Aquifer Performance Testing of the Sandstone Aquifer, Lower West Coast Planning Area

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EXECUTIVE SUMMARY

The South Florida Water Management District (SFWMD) is updating and improving the Lower West Coast Surficial and Intermediate Aquifers Systems Model to support the update to the Lower West Coast Water Supply Plan. SFWMD modeling staff identified a lack of hydraulic parameters, specifically leakance, for the Sandstone aquifer confining zone, which separates the upper (clastic) zone from the lower (carbonate) zone in some areas of the Lower West Coast planning area. To address this need, the SFWMD undertook a study to obtain these aquifer parameters. Existing wells and well clusters were evaluated, and two sites—one in Lee County and one in Collier County—were selected for aquifer performance testing. Multiple pumping tests were performed at each site, and subsequent analysis determined a leakance value of 0.022/day for the confining zone. Geophysical logs and water quality samples also were obtained from each aquifer performance test site. Water quality parameters fell within historical ranges for the area.

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ACRONYMS AND ABBREVIATIONS

APT	aquifer performance test
bls	below land surface
ft	foot
gpm	gallons per minute
IAS	intermediate aquifer system
LWC	Lower West Coast
LWCSIM	Lower West Coast Surficial and Intermediate Aquifer Systems Model
NGVD29	National Geodetic Vertical Datum of 1929
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
USGS	United States Geological Survey

INTRODUCTION

Background

To support water supply planning updates and other activities, the South Florida Water Management District (SFWMD or District) developed the Lower West Coast (LWC) Surficial Aquifer System Model (Marco Engineering, 2006) and is in the process of updating it to support the LWC Water Supply Plan Update. The model uses the U.S. Geological Survey (USGS) MODFLOW code (McDonald and Harbaugh 1988) and simulates an area encompassing all or portions of Lee, Collier, Monroe, Hendry, Charlotte, Glades, and Highlands counties (**Figure 1**). The current version of the model, referred to as the LWC Surficial and Intermediate Aquifer Systems Model (LWCSIM) is under development. It is based on the District's update to the hydrostratigraphy of these aquifers (Geddes et al. 2015) and consists of nine layers (**Figure 2**). To improve the calibration of the model in certain areas, SFWMD modeling staff desired more detailed hydraulic information on the confining zone that separates the upper (clastic) and lower (carbonate) zones of the Sandstone aquifer. In response to this request, District staff evaluated existing Sandstone aquifer wells in the region and selected two sites to conduct aquifer performance tests (APTs). The data generated from the APTs were used to estimate hydraulic parameters needed to further refine the model calibration.

Purpose

The purpose of this study was to identify existing well sites conducive to aquifer performance testing, and use the results to estimate leakance values for the Sandstone aquifer confining zone. This report documents the methods used, the data collected, and the analysis results. Information summarized in this report includes the hydrogeology of the study area, background water level data from selected well sites, data and analytical results from APTs, geophysical logs, and water quality data. Results of the APT analyses were used to further refine the calibration of the LWCSIM, which will be used to support the LWC Water Supply Plan Update.

Project Description/Methodology

The study area was determined based on where in the LWCSIM domain the modelers wanted to refine calibration of the Sandstone aquifer (**Figure 3**). Modeling staff provided an initial list of wells for inclusion in the study, which was supplemented with wells from other sources and databases. Various agencies (e.g., Florida Geological Survey, USGS, local agencies) were consulted to assemble all available data and information on these wells. This information was reviewed to select wells for field reconnaissance, which was conducted to identify any wells on the list that were damaged, destroyed, or otherwise unsuitable for inclusion in the study. District modeling and hydrogeology staff selected two sites for further study; one in Lee County and the other in Collier County (**Figure 3**). At each site, the wells were geophysically logged and at least 2 weeks of background water level data were collected at 15-minute intervals prior to aquifer performance testing. In addition, new topographic surveys were conducted to update and refine elevation data. Once testing was completed, the APT data were graphically analyzed to obtain the hydraulic parameter estimations needed to update the model.

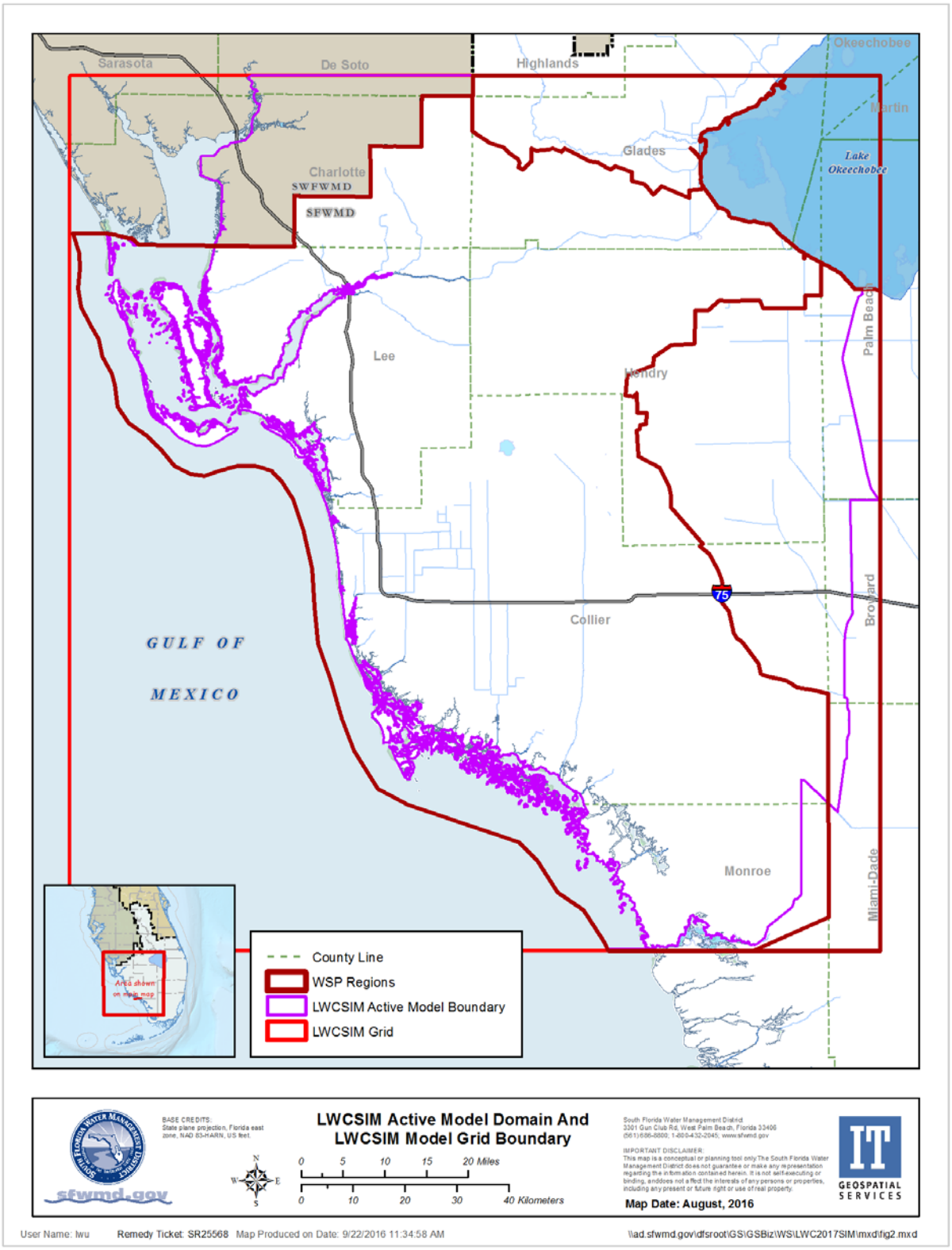


Figure 1. Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM) domain, encompassing the Lower West Coast planning area.

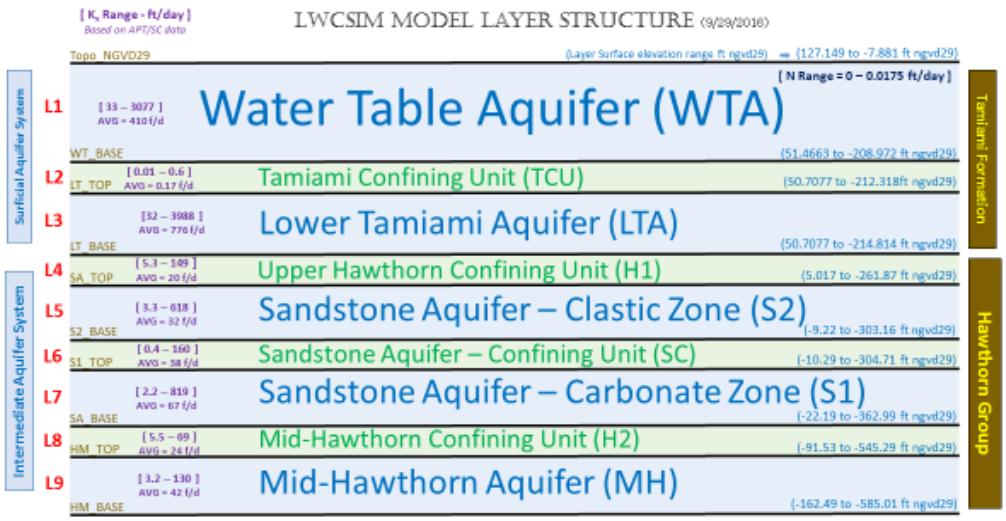


Figure 2. Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM) layers and regional hydrostratigraphy.

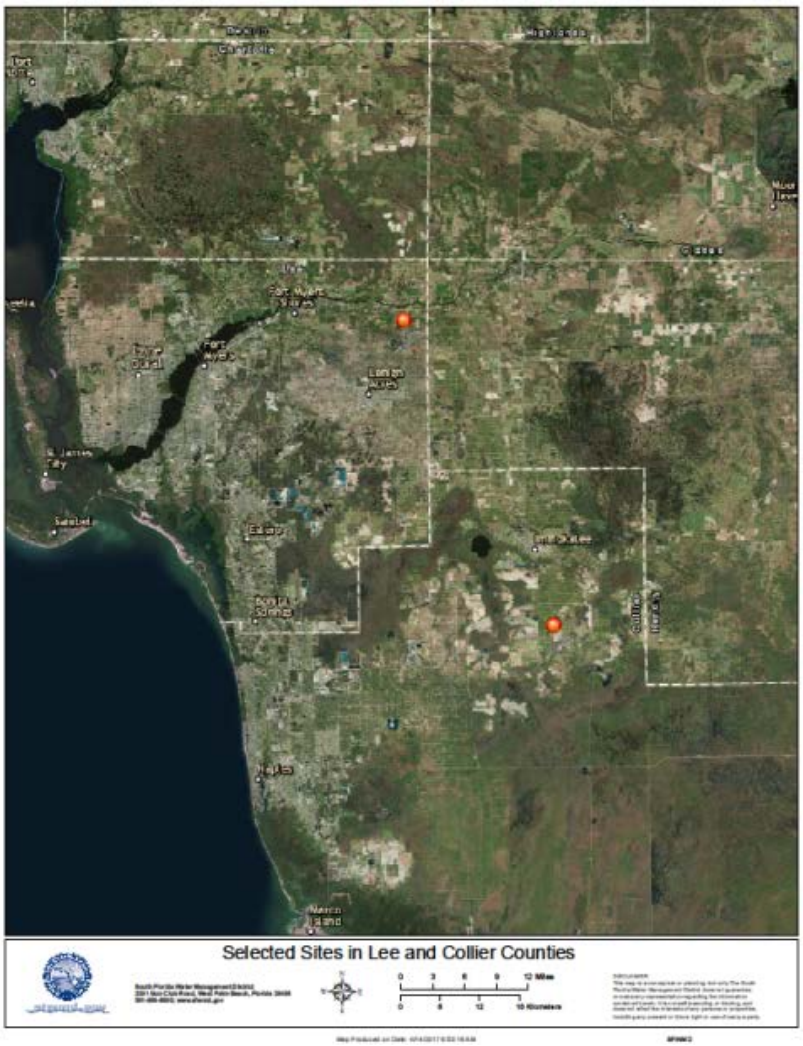


Figure 3. Selected study sites in Lee (top pin) and Collier (bottom pin) counties.

Region Description

The study area includes the eastern portions of Lee and Collier counties, and the western portion of Hendry County (**Figure 3**). The study area ranges in elevation between approximately 40 feet (ft) National Geodetic Vertical Datum of 1929 (NGVD29) near the Town of Immokalee to sea level along the Caloosahatchee River, downstream of SFWMD water control structure S-79. Land use in the study area is a mix of urban, residential, and agricultural, with some areas set aside for preservation. Many of the large tracts of undeveloped land that remain appear to be earmarked for future development.

STRATIGRAPHY/HYDROSTRATIGRAPHY

The layering of the model is based on the stratigraphy and hydrostratigraphy discussed in Geddes et al. (2015). Therefore, the following discussion of the stratigraphy and hydrostratigraphy is also based on that report.

Southwest Florida is underlain by three aquifer systems: the surficial aquifer system (SAS), the intermediate aquifer system (IAS), and the Floridan aquifer system (FAS). In the LWC Planning Area, the SAS consists of the water table aquifer and the Lower Tamiami aquifer. The Sandstone and Mid-Hawthorn aquifers comprise the IAS. The Floridan aquifer system underlies the IAS and is not discussed in this study. **Figure 4** shows the generalized geology and hydrogeology in the project area.

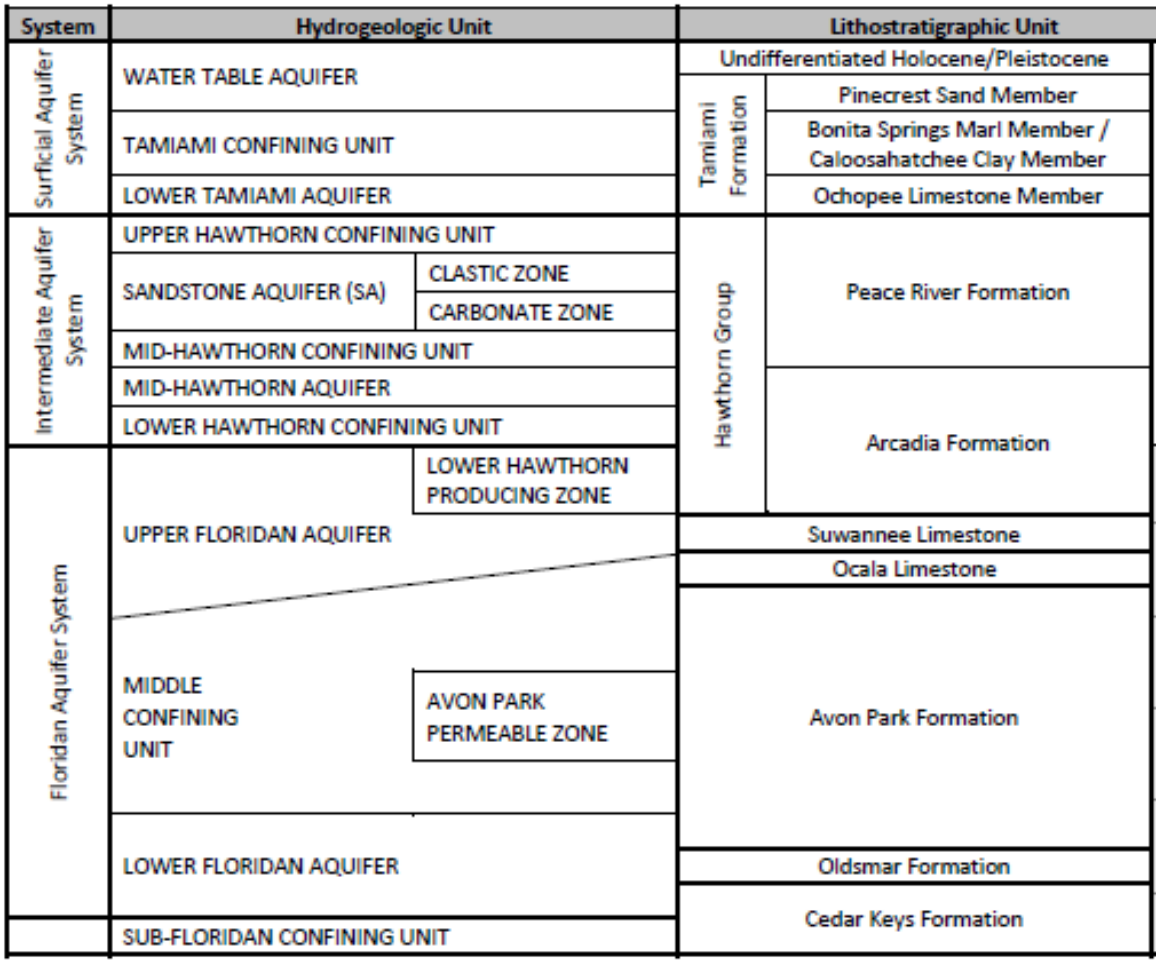


Figure 4. Generalized hydrogeologic and geologic units in the study area.

Lithology and Stratigraphy

In descending order, the stratigraphic units of significance in the study area are the undifferentiated Holocene/Pleistocene sediments, the Tamiami Formation, and the Peace River and Arcadia Formations of the Hawthorn Group (**Figure 4**). The lithology of the undifferentiated surficial sediments is highly variable. Medium- to fine-grained quartz sand, fossils, clays, and some freshwater limestone and marl are present within this unit. These extend to the top of the Tamiami confining unit, or, where the confining unit is absent, the top of the Ochopee Limestone of the Tamiami Formation. In a few areas, the Tamiami Formation is entirely absent and the surficial sediments rest directly on top of the Peace River Formation. The undifferentiated surficial sediments grade into the Anastasia Formation to the east and into Miami Limestone to the south (Bryan et al. 2013).

The Tamiami Formation is composed of two units and nine members—none of which are present throughout the entire study area. The upper confining unit is predominantly marl, and the lower water-bearing unit is the Ochopee Limestone. This unit is approximately equivalent to the Gray Limestone aquifer, located in the extreme eastern portion of the study area (Reese and Cunningham 2000). Lithology of the Ochopee Limestone unit varies from fine- to coarse-grained sand and fossiliferous limestone (Scott 2001). The presence of these two units varies spatially, and the Ochopee Limestone is absent in much of the study area. The confining unit is thicker where the Ochopee Limestone is absent and in portions of southwestern Lee County and northwestern Collier County.

The Peace River Formation is Miocene-aged clays and carbonates interbedded with quartz sands. Phosphate may be gravel- to sand-sized. Approximately two-thirds of the formation is siliciclastic and one-third (typically the lower portion) is carbonate. The Peace River Formation underlies the entire study area.

The underlying Arcadia Formation of the Hawthorn Group is predominately carbonate and exists throughout the study area. The contact between the two formations may be distinct or gradational. The Arcadia Formation primarily is dolostone and limestone with beds of clay, quartz sand, and phosphate grains (Scott 1988). The base of the Arcadia Formation is confining in nature and primarily consists of clay and mud.

Hydrogeology

The hydrogeology of southwest Florida is complex. Lateral facies changes and variable bed thicknesses lead to large local variations in hydrogeologic units. The heterogeneous natures of the units and the sparse availability of data in some places pose particular challenges for regional mapping. Local variability in the hydrogeologic units cannot be captured fully in surface and isopach maps. For the purposes of this study, the generalized unit criteria/definitions in the following sections have been used. Maps for areas without a significant presence of a given aquifer or confining unit have been generalized from data compiled for this study. The absence of units was reported by many local well construction and testing reports, and that information was supplemented by review of lithology and geophysical data.

While aquifer units and their thicknesses were explicitly mapped for this study, the thicknesses of the confining units were not. The confining unit isopach maps were derived by subtracting the top elevation of an aquifer from the base elevation of the overlying aquifer. Due to this approach, confining units were defined solely on the basis of the aquifer they overlie (e.g., the Tamiami confining unit overlies the Lower Tamiami aquifer, the Upper Hawthorn confining unit overlies the Sandstone aquifer). Therefore, where an aquifer was absent, its associated confining unit was undefined (and thus also absent). Areas where a confining unit was undefined (because the underlying aquifer was absent or insignificant) have been delineated separately from areas where the confining unit was absent or insignificant (although the underlying aquifer was present).

Water Table Aquifer

The water table aquifer is composed primarily of quartz sand and shell with minor amounts of organic material. A dense limestone cap rock is present in some areas. The water table aquifer is absent or insignificant (defined as a thickness of 5 ft or less) in places within the LWC Planning Area, and the basal confinement is geographically variable. Where present, the Bonita Springs Marl and low-permeability portions of the Pinecrest Sand facilitate confinement at the base of the water table aquifer.

In general, a water table aquifer is considered to be an unconfined unit extending from the water table to the first persistent confining unit. In the LWC Planning Area, the terminology more specifically refers to the permeable materials from the water table to the top of the Tamiami confining unit. However, confinement between the water table aquifer and the underlying Lower Tamiami aquifer is not consistent. Where the Tamiami confining unit is absent or insignificant (defined as a thickness of 5 ft or less), the water table aquifer, by definition, will encompass any permeable units above the upper Peace River confining beds. However, to facilitate development of more hydraulically correct model layering, where possible, the Ochopee Limestone of the Lower Tamiami aquifer was discretely mapped where the Tamiami confining unit was absent.

Lower Tamiami Aquifer

The Lower Tamiami aquifer is predominantly sandy biogenic limestone and calcareous sandstone. The aquifer encompasses all the water-producing limestone and, in some areas, portions of the underlying permeable sand. The upper confinement unit (Tamiami confining unit) is absent or insignificant (defined as a thickness of 5 ft or less) in some areas.

In the northern portions of the study area, Charlotte County and into the Southwest Florida Water Management District, well reports typically do not distinguish sub-units of the surficial aquifer system (SAS). However, BEM Systems, Inc. and EarthFX (2003) suggested that the Ochopee Limestone might be mappable in this area. Given that this area is separated from permitted Lower Tamiami aquifer water users to the south by a large area where the Lower Tamiami aquifer is absent or insignificant (defined as a thickness of 5 ft or less), discrete mapping of the Lower Tamiami aquifer was deemed a low priority for this study. Project maps in this region reflect the entire thickness of the SAS as the water table aquifer.

Throughout most of the study area, the lower permeable clay and fine-grained sands of the Peace River Formation provide basal confinement (Upper Hawthorn confining unit) to the Lower Tamiami aquifer. However, in some areas, this confinement is absent or insignificant (defined as a thickness of 10 ft or less). In some locations, the Lower Tamiami aquifer or undifferentiated SAS lies directly on top of the Sandstone aquifer.

Sandstone Aquifer

The Sandstone aquifer, except where absent or insignificant (defined as a thickness of 10 feet or less) (**Figure 5**), is contained entirely within the Peace River Formation of the Hawthorn Group and is part of the IAS. The aquifer typically occurs as two distinct permeable units, an upper clastic zone and a lower carbonate zone. The Sandstone aquifer is composed of sandstone, sandy limestones, dolostones, and calcareous sands, which may be contiguous or separated by varying amounts of low-permeability silt and clay. Where a confining unit is present, the Sandstone aquifer is separated from the overlying Lower Tamiami aquifer by the lower permeable clays and dolosilts of the Peace River Formation (Upper Hawthorn confining unit). The Sandstone aquifer is separated from the underlying Mid-Hawthorn aquifer by low-permeability clays and marls of the basal Peace River Formation (Mid-Hawthorn confining unit), which are present throughout the study area (**Figure 6**). Areas where the upper clastic zone and lower carbonate zone are absent or insignificant (defined as a thickness of 10 ft or less) are shown in **Figures 7** and **8**.

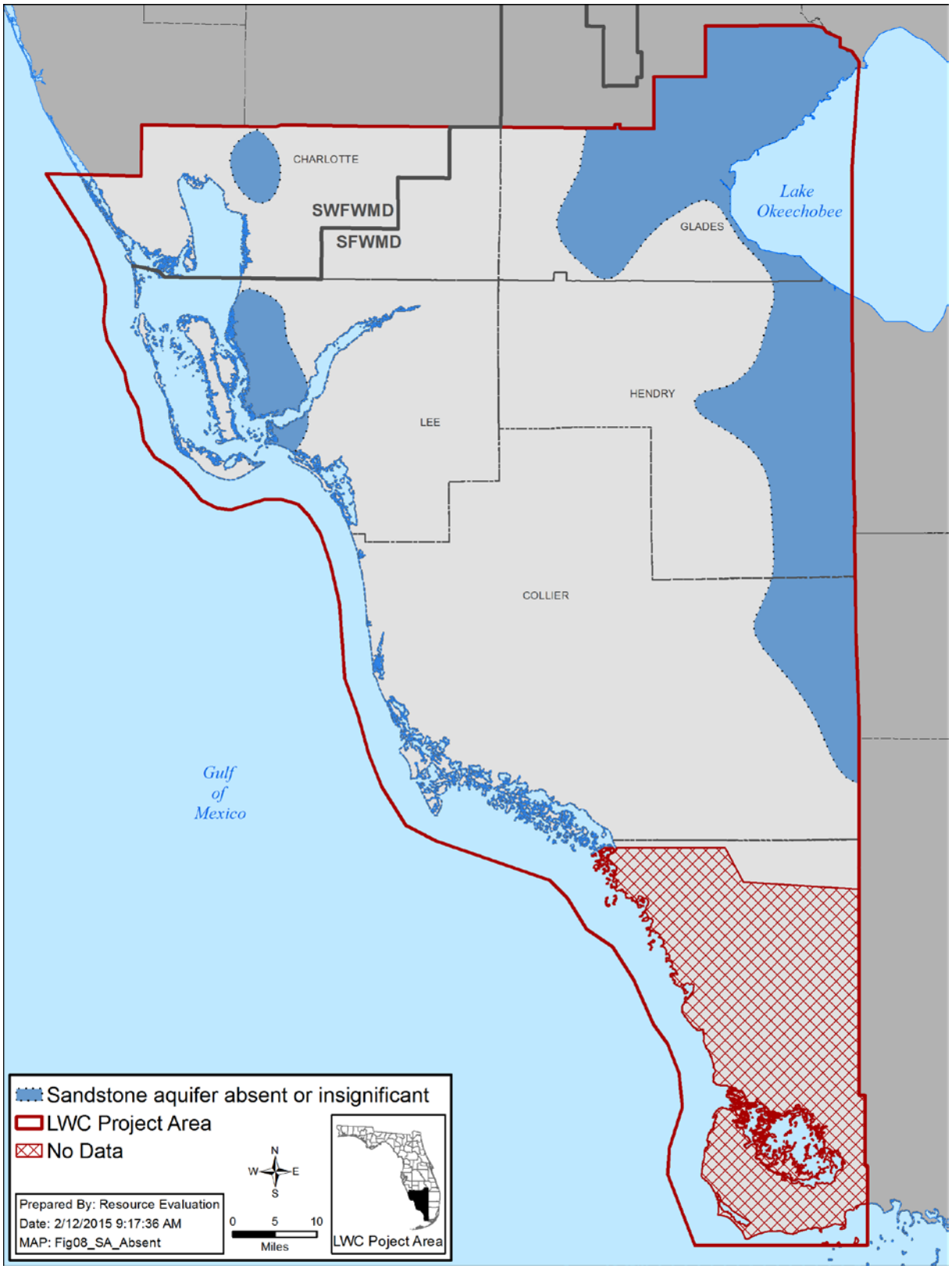


Figure 5. Generalized areas where the Sandstone aquifer is absent/insignificant.

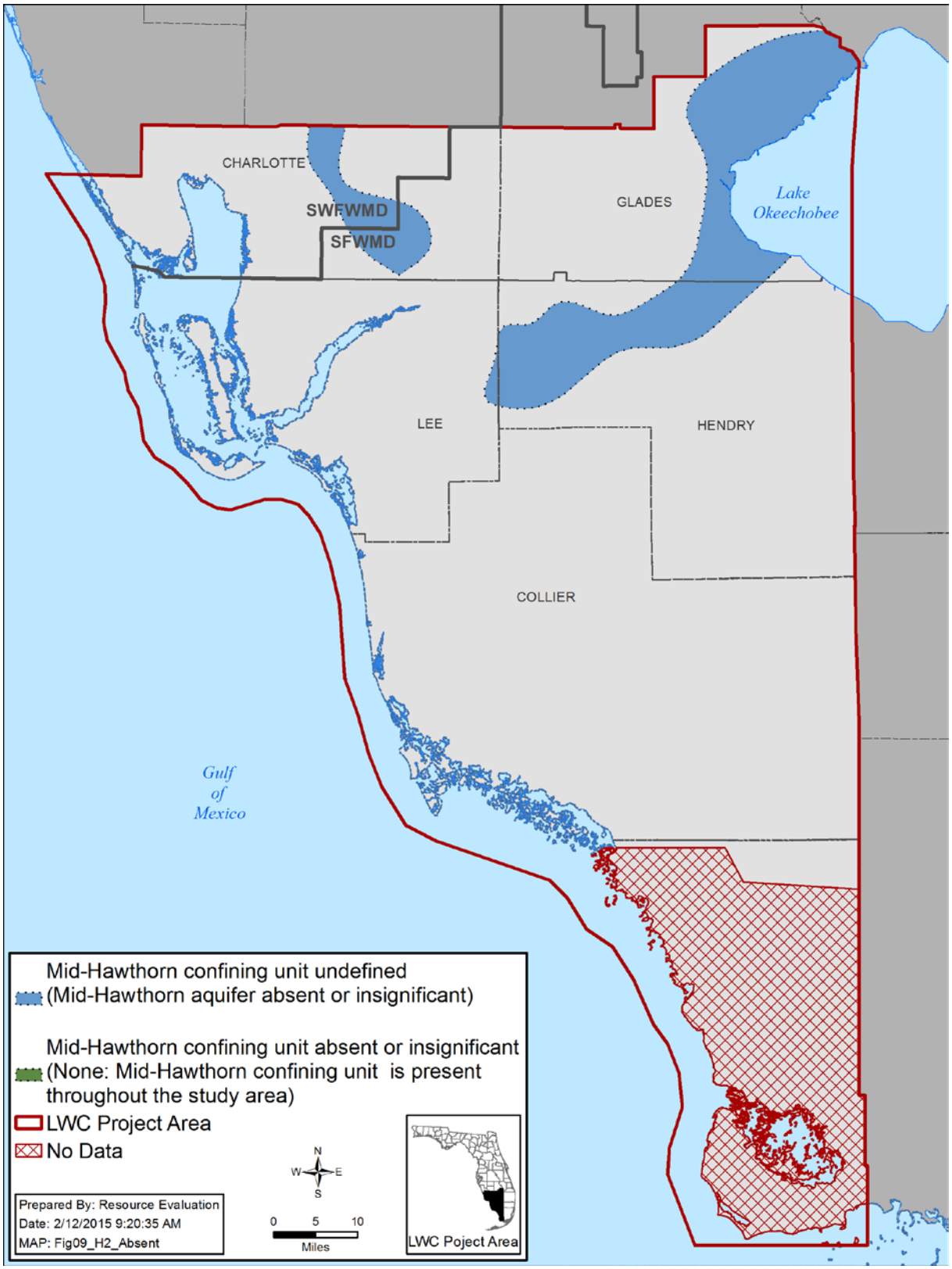


Figure 6. Generalized areas where the Mid-Hawthorn confining unit is undefined.

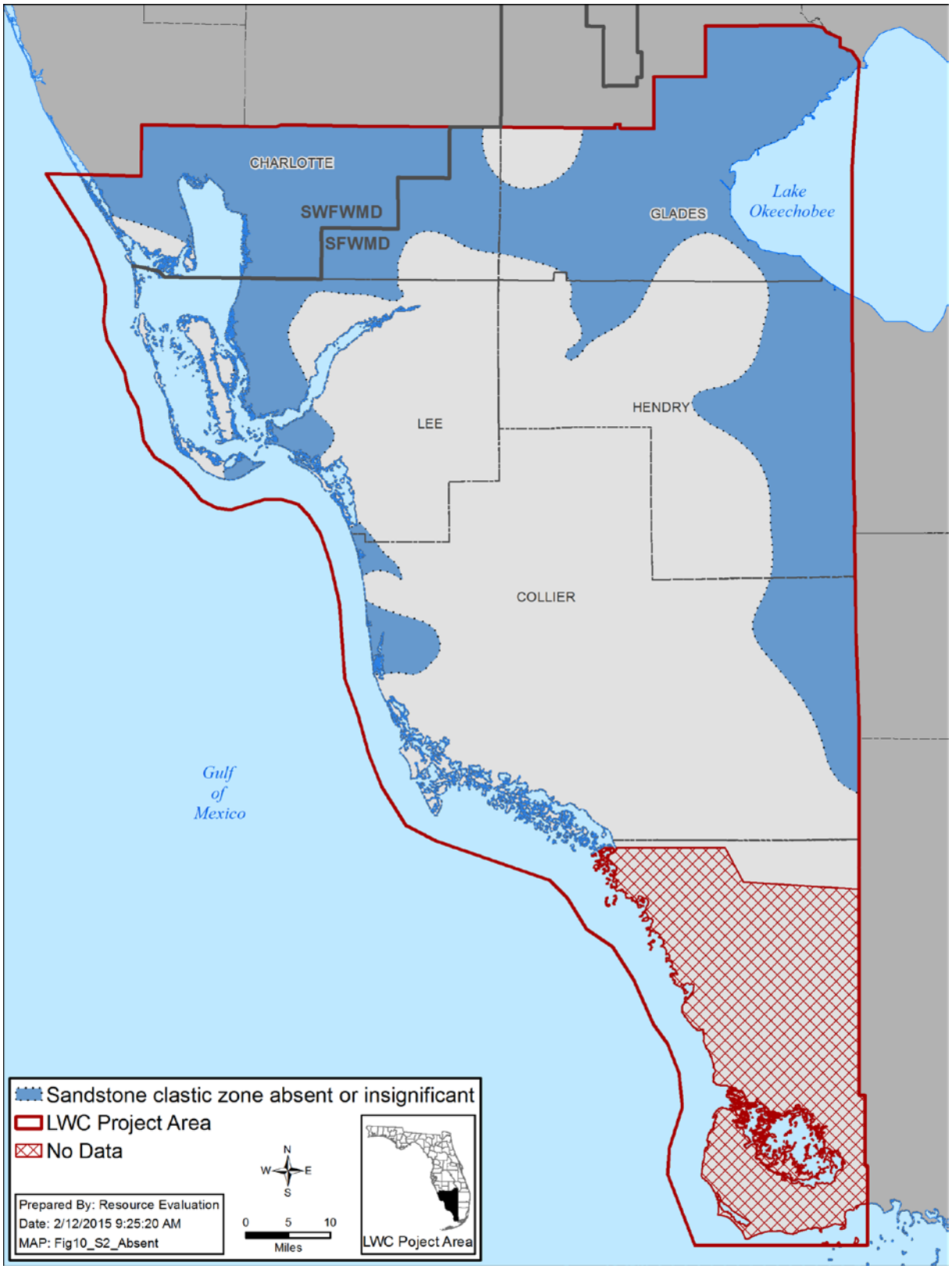


Figure 7. Generalized areas where the Sandstone aquifer clastic zone is absent/insignificant.

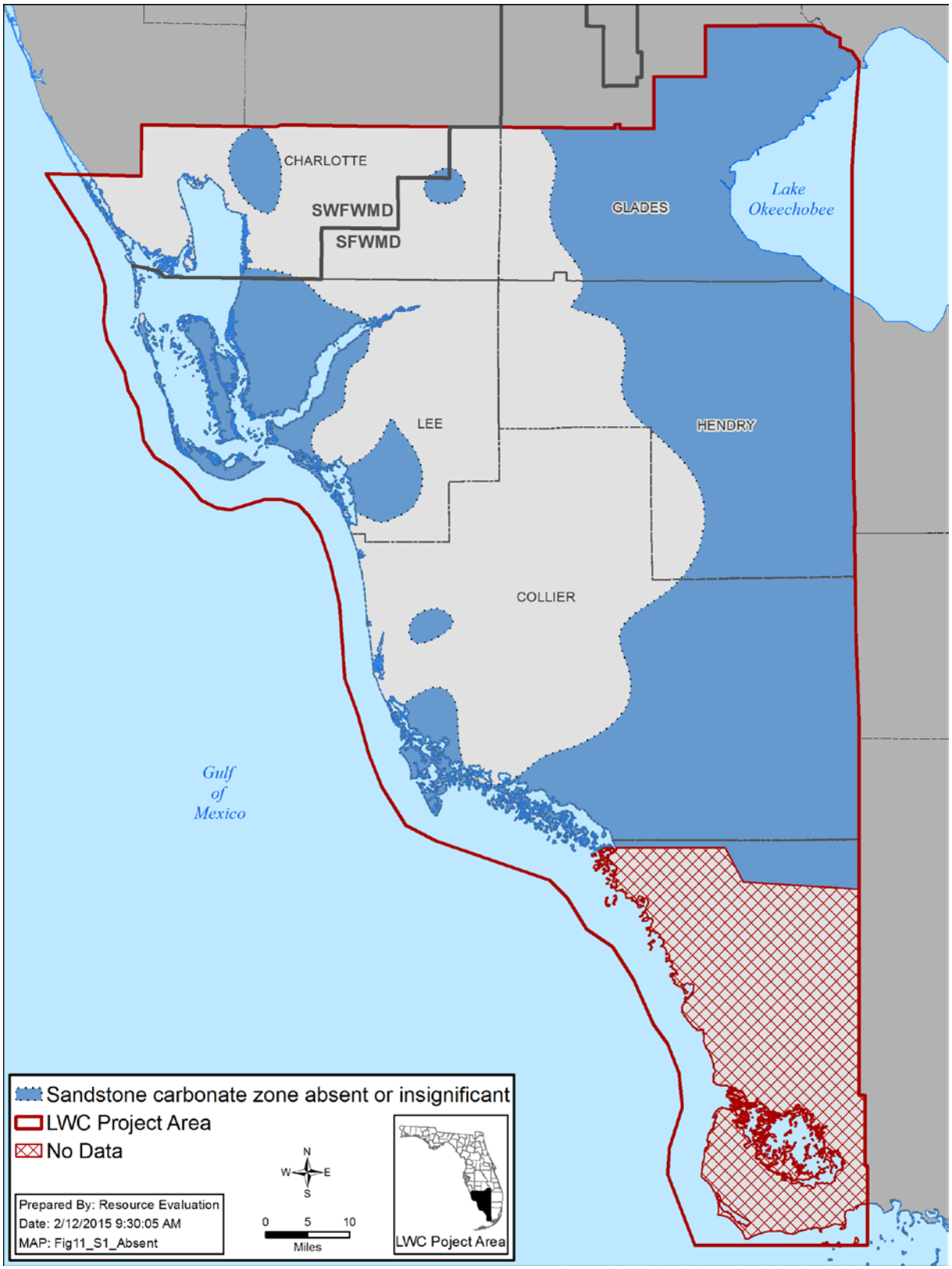


Figure 8. Generalized areas where the Sandstone aquifer carbonate zone is absent/insignificant.

The Sandstone aquifer was not explicitly mapped by BEM Systems, Inc. and EarthFX (2003). As a surrogate for the aquifer, BEM Systems, Inc. and EarthFX (2003) mapped the net thickness of sand within the Peace River Formation. One result of that method was what appeared to be a thick sequence of the Sandstone aquifer in eastern Hendry County where previous studies reported the aquifer as absent. While the unit is lithologically present, results from this study found little support for significant Sandstone aquifer production capability in eastern Hendry and Collier counties. Data for assessment of the productivity of the IAS in those regions are sparse and often restricted to lithologic descriptions. However, those descriptions indicate that the coarse- to pebble-sized sand beds that yield much of the productivity in western Hendry and central Collier counties contain an increasing component of fine-grained materials to the east. The thickest and most productive portion of the Sandstone aquifer aligns roughly with a paleo-topographic depression in the limestone surface of the underlying Arcadia Formation (Cunningham et al. 1998) that is considered to have provided a pathway for southward transport of siliclastics during the Miocene epoch.

For the purposes of this study, the Sandstone aquifer was mapped as a single aquifer. In addition, individual maps were prepared for the upper clastic (base) and lower carbonate (top) units. The base of the upper clastic unit does not necessarily correspond to the top of the lower carbonate unit where separated by a confining unit. The undifferentiated Sandstone aquifer top surface was interpolated using data from 410 wells, including 35 locations where the aquifer is absent

The elevation of the top of the Sandstone aquifer ranges from 5 to -262 ft NGVD29, with the highest elevations in central-northern Collier County and the lowest in north-central Hendry County (**Figure 9**). The base of the Sandstone aquifer (**Figure 10**) occurs at a maximum elevation of -26 ft NGVD29 in western Glades County and a minimum of -363 ft NGVD29 in north-central Collier County. The thickness of the Sandstone aquifer ranges from 0 ft in west-central Glades, eastern Hendry, and northeastern Collier counties to 264 ft in north-central Collier County (**Figure 11**).

Clastic Zone

The elevation of the base of the clastic zone ranges from -11 to -280 ft NGVD29. The highest elevation was found in western Glades County and the lowest in north-central Hendry County (**Figure 12**). The thickness of the clastic zone ranges from 0 ft in central to northern Charlotte, central to northern Glades, eastern Hendry, and northeastern Collier counties to 169 ft in central Collier County (**Figure 13**).

Carbonate Zone

The elevation of the top of the carbonate zone ranges from -12 to -306 ft NGVD29, with the highest elevation in western Glades County and the lowest in central Collier County (**Figure 14**). The thickness of the carbonate zone ranges from 0 ft in central to western Lee, eastern Glades, Hendry, and Collier counties to 95 ft in central Collier County (**Figure 15**).

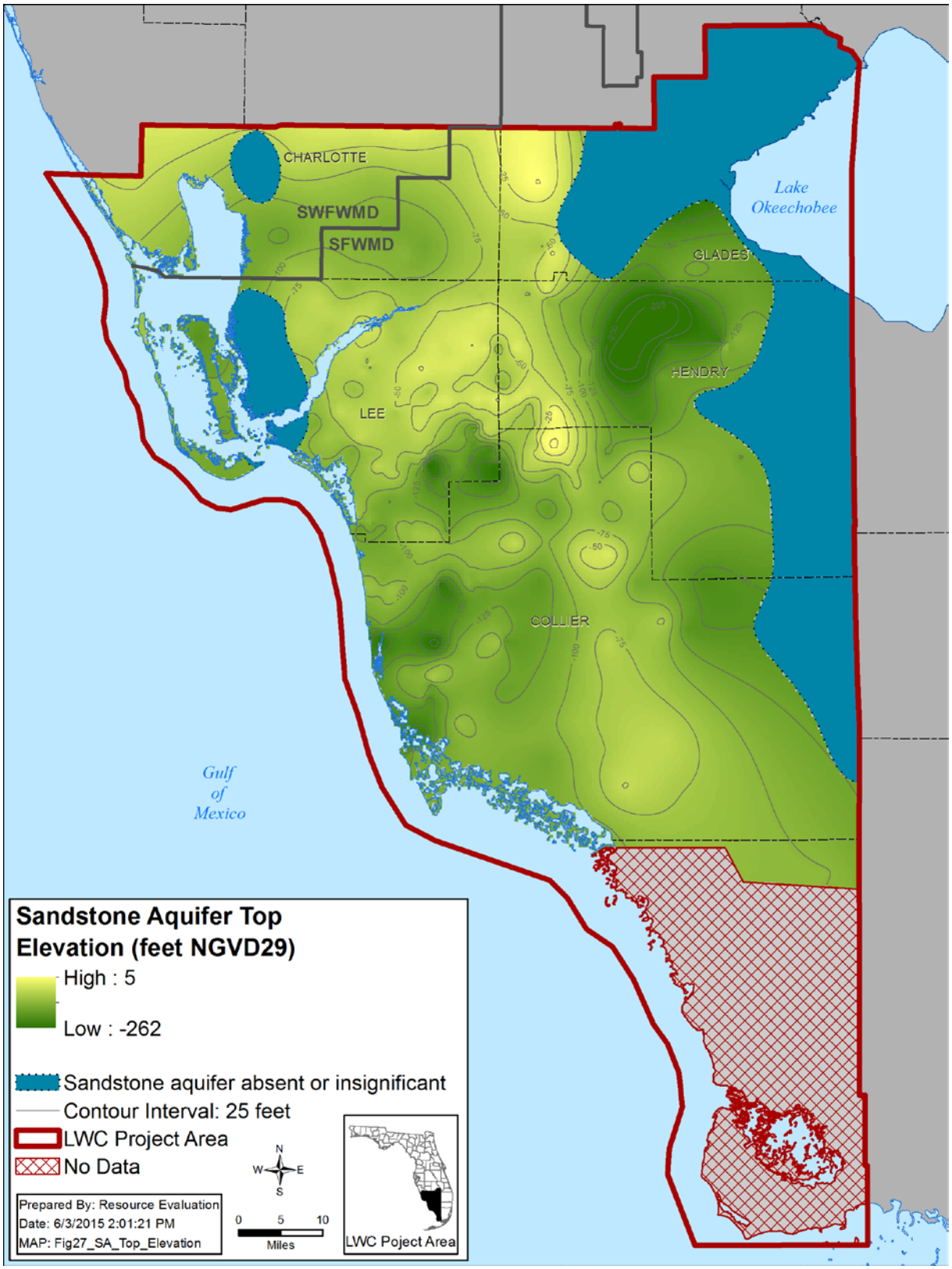


Figure 9. Elevation of the top of the Sandstone aquifer.

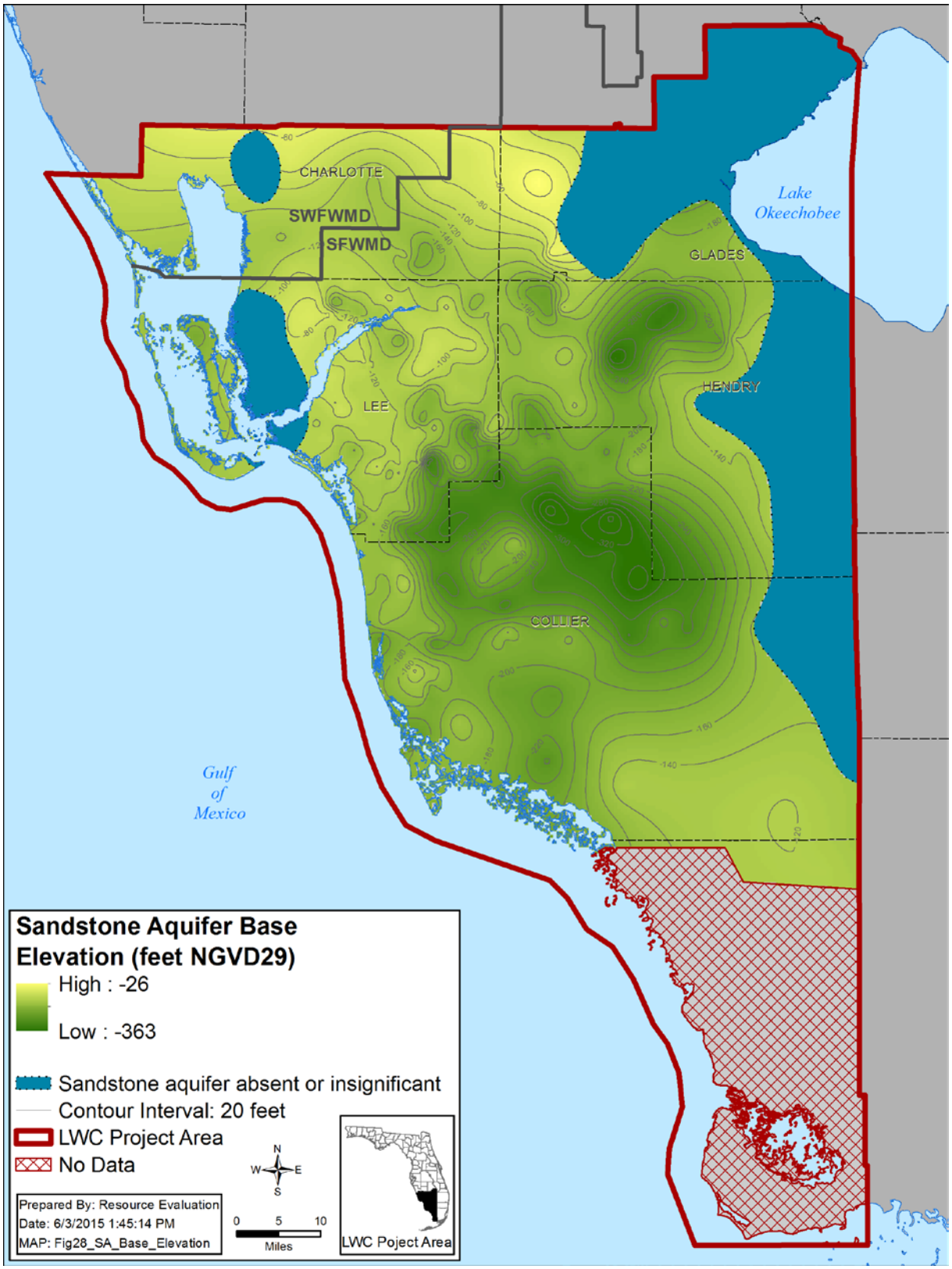


Figure 10. Elevation of the base of the Sandstone aquifer.

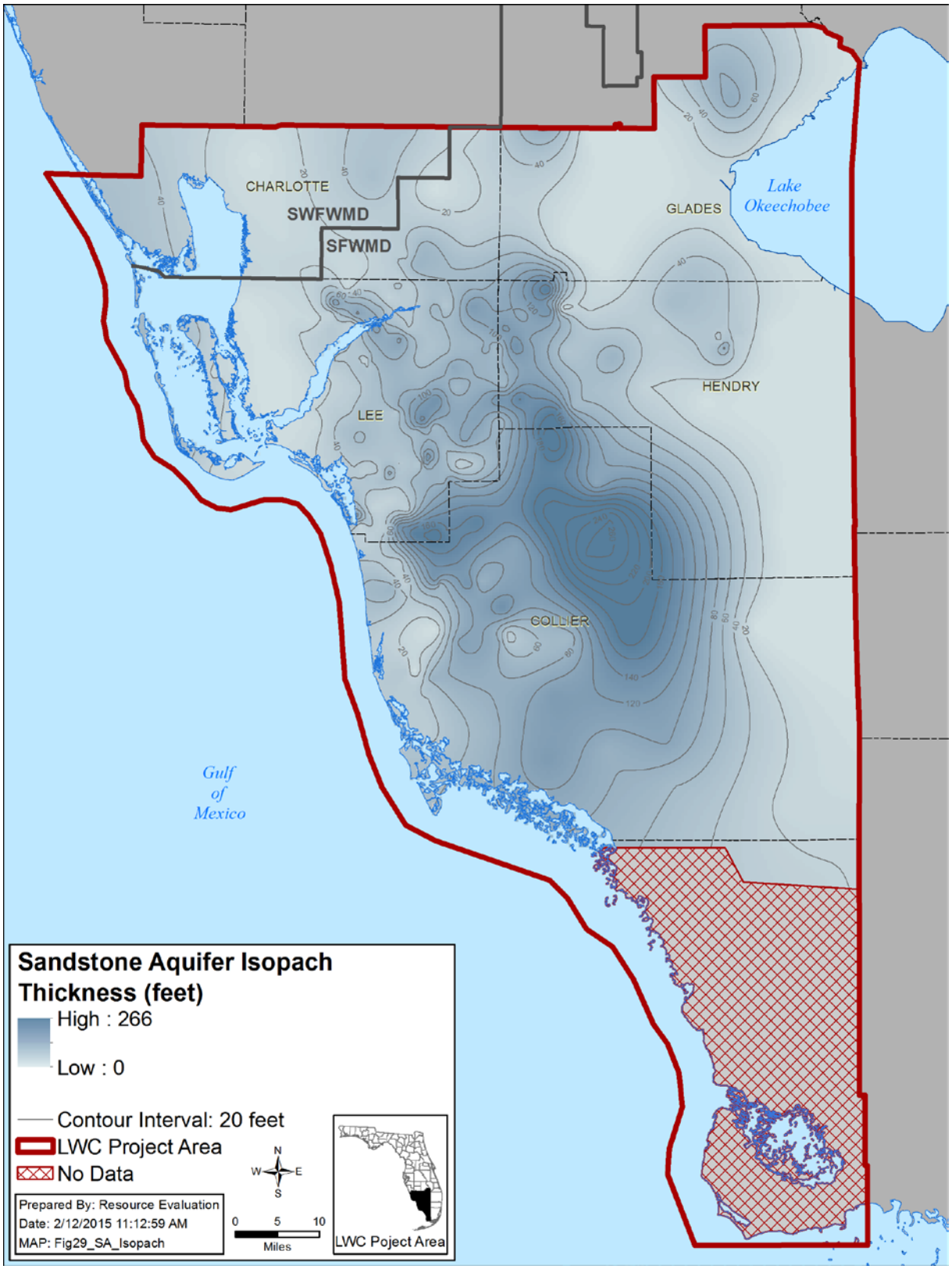


Figure 11. Thickness of the undifferentiated Sandstone aquifer.

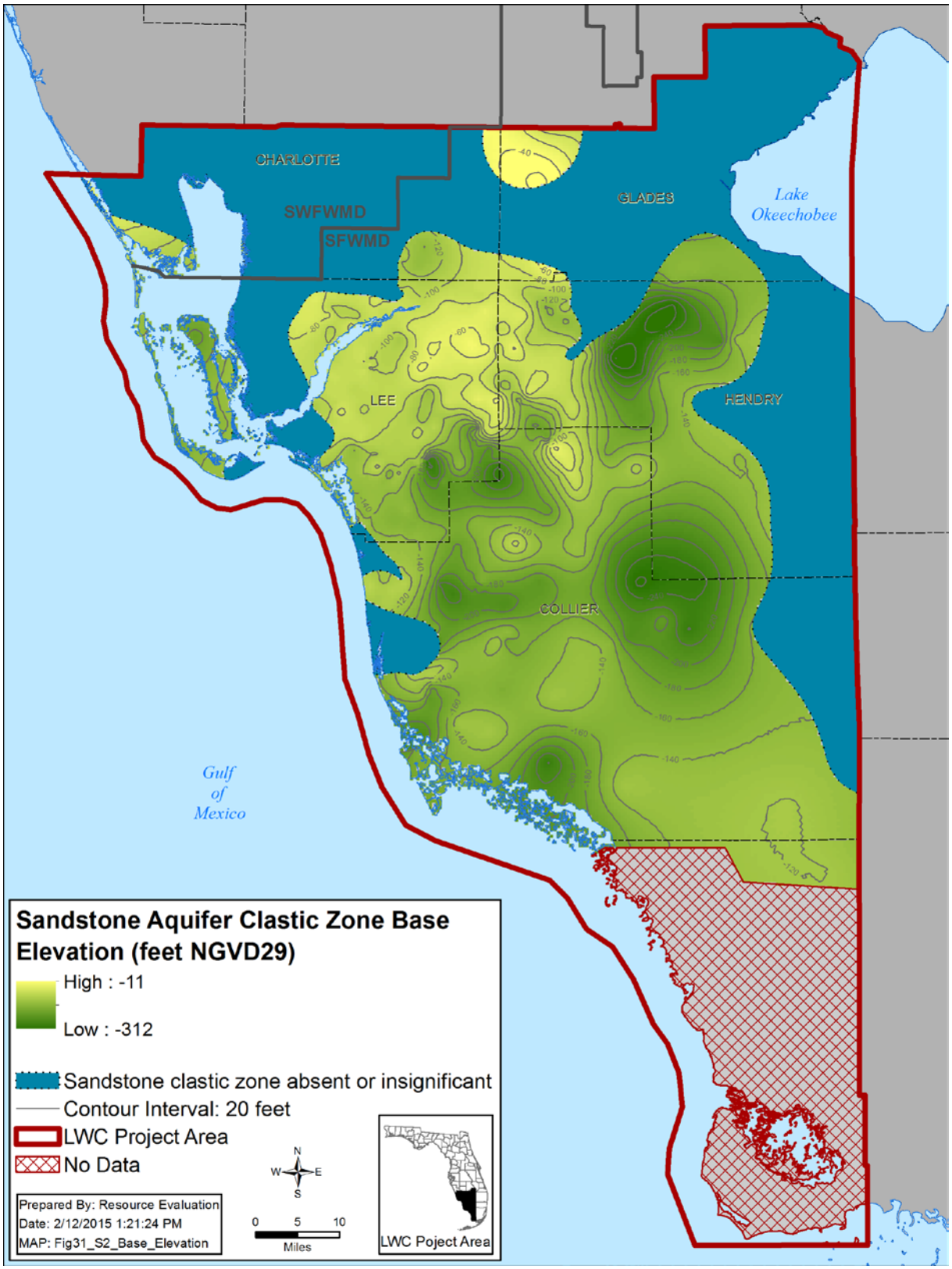


Figure 12. Elevation of the top of the clastic zone of the Sandstone aquifer.

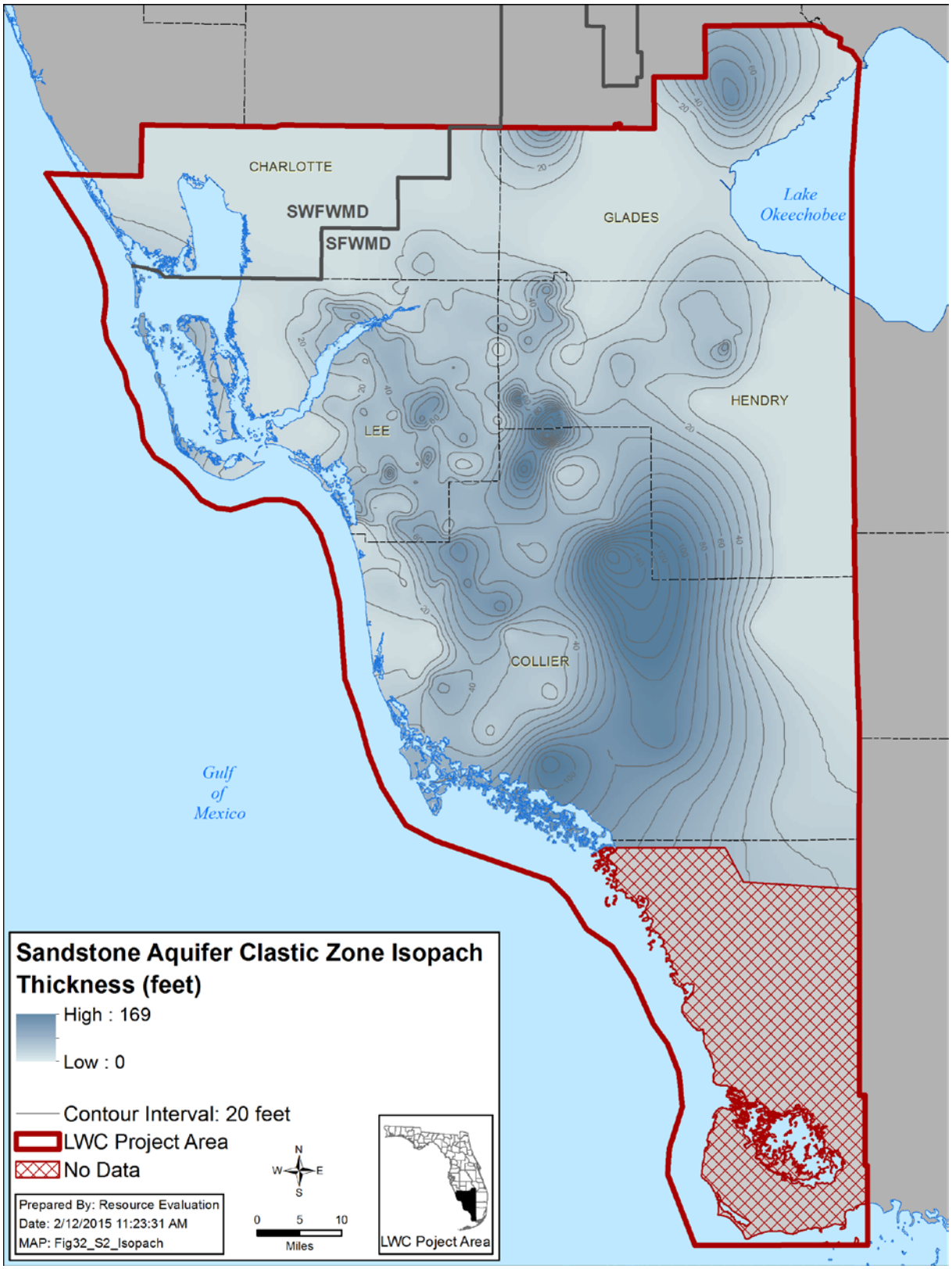


Figure 13. Thickness of the clastic zone of the Sandstone aquifer.

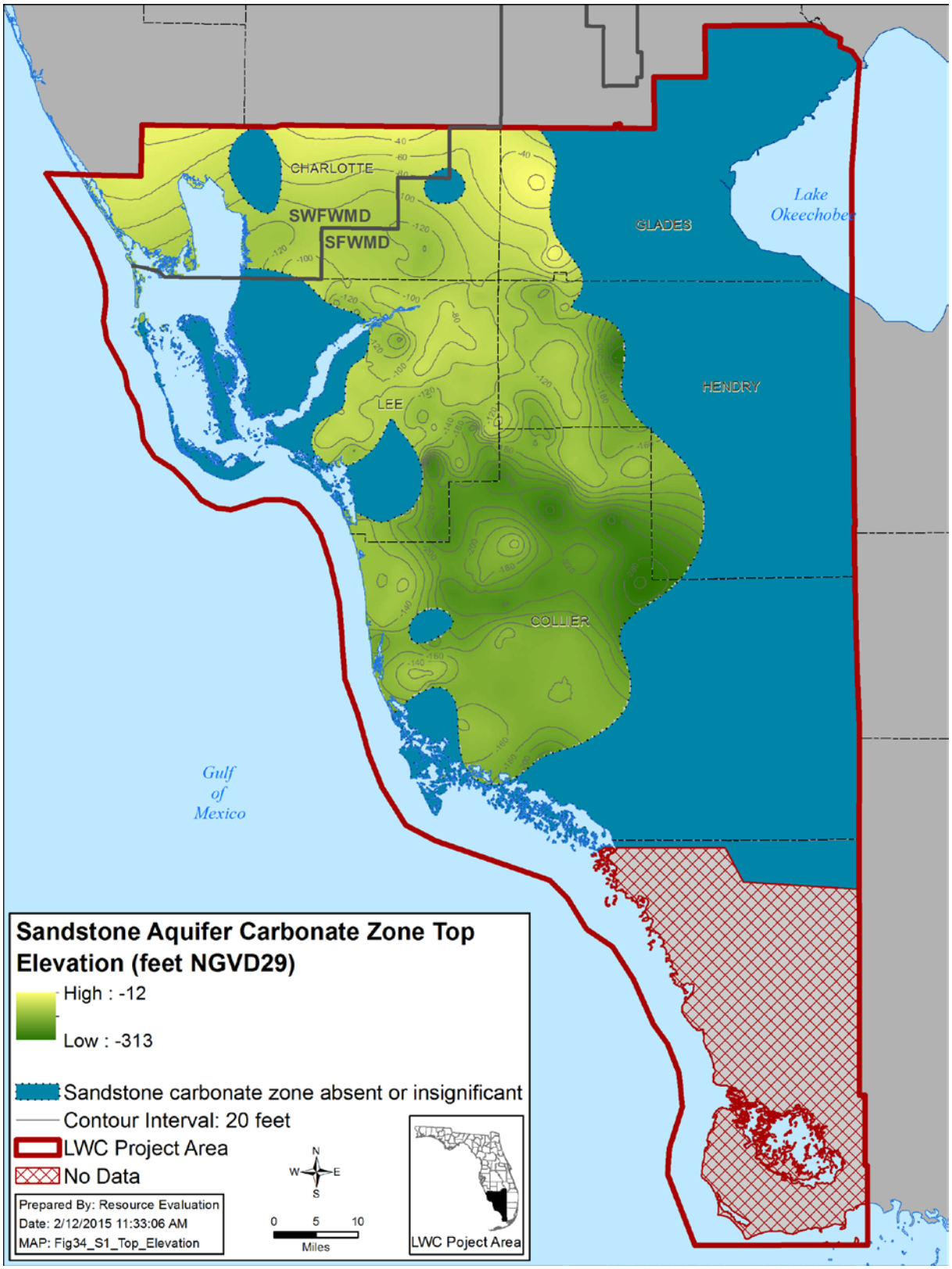


Figure 14. Elevation of the top of the carbonate zone of the Sandstone aquifer.

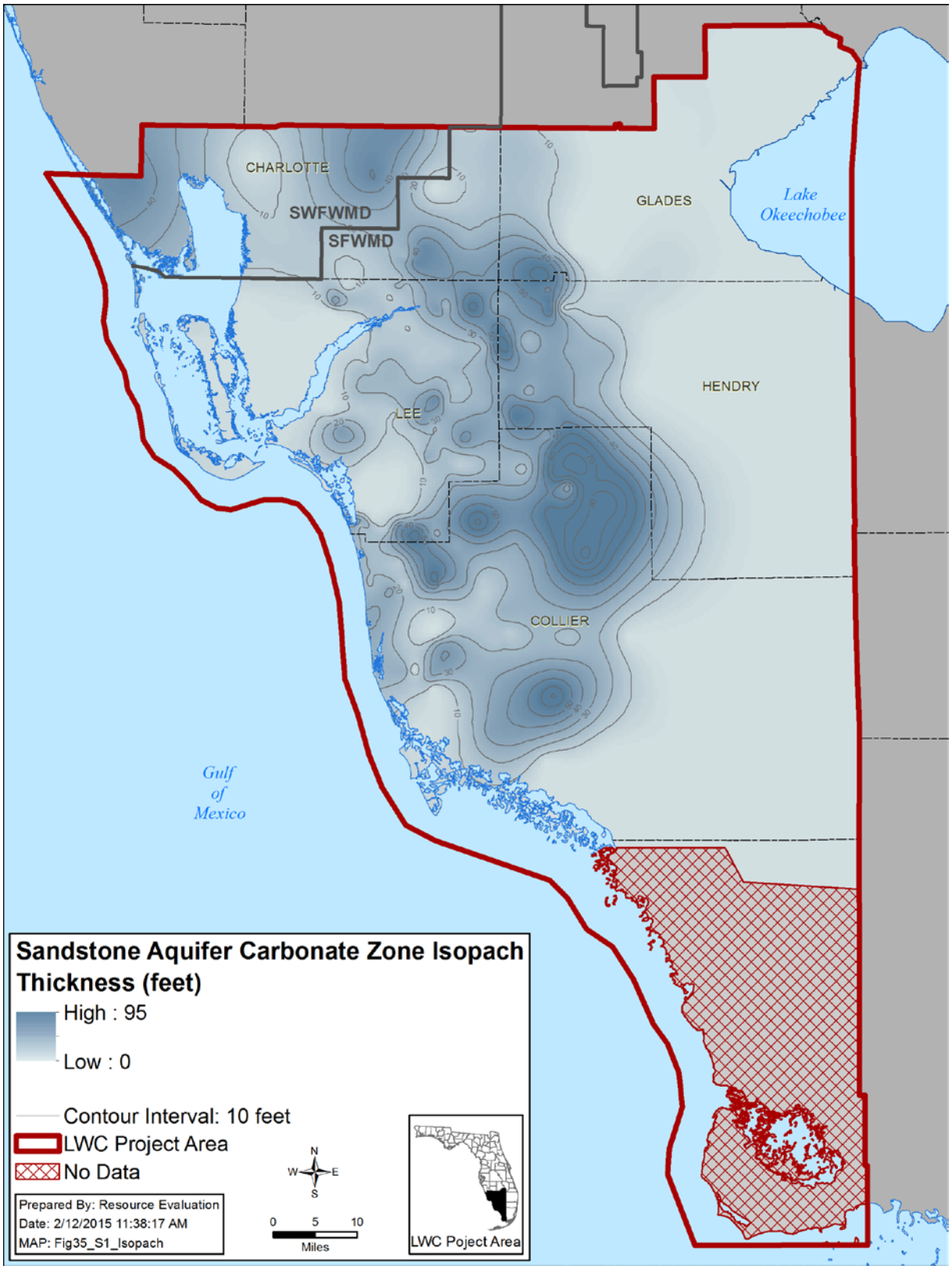


Figure 15. Thickness of the carbonate zone of the Sandstone aquifer.

SITE SELECTION

SFWMD modeling staff provided the initial list of well sites considered for testing, including the monitor wells being used as targets to calibrate the model layers representing the Sandstone aquifer. The list was supplemented with additional wells from the District's DBHYDRO and ePermitting (water use permitting) databases, the USGS National Water Information System (NWIS) database, Florida Geological Survey, and Lee and Collier county databases. Information gathered on the wells included location, diameter, total depth, casing depth, and the Sandstone aquifer zone (clastic or carbonate) in which they were completed. Sites with both a clastic zone and carbonate zone well were determined also. The list of candidate well sites was further refined based on the following criteria: location within the model domain's primary area of interest, accessibility by field vehicles and equipment, ability to accommodate geophysical logging tools, and suitability of the site for APT operations (e.g., adequate drainage for discharge). Field inspections of the reduced list of candidate sites were conducted to verify that all the criteria were met. Summaries of the field visits are provided in **Appendix A**. From these evaluations, two sites with multiple wells were selected for testing: one in Lee County and one in Collier County (**Figure 3**).

SITE DESCRIPTIONS

The Lee County APT site is located in Lehigh Acres, Florida on Joel Boulevard, approximately 3.1 miles south of the intersection of State Road 80 and Joel Boulevard (**Figure 16**). The site consists of three USGS monitoring wells (L-1137, L-727, and L-2187) located in the eastern right-of-way of Joel Boulevard. L-1137 is a shallow water table aquifer well and is cased to 15 ft below land surface (bls), with a total depth of 20 ft. L-727 is finished in the clastic zone of the Sandstone aquifer and is cased to 67 ft bls, with a total depth of 71 ft bls. L-2187 is finished in the carbonate zone of the Sandstone aquifer and is cased to 136 ft bls, with a total depth of 154 ft bls. All the wells partially penetrate their respective aquifers; the impact of this on the APT results is discussed in the APT analysis section of this report. L-727 is equipped with a USGS data recorder; L-1137 and L-2187 were not instrumented at the time of this study. **Figure 17** is a photograph of the site, **Figure 18** shows an areal schematic of the site, and **Figure 19** shows a conceptual hydrogeologic cross-section of the site. The cross-section is based on regional information and information collected at the site.

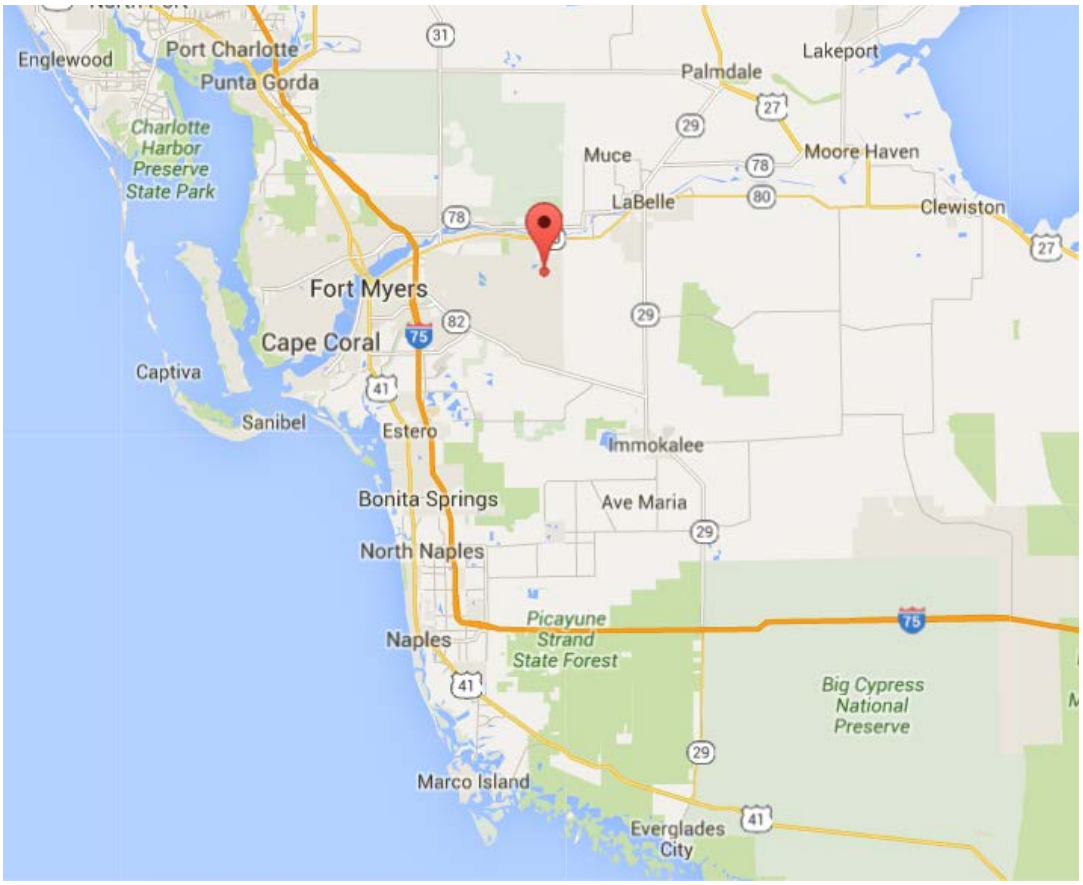


Figure 16. Location of the Lee County aquifer performance test site.

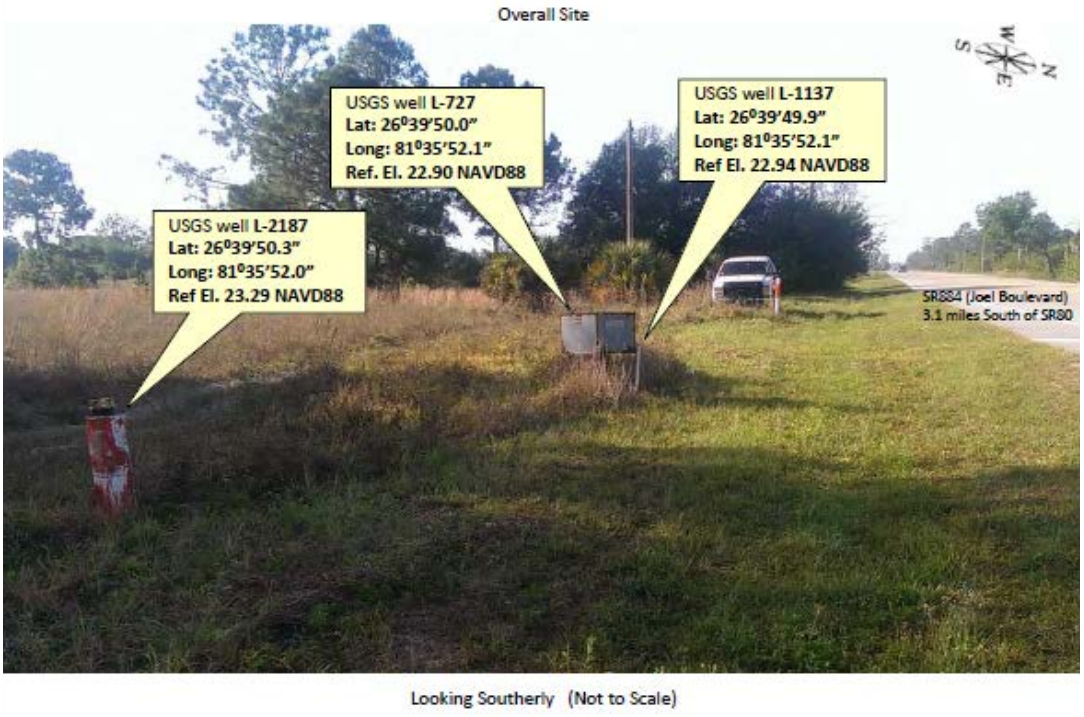
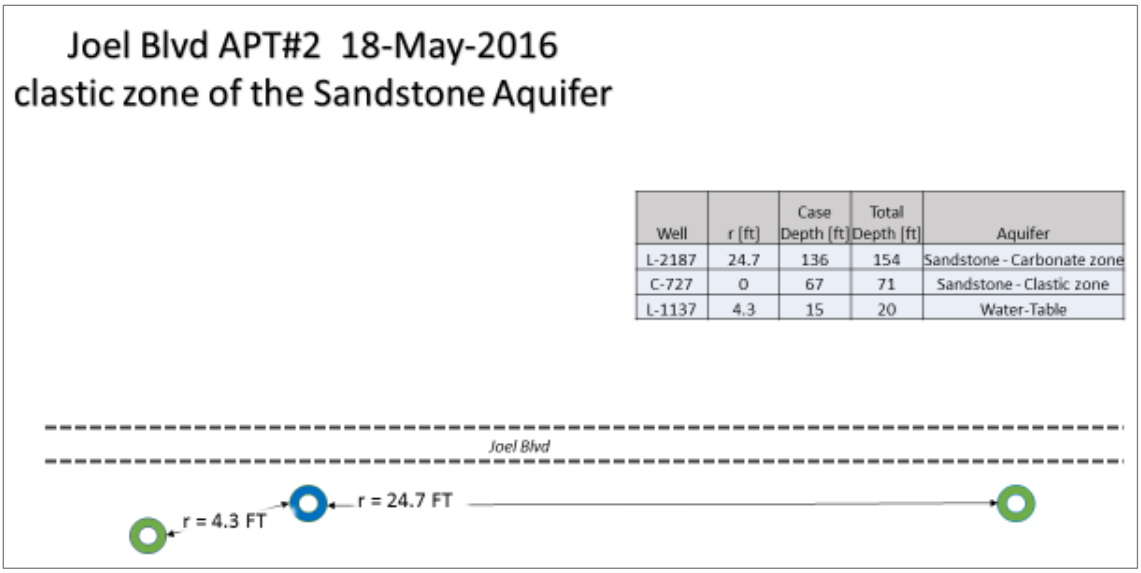
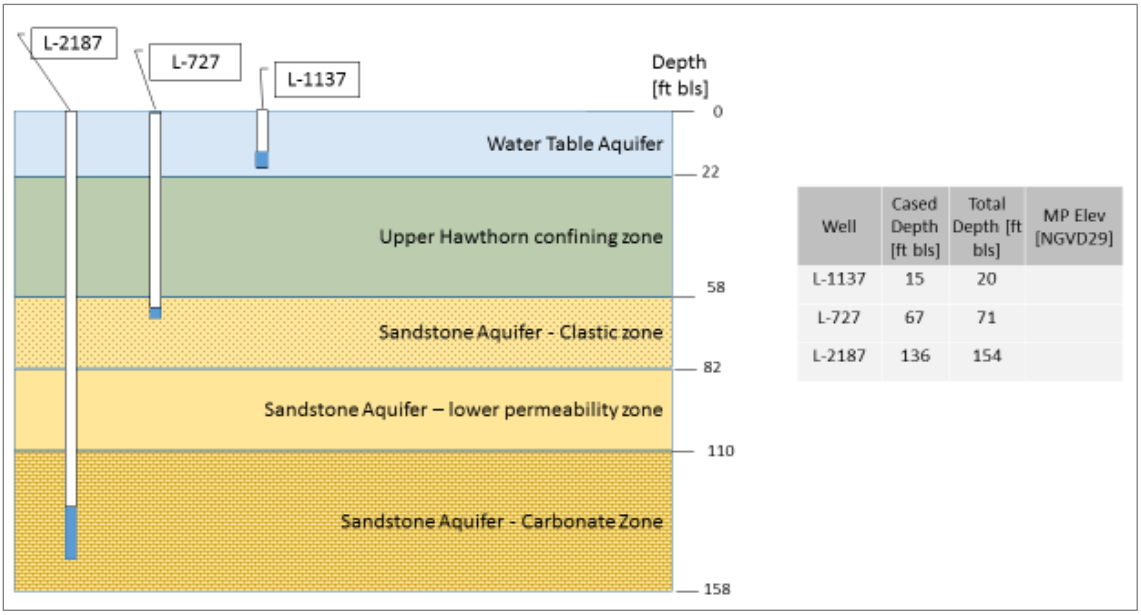


Figure 17. Photograph of the Lee County aquifer performance test site.



Well	r [ft]	Case Depth [ft]	Total Depth [ft]	Aquifer
L-2187	24.7	136	154	Sandstone - Carbonate zone
C-727	0	67	71	Sandstone - Clastic zone
L-1137	4.3	15	20	Water-Table

Figure 18. Areal schematic of the Lee County aquifer performance test site.



Well	Cased Depth [ft bls]	Total Depth [ft bls]	MP Elev [NGVD29]
L-1137	15	20	
L-727	67	71	
L-2187	136	154	

Figure 19. Conceptual cross-section of the Lee County aquifer performance test site.

The Collier County APT site is located on County Highway 858 (Oil Well Road), approximately 3.4 miles west of the intersection of County Road 858 and State Road 29 (**Figure 20**). **Figure 21** shows that the site consists of four USGS monitoring wells (C-503, C-1073, C-689, and C-684) located in the southern right-of-way of County Road 858. C-503 is a shallow water table aquifer monitoring well cased to 8 ft bls, with a total depth of 20 ft bls. C-1073 is completed in the clastic layer of the Sandstone aquifer and is cased to 100 ft bls, with a total depth of 160 ft bls. C-689 is completed in the carbonate zone of the Sandstone aquifer and is cased to 230 ft bls, with a total depth of 265 ft bls. Finally, C-684 is completed in the Mid-Hawthorn aquifer and is cased to 440 ft bls, with a total depth of 490 ft bls. C-684 flows at land surface. C-503 is equipped with a USGS data recorder; the other wells were not instrumented at the time of this study. All the wells partially penetrate their respective aquifers; the impact of this situation is discussed in the APT analysis section of this report. **Figures 22** and **23** are based on regional information and information collected at the site.

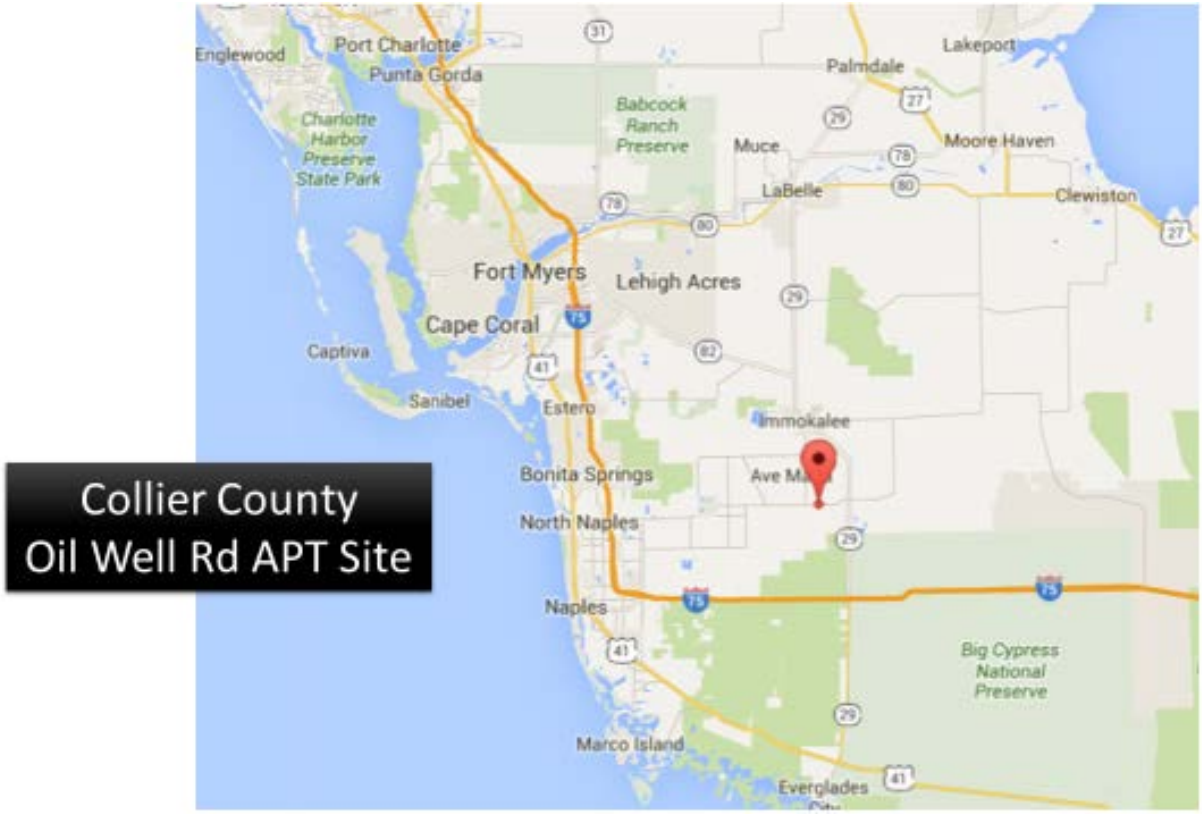


Figure 20. Location of the Collier County aquifer performance test site.

Figure 21. Photograph of the Collier County aquifer performance test site.

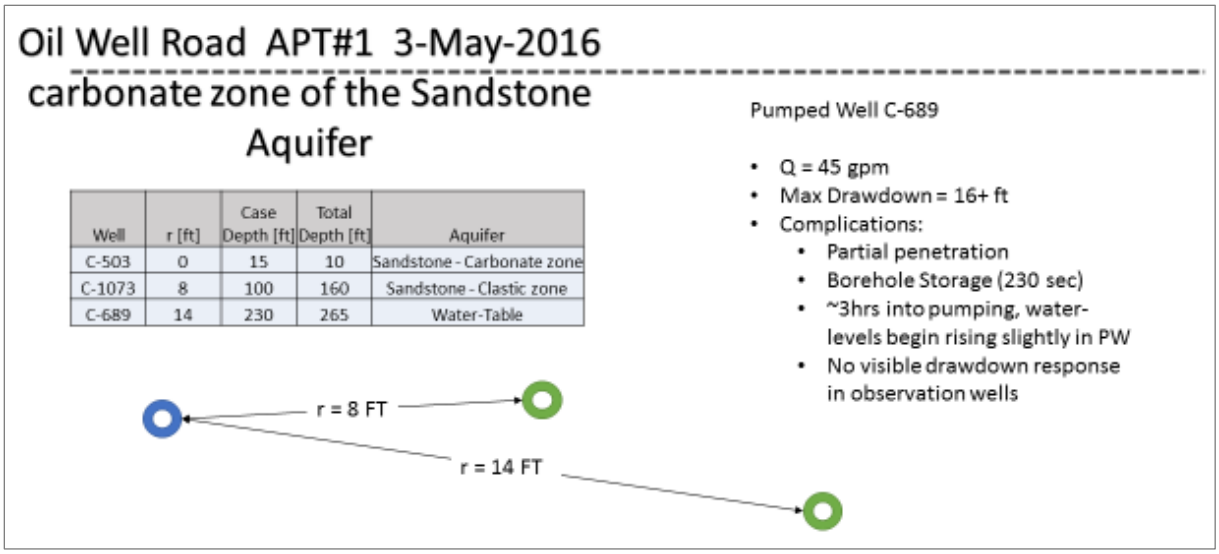


Figure 22. Areal schematic of the Collier County aquifer performance test site.

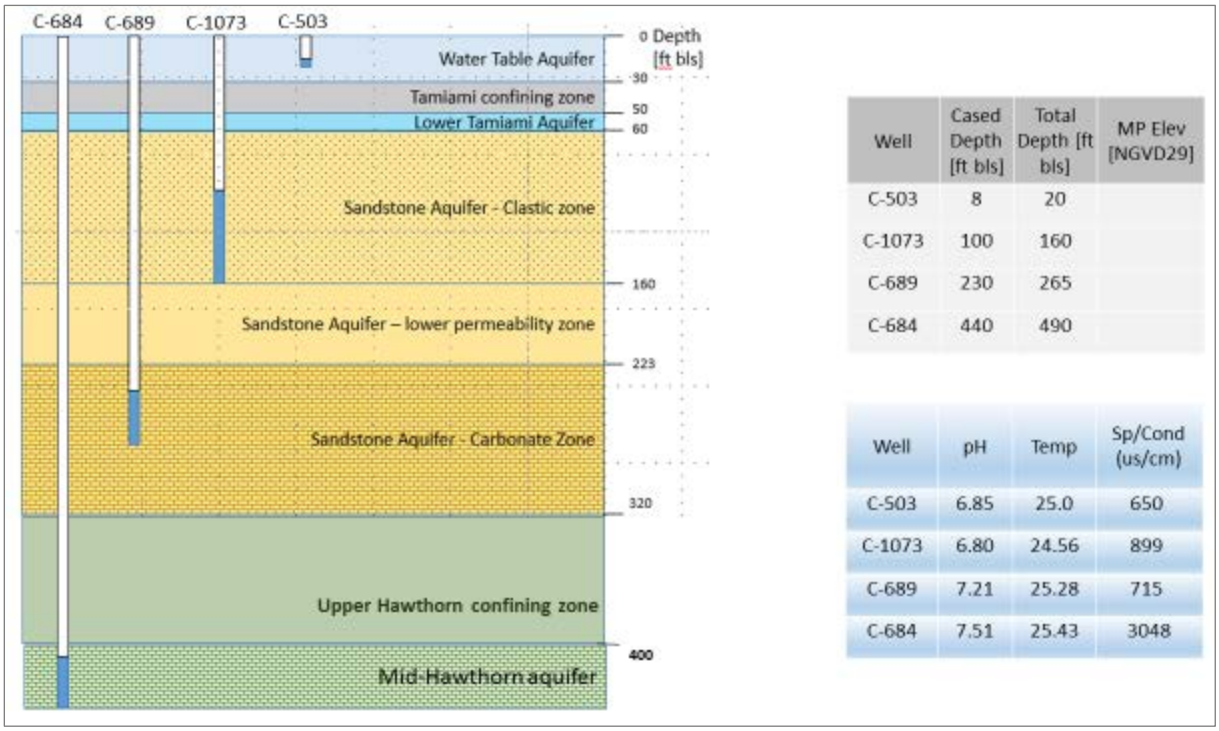


Figure 23. Conceptual hydrogeologic cross-section of the Collier County aquifer performance test site.

HYDROGEOLOGIC TESTING

Once the two APT sites were selected, additional data were collected at each site before the APTs were performed. Data collection included updating the topographic survey information at each site, collecting at least 2 weeks of background water level data, and conducting geophysical logging on the Sandstone aquifer wells. Survey reports for each site are provided in **Appendix B**. Water levels were collected at 15-minute intervals by the existing USGS monitoring equipment (reprogrammed to record at the more frequent intervals during the background period) or by the temporary installation of data loggers in the wells not equipped with USGS monitoring equipment. Background water levels exhibited the expected characteristics of seasonal decline associated with the end of the dry season, diurnal fluctuation, and response to rainfall events. Hydrographs of the background water levels are provided in **Appendix C**. To confirm well integrity, hydrostratigraphy, and presence of the Sandstone aquifer confining unit at each site, geophysical logs (electric, dual induction, natural gamma, and video) were run on the four Sandstone aquifer wells (C-689, C-1073, L-1977, and L-2187). The electric, dual induction, and natural gamma logs are provided in **Appendix D**.

Aquifer Performance Tests

A series of constant-rate APTs were conducted on May 3 and 4, 2016 at the Collier County site, and on May 17 and 18, 2016 at the Lee County site. Each zone (clastic and carbonate) of the Sandstone aquifer was pumped separately at each site while all wells were monitored for water levels. A variety of pumps were available for the APTs; the specific pump type (submersible or centrifugal) and size used for each APT was determined based on anticipated pumping rate, anticipated drawdown during the test, and well diameter of each pumped well. A totalizing flowmeter was used to manage and record discharge rates. Water levels were collected using an In-Situ™ Virtual Hermit Aquifer Testing Kit, which allowed for simultaneous management of multiple data loggers during the pumping and recovery phases of the APTs.

Collier County Site APT

The carbonate zone of the Sandstone aquifer at this site was pumped on May 3, 2016. Well C-689 was pumped at a rate of 45 gallons per minute (gpm) for a period of approximately 8.5 hours (9:30 a.m. to 5:56 p.m.). Water was discharged to a dry roadside swale approximately 60 ft from the pumped well. Examination of the water level data showed that recharge from the swale did not affect the test due to the confining layer overlying the Sandstone aquifer and the relatively short duration of the test. After pumping was terminated, recovery water levels were recorded for more than an hour, ending at 7:13 p.m. Maximum drawdown in the pumped well was approximately 16.9 ft. The well recovered to within 2 ft of background levels when data collection was terminated and the pumping and monitoring equipment was removed. Manual water level readings in all the wells were taken periodically throughout the pumping and recovery phases.

A plot of water levels obtained during the APT (**Figure 24**) shows drawdown in the pumped carbonate zone well (C-689) and in the clastic zone monitor well (C-1073). Drawdown in the water table monitoring well is not shown because water levels in that well fluctuated less than 0.1 ft during the test. Based on the specific capacity of the well (45 gpm ÷ 16.9 ft = 2.7 gpm), transmissivity was estimated at 722 ft^2/day. This value is considered low due to the partial penetration of the pumped well.

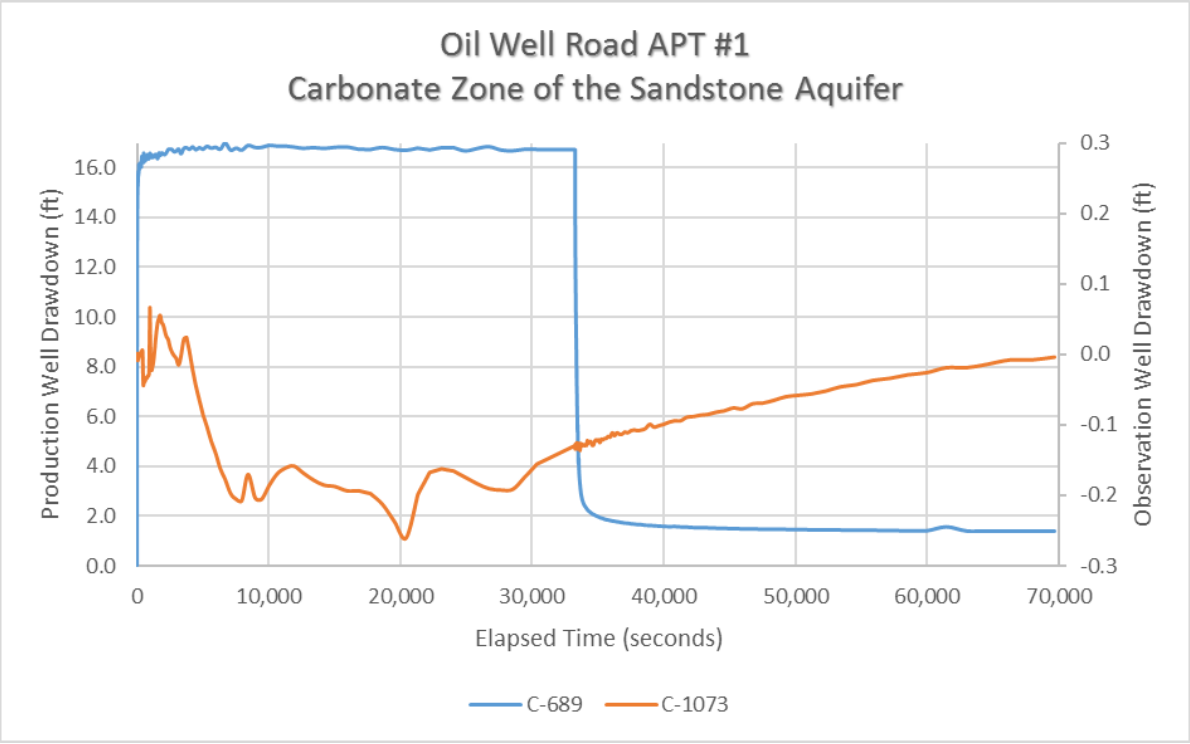


Figure 24. Drawdowns from the carbonate zone aquifer performance test at the Collier County site.

Figure 25 illustrates the Cooper-Jacob (1946) solution for the pumped well for this test data. In this analysis, the data between 239 and 10,000 seconds (approximately 4 and 166 minutes) were used because they represent the time after the initial borehole storage was removed and before the water levels in the pumped well showed minor recovery. Analysis of the data during this time period results in a transmissivity value of 2,292 ft^2/day and a storage value of 1.0E-20. This transmissivity value is considered high because the data show that the producing zone is responding as a leaky aquifer. Therefore, the transmissivity value for the carbonate zone probably is between these two extremes (722 and 2,292 ft^2/day). The storage value obtained from this analysis is not accurate due to the effects of borehole storage and partial penetration of the wells.

Figure 26 represents a Moench (1997) solution for leaky aquifers. This analysis results in a transmissivity value of 1,215 ft^2/day, which is within the range estimated earlier. A storage value of 0.0005 is estimated from this analysis. Leakance values estimated from this analysis are not considered reasonable because the resulting vertical hydraulic conductivity appears to be much larger than the horizontal hydraulic conductivity at the site.

The clastic zone of the Sandstone aquifer at the Collier County site was pumped on May 4, 2016. C-1073 was pumped at a rate of 30 gpm for approximately 3 hours (9:00 a.m. to 11:59 a.m.). Water was discharged to a dry roadside swale approximately 192 ft from the pumped well. Recovery water levels were recorded for 24 minutes, commencing at shutdown of the pump and ending at 12:23 p.m. Maximum drawdown in the pumped well was approximately 21 ft, which occurred 49 minutes into the test. Water levels in the pumped well recovered slightly after this time through the duration of pumping, and the well recovered to background levels almost immediately upon cessation of pumping. The well developed some sand during the test, which may have caused the check valve on the suction hose to malfunction, resulting in immediate recovery and possibly some inaccuracy in the flowmeter readings. Manual water level readings in all the wells were taken periodically throughout the pumping and recovery phases to confirm the electronically recorded data.

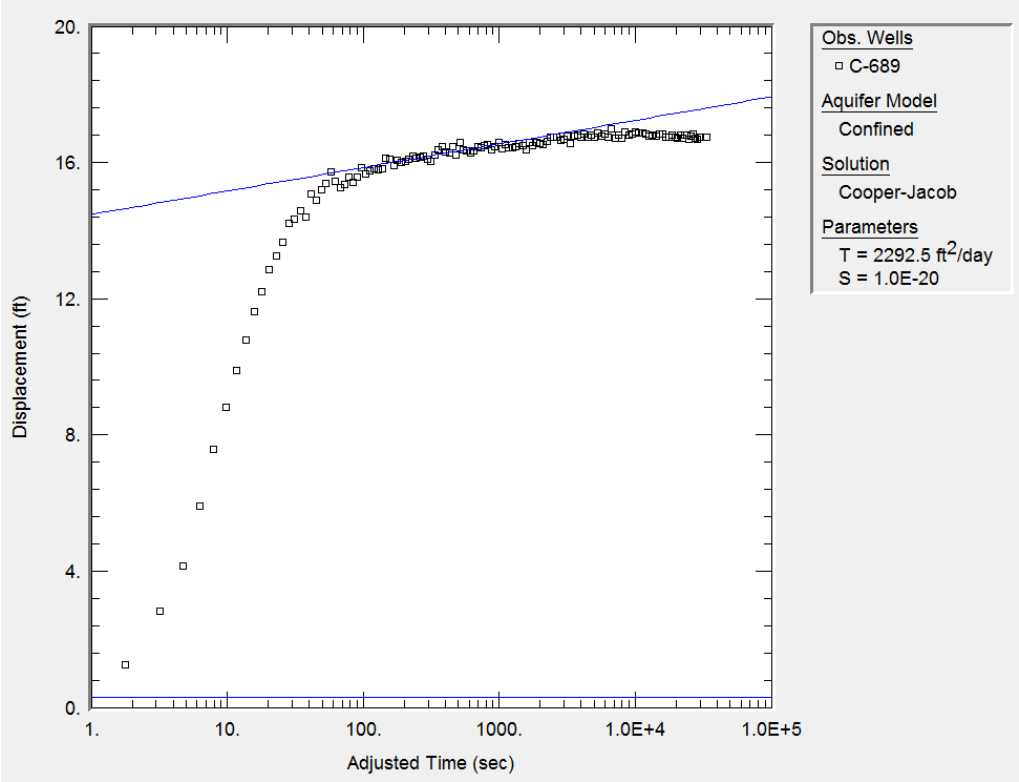


Figure 25. Cooper-Jacob (1946) solution for the carbonate zone aquifer performance test at the Collier County site.

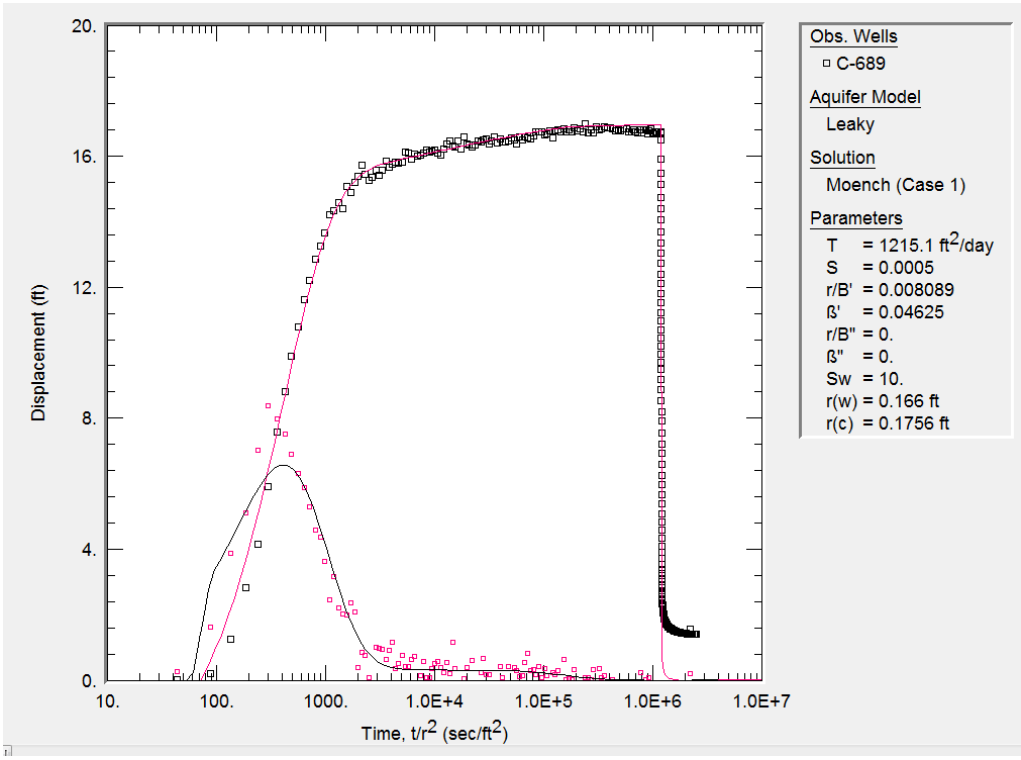


Figure 26. Moench (1997) solution for the carbonate zone at the Collier County site (C-689 pumped well, C-1073 observation well).

Figure 27 shows the drawdowns obtained from the pumped (C-1073) and monitor (C-689 and C-503) wells during the clastic zone APT at the Collier County site. The slight recovery in the pumped well can be seen, along with the instantaneous recovery thought to be caused by a malfunction in the check valve. Also, the somewhat unusual response of C-689 is shown where it exhibited steady drawdown from the beginning of the test through approximately 100 minutes, and then began an almost symmetrical recovery while the test well was still being pumped. The clastic zone transmissivity estimated from the specific capacity of the pumped well was 375 ft^2/day.

Figure 28 represents a Moench (1997) solution for leaky aquifers. This analysis results in a transmissivity value of 1,215 ft^2/day, which is reasonably close to the specific capacity estimate. Some issues with these data and analyses include that the drawdown curve is linear for only the first 10 seconds of the test, and that the distribution of the data (shape of the curve) implies the tested zone may have been behaving like an unconfined aquifer.

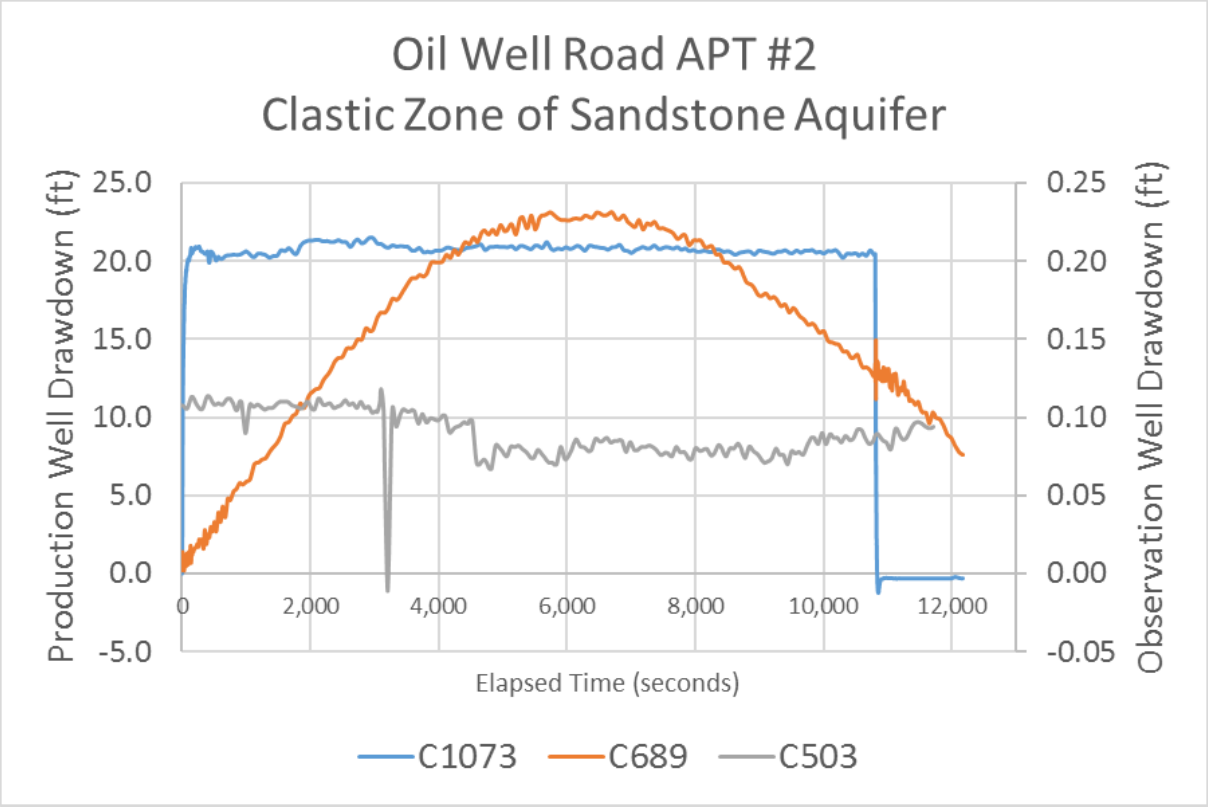


Figure 27. Drawdowns from the clastic zone aquifer performance test at the Collier County site.

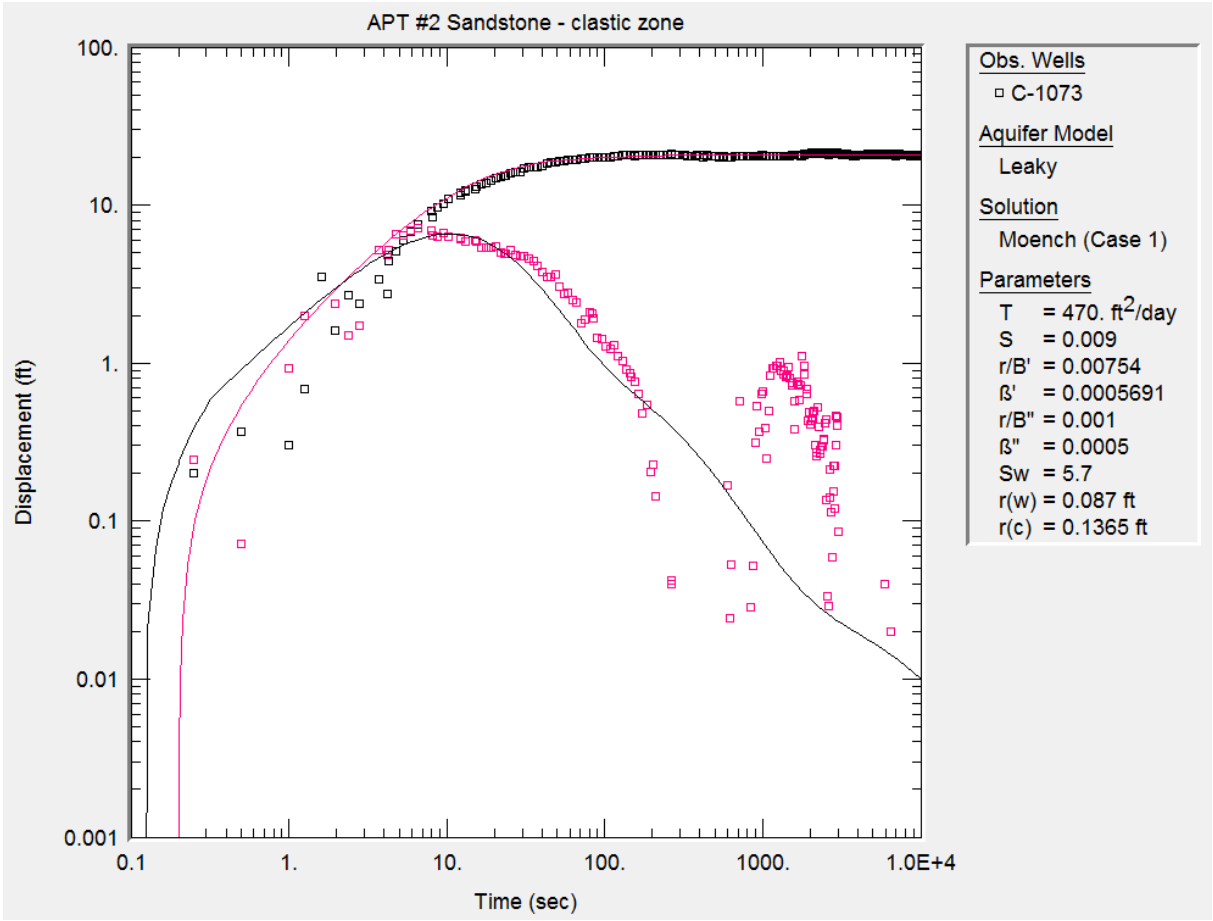


Figure 28. Moench (1997) solution for the clastic zone at the Collier County site (C-1073 pumped well, C-689 observation well).

Lee County Site APT

The carbonate zone of the Sandstone aquifer at the Lee County site was pumped on May 17, 2016. Well L-2187 was pumped at an approximate rate of 74 gpm for approximately 8 hours (8:40 a.m. to 4:48 p.m.). Water was discharged to a dry roadside swale approximately 100 ft from the pumped well. Maximum drawdown in the pumped well was approximately 4.5 ft. After pumping terminated, water levels recovered to background conditions by 6:32 p.m. Manual water level readings in all the wells were taken periodically throughout the pumping and recovery phases.

A plot of water levels obtained during this APT (**Figure 29**) shows drawdowns in the pumped well (L-2187), the clastic zone monitor well (L-727), and the water table monitor well (L-1137). This test appeared to produce the most useful data of the four tests performed, so more analyses were conducted with these data. **Figure 30** shows a Theis (1935) solution for the recovery data for pumped well L-2187. This analysis yields a transmissivity value of 4,441 ft^2/day, not accounting for the partial penetration of the test well. **Figure 31** shows a Cooper-Jacob (1946) solution for the recovery data for pumped well L-2187, which yields a transmissivity value of 4,700 ft^2/day and a storage value of 0.000575, basing the analysis on two log cycles of recovery data from 10 to 1,000 seconds. **Figure 32** shows a Moench (1997) analysis that uses the above transmissivity and storage values to calculate the leakance value. Assuming all leakance comes from above and no well skin, the leakance value calculated from this analysis is 0.022/day, and the vertical hydraulic conductivity value is 0.44 ft/day.

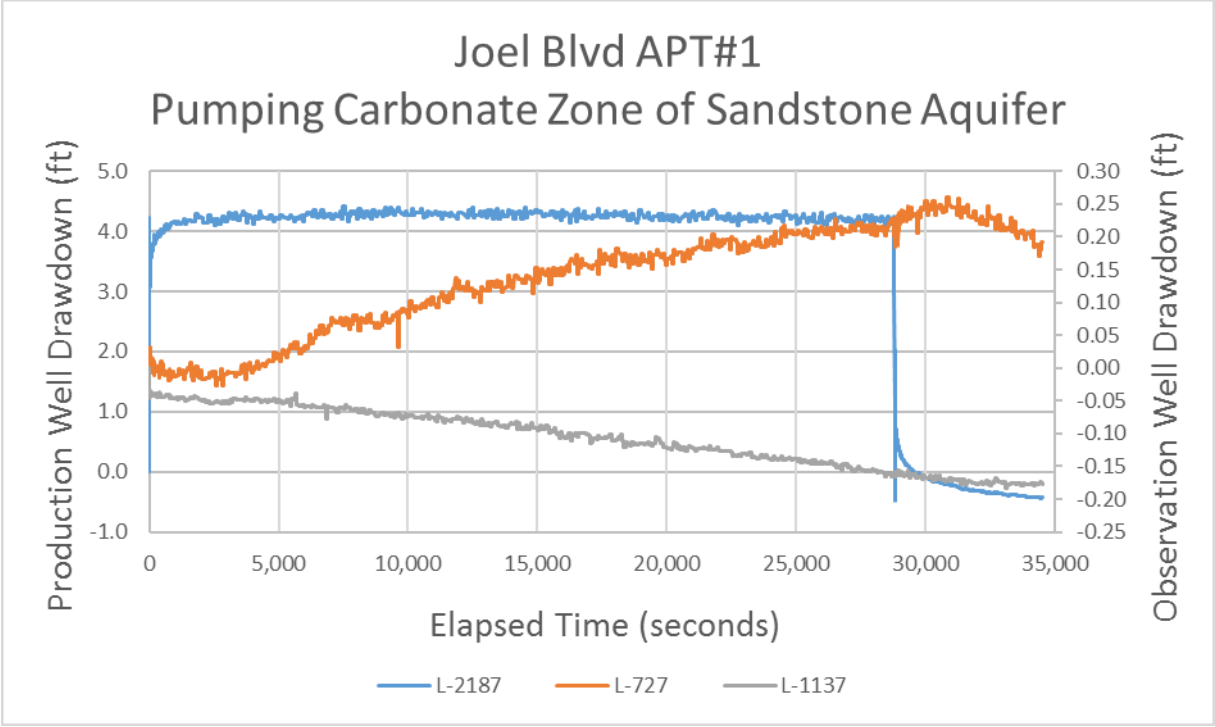


Figure 29. Drawdowns from the carbonate zone aquifer performance test at the Lee County site.

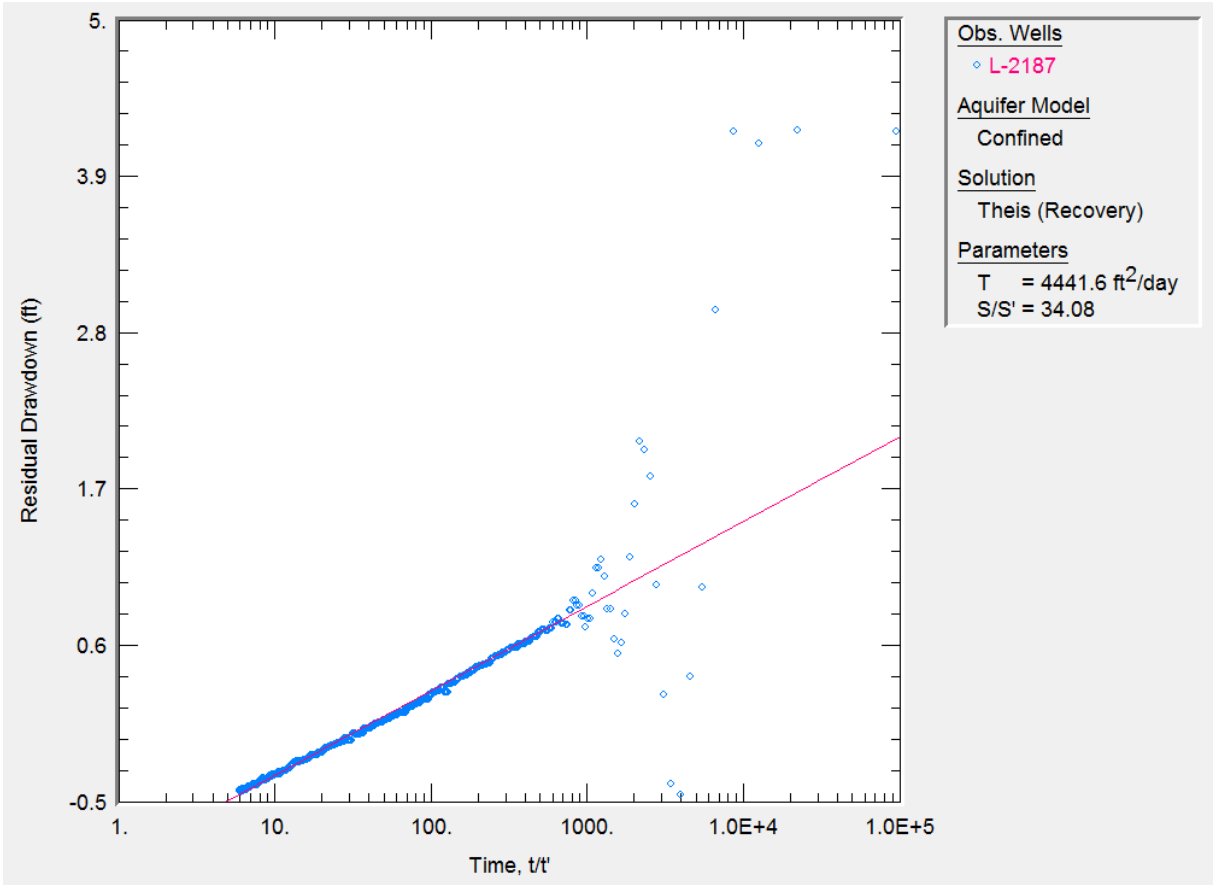


Figure 30. Theis (1935) solution for the recovery data from pumped well L-2187 at the Lee County site.

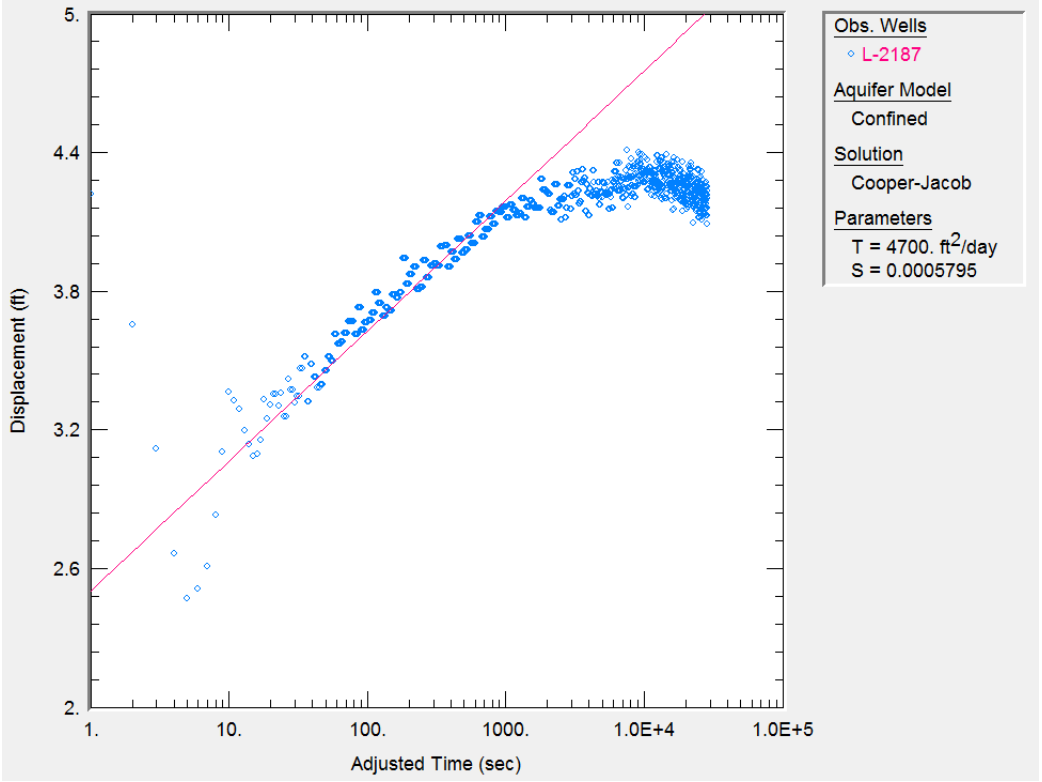


Figure 31. Cooper-Jacob (1946) solution for the recovery data at the Lee County site.

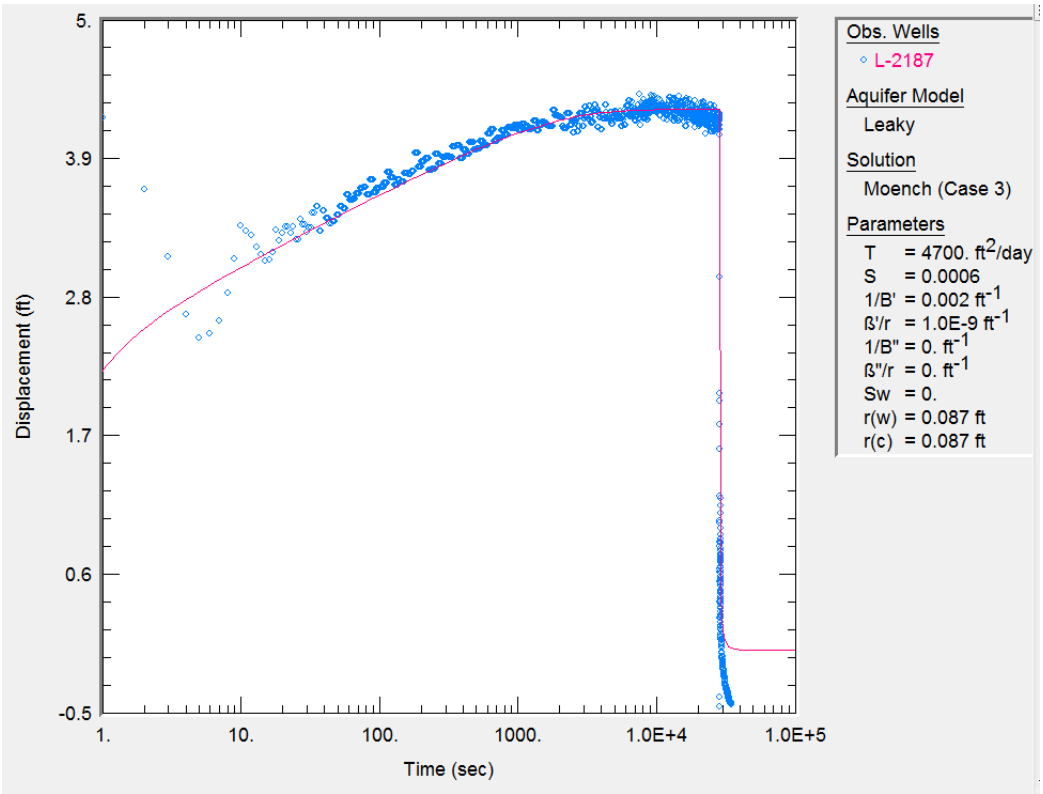


Figure 32. Moench (1997) solution for the carbonate zone aquifer performance test at the Lee County site (L-2187 pumped well, L-727 observation well).

The clastic zone of the Sandstone aquifer at the Lee County site was pumped on May 18, 2016. L-727 was pumped at a rate of 5 gpm for approximately 1.5 hours (10:11 a.m. to 11:25 a.m.). An obstruction in the well casing and the low productivity of the well limited the pump type that could be used and the pumping rate. Water was discharged to the ground approximately 20 ft from the pumped well. Maximum drawdown in the pumped well was approximately 30 ft and recovered to background conditions soon after pumping stopped. This pumping test may have been impacted by an overnight rainfall event prior to the test.

Figure 33 shows drawdowns from the clastic zone APT at the Lee County site. Only a Cooper-Jacob (1946) analysis could be applied using these data (**Figure 34**). Transmissivity and storage values estimated from these data are not considered reliable because the borehole storage associated with the low pumping rate (5 gpm) was not accounted for, the well only had partial penetration, less than one full log cycle of linear drawdown data was obtained, and there was a rainfall event the evening before the test.

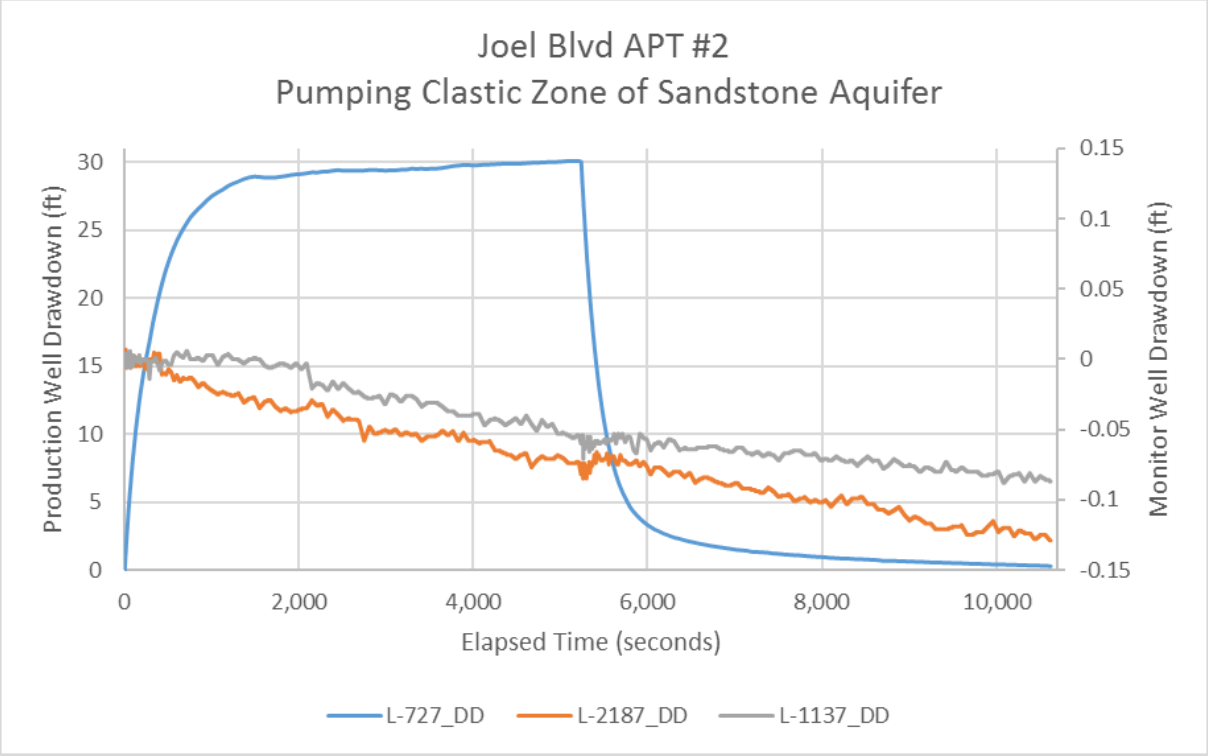


Figure 33. Drawdowns from the clastic zone aquifer performance test at the Lee County site.

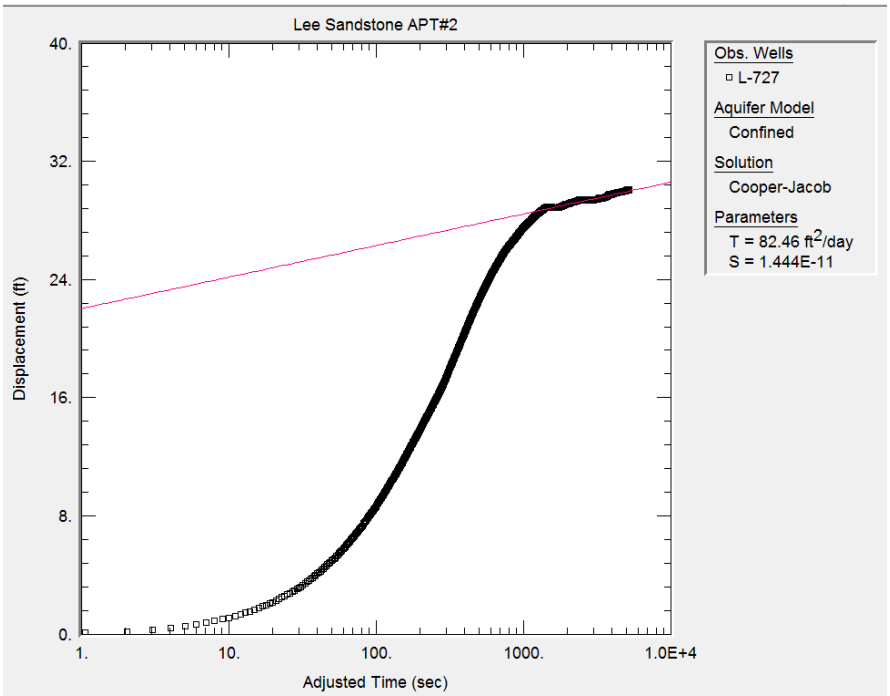


Figure 34. Cooper-Jacob (1946) solution for the clastic zone aquifer performance test at the Lee County site (L-727 pumped well).

WATER QUALITY SAMPLING

Groundwater in all wells at both sites was sampled during the APTs and analyzed for field parameters (e.g., temperature, pH, conductivity) as well as common cations and anions. All water quality parameters were within historical ranges for wells completed in the study area aquifers. Water quality in the aquifers at the Collier County site appeared to be more stratified than the Lee County site (i.e., there are greater differences in water quality at the southern site). This is particularly evident in the sulfate and total dissolved solids data. Water quality data from the Lee County and Collier County sites are summarized in **Tables 1** and **2**, respectively. More complete information regarding the results of the water quality sampling and analyses is provided in **Appendix E**.

Table 1. Water quality data from the Lee County aquifer performance test site.

Parameter	L-1137	L-727	L-2187	Units
Alkalinity, Total, $CaCO_3$	225	260	221	mg/L
Calcium	88.2	132.4	108.9	mg/L
Sodium	8.9	81	220.3	mg/L
Hardness, as $CaCO_3$	256.4	483.3	465.5	mg/L
Potassium	0.3	3.6	11.2	mg/L
Chloride	13.6	179	385	mg/L
Magnesium	8.8	37.1	47	mg/L
Silica	5.46	57.5	28.3	mg/L
Total Dissolved Solids	270	801	1168	mg/L
Strontium, Dissolved	280	1100	2110	ug/L
pH, Field	7	6.9	7	
Specific Conductivity, Field	483	1356	1952	uS/cm
Sulfate	15.7	126	175	mg/L

Table 2. Water quality data from the Collier County aquifer performance test site.

Parameter	C-503	C-1073	C-689	C-684	units
Alkalinity, Total, $CaCO_3$	261	389	260	211	mg/L
Hardness, as $CaCO_3$	299.3	434.9	241.6	1004.9	mg/L
Potassium	10.1	2.2	11	41.2	mg/L
Sodium	21.6	26.8	56.8	382.6	mg/L
Strontium, Dissolved	311	664	424	174	ug/L
Magnesium	8.4	13.2	24.1	2130	mg/L
Calcium	106	152.5	57	111.7	mg/L
Chloride	42	64.4	76.6	138	mg/L
Silica	8.93	17.3	23.5	23.2	mg/L
Total Dissolved Solids	384	566	404	2507	mg/L
Specific Conductivity, Field	650	899	715	3048	uS/cm
pH, Field	6.8	6.8	7.2	7.5	
Temp	25	24.6	25.3	25.4	mg/L
Sulfate	4.9	5.2	2.8	1278	mg/L

SUMMARY

The SFWMD selected two sites in Lee and Collier counties to conduct APTs in order to characterize the leakance of the Sandstone aquifer confining unit in support of the LWCSIM update. Many existing well clusters were evaluated, and two sites were selected for further testing, one in Lee County and one in Collier County. Due to variability at the sites and the pump tests, the Lee County site yielded more useful data than the Collier County site. The APTs at the Lee County site yielded a leakance value of 0.022/day, which translates to a vertical hydraulic conductivity value of 0.44 ft/day. Water quality data and geophysical logs were collected at both sites to further characterize the groundwater resources of the area. All data collected from both locations were consistent with regional trends and previously published data.

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APPENDICES

APPENDIX A
FIELD NOTES AND PHOTOS FROM SITE INSPECTIONS

Well ID	L-1977
Latitude/Longitude	264321.2/813656.3
Notes	• Well located in residential yard – a lot closer to SR78 than coordinates map it to • 4-inch PVC casing cemented inside 6- or 8-inch PVC • Measured depth at 138 ft (database says 185) • 2-inch well adjacent (2-inch PVC casing inside 6-inch PVC) • 2-inch casing broken off and filled with sand • No obvious discharge point for APT

Well ID	L-2187
Latitude/Longitude	263951.3/813553.3
Notes	• Well on east side of Joel Blvd, not west as coordinates indicate • 3 wells on site o One with a recorder platform but no recorder – measured as 20 ft deep o One with recorder box, depth not measured o One with no recorder or platform, measured depth 155 ft • No swale for APT discharge

Well ID	W-50029
Latitude/Longitude	264259.2/812756.3
Notes	• Property under construction and posted, no access to site

Well ID	W-50042
Latitude/Longitude	264449.2/812615.3
Notes	• No sign of well at coordinates • Site is a busy intersection in LaBelle, utilities everywhere

Well ID	HE-555
Latitude/Longitude	263846.3/812606.3
Notes	• Two wells and additional enclosure found at site (Sears Rd and SR29) • All locked or have data platform installed so wells not measured • Large canal available for APT discharge

Well ID	HE-529
Latitude/Longitude	263311.1/812509
Notes	• Well past end of paved road where slight bend to the east, before locked gate, completely overgrown, very hard to see • Well on left (west) side of road. Well is completely engulfed by palmetto. Has recorder box on it, probably no recorder inside • Second well found, 4-inch steel casing, measured depth at 16 ft (HE-554?) • Another casing in ground, looks like bollard, not well

Well ID	C2055
Latitude/Longitude	262510.3/812236.3
Notes	• Well not found at coordinates • C-298 found just to the east of coordinates across from Collier Enterprises technology park • 200-foot tape did not touch bottom • 4-inch PVC cemented in galvanized pipe • No info in database found (yet)

Well ID	C2054
Latitude/Longitude	262603.3/812700.3
Notes	• Well behind fence at Immokalee water or sewer plant – not accessible to be measured • No discharge site for APT (residential area, no swales or storm sewers seen)

Well ID	L-2215
Latitude/Longitude	263129.2/812515.9
Notes	• Three wells found on site • All have recorders • Two appear to be 4-inch • Roadside swale probably OK for APT discharge but road construction looks pending

Well ID	L-1625
Latitude/Longitude	263330.3/813942.3
Notes	• Road and site being developed • What appeared to be the remains of the well were found on the side of the road

Well ID	W-10472
Latitude/Longitude	262757.3/814222.3
Notes	• Site is active Youngquist rock mine – gated, locked, and posted • Scouted location from road, no sign of well seen

Well ID	L-1981
Latitude/Longitude	263738.3/814532.3
Notes	• Site is corkscrew wellfield – gated, locked, and posted • Well not found

Well ID	L-1835
Latitude/Longitude	262707.3/814353.3
Notes	• Well pushed over, broken off, and loose

Well ID	W-16942
Latitude/Longitude	262014.3/813952.3
Notes	• Road impassible about 1 mile from site (flooded) • Well not found

Well ID	L-1984
Latitude/Longitude	262714.3/814145.3
Notes	• Well found at coordinates • Has recorder box on it • Well pushed over a bit • L-1996 in same location but not found (check both wells to make sure we know which is which)

Well ID	W-15530
Latitude/Longitude	261734.3/812854.3
Notes	• Found 4 wells on south side of Oil Well Road, just east of oil well grade • Two were labeled (C-985 and C-989) • One had a valve on it (flowing? Lower Hawthorn or Floridan?) • C-985: 8-inch PVC measured 166 ft deep • C-989: 8-inch PVC measured over 200 ft deep – well tag AAC4794 • 8-inch PVC well measured 45 ft deep – two tags on well, GPS tag AI1714, District tag C-00984?

Well ID	C-2060
Latitude/Longitude	261842.3/813831.3
Notes	• Site flooded and inaccessible – well not found at coordinates • However, two wells seen at entrance to Bird Rookery Swamp entrance, ~0.25 miles to the east • No labels on wells • 4-inch PVC cemented in 10-inch? PVC measured 118 ft deep • Other well 2-inch cemented in 12-inch casing, valved (flowing?) – also 2-inch access port to annular space measured ~95 ft deep

Well ID	L-5668
Latitude/Longitude	262514.3/814717.3
Notes	• Two wells found on SW corner of intersection – not NE as coordinates indicate • No markings on wells • Both have locked caps • Both 4-inch PVC cemented inside 10- to 12-inch PVC • Swale/storm sewer inlet good for APT

Well ID	L-2183
Latitude/Longitude	262709/814252
Notes	• Coordinates not precise • Two wells found a couple tenths of a mile east of coordinates at NE corner of new development (Corkscrew Shores) • Wells marked G-I and G-II • Looks like USGS construction – 4-inch steel cemented in 8- or 10-inch PVC • G-II had what appeared to be sampling apparatus hanging in it • No depths measured

Well ID	L-5664
Latitude/Longitude	262515.3/813933.3
Notes	• Site gated and posted – well not found • Shallow well found around “corner” by stop sign on Arby Rd • 4-inch PVC measured at 35 ft deep • Photo missing – must have accidentally deleted

Well ID	L-2192
Latitude/Longitude	262700.3/813824.3
Notes	• Well found at coordinates • 4-inch PVC cemented inside 8-inch PVC • Locked well cap – depth not measured • 4-inch PVC flush with ground adjacent filled with dirt

Well ID	L-614
Latitude/Longitude	262703/813358
Notes	• Coordinates not precise • Well not found

Well ID	L-615
Latitude/Longitude	262702/813642
Notes	• Coordinates not precise • 4 wells found; 2 have markings • C-1138, 4-inch steel, measured depth 12 ft • L-2313, flower with spigot • One well has recorder, no access to measure depth • Last well looks destroyed • Site swale looks OK for APT discharge

Well ID	L-2186
Latitude/Longitude	263344.5/813616.2
Notes	• 4 wells found on site, all 4-inch steel cemented in 8-inch PVC • L-1963 measured depth 73 ft • One well flower with valve • Last well couldn't remove cap to measure depth • No obvious place for APT discharge

Wells not included in recon:

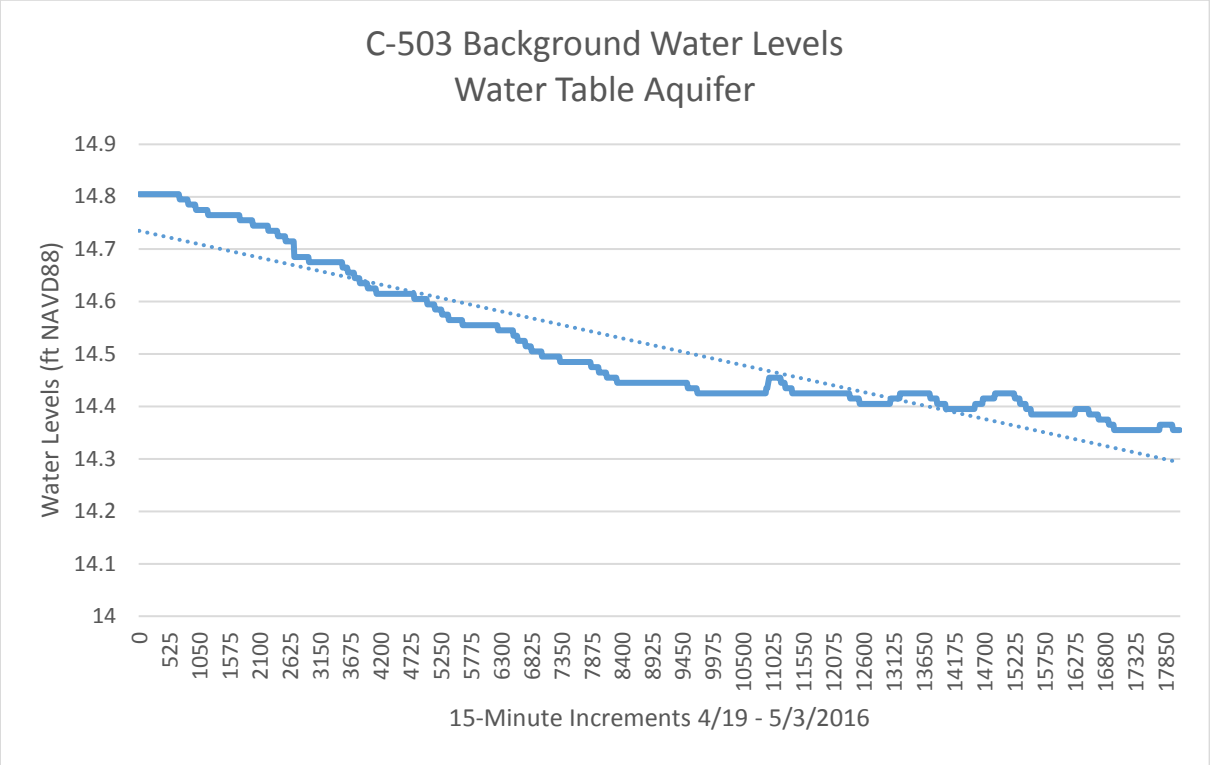
W-18075	Far from area of interest, no access
W-18069	Far from area of interest, no access
L-646	Far from area of interest, minimal SSA
L-648	Far from area of interest, minimal SSA
W-17534	Extremely remote, no access
HE-1116	Very far east
HE-1110	Very far east
CR00032	Far from area of interest
W-14919	Far from area of interest
HY00006	Far from area of interest
CR00062	Remote, not accessible
CR00047	USGS wells being destroyed/replaced along Golden Gate Blvd
W-15557	Well in lake in development
L-603	Far from area of interest in developed subdivision
W-18071	Well plots in Caloosahatchee River – no well apparent in aerials on either shore
WA-25	Well has very precise coordinates that plot under tennis courts – possibly worth a look

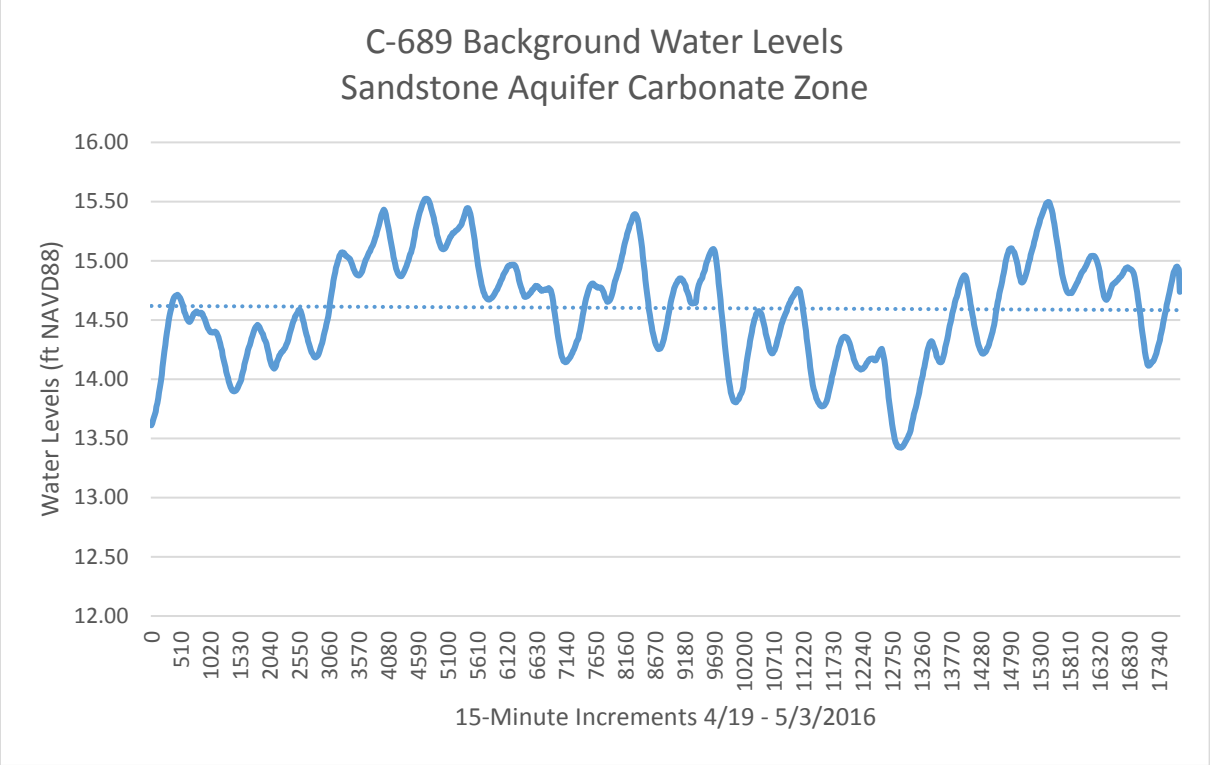
APPENDIX B
SURVEY REPORTS

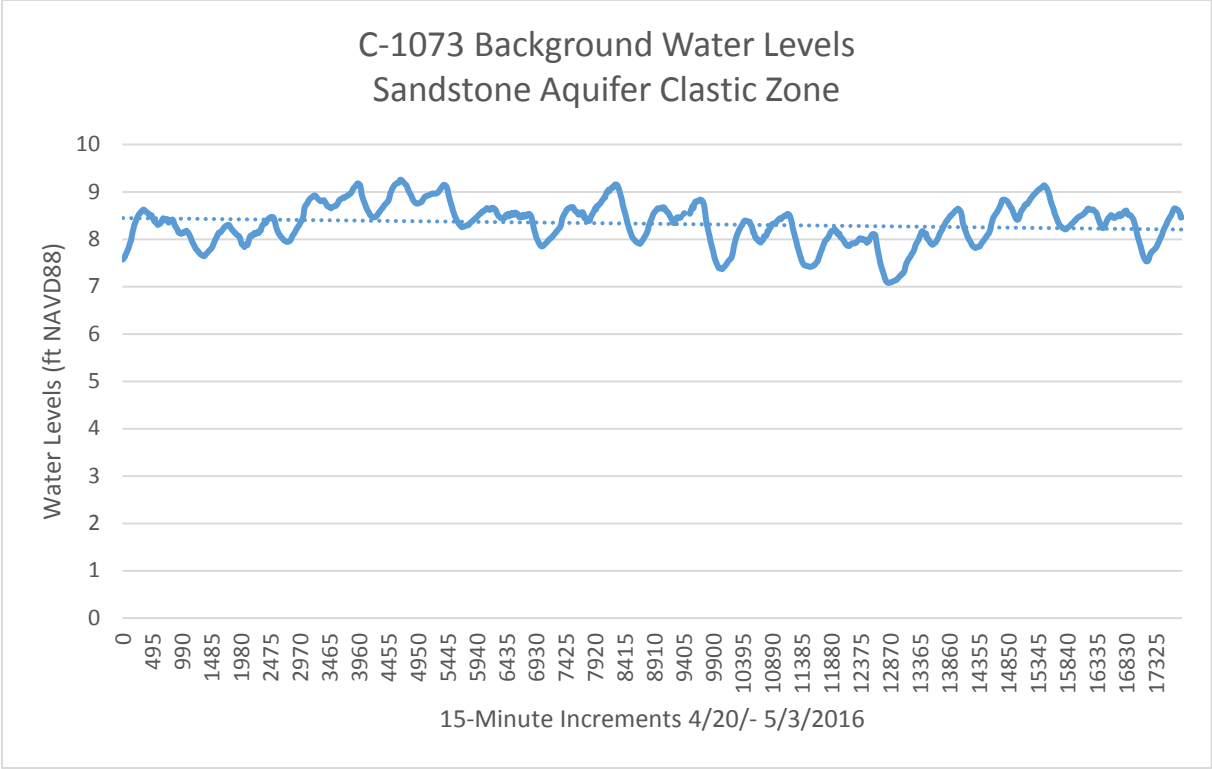
Lee County APT Site Survey Report

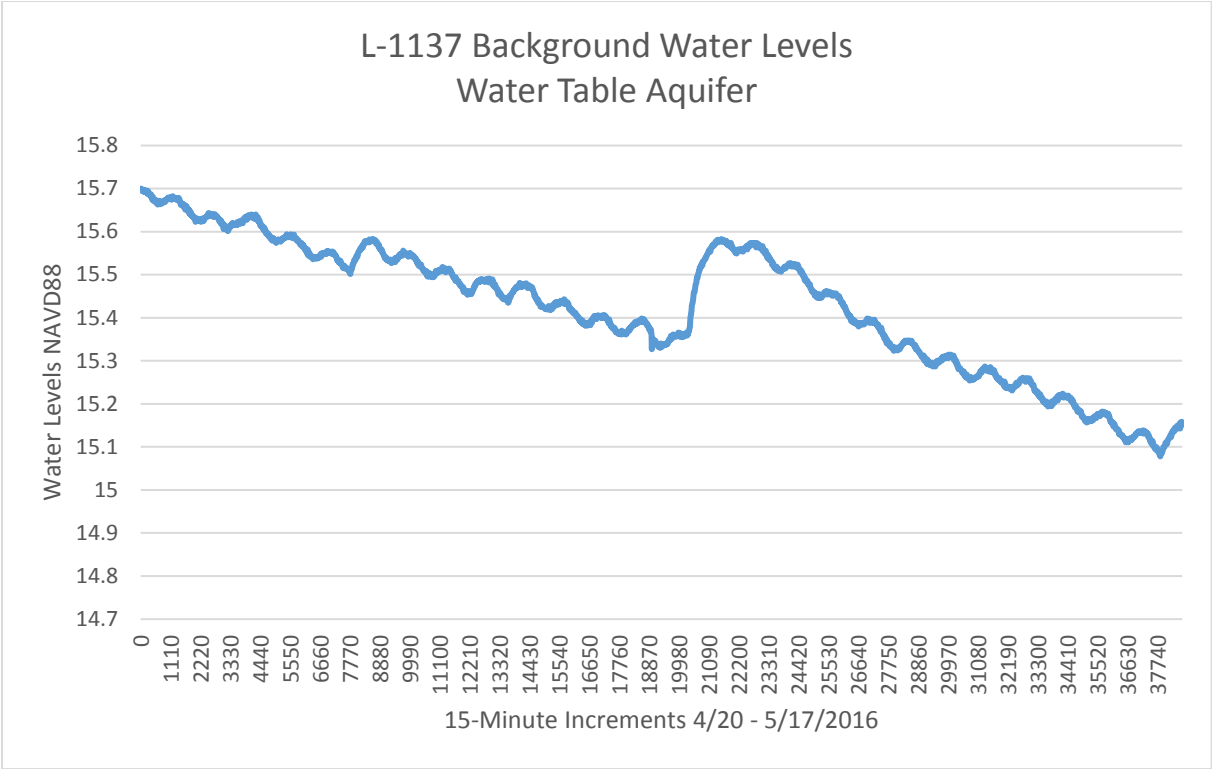
Collier County APT Site Survey Report

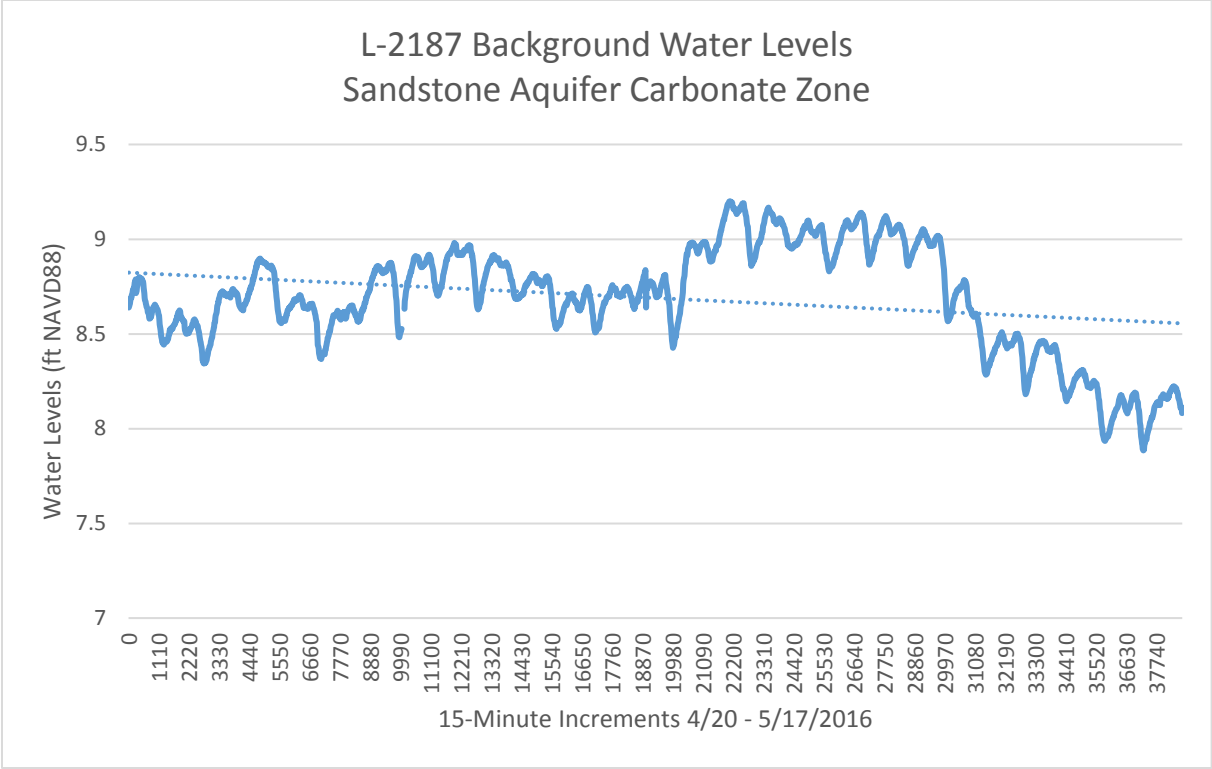
APPENDIX C
BACKGROUND WATER LEVELS

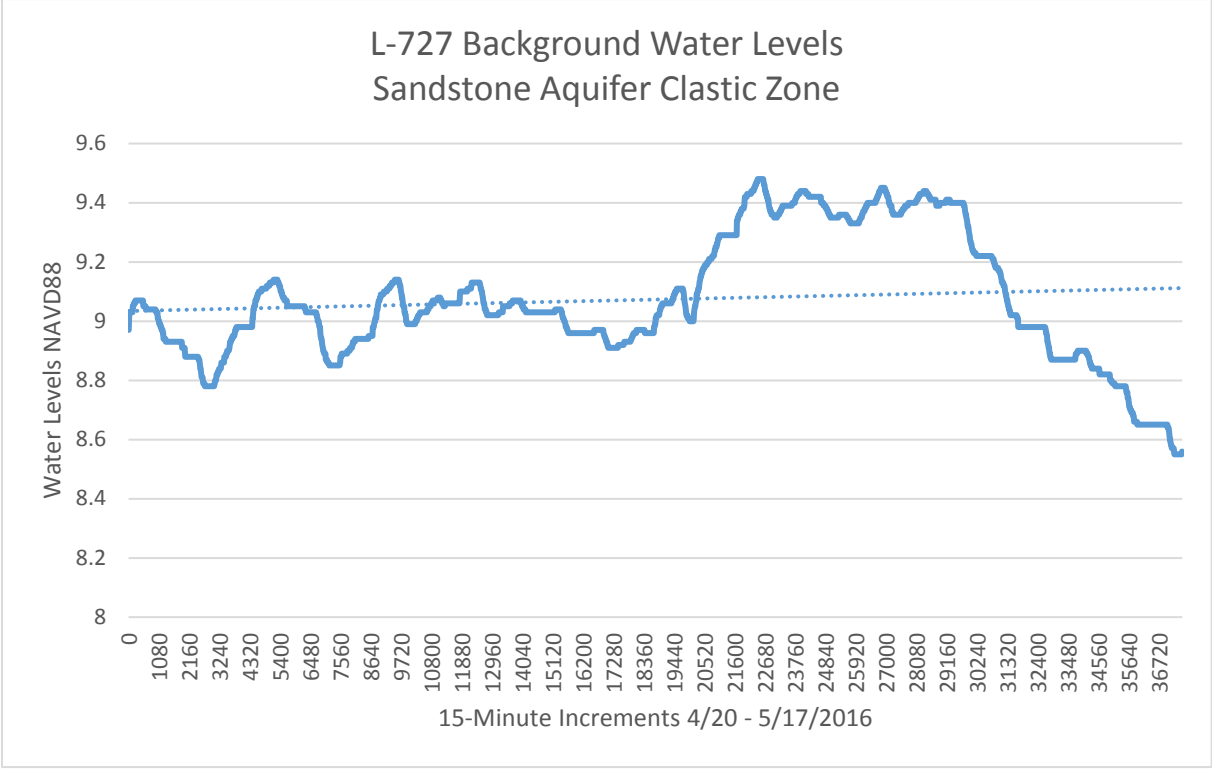





C-1073 Background Water Levels
Sandstone Aquifer Clastic Zone
Water Levels (ft NAVD88)
10
9
8
7
6
5
4
3
2
1
0
0
495
990
1485
1980
2475
2970
3465
3960
4455
4950
5445
5940
6435
6930
7425
7920
8415
8910
9405
9900
10395
10890
11385
11880
12375
12870
13365
13860
14355
14850
15345
15840
16335
16830
17325
15-Minute Increments 4/20/- 5/3/2016


L-1137 Background Water Levels
Water Table Aquifer
Water Levels NAVD88
15.8
15.7
15.6
15.5
15.4
15.3
15.2
15.1
15
14.9
14.8
14.7
0
1110
2220
3330
4440
5550
6660
7770
8880
9990
11100
12210
13320
14430
15540
16650
17760
18870
19980
21090
22200
23310
24420
25530
26640
27750
28860
29970
31080
32190
33300
34410
35520
36630
37740
15-Minute Increments 4/20 - 5/17/2016


L-2187 Background Water Levels
Sandstone Aquifer Carbonate Zone
Water Levels (ft NAVD88)
9.5
9
8.5
8
7.5
7
0
1110
2220
3330
4440
5550
6660
7770
8880
9990
11100
12210
13320
14430
15540
16650
17760
18870
19980
21090
22200
23310
24420
25530
26640
27750
28860
29970
31080
32190
33300
34410
35520
36630
37740
15-Minute Increments 4/20 - 5/17/2016


L-727 Background Water Levels
Sandstone Aquifer Clastic Zone
Water Levels NAVD88
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
0
1080
2160
3240
4320
5400
6480
7560
8640
9720
10800
11880
12960
14040
15120
16200
17280
18360
19440
20520
21600
22680
23760
24840
25920
27000
28080
29160
30240
31320
32400
33480
34560
35640
36720
15-Minute Increments 4/20 - 5/17/2016

APPENDIX D
GEOPHYSICAL LOGS

APPENDIX E
WATER QUALITY INFORMATION

Table E-1. Water quality information for station C-503.

Test Number	Test Name	Storet Code	Method	Measure Date	Value*	Sig. Fig. Value	Uncertainty	MDL	PQL	RDL
67	Alkalinity, Tot, $CaCO_3$	410	SM2320B	5/20/2016 8:17	261	261	±27	1	4	1
30	Calcium	915	SM3120B	5/31/2016 12:30	106	106	±9.3	0.3	1	0.3
32	Chloride	941	SM4110B	5/23/2016 11:52	42	42	±2.0	0.1	0.4	0.1
35	Hardness as $CaCO_3$	905	SM3120B	5/31/2016 12:30	299.3	299	±15.6	1	4	1
31	Magnesium	925	SM3120B	5/31/2016 12:30	8.4	8.4	±0.6	0.1	0.4	0.1
10	pH, Field (no units)	400	SFWMD-FSQM	5/17/2016 12:08	6.8	6.8	N/A	N/A	N/A	N/A
29	Potassium	935	SM3120B	5/31/2016 12:30	10.1	10.1	±0.8	0.1	0.4	0.1
27	Silica	955	SFWMD 3120	5/31/2016 14:13	8.93	8.93	±0.48	0.05	0.2	0.05
28	Sodium	930	SM3120B	5/31/2016 12:30	21.6	21.6	±1.6	0.4	1	0.4
9	Specific Conductivity, Field (µS/cm)	94	SFWMD-FSQM	5/17/2016 12:08	650	650	N/A	N/A	N/A	N/A
53	Strontium, Dissolved (µg/L)	1080	SM3120B	6/21/2016 9:58	311	311	±19.6	0.3	0.6	0.3
33	Sulfate	946	SM4110B	5/23/2016 11:52	4.9	4.9	±0.2	0.1	0.4	0.1
7	Temperature (°C)	10	SFWMD-FSQM	5/17/2016 12:08	25	25	N/A	N/A	N/A	N/A
97	Total Dissolved Solids	515	SM2540C	5/23/2016 13:36	384	380	±52	22	88	22

* All values reported in mg/L unless noted otherwise.
Additional information: Sample ID = P84183-4; Collection Date and Time = 5/17/2016 12:08; Receive Date and Time = 5/19/2016 15:58; LIMS Number = 56470004.
MDL = method detection limit; N/A = not applicable; PQL = practical quantification limit; RDL = reporting detection limit.

Table E-2. Water quality information for station C-684.

Test Number	Test Name	Storet Code	Method	Measure Date	Value*	Sig. Fig. Value	Uncertainty	MDL	PQL	RDL
67	Alkalinity, Tot, $CaCO_3$	410	SM2320B	5/20/2016 8:25	211	211	±22	1	4	1
30	Calcium	915	SM3120B	5/31/2016 12:32	111.7	111.7	±9.8	0.3	1	0.3
32	Chloride	941	SM4110B	5/23/2016 12:07	138	138	±6.5	0.1	0.4	0.1
35	Hardness as $CaCO_3$	905	SM3120B	5/31/2016 12:32	1,004.9	1,005	±52.3	1	4	1
31	Magnesium	925	SM3120B	5/31/2016 15:15	174	174	±12.4	0.4	1.6	0.4
10	pH, Field (no units)	400	SFWMD-FSQM	5/17/2016 11:25	7.5	7.5	N/A	N/A	N/A	N/A
29	Potassium	935	SM3120B	5/31/2016 15:15	41.2	41.2	±3.3	0.4	1.6	0.4
27	Silica	955	SFWMD 3120	5/31/2016 14:14	23.2	23.2	±1.23	0.05	0.2	0.05
28	Sodium	930	SM3120B	5/31/2016 15:15	382.6	382.6	±28.0	1.6	4	1.6
9	Specific Conductivity, Field (µS/cm)	94	SFWMD-FSQM	5/17/2016 11:25	3,048	3,048	N/A	N/A	N/A	N/A
53	Strontium, Dissolved (µg/L)	1080	SM3120B	6/21/2016 10:10	2,130	2,130.00	±134.2	1.2	2.4	1.2
33	Sulfate	946	SM4110B	5/23/2016 12:29	1,278	1,278	±47.3	2	8	2
7	Temperature (°C)	10	SFWMD-FSQM	5/17/2016 11:25	25.4	25.4	N/A	N/A	N/A	N/A
97	Total Dissolved Solids	515	SM2540C	5/23/2016 13:38	2,507	2,510	±309	22	88	22

* All values reported in mg/L unless noted otherwise.
Additional information: Sample ID = P84183-5; Collection Date and Time = 5/17/2016 11:25; Receive Date and Time = 5/19/2016 15:58; LIMS Number = 56470005.
MDL = method detection limit; N/A = not applicable; PQL = practical quantification limit; RDL = reporting detection limit.

Table E-3. Water quality information for station C-689.

Test Number	Test Name	Storet Code	Method	Measure Date	Value*	Sig. Fig. Value	Uncertainty	MDL	PQL	RDL
67	Alkalinity, Tot, $CaCO_3$	410	SM2320B	5/6/2016 10:24	260	260	±27	1	4	1
30	Calcium	915	SM3120B	5/19/2016 13:16	57	57	±5.0	0.3	1	0.3
32	Chloride	941	SM4110B	5/6/2016 11:29	76.6	76.6	±3.6	0.1	0.4	0.1
35	Hardness as $CaCO_3$	905	SM3120B	5/19/2016 13:16	241.6	242	±12.6	1	4	1
31	Magnesium	925	SM3120B	5/19/2016 13:16	24.1	24.1	±1.7	0.1	0.4	0.1
10	pH, Field (no units)	400	SFWMD-FSQM	5/3/2016 11:04	7.2	7.2	N/A	N/A	N/A	N/A
29	Potassium	935	SM3120B	5/19/2016 13:16	11	11	±0.9	0.1	0.4	0.1
27	Silica	955	SFWMD 3120	5/13/2016 10:04	23.5	23.5	±1.25	0.05	0.2	0.05
28	Sodium	930	SM3120B	5/19/2016 13:16	56.8	56.8	±4.2	0.4	1	0.4
9	Specific Conductivity, Field (µS/cm)	94	SFWMD-FSQM	5/3/2016 11:04	715	715	N/A	N/A	N/A	N/A
53	Strontium, Dissolved (µg/L)	1080	SM3120B	6/21/2016 10:01	424	424	±26.7	0.3	0.6	0.3
33	Sulfate	946	SM4110B	5/6/2016 11:29	2.8	2.8	±0.1	0.1	0.4	0.1
7	Temperature (°C)	10	SFWMD-FSQM	5/3/2016 11:04	25.3	25.3	N/A	N/A	N/A	N/A
97	Total Dissolved Solids	515	SM2540C	5/5/2016 14:14	404	400	±54	22	88	22

* All values reported in mg/L unless noted otherwise.
Additional information: Sample ID = P84182-2; Collection Date and Time = 5/3/2016 11:04; Receive Date and Time = 5/5/2016 12:26; LIMS Number = 56469002.
MDL = method detection limit; N/A = not applicable; PQL = practical quantification limit; RDL = reporting detection limit.

Table E-4. Water quality information for station C-1073.

Test Number	Test Name	Storet Code	Method	Measure Date	Value*	Sig. Fig. Value	Uncertainty	MDL	PQL	RDL
67	Alkalinity, Tot, $CaCO_3$	410	SM2320B	5/6/2016 10:54	389	389	±40	1	4	1
30	Calcium	915	SM3120B	5/19/2016 13:19	152.5	152.5	±13.4	0.3	1	0.3
32	Chloride	941	SM4110B	5/6/2016 11:45	64.4	64.4	±3.0	0.1	0.4	0.1
35	Hardness as $CaCO_3$	905	SM3120B	5/19/2016 13:19	434.9	435	±22.6	1	4	1
31	Magnesium	925	SM3120B	5/19/2016 13:19	13.2	13.2	±0.9	0.1	0.4	0.1
10	pH, Field (no units)	400	SFWMD-FSQM	5/4/2016 9:48	6.8	6.8	N/A	N/A	N/A	N/A
29	Potassium	935	SM3120B	5/19/2016 13:19	2.2	2.2	±0.2	0.1	0.4	0.1
27	Silica	955	SFWMD 3120	5/13/2016 10:07	17.3	17.3	±0.92	0.05	0.2	0.05
28	Sodium	930	SM3120B	5/19/2016 13:19	26.8	26.8	±2.0	0.4	1	0.4
9	Specific Conductivity, Field (µS/cm)	94	SFWMD-FSQM	5/4/2016 9:48	899	899	N/A	N/A	N/A	N/A
53	Strontium, Dissolved (µg/L)	1080	SM3120B	6/21/2016 10:03	664	664	±41.8	0.3	0.6	0.3
33	Sulfate	946	SM4110B	5/6/2016 11:45	5.2	5.2	±0.2	0.1	0.4	0.1
7	Temperature (°C)	10	SFWMD-FSQM	5/4/2016 9:48	24.6	24.6	N/A	N/A	N/A	N/A
97	Total Dissolved Solids	515	SM2540C	5/5/2016 14:18	566	570	±73	22	88	22

* All values reported in mg/L unless noted otherwise.
Additional information: Sample ID = P84182-4; Collection Date and Time = 5/4/2016 9:48; Receive Date and Time = 5/5/2016 12:26; LIMS Number = 56469004.
MDL = method detection limit; N/A = not applicable; PQL = practical quantification limit; RDL = reporting detection limit.

Table E-5. Water quality information for station L-727.

Test Number	Test Name	Storet Code	Method	Measure Date	Value*	Sig. Fig. Value	Uncertainty	MDL	PQL	RDL
67	Alkalinity, Tot, $CaCO_3$	410	SM2320B	5/20/2016 8:34	260	260	±27	1	4	1
30	Calcium	915	SM3120B	5/31/2016 12:41	132.4	132.4	±11.6	0.3	1	0.3
32	Chloride	941	SM4110B	5/23/2016 12:51	179	179	±8.4	0.1	0.4	0.1
35	Hardness as $CaCO_3$	905	SM3120B	5/31/2016 12:41	483.3	483	±25.2	1	4	1
31	Magnesium	925	SM3120B	5/31/2016 12:41	37.1	37.1	±2.6	0.1	0.4	0.1
10	pH, Field (no units)	400	SFWMD-FSQM	5/18/2016 11:05	6.9	6.9	N/A	N/A	N/A	N/A
29	Potassium	935	SM3120B	5/31/2016 12:41	3.6	3.6	±0.3	0.1	0.4	0.1
27	Silica	955	SFWMD 3120	5/31/2016 14:43	57.5	57.5	±3.05	0.1	0.4	0.1
28	Sodium	930	SM3120B	5/31/2016 12:41	81	81	±5.9	0.4	1	0.4
9	Specific Conductivity, Field (µS/cm)	94	SFWMD-FSQM	5/18/2016 11:05	1356	1,356	N/A	N/A	N/A	N/A
53	Strontium, Dissolved (µg/L)	1080	SM3120B	6/21/2016 10:13	1100	1,100.00	±69.3	0.6	1.2	0.6
33	Sulfate	946	SM4110B	5/23/2016 12:51	126	126	±4.7	0.1	0.4	0.1
7	Temperature (°C)	10	SFWMD-FSQM	5/18/2016 11:05	26.5	26.5	N/A	N/A	N/A	N/A
97	Total Dissolved Solids	515	SM2540C	5/23/2016 13:39	801	800	±101	22	88	22

* All values reported in mg/L unless noted otherwise.
Additional information: Sample ID = P84183-2; Collection Date and Time = 5/18/2016 11:05; Receive Date and Time = 5/19/2016 15:58; LIMS Number = 56470002.
MDL = method detection limit; N/A = not applicable; PQL = practical quantification limit; RDL = reporting detection limit.

Table E-6. Water quality information for station L-1137.

Test Number	Test Name	Storet Code	Method	Measure Date	Value*	Sig. Fig. Value	Uncertainty	MDL	PQL	RDL
67	Alkalinity, Tot, $CaCO_3$	410	SM2320B	5/6/2016 10:41	225	225	±23	1	4	1
30	Calcium	915	SM3120B	5/19/2016 13:17	88.2	88.2	±7.8	0.3	1	0.3
32	Chloride	941	SM4110B	5/6/2016 11:37	13.6	13.6	±0.6	0.1	0.4	0.1
35	Hardness as $CaCO_3$	905	SM3120B	5/19/2016 13:17	256.4	256	±13.4	1	4	1
31	Magnesium	925	SM3120B	5/19/2016 13:17	8.8	8.8	±0.6	0.1	0.4	0.1
10	pH, Field (no units)	400	SFWMD-FSQM	5/3/2016 15:00	7	7	N/A	N/A	N/A	N/A
29	Potassium	935	SM3120B	5/19/2016 13:17	0.3	0.3	±0.1	0.1	0.4	0.1
27	Silica	955	SFWMD 3120	5/13/2016 10:06	5.46	5.46	±0.29	0.05	0.2	0.05
28	Sodium	930	SM3120B	5/19/2016 13:17	8.9	8.9	±0.8	0.4	1	0.4
9	Specific Conductivity, Field (µS/cm)	94	SFWMD-FSQM	5/3/2016 15:00	483	483	N/A	N/A	N/A	N/A
53	Strontium, Dissolved (µg/L)	1080	SM3120B	6/21/2016 10:02	280	280	±17.6	0.3	0.6	0.3
33	Sulfate	946	SM4110B	5/6/2016 11:37	15.7	15.7	±0.6	0.1	0.4	0.1
7	Temperature (°C)	10	SFWMD-FSQM	5/3/2016 15:00	25.2	25.2	N/A	N/A	N/A	N/A
97	Total Dissolved Solids	515	SM2540C	5/5/2016 14:16	270	270	±40	22	88	22

* All values reported in mg/L unless noted otherwise.
Additional information: Sample ID = P84182-3; Collection Date and Time = 5/3/2016 15:00; Receive Date and Time = 5/5/2016 12:26; LIMS Number = 56469003.
MDL = method detection limit; N/A = not applicable; PQL = practical quantification limit; RDL = reporting detection limit.