Polk Regional Water Cooperative
Combined Projects Implementation Phase I

Technical Memorandum
SOUTHEAST WELLFIELD
WELL COMPLETION REPORT

DRAFT | July 2019

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1.0 INTRODUCTION

1.1 Background

Polk County has traditionally relied on fresh groundwater from the upper Floridan aquifer (UFA) as a primary water source for urban, agricultural, and industrial uses. Previous central Florida planning efforts and the South Florida Water Management District (SFWMD), along with Southwest Florida Water Management District (SWFWMD) water supply planning and assessment investigations, have documented that the rate of groundwater withdrawal in certain areas of Polk County is either rapidly approaching, or has surpassed the maximum rate that can be sustained without causing harm or adverse impacts to the water resources and related natural systems, as documented in the Central Florida Water Initiative (CFWI) 2015 Regional Water Supply Plan (RWSP). Meanwhile, SWFWMD's November 2015 RWSP for the Heartland Planning Region identified that an increase in water supply will need to be developed to meet demand in Polk County from 2010 through 2035. Brackish groundwater from the lower Floridan aquifer (LFA) has been identified as a potential key alternative water supply (AWS) source for public supply, but little data from the aquifer system was available from which to draw firm conclusions. In 2008, Polk County initiated drilling of a deep exploratory well, referred to as Southeast Deep Exploratory Well 1, or SE-DEW-1, to investigate the hydrogeologic conditions of the Floridan aquifer system and collect necessary data to determine suitability of the upper portion of the lower Floridan for water supply (PBSJ, 2010). The well was co-funded by SFWMD and became one of only a handful of wells which explored the LFA system in Polk County.

Drilling and testing of SE-DEW-1 was completed in 2009 and became the basis for a water use permit (WUP) issued to Polk County in 2014. SE-DEW-1 represents the southern end of the proposed wellfield alignment, which will ultimately be comprised of 15 raw water supply wells adjacent to Walk in Water Road in southeastern Polk County. Because the WUP was intended to serve numerous communities, and because the local governments in Polk County recognized the benefits of collaboration on regional water supply issues, they formed the Polk Regional Water Cooperative (Cooperative).

The Cooperative was created by an interlocal agreement to provide a mechanism for innovative regional cooperation amongst local governments. This regional cooperation includes developing, recovering, storing, and supplying water for county or municipal purposes to reduce adverse environmental effects of excessive or improper withdrawals of water from concentrated areas. The intent of the Cooperative is to encourage the development of fully integrated robust public water supply systems comprised of diverse sources managed in a manner that take full advantage of Florida's intense climatic cycles to ensure reliable, sustainable and drought resistant systems, which maximize the use of AWS to the greatest extent practicable. To accomplish this effort the Cooperative intends to access State funds and other private or public funding sources to develop AWS.

1.2 Purpose

The primary purpose of this project is to obtain additional hydrogeologic data at the Southeast Test Production Well Site (SE-TPW) to increase the understanding of the LFA in this part of Polk County. This project would supplement and validate the data collected during the 2009 APT at SE-DEW-1. The SE-TPW drilling program was developed to identify and quantify production intervals within the LFA, determine water quality within those intervals, evaluate hydraulic properties of the LFA (specific capacity, transmissivity, storage and leakance) and evaluate potential zones for concentrate disposal. The construction of a test/production well and LFA monitor were constructed and tested in such a manner to confirm hydrogeologic information as the basis for design of future water supply and treatment facilities.

The objectives of the drilling and testing program include:

1) Confirm raw water productivity within the LFA;
2) Determine the quality of water in the LFA including at the end of a 14-day constant rate discharge test;
3) Evaluate the hydraulic properties of select LFA intervals;
4) Qualitatively evaluate the degree of confinement between the UFA and LFA and within the LFA;
5) Evaluate potential zones for concentrate disposal above and below the USDW.

1.3 Project Description

The drilling program at the SE-TPW included construction of the following test/monitor wells:

1) Surficial aquifer monitor well SE-SA to monitor surficial aquifer water level fluctuations during the 14-day APT.
2) Upper Floridan aquifer construction water well/monitor well SE-UFA to monitor UFA water levels and/or quality fluctuations. Additionally, this well would be used for construction water supply at the Southeast site. This monitor well will allow for tracking of UFA versus LFA heads as the borehole advances through different hydrostratigraphic intervals. SE-UFA was finished as an UFA monitor well open to the Ocala Limestone.
3) Lower Floridan aquifer Test/Production Well, SE-TPW, is the location where exploratory drilling and testing were accomplished during the project. The primary purpose of this well is to confirm raw water quality within the LFA and to identify suitable injection zones for concentrate disposal. Lithologic samples were collected during advancement of the pilot hole and water quality samples obtained to track how water quality degrades with depth. Aquifer parameters were calculated from during packer testing, step drawdown testing and constant rate discharge testing. Geophysical logging was conducted within the pilot hole providing additional hydrogeologic data. After construction of SE-LFA, a long duration constant rate discharge test of 14-days was completed.
4) Lower Floridan aquifer monitor well SE-LFA was constructed as an observation well to be utilized during the 14-day constant rate discharge at SE-TPW. The use of a monitor well which is open to the same interval as the Test/Production well allows for analytical solutions for hydraulic conductivity, transmissivity, storage and leakance.

The well design and construction sequencing were documented in the, "Lower Floridan Aquifer Hydrogeologic Investigation, Southeast Polk Test Well Site Well Construction and Testing Plan," prepared by TeamOne in March of 2018 (**Appendix A)**. This plan was reviewed and approved by the SWFWMD prior to implementation. The SE-TPW site is located approximately 8.4 east of downtown Lake Wales, on the east site of Boy Scout Camp Road, approximately 0.55 miles north of SR 60 (**Figure 1.1**). The SE-TPW site is located approximately 8.7 miles north-northwest of the SE-DEW-1 site. Land surface elevations at the SE-TPW wells ranged from 124.86 to 128.00 ft NAVD. The SE-TPW site is located on the eastern flank of the Lake Wales Ridge. The location for each well at the site is shown on **Figure 1.2.** The distance between SE-TPW and the LFA monitor well is 200 feet.

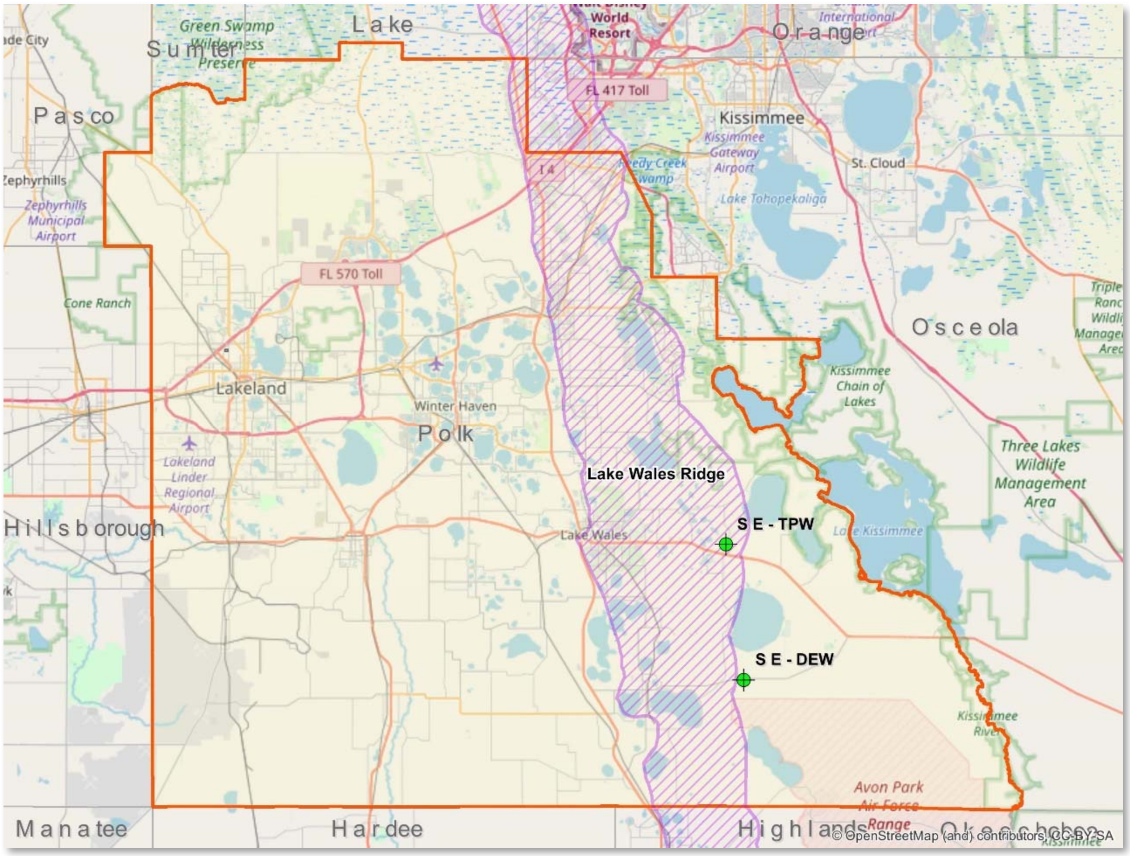

Figure 1.1 Location Map

2.0 EXPLORATORY DRILLING AND WELL CONSTRUCTION

2.1 Surficial Aquifer Well SE-SA

Huss Drilling, Inc. (HD) was sub-contracted to Florida Drilling (FD) for installation of the surficial and upper Floridan aquifer monitor wells at the SE-TPW. HD mobilized to the site during the week of May 21, 2018 and drilled a pilot hole to 100 ft. below land surface (bls) using mud rotary. Cuttings were monitored continually during advancement of the borehole and classified in the field. Samples indicated a clean poorly graded sand from land surface to 55 ft. bls where a very silty organic layer were present to 58 ft. bls. This interval was underlain by a poorly graded sand and poorly graded sand with silt, to 100 ft. bls.

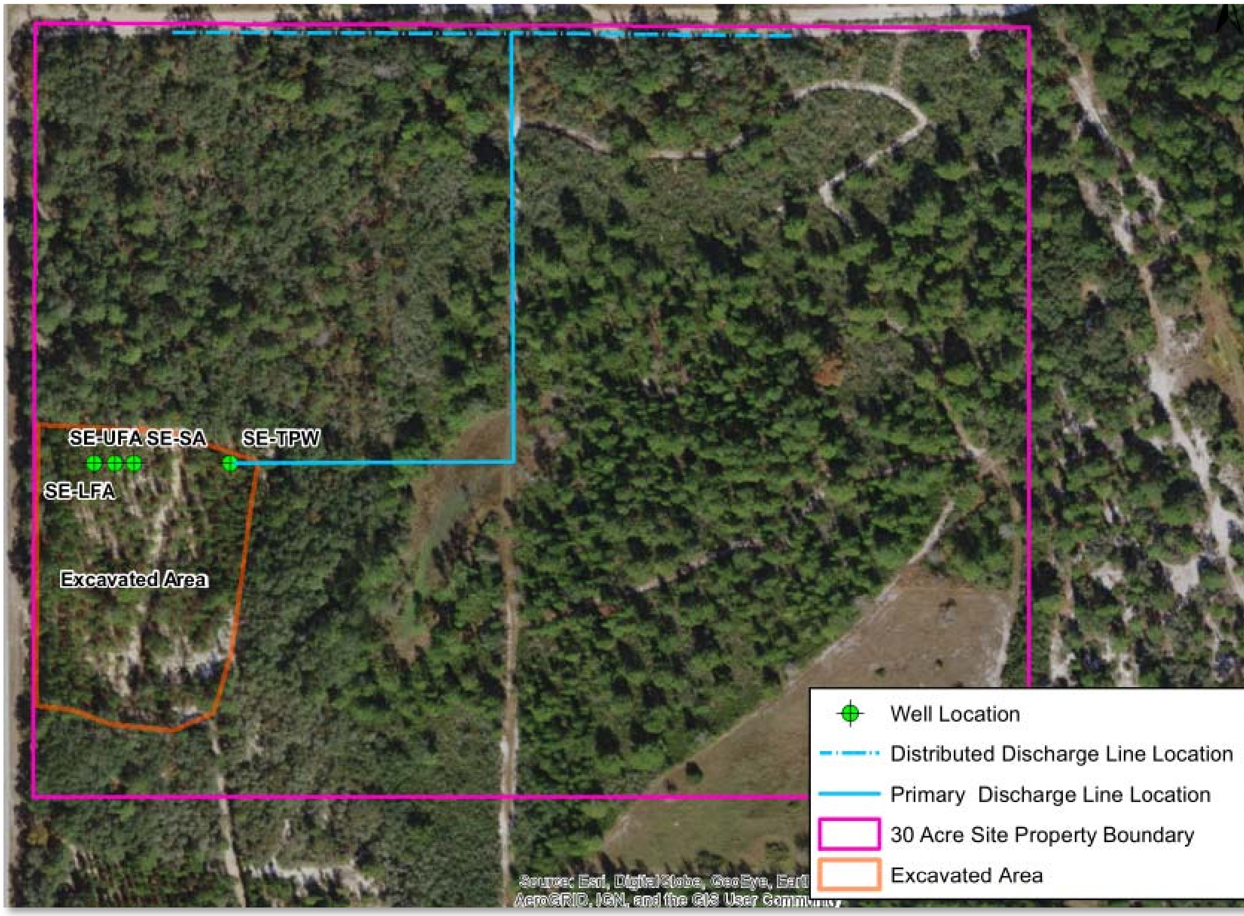

Figure 1.2 Southeast Test Well site well locations

HD advanced a nominal 10-inch bit to 75 ft. bls using mud rotary to allow for installation of 4-inch PVC casing with a 20-foot-long 0.010-inch slot screen, which was set from 55 to 75 ft. bls. A 20/30 silica sand filter pack was installed around from 55 to 75 ft. bls with a 2-foot fine sand seal from 53 to 55 ft. bls. The monitor well was grouted from 53 ft. bls to land surface, using Type II neat cement grout. A protective well casing with locking cap were provided and a concrete well pad installed. Following installation of the SE-SA, HD developed the monitor well until the discharge was not visually turbid and clear water was produced. An as-built well construction diagram is provided as **Figure 2.1.**

2.2 Upper Floridan Aquifer Construction Water/Monitor Well SE-UFA

Construction of water well/upper Floridan aquifer monitor well, SE-UFA, began on June 4, 2018 with split spoon sampling from 100 to 125 ft. bls to confirm depth to top of the Hawthorn Confining Unit (HCU). The first persistent clay layer occurred at 102 ft. bls, as a high plasticity clay (CH) from 102 to 105 ft. bls., underlain by low plasticity clay with shell fragments and phosphate. HD reamed with a 16-inch bit and set a 12-inch PVC casing to 105 ft. bls and grouted it in to land surface with Type II neat cement grout.

Once the surface casing was installed, HD advanced a nominal 12-inch pilot hole to 275 ft. bls, into the Ocala Limestone, which occurred as a moderately hard pale brown, fossiliferous wackestone. HD set a 6-inch black steel casing to 260 ft. bls and tremie grouted it to land surface with Type II neat cement grout. Once

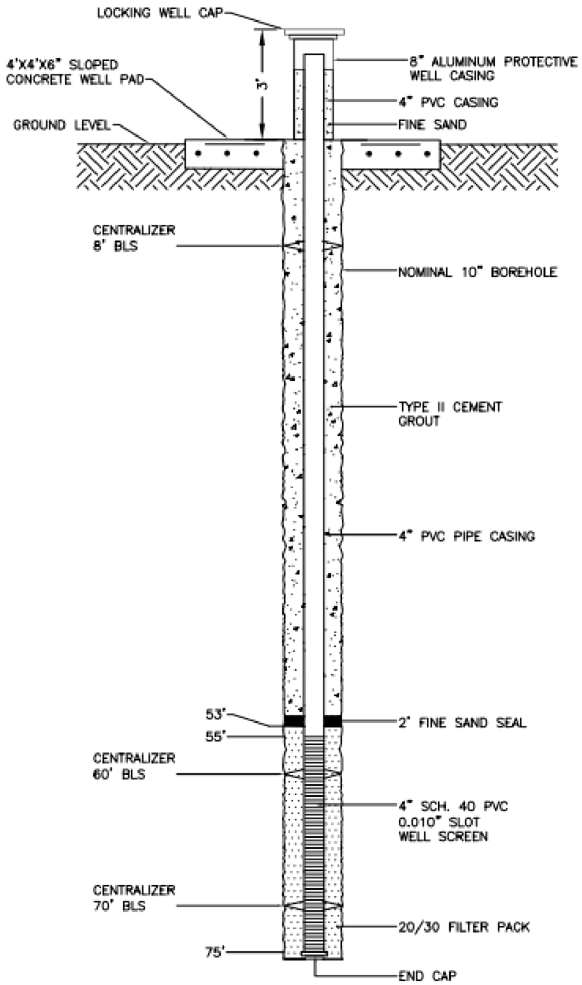

Figure 2. 1 Monitor well SE-SA as-built diagram

the 6-inch casing was installed HD advanced a nominal 6-inch borehole to 400 ft. bls. The 12-inch surface casing was extended to 3 feet above land surface and concrete well pad installed. SE-UFA was developed with a submersible pump until discharge was not visually turbid and clear water was produced. An as-built well construction diagram is provided as **Figure 2.2.**

2.3 Lower Floridan Aquifer Test/Production Well SE-TPW

The week of June 11, 2018, FD set a 36-inch diameter pit casing for the Test/Production well (TPW) to 52 ft. bls. Once the pit casing was installed FD reamed with a 32-inch bit to 185 ft. bls. and set the 26-inch diameter black steel surface casing to 182 ft. bls. using 102 barrels neat cement grout, into moderately hard sandy limestone of the Arcadia Formation. Using an 11⅞-inch bit, FD advance a pilot hole to 400 ft. bls to determine casing setting depth. After review of the logs, the 20-inch diameter intermediate casing was set to 382 ft. bls. FD grouted in the 20-inch casing using 74 barrels of neat cement grout. After drilling out the grout plug FD switched to reverse air and continued drilling the pilot hole.

During reverse air drilling FD performed short duration specific capacity tests when making connections of new drill pipe. After running specific capacity tests a water quality sample was obtained to analyze for field

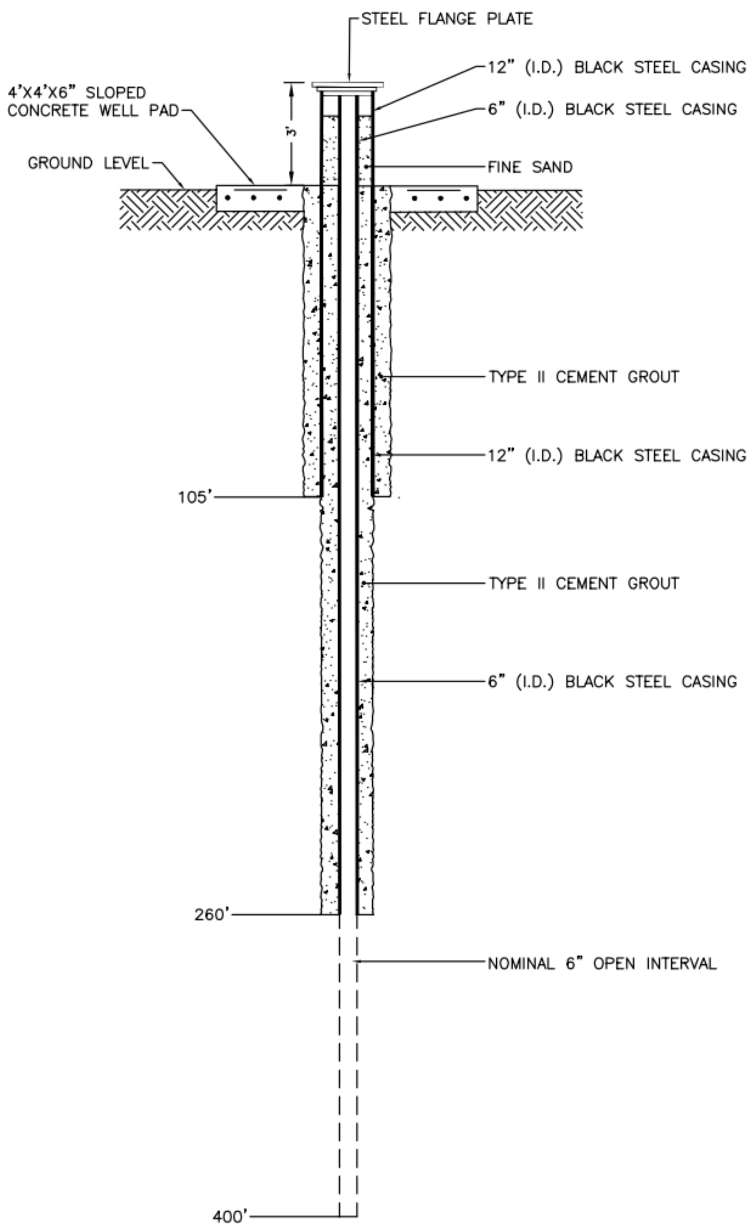

Figure 2.2 Monitor Well SE-UFA as-built diagram

parameters (pH, specific conductance, chloride and sulfate). Intermittently, samples were also collected for laboratory analyses to confirm values obtained in the field. Both field and laboratory results are provided in **Appendix B.**

From August 8th to 20th, the SE-TPW pilot hole was advanced to 1,640 ft. bls followed by geophysical logging and optical borehole imaging (OBI) logging run by the USGS. OBI logs are available as **Appendix C**. Based on the results of logging three intervals were selected for packer testing:

1) Test centered on 1,525 ft. bls to obtain data on water chemistry and hydraulics of MCUII;

2) Test centered on 975 ft. bls (lower flow zone of APPZ) to obtain representative water chemistry and hydraulic data;

3) Test centered at 1,200 ft. above anhydrite-bearing strata to confirm hydraulic data.

After packer testing was complete, FD reamed the pilot hole from September 10th to October 4, 2018, to a nominal 20-inches to allow for installation of the 12-inch diameter black steel inner casing. A total of 443 barrels of Type II neat cement grout were used to set the inner casing. On October 18, 2018, FD center punched the grout plug and continued to advance a pilot hole to 2,000 ft. bls, to prepare for a 14-day aquifer performance test (APT). By October 29, 2018, FD advanced a nominal 12-inch pilot hole to 2,003 ft. bls. The USGS returned to the site to log the interval from 1,600 to 2,003 ft. bls.

Once the lower Floridan monitor well SE-LFA had been completed, FD set a discharge line 580 feet east of SE-TPW and prepared for the 14-day APT, which began on December 8, 2018. On December 13, 2018, the 14-day APT was terminated due to discharge water moving off site onto adjacent parcels. FD, the SWFWMD and the consultant team developed a revised discharge plan which included a dispersed or distributed discharge configuration which allowed flows to be discharged at discrete points along 1,000 feet of discharge pipe placed along the north property line. After background data was collected for 72 hours, the 14-day APT restarted on January 8, 2019 and ran until recovery testing on January 22, 2019. Daily water quality samples were collected for both field and laboratory analysis. During the final day of pumping, primary and secondary drinking water parameters along with reverse osmosis (RO) parameters were collected for laboratory analysis.

After the 14-day test, FD worked two shifts per day to expedite the schedule and continued to advance a pilot hole from 2,003 to 3,000 ft. bls. Total depth was reached on February 22, 2019. An as-built well construction diagram is provided as **Figure 2.3**. After construction was complete, six additional packer tests were run in the interval from 1,600 ft. bls to total depth within the following intervals:

- single packer test from bottom of the casing string at to 2,000 ft. bls to confirm water quality of the production zone;
- single packer test from 1920 ft. bls to total depth to evaluate hydraulic properties of strata underlying the production zone;
- single packer test from 2,320 ft. bls to total depth to evaluate hydraulic properties of the injection zone;
- straddle packer test above about 2,310 ft. bls to evaluate hydraulic properties of the injection zone;
- straddle packer test below about 2,390 ft bls (2,390 – 2,430 ft. bls) to locate base of USDW and evaluate upper injection zone;
- straddle packer test centered at 2,150 ft. bls to evaluate upper confining strata hydraulics and water quality.

2.4 Lower Floridan Aquifer Monitor Well SE-LFA

On August 6th Florida Drilling, Inc. mobilized a rig to begin construction of LFA monitor/observation well SE-LFA, and set a 24-inch diameter pit casing to 50 ft. bls. After the pit casing was set, FD advanced a pilot hole to 387 ft. bls., then reamed a nominal 24-inch borehole to 194 ft. bls followed by setting an 18-inch diameter black steel surface casing and cemented it in place. On August 14th, FD started reaming a nominal 18-inch diameter borehole to 387 ft. bls and set the 12-inch diameter

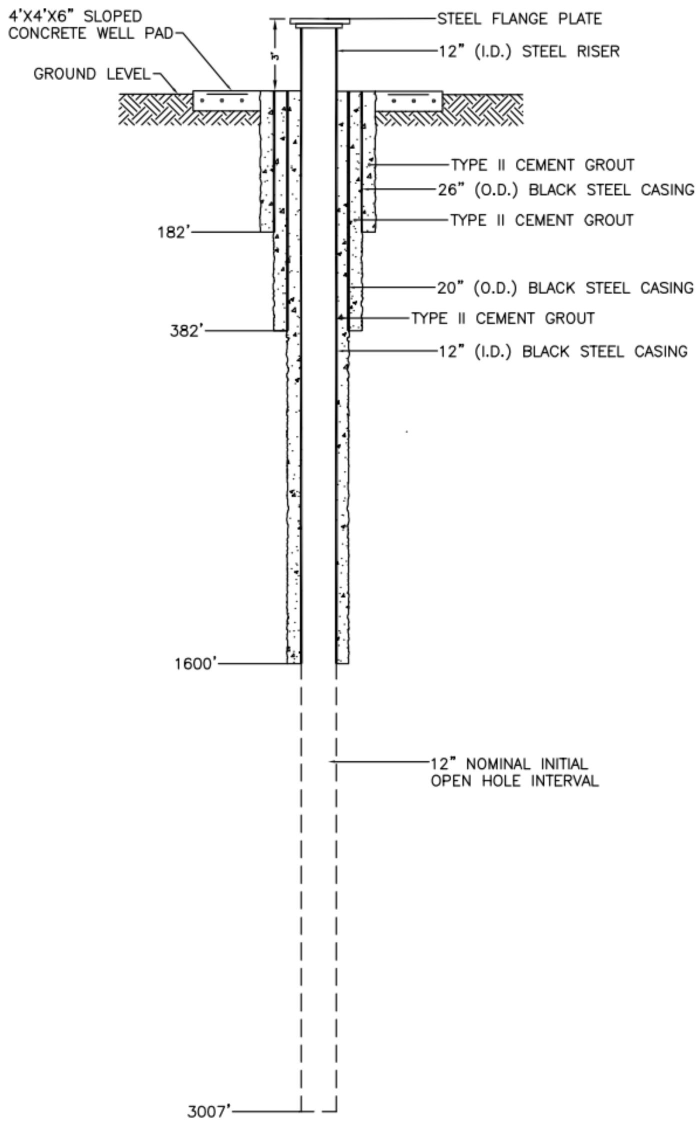

Figure 2.3 Monitor Well SE-TPW as-built diagram

intermediate casing string to 385 ft. bls. FD started drilling a pilot hole from 385 ft. bls on October 16th and advanced it to 2,000 ft. bls by November 20, 2018. After drilling total depth of 2,000 ft. bls FD logged the borehole prior to setting a 4.5-inch casing to 1,600 ft. bls with cement baskets. By December 5th the inner casing string at SE-LFA was grouted in place. FD developed using an airlift until the discharge was not visually turbid. An as-built well construction diagram is provided as **Figure 2.4**.

3.0 STRATIGRAPHIC FRAMEWORK

TeamOne geologists collected representative formation samples during advancement of pilot holes at the SE-TPW. The samples were described by their lithology color, their degree of induration and texture. Depths are reported in feet below land surface (ft bls). The land surface elevation at well SE-TPW is 124.86 ft NAVD.

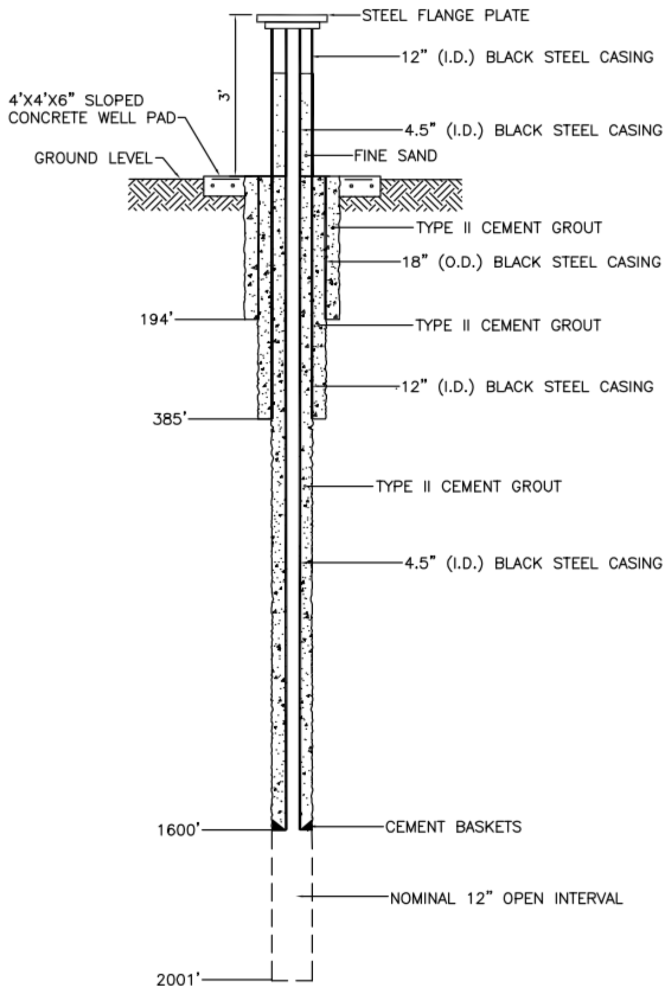

Figure 2.4 Monitor Well SE-LFA as-built diagram

geologic units encountered at the site include, in descending order are: undifferentiated sand and clay deposits, Hawthorn Confining Unit, Ocala Limestone, Avon Park Formation, Oldsmar Formation and the Cedar Keys Formation. A stratigraphic column detailing the hydrogeology and hydrostratigraphy encountered at the SE-TPW is presented below in **Figure 3.1**. A lithologic log is provided in **Appendix D**. Textural terms used to characterize siliclastic sediments are based on the Unified Classification System. Textural terms used to characterize carbonate rocks in lithologic log descriptions are based on the classification system of Dunham (1962). Geophysical logs and OBI logs were also used in describing the geologic formations encountered.

Well SE-TPW penetrates strata of Holocene to Paleocene age, which can be divided into three main intervals. The upper strata from land surface to approximately 248 ft bls consists of mixed siliciclastic and carbonate strata of Holoecene to Miocene age that constitute the Surficial Aquifer System and Intermediate Aquifer System (also referred to as the Intermediate Confining Unit). The strata from 440 to 2,543 ft bls consists predominantly of carbonate rocks (limestone, dolomites, and dolomitic limestones) of Late Eocene to Early Eocene age that constitute the Floridan Aquifer System. The underlying evaporitic (mixed dolomite and bedded anhyrdrite) Cedar Keys Formation (Paleocene) constitutes the Sub-Floridan Confining Unit.

Stratigraphic formations are, by definition, mappable bodies of rock that are lithologically distinct from adjoining strata (i.e, have different rock types). However, the formations that constitute most of the Floridan Aquifer System (Suwannee Limestone, Ocala Limestone, Avon Park Formation, and Oldsmar Formation) are defined based on their age (i.e., are biostratigraphic units) rather than their lithology (Miller 1986). For example, the Avon Park Formation is now commonly defined as carbonate rocks of Middle Eocene age in peninsular Florida (Miller 1986), although the Middle Eocene strata were originally subdivided, in ascending order, into the Lake City Limestone and the Avon Park Limestone (Applin and Applin 1944). Formation boundaries have historically been placed at positions in wells or exposures at the nearest lithological change to a biostratigraphic transition. In practice, locating the depths of formation boundaries in the Floridan Aquifer System can be very difficult from well cuttings and geophysical logs. Indeed, Reese and Memberg (2000) proposed that individual formation names of the Eocene strata be abandoned for the Floridan Aquifer System in the subsurface and the strata combined in an "Eocene Group."

Formation boundaries were identified in the evaluation of the SE-TPW data based on typical lithologies, fossil types, and geophysical characteristics of each unit. The formation boundary determinations considered previous U.S. Geological Survey stratigraphic analyses for or including Polk County (Spechler & Kroening 2007; Reese and Richardson 2008).

3.1 Holocene, Pleistocene, and Pliocene Series

The Pliocene and younger aged surficial sediments are mainly comprised of varying percentages of undifferentiated sand at the SE-TPW, and are present from land surface to 102 feet bls. The sands are generally clean though a silty interval occurred from 55 to 58 ft. bls. The description of the undifferentiated surficial sands in the lithologic log in **Appendix D,** which is based on split-spoon and mud rotary sampling during construction of surficial aquifer well, SE-SA and upper Floridan monitor well SE-UFA.

3.2 Miocene Series

The Hawthorn Group of Miocene age includes the lower Arcadia Formation and the upper Peace River Formation and consists of an interbedded sequence of widely varying lithologies and components that include limestone, mudstone, dolomite, dolosilt, shell, quartz sand, clay, abundant phosphate grains, and mixtures of these materials. The Hawthorn Group extends from approximately 105 ft. to 248 ft. bls. The top of the Hawthorn Group is identified by a downhole change, observed in the split spoon samples, from softer clayey sand to a denser calcareous phosphatic clay and sandy limestones of the Arcadia Formation from 174 to 248 ft. bls.

3.3 Oligocene Series

The Suwannee Limestone was not present at this location.

3.4 Eocene Series

3.4.1 Ocala Limestone

The Eocene Series in peninsular Florida consists, in descending order, of the Ocala Limestone (Late Eocene), Avon Park Formation (Middle Eocene), and Oldsmar Formation (Early Eocene). The Ocala Limestone typically is relatively a light colored, often chalky appearing limestone that is relatively pure, as manifested by low gamma ray activities. The Ocala Limestone varies from a mudstone and wackestone in the upper portion to packstone and grainstone in the lower portion. At the SE-TPW, the Ocala Limestone extends from

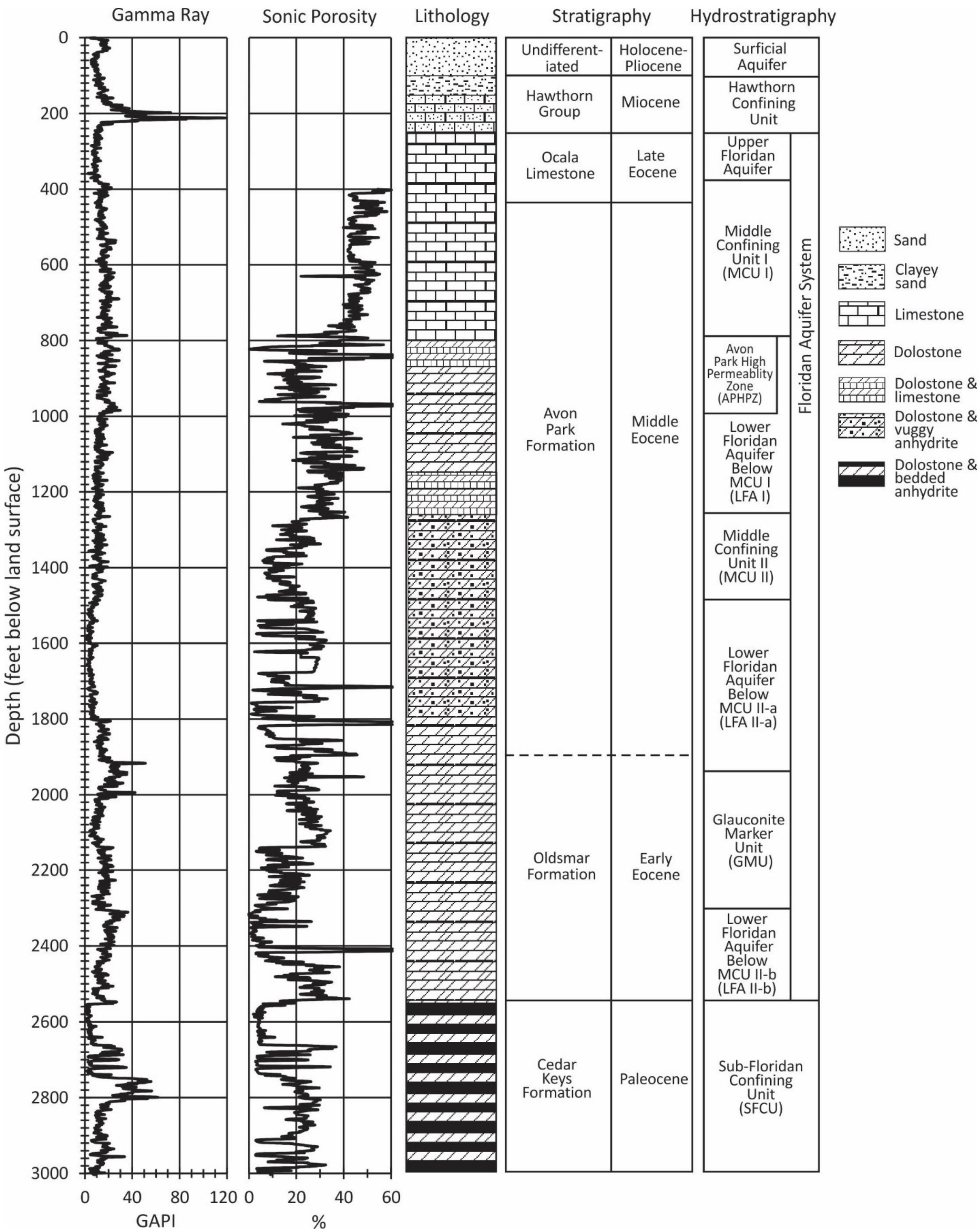

Figure 3. 2 Well SE-TPW lithologic, stratigraphic and hydrostratigraphic columns

approximately 248 to 435 ft. bls. The top of the Ocala Limestone is identified by a change observed in the drill cuttings from a light gray limestone to a very pale brown limestone with foraminifera. The formation is characterized by the presence of large (several millimeter-sized) flat, discoidal foraminifera belonging to the genus *Lepidocyclina*. *Lepidocylina* constitutes most of the cuttings between about 290 and 379 ft bls. The lower part of the formation is partially dolomitic. The base of the Ocala Limestone occurs at about 435 ft bls in SE-TPW based on the transition to more typical Avon Park Formation fossils.

3.4.2 Avon Park Formation

The Middle Eocene aged Avon Park Formation consists primarily of fossiliferous limestone interbedded with dolomitic limestone and vuggy dolostone. The Avon Park Formation varies from a wackestone to grainstone with minor mudstone. At the SE-TPW, the Avon Park Formation extends from approximately 435 to 1,910 feet bls. The upper part of the Avon Park Formation is characterized by common small echinoids belong to the genus *Neolaganum*. The foraminifera fauna is often dominated by millimeter-sized cone-shaped foraminifera belong to the genus *Dictyoconus* and similar genera. However, cone-shaped "dictyoconid" foraminifera are not particularly common in the TPW cuttings. The Avon Park Formation in TPW is composed mostly for pale yellowish brown dolostones and calcareous dolostones, and subsidiary limestones and dolomitic limestones. Anhydrite is common below 1,271 ft bls and occurs as clear crystals and opaque white masses with vugs. Dissolution of the vug-filled anhydrite intervals between 790 and 1,260 ft bls formed high-transmissivity flow zones.

3.4.3 Oldsmar Formation

The Early Eocene aged Oldsmar Formation consists primarily of dolomitic recrystallized microcrystalline limestone in the upper section and crystalline, low porosity, dolostones in the lower section. The Oldsmar Formation varies from a packstone to wackestone to grainstone. Anhydrite is locally present as small nodules. The boundary between the Avon Park Formation and Oldsmar Formation is lithologically indistinct. Reese and Richardson (2008) mapped across South Florida a marker unit, referred to as the "glauconite marker horizon," which approximately marks the top of the Oldsmar Formation. The "glauconite marker horizon" is also marked by a pronounced increase in gamma ray activity (Reese and Richardson 2008). Based on the gamma ray log, known thickness of the Avon Park Formation in Polk County and the Reese and Richardson's map of the top of glauconite marker horizon, the top of the Oldsmar Formation is placed at approximately 1,910 ft bls in well SE-TPW. Trace amounts of glauconite is observed in cuttings from 1,920 to 1,930 ft. bls and increased gamma ray activity occurs below 1,910 ft bls. The sonic log shows a sharp decrease on overall porosity below 2,140 ft bls, which reflects the presence of beds of hard, very low porosity dolostone.

3.5 Paleocene Series

3.5.1 Cedar Keys Formation

The Avon Park Formation is underlain by the late Paleocene-aged Cedar Keys Formations. The top of the Cedar Keys Formation is usually placed at the top of first thick bedded anhydrite unit below the Oldsmar Formation, which occurs at 2543 ft bls in well TPW, as visible on the OBI log. The top of the Cedar Keys Formation is also evident by a sharp increase in resistivity on the dual induction-laterolog (DIL). The Cedar Keys Formation consists primarily of dolostone and evaporites (gypsum and anhydrite) with less abundant limestone. The Cedar Keys Formation was approximately 1,470 ft thick at the TECO Polk Power Station injection well located in the southwestern part of the county (MWH 2013). The upper Cedar Keys Formation penetrated between 2,543 and 3,000 ft bls in well TPW consists mostly of interbedded anhydrites and shallow water dolostones containing vuggy anhydrite.

4.0 HYDROGEOLOGIC FRAMEWORK

Traditionally, the hydrogeology of peninsular Florida has been divided into three main units, the Surficial Aquifer System (SAS), Intermediate Confining Unit (ICU) or aquifer system, and the Floridan Aquifer system (FAS, Miller 1986). The nomenclature and naming conventions used in this report are consistent with the SWFWMD current understanding of the regional hydrostratigraphy (Arthur et al. 2008). Three major hydrostratigraphic units occur in west-central Florida: the surficial aquifer (SA), a confining unit within the Hawthorn Group (the Hawthorn confining unit; HCU) that contains small local aquifers of the Hawthorn aquifer system where present, and the FAS. The FAS is divided into two aquifers, an UFA and the LFA separated by one or more regional middle confining units (MCU I and/or MCU II). The hydrostratigraphic units at the SE-TPW are described below and the hydrostratigraphy of the SE-TPW site is summarized in **Figure 3.1.**

4.1 Surficial Aquifer

The SAS in Florida is defined as the "permeable hydrogeologic unit contiguous with land surface that is comprised principally of unconsolidated clastic deposits" (Southeastern Geological Society Ad Hoc Committee, 1986). The surficial aquifer System comprises all materials from the water table to the top of the underlying confining unit of the Hawthorn Group. In Polk County, the base of the surficial aquifer is marked by a transition to the low hydraulic conductivity clayey strata of the Hawthorn Group.

The Surficial Aquifer (SA) at the SE-TPW area consists predominantly of unconsolidated quartz sands. The base of the SA is marked by a transition to the more clay-rich strata of the Intermediate Confining Unit (ICU). The base of the SAS occurs at roughly 140 ft bls.

4.2 Hawthorn Confining Unit

The confining unit between the SA and the UFA at this occurs in the Hawthorn Group and is present from 102 to 248 ft bls. The base of the confining unit is marked by a downhole transition to the lighter-colored and more transmissive fossiliferous limestones of the Ocala Limestone.

4.3 Floridan Aquifer System

The FAS is one of the most productive aquifers in the United States and underlies all of Florida and parts of Georgia and South Carolina for a total area of about 100,000 square miles (Miller, 1986). The FAS consists of an extensive sequence of thickly bedded Tertiary-aged limestones and, less abundant dolostones that are connected to varying degrees. The FAS is quite heterogeneous as far as hydraulic conductivity. Flowmeter log data show that the aquifer consists of a number of zones with very high hydraulic conductivities, which are commonly solution-riddled or fractured, separated by confining or semi-confining intervals of rock with low hydraulic conductivities. Confining units within the FAS in South Florida vary greatly in thickness and vertical continuity. An important factor controlling transmissivity within the FAS in SE-TPW is whether secondary porosity features, particularly vugs and small cavities, are open or filled with anhydrite. High transmissivity flow zones are characterized by the presence of a network of dissolutional cavities that are apparently interconnected with considerable areal extent.

The middle confining unit is defined as the interval of lesser transmissivity strata that hydraulically separates the UFA from the LFA (LFA; Miller 1986). SE Polk County lies within a northwest trending band through central Florida in which two separate confining units are present, referred to, as middle confining unit I (MCU I) and middle confining unit I (MCU II), which overlap and are separated by several hundred feet of permeable rock. In this overlap area, two hydraulically distinct aquifers are present below each of the overlapping middle confining units, which are referred to by the SWFWMD as LFA below MCU I and LFA below MCU II, respectively. MCU I pinches out the western part of the state, whereas MCU II pinches out in the east. LFA below MCU I has also been referred to the Middle Floridan aquifer. MCU II is absent in the eastern part of the state where the top of the LFA in considered the base of MCU I. A very high transmissivity interval, called the Avon Park high permeability zone (APHPZ), is present within the upper part of the LFA below MCU I in southeastern Polk County.

4.3.1 Upper Floridan Aquifer

The upper Floridan Aquifer (UFA) is present from 248 to 379 ft bls in well TPW. The UFA includes most of the Ocala Limestone and consists of fossiliferous limestones in which large foraminifera (particularly *Lepidocyclina*) constitute most of the recovered cuttings. The surface casing in well TPW was set at 380 ft bls, casing off the UFA. No hydraulic testing and open-hole borehole geophysical logging was performed on the aquifer.

4.3.2 Middle Confining Unit I

MCU I consists of lower hydraulic conductivity strata that provides hydraulic separation between the UFA and LFA below MCU I. The flowmeter interpretation log shows that the top of the APPZ occurs at about 780 ft bls (**Fig. 4-1**). Hence, the MCU-I is approximately 401 ft thick in well TPW. MCU-I is more appropriately described as a semi-confining unit as the strata does not have a particularly low transmissivity. Rather the transmissivity of MCU-1 is markedly less than that of the overlying UFA and underlying APPZ.

4.3.3 Lower Floridan Aquifer below MCU I

The lower Floridan aquifer below MCU I (LFA I) at the SE-TPW site consists of transmissive strata between the MCU I and the low permeability anhydrite-bearing strata of MCU II. The very high transmissivity APHPZ occurs is zone of LFA I that occurs at the top of the aquifer. The top of the LFA below MCU I, as well as APHPZ, occurs at 780 ft bls. The flowmeter interpretation log (Fig. 4-2) shows only minor water production from the part of LFA I below MCU I beneath the APHPZ.

4.3.4 Avon Park High-Permeability Zone

The Avon Park high-permeability zone (APHPZ) is a zone of highly transmissive fractured dolostone within the middle part of the Avon Park Formation. This fractured unit has been mapped from central down into southern Florida and dips from north to south. The APHPZ can occur in the UFA or LFA below MCU I depending on location and presence of MCU I. The APHPZ occurs between 780 and 988 ft bls based on the flowmeter interpretation log (Fig. 4-2). The unit contains freshwater at the SE-TPW site. The OBI log shows that the enhanced permeability of the zone is due to mostly to dissolutional features (apparently of evaporite minerals) rather than fracturing.

4.3.5 Middle Confining Unit II

Middle Confining Unit II is less permeable and thus a more effective confining unit than MCU I. A characteristic feature of MCU II is the presence of anhydrite. The top of the anhydrite occurs at about 1,271 ft bls on the OBI log. The 1,271 ft bls depth coincides with a decrease in porosity on the sonic log. Anhydrite occurs as centimeter-sized scattered nodules and as layers of coalesced nodules, which is described in the geological literature as having a "chicken-wire" texture. In the overlying LFA below MCU I strata (including the APHPZ) anhydrite nodules were formerly present, but were dissolved to form small vugs. Courses of these dissolved nodules in the APHPZ may contribute to the overall permeability of the zone. The OBI log shows no evidence of pervasive fracturing that could compromise the confining characteristics of the zone. The MCU II is composed of horizontally bedded dolomitic strata.

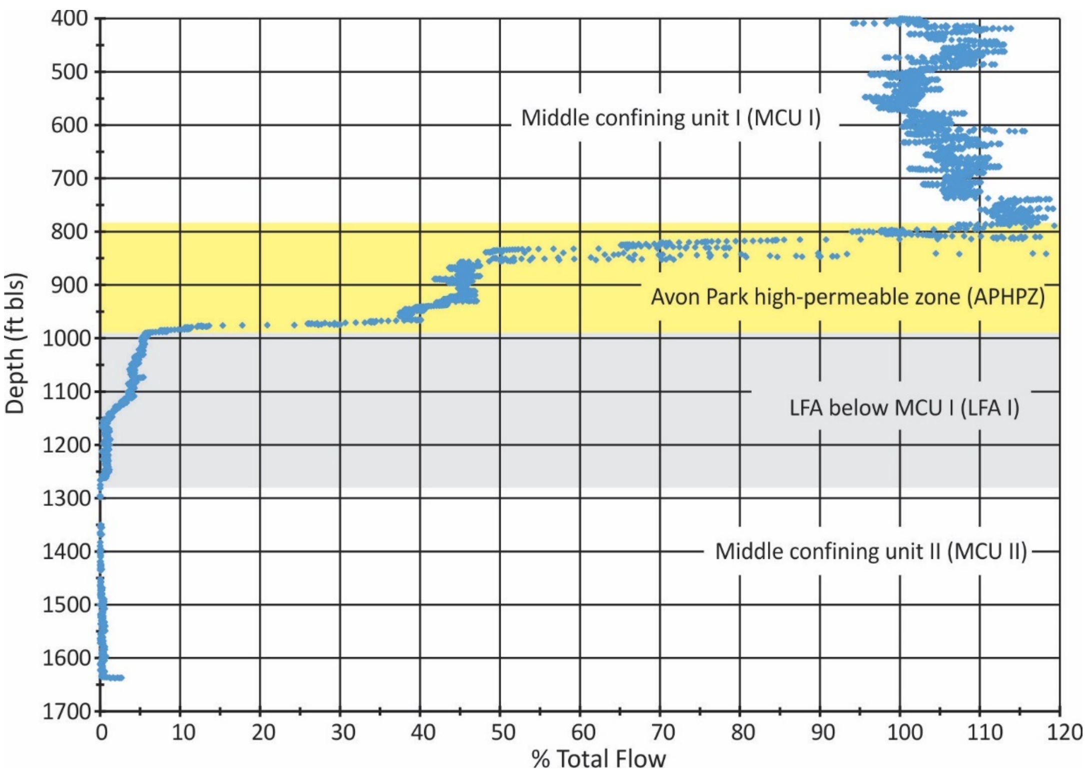

Figure 4-3 Flowmeter interpretation log for the TPW 382 to 1,638 ft bls pilot hole

4.3.6 Lower Floridan Below MCU II-a (LF II-a)

Lower Floridian aquifer below MCU II-a (LFA II-a) is the proposed production interval for the SE Wellfield. This unit is the upper part of the LFA above the glauconitic marker unit (GMU)

The top of LFA-IIa is placed at 1,485 ft bls, below which depth there is an increase in porosity compared to the overlying MCU-II strata. The flowmeter interpretation log run from 1,600 ft to total depth (3,000 ft bls) indicated that most of the LFA-IIa flow entered the well below 1,799 ft bls (Fig. 4-3). A major flow zone occurs at 1,799 to 1,810 ft bls and a secondary zone occurs between 1,900 and 1,915 ft bls. The base of LFA-IIa is paced at the bottom of the lower flow zone.

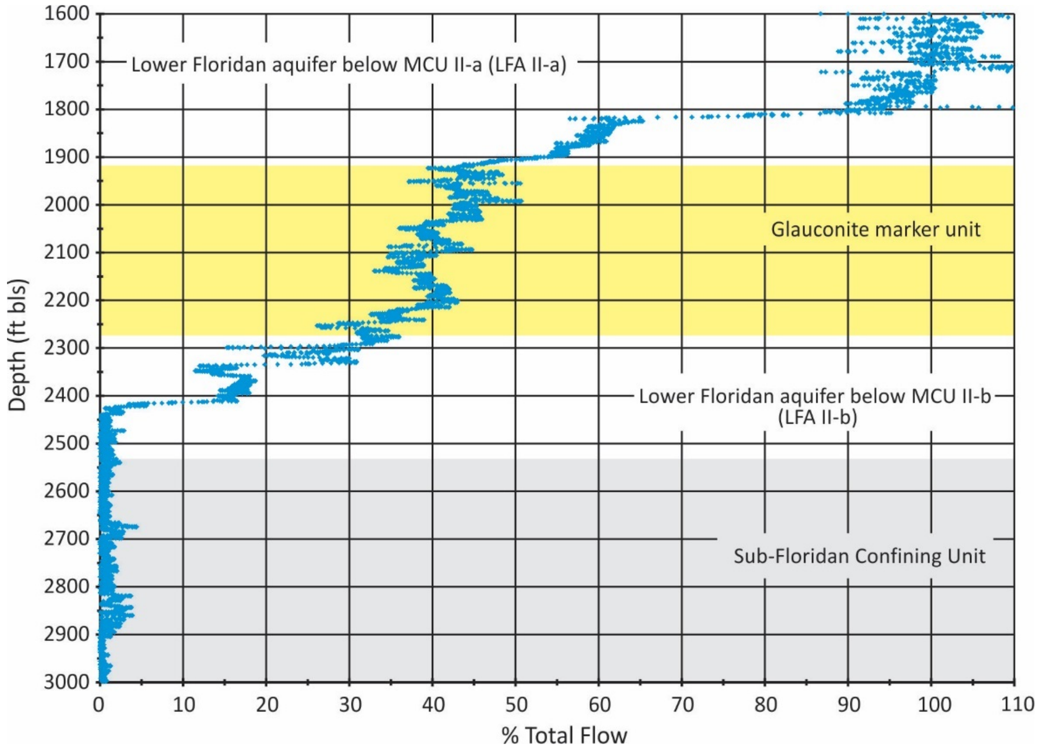

Figure 4-2 Flowmeter interpretation log for the TPW 1,600 to 3,000ft bls pilot hole

4.3.7 Glauconite Marker Unit

The glauconite marker unit (GMU) is a low porosity unit within LFA below MCU II separating more permeable upper and lower intervals identified as LFA II-a and LFA II-b, respectively. The GMU occurs between approximately 1,915 and 2,280 ft bls. The bottom of the GMU is placed at the top of the uppermost flow zone of LFA II-b. The GMU consists predominantly of dolomitic strata with an overall lower transmissivity than that of the overlying and underlying aquifer units. The GMU is the confining unit between the proposed production and injection zones. Despite its name, the distinctive green-colored mineral glauconite is not present throughout the entire GMU. A horizon that appears to be contain some glauconite occurs at the top of this interval.

A sharp decrease in porosity occurs below 2,140 ft bls reflecting a transition to better indurated dolostones. The flowmeter interpretation log suggests some production from the GMU. However, lateral flow into a wells is controlled mainly by horizontal hydraulic conductivity, whereas vertical confinement is controlled by vertical hydraulic conductivity. Analysis of cores from the SE-DEW, located approximately 8.7 miles to the south-southeast, indicate that the low porosity dolostones have very low vertical hydraulic conductivities (6.24×10^{-3} to 2.83×10^{-7} ft/d). Continuous beds of unfractured low-porosity and permeability dolostone would be expected to provide effective vertical confinement. Secondary porosity features (cavities and fractures) are locally present in the GMU. However, the OBI log shows only very localized fracturing; none that would compromise the integrity of the confining strata.

4.3.8 Lower Florida Aquifer Below MCU II-b (LFA II-b)

Lower Floridian aquifer below MCU II-b (LFA II-b) is the lowest part of the LFA and is the proposed injection zone. The flowmeter log indicates that two transmissive zones are present between 2,328 and 2,425 ft bls. The dolostone is vuggy and the local enhanced permeability appears on the OBI log to be due to solutional features (apparently from the dissolution of anhydrite) rather than fracturing. Anhydrite nodules are present below 2,538 ft bls and the top of the uppermost massive anhydrite bed marking the base of the Floridan Aquifer System occurs at 2,543 ft bls on the OBI log.

4.3.9 Sub-Floridan Confining Unit

The Sub-Floridan Confining Unit (SFCU) consists of low permeability carbonate and anhydrite beds belonging to the Cedar Keys Formation. The base of the SFCU was reported to occur at 3,960 ft bls at the TECO Polk Power Station injection well IW-1 (MWH 2013). The anhydrite appears in the OBI logs as planar to crenulate laminated beds, scattered nodules, and coalesced nodule ("chicken-wire") layers. The anhydrite-rich strata (e.g., between 2,560 and 2,660 ft bls) has a very low (~ 5%) porosity. The carbonate strata have a high porosity (20 to 30%) but appear to be fine-grained and likely have a low permeability.

5.0 HYDROGEOLOGIC TESTING

The hydrogeologic testing program was designed to obtain information on the hydraulic properties of the proposed production and injection zones and intervening and overlying confining strata (TeamOne 2018). The SE-TPW hydrogeology testing program included the following elements:

- Description of well cuttings
- Geophysical logging
- Packer testing
- Specific capacity and water level measurements during drilling

5.1 Geophysical Logging Program

Borehole geophysical surveys are performed by lowering sensing devices (sondes) attached to a wireline into a borehole and recording various physical properties of the penetrated strata. The geophysical logging program implemented during the construction of the SE-TPW was designed to collect information on the geology and hydrogeology of penetrated strata, particularly the location and properties of high transmissivity intervals that are suitable for raw water production and concentrate injection and confining strata that would impede vertical flow of water into the proposed production zone and the upward migration of water out of the injection zone. Borehole geophysical logs were run after the completion of the nominal 12-inch diameter pilot hole for the production casing (drilled to 1,642 ft bls) and on the nominal 12-inch diameter borehole drilled from the production casing (1,600 ft bls) into the upper part of the Cedar Keys Formation (3,000 ft bls total depth).

The geophysical logs were run by the MV Geophysical Survey, Inc. The U.S. Geological ran an OBI log on both borehole segments. The types of logs run and the information they provided is summarized in **Table 5-1.** Copies of geophysical logs are provided in **Appendix E**.

Table 5.1 Geophysical Logs and The Types of Information

Geophysical Log	Information provides
Caliper	Borehole diameter. Used to identify difference in rock hardness and the presence of fractured or cavernous interval, and to estimate annulus (required cement) volumes for grouting casings.

Spontaneous potential	Variations in salinity. The SP log is typically run as it is on the same tool as the DIL, but it usually does not provide much information in carbonate rocks.
Gamma ray	Natural radioactivity of rock. Used for lithological identification and correlation.
Sonic	Travel time of sound wave in the formation. Used to determine porosity and identify fractured zones.
Dual induction laterolog (DIL)	Resistivity of formation. Use to identify rock types, determine formation water salinity, and identify permeable zones.
Temperature	Water temperature within casing and borehole. Used to evaluate continuity of cement and zones of water flow into the well.
Fluid conductivity	Salinity of water inside well. Used to evaluate changes in formation salinity and the location of flow zones.
Flowmeter	Relative transmissivity of strata; identification of flow zones.
Optical borehole Imaging	A very high-resolution, wraparound optical image of the borehole wall. Used to image sedimentary structures and secondary porosity features that could result in enhanced hydraulic conductivity.

Information from the geophysical logs was utilized in both and geological and hydrogeological evaluations of the SE-TPW. A summary of the SE-TPW geophysical log interpretation is provided in **Table 5.2**.

Table 5.2 SE-TPW geophysical log interpretation

Depths (ft bls)		Description
Top	Bottom	
370	790	Porous rock with sonic porosities mostly between 35 and 42%, moderate borehole enlargement (13 to 16-in. dia. for 11 7/8-in. bit). Intervals consists mostly of peritidal facies on the OBI log; mostly massive and laminated (planar, crenulated/stromatolitic) strata. Minimal large secondary porosity features (vugs) compared to below. Minor faults (< 1 ft displacement) at 690 to 711 ft and 739 to 747 ft; healed (planar contact), not flow features.
790	1,260	Avon Park permeable zone and Lower Floridan Aquifer below MCU I. Flowmeter log indicates that the APHPZ occurs between approximately 800 and 988 ft bls. The APHPZ contains fresh groundwater. OBI logs shows typical peritidal facies with both horizontally laminated facies and vuggy horizons, which are interpreted to be former evaporite horizons (dissolved gypsum or anhydrite nodules). Secondary porosity from evaporite dissolution appears to act as flow zones. Large vugs/small cavities pronounced from 840 - 850 ft. Anhydrite generally absent on OBI log (with minor possible exceptions).

1,260	1,485	Middle Confining Unit II (MCU II). Common anhydrite is first evident in the OBI log at about 1,271 ft bls. Anhydrite occurs as centimeter-sized scattered nodules and as layers of coalesced nodules, which is described in the geological literature as a "chicken-wire" texture. The boundary LFA below MCU I and MCU II boundary is also marked by a sharp downhole decrease in sonic porosity from values mostly greater than 22% to values most less than 22%. No fracturing evident that could compromise integrity of confinement.
1,485	1,600	General increase in sonic porosity to values most commonly in the 20 to 25% range; several low porosity (< 10%) beds up to about 8 ft thick. Vugs are filled with anhydrite.
1,600	1,799	Two main lithologies are present. Low porosity facies (sonic porosities <= 15%) and a moderate porosity facies with sonic porosities > 20%. Low porosity intervals are characterized by vugs that are filled with anhydrite (e.g., 1674 to 1699 and 1755 to 1786 ft) as visible on the OBI log. Some transit time peaks at 1705 to 1715 ft, which is an interval with large open vugs (small cavities). The flowmeter log interpretation indicates that this interval is a minor flow zone.
1,799	1,810	Sonic transit time peak (225 usec/ft and sonic porosity of 65%) that is a major flow zone; flowmeter interpretation logs indicates that it is the most transmissive zone in the 1600 to 3000 ft logged interval. Secondary porosity is dominated by large open vugs on OBI log. A sharp decrease in temperature at 1806 to 1820 ft bls and decrease in fluid conductivity at 1800-1810 ft bls also indicate that this interval is a flow zone; water that is cooler and fresher than water that entered the borehole from below .
1,810	1,850	Low porosity (7 - 12%) dolostone with anhydrite filled vugs.
1,850	1,936	Mixed interval with both low and moderate sonic porosity intervals; variable degree of filling of vugs with anhydrite. Flowmeter interpretation log indicates some flow from this interval
1,936	2,140	Moderate sonic porosities (mostly in the 15 to 25% range), minimal anhydrite is evident on the OBI log. At most minor flow on flowmeter interpretation log. Softer strata indicated by a larger borehole diameter than above and below, peaking at about 15 inches at 2100 ft. No significant fracturing.
2,140	2,220	Sharp decrease in sonic porosity and return of borehole diameter to bit size (12-inches). No corresponding major change on the OBI log (anhydrite is still not evident), minimal flow contribution. Choppy sonic logs reflecting variable porosities (7 to 23%). No anhydrite is evident on the OBI log, vugs are open. No significant fracturing.
2,220	2,300	Interval may contribute about 10% of the total flow on the flowmeter interpretation log. Choppy sonic logs reflecting variable porosities (7 to 22%). No significant fracturing.
2,300	2,320	Flow zone on flowmeter interpretation log, open vugs on OBI log. Top of LFA II-b.
2,320	2,406	Low sonic porosities (=> 10.5%), no significant flow is indicated by flowmeter interpretation log, borehole diameter is close to 12 inches (gauge). Dual induction long interpretation (using Archie's law) indicates increasing salinity between 2300 and 2400; the base of the USDW (10,000 mg/L TDS isopleh) likely occurs within this interval.
2,406	2,416	Major flow zone on the flowmeter interpretation log, large sonic transit time peak (225 usec/ft, sonic porosity = 65%), interval contains open vugs on the OBI log.

2,416	2,543	Low sonic porosities (<15%) down to 2440 ft, then moderate porosities (15 - 30%). Negligible flow below 2416 ft on the flowmeter interpretation log. Planar to crenulate (locally stromatolitic) laminations and vuggy intervals without anhydrite. Dual induction log indicates saline groundwater.
2,543	3,000	Top of uppermost bedded anhydrite of Cedar Keys Formation occurs at 2543 ft. The anhydrite appears in the OBI logs as planar to crenulate laminated beds, scattered nodules, and coalesced nodule ("chicken-wire") layers. The anhydrite-rich strata (e.g., between 2,560 and 2,660 ft bls) has a very low (~ 5%) porosity. The carbonate strata has a moderate to high porosity (20 to 30%) but appears fine-grained and likely has a low permeability. Hypersaline pore waters is indicated by dual induction log interpretation (specific conductance > 100,000 µS/cm)

5.2 Packer Testing

Six (6) packer tests were performed during after the drilling of the pilot hole for SE-TPW from 1,600 to 3,000 ft bls. The objectives of the packer testing program were to sample the production zone, hydraulically characterize potential injection zone strata and overlying confining strata, and collect water samples to be used to determine the base of the USDW. Both single (off-bottom) and straddle pack tests were performed. Single-packer tests involve setting one packer to hydraulically isolate the top or bottom of the borehole. Straddle-packer tests involve the setting of the two packers to hydraulically isolate the intervening interval of the borehole. The tested intervals were pumped with a submersible pump and water-level versus time data were collected using pressure-transducers.

The data showed strong borehole/drill pipe effects which precluded analysis using standard Theis curve matching and Cooper and Jacob straight-line methods. High transmissivity intervals exhibited oscillatory responses and pumping test data were impacted by salinity changes. Transmissivity and hydraulic conductivity were instead roughly estimated using the Driscoll (1986), method which relates transmissivity to specific capacity (pumping rate divided by drawdown). Drawdowns from the recovery phase was used as it was less impacted by changes in salinity (i.e., salinity within pipe and borehole did not materially change). The packer test hydraulic data are summarized in **Table 5-3**.

Table 5.3 Summary of SE-TPW packer tests

Test No.	Depths (ft bls)	Q (gpm)	Drawdown (ft)	Specific capacity (gpm/ft)	Transmissivity (ft^2/d)	Average hydraulic conductivity (ft/d)
1	1600 - 2000	90	7.97	11.3	3,019	7.55
2	1920 - 3000	88	6.62	13.3	3,554	3.29
3	2322 - 3000	78	6.18	12.6	3,374	4.98
4	2390 - 2450	60	4.08	14.8	3,932	5.80
5	2250 - 2310	60	4.92	12.2	3,260	4.81
6	2150 - 2210	8	11.76	0.68	182	0.27

5.3 Aquifer Performance Test

A 14-day constant-rate aquifer performance test was initiated on December 8, 2018 (APT-1), but had to be terminated on December 12, 2018, due to concerns over the discharge water flowing onto neighboring properties. The test was restarted on January 8, 2019 (APT-2), and successfully completed. Well SE-TPW was pumped and water levels were recorded in the production zone monitoring well (SE-LFA, located 200 ft west of TPW) and SE-UFA monitoring well. The test conditions were as follows:

- Average pumping rate: 1,105 gpm
- Pumped well drawdown: 80 ft
- Specific capacity: 13.8 gpm/ft
- Observation well (SE-LFA) maximum drawdown: 12.4 ft

Water levels in the SE-UFA well fluctuated over the duration of the APT with a slight declining trend. The decline trend is evident in other UFA wells in Polk County distant from the APT site (e.g, **Fig. 5-1**), which suggests that the decline in water levels is well SE-UFA during the test was a regional event rather than being induced by the LFA pumping.

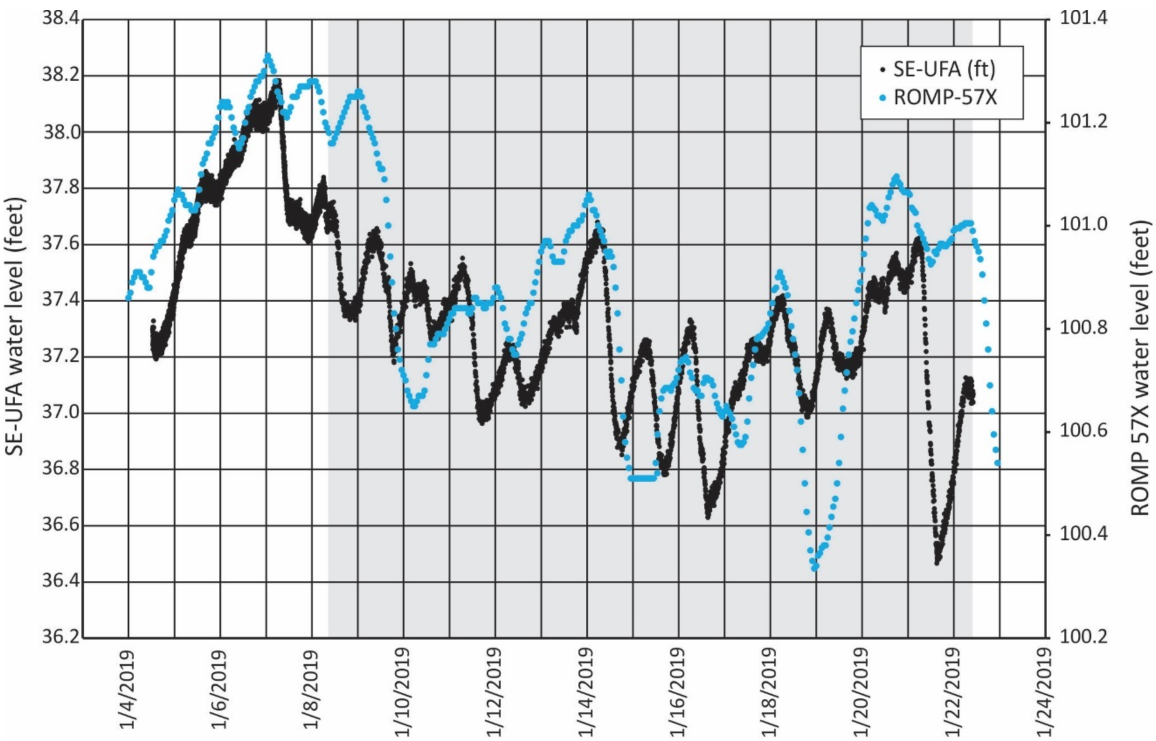

Figure 5-4 Plot of UFA water levels from SE-UFA and ROMP 57X (located 7.3 miles W of the TPW site). APT period is shaded gray (Source: John Ferguson)

The time-drawdown data from the LFA observation was evaluated using the Hantush-Walton (Hantsuh and Jacob 1955; Walton 1962) modification of the Theis (1953) method for leaky aquifers (**Figure 5-2**) and the Cooper and Jacob (1946) straight-line method for both the pumping (**Figure 5-3**) and recovery data (**Figure 5-4**). The results of APT-2 are summarized in **Table 5-4**. The leakance value was calculated using a r/B value of 0.3.

The early data plot off the Theis curve. Because time is plotted on a logarithmic scale, small time errors can have relatively large impacts on where early test data plot, but essentially no impact of the plotting of later data. Time errors may be due to time = 0 in the data not corresponding to the exact moment the pump was turned on and the aquifer potentiometric surface starts to respond to pumping. Lags in the pump reaching the final APT pumping rate and borehole head loses can also impact early test data (Maliva 2016). Applying an empirical 0.7 minute time correction to the APT-2 data results in a tighter overall curve match, but has no impact on the calculated aquifer hydraulic parameters (**Figure 5-5**).

A Hantush-Walton analysis of the SE-LFA data for the initial four-day APT, performed at an average pumping rate of 1,250 gpm, gave a transmissivity of 3,830 ft^2/d, storativity of 1.5×10^{-3} and leakance of 1.0×10^{-2} d^{-1}. The calculated leakance represents leakage from both above and below the production interval. The very low permeability of the overlying anhydrite-rich MCU II suggests that most of the leakage was from below.

Table 5.4 Summary of APT hydraulic parameters

Method	Transmissivity (ft^2/d)	Storativity	Leakance (d^{-1})
LFA - Hantush-Walton (curve match)	3,810	1.1×10^{-3}	8.6×10^{-3}
LFA - Cooper & Jacob (straight-line)	4,840	9.0×10^{-4}	-
LFA - Cooper & Jacob Recovery	4,808	-	-
TPW (Driscoll 2000 x SC estimation)	3,690	-	-

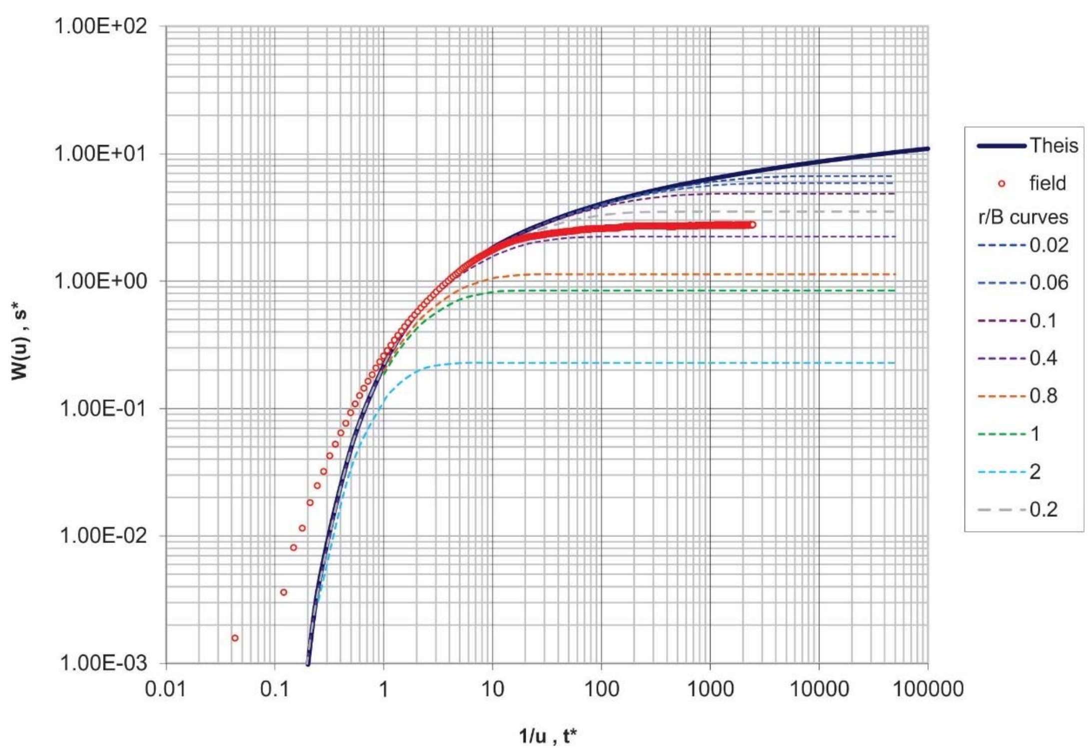

Figure 5-2 Hantush-Walton curve-match for the APT-2 data for SE-LFA

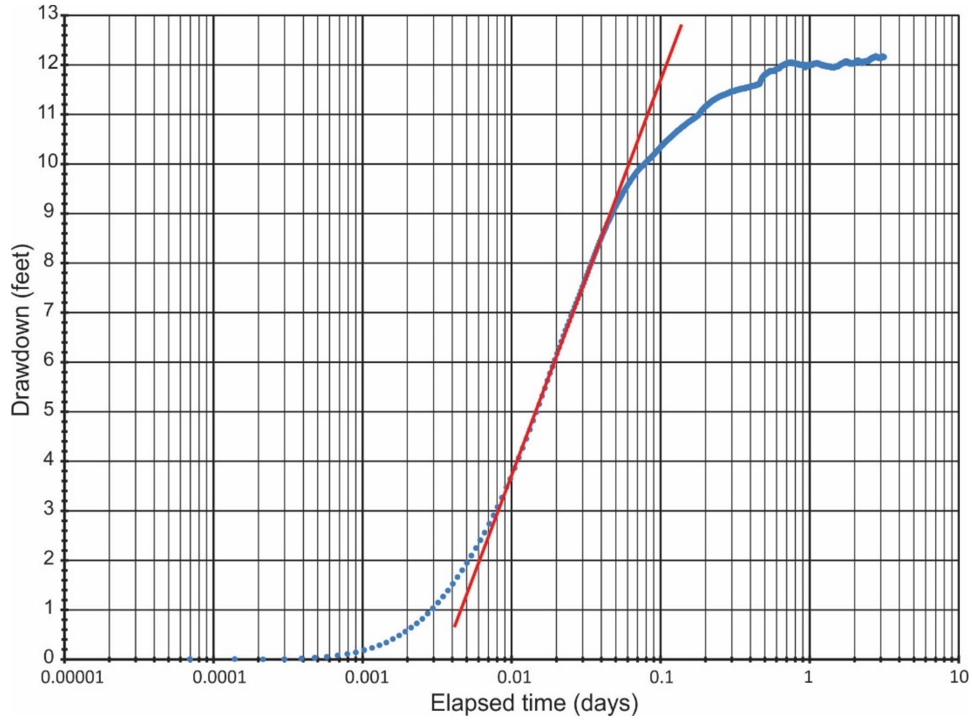

Figure 5-3 Cooper and Jacob plot for the APT-2 pumping data for SE-LFA

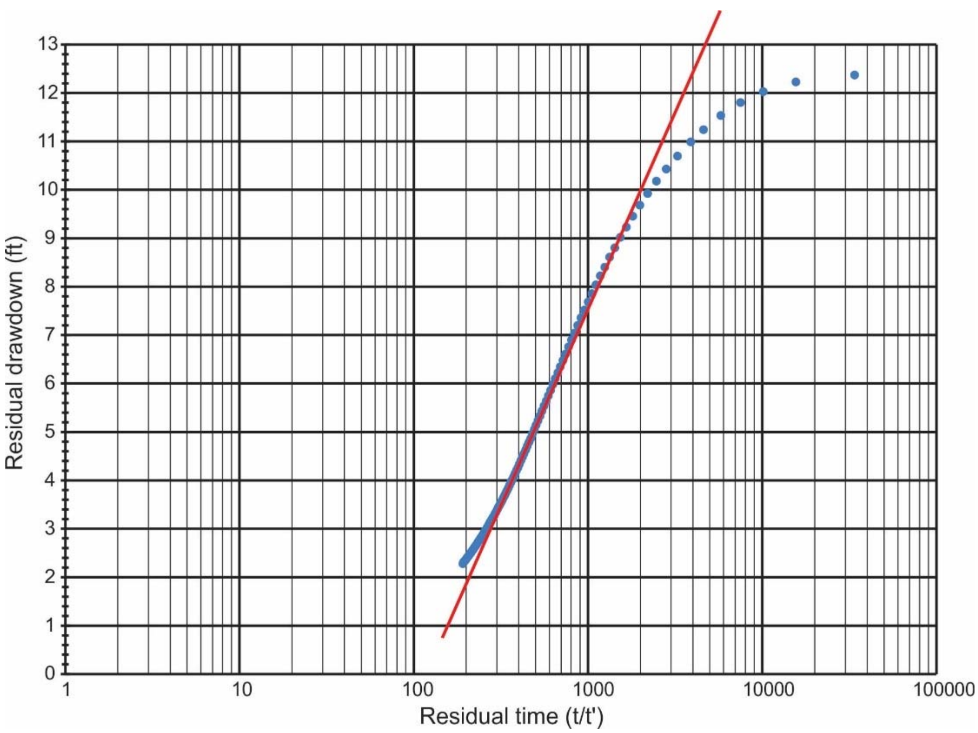

Figure 5-4 Cooper and Jacob plot for the APT-2 recovery data for SE-LFA

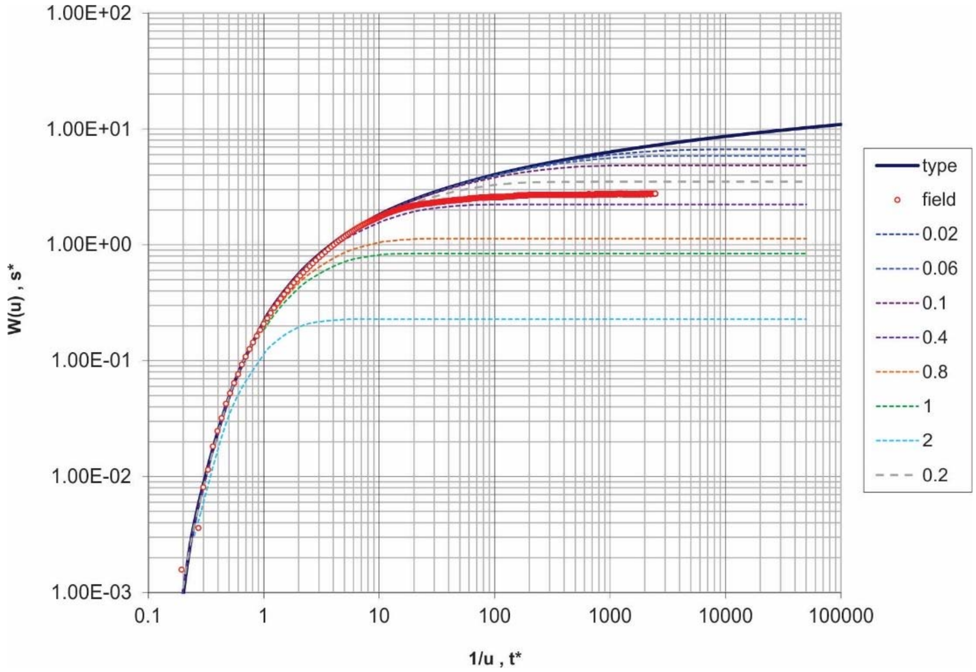

Figure 5-5 Time-corrected Hantush-Walton curve-match for the APT-2 data for SE-LFA

Samples of the discharge water from the APT-2 were collected daily and analyzed in the field and laboratory salinity parameters. A plot of the water quality data versus time shows that salinity stabilized after about 5 days of pumping (**Figure 5-6**). The final TDS concentration was 3,200 to 3,300 mg/L, which is quite higher than the 1,100 mg/L TDS at the end of the SE-DEW APT.

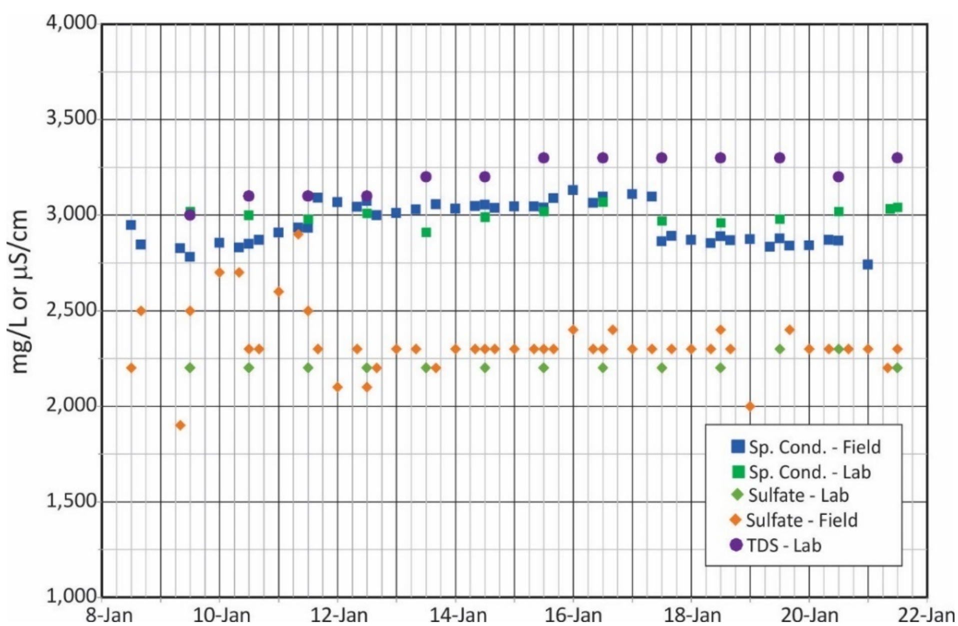

Figure 5-6 Discharge water quality data from the SE-TPW APT-2

5.4 Hydraulic Heads

Static depths to water in SE-TPW wells were measured each morning. The depth to water data are compiled in **Appendix F**. Daily measured water elevation versus depth in well SE-TPW and UFA water elevation measured the same day in the completed well SE-UFA are provided as **Figure 5-6**. The key observation in the water elevation data is that there is an approximately 29 ft difference in head between the open borehole down to 1,600 ft bls (production casing seating depth) and the upper part of the open borehole below production casing. The head difference occurs across MCU II between LFA I and LFA II-a, which is very strong evidence that MCU-II is a highly effective confining unit at the SE-TPW site. The salinity difference between LFA I (LFA below MCU I including the APHPZ) and upper LFA II-a is modest and would not materially impact the measured water level difference.

The hydraulic heads are inconclusive as far as internal confinement within the LFA. Depths to water in the well during 24-hours a day drilling would reflect aquifer pressures, aquifer salinities, borehole water salinity, and any dynamic effects from drilling.

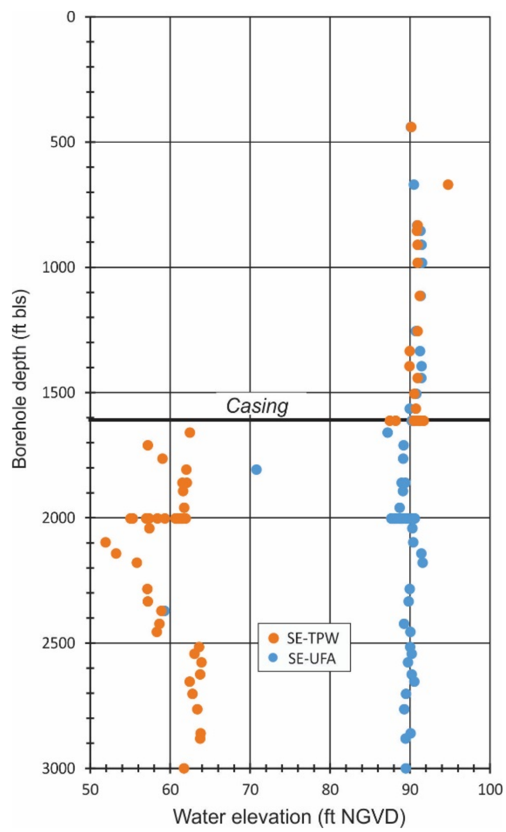

Figure 5.6 Water elevation versus depth data from well SE-TPW. Water elevations were measured daily each morning. Also plotted are the UFA water elevations measured in the completed well SE-UFA at the same approximate time as corresponding the SE-TPW elevation. Data are not corrected for salinity differences.

5.5 Comparison of the Hydrogeology of SE-TPW and SE-DEW

The hydrogeology encountered in the SE-TPW and the Southeast Polk County Deep Exploratory Well (SE-DEW, PBS&J 2010), located at the southern end of the proposed Southeast Wellfield, are generally similar (**Figure 5-7**). Key differences between the SE-DEW and SE-TPW are that a lower transmissivity and greater salinity were encountered in the proposed production interval (LFA II-a) in the SE-TPW well. The transmissivity obtained from the SE TPW aquifer performance test (APT) was 3,810 ft^2/d, which is much lower than the calculated value of 15,300 ft^2/d from the SE-DEW APT. The produced water at the end of the SE-TPW APT had a total dissolved solids (TDS) concentration of 3,220 mg/L compared to a value of 1,100 mg/L from the end of the SE-DEW APT.

Packer test data for the proposed injection interval (LFA II-b) from the SE-DEW suggest a transmissivity of 6,900 ft^2/d for the upper zone (2,188 to 2,373 ft bls) and 3,240 ft^2/d for the lower zone (2,373 to 2,521 ft^2/d). The estimated transmissivity of the LFA II-b in the SE-TPW is 3,374 ft^2/d from the packer test run from 2,322 – 3000 ft bls.

The lower transmissivity of LFA II-a at the SE-TPW site would result in greater drawdowns for a given pumping rate than would occur at the SE-DEW site. Similarly, the lower transmissivity of LFA II-b at SE-TPW site would result in greater pressure increases for a given injection rate than would occur at the SE-DEW site.

Data are available for the south (SE-DEW) and near the north ends (SE-TPW) of the proposed production well alignment. It is unknown whether the data from SE-DEW or SE-TPW are more representative of the wellfield as a whole and where in the proposed wellfield lies the boundary between the relatively low transmissivity and high TDS water encountered at SE-TPW and the higher transmissivity and lower TDS water encountered at SE-DEW.

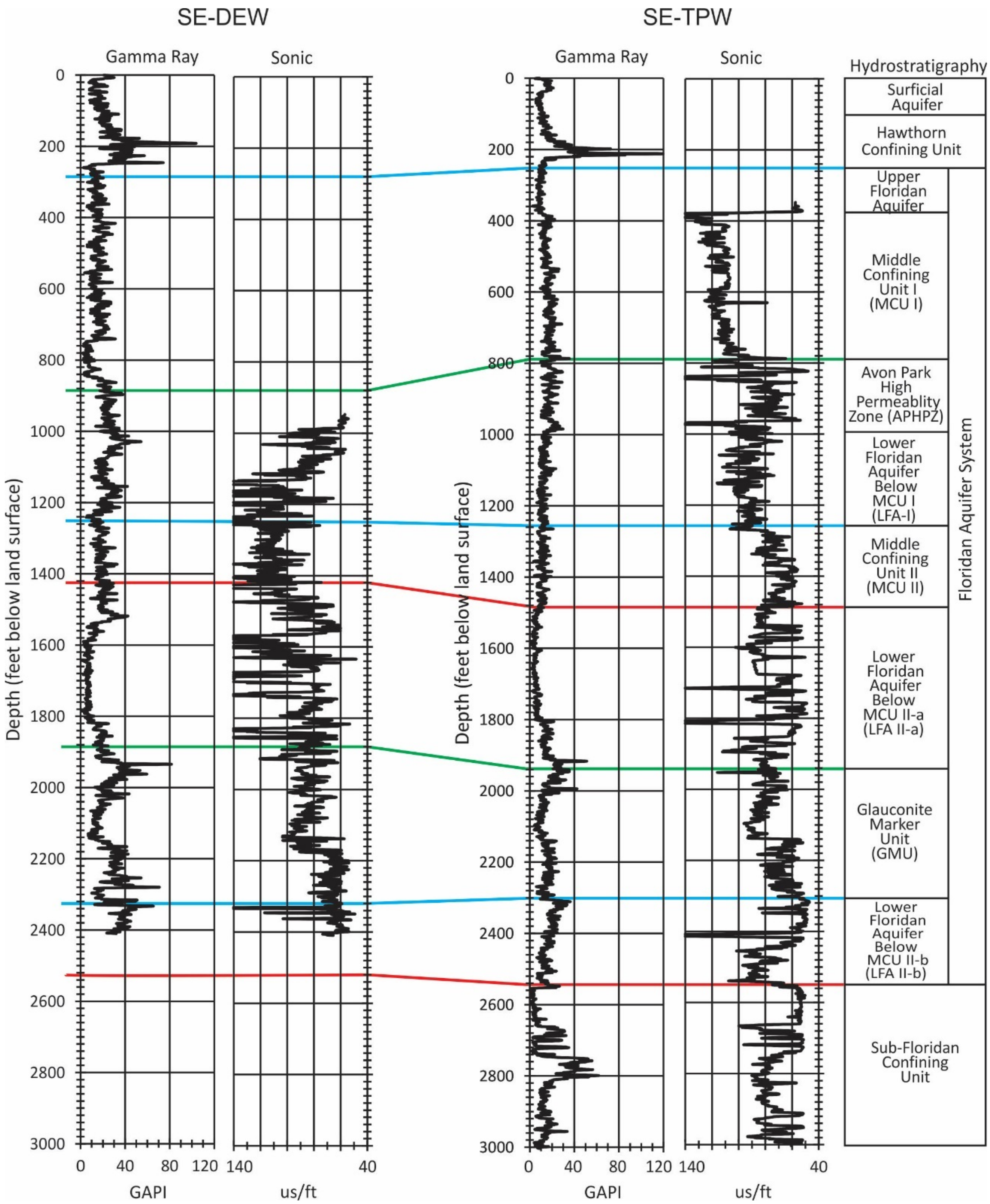

Figure 5-7 Comparison of hydrogeology of SE-DEW and SE-TPW

6.0 WATER QUALITY

Data on groundwater were obtained from analyses of samples from the reverse-air discharge, packer tests, and aquifer performance tests.   Descriptions of the data follows.

6.1 Reverse-Air Discharge

Samples of the reverse air discharge were collected every 30 feet (drill rod addition) and analyzed in the field for specific conductance temperature, chloride, sulfate, and pH. Water samples were collected less frequently for analysis by ENCO Laboratories for total dissolved solids, specific conductance, chloride, sulfate, and pH. The reverse-air discharge water quality data for a given depth is not necessarily representative of the formation water quality at that depth because of mixing with water produced higher in the borehole. However, changes in the composition of the reverse-air discharge can provide qualitative information on formation water quality and water production. A plot of specific conductance and TDS, chloride, and sulfate concentrations versus depth is provided as **Figure 6-1.**

The reverse-air discharge data indicates a TDS concentration of 1,000 mg/L or less down to at least 1,600 ft bls. Below 1,800 ft bls, TDS increases to approximately 3,000 mg/L, the value obtained from the aquifer performance test (from 1,600 to 2,000 ft bls). The flowmeter logs indicate that flow into the production well is dominated by flow zones located below 1,800 ft bl. A transition to TDS values greater than 10,000 mg/L occurs between 2,300 and 2,350 ft bls, which suggests that the base of the Underground Source of Drinking Water (USDW) occurs in this interval. Samples below 2,400 ft bls are of roughly seawater salinity (> 30,000 mg/L).

6.2 APT and Packer Tests

Water samples were collected at the end of APT-2 and analyzed for Florida primary and secondary drinking water standards, major cations and anions, and reverse-osmosis design parameters. A copy of the laboratory report is provided as **Appendix G.** Water samples were collected at the end of each packer test and analyzed for major cations and anions. The results of the water quality analyses for major cations and anions are summarized in **Table 6-1**.

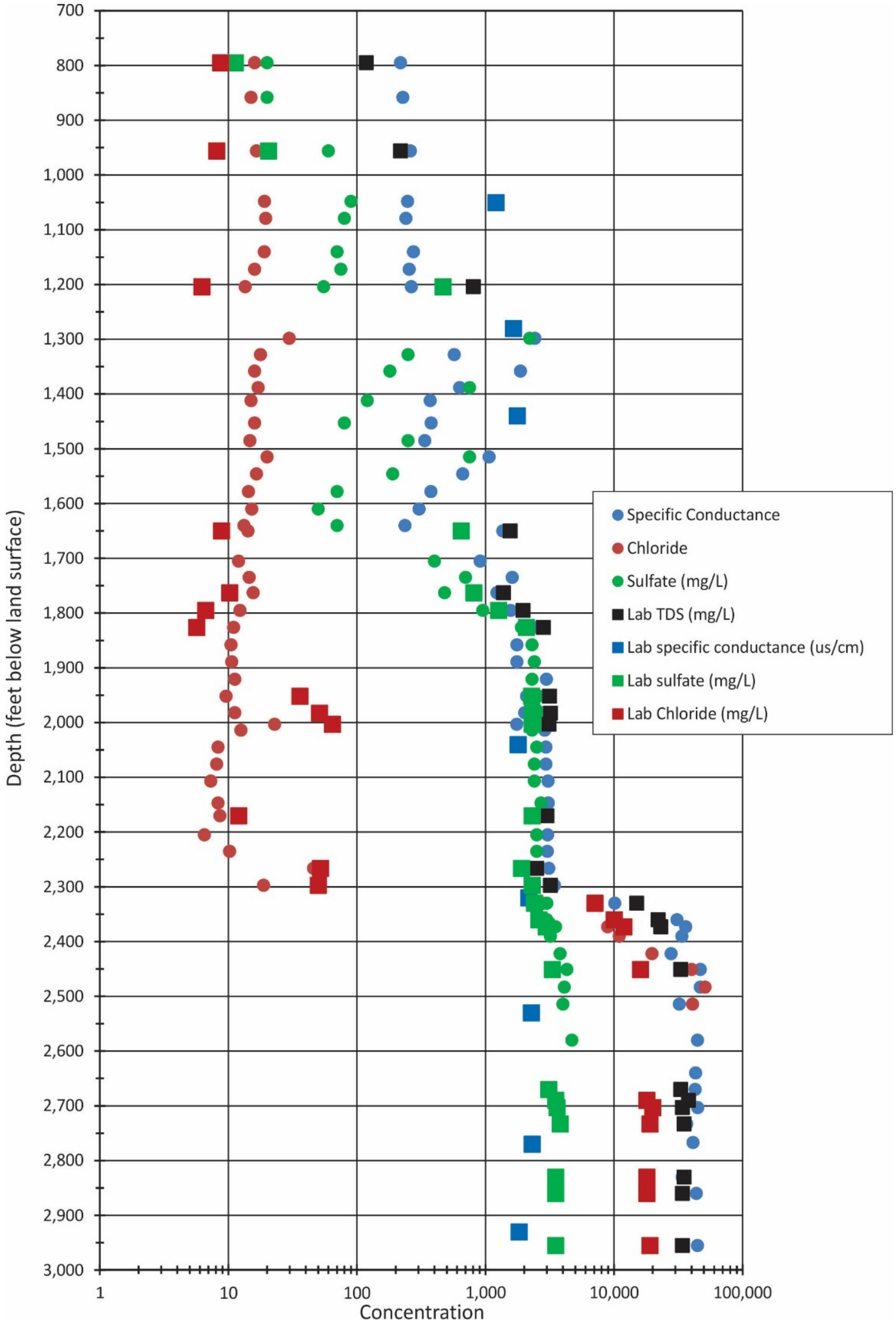

Figure 6-5 Plot of reverse-air discharge water quality versus depth

Table 6.1 Summary of water quality data from APT-2 and the packer tests laboratory analyses

Parameter	APT-2	PT-1 (1600 – 2000 ft)	PT-2 (1920 – 3000 ft)	PT-3 (2322 – 3000 ft)	PT-4 (2390 – 2450 ft)	PT-5 2250 – 2310 ft)	PT-6 2150 – 2210 ft
Specific conductance (µS/cm)	3,030	2,210	24,600	47,000	47,000	13,900	13,900
Total dissolved solids (mg/L)	3,220	1,940	15,900	27,900	32,200	8,970	9,180
Chloride (mg/L)	11.6	88.6	7,610	15,550	16,900	3,900	3,820
Sulfate (mg/L)	2,200	1,150	2,340	3320	3,460	1,900	1,950
Sodium (mg/L)	6.39	48.6	4,000	7,810	8,470	1,910	1,890
Bicarbonate alkalinity (mg/L)	61.0	63.6	99.5	116	116	94.4	83.2
Calcium (mg/L)	541	334	671	1,000	1,040	471	463
Magnesium (mg/L)	202	119	518	863	949	310	316
Potassium (mg/L)	2.15	<5.0	150	291	318	70.3	70.3
Fluoride (mg/L)	3.67	2.02	1.18	0.893	0.926	1.29	1.26
Iron (mg/L)	0.126	2.73	6.66	2.94	4.93	2.77	5.88
Hydrogen sulfide (mg/L)	0.265	-	0.639	0.383	0.124	0.232	0.178

6.3 Base of the Underground Source of Drinking Water

Straddle packer tests PT-4 (2,390 to 2,450 ft bls) and PT-5 (2,250 to 2,310 ft bls) bracket the base of the regulatory Underground Source of Drinking Water (USDW), which is defined as the 10,000 mg/L total dissolved solids (TDS) isopleth. The reverse-air discharge data also shows in increase in salinity to levels greater than 10,000 mg/L between 2,300 and 2,350 ft bls.

A plot of log-derived specific conductance versus depth was prepared using the Archie (1942) equation and formation resistivity values obtained from the deep induction log and porosity values from the sonic log (Fig. 6-2). The plot has a high degree of scatter caused by the lithological diversity and common secondary pores. The plot does show a pronounced increase in overall specific conductance and thus TDS below 2,300 ft bls.

The combined data indicate that the base of the USDW occurs at about 2,320 ft bls (± 20 ft) in well SE-TPW.

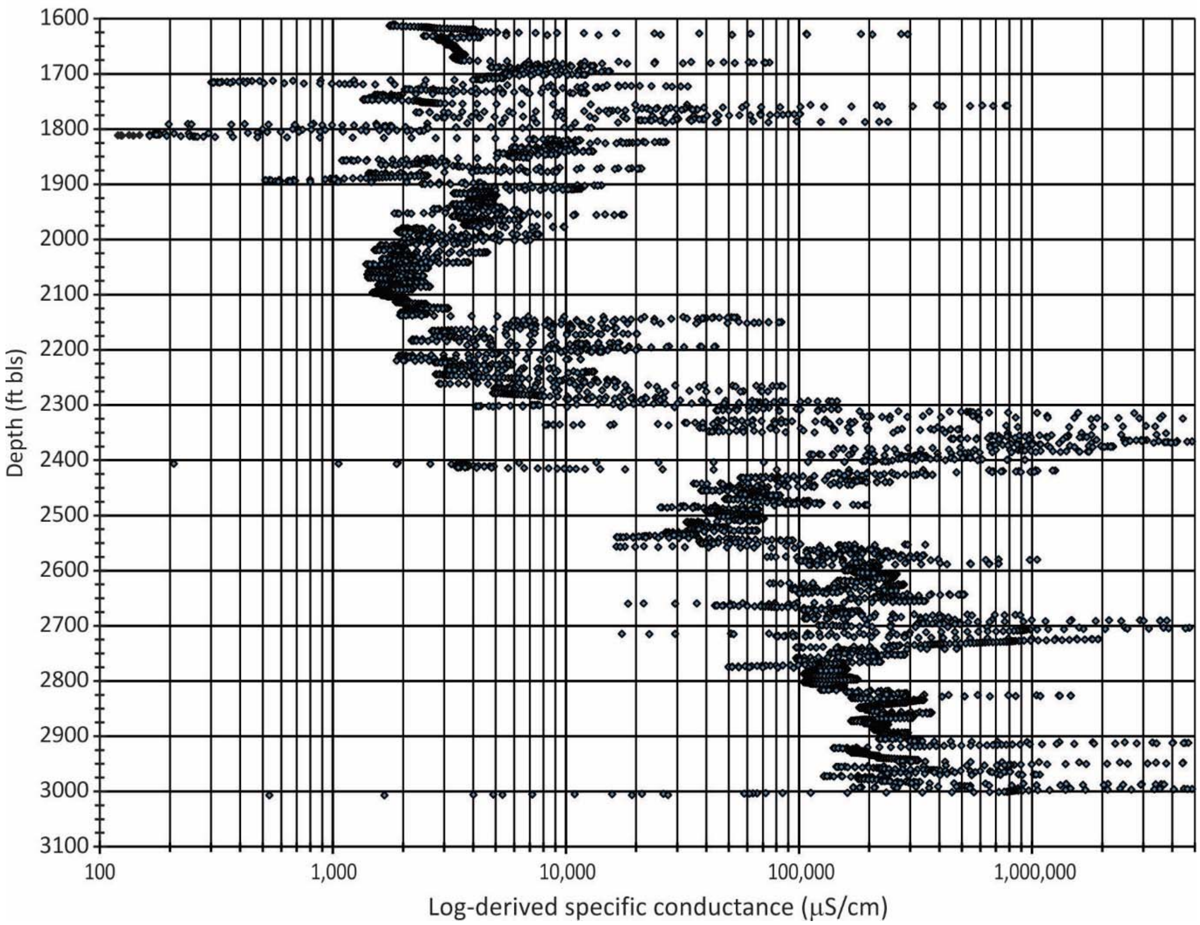

Figure 6-2 Plot of log-derived specific conductance for well SE-TPW

6.4 Groundwater Chemistry

A piper plot of APT and packer test data show that two distinct water types are present (**Figure 6-3**). The production zone water samples (APT and PT-2) are calcium-sulfate waters in which the dissolved solids were derived primarily from the dissolution of gypsum and/or anhydrite present in the formation. The deeper more saline groundwaters are sodium-chloride type reflecting an ultimate seawater source of the dissolved solids.

The saturation state of waters with respect to the calcium sulfate (anhydrite and gypsum), carbonate, and other ionic minerals (barite and fluorite) were calculated using the USGS PHREEQC code (Parkhurst and Appelo 1999). The saturation state of minerals in different waters are expressed in terms of their saturation indices, which are the logs of the ratios of their ion activity product and solubility product. Saturation indices of less than zero indicate unsaturated conditions (and thus mineral tend to dissolved), whereas values greater than zero indicate supersaturated conditions (and thus minerals tend to precipitate out of solution). The SI values for LFA II-a from the SE-DEW and SE-TPW APTs are summarized in Table 6-2.

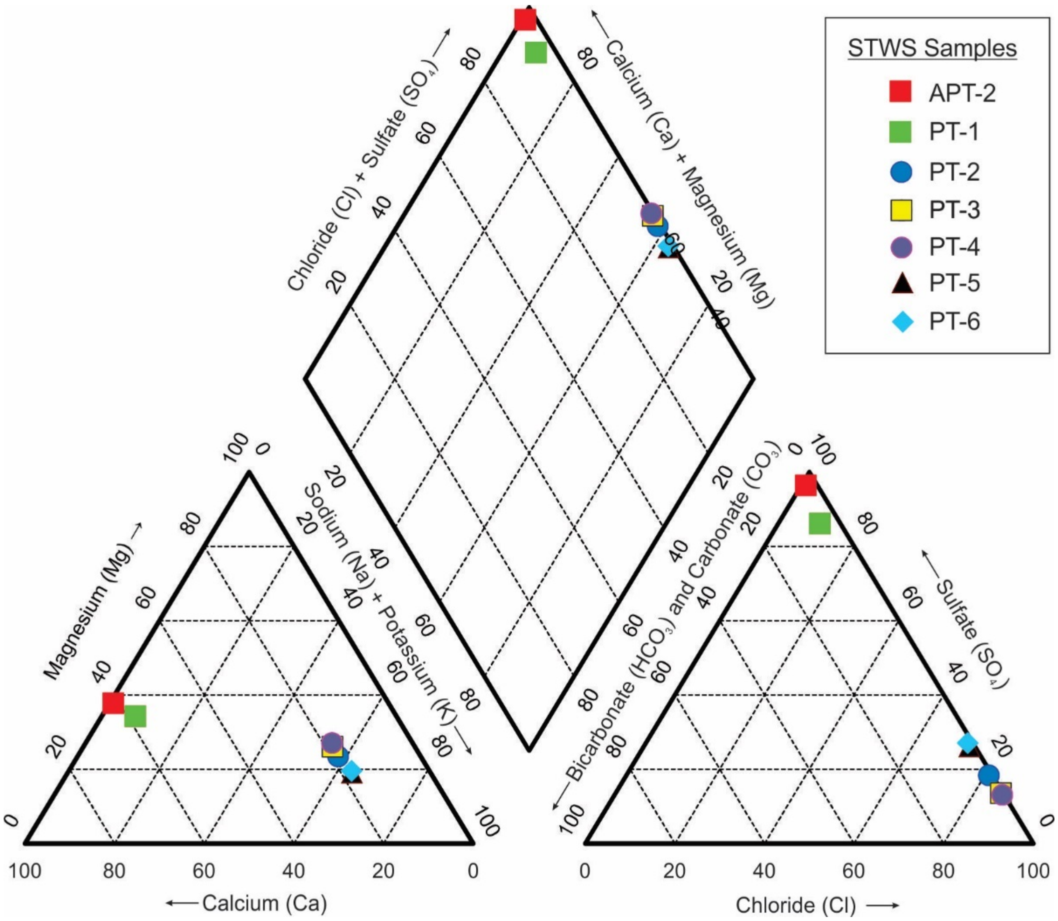

Figure 6-3 Piper diagram of SE-TPW APT and packer test water samples.

Table 6.2 Calculated saturation states of the APT water samples.

Mineral	Saturation indices (log[IAP/Ksp])		
	SE DEW APT	SE TPW APT-1	SE TPW APT-2
Calcite ($CaCO_3$)	0.14	0.26	0.29
Aragonite ($CaCO_3$)	0.00	0.12	0.14
Dolomite ($CaMg(CO_3)_2$)	0.19	0.44	0.48
Anhydrite (CaSO4)	-0.84	-0.28	-0.24
Gypsum ($CaSO_4{\cdot}H_2O$)	-0.62	-0.06	-0.02
Barite ($BaSO_4$)	0.64	-0.47	-0.49
Fluorite (CaF_2)	-1.39	0.08	0.43

The production interval water samples from the SE-TPW APT-2 are mildly undersaturated with respect to anhydrite and close to saturation with respect to gypsum (a hydrated calcium sulfate mineral). The degree of undersaturation of the proposed production interval with respect to the calcium sulfate minerals at the SE

-TPW site is less than (SI is more negative) that at the SE-DEW site due to a greater TDS concentration at the SE-TPW site. In as much as the TDS of LFA II-a is derived largely from the dissolution of anhydrite and gypsum, dissolution of these minerals proceeded further in the SE-TPW vicinity and the water chemistry evolved closer to saturation.

The water chemistry data for all three samples indicate that they are slightly supersaturated with respect to calcite. Gypsum and anhydrite dissolution releases calcium, which increases the saturation state of groundwaters with respect to calcium carbonate minerals. However, calculated calcite saturation states are highly sensitive to pH and measured pH values have large potential for errors if careful sampling and analysis procedures are not followed. Degassing of CO_2 upon exposure of water to the atmosphere can cause a decrease in dissolved CO_2 and an associated increase in pH and thus the saturation state of carbonate minerals. Hence, the mild calculated degrees of supersaturation with respect to calcite may not reflect aquifer conditions. Typically, groundwaters in long contact with carbonate minerals in aquifers are at (or very close to) calcite saturation.

7.0 CONCLUSIONS

The SE-TPW hydrogeologic testing program which was completed in 2019 resulted in the following findings:

- An LFA II-a production interval is present at the SE-TPW site, but the transmissivity of the zone (3,810 ft^2/d) is considerably less than that at the SE-DEW-1 well site (15,300 ft^2/d). A lesser transmissivity toward the north end of the SE Wellfield would result in greater drawdowns for a given pumping rate. SE-TPW had approximately 80 ft of drawdown during the pumping test at a pumping rate of 1,105 gpm, which corresponds to a specific capacity (SC) of 13.8 gpm/ft. The corresponding drawdown at the permitted capacity (1,800 gpm) is 130 ft. There will be additional drawdown from the pumping of the other production wells. The data from the 12-day APT at the SE-TPW site indicate an LFA II-a storativity of 1.1×10^{-3} and leakance of 8.6×10^{-3} d^{-1}.
- Data are available for the south (SE-DEW-1) and near the north ends (SE-TPW) of the proposed production well alignment. It is unknown whether the data from the SE-DEW-1 or SE-TPW sites are more representative of the wellfield as a whole and where in the proposed wellfield lies the boundary between the relatively low transmissivity and high TDS water encountered at the SE-TPW site and the higher transmissivity and lower TDS water encountered at the SE-DEW-1 site.
- LFA II-b has a transmissive zone that is suitable for use as an injection zone. Packer test data for the proposed injection zone (LFA II b) from the SE-DEW suggest a transmissivity of 6,900 ft^2/d for the upper zone (2,188 to 2,373 ft bls) and 3,240 ft^2/d for the lower zone (2,373 to 2,521 ft^2/d). The estimated transmissivity of LFA II-b in the SE-TPW is 3,374 ft^2/d from the packer test run from 2,322 to 3000 ft bls. The lesser transmissivity in SE-TPW would result in a great injection pressure required for a given injection rate. Injection wells with a target capacity of 700 to 1,000 gpm appear to be technically feasible at injection pressures of less than 100 psi.
- LFA II-a and LFA II-b are separated by approximately 375 feet of confining strata (GMU) in the SE-TPW (approximately 450 ft in SE-DEW-1). If the low porosity dolostones present in the GMU in the wellfield area have similar low hydraulic conductivity values as indicated by the APT leakance values and measured in core samples from the SE-DEW-1 well (PBS&J 2010), then the unit would be expected to provide effective confinement between the production and injection intervals, provided that the strata are not compromised by extensive fracturing or solution conduits. There is no suggestion of significant fracturing in the SE-TPW OBI log. A key uncertainty impacting raw water

quality (salinity) during long-term production from the proposed wellfield is the properties of the GMU throughout the project site vicinity, particularly whether the low porosity dolomitic strata are continuous and not compromised by fracturing and other secondary porosity features.

- The salinity (TDS concentration) of the production interval in the SE-TPW is approximately 3,200 mg/L compared to a TDS concentration of 1,100 mg/L obtained from the SE-DEW APT. The groundwater in LFA II-a is a calcium-sulfate type in which the TDS were derived primarily from the dissolution of calcium sulfate minerals in the formation (anhydrite and gypsum). LFA II-b contains a sodium-chloride type water in which the TDS have an ultimate seawater source.
- Confinement between the UFA and LFA II-a is provided by 1,106 ft of strata including MCU I and MCU II. MCU II, due to the presence of intact anhydrite and very low porosity, is a particularly is a highly effective confining unit in the SE-TPW vicinity. The very low permeability (leakance) of MCU II is expected to prevent drawdowns from LFA II-a pumping from materially impact water levels in the UFA, much less in the surficial aquifer and environmentally sensitive environments

The overall results of the SE-TPW aquifer testing program confirm that a suitable brackish water production interval (LFA II-a) and injection zone (LFA II-b) are present at the northern end of the proposed Polk Southeast wellfield. The pumping test results and hydrogeological characteristics of the confining strata above LFA II-a support that pumping of LFA II-a will not materially impact water levels in the UFA or adversely impact surface water bodies and sensitive environments.

8.0 REFERENCES

Applin, P. L., and Applin, E. R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: American Association of Petroleum Geologists Bulletin, v. 28, p. 1673-1753.

Archie, G. E. (1942) The electrical resistivity log as an aid in determining some reservoir characteristics: Transactions American Institute of Mining Metallurgical and Petroleum Engineers, *146*, 54-67.

Arthur, J. D., Fischler, C., Kromhout, C., Clayton, J. M., Kelly, G. M., Lee, R. A., Li, L., O'Sullivan, M., Green, R. C. and Werner, C . L. (2008) Hydrogeologic framework of the Southwest Florida Water Management District. Florida Geological Survey Bulletin No. 68.

Cooper, H. H., Jr., & Jacob, C. E. (1946) A generalized graphical method for evaluating formation constants and summarizing well-field history. Transactions American Geophysical Union, 27, 526-534.

Driscoll, F.G., 1986, Groundwater and Wells, 2nd Edition: Johnson Filtration Systems, St. Paul, MN, 1089 p.

Hantush, M. S., & Jacob, C. E. (1955) Non-steady radial flow in an infinite leaky aquifer. American Geophysical Union Transactions, 36, 95-100.

Hantush, M. S. (1966) Analysis of data from pumping tests in anisotropic aquifers. Journal of Geophysical Research, 71, 421-426.

Maliva, R. G. (2016) Aquifer Characterization Techniques, Springer, Cham, Switzerland.

Miller, J.A., 1986, Hydrogeologic framework of the Floridan aquifer system in Florida, and in parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1403-B.

MWH (2013) Well Completion Report for the Polk Power Station Injection Well IW-1 and Dual-Zone Monitor Well DZMW-1 (June 2013).

Parkhurst, D.L., and Appelo, C.A.J., 1999, PHREEQC (Version 2) – A computer program for speciation, batch reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey, Water-Resources Investigations Report 99-42549

PBS&J (2010) Construction and Testing Report, Southeast Polk County Deep Exploratory Well, Frostproof, Florida.

Reese, R.S., and Memberg, S.J., 2000, Hydrogeology and the distribution of salinity in the Floridan aquifer system, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 99-4061, 52 p., 2 pls.

Reese, R. S., & Richardson, E. (2008). Synthesis of the hydrogeologic framework of the Floridan aquifer system and delineation of a major Avon Park permeable zone in central and southern Florida. U.S. Geological Survey Scientific Investigation Report 2007-5207..

Southeastern Geological Society Ad Hoc Committee, 1986, Hydrogeological Units of Florida, Florida Geological Survey Special Publication No. 28, Compiled by Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition.

Spechler, R. M., & Kroening, S. E. (2007). Hydrology of Polk County, Florida. U.S. Geological Survey Scientific Investigations Report 2006-5320.

TeamOne (2018). Lower Floridan Aquifer Hydrogeologic Investigation, Southeast Polk Test Well Site Well Construction and Testing Plan.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Transactions American Geophysical Union, 16, 519-524.

Walton, W. C. (1962) Selected analytical methods for well and aquifer evaluation. Illinois State Water Survey Bulletin 49