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Document Title: **Canal Pump Station 4 ASR Well System Completion Report**

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MWH

Cape Coral
FLORIDA

PROFESSIONAL ENGINEER

The engineering features of the IRR-6C *Canal Pump Station 4 ASR Well System Completion Report* for the City of Cape Coral, 2009, were prepared by, or reviewed by, a Licensed Professional Engineer in the State of Florida.

Ronald M. Cass, P.E.

10-25-09
Date

64922
License No.

PROFESSIONAL GEOLOGIST

The geological evaluation and interpretations contained in the IRR-6C *Canal Pump Station 4 ASR Well System Completion Report* for the City of Cape Coral, 2009, were prepared by, or reviewed by, a Licensed Professional Geologist in the State of Florida.

Gordon P. Kennedy, P.G.

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Distribution

Name	Name	Name
Bill Peak – CCC	Bill Steckroat - CCC	Shawn Kopko- CCC
Jody Sorrels – CCC	Andy Fenske - CCC	Mike Cason – CCC
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David Rhodes, FDEP, Fort Myers	James Alexander, FDEP, Tallahassee	Steve Anderson, SFWMD, West Palm Beach
Ron Reese, USGS, Fort Lauderdale		

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GLOSSARY

Term	Definition
als	Above Land Surface
AMP	Above Measuring Point
APT	Aquifer Performance Test
ASR	Aquifer Storage and Recovery
ASTM	American Society For Testing And Materials
BDL	Below Detection Limit
bls	Below Land Surface
°C	Degrees Celsius
cm/sec	Centimeters per Second
CPS-4	Canal Pump Station 4
EPA	Environmental Protection Agency
FAC	Florida Administrative Code
FAS	Floridan Aquifer System
FDEP	Florida Department of Environmental Protection
ft	Feet
gpd	Gallons Per Day
gpd/ft	Gallons Per Day Per Foot
gpm	Gallons Per Minute
gpm/ft	Gallons Per Minute Per Foot
HDPE	High Density Polyethylene
IAS	Intermediate Aquifer System
ID	Inside Diameter
lbs	Pounds
LFA	Lower Floridan Aquifer
mgd	Million Gallons Per Day
mg/L	Milligrams per Liter
MWH	MWH Americas, Inc.
OD	Outside Diameter
NGVD	National Geodetic Vertical Datum
CPS-4	Canal Pump Station 4
psi	Pounds per Square Inch
PtCo	Platinum-Cobalt

Term	Definition
PVC	Polyvinyl Chloride
RIDS	Regional Irrigation Distribution System
SAS	Surficial Aquifer System
SFWMD	South Florida Water Management District
SMW	Shallow Monitor Well
SZMW	Storage Zone Monitor Well
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids
UFA	Upper Floridan Aquifer
µS/cm	Micro Siemens per Centimeter
USDW	Underground Source of Drinking Water
WTMW	Water Table Monitor Well

Executive Summary

This report summarizes the construction and testing of the Canal Pump Station 4 (CPS-4) Aquifer Storage and Recovery (ASR) System, one of three ASR Systems constructed for the City. The ASR systems are designed to each have 1 million gallons per day storage capacity in the Upper Floridan aquifer. The CPS-4 ASR System consists of one ASR test production well (ASR TPW), two storage zone monitor wells (SZMW-1 and SZMW-2), and one shallow monitor well (SMW-1). The SZMW-1 and SZMW-2 will be used to monitor the storage zone at the City property boundary and at the anticipated distal edge of the storage zone bubble, respectively, and the SMW-1 will be used to monitor the adjacent aquifer overlying the storage zone bubble. A summary of construction and testing activities is presented below:

- Construction of the CPS-4 ASR system was permitted under the Florida Department of Environmental Protection (FDEP) Construction Permit No. 247165-003-UC, issued on May 30, 2007 for a Class V Group 7 ASR injection well with two storage zone monitor wells and one shallow monitor well.

- The ASR TPW was drilled and tested to 1,200 feet below land surface (bls). The well was then back plugged to 871 feet bls with neat cement and a 14.48-inch inside diameter (ID) fiberglass reinforced plastic (FRP) casing was installed to 783 feet bls.

- The three monitor wells were constructed with 6.625-inch outside diameter (OD) polyvinyl chloride (PVC) casing. The two storage zone monitor wells, SZMW-1 and SZMW-2, were completed with open boreholes from 780 to 871 and 800 to 900 feet bls, respectively and the shallow monitor well, SMW-1, was completed with an open borehole from 500 to 600 feet bls.

- Following initial test results, an acid treatment was completed on the CPS-4 ASR TPW, which improved the specific capacity from an initial 9 gallons per minute per foot (gpm/ft) at a flow rate of 620 gpm to 19 gpm/ft at 660 gpm.

- Water quality samples were collected at 30-foot intervals in the pilot hole during reverse-air drilling to identify changes in the salinity of groundwater with depth. Water quality of the completed production/storage interval is brackish, and contains chloride and TDS concentrations of approximately 461 mg/L and 1,170 mg/L, respectively.

- Geophysical logs were conducted after each stage of pilot hole drilling, prior to packer testing and before casing installation. The logs provide a continuous record of the geophysical properties of the subsurface formations.

- Packer tests were performed over five selected intervals: 755 to 785 feet, 815 to 855 feet, 858 to 898 feet, 900 to 968 feet, and 1,060 to 1,200 feet bls within the Upper Floridan Aquifer.

- Rock cores were collected during pilot hole drilling. Core samples were sent to Ardaman and Associates for analysis to determine vertical and horizontal hydraulic conductivity, vertical and horizontal porosity, and specific gravity. Six rock cores were evaluated from the Floridan Aquifer System from the following intervals: 673 to 683 feet, 702 to 712 feet, 817 to 824 feet, 830 to 840 feet, 890 to 900 feet, and 1,037 to 1,047 feet bls.

- A 72-hour Aquifer Performance Test (APT) was conducted on the completed ASR System beginning on May 19, 2008. The Transmissivity of the storage zone interval is approximately 21,000 gpd/ft, based on the analytical solutions for the data collected during the APT. In comparison, a Transmissivity estimate based on the post-acidification Step Drawdown Test results is approximately 35,000 gpd/ft.

- The hydrogeologic characteristics and design factors that are considered important to good performance of an ASR system are present at the CPS-4 ASR site. These factors include storage zone thickness, Transmissivity, native water quality, confinement, and absence of potential conduit flow zones.

- Installation of surface facilities, including treatment and pumping facilities should be completed so that cycle testing can be conducted.

1.0 Introduction

In 2004, the City of Cape Coral selected MWH Americas, Inc. (MWH) as the Program Manager at Risk for the expansion of the Water, Wastewater, Irrigation Facilities, and Phase 2 Utility Extension Services. This Aquifer Storage and Recovery (ASR) well syetem completion report summarizes the construction and testing of the Canal Pump Station 4 (CPS-4) ASR System permitted under IRR-2 and completed as Work Authorization IRR-6C under the framework agreement as recommended by the MWH Facilities Master Plan. This report documents the methods and procedures used during well construction and analysis of testing, as well as conclusions and recommendations for operation.

1.1 Background

The City of Cape Coral is supplementing canal water usage for irrigation water supply by constructing three ASR Systems. The second of three systems to be constructed is the CPS-4 ASR System. A vicinity map of the CPS-4 ASR System is provided as Figure 1-1. A site map showing the location of the ASR test production well (TPW) and associated monitor wells is provided as Figure 1-2. The project site is located adjacent to the Canal Pump Station 4 at 2522 Retunda Avenue, Cape Coral, Lee County, Florida.

The MWH Facilities Master Plan estimates the average daily irrigation demands at build-out to be 132 million gallons per day (mgd). The reclaimed flows from the three water reclamation facilities (Everest, Southwest, and North Cape) at build-out will be approximately 50 mgd. The permitable withdrawals from the Cape Coral fresh water canal system are estimated to be approximately 47 mgd. The water available from these two sources is approximately 97 mgd, leaving a potential irrigation water source deficit of 35 mgd. Several studies have identified ASR as having a high potential to provide the City with the necessary additional supply of irrigation water (Missimer & Associates, 1989; Dames & Moore, 1998; Camp Dresser & McKee, 2005). Additionally, the City is a stakeholder in a Regional Irrigation Distribution System (RIDS) investigated by the South Florida Water Management District (SFWMD). The RIDS Master Plan for the Lower West Coast area (SFWMD, 2002) and Feasibility Study for the Cape Coral area (SFWMD, 2004) identified significant volumes of surface water and reclaimed water could be available to Cape Coral for ASR wells during the wet season. As such, construction of the ASR facilities was eligible and received funding from the SFWMD Alternative Water Supply Program.

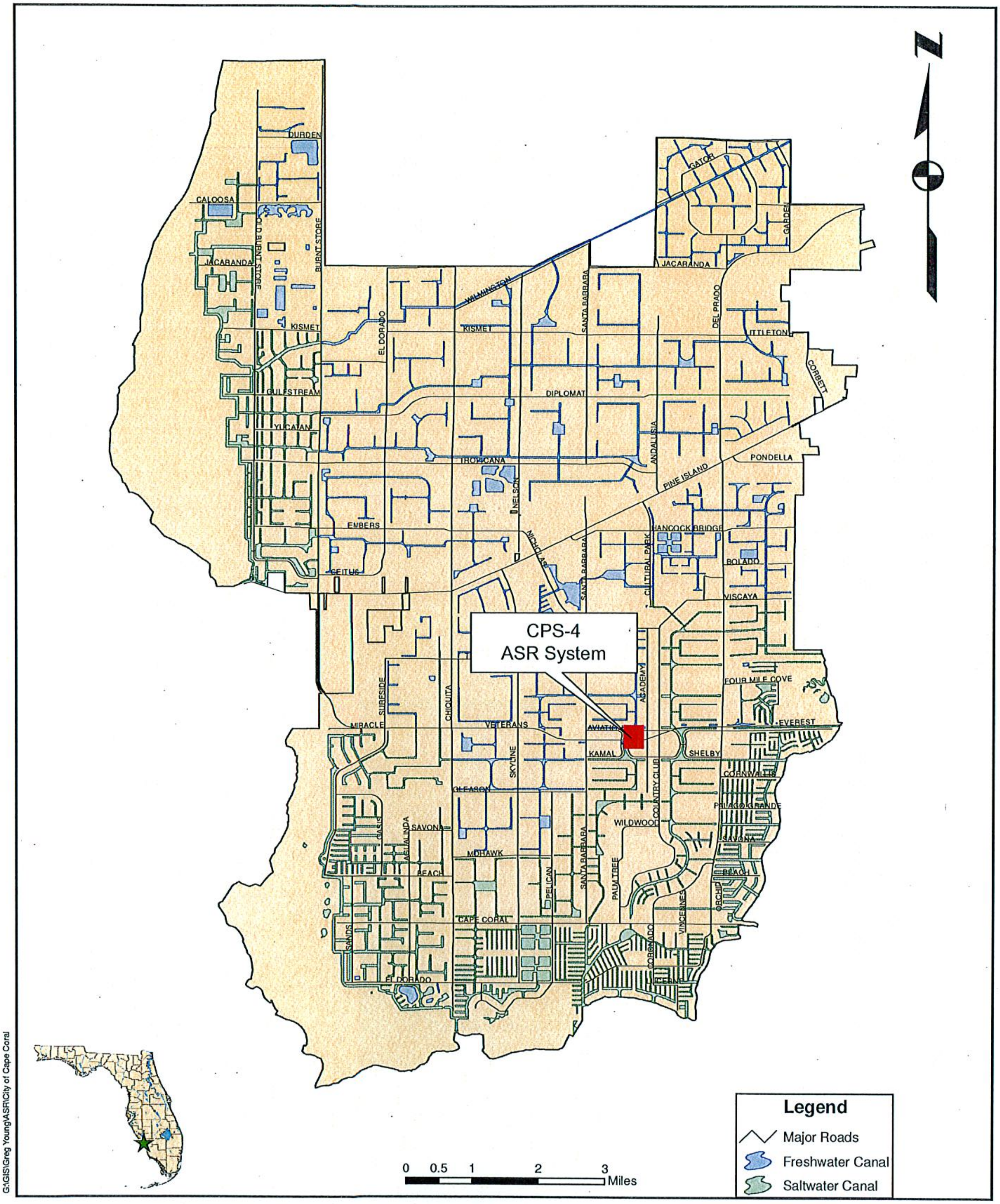

Figure 1-1 CPS-4 ASR System Vicinity Map

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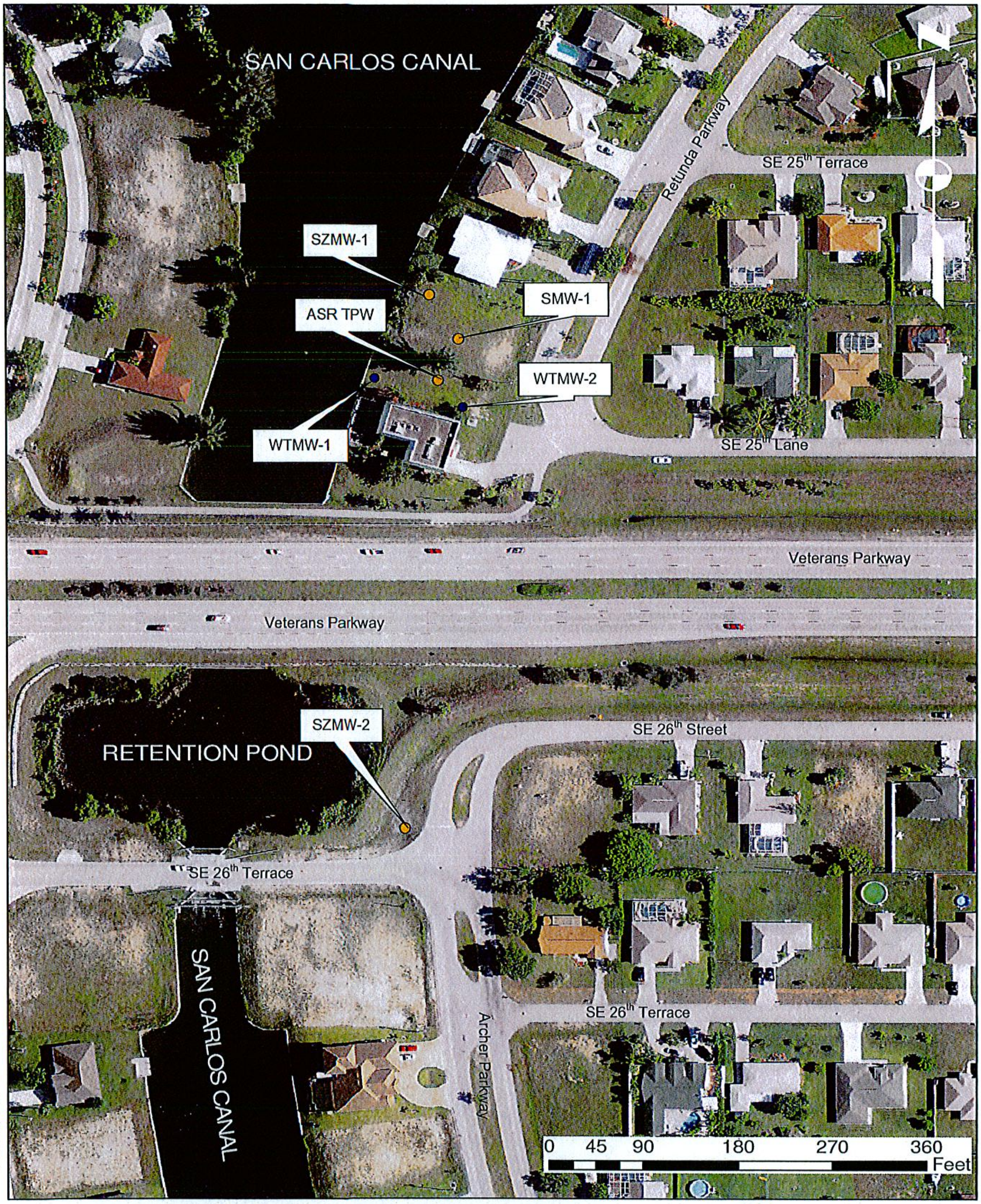

Figure 1-2 CPS-4 ASR System Site Map

On May 30, 2007, the FDEP issued Construction Permit No. 247165-003-UC. This permit allowed for the construction of one Class V Group 7 ASR Well System including the ASR-TPW, two storage zone monitor wells (SZMW-1 and SZMW-2) and one shallow monitor well (SMW-1). A copy of the FDEP permit is located in Appendix A.

The Cape Coral City Council authorized MWH to design, observe, and document the construction and testing of three ASR Systems. Design was conducted under IRR-6 work authorization. Construction of the CPS-4 ASR Systems was approved by City Council on August 6, 2007. The work was conducted under P.O. No. 099958, issued by the City on September 12, 2007. The installation of pumps and surface facilities are being designed and installed under the IRR-7 Work Authorization. Cycle testing will be initiated following the completion of surface facilities.

The ASR TPW was designed to Class V Group 7 FDEP standards as required by Chapter 62-528.410 Florida Administrative Code (F.A.C.). fiberglass reinforced pipe (FRP) casing was used as the final casing to minimize potential problems with corrosion from the stored and recovered water. The ASR storage interval is the Suwannee Limestone of the Upper Floridan aquifer (UFA) located at a depth between 783 and 870 feet below land surface (bls). The ASR TPW was designed and constructed to have an injection and recovery capacity of 1 mgd, approximately 700 gallons per minute (gpm).

1.2 Purpose

The purpose of this report is to document the information obtained during the construction and testing of ASR TPW, SZMW-1, SZMW-2, and SMW-1 at the City's CPS-4 site. The following information is included this report:

- Construction methods
- Description of methods used to analyze the data
- Documentation of the approved casing setting depths for the storage zone and monitoring intervals
- Verification that the ASR TPW is suitable for the designed storage and recovery rates to allow long term operational testing of the well

1.3 Scope of Services

Rowe Drilling Corporation of Tallahassee, FL, the contractor, conducted the drilling, construction, and testing activities of the CPS-4 ASR Well System. MWH was the City's onsite representative, providing construction observation and technical services required to comply with the construction permit.

Weekly reports documenting the construction and testing of the wells were submitted in accordance with Chapter 62-528 F.A.C., to the FDEP, and the Technical Advisory Committee (TAC). Copies of the weekly reports are included in Appendix B. The TAC includes members of local, state, and federal agencies, including state and local representatives of the FDEP, the South Florida Water Management District (SFWMD), and U.S. Environmental Protection Agency (USEPA). Construction and testing activities were reported in accordance with Specific Condition 14 of the Permit. This final report was prepared as required by Specific Condition 16 of the Permit.

2.0 Geology and Hydrogeology

The study area of northwestern Lee County is underlain by rocks of Cenozoic age to a depth of about 5,000 feet (Meyer, 1989). These rocks are composed of carbonates, with minor amounts of evaporates in the lower portion and clastics in the upper portion (Reese, 2000). In this section, the stratigraphy and identified aquifer systems encountered during drilling and testing operations for the CPS-4 ASR System will be discussed from youngest to oldest in age. Geologic formations were identified based on interpretations of the lithology, geophysical logs and/or video survey descriptions (Appendices B, C and D).

2.1 Stratigraphic Framework

Sediments encountered during the construction of the CPS-4 ASR System range in age from Late Pleistocene to Eocene. MWH collected geologic formation samples (well cuttings) from the pilot hole during drilling operations and described them based on their dominant lithologic and textural characteristics, and, to a lesser extent, color using the Folk (1980) classification system for carbonate rocks. Detailed lithologic logs are provided in Appendix C. A description of the lithostratigraphy and its relationship to the hydrostratigraphy of the study area is provided below. A generalized stratigraphic and hydrostratigraphic column of the site is shown in Figure 2-1.

2.1.1 Pliocene - Pleistocene Series

The undifferentiated deposits encountered during drilling operations include predominately siliciclastic and carbonate deposits of the Pamlico Sand Formation and the Undifferentiated Fort Thompson/Caloosahatchee Formation. During drilling of the pilot hole, undifferentiated Plio-Pleistocene surficial deposits consisted primarily of unconsolidated sand, marine bivalvia and gastropoda shell, limestone and small percentages of marl. This unit was observed at the CPS-4 site to a depth of approximately 40 feet.

2.1.2 Miocene Series

The Hawthorn Group unconformably underlies undifferentiated Pliocene-Pleistocene deposits, and is a lithologically complex sequence of silt, clay, calcareous clay, dolosilt, quartz sand, phosphate, limestone, and dolomite (Scott, 1988). It is a regional stratigraphic unit of early Pliocene to Miocene age that underlies all of South Florida. The Hawthorn Group is comprised of an upper, primarily clay unit (Cape Coral Member of the Peace River Formation), and a lower, primarily carbonate unit (Arcadia Formation). Locally, the base of the Peace River Formation contains the Lehigh Acres Sandstone Member (Missimer and associates, 1985). The two formations are separated by a major regional disconformity. At the CPS-4 ASR site, the Hawthorn Group occurs from approximately 40 to 724 feet bls.

A regional disconformity separates the Peace River Formation from the Arcadia Formation (Scott, 1988, and Cunningham, et al, 2001). The lower 500 feet of the Arcadia Formation consists of 3 to 4 large scale, transgressive-regressive cycles. Each

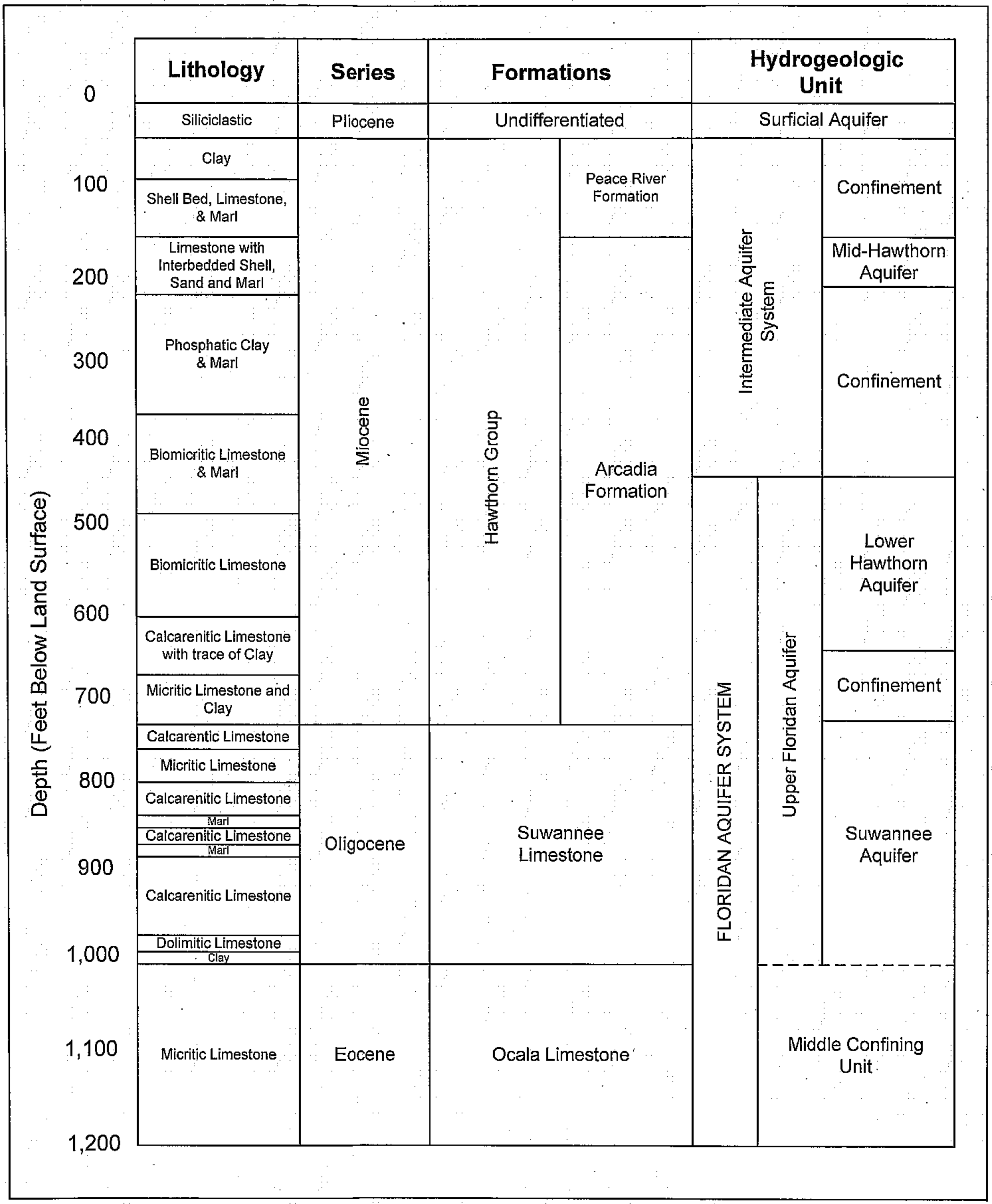

Figure 2-1 CPS-4 ASR System Stratigraphic and Hydrostratigraphic Column

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cycle consists of a lower thick limestone unit and an upper mixture of minor carbonate and clastic units (Missimer and associates, 1985).

2.1.2.1 Peace River Formation

The Peace River Formation of the Hawthorn Group consists of sandstones, sands, sandy limestones, dolomitic clays or dolosilts, and fossilized shell material (Scott, 1988 and Bennett and Rectenwald, 2004). The formation occurs from approximately 40 to 140 feet bls. The Peace River formation has been subdivided into two named members, the Cape Coral Clay member and the Lehigh Acres Sandstone member (Missimer and associates, 1985). The Cape Coral Clay consists of a light olive gray, moderately hard, semi-cohesive clay with varying amounts of shell fragments, marls, and phosphate nodules. This unit occurs from 40 to 95 feet. The Lehigh Acres Sandstone member does not occur at this site. A shell and limestone bed occurs from 95 to 140 feet bls.

2.1.2.2 Arcadia Formation

The lower part of the Hawthorn Group, the Arcadia formation, consists predominately of limestone and dolostone containing varying amounts of quartz sand, clay and phosphate grains (Scott, 1988). The Arcadia Formation is important from a resource viewpoint as a water supply source for the City of Cape Coral. Hydrologically, it incorporates several aquifers and confining units identified within the Hawthorn Group.

The Arcadia Formation occurs from approximately 140 to 724 feet bls at the CPS-4 ASR Site. The formation is lithologically complex, containing limestone and dolomite beds of varying thickness. The limestones are light olive gray to yellowish gray and grayish orange micrites and biomicrites with moderate to good porosity. The formation is interbedded with yellowish gray marl or lime mud and occasional light olive gray dolomitic silty clay. Phosphate grains are abundant throughout the Arcadia Formation. The lithology from 570 to 724 ft bls represents a transition zone of very pale orange to grayish orange biomicrite limestone with interbedded layers of white to light gray marls and clays. The base of the Arcadia Formation is accompanied by a slight attenuation of gamma ray activity.

2.1.3 Oligocene Series

The Suwannee Limestone of Oligocene Age occurs from approximately 724 to 1,000 feet bls at the CPS-4 ASR TPW. The contact between the Hawthorn Group and the Suwannee Limestone was identified based on interpretations from the lithology, geophysical logs and biostratigraphy. A disconformity separates the Hawthorn Group from the Suwannee Limestone (Reese, 2000).

The limestone is very pale orange biomicrite with a medium-grained calcarenitic texture. The unit is composed of moderately to well-sorted foraminifera, pelloids, and abraded echinoderm and mollusk fragments. The contact between the Hawthorn Group and the Suwannee Limestone is marked by an attenuation of the natural gamma activity primarily due to the decrease in phosphate content in the upper Suwannee Limestone. In addition, the Suwannee Limestone is characterized by higher sonic transit times and very slight decrease in dual induction resistivity (Appendix D) as compared to the basal facies of the Arcadia Formation.

Two intervals, 837 to 839 ft bls and 855 to 870 ft bls, exhibit characteristics of higher flow zones. These intervals of increased flow are identified by both the flow log and the sonic variable density log (Appendix D). Several lower permeability semi-confining intervals consisting of marl and clay are present from 770 to 780 ft bls, 843 to 850 ft bls, and 970 to 1,000 ft bls.

2.1.4 Eocene Series

The Ocala Limestone of late Eocene Age begins at 1,000 feet bls and continued to the total depth of the CPS-4 ASR TPW at 1,200 feet bls. The Ocala Limestone shares similar general lithology (very pale orange to grayish orange, fossiliferous, soft, poorly consolidated, micritic, limestone) as the Suwannee Limestone. Geophysical logs and biostratigraphy were methods used to identify the top of the Ocala Limestone. In the geophysical log the top of the Ocala Limestone is identified by a significant attenuation of the natural gamma response due to the absence of phosphate. There is also a slight increase in the dual induction resistivity and a significant decrease in the flow log below 1,025 ft bls. Biostratigraphic designation for identifying the top of the Ocala Limestone occurred at a depth of 1,070 feet bls, with the first occurrence of the diagnostic foraminifer Lepidocyclina ocalana.

2.2 Hydrogeologic Framework

Three major aquifer systems underlie the study area of Cape Coral, Florida: the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS), and the Floridan Aquifer System (FAS), with the FAS being the focus of this study. These aquifer systems are composed of multiple, discrete aquifers separated by low permeability semi-confining units that occur throughout this Tertiary/Quaternary age sequence.

2.2.1 Surficial Aquifer System

The SAS consists of the water-table aquifer and hydraulically connected units above the top of the first occurrence of laterally extensive and vertically persistent beds of much lower permeability (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). At the CPS-4 ASR Site, the SAS occurs within the undifferentiated Plio-Pleistocene water saturated sediments of the Pamlico Sand Formation, and Undifferentiated Fort Thompson/Caloosahatchee strata. The base of the surficial aquifer system at the location of the ASR TPW occurs at contact with the Cape Coral Clay Member of the Hawthorn Group at a depth of 40 feet bls. The aquifer is unconfined and in direct contact with atmospheric pressure. Recharge to the aquifer originates principally from rainfall, with some secondary recharge emanating from leakage from surface water bodies and as movement of groundwater flows down gradient through the sites. Discharge from the surficial aquifer occurs through evapotranspiration, drainage to surface water bodies, downward leakance to deeper aquifers, lateral groundwater flow.

2.2.2 Intermediate Aquifer System

Aquifers that lie beneath the SAS and above the FAS in southwestern Florida are grouped within the IAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). The IAS does not outcrop and contains water under confined conditions (Miller, 1986).

A productive horizon, locally called the Mid-Hawthorn Aquifer, occurs from 140 to 210 feet bls. The Mid-Hawthorn aquifer occurs within limestones in the upper portion of the Arcadia Formation of the Hawthorn Group (Knapp *et al.,* 1986 and Miller, 1986). This aquifer is currently the major source of water supply to residents served by domestic self-supply wells in Cape Coral. Semi-confing marls, clays, and limestones were encountered from 210 to 420 feet bls.

2.2.3 Floridan Aquifer System

The FAS is defined as a vertically continuous sequence of permeable carbonate rocks of Tertiary age that are hydraulically connected in varying degrees, and whose permeability is generally several orders of magnitude greater than that of the rocks that bound the system above and below (Miller, 1986). The system is subdivided into the upper Floridan Aquifer (UFA), middle confining unit (MCU) and the lower Floridan Aquifer (LFA) based on hydraulic characteristics.

2.2.3.1 Upper Floridan Aquifer

The top of the FAS, as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986) coincides with the top of a vertically continuous permeable early Miocene to Oligocene-aged carbonate sequence. At the CPS-4 ASR site, the UFA occurs from approximately 460 to 1,000 feet bls and chiefly consists of permeable zones in the lower Hawthorn Group, Suwannee Limestone, and upper Ocala Limestone.

During construction and testing, two predominant permeable zones were identified within the UFA. The productive zones in the upper Floridan aquifer were identified using lithology, geophysical logs (i.e. fluid resistivity, flowmeter and temperature), borehole video survey (evidence of vuggy porosity), and packer testing. Video Survey Descriptions and DVD provided as Appendix E.

The first transmissive horizon includes the lower portion of the Basal Hawthorn Unit (Reese, 2000), and occurs from 460 to 670 feet bls. This aquifer is locally named the Lower Hawthorn aquifer. The predominant lithologies present are interbedded yellowish-gray fossiliferous limestones and light gray limestones interbedded with marls. The Lower Hawthorn aquifer's limestones have a variable texture, are very hard, and have good porosities. This aquifer is currently the major source for public water supply to the residents in Cape Coral, Florida.

The second productive interval within the UFA was identified from 724 to 1,000 feet bls in the Suwannee Limestone. This aquifer is locally named the Suwannee Aquifer. A confining interval between the Suwannee and Lower Hawthorn Aquifer is approximately 80 feet thick and consists of yellowish gray marls. This aquifer is composed of interbedded moderately biomicritic to calcarenitic very pale orange to grayish orange limestones and marls. The aquifer becomes less permeable with depth due to interbedding and increased lime mud and fine-grained material which act as confinment. The base of the Suwannee Limestone is composed predominantly of moderately hard, low porosity limestones, interbedded with lime mud or marl.

2.2.3.2 Middle Confining Unit

The MCU was identified from approximately 1,000 to total depth of the well (1,200 feet bls) in the CPS-4 ASR TPW. This evidence is supported by previous work from Reese (2000) who has identified the MCU to occur from approximately 1,050 to 1,990 feet bls in southwestern Florida. Lithologic descriptions, geophysical logging and packer testing were used in locating the top of the MCU.

The MCU is located in the Ocala Limestone at the CPS-4 ASR site. The Ocala Limestone is primarily a low porosity, yellowish brown micritic limestone, interbedded with thin layers of clay. Miller (1986) and Reese (2000) support these findings by observing that portions of the MCU are fine grained and have low permeability, thereby acting as interaquifer confining units within the FAS. The top of the MCU was evident due to a decrease in the sonic porosity and flow logs conducted on the borehole. This decrease in production is supported by a very low specific capacity, 0.6 gpm/ft, calculated during a packer test (Packer Test #1) in the interval from 1,060 to 1,200 feet bls as discussed in Section 4.

2.2.3.3 Lower Floridan Aquifer

In the study area, the LFA likely consists of portions of the Avon Park Formation, Oldsmar Formation, and the upper part of the Cedar Keys Formation (Meyer, 1989). Ground water in the lower Floridan aquifer is compared closely to the chemical nature of modern seawater. The transmissivity of the lower dolostone (locally called the Boulder Zone; Miller, 1986) is slightly higher than the overlying dolostones (Meyer, 1989). The high permeability in the Boulder Zone is due to the cavernous porosity and extensive fracturing present (Miller, 1986, Meyer, 1989, and Reese, 1994). The LFA was not encountered at the CPS-4 site during drilling operations.

3.0 Well Construction

This section describes the construction activities of the ASR System at the CPS-4 site. Four wells were constructed for this system; one ASR test production well (ASR TPW), two storage zone monitor wells (SZMW-1 and SZMW-2), and one shallow monitor well (SMW-1). Locations of the FDEP approved monitor wells are as follows: SZMW-1 is located 97 feet northwest of the ASR TPW at the northern property boundary. The SZMW-2 well is located on City owned property on the northwest corner of SE 26th Terrace and Archer Parkway, 485 feet south of the ASR TPW and monitors near the edge of the storage zone "bubble". The SZMW-2 lot address is 423 SE 26th Terrace. SMW-1 is located 64 feet northeast of the ASR TPW and monitors the aquifer above the storage zone.

The locations of the wells are shown in Figure 1-2. A summary of the construction activities for each well was prepared in the form of daily reports and weekly summaries for each well. The weekly reports are provided in Appendix B.

3.1 Site Development

The ASR TPW location is gently sloping westward to the seawall with a steeper slope eastword to the swale along Retunda Parkway with a north-south trending ridge across the site. Elevations varyied from 6.96 to 9.64 feet above the North Geodectic Vertical Datum of 1929 (NGVD) with an average elevation of 8.86 ft NGVD for the construction area. The boundary survey is provided in Appendix F.

Two water table monitoring wells (WTMWs) were installed prior to the start of drilling activities. The WTMWs allowed the collection of samples in order to monitor the water quality of the surficial aquifer during construction and testing of the ASR system. WTMW-1 was located near the San Carlos Canal west of the TPW and WTMW-2 was located west of SMW-1 near Retunda Parkway. The locations of the WTMWs are shown in Figure 1-2 previously presented.

Each WTMW was constructed to a depth of approximately 20 feet bls. The wells were completed with 10 feet of 4-inch diameter 0.010-inch-slot Schedule 40 PVC screen at the base and approximately 10 feet of 4-inch diameter Schedule 40 PVC riser from the top of screen to land surface. The annulus of the WTMW's were backfilled with silica sand to approximately one foot above the screen interval with a bentonite seal above the sand and grouted to land surface.

Following their construction, the WTMWs were developed for approximately one hour. Water quality tests to measure conductivity, chloride, pH, and temperature were conducted on samples from each well, to obtain initial background measurements. The WTMWs were developed, sampled, and analysed weekly. Results were provided as part of the weekly report to the TAC (Appendix B). Figure 3-1 shows a schematic diagram of a typical WTMW.

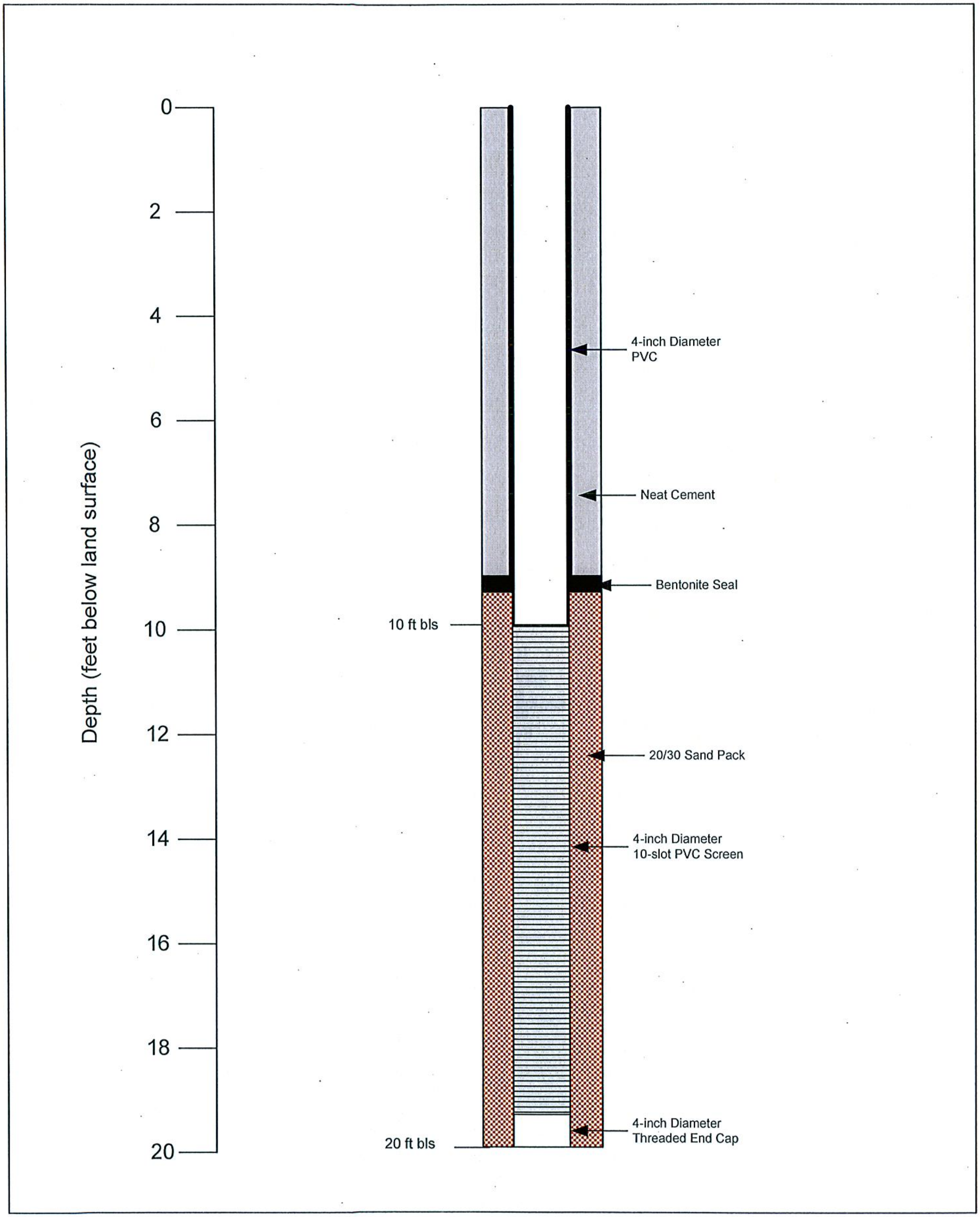

Figure 3-1 Water Table Monitor Well Schematic

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3.2 ASR Test Production Well

3.2.1 Containment Pad

A temporary containment pad consisting of a crushed limestone berm approximately 2.5 feet high overlain by high-density polyethylene (HDPE) material was constructed to contain drilling fluids produced during construction activities. Following completion of the ASR TPW, the HDPE material was removed from the site.

The containment pad was designed to protect the surficial aquifer by containing fluid spills and brackish formation water encountered during drilling operations. A pump or vaccuum truck was used to remove fluids from the containment pad for trnsportation to an off site disposal location approved by the FDEP.

3.2.2 Well Construction

The ASR TPW drilling and construction operations began January 14, 2008. Well construction activities were substantially complete on May 14, 2009. Well testing activities concluded on May 26, 2009 with the completion of the aquifer performance test. Drilling operations were normally conducted 10 hours per day, 5 days per week. A schematic diagram of the completed well is presented in Figure 3-2. An As-Built diagram is available in Appendix G. A detailed summary of well construction and testing activities associated with the ASR TPW is included in Table 3-1.

The surficial aquifer and the upper portion of the Hawthorn Group were drilled using the mud rotary drilling method with bentonite based drilling mud to a depth of 505 feet bls. During mud rotary drilling operations, all drilling fluid was contained in a closed circulation system. Intermediate casing, 26-inch OD Steel, was installed to 495 feet bls. The borehole was drilled through the lower portion of the Hawthorn Group and into the upper portion of the Ocala Limestone to a total depth of 1,200 feet bls using the reverse air drilling method. The reverse air drilling method allowed for the collection of formation water samples. Following evaluation of potential storage zones, the well was backplugged with neat cement to 869 feet bls and the final casing was set at 783 feet bls.

The diameter of the drill bits used and depths to which the bits penetrated were a function of geology, well design, and regulatory requirements for the project. Extensive sampling and testing was conducted within the borehole to aid in the final design of each well. Specifics of the testing program and data obtained from testing are presented in Section 4.

3.2.3 Surface Casing

A 12.25-inch diameter pilot hole was initially drilled to 37 feet bls. A nominal 37-inch diameter borehole was then drilled to a depth of 38 feet bls and 38 feet of 34-inch diameter steel casing was installed and grouted in place. The purpose of the surface casing was to prevent unconsolidated surficial material from collapsing into the borehole during drilling operations, maintain the strength and integrity of the surficial material from the weight and vibration of the drill rig, and to isolate the surficial aquifer from drilling materials and fluids used in the construction of the well.

3.2.4 Pilot Hole Drilling Operations

A 12.25-inch diameter pilot hole was drilled to determine an intermediate casing depth. The drilling of a pilot hole allows better identification of target zones without drilling the final borehole, minimizes attenuation effects of large diameter boreholes on geophysical logs and maintains the vertical alignment of the borehole during reaming activities.

Inclination surveys were conducted on the borehole during both pilot hole and reamed hole drilling operations to ensure the borehole did not deviate significantly from plum and prevent, hinder, or interfere with casing and cement grout placement. Surveys were performed every 60 feet during drilling operations. In accordance with vertical drift specifications for the well, each inclination measurement was less than one degree and consecutive survey measurements differed no more than 0.5 degrees. The survey results were recorded with a Sure-Shot tool. The average inclination during construction of the ASR TPW was 0.41 degrees for the pilot hole and 0.48 degrees for the reamed hole. The results of the inclination surveys conducted during drilling operations are presented in Appendix H.

Lithologic samples were collected at 10-foot intervals and at changes in the lithology during pilot hole drilling operations (Appendix B). Lithologic samples were used to help determine formation changes and the hydrologic and physical properties of the aquifers and are used in conjunction with the geophysical logs to better identify specific hydrogeologic zones.

Table 3-1 ASR TPW Construction Chronology

Start Date	End Date	Description of Activities
1/14/2008	1/16/2008	Drilled 12.25 inch diameter pilot hole to 37 ft bls
1/17/2008	1/22/2008	Reamed 37-inch diameter borehole to depth of 38 ft bls.
1/22/2008	1/22/2008	Set and cemented 34-inch outer diameter steel surface casing to 38 ft bls.
1/28/2008	2/06/2008	Drilled 12.25 inch diameter pilot hole to 505 ft bls using direct mud rotary drilling methods.
2/07/2008	2/07/2008	Conducted geophysical logging suite to 505 ft bls.
2/08/2008	2/27/2008	Reamed the pilot hole from land surface to 496 ft bls using direct mud rotary drilling methods with a 32-inch diameter drill bit.
2/28/2008	3/03/2008	Conducted caliper/gamma ray logs to 496 ft bls.
2/28/2008	2/28/2008	Set and cemented the 26-inch outer diameter intermediate casing to 495 ft bls.
3/13/2008	4/11/2008	Drilled 9.875-inch pilot hole to a depth of 1200 ft bls using reverse-air rotary methods.
3/18/2008	3/18/2008	Cored Interval 673 to 683 ft bls – Core #1A
3/26/2008	3/26/2008	Cored Interval 702 to 712 ft bls – Core #1B
4/01/2008	4/01/2008	Cored Interval 817 to 824 ft bls – Core #2A
4/02/2008	4/02/2008	Cored Interval 830 to 840 ft bls – Core #2B
4/04/2008	4/04/2008	Cored Interval 890 to 900 ft bls – Core #3
4/09/2008	4/09/2008	Cored Interval 1037 to 1047 ft bls – Core #4
4/15/2008	4/16/2008	Conducted geophysical logging suite to 1199 ft bls.
4/25/2008	4/25/2008	Performed constant-rate single packer test from 1060 to 1200 ft bls – Packer Test #1
5/06/2008	5/07/2008	Performed constant-rate straddle packer test from 858 to 898 ft bls – Packer Test #2
5/20/2008	5/21/2008	Performed constant-rate straddle packer test from 815 to 855 ft bls – Packer Test #3
7/08/2008	7/09/2008	Performed constant-rate straddle packer test from 755 to 785 ft bls – Packer Test #4
7/22/2008	7/23/2008	Backplugged pilot hole with grout to 968 ft bls.
7/28/2008	7/29/2008	Performed constant-rate single packer test from 900 to 968 ft bls – Packer Test #5
8/5/2008	8/6/2008	Backplugged pilot hole with grout to 869 ft bls.
8/8/2008	8/13/2008	Backfilled pilot hole with silica sand to 787 ft bls. Set bridge plug with neat cement to 777 ft bls.
8/15/2008	8/29/2008	Reamed the pilot hole from 502 to 784 ft bls with nominal 25-inch diameter bit
9/03/2008	9/03/2008	Perform gamma and XY caliper geophysical logging to 784 ft bls.
9/05/2008	9/12/2008	Set and cemented the 16.6-inch diameter final FRP casing string to a depth of 783 ft bls.
9/18/2008	9/18/2008	Performed pressure test on FRP casing.
9/22/2008	9/24/2008	Drilled out cement plug and gravel backfill to 871 ft bls using reverse-air rotary drilling methods.
9/29/2008	9/29/2008	Conducted caliper/gamma ray and video logs from surface to 871 ft bls.
10/17/2008	10/17/2008	Pump developed well at 1,150 gpm for 7 hours.
10/20/2008	10/20/2008	Performed step rate drawdown pump test.
4/14/2009	4/14/2009	Acidized well with 2,500 gallons of 28% hydrochloric acid.
4/14/2009	4/25/2009	Performed post acidization development.
5/15/2009	5/15/2009	Performed step rate drawdown pump test.
5/19/2009	5/26/2009	Performed Aquifer Performance Test
5/27/2009	5/27/2009	Installed a permanent wellhead assembly.
6/9/2009	6/9/2009	Disinfected well with chlorine.

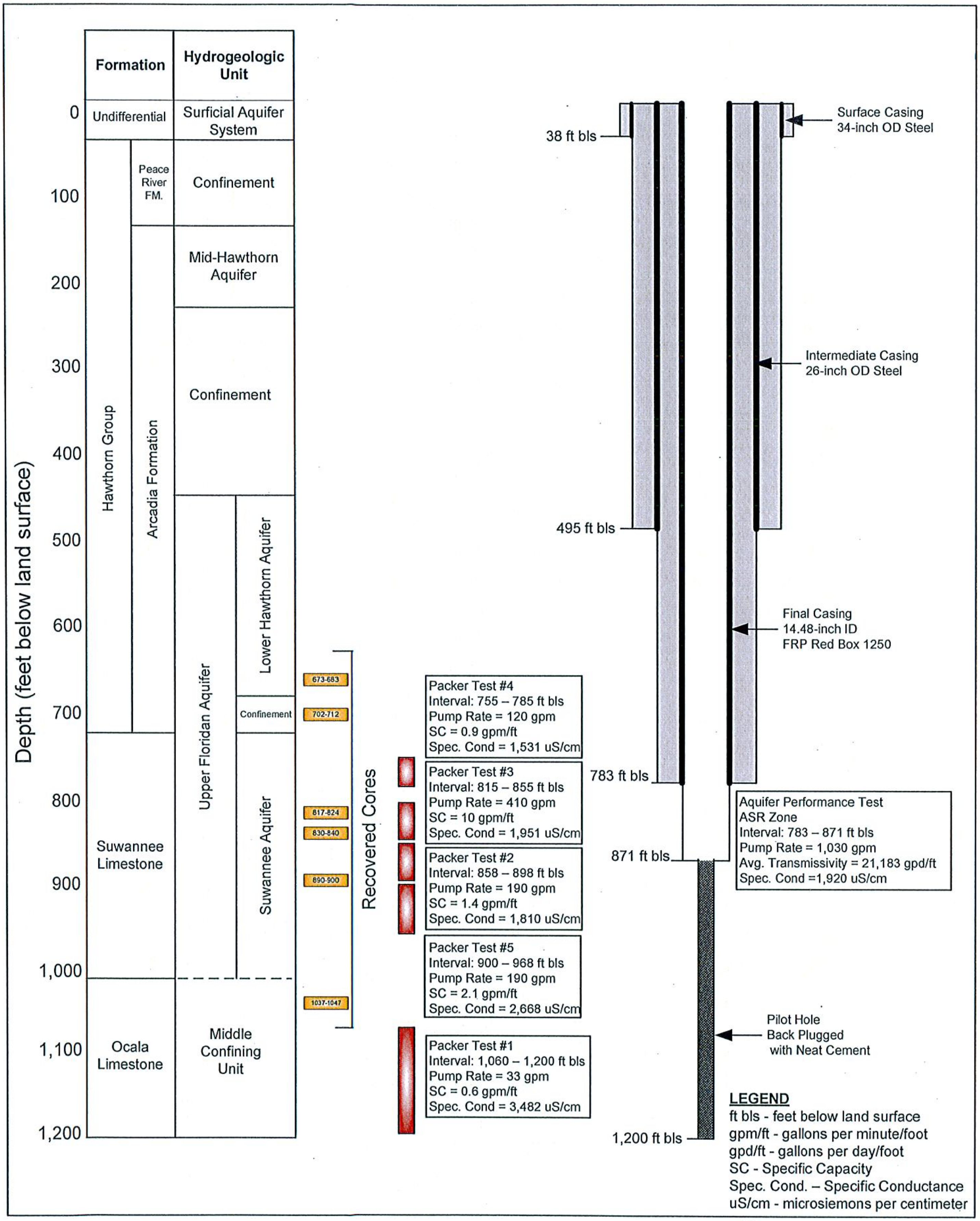

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Figure 3-2 CPS-4 ASR TPW Schematic and Hydrogeologic Summary

3.2.5 Intermediate Casing

The 12.25 inch diameter pilot hole was drilled to a depth of 505 feet. Geophysical logging consisting of XY caliper, gamma ray, dual induction, spontaneous potential, and borehole compensated sonic was performed to aid in intermediate casing seat depth selection. Geophysical logging is described in Section 4, Data Collection and Analysis. Geophysical logs are available in Appendix C. The pilot hole was subsequently reamed with a 32-inch diameter two-stage reaming bit to 496 feet bls. XY caliper and gamma ray geophysical logging was performed on the reamed hole. The XY caliper log shows the geometry of the borehole and provides annular volume information for cementing operations. The 26-inch diameter intermediate steel casing was installed to 495 feet bls as approved by the FDEP. Mill certificates for the intermediate casing are provided in Appendix I. Intermediate casing grouting operations are summarized in Table 3-2.

Table 3-2 ASR TPW 26-inch Steel Intermediate Casing Grout Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (Barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
2/29/2008	1	Neat	15.2	188	1054.7	0	35
3/03/2008	2	Neat	15.3	32	179.5	0	0

3.2.6 Pilot Hole Drilling and Testing

A 9.875-inch diameter pilot hole was advanced from the base of the intermediate casing using reverse air drilling techniques to a total depth of 1,200 feet bls. The reverse air drilling method allowed water quality analyses and specific capacity measurements to be performed at approximately 30-foot intervals. Water quality and specific capacity measurements are presented in Section 4.1.5. Excess water produced from the well during reverse air drilling was discharged into San Carlos Canal. The groundwater produced from the ASR TPW was diverted through a flocculant treated settling tank and discharged through an additional settling tank fitted with a silt bag to retain silt-sized particles before entering the canal. A silt curtain was installed across the canal to provide an additional measure of containment.

On March 13, 2008, Sanders Laboratory of Nokomis, Florida collected groundwater samples from the open hole to fulfill the requirements of the Generic Discharge Permit as required by the FDEP when discharging groundwater into surface water bodies. The water produced from the ASR TPW was again sampled and analyzed by Sanders Laboratory 30 days, 6 months, and 1 year after the initial sampling. The results from the Generic Discharge Permit sampling are presented in Appendix J.

During open hole drilling operations, six rock cores measuring 4-inches in diameter were recovered using a 10 foot diamond tipped core barrel. Samples of the recovered cores were sent to Ardaman and Associates of Orlando, Florida for analysis. Coring operations and results of the analyses are discussed in Section 4. Packer tests were performed within the open hole over five intervals. Analyses of the packer tests are provided in Section 4.

3.2.7 Back Plugging

Upon approval of the planned storage zone of 780 feet to 870 feet bls, by the FDEP, the open hole was back plugged from 1,200 to 869 feet bls in four stages, with a total of 62 barrels of neat cement as shown in Table 3-3. The open hole was then backfilled with 11 cubic feet sillica sand from 869 to 787 feet bls, followed by 1 barrel of neat cement to protect the integrity of the storage zone during reaming operations.

Table 3-3 ASR TPW Back Plug Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (Barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
7/22/2008	1	Neat	14.2	29	163	970	1035
7/23/2008	2	Neat	14.5	11	62	970	968
8/05/2008	3	Neat	15.2	17	94	870	893
8/06/2008	4	Neat	15.1	5	28	870	869

3.2.8 Final Casing

A nominal 25-inch diameter open hole was reamed from the base of the intermediate casing (495 feet bls) to 783 feet bls. Following reaming operations, a XY caliper and a gamma ray log were performed to verify the borehole was clear of obstruction and provide annular volume information for grouting operations. On September 5, 2008, the final casing consisting of 14.48 ID FRP, was installed to 783 feet bls as approved by the FDEP. The FRP is manufactured by Future Pipe Industries of Houston, Texas. The technical specification sheet is provided Appendix K. The casing was grouted in place in eight stages as summarized in Table 3-4.

Table 3-4 ASR TPW Final Casing Grout Summary

Date	Stage	Cement Type	Density (lbs/gal)	Total Volume (Barrels)	Total Volume (cuft)	Theoretical Tag (ft bls)	Actual Tag (ft bls)
9/6/2008	1	Neat	15.6	45	238	770	761
9/6/2008	2	Neat	15.6	45	238	748	731
9/7/2008	3	Neat	15.6	42	234	631	652
9/8/2008	4	Neat	15.1	43	236	610	621
9/9/2008	5	Neat	15.6	43	236	521	517
9/10/2008	6	4% gel	14.1	55	310	371	350
9/11/2008	7	4% gel	14.1	55	310	200	179
9/12/2008	8	4% gel	14.1	64	359	0	0

3.2.9 Casing Pressure Test

A final casing pressure test, witnessed by FDEP and MWH, was successfully completed on September 18, 2008 on the 14.48 ID FRP casing. The wellhead was sealed at the surface with a temporary wellhead to facilitate the test. The base of the casing was sealed with neat cement from the recently completed casing cementing operations. The well was filled with water and pressurized to 118 psi. During the 60-minute test, the total pressure within the casing decreased by 1 psi for a change of less than 1 percent, meeting the test tolerance limit of +/- 5 percent (Table 3-5) per FDEP requirements. A copy of the test gauge calibration certificate is contained in Appendix L.

3.2.10 Well Development

Once the cement plug and sand were drilled out to 920 feet bls, the well was developed using reverse air near the bottom of the borehole for approximately 5 hours. Water quality samples were collected and tested for specific conductivity, dissolved oxygen, chloride, pH and temperature approximately every 60 minutes.

Following air development, the well was developed using a submersible pump. Pump development was conducted on the well on October 17, 2008 for approximately seven hours at a pumping rate of approximately 1,150 gpm. Water quality parameters consisting of specific conductivity, dissolved oxygen, chloride, pH, and temperature were measured. Pump development was deemed complete when water quality results remained within 5% of two subsequent readings. Pump Development water quality measurements are available in Appendix M

Table 3-5 ASR TPW Pressure Test Summary

Time	Elapsed Time (Minutes)	Pressure (psi)
1040	0	118.00
1045	5	117.90
1050	10	117.80
1055	15	117.80
1100	20	117.80
1105	25	117.80
1110	30	117.60
1115	35	117.60
1120	40	117.50
1125	45	117.50
1130	50	117.50
1135	55	117.25
1140	60	117.00

3.2.11 Acidization

An initial step drawdown test was completed on October 20, 2008. Specific capacity at pumping rate, 620 gpm, measured 9 gallons per minute per foot (gpm/ft). Due to low specific capacity during the initial step drawdown test, acidization of the ASR-TPW was conducted by HydroChem Industrial Services on April 14, 2009. The open hole section of the borehole was acidified with 2,500 gallons of 28% hydrochloric acid. All pumping associated with well acidization was completed on February 12, 2008. After acidization operations, the well was monitored for pressure increases and flushed with fresh water. No increase in pressure was noted. Post acidization pump development began on April 15, 2009 and concluded on April 25, 2009. A total of 185,340 gallons were developed using a submersible pump from the well. Developed water was neutralized and removed to an off site disposal location approved by the FDEP. Approximately 1,437,500 gallons were developed and discharged to San Carlos Canal. Pump development water quality measurements are available in Appendix M.

A post acidization step drawdown test was conducted on May 15, 2009 that indicated the specific capacity increased to an average of 19 gpm/ft at a pump rate of 660 gpm. This represents a 111% increase in specific capacity which will reduce drawdown waterlevel and injection pump pressures during ASR operation. A description of the step drawdown test methods and summary of results are provided in Section 4.

3.3 Monitor Wells

This section of the report describes the construction activities for the three monitoring wells installed at the CPS-4 site. The purpose of monitor wells is to monitor changes in water quality in the vicinity of the ASR TPW when in operation.

3.3.1 Containment Pads

Temporary bermed earth containment pads overlain by high-density polyethylene (HDPE) sheeting were constructed for use during drilling of the monitoring wells, SZMW-1, SZMW-2, and SMW-1. Following completion of the wells, the containment pads were dismantled and removed from the site. As-Built diagrams are available in Appendix G.

The containment pads were designed to protect the surficial aquifer by containing drilling fluid and brackish formation water encountered during the drilling of the wells. A pump was installed into the containment pads to remove fluids from the pads to an onsite storage system for removal to the approved FDEP off site disposal location.

3.3.2 Well Construction

The construction and testing operations of the monitor wells began August 12, 2008 at SZMW-2 and concluded on May 26, 2009 with the completion of the APT. The locations of SZMW-1, SZMW-2, and SMW-1 are shown in Figure 1-2. Schematic diagrams of the completed wells are included in Figure 3-3. A summary of well construction and testing activities associated with SZMW-1, SZMW-2, and SMW-1 are included in Tables 3-6, 3-7 and 3-8.

Table 3-6 SZMW-1 Construction Chronology

Start Date	End Date	Event
12/11/2008	12/12/2008	Drilled 23-inch diameter borehole to depth of 41 ft bls.
12/13/2008	12/13/2008	Set and cemented 40 ft of 18-inch diameter steel surface casing.
3/4/2009	3/17/2009	Drilled 12.25 -inch pilot hole to 510 ft bls with mud rotary methods.
3/18/2009	3/18/2009	Conducted geophysical logging suite to 510 ft bls.
3/19/2009	3/27/2009	Reamed 17-inch pilot hole to 503 ft bls using mud rotary methods.
3/30/2009	3/30/2009	Conducted caliper/gamma ray logs to 503 ft bls.
3/31/2009	3/31/2009	Set and cemented the 12-inch diameter intermediate casing to 500 ft bls.
4/06/2009	4/09/2009	Drilled 11.875-inch pilot hole to of 870 ft bls using reverse-air methods.
4/10/2009	4/17/2009	Conducted geophysical logging suite to 870 ft bls.
4/29/2009	4/29/2009	Performed constant-rate single packer pump test from 780 to 870 ft bls.
5/01/2009	5/02/2009	Backfilled pilot hole with limestone gravel to 785 ft bls.
5/04/2009	5/08/2009	Set and cemented 6-inch diameter PVC casing to a depth of 780 ft bls.
5/12/2009	5/12/2009	Drilled out cement plug and sand backfill to 871 ft bls using reverse-air.
5/12/2009	5/13/2009	Conducted straight air development for 4 hours.
5/13/2009	5/13/2009	Performed final geophysical logging suite.
5/14/2009	5/14/2009	Pump developed well at 80 gpm for 3 hours.
5/14/2009	5/14/2009	Performed step rate drawdown test.
5/19/2009	5/26/2009	Performed APT
5/28/2009	5/28/2009	Installed a permanent wellhead assembly.
6/9/2009	6/9/2009	Disinfected well

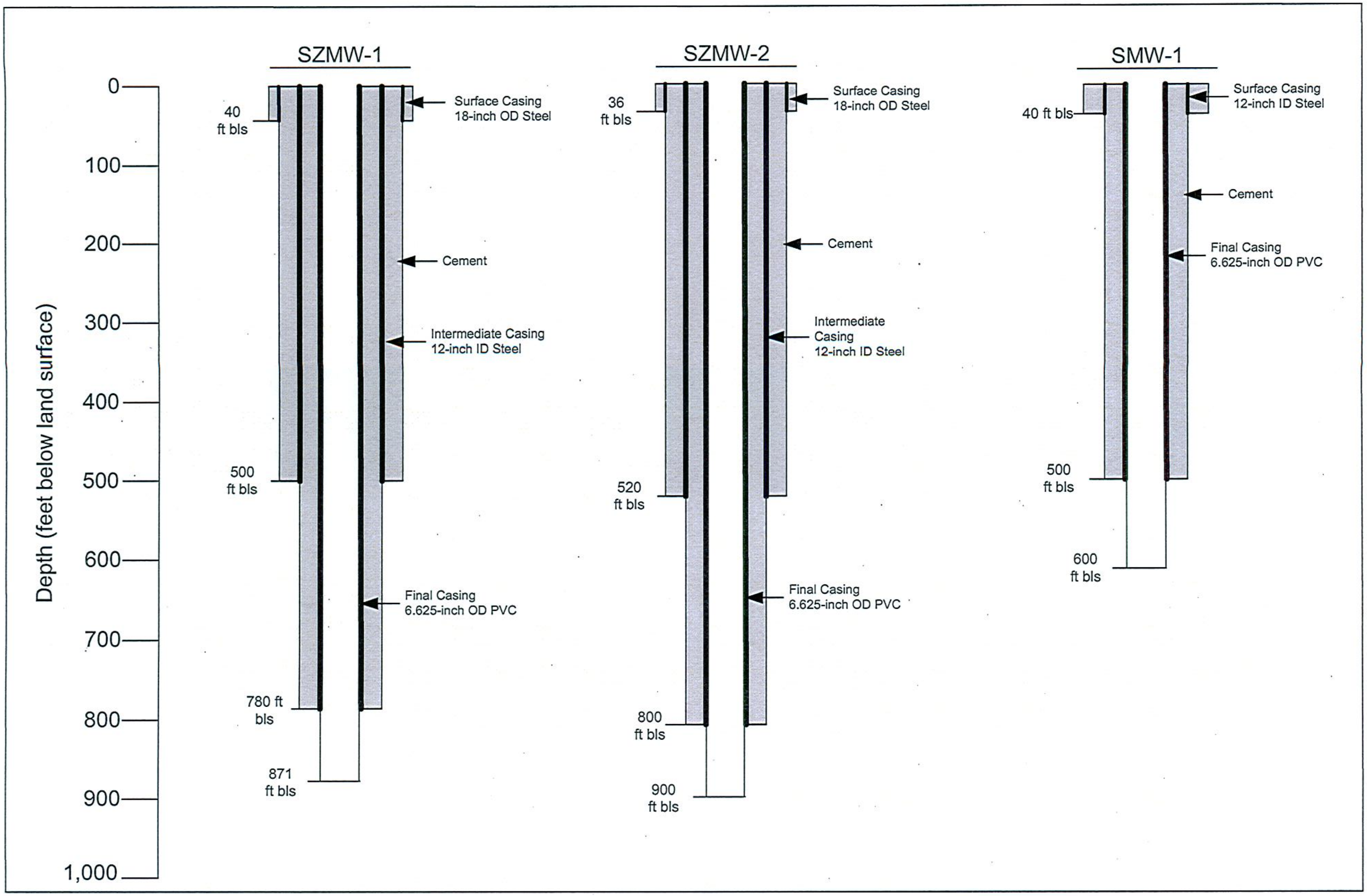

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Figure 3-3 CPS-4 ASR System Monitor Wells Schematic Diagram

Table 3-7 SZMW-2 Construction Chronology

Start Date	End Date	Event
8/12/2008	8/12/2008	Drilled 12.25 -inch pilot hole to 69 ft bls with mud rotary methods.
8/13/2008	8/13/2008	Drilled 25-inch diameter borehole to depth of 41 ft bls.
8/13/2008	8/13/2008	Set and cemented 36 ft of 18-inch diameter steel surface casing.
8/25/2008	9/10/2008	Drilled 12.25 -inch pilot hole to 529 ft bls with mud rotary methods.
9/18/2008	9/18/2008	Conducted geophysical logging suite to 529 ft bls.
9/19/2008	9/30/2008	Reamed 17-inch pilot hole to 525 ft bls using mud rotary methods.
9/30/2008	9/30/2008	Conducted caliper/gamma ray logs to 525 ft bls.
10/01/2008	10/03/2008	Down hole fishing of lost bit and collar.
10/04/2008	10/21/2008	Reamed 17-inch pilot hole to 525 ft bls using mud rotary methods.
10/21/2008	10/21/2008	Conducted caliper/gamma ray logs to 525 ft bls.
10/22/2008	10/27/2008	Set and cemented the 12-inch diameter intermediate casing to 520 ft bls.
11/01/2008	11/20/2008	Drilled 11.75-inch pilot hole to of 870 ft bls using reverse-air methods.
11/21/2008	11/21/2008	Conducted geophysical logging suite to 870 ft bls.
12/03/2008	12/04/2008	Performed constant-rate single packer pump test from 780 to 870 ft bls.
12/08/2008	12/16/2008	Drilled 11.75-inch pilot hole to of 900 ft bls using reverse-air methods.
12/17/2008	12/17/2008	Conducted geophysical logging suite to 900 ft bls.
1/07/2009	1/20/2009	Backfilled pilot hole with sand to 805 ft bls.
1/21/2009	1/21/2009	Set and cemented 6-inch diameter PVC casing to a depth of 800 ft bls.
2/02/2009	2/11/2009	Drilled out cement plug and gravel backfill to 900 ft bls using reverse-air.
2/11/2009	2/11/2009	Conducted straight air development for 1 hour.
2/12/2009	2/12/2009	Performed final geophysical logging suite.
3/05/2009	3/05/2009	Pump develop well for approximately 6 hrs at 70 gpm.
3/11/2009	3/19/2009	Installed a permanent wellhead assembly.
5/19/2009	5/26/2009	Performed APT
6/09/2009	6/9/2009	Disinfected well.

Table 3-8 SMW-1 Construction Chronology

Start Date	End Date	Event
12/18/2008	12/18/2008	Drilled 9 7/8 -inch pilot hole to 42 ft bls with mud rotary methods.
12/19/2008	12/20/2008	Drilled 17-inch diameter borehole to depth of 41 ft bls.
12/20/2008	12/20/2008	Set and cemented 40 ft of 12-inch diameter steel surface casing.
12/26/2008	1/12/2009	Drilled 11 7/8-inch pilot hole to of 520 ft bls using mud rotary methods.
1/14/2009	1/14/2009	Conducted geophysical logging suite to 520 ft bls.
2/03/2009	2/06/2009	Set and cemented 6-inch diameter PVC casing to 500 ft bls.
2/17/2009	2/24/2009	Drilled 5.875-inch pilot hole to of 600 ft bls using reverse-air methods.
2/24/2009	2/25/2009	Conducted straight air development for 6 hours.
2/27/2009	2/27/2009	Performed final geophysical logging suite.
3/12/2009	3/12/2009	Pump develop well for approximately 8 hrs at 75 gpm.
4/27/2009	4/27/2009	Performed step rate drawdown test
5/19/2009	5/26/2009	Performed APT
5/27/2009	5/27/2009	Installed a permanent wellhead assembly.
6/9/2009	6/9/2009	Disinfected well.

Steel surface casings were initially installed and grouted in place to the depths indicated in Table 3-9. The purpose of the surface casing was to prevent surficial material from collapsing into the borehole during drilling operations, maintain the strength and integrity of the surficial material from the weight and vibration of the drill rig, and to protect the surficial aquifer from drilling materials and fluids used in the construction of the well.

Table 3-9 Monitor Well Construction Summary

Well	Steel Surface Casing (ft bls)	Intermediate 12-inch ID Steel Casing (ft bls)	Final 6.625-inch OD PVC Casing (ft bls)	Total Depth (ft bls)
SZMW-1	40	500	780	871
SZMW-2	36	520	800	900
SMW-1	40	-	500	600

The surficial aquifer and the upper portion of the Hawthorn Group at the monitor well locations were drilled using the mud rotary method with bentonite based drilling fluid. During mud rotary drilling operations, all drilling fluid was contained in a closed system. The boreholes were drilled from below the intermediate casing depth of the storage zone monitoring wells, and below the final casing for SMW-1 to total depth using reverse air drilling techniques. The reverse air drilling method allowed for the collection of formation water samples with depth.

3.3.3 Pilot Hole Drilling Operations

A 12.25 inch diameter pilot hole was drilled to determine an intermediate casing depth for SZMW-1 and SZMW-2. An 11.875-inch diameter pilot hole was drilled to determine a final casing depth for SMW-1. A summary of the total well depths is provided in Table 3-9. The pilot hole was drilled to minimize negative effects of large diameter boreholes on geophysical logs and to maintain the vertical alignment of the borehole during reaming activities.

The diameter of the drill bits used and depths to which the bits penetrated was a function of the geology, well design and regulatory requirements for the project. Extensive sampling and testing were conducted in each borehole to aid in the final design of each well. Specifics of the testing program and data obtained from testing are presented in Section 4.2.

Inclination surveys were conducted on the pilot and reamed boreholes to ensure the boreholes did not deviate significantly from plum and prevent, hinder, or interfere with casing and cement grout placement. Surveys were performed every 60 feet during drilling to record the inclination of the borehole. In accordance with vertical drift specifications for the well, each inclination measurement was less than one degree and consecutive survey measurements differed no more than 0.5 degrees. The survey results were recorded with a Sure-Shot tool. The average inclination during construction of SZMW-1 was 0.53 degrees for the pilot hole and 0.70 degrees for the reamed hole. The average inclination during construction of SZMW-2 was 0.53 degrees for the pilot hole and 0.64 degrees for the reamed hole. The average inclination during construction of SMW-1 was 0.71 degrees for the pilot hole.The results of the inclination surveys conducted during drilling operations are presented in Appendix H.

Lithologic samples were collected at 10-foot intervals and at changes in the lithology during pilot hole drilling operations. The lithology tables are presented in Appendix B. Lithologic samples were used to help determine formation changes and the hydrologic and physical properties of the aquifers.

It was determined, from the lithology, that casing depths drilled for the monitor wells indicated the composition of the formation was sufficient to support the weight of the casing and provide a good seal with the grout. Geophysical logging, consisting of XY caliper, gamma ray, dual induction, spontaneous potential, and borehole compensated sonic log were performed after pilot hole drilling was concluded. Geophysical logging is described in Section 4, Data Collection and Analysis.

The pilot holes for SZMW-1 and SZMW-2 were reamed with a nominal 17-inch diameter two-stage bit from the base of the surface casing to depths of 503 and 525 feet bls respectively. Intermediate casings were installed at the FDEP approved depths of 500 feet bls for SZMW-1 and 520 feet bls for SZMW-2. Prior to the placement of the intermediate casing, geophysical logging consisting of an XY caliper and a gamma ray log was performed. These logs were used to determine the physical properties of the borehole and provide annular volume information for cementing operations.

3.3.4 Open Hole Drilling Operations

After the intermediate casing was set and grouted in place, open hole drilling of SZMW-1 and SZMW-2 resumed employing the reverse air drilling method using a 11.875-inch diameter bit to a total depth of 871 and 900 feet bls, respectively. The reverse air drilling method allowed water quality analyses and specific capacity measurements to be collected at approximately 30-foot intervals. Excess water produced from the monitor wells during reverse air drilling was discharged into San Carlos Canal. The groundwater produced from the monitor wells was filtered through three setting tanks and discharged through a silt bag to retain silt-sized particles before entering the canal. In addition, a silt curtain was installed across the canal to provide an additional measure of containment.

Following the open hole drilling operations at the monitor wells, a geophysical logging suite consisting of XY caliper, gamma ray, dual induction, spontaneous potential, borehole compensated sonic, temperature (static and dynamic), flow (static and dynamic), fluid conductivity (static and dynamic), and video survey was performed. The geophysical logs are discussed in Section 4.

3.3.5 Packer Tests

Single packer tests were performed within the open hole for SZMW-1 and SZMW-2. Packer tests are performed to provide information on the water quality and hydraulic characteristics within a discreet interval of the borehole. A single packer test was performed over the interval of 780 to 870 feet bls in SZMW-1 and over the interval of 800 to 870 feet bls in SZMW-2. Water quality laboratory results and analyses of the packer testing data are described in Section 4.

3.3.6 Final Casing

After packer testing, and upon approval of the proposed monitor zones for SZMW-1 and SZMW-2 by the FDEP, the open holes were backfilled with sand and capped with a drillable cement bridge plug to 781 feet bls at SZMW-1 and to 805 feet bls at SZMW-2 to protect the integrity of the open hole during grouting operations.

The final casings consisted of 6.625-inch OD PVC set in the borehole at the FDEP approved depths of 800 feet bls for SZMW-2 on January 1, 2009 and 780 feet for SZMW-1 on May 21, 2009. Following grouting operations, the sand and gravel backfill were removed with a 5.875-inch bit using the reverse air drilling method to restore the open hole monitor zone portion of the wells. The monitor zone for each SZMW was subsequently air developed and samples were collected for analysis.

Final casing at SMW-1, consisting of 6.625-inch OD PVC, was set at 500 feet bls following backfilling of the open hole with limestone and capped with a drillable cement bridge plug to 504 feet bls The open hole portion of SMW-1 was drilled with a 5.875-inch bit to the total of depth of 600 feet bls using the reverse air drilling method.

3.3.7 Pump Development

Pump development was conducted upon completion of the monitor wells. Field water quality analysis consisted of specific conductivity, dissolved oxygen, chloride, pH, and temperature. Pump development was deemed complete when water quality results remained within 5% of two subsequent readings. Results of the water quality measurements from pump development are available in Appendix M.

4.0 Data Collection and Analysis

This section describes the hydrogeologic testing for the four wells at the CPS-4 ASR System: ASR TPW, SZMW-1, SZMW-2, and SMW-1. Data collection during the drilling and construction of the CPS-4 wellfield consisted of formation samples, geophysical logging, water quality sampling, and specific capacity testing. The collected data was used to characterize the lithology, water quality, and hydrogeologic characteristics of the at the CPS-4 facility. Cores were taken during drilling operations at selected depths to determine possible storage zones and hydrogeologic properties of the aquifers. Packer tests were performed to determine hydraulic characteristics and water quality of isolated intervals. An aquifer performance test (APT) was performed to measure the hydrogeologic properties of the Storage Zone.

4.1 ASR Test Production Well

4.1.1 Formation Samples

Formation cuttings were collected during pilot hole drilling. Samples were collected every 10 feet from land surface to the total depth of the well. Samples were characterized for rock type, color, consolidation, texture, cementation, hardness/induration, fossil type, and visible porosity and permeability. The lithologic samples aided in identifying the contacts between formations, selection of core intervals, selection of packer test intervals, and understanding the overall physical characteristics of formations penetrated by the borehole. Descriptions of the lithology encountered during drilling of the ASR TPW are presented in Appendix B.

4.1.2 Rock Core Sampling and Analysis

During drilling of the CPS-4 ASR TPW, the contractor recovered conventional cores using a 4-inch diameter, 10-foot long core barrel and diamond core bit. Six rock cores were retrieved from the Floridan Aquifer System between 673 and 1,047 feet bls to aid in the identification of a storage zone and confinement above and below this storage zone. A summary of the coring program conducted at this site is presented in Table 4-1.

Table 4-1 ASR TPW Core Summary

Core #	**Date Cored**	**Cored Interval** (ft bls)	**Recovered** (ft)	**Recovered** (%)
1A	3/18/2008	673 – 683	3.7	37
1B	3/26/2008	702 – 712	7.0	70
2A	4/01/2008	817 – 824	3.0	40
2B	4/02/2008	830 – 840	8.0	80
3	4/04/2008	890 – 900	10	100
4	4/09/2008	1037 – 1047	10	100

MWH sent ten core sections obtained during coring operations to Ardaman and Associates, Inc., located in Orlando, Florida to be tested for the following parameters: vertical and horizontal hydraulic conductivity, vertical and horizontal porosity and specific gravity. Seven of the ten samples sent were tested for these parameters. The core analyses results are summarized in Table 4-2.

Table 4-2 ASR TPW Core Analyses Summary

Core No.	Sample Depth (ft)	Vertical Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (cm/sec)	Vertical Porosity (%)	Horizontal Porosity (%)	Specific Gravity
1A	676.2	$1.4x10^{-8}$	$6.7x10^{-8}$	39.8	39.9	2.69
1B	706.8	$3.5x10^{-4}$	$3.9x10^{-4}$	50.1	49.4	2.72
2A	818.2	$1.0x10^{-7}$	$4.1x10^{-7}$	41.6	43.9	2.72
2B	835.6	$6.8x10^{-4}$	$1.6x10^{-3}$	44.4	43.0	2.72
3	890.5	$7.6x10^{-4}$	$1.6x10^{-3}$	47.7	46.2	2.73
3	895.8	$5.7x10^{-4}$	$5.8x10^{-4}$	44.6	43.1	2.72
4	1,044.7	$2.2x10^{-5}$	$5.5x10^{-5}$	45.7	43.0	2.72

Hydraulic conductivity and porosity were measured in general accordance with American Society for Testing and Materials (ASTM) Standard D 5084 "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter" using constant head (Method A). Specific gravity measurements were made in general accordance with ASTM Standard D 854 "Specific Gravity of Soil Solids by Water Pycnometer" using approximately 50 gram specimens ground to pass the U.S. Standard No. 40 sieve. Unconfined compression tests were performed in general accordance with ASTM Standard D 7012 "Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures" using the unconfined test method (Method C). Full laboratory reports from Ardaman and Associates, Inc are available in Appendix N.

4.1.3 Geophysical Logging and Analysis

Geophysical logs were run in pilot holes, reamed holes, and final open borehole of the CPS-4 ASR TPW. The geophysical logging sequence during drilling is summarized in Table 4-3.

Table 4-3 CPS-4 ASR TPW Geophysical Summary

Date	Logged Interval (ft bls)	XY Caliper	Gamma Ray	Spontaneous Potential	Dual Induction	Temperature	Fluid Conductivity	Flowmeter	Sonic w/VDL	Video Survey
2/07/2008	0 - 505	X	X	X	X				X	
2/28/2008	0 - 496	X	X							
4/15-16/2008	0 - 1,199	X	X	X	X	X	X	X	X	X
9/03/2008	495 - 784	X	X							
9/29/2008	0 - 871	X	X						X	X

Geophysical logs were conducted in the pilot hole after each stage of pilot hole drilling and gamma and XY caliper logs were run in the reamed hole before casing installation. The logs provide a continuous record of the geophysical properties of the subsurface formations and formation fluids within the borehole. Analyses of the logs were used to assist in the interpretation of stratigraphy, to provide estimates of permeability, porosity, bulk density, electrical resistivity, and to estimate the total dissolved solids of the formation fluids (Archie, 1942, Reese, 1994, and Reese, 2000). Geophysical logs are presented in Appendix D.

The geophysical logs were correlated to lithologic logs to aid in identifying geologic contacts and were used to obtain specific hydrogeologic data pertaining to the formations. The geophysical data, in conjunction with water quality, specific capacity results, and lithologic descriptions were used to determine casing seat depths, packer-test intervals, and the storage zone interval.

4.1.4 Water Quality Sampling and Analysis

4.1.4.1 Water Quality During Drilling

Water quality samples were collected at 30-foot intervals from the pilot hole during open circulation reverse-air drilling. Sampling started at a depth of 540 feet bls and continued to the total depth of the well at 1,200 feet bls. Samples were collected from the discharge point of the fluid circulation system. The samples were analyzed on-site for dissolved oxygen, temperature, pH, conductivity, and chloride. These data were used to measure water quality relative to depth and identify increased salinity of groundwater with depth if present.

The reverse-air drilling water quality results provide an indication of water quality trends versus depth. Pilot hole water quality measurements are presented in Table 4-4.

Table 4-4 ASR TPW Drilling Water Quality

Date	Depth (ft bls)	Specific Conductivity (µS/cm)	Dissolved Oxygen (%)	pH (S.U.)	Temperature (°C)	Chloride (mg/L)
3/13/2008	540	2,762	51.4	8.51	24.36	666
3/14/2008	568	2,969	71.8	7.68	24.32	700
3/14/2008	601	--	--	--	--	625
3/17/2008	631	1,947	70.7	7.65	26.61	637
3/17/2008	660	1,974	56.1	7.58	25.39	650
3/27/2008	692	1,914	51.8	7.79	24.89	650
3/28/2008	724	1,844	59.1	7.76	23.03	625
3/28/2008	756	1,769	56.6	7.58	22.49	625
3/28/2008	785	2,014	51.6	7.28	23.02	575
3/31/2008	817	1,647	49	7.03	25.47	525
4/3/2008	848	1,969	54.3	7.78	23.99	475
4/3/2008	880	1,929	46.1	7.36	27.77	425
4/7/2008	911	1,982	22.7	7.55	22.09	488
4/7/2008	942	2,066	26.6	7.59	21.80	475
4/8/2008	974	2,164	51.3	7.79	24.94	525
4/8/2008	1,005	2,345	32.6	7.57	28.22	575
4/8/2008	1,037	3,186	39.2	7.19	28.41	800
4/10/2008	1,068	3,206	26.4	7.13	22.94	838
4/10/2008	1,099	3,145	31.4	7.56	26.56	850
4/10/2008	1,131	3,318	27.3	7.38	28.24	900
4/10/2008	1,163	3,158	23.6	7.11	20.78	840
4/11/2008	1,200	3,179	52.4	7.08	27.74	888

Reverse air water quality samples indicate specific conductivity and chloride measurements generally increase with depth.

4.1.4.2 Log Derived Total Dissolved Solids Analysis

The Sonic porosity and Dual Induction log resistivity were used to calculate a log-derived Total Dissolved Solids (TDS) plot (Figure 4-1) for the ASR TPW based on the method developed by Callahan (1996) and using empirical data from South Florida compiled by Reese (1994).

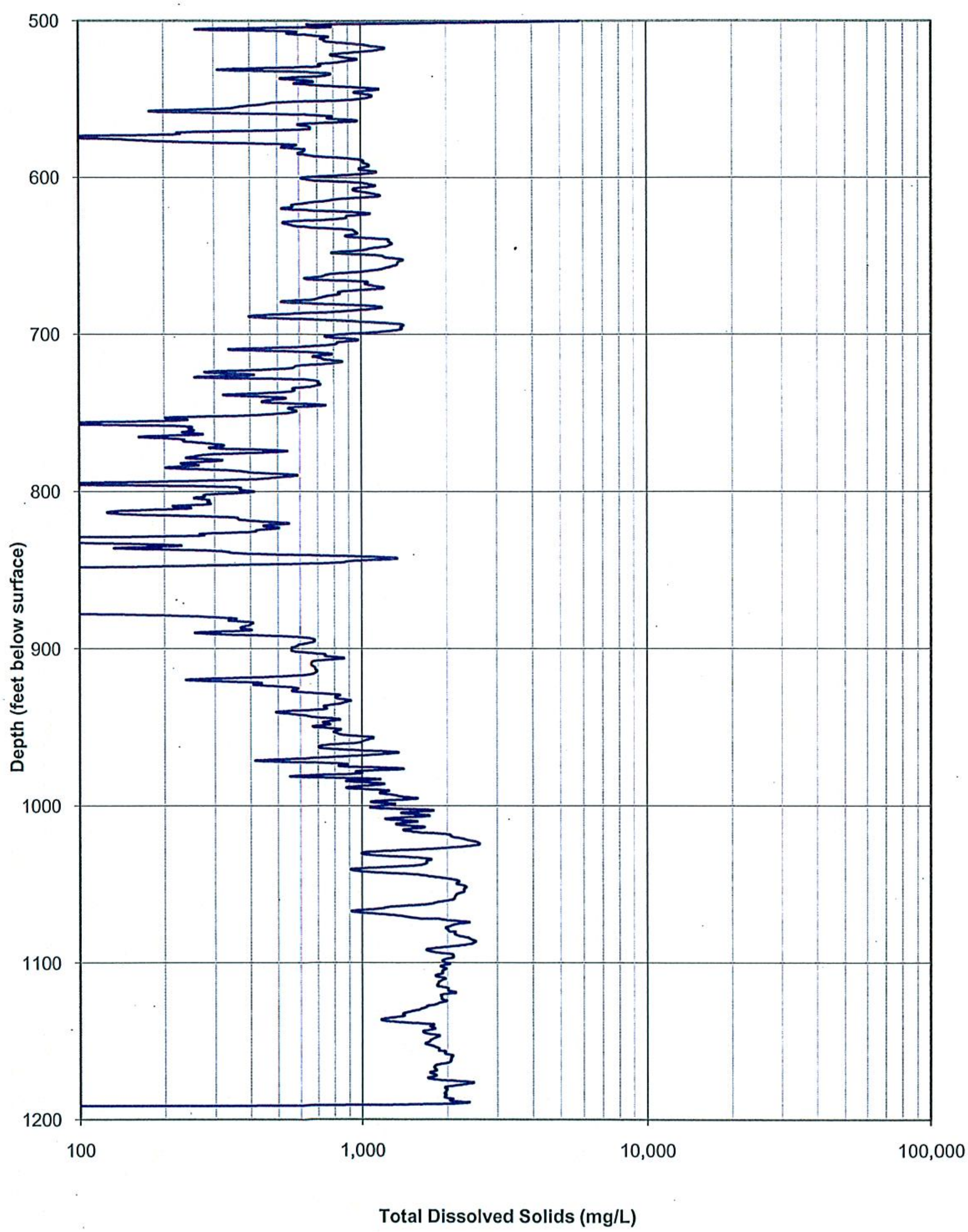


Figure 4-1 Log Derived Total Dissolved Solids Plot for the ASR TPW

The log derived TDS ranged from approximately 200 to 2,600 mg/L with the lowest TDS concentrations occurring within the storage zone 783 to 871 ft bls in the ASR TPW. The plot indicates that the USDW at this site extends below the depth of 1,200 feet bls.

4.1.4.3 Storage Zone Background Water Quality

After construction activities were finished for the ASR TPW, the completed well was developed by evacuating at least three well volumes of water from the well and the chloride concentration, temperature, pH, and specific conductivity measurements stabilized. Water samples from the storage zone were collected for analysis by Sanders Laboratories, Inc. on May 20, 2009. The samples were analyzed for primary and secondary drinking water standards and minimum criteria parameters using EPA and/or Standard Method procedures. Results of primary, secondary, bacteriological, and radionuclide water quality parameters are listed in Table 4-5. The volatile and synthetic organics analyses with the exception of Total HAA's, dichloroacetic acid, and chlorite resulted in below detection limits and not listed in Table 4-5. The three parameters listed resulted in slightly above detection limits but below maximum contaminations limits. The complete laboratory of primary and secondary testing results are available in Appendix O.

4.1.5 Hydraulic Testing and Analysis

4.1.5.1 Specific Capacity Testing

Specific capacity testing was performed at approximately 30-foot intervals in the pilot hole during reverse-air drilling. Testing began at a depth of 540 feet bls and continued to the total depth of the well, 1,200 feet bls. Drilling operations were halted while each test was conducted. The well was allowed to recover to determine static water level in the pilot hole. During the test the flow rate and drawdown were measured. The specific capacity measurement is an indication of the flow at that depth in the pilot hole relative to the rest of the borehole. Results of the specific capacity with depth are provided in Table 4-6 and also located in Appendix R.

4.1.5.2 Packer Testing

Packer testing was conducted during drilling operations to isolate and test possible storage zones, aquifer parameters, and recover discreet interval samples for water quality analysis. Intervals were selected for packer testing based on the specific capacity testing, geophysical logging, and lithologic characteristics. A summary of the packer test intervals and specific capacity results calculated to account for friction loss within the packer assembly pipe are presented in Table 4-7.

Five packer tests were performed in the ASR TPW. A single packer was used for Packer Test 1 to isolate the interval from 1,060 feet bls to the total depth of the well (1,200 feet bls). A straddle packer configuration was used for Packer Tests 2 through 5 to isolate discrete borehole depth intervals. The "straddle" or distance between bottom and top packers was chosen based on the anticipated interval of each potential flow zone.

Table 4-5 ASR TPW Completed Water Quality Results

Type	Parameter	ASR TPW (783 – 870 ft bls)
Primary Inorganic	Antimony (mg/L)	0.0063
	Arsenic (mg/L)	BDL
	Barium (mg/L)	0.020
	Beryllium (mg/L)	BDL
	Cadmium (mg/L)	BDL
	Chromium (mg/L)	BDL
	Cyanide (mg/L)	0.0082
	Fluoride (mg/L)	2.1
	Iron (mg/L)	0.039
	Mercury (mg/L)	BDL
	Nickel (mg/L)	BDL
	Nitrate (mg/L)	BDL
	Nitrite (mg/L)	0.03
	Total Nitrate, Nitrite(mg/L)	0.43
	Selenium (mg/L)	BDL
	Sodium (mg/L)	290
	Thallium (mg/L)	BDL
Secondary Inorganic	Aluminum (mg/L)	BDL
	Copper (mg/L)	BDL
	Chloride (mg/L)	461
	Lead (mg/L)	BDL
	Manganese (mg/L)	BDL
	Silver (mg/L)	BDL
	Sulfate (mg/L)	224
	Color (PtCo Color Units)	BDL
	Odor (TON)	24
	pH (std units)	7.49
	Total Dissolved Solids(mg/L)	1170
	Zinc (mg/L)	0.017
	Surfactants (mg/L)	0.064
Bacteriological	Fecal Coliform (CFU/100ml)	BDL
	Enterococcus (MPN/100ml)	BDL
	EColi (CFU/100ml)	BDL
Radionuclide's	Gross Alpha (pCi/l)	21±2.9
	Uranium (pCi/l)	BDL
	Radium-226 (pCi/l)	6.8±0.3
	Radium-228 (pCi/l)	BDL

Table 4-6 ASR TPW Specific Capacity During Drilling Operations

Depth (ft bls)	**Static Water Level** (ft als)	**Flow Water Level** (ft als)	**Drawdown** (ft)	**Flow Rate** (gpm)	**Specific capacity** (gpm/ft)
540	6.80	0.00	6.80	140	20
568	6.80	0.00	6.80	137	20
631	6.00	0.00	6.00	127	21
660	8.10	0.00	8.10	149	18
692	7.10	0.90	6.20	133	21
724	7.90	5.50	2.40	124	50
756	6.50	5.00	1.50	124	82
785	7.70	0.00	7.70	117	15
817	7.70	5.50	2.20	130	59
848	7.20	6.00	1.20	124	103
880	5.75	4.50	1.25	142	114
911	7.50	6.75	0.75	130	173
942	7.25	5.75	1.50	142	95
974	8.25	7.50	0.75	149	199
1,005	8.00	7.25	0.75	149	199
1,037	7.90	7.00	0.90	155	172
1,068	8.00	7.50	0.50	124	248
1,099	8.00	7.00	1.00	142	142
1,131	7.60	6.10	1.50	155	103
1,163	8.10	7.20	0.90	149	166
1,200	7.80	6.60	1.20	130	108

Table 4-7 ASR TPW Packer Test Summary

Packer Test Number	**Test Interval** (ft bls)	**Pump Rate** (gpm)	**Maximum Drawdown*** (ft)	**Specific Capacity*** (gpm/ft)
5	900-968	190	90	2.1
4	755-785	120	133	0.9
3	815-855	410	41	10.0
2	858-898	190	136	1.4
1	1,060-1,200	33	55	0.6

* Adjusted for friction loss

The following procedures were used to perform the packer tests:

1) To test each isolated depth interval, a packer assembly, attached to drill pipe, was lowered into the borehole. The packer was then inflated to seal off the selected depth interval. A pressure transducer was set in the annular space between the open hole and the drill pipe above the top packer to measure water pressure/levels above the packer to verify that the packer seal was not leaking. A second pressure transducer was set in the drill pipe to approximately 100 to 130 feet bls, to monitor water levels in the isolated interval.

2) In-Situ Mini-Troll pressure transducers were used to record and store water level measurements and were used in junction with Rugged Readers to monitor the measurements during the packer tests. Data from each packer test was analyzed using Aqtesolv Pro software for calculating transmissivities and the solutions are provided in Appendix Q.

3) A submersible pump was set into the drill pipe to a depth of approximately 100 to 140 feet bls. A pre-test was conducted to establish a maximum pumping rate and to stabilize water quality parameters to ambient conditions. After water quality stabilized and pump rates were selected, the pump was turned off and the water level was allowed to return to static conditions prior to the pumping portion of the packer test.

4) During the pumping phase of packer testing, water levels and pumping rates were monitored and recorded and water samples were collected and analyzed for field parameters. Each packer test was conducted for approximately 4 to 5 hours, which was dependent on pumping rate and/or drawdown stabilization.

5) Toward the end of the pumping phase of the test, water samples were also collected for analysis by Sanders Laboratories. The laboratory results for each packer test are summarized in Table 4-8. The analytical results for the samples collected during packer tests showed higher conductivity, chloride, and TDS values at shallower depths than observed during reverse air drilling. This variance in water quality is due to drilling fluid water quality samples being partially diluted with fresher water of overlying flow zones. The certified laboratory water quality report for each packer test is presented in Appendix P.

6) Following the pumping phase of the test, water level recovery was monitored and recorded until the water level had stabilized to pre-pumping, ambient conditions. Upon completion of the test, the packer assembly was deflated and removed from the borehole. Water level data was downloaded from the data logger on site after each packer test.

Packer test recovery data were used to calculate hydraulic parameters of each packer test interval. Water level data from the annular transducer was also reviewed to confirm the integrity of the top packer seal. Water levels above the packer assembly showed no effect resulting from pumping.

Table 4-8 ASR TPW Packer Test Water Quality Parameters

Type	Parameter	**Packer Test 1** 1,060 – 1,200 ft bls	**Packer Test 2** 858 – 898 ft bls	**Packer Test 3** 815 – 855 ft bls	**Packer Test 4** 755 – 785 ft bls	**Packer Test 5** 900 – 968 ft bls
Primary Inorganic	Aluminum (mg/L)	BDL	BDL	BDL	BDL	0.035
	Arsenic (mg/L)	BDL	BDL	BDL	BDL	BDL
	Barium (mg/L)	0.016	0.017	0.021	0.020	0.022
	Fluoride (mg/L)	2.2	2.0	2.1	1.7	2.0
	Nitrate (mg/L)	BDL	BDL	BDL	0.13	0.02
	Sodium (mg/L)	458	266	270	250	333
Secondary Inorganic	Chloride (mg/L)	830	456	420	394	587
	Iron (mg/L)	0.063	BDL	0.063	0.294	0.070
	Manganese (mg/L)	0.018	0.004	0.004	0.023	0.007
	Sulfate (mg/L)	302	191	166	152	231
	Color (PtCo Color Units)	5	5	3	5	BDL
	Total Dissolved Solids (mg/L)	1940	1160	1150	1080	1450
Additional Parameters	Ammonium (mg/L)	0.36	0.27	0.21	0.14	0.20
	Bicarbonate Alkalinity (mg/L)	183	194	189	181	194
	Calcium (mg/L)	67.1	51.4	59.6	51.6	60.6
	Carbon Dioxide (mg/L)	162	172	167	160	172
	Carbonate Alkalinity (mg/L)	0.58	1.49	1.31	1.35	1.56
	Hydrogen Sulfide (mg/L)	0.08	0.40	0.30	0.29	0.39
	Magnesium (mg/L)	92.2	65.0	65.5	57.8	71.9
	Potassium (mg/L)	30.8	21.5	21.3	19.7	19.5
	Silica (mg/L)	19.5	16.0	19.2	14.6	18.5
	Strontium (mg/L)	16	11	11	11	11

Packer test recovery data were analyzed using three separate solution methods that best fit the recovery curves: the Hantush (1960) method for semi-confined aquifers with Aquitard storage, the $Moench_1$ (1985) Constant head method, and the $Moench_2$ (1985) No Flow method. A summary of the Transmissivity values calculated for the recovery data of each packer test is presented in Table 4-9.

Table 4-9 ASR TPW Packer Testing Analysis Results

Packer Test Number	Test Interval (ft bls)	Transmissivity (gpd/ft)			
		Hantush (1960)	$Moench_1$ (1985)	$Moench_2$ (1985)	Average
5	900-968	4,185	4,502	3,901	4,196
4	755-785	3,635	2,273	4,078	3,329
3	815-855	7,721	8,014	7,480	7,738
2	858-898	1,875	2,890	3,188	2,651
1	1,060-1,200	573	572	840	662

1 Constant Head solution
2 No Flow solution

The average Transmissivity (gal/day/ft) values calculated from analysis of packer tests 1 through 5 are 662, 2651, 7738, 3329, and 4196 gal/day/ft respectively. Resultant transmissivity values from analysis of packer tests are not indicative of bulk conduit flow zones. The analytical results including the time-displacement curves for the packer tests are presented in Appendix Q.

4.1.5.3 Step Drawdown Testing

Following completion of drilling activities, an initial step drawdown test on the ASR TPW was conducted on October 20, 2008. The test consisted of five steps each conducted for one hour. The well was pumped at 180, 410, 620, 905, and 1150 gpm. Multiple testing equipment errors were encountered including pressure transducer failure and erratic pumping rates. The step drawdown test results show a specific capacity of 9 gpm/ft at a pump rate of 620 gpm. Results for the pre-acidization step drawdown test are shown in Table 4-10. Based on the specific capacity results obtained, a conventional acid treatment was conducted.

Following acidization and redevelopment, a second step drawdown test was performed on May 15, 2009 to evaluate production improvement. The test consisted of five steps each conducted for approximately 45 minutes. The well was pumped at 530, 660, 800, 1040, and 1250 gpm. The step drawdown test results show a specific capacity. Results for the pre-acidization, and post-acidization step drawdown tests are summarized in Table 4-10. The results indicate that the specific capacity increased to 19 gpm/ft at 660 gpm or 111 percent above the pre-acidization step drawdown test.

Table 4-10 Pre and Post Acidization Step Drawdown Test

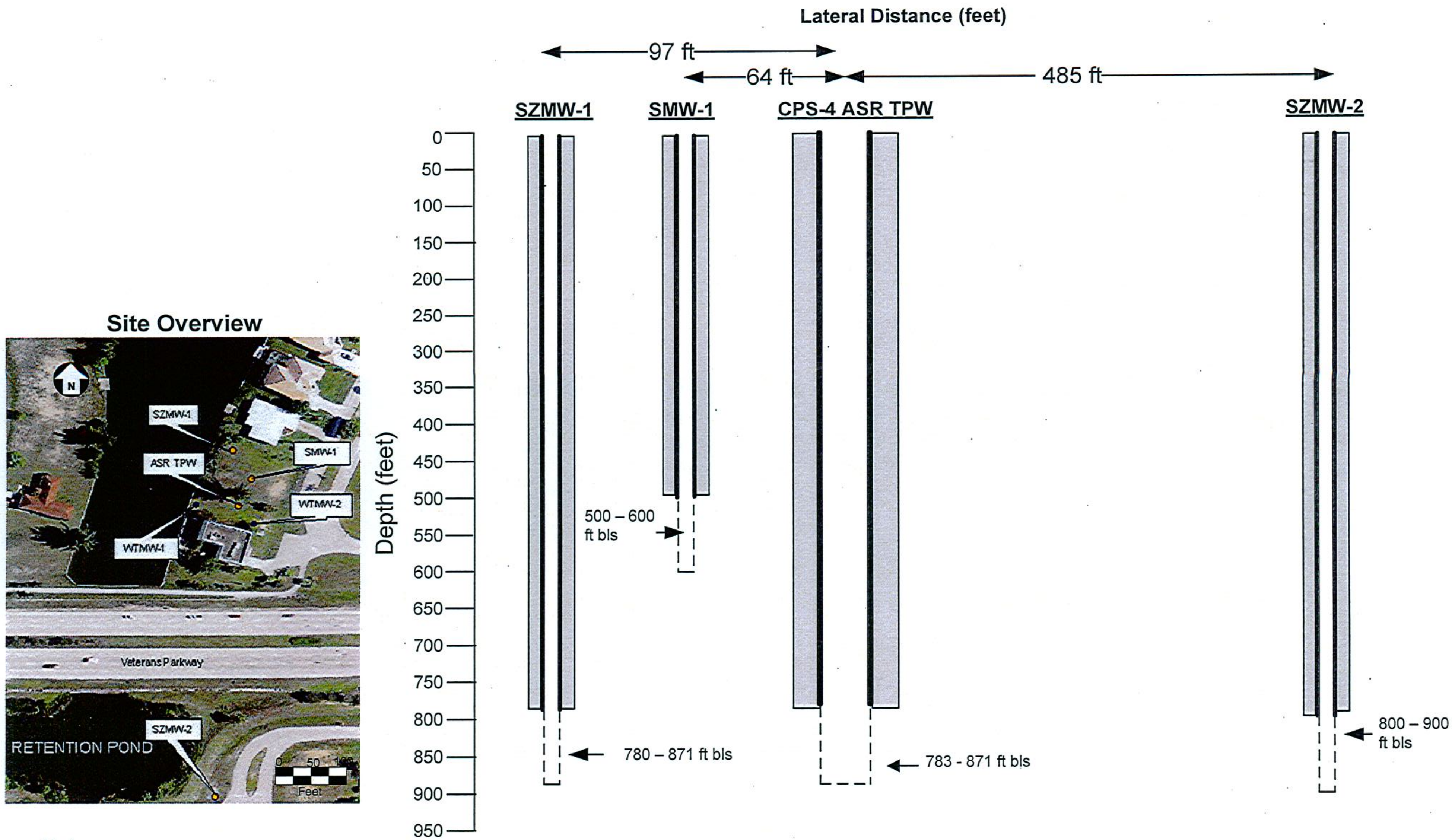
Test	Step	Pump Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)
Pre-Acidization	1	180	4.96	36.3
	2	410	45.02	9.1
	3	620	68.57	9.0
	4	905	108.14	8.4
	5	1,150	136.02	8.5
Post-Acidization	1	530	25.20	21.0
	2	660	34.20	19.0
	3	800	45.50	18.0
	4	1,040	61.10	17.0
	5	1,250	71.50	17.0

4.1.5.4 Aquifer Performance Test

An APT was conducted on the CPS-4 ASR System to determine the hydraulic properties of the storage zone located from 783 to 871 feet bls. The principle factors of aquifer performance, transmissivity and storage coefficients are calculated from the drawdown and/or recovery data obtained from the proximal monitor wells completed within the same interval. For semi-confined aquifers, the hydraulic parameter of leakance of the semi-pervious layer(s) can also be determined. The ASR TPW was the pumped well and SZMW-1, SZMW-2, and SMW-1 were used as monitor wells.

Well SZMW-1 is located 97 feet northwest of the ASR TPW. The SZMW-2 well is located 485 feet south of the ASR TPW. SMW-1 is located 64 feet northeast of the ASR TPW. The spatial relationship of the wells is shown in Figure 4-2. The APT consisted of three phases: a background phase was conducted to determine ambient non-pumping conditions; a pumping phase to determine water level drawdown in the three monitor wells resulting from pumping the ASR TPW; and a recovery phase to determine residual drawdown and return to static water level conditions.

The background phase consisted of recording water level measurements in all four wells for a period of 60 hours. The drawdown phase consisted of pumping the ASR TPW at constant-rate of 1,300-gpm for 72-hours while recording water level changes in the ASR TPW and monitoring wells SZMW-1, SZMW-2, and SMW-1. Recovery data was monitored in all wells for 96 hours.



Note
ft bls = feet below land surface
Surface and intermediate casing are not depicted

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Figure 4-2 Spatial Relationship of CPS-4 ASR System Wells

Beginning May 15th, 2008 background data was collected to measure the diurnal trends in the testing area. Water levels in the ASR TPW remained generally stable as the well recovered from an APT pre-test performed to establish a desired pumping rate at the ASR, Figure 4-3. Variations in water levels at the monitoring wells the result of daily withdrawls from the Cape Coral South Wellfield. The ASR TPW may not have recorded these water level changes because of the low sensitivity of the InSitu troll.

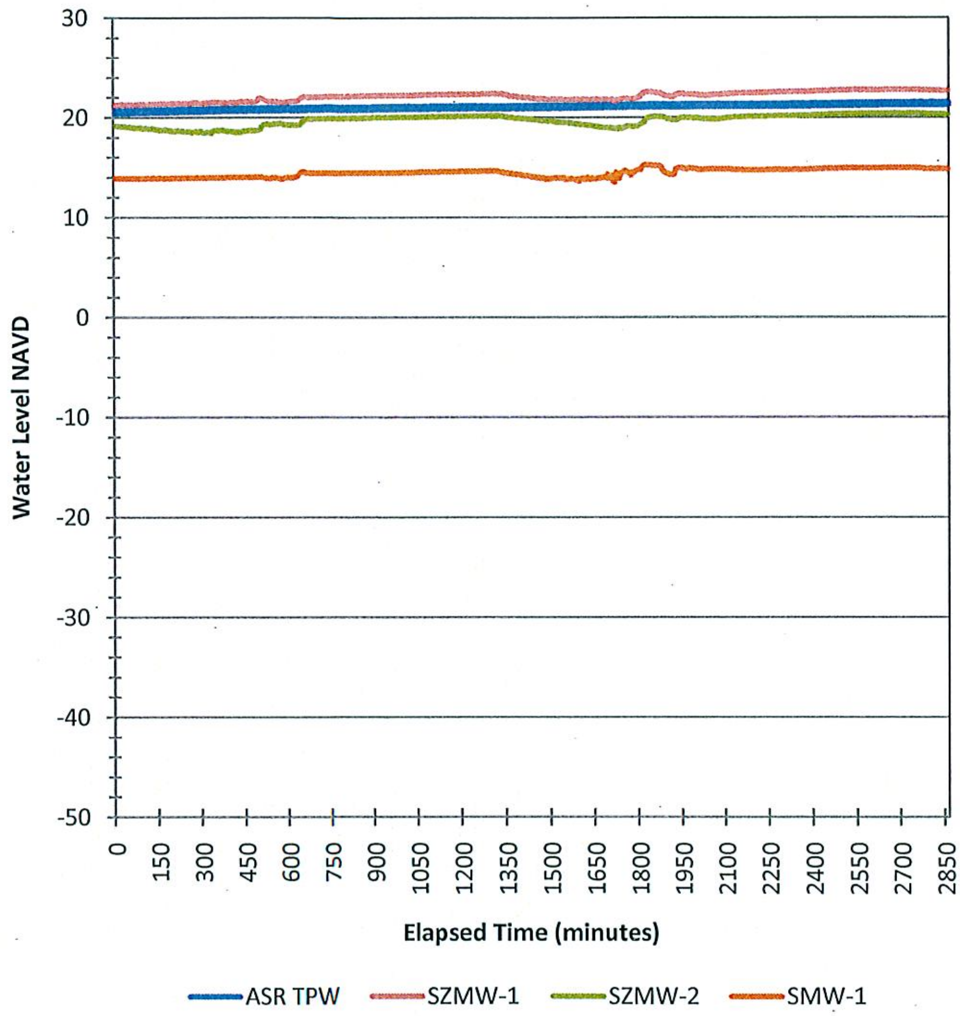

Figure 4-3 Background Data for APT

On May 18, 2008 the drawdown phase of the APT was attempted by pumping the ASR TPW at 1,020 gpm. Within two hours the pumping rate had dropped below 800 gpm because of a pump malfunction. The test was terminated and the wells were allowed to recharge for approximately 24 hours. Water levels had returned to background levels on May 19, 2008 and the drawdown phase of the APT started by pumping the ASR TPW at

1,050 gpm. The pumping rate dropped to 1,030 gpm over the first half hour and minor adjustments were made at the discharge valves to maintain the 1,030 gpm flow rate. The drilling contractor operated the pump at 1030 gpm uninterrupted for the next 72 hours. In-Situ Level Troll transducers continuously measured and recorded water levels during the drawdown phase. Plots of the drawdown data for the pumped well and monitor wells are shown in Figures 4-3 to 4-6. Within the storage zone maximum drawdown observed in the ASR TPW, SZMW-1, and SZMW-2 was 66.86 feet, 45.17 feet, and 30.55 feet, respectively.

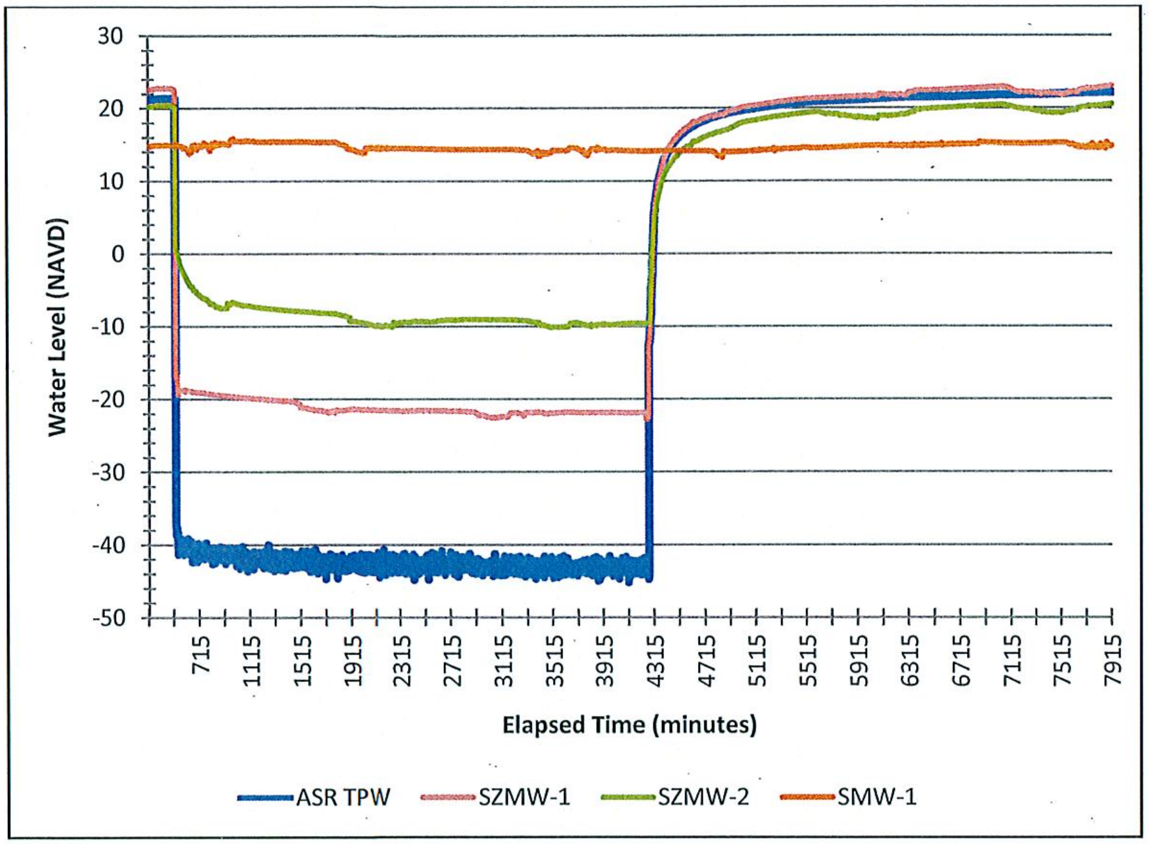

Figure 4-4 Drawdown Data for APT

Three analytical solutions were used to estimate the transmissivity, storage coefficient, and leakance at the site: Cooper-Jacob (1946), Hantush-Jacob (1955). Moench$_1$ (1985), and A summary of the APT analyses for the pumped monitoring zones (SZMW-1 and SZMW-2) are provided in Table 4-11. The transmissivity for each solution show similar results and is supported by the specific capacity tests recorded from other subject wells within the City of Cape Coral. The dimensionless parameter r/B characterizes the leakage across the aquitard(s) to the pumped aquifer, from this value leakance was calculated (Walton, 1960).

$$\text{Leakance} = \frac{4T(r/B)}{r^2}$$

Where:

T = Transmissivity (ft^2/day)
r/B = Dimensionless parameter from type curve
r = Radius between wells (ft)

Table 4-11 Storage Zone Aquifer Properties

Monitor Well	Solution Method	Transmissivity (gpd/ft)	Storage Coefficient	Leakance (1/day)
ASR TPW	Cooper-Jacob	22,400	3.74×10^{-3}	NA
	Hantush-Jacob	20,880	3.66×10^{-3}	NA
	$Moench_1$	20,270	4.01×10^{-5}	NA
	Average	21,183	2.48×10^{-3}	NA
SZMW-1	Cooper-Jacob	21,130	2.60×10^{-5}	NA
	Hantush-Jacob	20,860	1.14×10^{-4}	2.78×10^{-2}
	$Moench_1$	20,160	2.61×10^{-6}	2.90×10^{-2}
	Average	20,717	4.75×10^{-5}	2.84×10^{-2}
SZMW-2	Cooper-Jacob	21,190	4.01×10^{-5}	NA
	Hantush-Jacob	22,240	3.33×10^{-5}	3.27×10^{-3}
	$Moench_1$	22,550	3.08×10^{-5}	3.19×10^{-3}
	Average	21,993	3.47×10^{-5}	3.23×10^{-3}

NA – Not Available - Method does not provide r/B required for calculation

Based on these considerations and the site-specific hydrogeologic data collected during drilling and aquifer testing, the Hantush-Jacob (1955) for a leaky confined aquifer method analytical model best represents the hydraulic properties of conditions present at this site. A log/log plot of drawdown versus time, utilizing the Hantush-Jacob (1955) solution, for the pumped monitor zones (SZMW-1 and SZMW-2) is provided in Figures 4-6 and 4-7, respectively. The water level data and log/log plots of drawdown versus time for the Cooper-Jacob solution and the Moench solution are provided in Appendix T.

Hantush-Jacob (1955) is a solution derived for unsteady flow to a fully penetrating well in a homogeneous, isotropic leaky confined aquifer. The solution assumes a line source for the pumped well and therefore neglects wellbore storage.

The results of this solution for SZMW-1 and SZMW-2 yielded a transmissivity value of 20,860 and 22,240 gpd/ft, a storage coefficient of 1.14 x 10^{-4} and 2.33 x 10-5, and an (r/B) value of 0.02 and 0.07, respectively. The dimensionless parameter r/B characterizes the leakage across the aquitard(s) to the pumped aquifer. The transmissivity calculated with the Hantush-Jacob analysis is comparable to the average of all three pump test analysis methods used in this analysis as shown in Table 4-11.

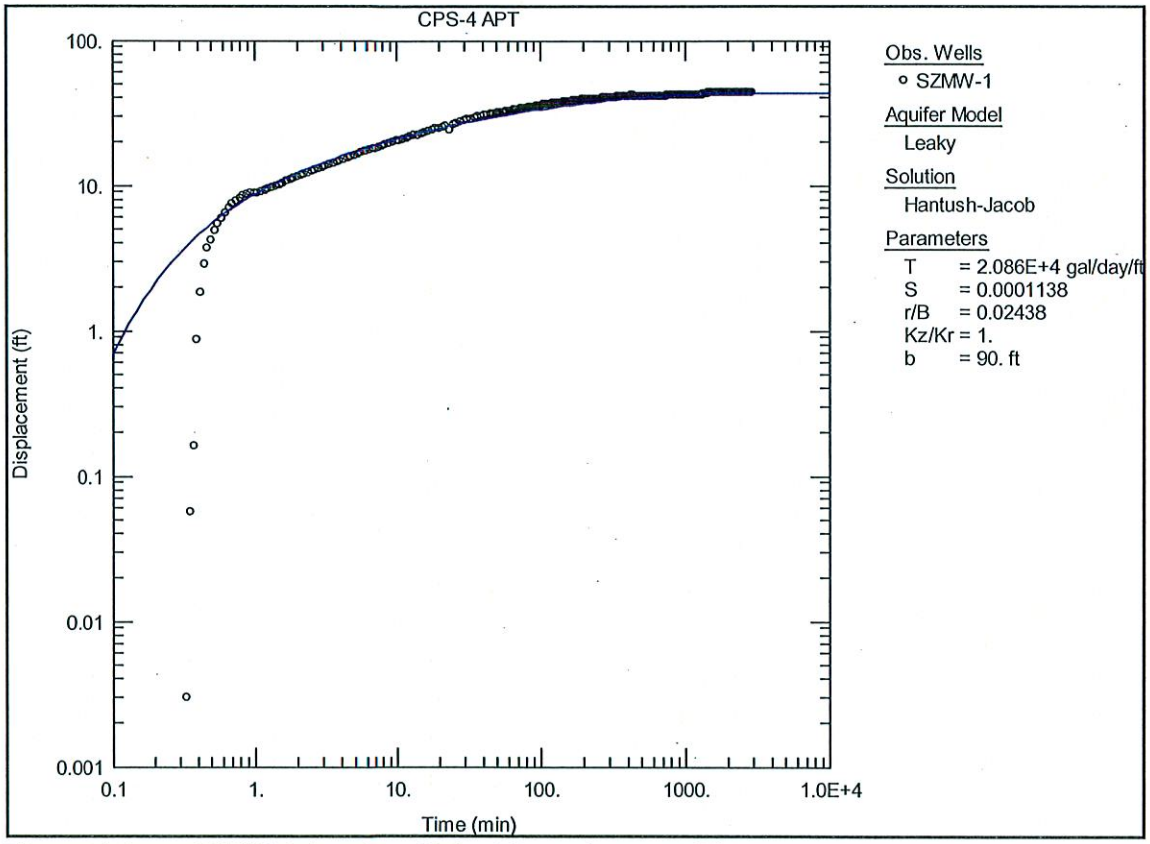

Figure 4-6 SZMW-1 Log-Log Plot of Drawdown vs. Time

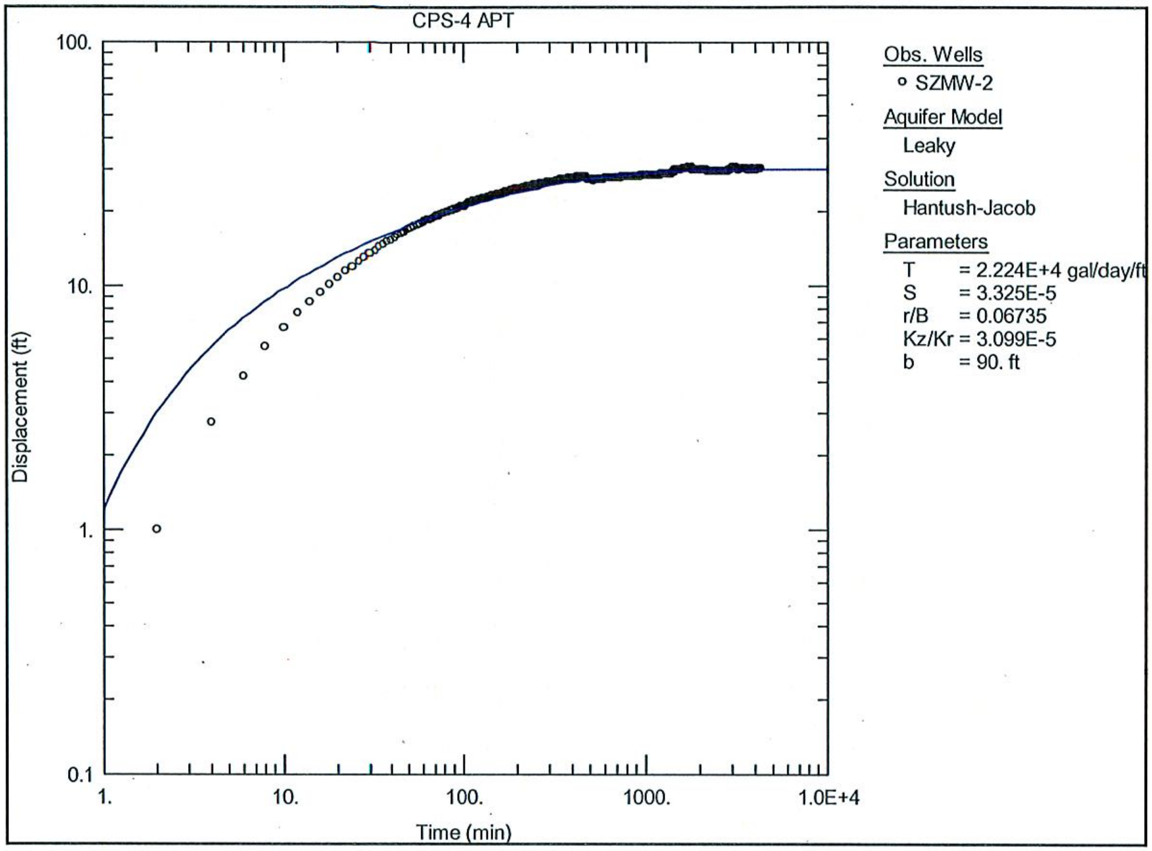

Figure 4-7 SZMW-2 Log-Log Plot of Drawdown vs. Time

4.1.5.5 Injection Pressure Analysis

A three-dimensional, steady state, finite difference groundwater flow model using MODFLOW2000 was developed to estimate drawdown caused by aquifer withdrawals or injection in and around the City of Cape Coral. The model has variable cell spacing, with a uniform maximum horizontal resolution of 500 feet^2 in the area representing the City of Cape Coral. The model vertically represents seven layers, representing alternating aquifer and confining units documented and observed in the local and semi-regional area.

This model was used to estimate pressure changes resulting from injection at the CPS-4 ASR System into the completed storage zone at a rate of 1 mgd. The aquifer unit representing the storage zone, and aquifer units above and below the storage zone, were monitored during the injection simulation for pressure changes (Figure 4-8).

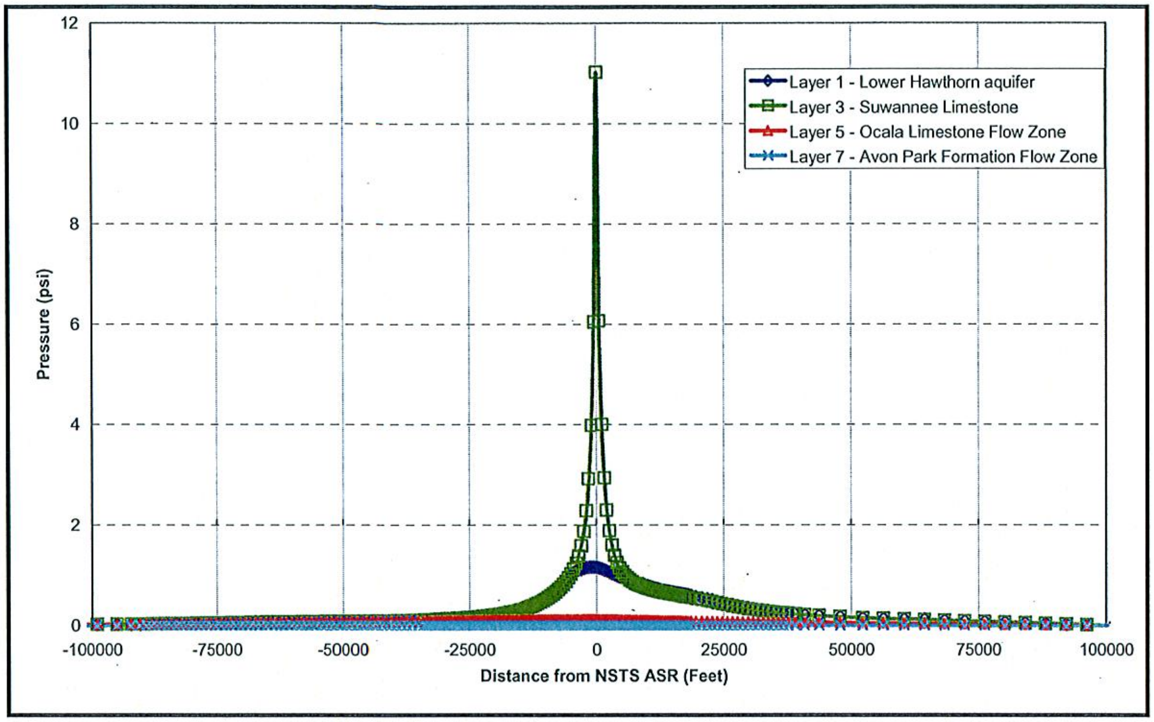

Figure 4-8 CPS-4 ASR Pressure Profile at 1 MGD Injection Rate

The maximum pressure increase per layer is listed on Table 4-12. Simulated pressures do not represent pressures significant enough to cause vertical or horizontal fracturing of the storage zone or overlying/underlying confining and/or aquifer layers. The overburden pressure of the uppermost aquifer layer would have to be exceeded to induce horizontal fracturing in the formation, which has been estimated at approximately 450 psi (1 psi per foot of depth to the top of the lower Hawthorn aquifer). Approximately half of the overburden pressure (0.55 psi per foot) would be required to initiate vertical fracturing. Based on simulation modeling of 1 MGD injection, a maximum average pressure of 11.02 psi is observed in the storage zone within a 500-foot^2 area surrounding the ASR TPW. The modeled pressure is not significant enough to cause detrimental stress on the aquifer structure.

Table 4-12 ASR TPW Maximum Modeled Pressure Increase per Layer

Model Layer	Hydrogeologic Unit	Maximum Modeled Pressure (psi)
1	lower Hawthorn aquifer	1.16
2	Suwannee Limestone confining unit	2.89
3	Suwannee Limestone aquifer	11.02
4	Ocala Formation confining unit	5.32
5	Ocala Formation flow zone	0.31
6	Avon Park Formation confining unit	0.05
7	Avon Park Formation flow zone	0.00

4.2 Monitor Wells

4.2.1 Formation Samples

Formation cuttings were collected during pilot hole drilling of wells SZMW-1, SZMW-2 and SMW-1. Samples were collected every 10 feet from land surface to the total depth of the well.

Samples were characterized for rock type, color, consolidation, texture, cementation, hardness/induration, fossil type, and visible porosity and permeability. The lithologic samples aided in identifying the contacts between formations, selection of packer test intervals, and understanding the overall physical characteristics of formations penetrated by the borehole. Descriptions of the lithology encountered during drilling of the monitor wells are presented in Appendix B.

4.2.2 Geophysical Logging and Analysis

Geophysical logs for the monitor wells were conducted in the pilot holes after each stage of drilling and after reaming. The logs provide a continuous record of the geophysical properties of the subsurface formations. Analyses of the logs were used to assist in the interpretation of lithology, provide estimates of permeability, porosity, bulk density, and resistivity. Geophysical logs are presented in Appendix C.

The geophysical logs aided in identifying geologic contacts, and used to obtain hydrogeologic data pertaining to the formations. Geophysical logs were conducted in the pilot hole, reamed hole, and final open borehole for both storage zone monitor wells. Geophysical logs were conducted in the pilot hole, and final open borehole for SMW-1. A summary of geophysical logging conducted at the monitor wells are provided in Table 4-13. The geophysical data, in conjunction with water quality, specific capacity testing, and lithology information was used in determining optimum casing depths for each well, packer-test intervals for wells SZMW-1 and SZMW-2, and to select the monitor zone for the wells.

4.2.3 Water Quality Sampling and Analysis

4.2.3.1 Water Quality During Drilling

Water quality samples were collected in 20-foot intervals in the pilot hole for the monitor wells during reverse-air drilling. Samples were collected at the circulation discharge point. The samples were analyzed on-site for dissolved oxygen, temperature, pH, conductivity, and chloride. These data were used to identify TDS increases and general water quality trends with depth.

Table 4-13 Monitor Well Geophysical Summary

Well	Date	Logged Interval (ft bls)	XY Caliper	Gamma Ray	Spontaneous Potential	Dual Induction	Temperature	Fluid Conductivity	Flow	Sonic Porosity	Video
SZMW-1	3/18/2009	0-510	X	X	X	X				X	
	3/30/2009	0-503	X	X							
	4/10/2009	0-870	X	X	X	X	X	X	X	X	X
	5/13/2009	0-870	X	X							X
SZMW-2	9/18/2008	0-529	X	X	X	X				X	
	9/30/2008	0-525	X	X							
	10/21/2008	0-525	X	X							
	11/21/2008	0-870	X	X							
	12/17/2008	0-900	X	X	X	X	X	X	X	X	X
	2/12/2009	0-900	X	X							X
SMW-1	1/14/2009	0-520	X	X	X	X				X	
	2/27/2009	0-600	X	X	X	X	X	X	X	X	X

Reverse-air drilling at the monitor wells was conducted in an open system, with fluids generated from the well drilling operations discharged to the freshwater canal system. The water samples collected during reverse air drilling is a mixture of formation water from the entire open borehole. The water quality measurements do not necessarily reflect the water quality at the sampled interval. Water quality samples from reverse air drilling measure relative water quality trends versus depth and are provided in Appendix R.

4.2.3.2 Final Water Quality

Upon completion of development, the monitor wells were purged until at least three well volumes of water had been evacuated and chloride concentration, temperature, pH and specific conductivity measurements stabilized. Water samples were collected by Sanders Laboratories, Inc. following completion of each monitor well. The samples were analyzed for primary and secondary drinking water standards using EPA and/or Standard Method procedures. The complete results of these analyses are presented in Appendix O. A summary of the analysis results are provided in Table 4-14.

4.2.4 Hydrogeologic Testing and Analysis

4.2.4.1 Reverse Air Drilling Specific Capacity Testing

Specific capacity testing was performed in the pilot hole of the monitor wells during reverse air drilling at 60-foot intervals. Drilling operations were paused while each specific capacity test was conducted. Static water level in the pilot hole, flow rate, and drawdown were recorded. The resultant specific capacity measurement is an indication of the flow in that section of the pilot hole, relative to the rest of the pilot hole, and not an absolute value of that section of pilot hole. The specific capacity measurements during drilling operations for the monitor wells are available in Appendix S.

4.2.4.2 Packer Testing

Single packer testing was conducted in wells SZMW-1 and SZMW-2 to isolate and test potential monitor zones, characterize aquifer parameters, and collect samples for water quality analysis. Depth intervals corresponding to specific geologic horizons were selected for packer testing based on the ability to produce water as determined from specific capacity testing, geophysical logging, and lithologic characteristics. The main purpose of testing the monitor wells was to insue the completed monitoring interval would produce sufficient water during future sampling and purging operations. The SZMW-1 packer was set to isolated the interval from 780 feet bls to the total depth of the well (870 feet bls). The SZMW-2 packer was set to isolated the interval from 800 feet bls to 870 feet bls (the total depth of the well at that time)

The following procedures were used to perform the packer tests:

1) To test each isolated interval a single packer assembly attached to drill pipe, was lowered into the borehole. The packer was then inflated to seal off the selected interval. A pressure transducer was set in the drill pipe. The drill pipe provides a conduit to the packer assembly, to monitor water levels in the isolated interval. A second pressure transducer was set above the top packer in the annular space between the open hole and the drill pipe to measure water levels above the packer and verify that the packer seal was not leaking. In-Situ Mini-Troll pressure transducers were used to record and store water level measurements. Data loggers were used to monitor the measurements during the tests.

2) In-Situ Mini-Troll pressure transducers were used to record and store water level measurements and were used in junction with Rugged Readers to monitor the measurements during the packer tests. Data from each packer test was analyzed using Aqtesolv Pro software for calculating transmissivities and the solutions are provided in Appendix N.

Table 4-14 Completed Monitor Water Quality Results

Type	Parameter	SZMW-1	SZMW-2	SMW-1
Primary Inorganic	Antimony (mg/L)	0.0030	BDL	0.0023
	Arsenic (mg/L)	BDL	BDL	BDL
	Barium (mg/L)	0.021	0.022	0.026
	Beryllium (mg/L)	BDL	BDL	BDL
	Cadmium (mg/L)	BDL	BDL	BDL
	Chromium (mg/L)	BDL	BDL	BDL
	Cyanide (mg/L)	BDL	BDL	BDL
	Fluoride (mg/L)	1.7	1.8	1.7
	Lead (mg/L)	BDL	BDL	BDL
	Mercury (mg/L)	BDL	BDL	BDL
	Nickel (mg/L)	BDL	BDL	BDL
	Nitrate (mg/L)	BDL	BDL	BDL
	Nitrite (mg/L)	BDL	BDL	BDL
	Total Nitrate (mg/L)	0.56	BDL	BDL
	Selenium (mg/L)	BDL	BDL	BDL
	Sodium (mg/L)	310	290	340
	Thallium (mg/L)	BDL	BDL	BDL
Secondary Inorganic	Aluminum (mg/L)	BDL	BDL	BDL
	Copper (mg/L)	BDL	BDL	BDL
	Chloride (mg/L)	473	516	592
	Iron (mg/L)	0.086	0.054	BDL
	Manganese (mg/L)	BDL	BDL	BDL
	Silver (mg/L)	BDL	BDL	BDL
	Sulfate (mg/L)	210	195	251
	Color (PtCo Color Units)	5	BDL	5
	Odor (TON)	4	35	24
	pH (std units)	7.57	7.56	7.53
	Total Dissolved Solids(mg/L)	1200	1220	1420
	Zinc (mg/L)	0.018	0.024	BDL
	Surfactants (mg/L)	0.076	0.80	0.052
Bacteriological	Fecal Coliform (CFU/100ml)	BDL	BDL	BDL
	Enterococcus (MPN/100ml)	BDL	BDL	BDL
	EColi (CFU/100ml)	BDL	BDL	BDL
Radionuclide's	Gross Alpha (pCi/l)	24±3.0	28±3.1	20±3.0
	Uranium (pCi/l)	0.16	0.17	0.06
	Radium-226 (pCi/l)	7.4±0.4	3.4±0.3	8.0±0.4
	Radium-228 (pCi/l)	BDL	BDL	0.3±0.2

3) For SZMW-1 and SZMW-2 packer tests a submersible pump was set into the drill pipe at 150 and 154 ft bls, respectively. A pre-test was conducted prior to establishing a maximum pumping rate and to stabilize water quality parameters to ambient conditions. Pumping rates for the SZMW-1 and SZMW-2 packer tests were 150 gpm and 160 gpm, respectively. After water quality stabilized and pump rates were selected, the pump was turned off and the water level was allowed to return to static conditions prior to the pumping portion of the packer test.

4) During the pumping phase of packer testing, water levels were monitored and recorded and water samples were collected and analyzed to monitor water quality. The pumping phase of the SZMW-1 packer test was conducted for 3 hours. The pumping phase of the SZMW-2 packer test was conducted for 5 hours. Both tests were terminated after at least three volumes had been purged and water levels and water quality measurements remained stable.

5) Toward the end of the pumping phase of the test, water samples were also collected for analysis by Sanders Laboratories. The analytical results for the samples collected during the packer tests showed higher conductivity, chloride, and TDS values at shallower depths than observed during reverse air drilling. This variance in water quality is due to drilling fluid water quality samples being partially diluted with fresher water of overlying flow zones. The certified laboratory water quality report for each packer test is presented in Appendix P.

6) Following the pumping phase of the test, water level recovery was monitored and recorded until the water level had stabilized to pre-pumping, ambient conditions. Upon completion of the test, the packer assembly was deflated and removed from the borehole. Water level data was downloaded from the data logger on site after each packer test.

Packer test recovery data were used to estimate hydraulic parameters of each tested interval for SZMW-1 and SZMW-2. Water pressure/level data from the annular transducer was also reviewed to confirm the reliability of the top packer seal. Water levels above the packer assembly showed no effect resulting from pumping. The packer test at SZMW-1 was completed on January 15, 2009 on the interval from 799 to 920 feet bls. The packer test at SZMW-2 was completed on December 11, 2008 on the interval from 790 to 910 feet bls. A summary of the packer test for each monitor well is provided in Table 4-15. The analytical results including the time-displacement curves for the packer tests are presented in Appendix Q.

Packer test recovery data were analyzed using three separate solution methods which best matched the recovery curves: the Hantush (1960) method for semi-confined aquifers with Aquitard storage, the Cooper Jacob (1946) method for confined aquifers, and the Theis (1935) method for confined aquifers. A summary of the packer test intervals conducted and physical parameters is presented in Table 4-16.

Table 4-15 Monitor Well Packer Test Summary

Well	Test Interval (ft bls)	Pump Rate (gpm)	Maximum Drawdown* (ft)	Specific Capacity* (gpm/ft)
SZMW-1	780-870	150	70	2.1
SZMW-2	800-870	160	116	1.4

*adjusted for friction loss

Table 4-16 Monitor Well Packer Test Aquifer Analysis Summary

Well	Transmissivity (gpd/ft)			
	Hantush (1960)	Cooper Jacob	Theis	Average
SZMW-1	4,038	4,403	4,508	4,316
SZMW-2	1,115	2,279	2,090	1,828

5.0 Conclusions and Recommendations

Construction of the ASR System at the City of Cape Coral's Canal Pump Station 4 has been successfully completed. One ASR test production well with 16-inch diameter fiberglass reinforced plastic casing set to 783 feet bls and an open hole extending from 783 to 871 feet bls with a design rate of 1 mgd. The two storage zone monitor wells, SZMW-1 and SZMW-2, located at radial distances of 97 and 485 feet, respectively, from the TPW, were completed from 780 to 871 feet, and from 800 to 900 feet bls, respectively. The shallow monitor well, SMW-1, located at a radial distance of 64 feet from the TPW, was completed from 500 to 600 feet bls. All wells were constructed in accordance with the requirements specified under FDEP Class V Group 7 well construction permit No. 247165-003-UC.

The storage zone of the ASR TPW is completed within the Suwannee Limestone of the Upper Floridan aquifer. The storage zone interval, located between the depths of 783 and 871 feet below land surface (bls), was proposed by MWH staff and approved by the FDEP Technical Advisory Committee (TAC) staff. The final casing and storage zone justification letter is provided in Appendix B. This storage interval is similar, but shallower, to that proposed in the application materials (810 – 950 feet). The proposed storage zone is comprised of calcarenitic limestone and has characteristics that are considered significant to obtain good recovery efficiencies. Hydrogeologic and design factors that contribute to good performance are discussed below, and are largely based on performance factors identified by Reese and Alvarez-Sarikian (2006) for existing South Florida ASR systems.

1. Storage Zone Thickness – the thickness of the proposed storage zone is approximately 90 feet. This compares to successful ASR projects in Southwest Florida which range from 45 feet (Marco Lakes) to 155 feet (Lee County WTP). A moderately small storage zone was chosen to limit uncertainties concerning productivity and confinement, and this conservative approach was taken to ensure an adequate interval for injection and recovery was present.

2. Transmissivity – Transmissivity within the storage zone is estimated to range from 20,000 to 45,000 gpd/ft. Transmissivity estimates were obtained from packer testing, step drawdown tests and the APT. Based on Packer Test 3, located in an interval of the storage zone, the transmissivity of the 90 foot storage zone was estimated to approach 45,000 gpd/ft (see Appendix B). Post-acidification step drawdown test results yielded specific capacities of approximately 20 gpm/ft, or a transmissivity estimate of approximately 40,000 gpd/ft. Aquifer testing following well completion resulted in a Transmissivity value of approximately 21,000 gpd/ft. The Transmissivity estimates at the CPS-4 site is in the low range compared to neighboring ASR sites but pump test results indicate the well would operate effectively at planned injection and withdrawal rates.

3. Native Water Quality – Based on packer test data collected, the chloride concentration of the planned storage zone ranges from approximately 425 to 500

mg/l. Based on final sampling, the ambient water within the storage zone is slightly brackish, and contains a chloride and TDS concentration of approximately 461 mg/L and 1,170 mg/L, respectively. This water quality is similar to the existing successful ASR project at Lee County WTP which has a native water quality chloride concentration of 500 mg/l.

4. Confinement - Approximately 80 feet of low permeability interbedded marl and clay confinement is present above the storage zone. Confinement below the storage zone is suggested by lower sonic porosities below 950 feet bls and Packer Tests 1 and 2 results that are an order of magnitude lower than those in the storage zone. Confinement above, and to a lesser extent below the storage zone are considered essential for a successful storage zone.

5. Absence of potential conduit flow - The sonic, flowmeter and video logs were reviewed for the presence of conduit flow zones, such as fracture zones or extensive secondary dissolution features that would contribute to loss of stored water. The borehole compensated (BHC) sonic variable density log and flowmeter logs indicate that there are no features within the storage zone interval that are characteristic of fracture zones. With the exception of a few bedding plane features, no significant features were observed in the video that would contribute to bulk conduit flow.

Design of the surface equipment, including recharge and recovery pumps, water treatment piping and electrical controls are currently being completed under the IRR-7 Work Authorization. MWH recommends initiation of cycle testing upon completion of facilities at the CPS-4 ASR site. Prior to completion of treatment facilities, a request to start cycle testing will be submitted to the FDEP. The request will include an updated Cycle testing plan. A preliminary plan was submitted in the October 14, 2006, letter from MWH to the Department.

The cycle testing plan will consist of progressively longer periods of injection, storage, and recovery of treated water from the ASR TPW. Water quality and flow information will be collected during the cycle testing period. At the conclusion of cycle testing, a report detailing and interpreting the collected information will be prepared and submitted to FDEP in support of an Operating Permit application for the system.

6.0 References

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Report Supplement

Lithologic Logs:

- ASR-TPW
- SZMW-1
- SZMW-2
- SMW-1

MWH

LITHOLOGY

IRR- 6C CPS ASR- 4 Production Well

WELL NUMBER	ASR (L1036)
PERMIT NUMBER	247165-003-UC
JOB NUMBER	3220276.703702
OWNER	City of Cape Coral

DEPTH (ft bls)	DESCRIPTION
0-5	Sand: grayish orange 10YR 7/4, medium to fine grained, silica, high porosity, well sorted, HCl reactivity-low to none.
5-15	Limestone: moderate yellowish brown 10YR 5/4, dolomitic, moderate to well indurated, slightly vuggy, low porosity imbedded with shell fragments (5%).
15-20	Sand: yellowish gray 5Y 8/1, medium to fine grained, silica, very poorly indurated, shell fragments (30-40%), trace silt.
20-25	Shell Bed: pieces and fragments of mollusk shells, mostly medium light grey N6 in color, silty clay (10-15%) yellowish gray 5Y 8/1 in color.
25-30	Shell Bed: pieces and fragments of mollusk shells: mostly medium light grey N6 and very pale orange 10YR 8/2 in color, medium to fine grained silica sand (15-20%); silt/carbonate mud (15-20%) light gray N7 in color, phosphate (5%).
30-40	Shell Bed: pieces and fragments of mollusk shells, mostly medium light grey N6 and very pale orange 10YR 8/2 in color, medium to fine grained silica sand (15%), silty clay (10-15%) greenish gray 5GY 6/1 in color
40-50	Clay: light olive gray 5Y 5/2, silty, shell pieces and fragments (10%), phosphate (5%) fine grain size.
50-70	Clay: light olive gray 5Y 5/2; silty, phosphate (5%) fine grain size.
70-80	Clay: light olive gray 5Y 5/2, phosphate (<5%) fine grain size.
80-95	Clay: light olive gray 5Y 5/2; shell pieces and fragments (10%), phosphate (<5%) fine grain size.
95-100	Shell fragments: pieces and fragments of mollusk shells, light olive gray 5Y 5/2 clay (25%)
100-110	Shell fragments (35%): pieces and fragments of mollusk shells Phosphate Nodules (35%), grayish black N2, 2-4 mm in length Marl (20%): light olive gray 5Y 5/2. phosphate (10%), fine grain size.
110-130	Shell fragments (50%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 Limestone (35%), yellowish gray 5Y 8/1, poor to moderately indurated, biomicrite Phosphate Nodules (5-10%): Grayish black N2, 2-4 mm in length, 5-10% very fine phosphate.

DEPTH (ft bls)	DESCRIPTION
130-140	Shell fragments (50%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 Limestone (40%), yellowish gray 5Y 8/1, poor to moderately indurated, biomicrite, 5-10% very fine phosphate.
140-150	Limestone (50%): light olive gray 5Y 6/1, poorly indurated, biomicrite Shell fragments (35%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 to very light gray N8: 10% very fine phosphate
150-170	Limestone (50%): light olive gray 5Y 6/1, poorly indurated, biomicrite Shell fragments (35%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 to very light gray N8: 5% very fine phosphate
170-190	Limestone (50%): yellowish gray 5Y 8/1; poorly indurated, biomicrite Shell fragments (35%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 to very light gray N8: 10% very fine phosphate
190-210	Limestone (60%): very pale orange 10YR 8/2, poorly indurated, biomicrite Shell fragments (35%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 to very light gray N8: 5% very fine phosphate
210-220	Clay (60%): light olive gray 5Y 5/2, silty, moderately cohesive Limestone (20%): very pale orange 10YR 8/2, poorly indurated, biomicrite Shell fragments (15%): pieces and fragments of mollusk shells, very pale orange 10YR 8/2 Phosphate (5%) fine grain size.
220-230	Marl (40%): yellowish gray 5Y 8/1, very soft, viscous. Limestone (25%): very pale orange 10YR 8/2, poorly indurated; biomicrite, Phosphate (25%): very fine; Clay (10%): light olive gray 5Y 5/2, silty, trace shell fragments
230-240	Marl (45%): yellowish gray 5Y 8/1, very soft, viscous. Limestone (40%): very pale orange 10YR 8/2, poorly indurated, biomicrite, Phosphate (15%): very fine, trace shell fragments
240-260	Marl (50%): yellowish gray 5Y 8/1, very soft, viscous. Limestone (45%): very pale orange 10YR 8/2, poorly indurated, biomicrite, Phosphate (5%): very fine, trace shell fragments
260-290	Marl (55%): yellowish gray 5Y 8/1, very soft, viscous. Limestone (40%): grayish orange 10YR 7/4, poorly indurated, micrite, chalky in nature Phosphate (5%): very fine, trace shell fragments
290-300	Marl (45%): greenish gray 5GY 6/1, very soft, viscous. Limestone (40%): very pale orange 10YR 8/2, poorly indurated, micrite, chalky in nature Clay (10%): light olive gray 5Y 5/2, silty Phosphate (5%): very fine

DEPTH (ft bls)	DESCRIPTION
300-330	Marl (65%): yellowish gray 5Y 8/1, very soft, viscous. Limestone (30%): very pale orange 10YR 8/2, poorly indurated, micrite, chalky in nature Phosphate (5%): very fine
330-340	Clay (60%): light olive gray 5Y 5/2, silty, moderately cohesive Limestone (35%): very pale orange 10YR 8/2, poorly indurated, micrite Phosphate (<5%), very fine
340-360	Marl (60%): yellowish gray 5Y 8/1, very soft, viscous. Limestone (30%): light olive gray 5Y 6/1, moderately indurated, micrite, Phosphate (<5%): very fine
360-380	Limestone (60%): light olive gray 5Y 5/2, moderately indurated, micrite, pinhole porosity evident Marl (35%): yellowish gray 5Y 8/1; very soft; viscous. Phosphate (<5%): very fine
380-390	Limestone (60%): yellowish gray 5Y 8/1 to white N9, moderately indurated, biomicrite, chalky in nature Clay (35%): greenish gray 5GY 6/1, very silty, viscous, poorly cohesive Phosphate (<5%): very fine
390-410	Limestone (75%): yellowish gray 5Y 8/1 to white N9, moderately indurated, biomicrite, chalky in nature, very small shell fragments evident Marl (25%): yellowish gray 5Y 8/1, very soft, viscous.
410-420	Limestone (60%): yellowish gray 5Y 8/1 to white N9, moderately indurated, biomicrite, chalky in nature Clay (35%): greenish gray 5GY 6/1, very silty, viscous, moderately cohesive Phosphate (<5%): very fine
420-430	Limestone: yellowish gray 5Y 8/1 to white N9, moderate to well indurated, biomicrite, chalky in nature, very small shell fragments evident
430-440	Limestone (90%): yellowish gray 5Y 8/1 to white N9, moderate to well indurated, biomicrite, chalky in nature, very small shell fragments evident Marl (10%): yellowish gray 5Y 8/1, very soft, viscous.
440-450	Limestone (75%): yellowish gray 5Y 8/1 to white N9, moderate to well indurated, biomicrite, chalky in nature, very small shell fragments evident Marl (25%): yellowish gray 5Y 8/1, very soft; viscous.
450-460	Limestone (90%): yellowish gray 5Y 8/1 to white N9, moderate to well indurated, biomicrite, chalky in nature, very small shell fragments evident Marl (10%): yellowish gray 5Y 8/1, very soft, viscous.
460-480	Limestone: yellowish gray 5Y 8/1 to white N9, moderate to well indurated, biomicrite, shell fragment content (10%)
480-490	Limestone (90%): yellowish gray 5Y 8/1 to white N9, moderate to well indurated, biomicrite, very small shell fragments evident Marl (10%): yellowish gray 5Y 8/1, very soft, viscous.

DEPTH (ft bls)	DESCRIPTION
490-505	Limestone: light gray N7 to white N9, moderate to well indurated, biomicrite, shell fragment content (10%)
505-530	Limestone: light gray N7 to white N9; moderately indurated, chalky in nature, biomicrite. Shell pieces and fragments (20%)
530-540	Limestone: light gray N7 to white N9, pelitic biomicrite, moderately hard, moldic and vuggy porosity, chalky, trace sparite.
540-570	Limestone: light gray N7 to white N9, moderately indurated, chalky in nature, biomicrite. Shell pieces and fragments (15%) Marl (10%), white N9, silty, poorly indurated to cohesive
570-580	Limestone: very pale orange 10 YR 8/2, moderately indurated, friable, biomicrite. Dolomite (25%), pale yellowish brown 10YR 6/2, well indurated. Pinhole porosity. Marl (15%), white N9; silty, poorly indurated to cohesive. Shell pieces and fragments (10%)
580-590	Limestone: very pale orange 10 YR 8/2 to white N9, moderately indurated, friable, biomicrite. Marl (15%), white N9, silty, poorly indurated to cohesive. Shell pieces and fragments (15%)
590-600	Limestone: very pale orange 10 YR 8/2, moderately indurated, biomicrite. Marl (15%), white N9, silty, poorly indurated to cohesive. Shell pieces and fragments (10%)
600-620	Limestone: very pale orange 10 YR 8/2, poorly to moderately indurated, calcarenitic, friable trace fossil fragments.
620-630	Limestone: grayish orange 10 YR 6/6, moderately indurated, calcarenitic, friable, trace fossil fragments.
630-650	Limestone: very pale orange 10 YR 8/2, poorly to moderately indurated, calcarenitic, moldic. Clay (5%): very light grey N8, silty, poorly cohesive. trace fossil fragments
650-680	Limestone: grayish orange 10 YR 6/6, moderately indurated, calcarenitic, trace fossil fragments. Clay: (5%) very pale orange 10 YR 8/2 to very light grey N8: silty, poorly cohesive. trace fossil fragments
680-700	Limestone: medium light gray N6 to yellowish gray 5Y 8/1; micritic, poorly indurated, moldic porosity, trace peletic and biogenic.
700-724	Limestone: medium light gray N6, biosparite, very fine grained (pelitic), moderately hard, very small vugs, trace biogenic. silty clay stringers, white N9; soft, low plasticity.
724-758	Limestone: grayish orange 10YR 7/4, calcarenitic, poorly indurated, small vugs, dolomitic, trace moldic, trace silty clay stringers.
758-763	Limestone: very pale orange 10 YR8/2, calcarenitic, moderately friable, vuggy porosity, trace sparite.
763-770	Limestone: yellowish gray 5Y 7/2, micrite, very hard, moldic, dictoconus cookei.
770-780	Limestone: yellowish gray 5Y 7/2, pelmicrite to carbonate mud, firm, low apparent porosity.

DEPTH (ft bls)	DESCRIPTION
780-790	Limestone: grayish orange 10YR 7/4, micrite, calcarenitic, poorly indurated, small vugs, biogenic, trace moldic, clay stringers, moderate porosity.
790-800	Limestone: very pale orange 10YR 8/2, biomicrite to sparite, calcarenitic, moderately friable, moderate porosity.
800-810	Limestone: grayish orange 10YR 7/4, calcarenitic, poorly indurated, low macroporosity (intergranular), interbedded with very fine grained argillaceous limestone and clay stringers, moderate porosity.
810-843	Limestone: very pale orange 10YR 8/2, calcarenitic, moderately indurated, moderate macroporosity (intergranular), slightly moldic.
843-850	Marl (70%): yellowish gray 5Y 8/1 to white N9, moderate cohesion, very low macroporosity. Limestone (30%): very pale orange 10 YR8/2, calcarenitic, moderately indurated, moderate porosity. Trace fossil fragments.
850-860	Limestone (60%) yellowish gray 5Y 8/1, biomicrite, calcarenitic, moderate to well indurated, moderate macroporosity (intragranular), moldic, biogenic. Clay (40%): Yellowish gray 5Y 8/1 to white N9, moderate cohesion, very low macroporosity.
860-870	Marl (70%): yellowish gray 5Y 8/1 to white N9, moderate cohesion, very low macroporosity. Limestone (30%): very pale orange 10 YR8/2, calcarenitic, moderately indurated, calcarenetic. Trace fossil fragments.
870-890	Limestone: very pale orange 10 YR8/2, calcarenitic, moderately indurated, low macroporosity (intergranular), calcarenetic, chalky.
890-910	Limestone: very pale orange 10 YR8/2, calcarenitic, soft, low macroporosity (intergranular), friable, calcarenetic, chalky.
910-920	Limestone: grayish orange 10YR 7/4, calcarenitic, soft, low macroporosity (intergranular), friable, calcarenetic.
920-930	Limestone: pale yellowish brown 10YR 6/2, calcarenitic, moderately hard, low to moderate macroporosity (intergranular and moldic), slightly vuggy, slightly moldic.
930-940	Limestone: pale yellowish brown 10YR 6/2, calcarenitic, moderate to very hard, high macroporosity (moldic) and low to moderate macroporosity (intergranular), fossiliferous. Interbedded with limestone of similar color, soft, friable, calcarenetic.
940-970	Limestone: grayish orange 10YR 7/4, calcarenitic, soft to moderately hard, low macroporosity (intergranular), slightly vuggy, friable, calcarenetic.
970-980	Limestone (90%): pale yellowish brown 10 YR 6/2, dolomitic, hard, low to moderate macroporosity (intergranular to vuggy), slightly vuggy. Clay (10%): dark yellowish brown, moderately cohesive, very low macroporosity, silty.
980-990	Limestone (85%): grayish orange 10YR 7/4, calcarenitic, soft to moderately hard, moderate macroporosity (vuggy to intergranular), vuggy, slightly friable, calcarenetic. Clay (15%): dark yellowish brown, moderately cohesive, very low macroporosity, silty.

DEPTH (ft bls)	DESCRIPTION
990-1,000	Clay (45%): pale yellowish brown 10YR 6/2, moderately cohesive, very low macroporosity, silty. Limestone (35%), grayish orange 10YR 7/4, soft to moderately hard, porosity not evident from sample cuttings, calcarenetic. Shell pieces (20%): layered and cemented shell pieces, moderate macroporosity (intragranular).
1,000-1,010	Limestone: pale yellowish brown 10YR 6/2, biomicrite, moderate to very hard, high macroporosity (moldic) and low to moderate macroporosity (vuggy), fossiliferous.
1,010-1,020	Limestone: pale yellowish brown 10YR 6/2, micrite, moderately hard, moderate macroporosity (vuggy to intergranular), vuggy, slightly dolomitic.
1,020-1,040	Limestone: very pale orange 10YR 8/2 to yellowish gray 5Y 8/1, micrite, soft to moderately hard, low macroporosity, friable.
1,040-1,070	Limestone: grayish orange 10YR 7/4, micrite, soft, low macroporosity, friable.
1,070-1,110	Limestone: very pale orange 10YR 8/2, micrite, soft, low macroporosity, friable, *Lepidocyclina sp.* present.
1,110-1,120	Limestone: grayish orange 10YR 7/4, micrite, soft, porosity indiscernible from sample collected, friable, Abundant *Lepidocyclina sp.* present.
1,120-1,140	Limestone: grayish orange 10YR 7/4, micrite, soft, low macroporosity, friable, *Lepidocyclina sp.* present.
1,140-1,170	Limestone: very pale orange 10YR 8/2, micrite, soft, low macroporosity, friable, *Lepidocyclina sp.* present.
1,170-1,180	Limestone (80%): very pale orange 10YR 8/2, micrite, soft, low macroporosity, friable, *Lepidocyclina sp.* present. Clay (20%): yellowish gray, poor to moderately cohesive, silty.
1,180-1,200	Limestone: very pale orange 10YR 8/2, micrite, soft, low macroporosity, friable, *Lepidocyclina sp.* present.

MWH

LITHOLOGY

IRR- 6C CPS- 4 Monitoring Well

WELL NUMBER	**SZMW-1 (L1037)**
PERMIT NUMBER	**247165-003-UC**
JOB NUMBER	**3220276.703702**
OWNER	**City of Cape Coral**

DEPTH (ft bls)	DESCRIPTION
0-5	Sand: grayish orange 10YR 7/4, medium to fine grained, silica, high porosity, well sorted, sub rounded.
5-17	Limestone: moderate yellowish brown 10YR 5/4, micrite, hard, low vuggy porosity, moderate to well indurated, dolomitic, trace shell fragments.
17-24	Sand: yellowish gray 5Y 8/1, medium to fine grained, silica, moderately high intergranular porosity, moderately well sorted, sub rounded, trace shell fragments, trace silt.
24-38	Shell Bed: medium light grey N6 and very pale orange 10YR 8/2, medium to fine grained silica sand; trace fine grained phosphate.
38-41	Clay: light olive gray 5Y 5/2, soft, low permeability, moderate plasticity, silty, trace shell pieces and fragments, trace fine grained phosphate.
41-55	Clay (50%): light olive gray 5Y 5/2, soft, moderately low plasticity, low permeability, silty. Limestone (50%): yellowish gray 5Y 8/1, micrite, trace shell fragments.
55-80	Clay: light olive gray 5Y 5/2; moderately stiff, moderately high plasticity, low permeability, trace shell fragments.
80-93	Clay: light olive gray 5Y 5/2, moderately soft, high plasticity, very low permeability.
93-100	Clay (60%): light olive gray 5Y 5/2, high plasticity, low permeability, trace coarse grained phosphate. Shell fragments (40%): yellowish gray 5Y 7/2, poor induration, predominantly bivalve fragments.
100-110	Clay (50%): light olive gray 5Y 5/2, high plasticity, low permeability, trace coarse grained phosphate. Shell fragments (50%): yellowish gray 5Y 7/2, poor induration, predominantly bivalve fragments.
110-120	Limestone (70%): yellowish gray 5Y 8/1, biomicrite, friable, trace very fine grained phosphate. Clay (30%): light olive gray 5Y 5/2, very soft, high plasticity, low permeability.
120-140	Limestone: yellowish gray 5Y 8/1, biomicrite, moderately friable, some shell fragments, predominately bivalves, trace very fine grained phosphate.

DEPTH (ft bls)	DESCRIPTION
140-150	Limestone: light olive gray 5Y 6/1, biomicrite, friable, moderate moldic permeability, some shell fragments, predominately bivalves, trace soft marl, trace very fine grained phosphate.
150-160	Limestone: light olive gray 5Y 6/1, biomicrite, friable, poor intergranular permeability, some shell fragments, predominately bivalves, trace very fine grained phosphate.
160-180	Limestone: yellowish gray 5Y 8/1; biomicrite, friable, poor intergranular permeability, some shell fragments, predominately bivalves, trace very fine grained phosphate.
180-210	Limestone: very pale orange 10YR 8/2, biomicrite, friable, moderate moldic and intergranular permeability, some shell fragments, predominately bivalves, trace very fine grained phosphate.
210-220	Clay: light olive gray 5Y 5/2, soft, high plasticity, low permeability, some yellowish gray limestone, trace fine grained phosphate.
220-240	Clay: light olive gray 5Y 5/2, moderately stiff, moderately high plasticity, low permeability, some shell fragments, predominately bivalves, trace very fine grained phosphate.
240-260	Limestone: yellowish gray 5Y 7/2, micrite, moderately indurated, low intergranular permeability, some marl, trace fine to very fine grained phosphate.
260-290	Marl: very light gray N8 to white N9, moderately stiff, moderate plasticity, low permeability, some shell fragments, trace very fine grained phosphate.
290-300	Clay: white N9 to light olive gray 5Y 5/2, very soft, moderate plasticity, very low permeability, trace shell fragments, trace very fine grained phosphate.
300-320	Marl: very light gray N8, moderately stiff to soft, moderate plasticity, low permeability,trace shell fragments, trace very fine grained phosphate.
320-330	Clay: light olive gray 5Y 5/2 to white N9, very soft, moderately high plasticity, very low permeability trace shell fragments, trace very fine grained phosphate.
330-350	Marl: yellowish gray 5Y 7/2 to grayish olive 10Y 4/2, moderately stiff, moderately low plasticity, low permeability, some shell fragments, trace coarse to very fine grained phosphate.
350-360	Marl: pale olive 10Y 6/2, moderately stiff to moderately soft, moderately high plasticity, low permeability, shell fragments, trace coarse grained nodules and very fine grained phosphate.
360-370	Clay: pale olive 10Y 6/2, very soft, moderately high plasticity, very low permeability, trace shell fragments, trace very fine grained phosphate.
370-380	Marl: pale olive 10Y 6/2, moderately stiff to moderately soft, moderately high plasticity, low permeability, trace shell fragments, trace coarse grained nodules and very fine grained phosphate.
380-400	Clay: pale olive 10Y 6/2, very soft, moderately high plasticity, very low permeability, trace shell fragments, trace fine grained phosphate.

DEPTH (ft bls)	DESCRIPTION
400-420	Marl: very light gray N8 to white N9, moderately stiff, moderate plasticity, low permeability, some shell fragments, trace very fine grained phosphate.
420-430	Marl: very light gray N8, moderately soft to very soft, moderate plasticity, low permeability, trace shell fragments, trace dolomite, trace coarse grained nodules and very fine grained phosphate.
430-450	Marl: pale olive 10Y 6/2, moderately soft, moderate plasticity, low permeability, trace shell fragments, trace coarse grained nodules and very fine grained phosphate.
450-460	Limestone (50%): yellowish gray 5Y 8/1, biomicrite, moderately hard, moderate moldic permeability, some gastropods and shell fragments. Clay (50%): very light gray N8, moderately soft, moderately high plasticity, low permeability.
460-470	Limestone: light gray N7 to yellowish gray 5Y 7/2, micrite, moderately hard to friable, moderately indurated, low intergranular permeability, some marl, trace coarse grained phosphate nodules.
470-480	Marl (50%): pale olive 10Y 6/2 to grayish olive 10Y 4/2, moderately stiff, moderately low plasticity, low permeability, medium grained phosphate (>1%). Limestone (50%): light gray N7 to yellowish gray 5Y 8/1, biomicrite, moderately hard, low intergranular permeability, predominately corals and bivalves.
480-500	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard, moderate moldic permeability, some gastropods and shell fragments, some marl.
500-510	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard, moderate moldic permeability, some gastropod, trace marl.
510-530	Limestone: pale olive 10Y 6/2 to yellowish gray 5Y 8/1, micrite, moderately soft, friable, low intergranular permeability, some marl, .
530-550	Limestone: yellowish gray 5Y 8/1 to pale olive 10Y 6/2, micrite, moderately soft, friable, low intergranular permeability, trace marl.
550-570	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard to friable, high moldic permeability, some gastropod, coral, and bivalves fragments, trace drusey sparite.
570-590	Marl: yellowish gray 5Y 7/2, moderately stiff, moderately low plasticity, low permeability, trace limestone, trace dolomite.
590-610	Limestone: light gray N7 to yellowish gray 5Y 7/2, calcarenitic, friable, moderately high vuggy permeability, trace coral and bivalves fragments, trace drusey sparite.
610-630	Limestone: very pale orange 10 YR 8/2, calcarenitic, friable, moderately high vuggy permeability, trace coral and bivalves fragments, trace drusey sparite.
630-650	Limestone: very pale orange 10 YR 8/2, calcarenitic, moderately hard to friable, moderate vuggy permeability.

DEPTH (ft bls)	DESCRIPTION
650-660	Limestone: grayish orange 10 YR 8/2, calcarenitic, moderately soft, friable, moderately low vuggy permeability.
660-680	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard to friable, high moldic permeability, some gastropod, coral, and bivalves fragments, trace drusey sparite.
680-690	Marl: yellowish gray 5Y 7/2, moderately soft, moderately high plasticity, low permeability, trace limestone.
690-700	Limestone: grayish orange 10 YR 8/2, calcarenitic, moderately soft, friable, moderately low vuggy permeability.
700-710	Limestone: very pale orange 10 YR 8/2 to very light gray N8, micrite, moderately hard to friable, high moldic permeability, some gastropod, coral, and bivalves fragments, trace drusey sparite.
710-720	Limestone: grayish orange 10 YR 8/2, calcarenitic, moderately soft, friable, moderately low vuggy permeability.
720-740	Limestone: yellowish gray 5Y 7/2 to light gray N7, calcarenitic, moderately hard, friable, moderately high permeability, trace gastropods and bivalves fragments, trace marl.
740-760	Limestone: light gray N7 to yellowish gray 5Y 7/2, calcarenitic, moderately hard, friable, moderately high permeability, trace gastropods and bivalves fragments.
760-780	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard to friable, high vuggy permeability, some gastropod and bivalves fragments, trace drusey sparite.
780-800	Limestone: grayish orange 10 YR 8/2, micrite, moderately soft, friable, moderately low vuggy permeability, trace calcarenitic.
800-820	Limestone: grayish orange 10 YR 8/2, calcarenitic, moderately soft, friable, moderately low vuggy permeability.
820-830	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard to friable, high vuggy permeability, some gastropod and bivalves fragments, trace drusey sparite.
830-840	Clay: white N9 to light olive gray 5Y 5/2, moderately stiff, moderate plasticity, low permeability, some limestone, trace shell fragments.
840-850	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard to friable, interbedded with clay (50%), white N9, moderately stiff, moderate plasticity, low permeability
850-860	Clay: white N9 to light olive gray 5Y 5/2, moderately stiff, moderate plasticity, low permeability, some limestone, trace shell fragments.
860-870	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, moderately hard to friable, high vuggy permeability, some gastropod and bivalves fragments, trace drusey sparite.

MWH

LITHOLOGY

IRR-6C ASR-4 SYSTEM – CPS

WELL NUMBER	**SZMW-2 (L1038)**
PERMIT NUMBER	**247165-003-UC**
JOB NUMBER	**3220276.703702**
OWNER	**City of Cape Coral**

DEPTH (ft bls)	DESCRIPTION
0-10	Shell Bed, medium light grey N6 to White N9; unconsolidated; angular; moderately well sorted; predominantly bivalves; trace coral, and gastropods.
10-20	Shell Bed, medium light grey N6 to White N9; unconsolidated; angular; moderately well sorted; predominantly bivalves; fine to very fine grained sand; trace silt.
20-40	Clay, dark greenish gray 5GY 4/1; moderately soft, moderately high plasticity; low permeability; trace limestone and shell fragments.
40-70	Clay, grayish olive 10Y 4/2; moderately stiff, moderate plasticity; low permeability; silty; trace shell fragments; trace fine grained phosphate.
70-95	Clay, dark greenish gray 5GY 4/1; moderately soft to soft, moderate plasticity; low permeability; trace limestone and shell fragments.
95-100	Shell Bed, grayish olive 10 Y 4/2 to yellowish gray 5Y 7/2; unconsolidated; angular; poorly sorted; predominantly bivalves; trace coarse grained phosphate.
100-120	Clay, grayish olive 10Y 4/2; moderately soft, moderate plasticity; low permeability; shell fragments, predominately bivalves; trace coarse grained phosphate.
120-150	Limestone, light olive gray 5Y 6/1 to yellowish gray 5Y 8/1; biomicrite; friable; moderate vuggy permeability; trace coarse grained to very fine grained phosphate.
150-190	Limestone, yellowish gray 5Y 8/1 to medium light gray N6; biomicrite; friable; moderately low intergranular permeability; marly; trace very fine grained phosphate.
190-210	Limestone, light olive gray 5Y 6/1 to yellowish gray 5Y 8/1; micrite; moderately hard to friable; moderate vuggy permeability; marly; trace very fine grained phosphate; trace shell fragments, predominately bivalves.
210-220	Limestone (70%), light olive gray 5Y 6/1 to yellowish gray 5Y 7/2; biomicrite; friable; moderately low moldic permeability; trace very fine grained phosphate. Clay (30%), light olive gray 5Y 5/2; moderately soft, moderately low plasticity; low permeability; trace very fine to coarse grained phosphate.
220-230	Clay (70%), grayish olive 10Y 4/2; soft, high plasticity; low permeability; trace very fine to medium grained phosphate.

DEPTH (ft bls)	DESCRIPTION
230-240	Limestone (30%), yellowish gray 5Y 7/2; micrite; moderately hard; low vuggy permeability; trace very fine grained phosphate.
240-250	Marl, yellowish gray 5Y 7/2, grayish olive 10Y 4/2, white N9; very soft; moderately low plasticity; low permeability; mottled appearance; fine grained phosphate (19%).
250-260	Clay (70%), grayish olive 10Y 4/2; soft, high plasticity; low permeability; trace very fine to medium grained phosphate. Limestone (30%), yellowish gray 5Y 7/2; micrite; moderately hard; low vuggy permeability; trace very fine grained phosphate.
260-270	Marl, yellowish gray 5Y 7/2 to white N9; moderately stiff; moderately high plasticity; low permeability; mottled appearance; trace fine grained phosphate.
270-300	Marl, yellowish gray 5Y 7/2 to white N9; very soft; moderately low plasticity; low permeability; mottled appearance; trace fine grained phosphate.
300-330	Marl, light olive gray 5Y 5/2 to yellowish gray 5Y 7/2; stiff to moderately stiff; moderately high plasticity; low permeability; mottled appearance; trace fine grained phosphate.
330-350	Marl, grayish olive 10Y 4/2 to light olive gray 5Y 5/2; stiff; moderately high plasticity; low permeability; mottled appearance; trace fine to medium grained phosphate.
350-370	Marl, light olive gray 5Y 5/2 to grayish olive 10Y 4/2; moderately stiff; moderately high plasticity; mottled appearance; low permeability; trace fine grained phosphate.
370-400	Marl, yellowish gray 5Y 7/2 to white N9; soft to moderately soft; moderate plasticity; low permeability; mottled appearance; trace fine to medium grained phosphate.
400-410	Marl, light olive gray 5Y 5/2 to grayish olive 10Y 4/2; soft to moderately soft; moderately high plasticity; mottled appearance; low permeability; trace fine grained phosphate.
410-420	Marl, yellowish gray 5Y 7/2 to white N9; moderately soft; moderate plasticity; low permeability; mottled appearance; trace fine to medium grained phosphate.
420-430	Marl, light olive gray 5Y 5/2 to grayish olive 10Y 4/2; moderately soft; moderately high plasticity; mottled appearance; low permeability; trace fine grained phosphate.
430-440	Marl, light olive gray 5Y 5/2 to white N9; moderately stiff; moderate plasticity; low permeability; mottled appearance; trace fine to medium grained phosphate.
440-460	Marl, light olive gray 5Y 5/2; stiff to moderately stiff; moderately low plasticity; low permeability; trace fine to medium grained phosphate.
460-485	Limestone, yellowish gray 5Y 8/1; biomicrite; moderately hard to friable; high moldic porosity; fossiliferous, primarily bivalves, gastropods and corals; very fine grained phosphate; marl (25%).
485-513	Marl (60%), white N9; soft to moderately soft carbonate mud; moderately high plasticity; low permeability. Limestone (40%), yellowish gray 5Y 8/1; biomicrite; moderately hard to friable; high moldic porosity; fossiliferous; very fine grained phosphate.

DEPTH (ft bls)	DESCRIPTION
513-530	Limestone, yellowish gray 5Y 8/1; biomicrite; moderately hard; high moldic porosity; fossiliferous, bivalves, gastropods and corals; very fine grained phosphate; trace marl.
530-540	Limestone: yellowish gray 5Y 8/1; micrite; moderately hard; moderate vuggy porosity; trace of marl.
540-550	Limestone: very light gray N8; biomicrite; hard; moderate vuggy and moldic porosity; 3-5% very fine phosphate.
550-560	Limestone: very light gray N8; biomicrite; moderately friable; high intergranular and moldic porosity; fossiliferous; 3-5% very fine phosphate.
560-570	Sand: very light gray N8 to light gray N7; very fine; carbonate; 10-15% very fine phosphate.
570-590	Limestone: yellowish gray 5Y 8/1 to very light gray N8; biomicrite; very friable; high intergranular porosity; 2-3% very fine phosphate.
590-600	Limestone: yellowish gray 5Y 8/1; biomicrite; very friable; high intergranular porosity; 2-3% very fine phosphate.
600-620	Clay: very light gray N8; moderately soft; plastic; trace of limestone; trace of phosphate.
620-630	Limestone: very pale orange 10 YR 8/2; micrite; very friable; high intergranular porosity; calcarenitic; trace of clay.
630-670	Limestone: very pale orange 10 YR 8/2; micrite; very friable; high intergranular porosity; poorly indurated; calcarenitic.
670-680	Clay: very light gray N8; moderately stiff; low plasticity; trace of limestone; trace of fine grained phosphate.
680-710	Limestone: yellowish gray 5Y 8/1 to very pale orange 10 YR 8/2; biomicrite; friable; high intergranular porosity; poor induration; calcarenitic.
710-740	Limestone: very pale orange 10 YR 8/2; biomicrite; very friable; high intergranular porosity; poorly indurated; calcarenitic.
740-750	Marl (70%), yellowish gray 5Y 7/2; moderately stiff; moderately low plasticity; low permeability; Limestone (30%), very pale orange 10 YR 8/2 biomicrite; very friable; moderate intergranular porosity; poorly indurated; calcarenitic texture.
750-800	Limestone: very pale orange 10 YR 8/2; biomicrite; very friable; high intergranular porosity; poorly indurated; calcarenitic; trace of marl.
800-850	Limestone: very pale orange 10 YR 8/2; biomicrite; very friable; high intergranular porosity; poorly indurated; calcarenitic.
850-870	Limestone: very pale orange 10 YR 8/2 to yellowish gray 5Y 8/1; biomicrite; very friable; high intergranular porosity; poorly indurated; calcarenitic; trace of marl.
870-880	Limestone: yellowish gray 5Y 8/1; micrite; friable; moderate moldic porosity; poorly indurated; calcarenitic to pelitic; trace coarse grained phosphate; trace silty clay.

DEPTH (ft bls)	DESCRIPTION
880-900	Limestone: very pale orange 10 YR 8/2; micrite; very friable; moderately low vuggy and intergranular porosity; poorly indurated; calcarenitic to oolitic; trace of marl.

MWH

LITHOLOGY

IRR- 6C CPS ASR- 4 Production Well

WELL NUMBER	SMW-1 (L1039)
PERMIT NUMBER	247165-003-UC
JOB NUMBER	3220276.703702
OWNER	City of Cape Coral

DEPTH (ft bls)	DESCRIPTION
0-5	Sand: grayish orange 10YR 7/4, medium to fine grained, silica, high porosity, well sorted, sub rounded.
5-15	Limestone: moderate yellowish brown 10YR 5/4, micrite, hard, low vuggy porosity, moderate to well indurated, dolomitic, trace shell fragments.
15-25	Sand: yellowish gray 5Y 8/1, medium to fine grained, silica, moderately high intergranular porosity, moderately well sorted, sub rounded, trace shell fragments, trace silt.
25-40	Shell Bed: medium light grey N6 and very pale orange 10YR 8/2, medium to fine grained silica sand; trace fine grained phosphate.
40-50	Clay: light olive gray 5Y 5/2, soft, low permeability, moderate plasticity, silty, trace shell pieces and fragments, trace fine grained phosphate.
50-70	Clay: light olive gray 5Y 5/2; high plasticity, low permeability, silty, fine grained phosphate (5%).
70-83	Clay: light olive gray 5Y 5/2, high plasticity, low permeability, fine grained phosphate (<5%).
83-101	Shell fragments: light olive gray 5Y 5/2, poor induration, predominantly bivalve fragments, fine grained sand (25%), moderate plasticity clay (15%).
101-108	Shell fragments: light olive gray 5Y 5/2, poor induration, predominantly bivalve fragments, moderate plasticity clay (35%).
108-130	Clay (40%): light olive gray 5Y 5/2, high plasticity, low permeability, trace fine grained phosphate. Limestone (40%): yellowish gray 5Y 8/1, poor to moderately indurated, biomicrite, trace very fine grained phosphate.
130-140	Shell fragments (50%): very pale orange 10YR 8/2, predominately bivalves. Limestone (40%), yellowish gray 5Y 8/1, poor to moderately indurated, biomicrite, trace very fine grained phosphate.
140-150	Limestone (50%): light olive gray 5Y 6/1, biomicrite, friable, moderate moldic permeability, trace soft marl, trace very fine grained phosphate. Shell fragments (25%): very pale orange 10YR 8/2 to very light gray N8, predominately bivalves.

DEPTH (ft bls)	DESCRIPTION
150-160	Limestone (50%): light olive gray 5Y 6/1, biomicrite, friable, poor intergranular permeability, trace very fine grained phosphate. Shell fragments (35%): very pale orange 10YR 8/2 to very light gray N8, predominately bivalves.
160-180	Limestone (50%): yellowish gray 5Y 8/1; biomicrite, friable, poor intergranular permeability, trace very fine grained phosphate. Shell fragments (35%): very light gray N8, predominately bivalves.
180-210	Limestone (60%): very pale orange 10YR 8/2, biomicrite, friable, moderate moldic and intergranular permeability, trace very fine grained phosphate, trace drusey sparite. Shell fragments (35%): very light gray N8, gastropods and bivalves.
210-222	Clay (75%): light olive gray 5Y 5/2, high plasticity, low permeability, trace fine grained phosphate. Limestone (25%): yellowish gray 5Y 8/1, poor to moderately indurated, biomicrite, trace fine to very fine grained phosphate.
222-240	Clay (75%): light olive gray 5Y 5/2, high plasticity, low permeability, trace fine grained phosphate. Limestone (25%): yellowish gray 5Y 8/1, poor to moderately indurated, biomicrite, trace fine to very fine grained phosphate.
240-260	Limestone: yellowish gray 5Y 7/2, micrite, moderately indurated, low intergranular permeability, marl (20%), trace fine to very fine grained phosphate.
260-290	Marl: very light gray N8 to white N9, moderately stiff, moderate plasticity, low permeability, shell fragments (15%), very fine grained phosphate (5%).
290-300	Clay: light olive gray 5Y 5/2, very soft, moderate plasticity, very low permeability, shell fragments (10%), very fine grained phosphate (10%).
300-320	Marl: very light gray N8, moderately stiff, moderate plasticity, low permeability, shell fragments (10%), very fine grained phosphate (8%).
320-330	Clay: light olive gray 5Y 5/2, very soft, moderate plasticity, very low permeability, shell fragments (10%), very fine grained phosphate (10%).
330-350	Marl: grayish olive 10Y 4/2 to yellowish gray 5Y 7/2, moderately stiff, moderately low plasticity, low permeability, shell fragments (15%),coarse to very fine grained phosphate (15%).
350-360	Marl: pale olive 10Y 6/2, moderately stiff to moderately soft, moderately high plasticity, low permeability, shell fragments (10%), coarse grained nodules and very fine grained phosphate (8%).
360-370	Clay: pale olive 10Y 6/2, very soft, moderately high plasticity, very low permeability, shell fragments (5%), fine to very fine grained phosphate (5%).
370-380	Marl: pale olive 10Y 6/2, moderately stiff to moderately soft, moderately high plasticity, low permeability, shell fragments (10%), coarse grained nodules and very fine grained phosphate (8%).

DEPTH (ft bls)	DESCRIPTION
380-400	Clay: pale olive 10Y 6/2, very soft, moderately high plasticity, very low permeability, shell fragments (5%), fine to very fine grained phosphate (5%).
400-415	Marl: very light gray N8 to white N9, moderately stiff, moderate plasticity, low permeability, shell fragments (15%), very fine grained phosphate (5%).
415-430	Marl (75%): light olive gray 5Y 5/2, moderately stiff, high plasticity, low permeability, trace phosphate nodules. Limestone (25%): yellowish gray 5Y 8/1, biomicrite, moderately hard, low intergranular permeability, predominately gastropods.
430-450	Limestone: light gray N7 to yellowish gray 5Y 7/2, micrite, hard, moderately indurated, low intergranular permeability, marl (10%), trace medium to very fine grained phosphate.
450-460	Marl (50%): pale olive 10Y 6/2 to grayish olive 10Y 4/2, moderately stiff, moderately low plasticity, low permeability, medium grained phosphate (>1%). Limestone (50%): light gray N7 to yellowish gray 5Y 8/1, biomicrite, moderately hard, low intergranular permeability, predominately corals and bivalves.
460-480	Limestone: light gray N7 to yellowish gray 5Y 7/2, micrite, moderately hard to friable, moderately indurated, low intergranular permeability, marl (10%).
480-490	Limestone: light gray N7 to yellowish gray 5Y 7/2, biomicrite, hard, moderate moldic permeability, marl (8%), trace very fine grained phosphate.
490-500	Limestone: yellowish gray 5Y 7/2, micrite, hard, moderately indurated, high moldic permeability, gastropod and bivalve fragments (15%), very fine grained phosphate (1%).
500-510	Limestone: very light gray N8 to yellowish gray 5Y 7/2, micrite, moderately hard, moderately high moldic permeability, gastropod and bivalve fragments (15%), very fine grained phosphate (4%).
510-520	Limestone: very light gray N8 to yellowish gray 5Y 7/2, micrite, hard, moderately indurated, high moldic permeability, gastropod and bivalve fragments (15%), thin clay laminations (4%), very fine grained phosphate (5%).
520-530	Limestone: light gray N7 to yellowish gray 5Y 7/2; micrite, very hard, moderately high vuggy permeability, dolomitie and sparry calcite, trace very fine grained phosphate.
530-560	Limestone: very light gray N8 to yellowish gray 5Y 7/2, micrite, hard, moderately indurated, high moldic permeability, gastropod and bivalve fragments (15%), very fine grained phosphate (5%).
560-570	Limestone: yellowish gray 5 Y 8/1, micrite to calcarenite, moderately hard to friable, moderately low moldic permeability, poor induration, trace gastropod and bivalve fragments trace marl.
570-580	Limestone: pale yellowish brown 10 YR 6/2 to olive gray 5Y 4/1, micrite, moderately friable, low vuggy permeability, moderate intergranular porosity, dolomitic, trace drusey sparite, trace shell fragments.

DEPTH (ft bls)	DESCRIPTION
580-590	Limestone: yellowish gray 5 Y 8/1, micrite to calcarenite, moderately hard to friable, moderately low moldic permeability, poor induration, marl (10%).
590-600	Limestone: yellowish gray 5 Y 8/1, micrite, hard to very hard, high vuggy and moldic permeability, gastropod and bivalve fragments (5%).