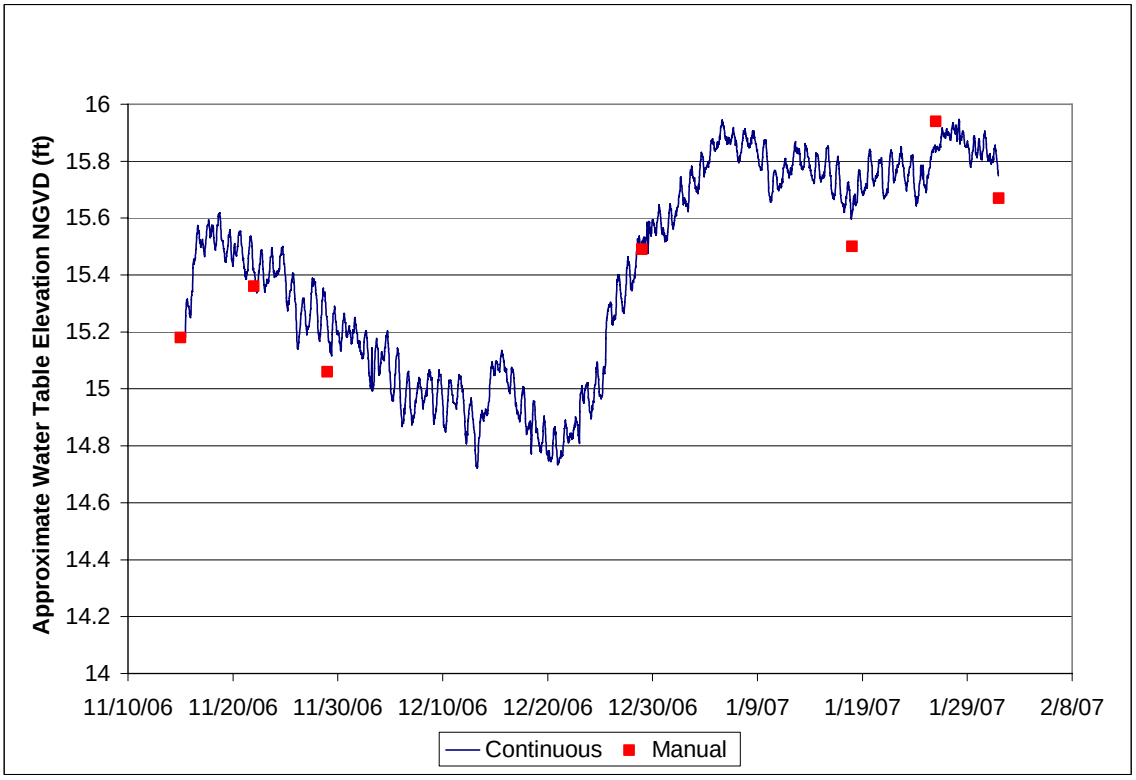

Figure 28. Continuous approximate Floridan Aquifer water levels at FL-01 with weekly manual measurements.

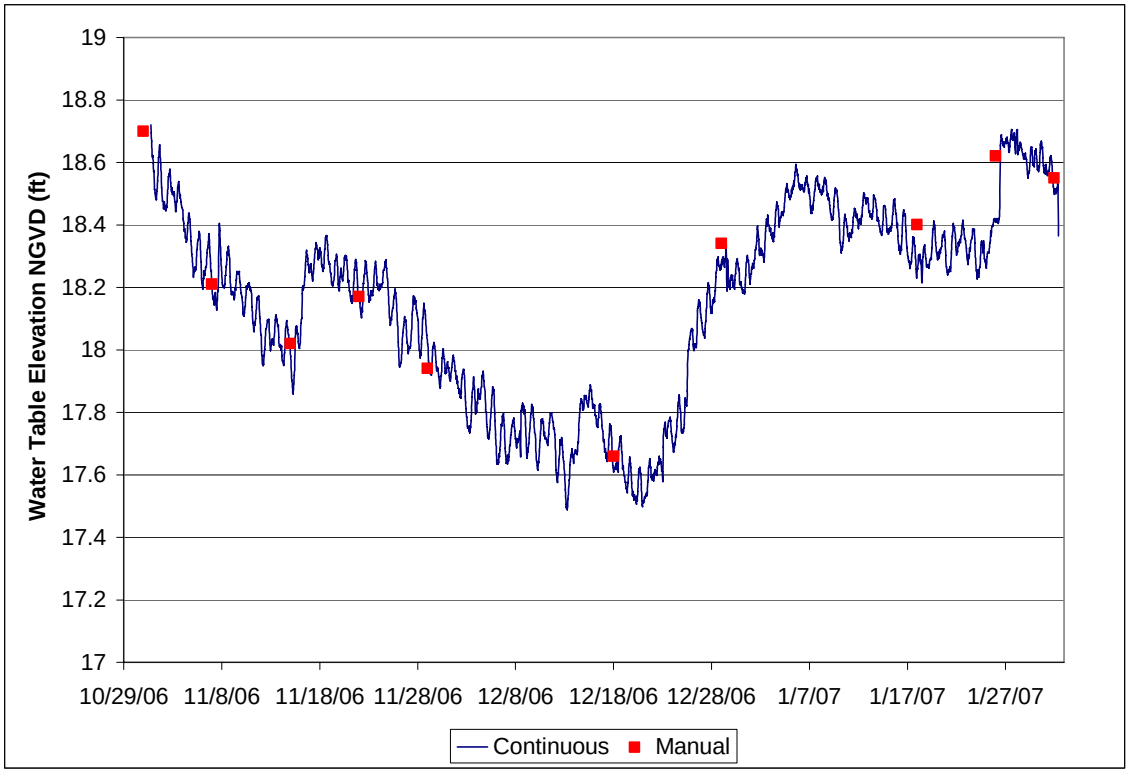

Figure 29. Continuous water-table measurements at FL-02 with weekly manual measurements.

ECO-4 was installed as a water-table monitor well. However, no significant clay unit was penetrated. The well was ended at 27 feet below land surface when rock was encountered. The well was screened from 17-27 feet below land surface (bls).

Approximately 18 feet from ECO-4, a Floridan Aquifer well was installed, FL-2. FL-2 passed through two significant clay units, one between 22 and 32 feet bls and the other between 37 and 44 feet bls. Several smaller clay layers or lenses were encountered between the two thickest clay units. Rock was encountered at 44 feet bls. The well was continued for an additional 20 feet through the limestone to a total depth of 64 feet. A 15-foot well screen was installed in the well, but the bottom six feet of the well was lost when the auger flight was extracted and the well casing pulled up. The final depth of the screen is from 43 to 58 feet bls.

Although ECO-4 is only 27 feet deep and FL-2 is 58 feet deep and finished in limestone, the water elevations in both wells match. Figure 30 illustrates the correspondence between the water elevations in the two wells. Both wells reflect water elevations in the Floridan Aquifer.

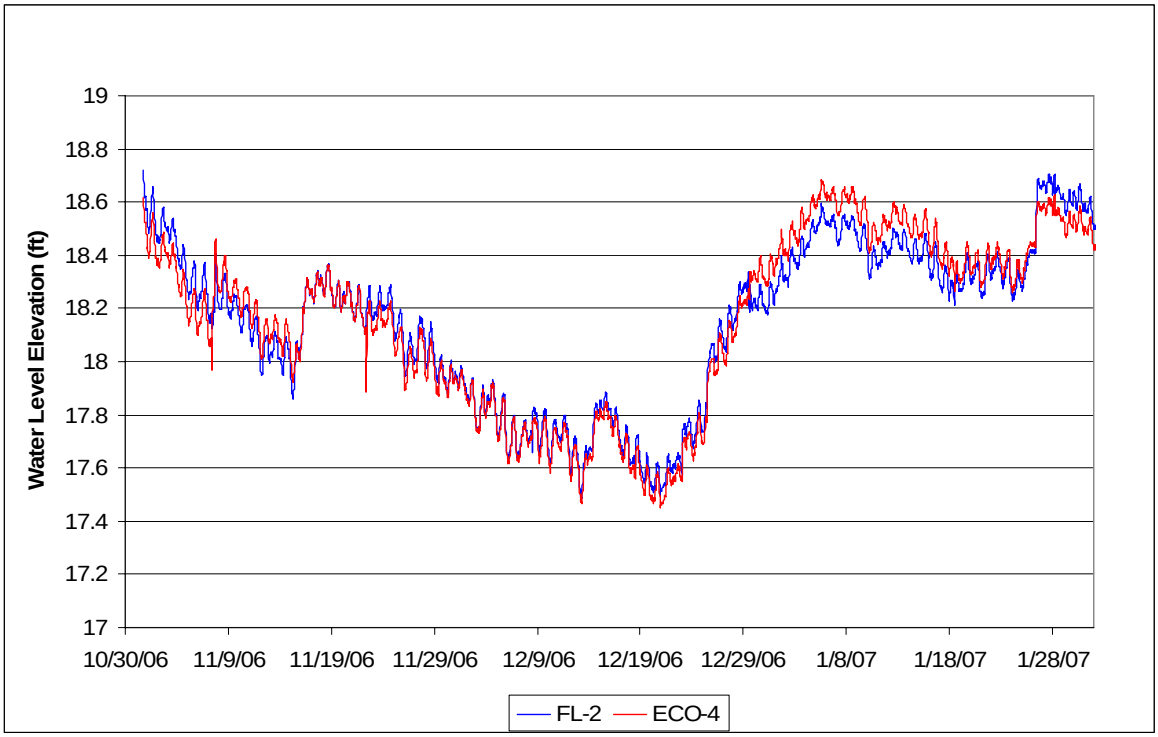

Figure 30. Water elevation comparison between FL-2 and ECO-4.

A second well was manually installed at the ECO-6 location to a depth of approximately four feet. This well is screened for its entire length below the ground surface. Because air entrapment or compression is believed to play a role in the rapid water-table response to rainfall events, this second well will provide a water-table comparison to the partially screened initial well. A water-table response in the cased well that is not present in the fully-screened well may indicate a water-table change due to air pressurization. Figure 31 illustrates the water levels recorded in the two wells and a possible air pressurization response.

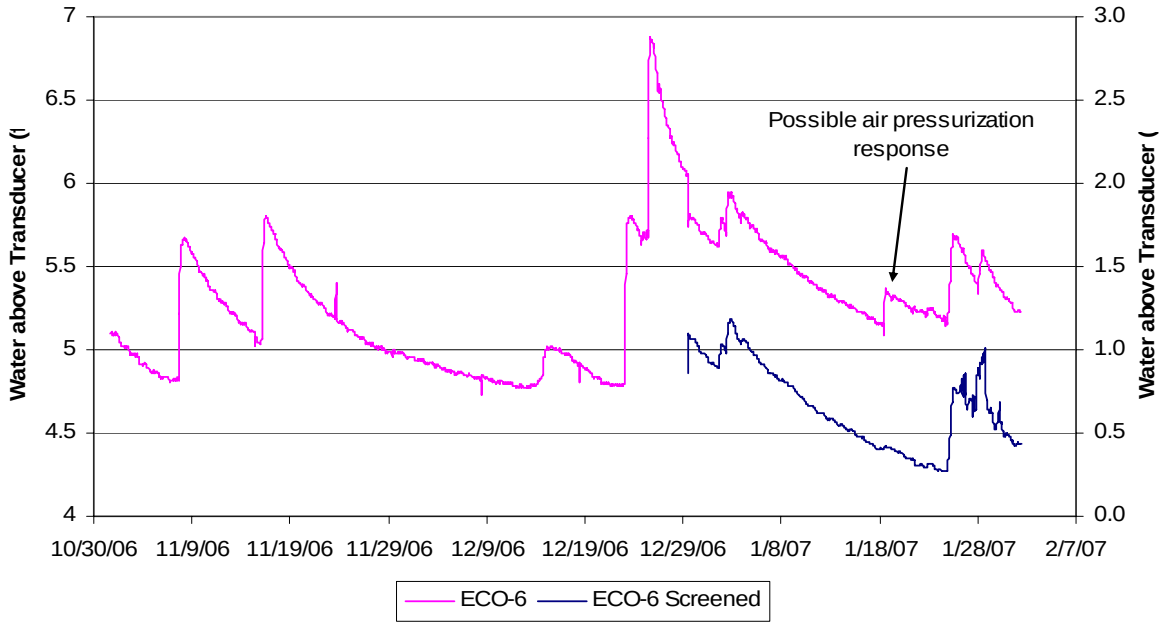

Figure 31. Water levels above the transducers at the ECO-6 wells illustrating a possible air pressurization event.

Appendix

Use of USF Eco-site to Establish and Monitor Hydrologic Processes

Brief explanations are included here. Please refer to the proposal for details on methodology and instruments used.

1. What is the general purpose of your research?

   The objective of the study is to measure evapotranspiration, recharge, and groundwater elevations in a transitional water-table environment. These measurements will be used to understand major hydrologic processes and their interdependence. The Findings from the study should be of immediate importance and use to water management entities. It will provide useful information for parameterization and conceptualization of processes for emerging integrated surface and groundwater computer models of the region.

2. Describe the methods you intend to use – number of plots, types of markers, etc.

   - Rainfall: Tipping-bucket rainfall gauge
   - Evapotranspiration:
     - Central Weather Station
     - Evaporation Pan
   - Soil Moisture: EnviroSMART soil moisture Probes
     - A 2-meter rail that slides vertically into a 2" PVC-cased dry well to a desired depth, accompanied by a data logger enclosed in a small box
   - Runoff: Doppler flow velocity meter
     - Runoff from a small basin will be routed to a channel where this velocity meter will be installed
   - Water Table: Ground water monitoring wells

   Survey Flags will be used to mark the location of instruments. There will be six soil moisture probes and seven wells installed.

3. Describe how you will minimize damage to soils and plants.

   Once the wells are installed, trips made to the site will only be to collect data from the loggers and to repair or replace equipment.

   The instruments described above (in section 2) are designed to have minimum damage to soils and plants. The study and the instruments require us to collect all the data in an undisturbed and natural state, which itself means we will try to minimize the damage. Also, we are aware of the importance of maintaining the health of the eco-area.

4. Identify (on a map) where you intend to conduct this work. Explain why these spots are desirable; this information may be used to suggest other locations in the EcoArea if there are problems of heavy or concurrent use.

   (Ref. Fig. 1)
   The Orange oval identifies the study area. The instruments will be installed along hill slope transect (towards the river).

5. How will your markers, plots, etc., be labeled so that we can tell they are yours? Describe your plan to repair damage, remove markers, etc., at the end of the study.
   All instrumentation sets will have labels saying “USF-CMHAS-SWFWMD Eco Area Project” and the Instrument Identification Number or the Location Number. Survey flags will be used to mark the instrument locations.
   The markers and instruments will be removed at the end of the study.

6. If you are working with vertebrates, provide information on your IACUC permit. We will not approve any use that violates IACUC rules.
   Not Applicable. We are not working with vertebrates or other animals.

7. Over what time period will your work be conducted? Any time extensions must be approved.
   The study will be conducted for a period of three years.

8. Permission to use the EcoArea is conditional on your providing the EAAC with reprints of all relevant publications and links to all web sites referring to this work. Seminars and publications must acknowledge the use of the EcoArea.
   Agreed.