Engineering Report on the Construction and Testing of Potable Water Aquifer Storage Recovery at the Winkler Avenue Pumping Station

Prepared for

The City of Fort Myers, Florida

March 2000

Prepared by

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SECTION 1

Introduction

Background

The City of Fort Myers (City) is experiencing a period of population growth along with an increased demand for additional water resources. The City has identified the need for increased water storage in order to help meet dry season and maximum day potable water needs. Aquifer storage recovery (ASR) is a cost-effective alternative for providing additional water during periods of high demands for potable water storage. ASR can provide significant potable water storage which will satisfy short and long term needs by augmenting the current water supply system on an as-needed basis.

CH2M HILL completed a feasibility study of the option to construct ASR facilities at the City's Winkler Avenue pumping station. Based on an evaluation of aquifer characteristics, competing groundwater use, native groundwater quality, and existing site facilities, CH2M HILL recommended that the City begin construction of an ASR test well. A location map showing the Winkler Avenue pumping station is presented in Figure 1-1. The Winkler Avenue pumping station is located in the western portion of Fort Myers, approximately 4000 feet east of the Caloosahatchee River.

A grant provided by alternative water supply funding program of the South Florida Water Management District (SFWMD) and administered by the Lee County Regional Water Supply Authority (LCRWSA) helped fund the construction of potable water ASR facilities at the Winkler Avenue Site. The long-term vision of these agencies will enable the City of Fort Myers to maximize freshwater availability in the future.

During the construction phase of the ASR program, a storage zone monitoring well (SZMW-1), a Mid-Hawthorn aquifer monitoring well (MHMW-1), two water table monitoring wells (WTMW-1, WTMW-2), and a test ASR well (ASR-1) were constructed at the Winkler Avenue pumping station. This well completion report provides the results of construction and preliminary testing activities to date; specifically, the report addresses well construction, testing documentation, and hydrogeologic interpretation of data. The data has been collected to enable permitting of the ASR well and to propose and obtain Florida Department of Environmental Protection (FDEP) approval to conduct ASR cycle testing.

ASR Overview

Potable water ASR is a method of water resources management in which treated surface water or groundwater is stored in a suitable aquifer and later recovered. Water is stored in the aquifer during periods of surplus water supply and is recovered from the same well when needs dictate. Recovery from the ASR well can occur when there is a shortage in raw water supply, insufficient water distribution or treatment capacity, during the dry season or periods of drought, or other emergency conditions.

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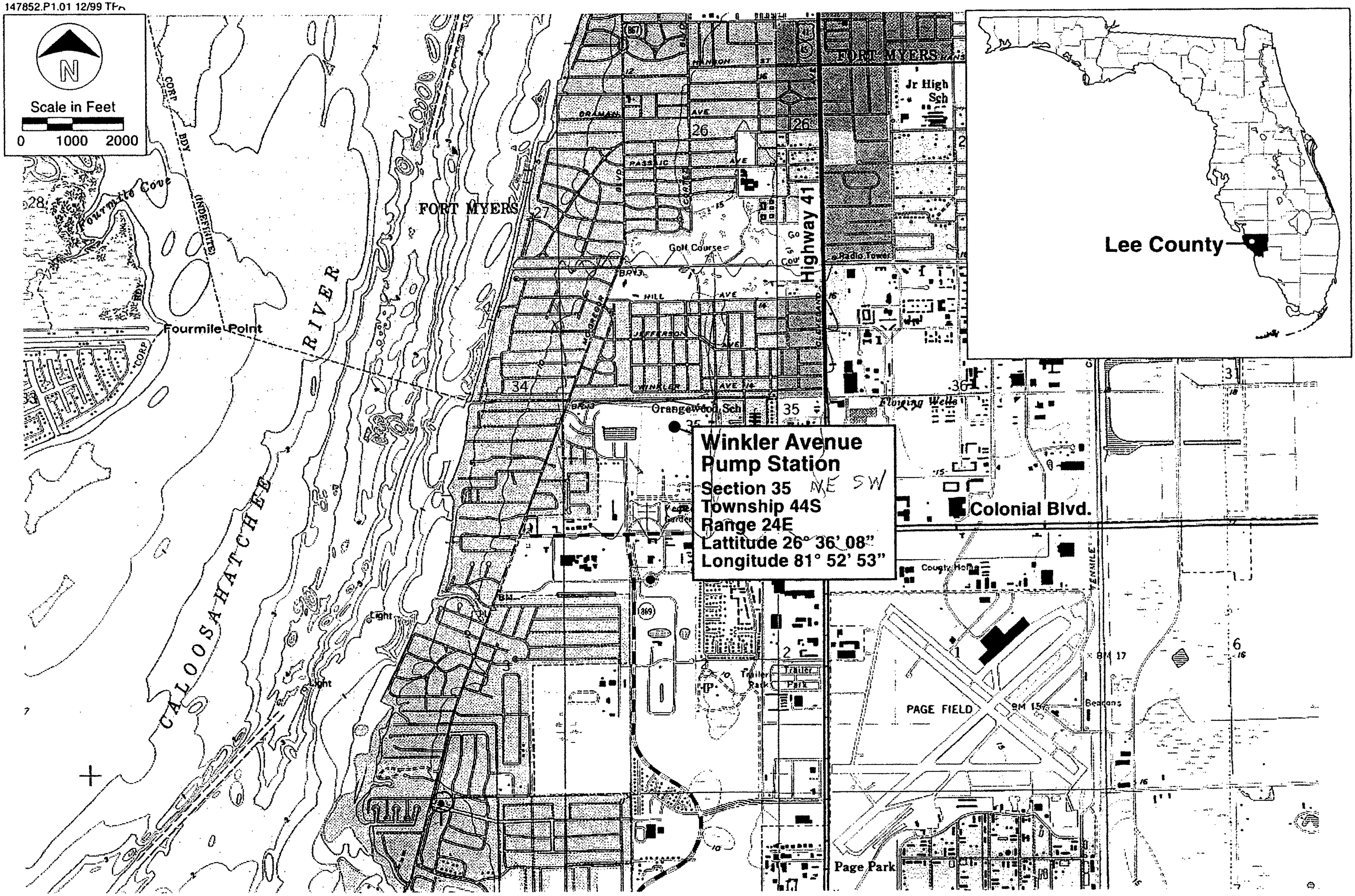

FIGURE 1-1
Project Location Map

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Advantages of ASR over other water storage methods include larger storage capacity, moderate cost, low operation and maintenance (O&M) cost, and minimal land requirements. An ASR system offers the water utility a storage facility where the amount of water that can be stored is only limited by the capacity of the aquifer. The amount of land required to accomplish the storage is much less than conventional storage methods because facilities can usually be located on previously existing/owned land such as parks, treatment plants, or pumping stations. The loss of a certain percentage of stored water which occurs due to evapotranspiration as a result of typical aboveground storage methods (e.g., reservoirs) is eliminated.

A typical ASR program uses a phased project approach. Phase I generally includes a feasibility investigation to evaluate the applicability of ASR to the utility system's specific needs and available resources. Phase I activities also include obtaining the necessary regulatory permits to begin construction of ASR wells and facilities. Phase II consists of site-specific construction and testing to confirm the feasibility of ASR. Phase III involves ASR expansion, if additional capacity is required, to provide the utility with a fully operational ASR system at the required capacity to meet dry season needs.

Phase I – Feasibility Study and Permitting

Feasibility Study

In 1998, CH2M HILL conducted a study on the feasibility of a potable water ASR system at the City's Winkler Avenue pumping station site. This study evaluated numerous site-specific categories including hydrogeology, water quality, surrounding water use, contamination potential, facilities available to provide recharge water and use recovered water, site constraints, environmental issues, and permitting and economic aspects. The Winkler Avenue pumping station was considered to be a strategic and cost effective location for the Phase II activities primarily due to its proximity to recovered water demand, favorable hydrogeology, and existing facilities onsite, including an above ground storage tank, and pumping station. Preliminary hydrogeologic data were collected from the 1998 CH2M HILL reports, *Lee County Utilities Fort Myers Beach WWTP Deep Injection Well Engineering Report* and *Engineering Report on the Construction and Testing of Artesian Test Production Well TP-1, Fort Myers, Florida.* Additional data was collected from the SFWMD Technical Publications 82-1 and 83-8. The results of this study included CH2M HILL's recommendation that the City proceed with construction of an ASR test well.

Permitting

Regulatory approval is required to construct, recharge, and recover water from an ASR well. Because the well is both a Class V injection well and a public supply well, ASR permitting involves close coordination with the FDEP, SFWMD, and other local permitting agencies. Permits obtained during the construction and testing activities are contained in Appendix A.

The FDEP Underground Injection Control (UIC) division regulates all injection activities in the state under Chapter 62-528, Florida Administrative Code (FAC). The FDEP TAC consists of representatives from FDEP Fort Myers, FDEP Tallahassee, SFWMD, USGS, and the U.S. Environmental Protection Agency (USEPA) Region IV (Atlanta). A pre-application meeting was held with the FDEP TAC on July 6, 1998, to obtain regulatory feedback on the testing program. Comments from FDEP were incorporated into a Class V injection well permit application was submitted to FDEP on July 24, 1998. A request for additional information was received from the FDEP TAC on September 2, 1998. The City responded to these comments in a September 18, 1998, letter and incorporated them into the final drilling and testing specifications. FDEP issued a draft permit to construct and test a Class V Group 7 ASR injection well on January 27, 1999. Following a 30-day public notice period, a public meeting was held on March 9, 1999, at the FDEP Fort Myers office to discuss issuance of the proposed permit. No representatives from the public attended. Subsequently, an FDEP Class V Group 7 injection well construction permit (FDEP File No. 143645-001-UC) was issued to the City on March 15, 1999.

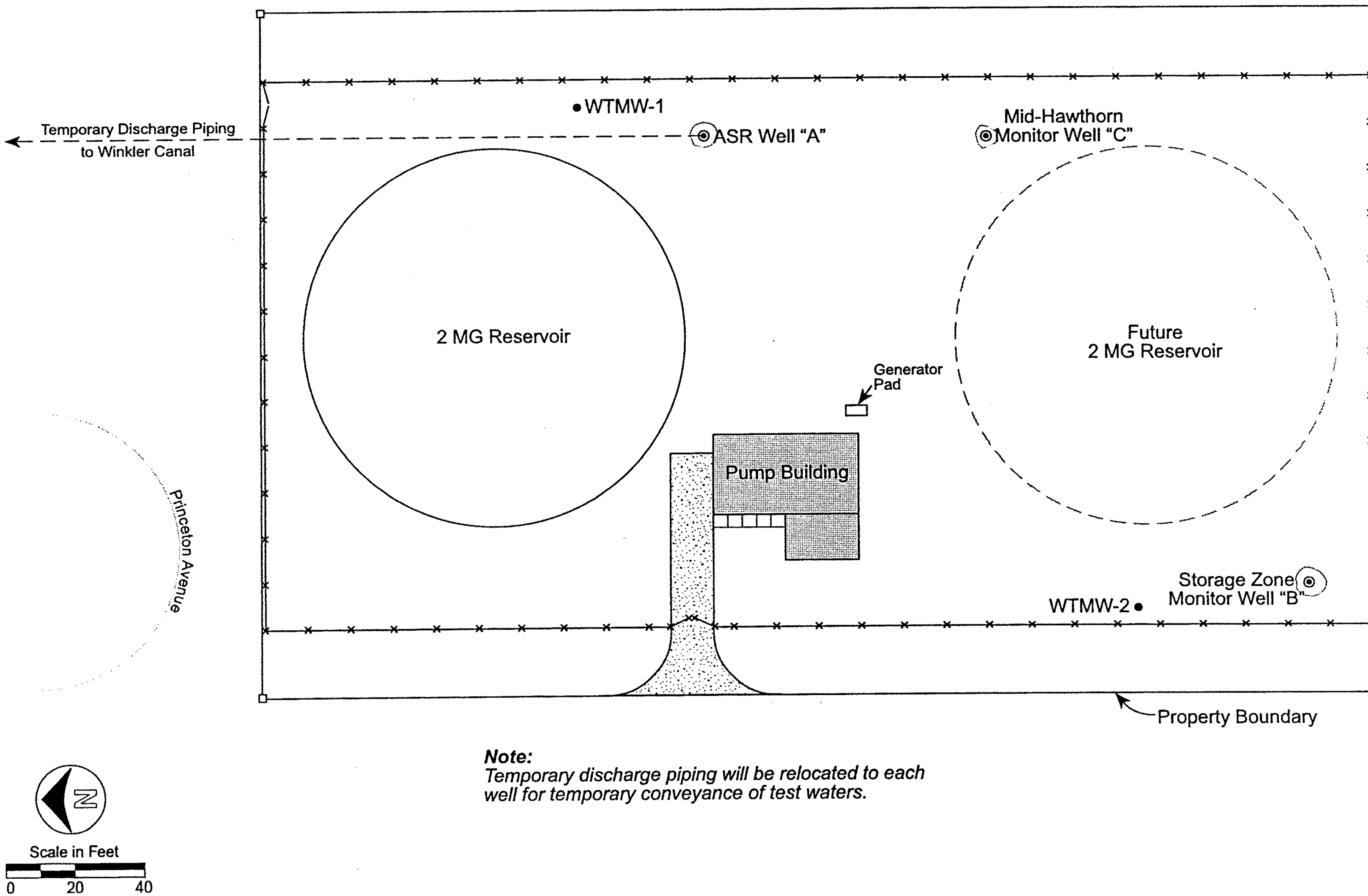
Prior to construction and testing activities, SFWMD well construction permits were obtained for the four planned monitoring wells (SZMW-1, MHMW-1, WTMW-1, WTMW-2) and one ASR well (ASR-1). The permits were obtained by Well Water Systems from SFWMD's Miami Well Construction Permitting Division. In addition, the Lee County Public Health Unit (LCPHU), a Division of the State of Florida Department of Health and Rehabilitative Services (HRS), requires involvement in the ASR permitting process in Lee County. A representative from the LCPHU visited and approved the proposed ASR site. As part of the approval process, additional water quality data must be furnished to the LCPHU prior to placing the public supply well into service following ASR cycle testing activities.

The SFWMD regulates groundwater and surface water withdrawals in the project area. An ASR program is generally considered to be zero consumptive use because water withdrawals are already accounted for at the withdrawal locations. ASR is a method to seasonally balance these withdrawals through storage in the subsurface providing a peaking mechanism for the water supply system. However, a WUP modification must be obtained through SFWMD prior to placing the ASR supply well into operation.

The SFWMD has been kept informed of the progress of the drilling and testing activities. Weekly summary reports have been provided throughout the construction and testing activities. A WUP permit application for the ASR facility has been prepared and was submitted with the City's March 1999 wellfield WUP application.

Following completion of all well construction activities, SFWMD well completion reports must be submitted by the drilling contractor documenting well completion details. These reports were completed on December 22, 1999, by Well Water Systems. Copies of these reports are contained in Appendix A. In addition, a Certification of Class V Well Construction Completion (FDEP Form 62-1.209(2)) and as-built engineering drawings must be submitted to the FDEP to comply with permit provisions. These forms will be completed and furnished to the FDEP upon completion of the surface facilities.

This report is being prepared to satisfy Specific Condition 15 of the FDEP Class V injection well construction permit. Operational testing shall not commence without FDEP written authorization. This report contains all information required under Specific Condition 8 prior to operational testing. With submittal of this report, authorization to proceed with injection and operational (cycle) testing is hereby requested.



Note:
Temporary discharge piping will be relocated to each well for temporary conveyance of test waters.

FIGURE 1-2
Potable Water ASR Site Plan
Winkler Avenue Pump Station

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Phase II - Drilling and Testing

Phase II of the Winkler Avenue ASR project includes both construction and a preliminary testing program. Activities to date include installation and testing of the ASR test well (ASR-1), followed by installation of a storage zone monitoring well (SZMW-1), a Mid-Hawthorn aquifer monitoring well (SMW-1), and two water table monitoring wells (WTMW-1, WTMW-2). Figure 1-2 shows the site plan for Winkler Avenue. Construction of the Winkler Avenue wells began on May 11, 1999 and was substantially completed on September 9, 1999. Final completion of well construction activities occurred on September 30, 1999 and all punch list items were completed on December 22, 1999.

Construction of wellhead facilities, potable and discharge water piping, and flow and pressure measurement devices to provide one fully operational ASR test well is forthcoming. Construction of these surface facilities will be completed in 2000.

Following construction of surface facilities, cycle testing will be conducted to further evaluate the water quality and hydrologic responses to ASR operations at this location. Cycle testing of the ASR system at the Winkler Avenue pumping station will provide the final data necessary to evaluate the ASR system and to provide operating protocol of the system.

The ASR well and monitoring wells were constructed by Well Water Systems, Fort Myers, Florida, between May 11, 1999 and September 30, 1999. CH2M HILL provided resident observation and technical support services during construction and testing of the wells. Geophysical surveys were completed by MV Geophysical Surveys, Inc., Fort Myers, Florida. Water quality samples were obtained and analyzed at the City of Fort Myers Membrane Water Treatment Plant (MWTP). Water samples were tested for primary and secondary drinking water standards by EQL, Port Charlotte, Florida and STL Precision, Miramar, Florida. A summary of construction activities is presented in Appendix B. CH2M HILL and the drilling contractor prepared daily and weekly reports which were submitted to the FDEP Technical Advisory Committee (TAC) on a weekly basis as required by the FDEP Class V injection well construction permit (Appendix C).

Packer tests, a constant-rate pumping test, geophysical logging, and borehole water quality data were used to evaluate potential ASR storage zones at the Winkler Avenue pumping station. During well construction, the optimal ASR storage zone was determined to be a water producing zone in the lower Hawthorn aquifer zone approximately 450 feet to 550 feet below land surface (bls). Adequate hydraulic confinement above and below a targeted storage zone is essential to create the most successful ASR system. The lower Hawthorn aquifer storage zone appears to have suitable upper confinement from the approximately 200 feet thick low hydraulic conductivity sediments of the lower Hawthorn confining zone. Hydrogeologic test results of the limestones and interbedded clay lenses of the underlying Suwannee Limestone provide lower confinement of the storage zone.

SECTION 2

Well Construction

The following section describes the construction, drilling, and testing of the ASR test well (ASR-1), storage zone monitoring well (SZMW-1), mid-Hawthorn monitoring well (MHMW-1), and two water table monitoring wells (WTMW-1 and WTMW-2) at the Winkler Avenue site. Table 2-1 presents generalized well construction details of the wells drilled at the Winkler Avenue pumping station. As-built well construction details of the Winkler Avenue wells are presented in Figure 2-1. The cement data for the deep wells, including cement type and quantity, are presented in Table 2-2. Appendix B presents a summary of well construction and testing activities at the Winkler Avenue pumping station. Daily reports of the well construction and site activity details are presented in Appendix C.

Lithologic samples were obtained from wells ASR-1, SZMW-1, and MHMW-1 every 10 feet from land surface to the total drilled depth of each well. A description of the lithologic samples is presented in Appendix D. Steel casing mill certificates and PVC specification sheets are presented in Appendix E. Geophysical logging activities on wells ASR-1, SZMW-1, and MHMW-1 are described in Section 4 and the logs are presented in Appendix F.

TABLE 2-1
Generalized Well Construction Details
Winkler Avenue ASR System

Well Name and Function	Final Casing Depth (feet bls)	Final Casing Diameter (inches)	Final Casing Material and Wall Thickness (inches)	Open Hole Interval and Depth (feet bls)
ASR-1 Recharge/Storage/Recovery	455	12	PVC (0.740)	Open Hole 455-553
SZMW-1 Storage Zone Monitoring Well	455	6	PVC (0.390)	Open Hole 455-553
MHMW-1 Mid-Hawthorn Aquifer Monitoring Well	150	6	PVC (0.390)	Open Hole 150-200
WTMW-1 ASR-1 Surficial Aquifer Monitoring Well	7.5	6	PVC (0.390)	Screened 7.5-12.5
WTMW-2 SZMW-1 Surficial Aquifer Monitoring Well	6	6	PVC (0.390)	Screened 7.5-12.5

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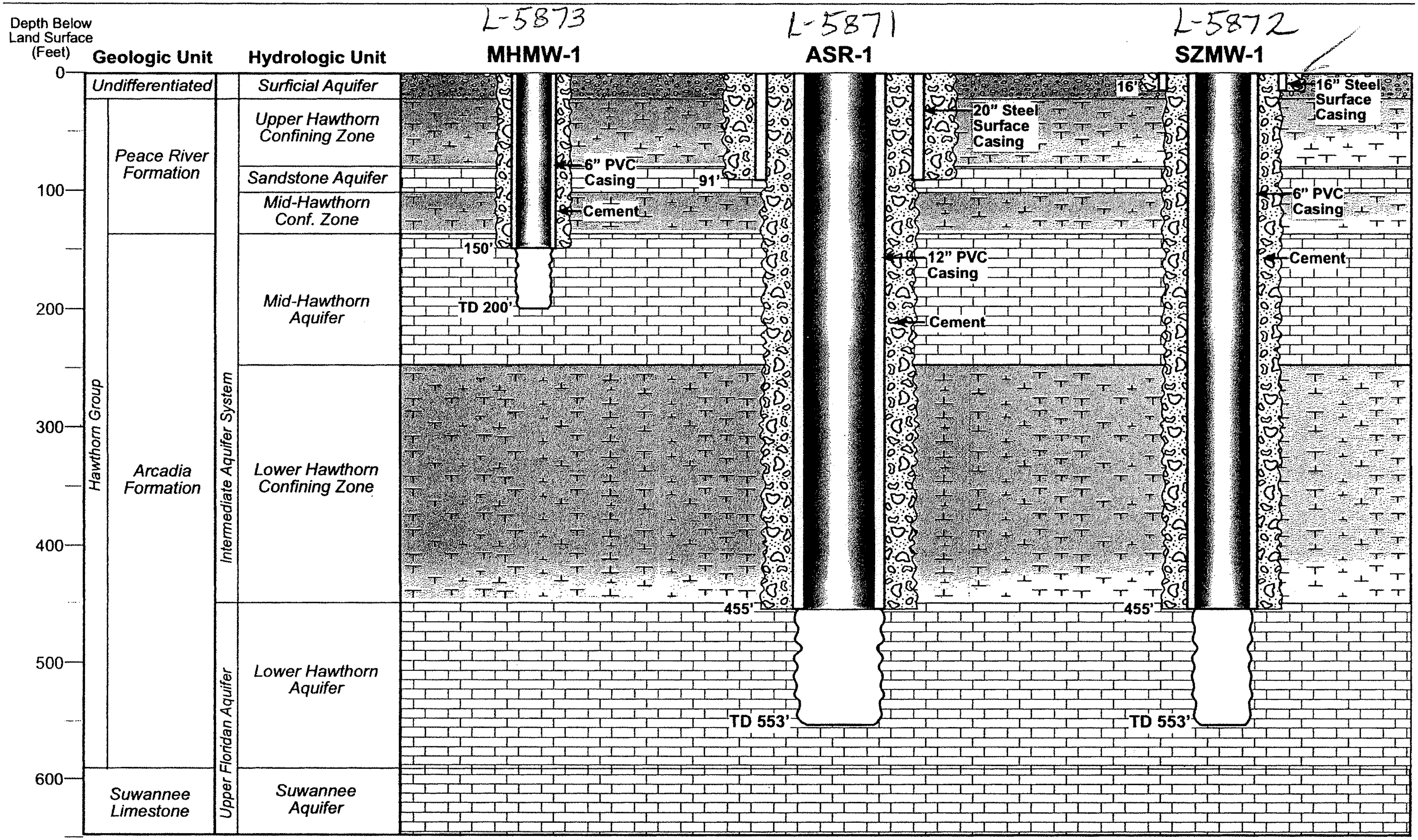

FIGURE 2-1
As-Built Well Construction Details
Winkler Avenue ASR Site
Fort Myers, FL

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TABLE 2-2
Cement Data
Fort Myers Winkler Avenue ASR System

Well Name	Outside Diameter of Casing (inches)	Casing Depth (feet bls)	Borehole Diameter (inch)	Cement ASTM C150 Type II	Quantity (feet^3)
ASR-1	20.00	91	28	Neat	310.5
	12.00	455	19	2% Bentonite cement mix	486.0
				Neat	36.5
Pilot hole backplug from 553 to 647 feet bls			9.625	Neat	70.0
SZMW-1	16.00	16	22	Neat	54.0
	6.56	455	12.25	2% Bentonite cement mix	31.5
				Neat	97.2
MHMW-1	6.56	150	12.25	2% Bentonite cement mix	128.3

ASR Test Well (ASR-1)

The ASR test well (ASR-1) was the first deep well to be drilled as part of the ASR system at the Winkler Avenue pumping station. Extensive data was collected during the drilling and testing of well ASR-1, including lithologic sampling every 10 feet, specific capacity testing, packer testing, a constant rate pumping test, water quality testing, and geophysical logging.

Construction of well ASR-1 began on May 12, 1999 and was substantially completed on June 23, 1999. Standard mud-rotary techniques were used to drill the pilot hole with a 9.625-inch drill bit to a depth of 122 feet bls. The hole was then reamed with a 28-inch bit to a depth of 96 feet bls and 91 feet of steel surface casing was installed. The 9.625-inch pilot hole was continued with mud-rotary techniques to a depth of 555 feet bls. The pilot hole was then reamed with a 19-inch diameter bit to a depth of 457 feet bls, followed by installation of 455 feet of 12-inch *Certa-Lok* PVC casing. Drilling of the 9.625-inch pilot hole continued under reverse-air conditions from 455 feet to a depth of 647 feet bls. The hole was then geophysically logged to identify the optimum production zones and storage zones for this well. Two primary flow zones were identified at 472 feet and 540 feet bls. The well was subsequently backplugged with neat cement to 553 feet bls, leaving an open hole interval from 455 feet to 553 feet bls.

A detailed discussion of the results of the specific capacity, packer, and constant rate pumping tests is presented in Section 4. The well was developed using reverse-air with the open-ended drill rod set at 540 feet bls, targeting the lower flow zone, for approximately one hour. Measurements of the sand concentration in the discharged water indicated that no sand was being produced at any time during well development. The well was also developed targeting the upper flow zone at 472 feet bls. The open-ended drill rod was set at 470 feet bls and development lasted for approximately 3 hours. No sand was measured in the discharged water.

Storage Zone Monitoring Well (SZMW-1)

Well SZMW-1 was constructed to monitor the effects of water injection and withdrawl in the lower Hawthorn aquifer storage zone and to serve as an observation well during pumping tests conducted on well ASR-1. Results from the aquifer performance tests are described in detail in Section 4.

Construction began on well SZMW-1 on July 23, 1999 and was substantially complete on August 5, 1999. The initial 22-inch pilot hole was drilled with the mud-rotary method to a depth of 18 feet bls followed by the installation of sixteen feet of 16-inch steel surface casing. Drilling continued using the mud-rotary technique with a 12.25-inch bit to a depth of 458 feet bls, followed by the installation of 455 feet of 6-inch *Certa-Lok* PVC casing. The open hole interval of well SZMW-1 was then drilled under reverse-air condition from 455 feet to 553 feet bls. The well was developed on August 4, 1999 using reverse-air.

Geophysical logging of well SZMW-1 was conducted at various stages of construction of the well. A detailed discussion and results of the logging are presented in Section 4. Water quality data from the storage zone are discussed Section 5.

Mid-Hawthorn Monitoring Well (MHMW-1)

The purpose of well MHMW-1 is to monitor water level fluctuations and water quality changes in the mid-Hawthorn aquifer due to the injection of potable water into the storage zone. Construction began on well MHMW-1 on July 28, 1999 and was substantially completed on July 30, 1999. A 12.25-inch pilot hole was drilled to 153 feet bls using the mud-rotary method. A single 6-inch *Certa-Lok* PVC casing string was installed to a depth of 150 feet bls. Drilling continued with a 5.5-inch bit to a depth of 160 feet bls using the mud-rotary method. After 160 feet bls, drilling was conducted using reverse-air to a total depth of 200 feet bls. The well was developed by over-pumping on August 5, 1999. Well construction details of well MHMW-1 are shown in Figure 2-1.

Geophysical logging and water quality data collected from well MHMW-1 are discussed in detail in Sections 4 and 5, respectively. There were no pumping tests conducted on well MHMW-1, however, the well was used as an observation well for the constant rate pumping test on well ASR-1, which is discussed in detail in Section 4.

Water Table Monitoring Wells (WTMW-1, WTMW-2)

Wells WTMW-2 and WTMW-2 were constructed on May 11, 1999. Well WTMW-1 is located approximately 40 feet north of Well ASR-1 and was drilled to a depth of 12.5 feet below land surface (bls). The well is completed with a screened interval from 7.5 feet bls to 12.5 feet bls.

WTMW-2 was constructed approximately 40 feet north of well SZMW-1 and was drilled to a depth of 11 feet bls with a screened interval from 6 feet to 11 feet bls. The purpose of these wells is to monitor any changes in the surficial aquifer water quality resulting from construction related spills during drilling activities at the site. These wells were sampled prior to construction activities in order to establish background water quality conditions. The wells were also sampled periodically during construction activities and will be sampled during long term ASR recovery periods to monitor water level data and potential changes in water quality. There were no observed changes in water quality in these wells during construction activities. Water quality data and results are presented in Section 5.

SECTION 3

Geology and Hydrogeology

This section briefly describes the regional geology and hydrogeology of the Fort Myers area and includes details on formations encountered at the Winkler Avenue pumping station site. Figure 3-1 presents a stratigraphic and hydrostratigraphic column of the Winkler Avenue site. The hydrostratigraphic nomenclature utilized in Figure 3-1 and discussed below is based on SFWMD Technical Publications 82-1 and 83-8.

The aquifers in Lee County are primarily comprised of carbonates and Miocene siliciclastics. The aquifer systems in Lee County are contained within sediments ranging in age from late Paleocene (55 million years old) to Holocene (recent) and include the Floridan aquifer system, the Intermediate aquifer system, and the surficial aquifer system. In general, groundwater is found only in limited quantities within the surficial aquifer and the very upper portions of the Intermediate aquifer.

Lithostratigraphic Descriptions

Sediments encountered during the construction of well ASR-1 ranged in age from Oligocene to Holocene. A brief of the Holocene to Oligocene age sediments and their relationship to the hydrostratigraphy of the site follows. Lithologic samples were collected at 10-foot intervals during installation of wells ASR-1, SZMW-1, and MHMW-1. Samples were described according to rock type and physical properties. Detailed lithologic logs of the wells are presented in Appendix D.

Undifferentiated Holocene and Pleistocene Series

Quartz sand, shell beds, clay, and limestone of varying thickness make up the undifferentiated Holocene and Pleistocene sediments in Lee County. The undifferentiated Pleistocene and Holocene age deposits at the site are present from land surface to approximately 22 feet bls and consist of unconsolidated shells and shell fragments. These sediments comprise the water table portion of the surficial aquifer at the site.

Pliocene Series

Tamiami Formation. The Tamiami Formation underlies most of Lee County. It varies in thickness from less than 10 feet to more than 100 feet thick, thickening to the south. Where present, the base of the Tamiami Formation forms the base of the surficial aquifer in Lee County. The Tamiami Formation was not encountered at the Winkler Avenue pumping station.

Miocene Series

Hawthorn Group. In Lee County the Hawthorn Group is divided into two members. The upper member is the Peace River Formation, which is made up primarily of olive gray and phosphatic clay with interbedded sandy limestone at the site. The lower member is a predominantly carbonate formation consisting of limestone and phosphatic limestone with

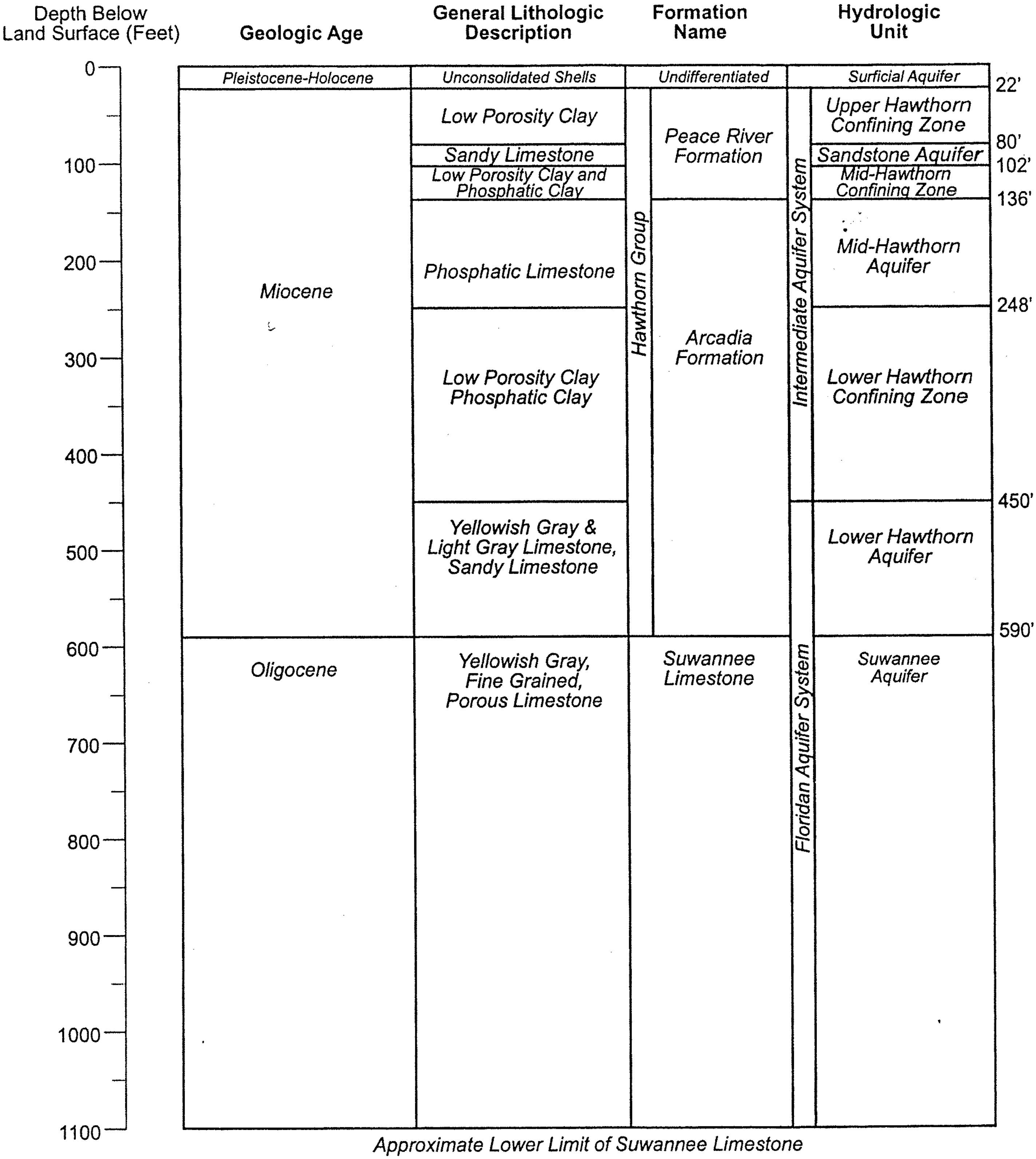

FIGURE 3-1
Stratigraphic and Hydrostratigraphic Column of the Winkler Ave. ASR Site

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interbedded phosphatic clay. The lower member of the Hawthorn Group is the Arcadia Formation. Aquifers within the Hawthorn Group are collectively referred to as the Intermediate aquifer system.

The top of the Peace River Formation was encountered at a depth of approximately 22 feet bls and is approximately 114 feet thick at the site. The top of the Peace River Formation is a low permeability unit that acts as a confining interval (upper Hawthorn Confining Zone) separating the surficial aquifer from the Sandstone aquifer. The Sandstone aquifer consists of moderately porous sandy limestone and is found between 80 feet bls and approximately 102 feet bls at the site. The mid-Hawthorn Confining Zone is present below the Sandstone aquifer over the interval from approximately 102 feet bls to 136 feet bls and consists of low permeability olive gray clay with a trace of phosphate.

The lower lithologic unit of the Hawthorn Group, the Arcadia Formation, was encountered at a depth of 136 feet bls and consists primarily of interbedded phosphatic limestone, clay and fine-grained limestone at the site. The Arcadia Formation is 454 feet thick at the site and is characterized by a moderate to high gamma ray signature (30 to 300 API units). The mid-Hawthorn aquifer is present at the site from 136 to 248 feet bls and consists primarily of limestone with interbedded clay. The lower Hawthorn Confining Zone separates the mid-Hawthorn aquifer from the lower Hawthorn aquifer and is present from 248 to 450 feet bls. The lower Hawthorn Confining Zone is made up primarily of clay and phosphatic clay with occasional interbedded micrite limestone lenses. The lower Hawthorn producing zone is present from 450 to 590 feet bls and consists of yellowish gray and light gray limestone and sandy limestone. The lower Hawthorn producing zone is underlain by the Floridan aquifer system.

Oligocene Series

Suwannee Limestone. The Oligocene Suwannee Limestone was encountered at a depth of approximately 590 feet bls and is characterized by a yellowish gray, fine grained, porous limestone. The Suwannee Limestone is part of the upper Floridan aquifer system, and characteristically exhibits generally high permeability and artesian pressure. It is believed the Suwannee Limestone extends to approximately 1,100 feet bls at the study site.

SECTION 4

Hydrogeologic Testing

Hydrogeologic testing during the construction of well ASR-1 included reverse-air pilot hole water sampling, geophysical logging, air-lift specific capacity testing, packer testing, and constant-rate pump testing. Results of the hydrogeologic testing were used to determine the hydraulic characteristics of the strata intercepted by the borehole, which, in turn, were used to determine the final design of the well.

The two final portions of the testing program were designed to determine the transmissivity (T) of the penetrated aquifer. These parameters are useful in determining the viability of an aquifer storage recovery system at the site and impacts in the surrounding area. Transmissivity is a measure of the capacity of an aquifer to transmit water and is defined as the amount of water that can flow through a vertical section of an aquifer of a certain width extending the full saturated height of the aquifer under a certain hydraulic gradient. Transmissivity is expressed in gallons per day per foot (gpd/ft) in this report.

Geophysical Logging

Geophysical logs were performed in the pilot hole intervals of wells ASR-1, SZMW-1, and MHMW-1 to correlate samples taken during drilling, to identify formation boundaries, to aid in the selection of packer test intervals, and to obtain specific geologic and hydrogeologic data pertaining to the underground formations. These data were then used to assist in the selection of the optimum casing setting depths for the wells and to identify the optimum ASR storage zone. Reamed hole caliper logs were also performed prior to casing installation to confirm the borehole diameter. Tables 4-1, 4-2, and 4-3 provide summaries of geophysical logging conducted on wells ASR-1, SZMW-1, and MHMW-1, respectively. Copies of each of the logs performed on the wells are provided in Appendix F.

ASR-1

The first geophysical log event for this borehole was conducted on the mud-drilled pilot hole to 122 feet bls. This run consisted of natural gamma ray (GR) and caliper logs. Results from these logs were used to evaluate the surficial aquifer and Peace River Formation at the site and to select the optimum setting depth for the shallow (20-inch) casing. A second logging run was completed after the pilot hole was reamed to a diameter of 28 inches and to a depth of 96 feet bls.

The third logging run was conducted after advancing the 9.625-inch diameter pilot hole to 550 feet bls. using reverse-air drilling techniques. This run included GR, long and short normal resistivity (LSN), SP, and caliper logs. The purpose of this logging run was to evaluate the geology and hydrogeology of the upper Suwannee Limestone.

A fourth logging run was completed after the pilot hole reamed to 19 inches and to a depth of 455 feet. This logging run included gamma ray and caliper logs and was run to confirm the characteristics of the reamed hole.

TABLE 4-1
Summary of Well ASR-1 Geophysical Logging Activities
Winkler Avenue Pumping Station

Logging Event	Date (1999)	Well Progress and Casing and Logging Depth	Type of Log Run[1]	Purpose
1	5/12	9.625" Pilot Hole to 121.75 Feet Logged to 120 Feet	C, GR	Evaluate Surficial Aquifer and Peace River Formation; Determine Shallow Casing Setting Depth
2	5/13	28.0" Reamed Hole to 96 Feet Logged to 93 Feet	C, GR	Confirm Reamed Hole Characteristics
3	5/19	9.625" Pilot Hole to 550 Feet 20" Steel Casing to 91 Feet	C, GR, LSN, SP	Evaluate Arcadia Formation; Determine Final Casing Setting Depth
4	5/25	19" Reamed Hole to 455 Feet 20" Steel Casing to 91 Feet	C, GR	Confirm Reamed Hole Characteristics
5	6/09	9.625" Pilot Hole to 647 Feet 12" PVC Casing to 455 Feet	C, GR, SP, LSN, ST, SFR, SFL	Evaluate Hydrogeology of the Arcadia and Suwannee Formations
6	6/10	9.625" Pilot Hole to 647 Feet 12" PVC Casing to 455 Feet	DFL, V	Evaluate Hydrogeology of the Arcadia and Suwannee Formations
7	6/11	9.625" Pilot Hole to 647 Feet 12" PVC Casing to 455 Feet	DFR, DT	Evaluate Hydrogeology of the Arcadia and Suwannee Formations

[1]Legend: Caliper (C), Natural Gamma Ray (GR), Long-Short Normal (LSN), Spontaneous Potential (SP), Temperature (T), Static Fluid Resistivity (SFR), Static Temperature (ST), Dynamic Temperature (DT), Dynamic Fluid Resistivity (DFR), Static Flow (SFL), Dynamic Flow (DFL), Video Log (V).

The pilot hole was logged again after the well was cased to a depth of 455 feet bls with a open hole interval to 647 feet bls. This logging run included a full suite of geophysical logs; gamma ray, caliper, LSN, spontaneous potential, temperature, fluid resistivity, and static flow logs. Results of this run were used to evaluate the geology and hydrogeology of the Arcadia Formation and upper portion of the Suwannee Limestone.

A sixth logging run was also completed on the final cased depth of 455 feet and total depth of 647 feet bls. This logging run consisted of a dynamic flow log and a color video log. A summary of the video log is presented in Appendix K. A seventh, and final, logging run was done with the same hole measurements. Dynamic fluid resistivity and temperature logs were run to further evaluate the hydrogeology of the Arcadia Formation and Suwannee Limestone under pumping conditions.

The geophysical log data indicated that the optimum interval to develop an ASR storage zone would be the producing intervals located between 453 feet and 553 feet bls. The pilot hole was backplugged from 647 feet to 553 feet bls to optimize both water quality and storage zone containment.

SZMW-1

Table 4-2 summarizes the geophysical logging completed on the Storage Zone Monitoring Well (SZMW-1). The first suite of logs conducted on the mud-drilled hole included caliper, natural gamma ray, and LSN and were completed to 458 feet bls. The purpose of this log run was to evaluate the geology of the well and confirm correlation to the previously drilled well ASR-1.

The second geophysical logging run was completed when the pilot hole was terminated at 533 feet bls. The borehole had been drilled from 458 feet to 553 feet bls using reverse-air drilling and therefore was filled with fresh (formation) water. The purpose of these logs was to obtain hydrogeological data of the final hole properties and confirm correlation with the bottom of the hole with ASR-1. The following logs were run under static conditions; GR, LSN, and caliper.

TABLE 4-2
Summary of Well SZMW-1 Geophysical Logging Activities
Winkler Avenue Pumping Station

Logging Event	Date (1999)	Well Progress and Casing and Logging Depth	Type of Log Run[1]	Purpose
1	7/29	12.25" Pilot Hole to 458 feet	C, GR, LSN	Evaluate Storage Zone Properties and Hydrogeology
2	8/05	6" Open Hole to 553 feet 6" Casing to 455 feet	C, GR, LSN	Final Logs, Evaluate Storage Zone Properties and Hydrogeology

[1]Legend:Caliper (C), Natural Gamma Ray (GR), Long-Short Normal (LSN).

MHMW-1

Table 4-3 summarizes the geophysical logging completed on the mid-Hawthorn aquifer Monitoring Well (MHMW-1). Two sets of geophysical logs were run. The first suite of logs were run on the 12.25-inch diameter mudded hole to 150 feet bls to evaluate the proposed casing setting depth. The logs included C, GR and LSN. The next suite of logs was conducted after the installation of the 6-inch diameter casing to 150 feet bls and included C, GR, and DI on the open borehole to 200 feet bls.

TABLE 4-3
Summary of Well MHMW-1 Geophysical Logging Activities
Winkler Avenue Pumping Station

Logging Event	Date (1999)	Well Progress and Casing and Logging Depth	Type of Log Run[1]	Purpose
1	7/29	12.25" Pilot Hole to 150 feet	C,GR,DI	Evaluate Casing Setting Depth
2	8/06	6" Open Hole to 200 feet 6" Casing to 150 feet	C, GR, LSN	Final Logs, Evaluate Storage Zone Properties and Hydrogeology

[1]Legend:Caliper (C), Natural Gamma Ray (GR), Long-Short Normal (LSN).

Air-Lift Specific Capacity Tests

Air-lift specific capacity data were collected during the reverse-air drilling of the pilot hole for well ASR-1 to provide hydraulic data on the well bore, to be used to determine approximate locations of water producing zones, and to estimate quantities of water produced from each zone. Each test was conducted for a duration of approximately 15 minutes, during which time waster level and flow rate measurements were taken to provide data for specific capacity calculations. Table 4-4 provides a summary of the air-lift specific capacity data with respect to depth. Figure 4-1 presents the air-lift specific capacity and normalized air-lift specific capacity data with respect to depth. Normalized specific capacity data were derived by dividing the specific capacity if the given interval by the vertical extent of the test interval. The normalized specific capacity curve presented in Figure 4-1 allows an evaluation of the productivity of the borehole which is unbiased by the amount of open borehole during testing.

Table 4-2 and Figure 4-1 show ASR-1 specific capacity data collected during reverse-air drilling. The specific capacity of the well steadily increased between 460 and 554 feet bls, from 25.0 to 59.7 gpm/ft of drawdown. Specific capacity did not increase between 554 and 585 feet bls indicating that there is little or no additional production occurring in this zone. Specific capacity increased again between 585 and 616 feet bls. Peak specific capacity was observed at 647 feet bls, the final specific capacity measurement. The highest normalized specific capacity measurement of 4.99 gpm/ft/ft of borehole was recorded between 455 and 460 ft bls.

TABLE 4-4
ASR-1 Specific Capacity Data During Reverse Air Drilling
Winkler Avenue Pumping Station

Depth (feet bls)	Flow rate (gpm)	Drawdown (feet)	Specific Capacity (gpm/ft)	Normalized Specific Capacity (gpm/ft/ft of borehole)
455-460	171	6.85	25.0	4.99
455-492	173	5.55	31.1	0.84
455-522	167	3.90	42.8	0.64
455-554	135	2.26	59.7	0.60
455-585	179	3.00	59.5	0.46
455-616	151	2.25	67.3	0.42
455-647	160	1.85	86.3	0.45

Packer Testing

Two packer tests were completed following installation and testing of the pilot hole in well ASR-1. The tests were performed to obtain hydraulic data on the permeability of specific lithologic zones and to obtain interval-specific water quality. Data from both sets were analyzed using the Cooper-Jacob straight line graphical method to determine aquifer transmissivity. Copies of the water level data obtained during the packer tests are provided in Appendix G.

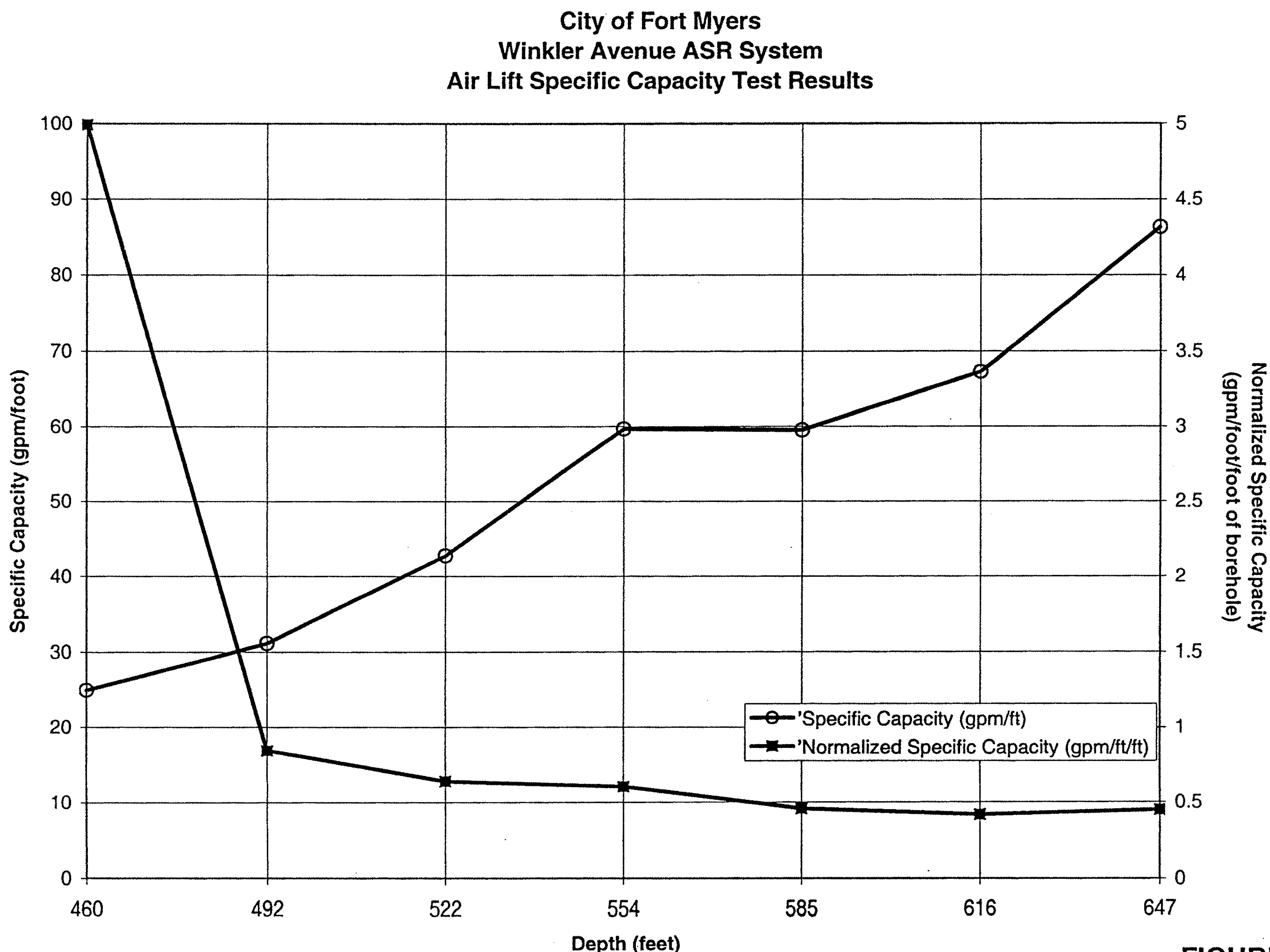

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FIGURE 4-1
Airlift Specific Capacity Test Results

The first packer test was conducted on June 16, 1999. The packer was set 573.67 feet bls and the pumping rate, measured with an orifice, was 479 gpm. Figure 4-2 presents the first packer test recovery data. Aquifer transmissivity was calculated to be approximately 218,000 gpd/foot. The second packer test was conducted on June 17, 1999. The packer was lowered to 574.80 feet bls and the well was pumped at a rate of 483 gpm. Recovery data from the second test are presented in Figure 4-3 and transmissivity was calculated to be approximately 199,000 gpd/foot.

Constant Rate Pumping Test

A constant rate pumping test was conducted on well ASR-1 to evaluate the hydrogeologic characteristics and water quality of the ASR storage zone. Groundwater produced during the pumping test was discharged into the Winkler Avenue drainage canal.

This test included the associated background and water level data recovery data collection. Water levels were measured using a pressure transducer and recorded by an *Insitu* Hermit 3000 data logger. Pumping rates were measured using a digital flow meter and a calibrated 8-inch mechanical flow meter. A copy of the flow meter certificate is provided in Appendix H. Water level data as a function of pumping and recovery time for each portion of the pumping test are provided in Appendix I.

The pump test began on well ASR-1 on October 23, 1999. The test began with approximately 90 hours of background water level data collection. The well was pumped for approximately 27 hours and then allowed to recover for approximately 26 hours. The pump test was planned to be run at a constant rate of 1400 gpm. However, due to an equipment failure, the well was pumped at approximately 1540 gpm during the first several hours of the pump test. After approximately 6.5 hours after pumping began, the disturbance in the signal from the digital transient flowmeter was corrected and the pumping rate was adjusted to 1400 gpm . The pumping rate remained at 1400 gpm throughout the remainder of the pump test. The pumping test water level summary data for wells ASR-1 and SZMW-1 are presented in Figure 4-4 and Figure 4-5, respectively.

Wells SZMW-1 and MHMW-1 were used as observation wells for the pumping test. Well drawdown and recovery data from wells ASR-1 and SZMW-1 were analyzed using the Cooper-Jacob straight line method to calculate aquifer transmissivity. Results from the analysis of the constant rate pumping test are presented in Table 4-5. In well SZMW-1, a maximum drawdown of 6.5 feet was observed during the pumping of ASR-1. The well SZMW-1 recovered to within 0.12 feet of the initial static water level approximately 25 hours after pumping stopped.

No water level changes in well MHMW-1 were observed during the pump testing of well ASR-1.

Figures 4-6 and 4-7 present the data collected from the pumping and recovery periods in well ASR-1, respectively. The transmissivity value for well ASR-1 during pumping was calculated at approximately 105,600 gpd/ft. The maximum observed drawdown level before recovery began was 48.9 feet bls. The water level in well ASR-1 recovered 45 feet within two minutes after recovery was initiated and had recovered to within one percent of

City of Fort Myers
Winkler Avenue ASR System
Packer Test Recovery Data
ASR Well, June 16, 1999

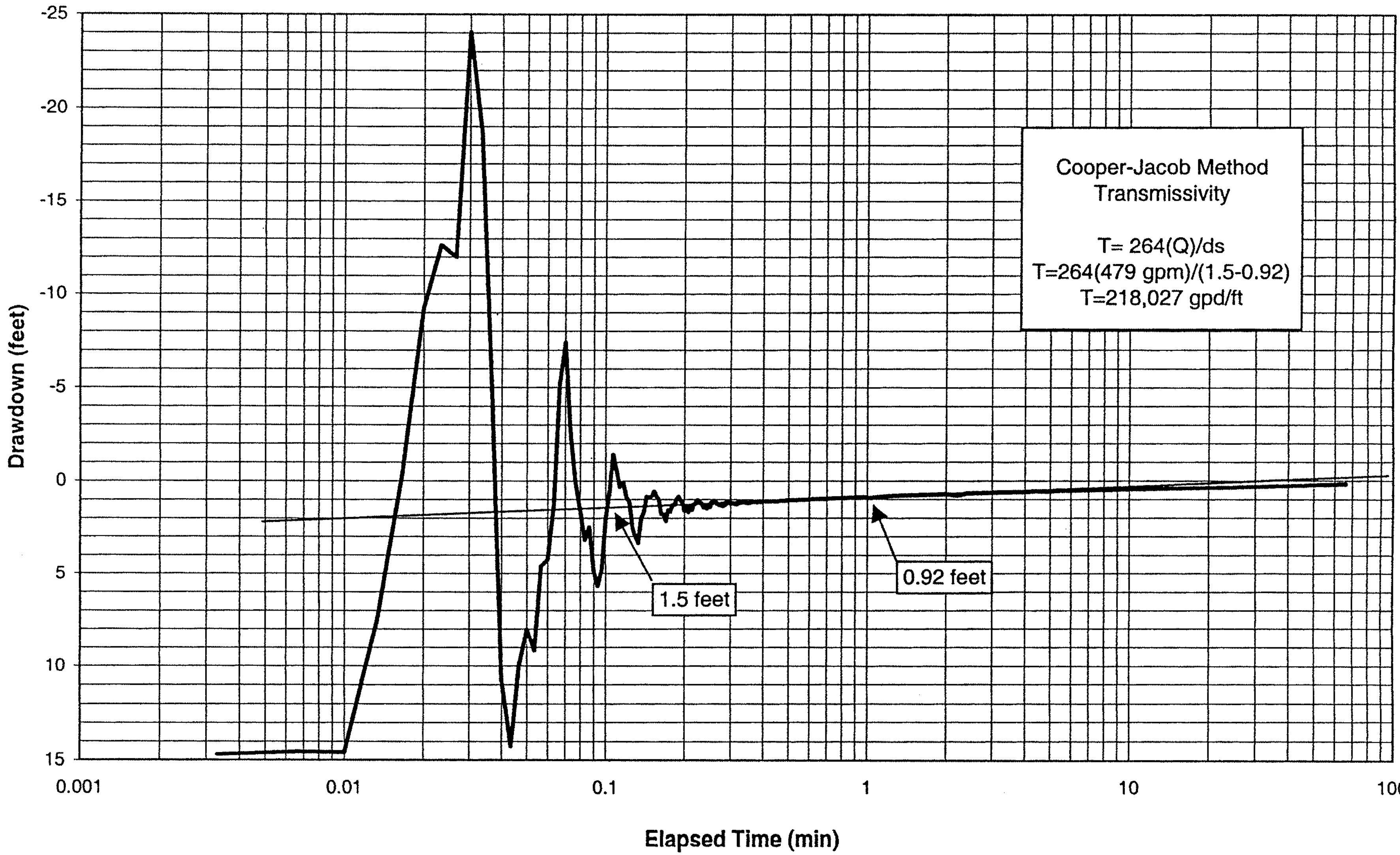

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FIGURE 4-2
ASR Packer Test Analysis 573.67 ft bls

City of Fort Myers
Winkler Avenue ASR System
Packer Test Recovery Data
ASR Well, June 17, 1999

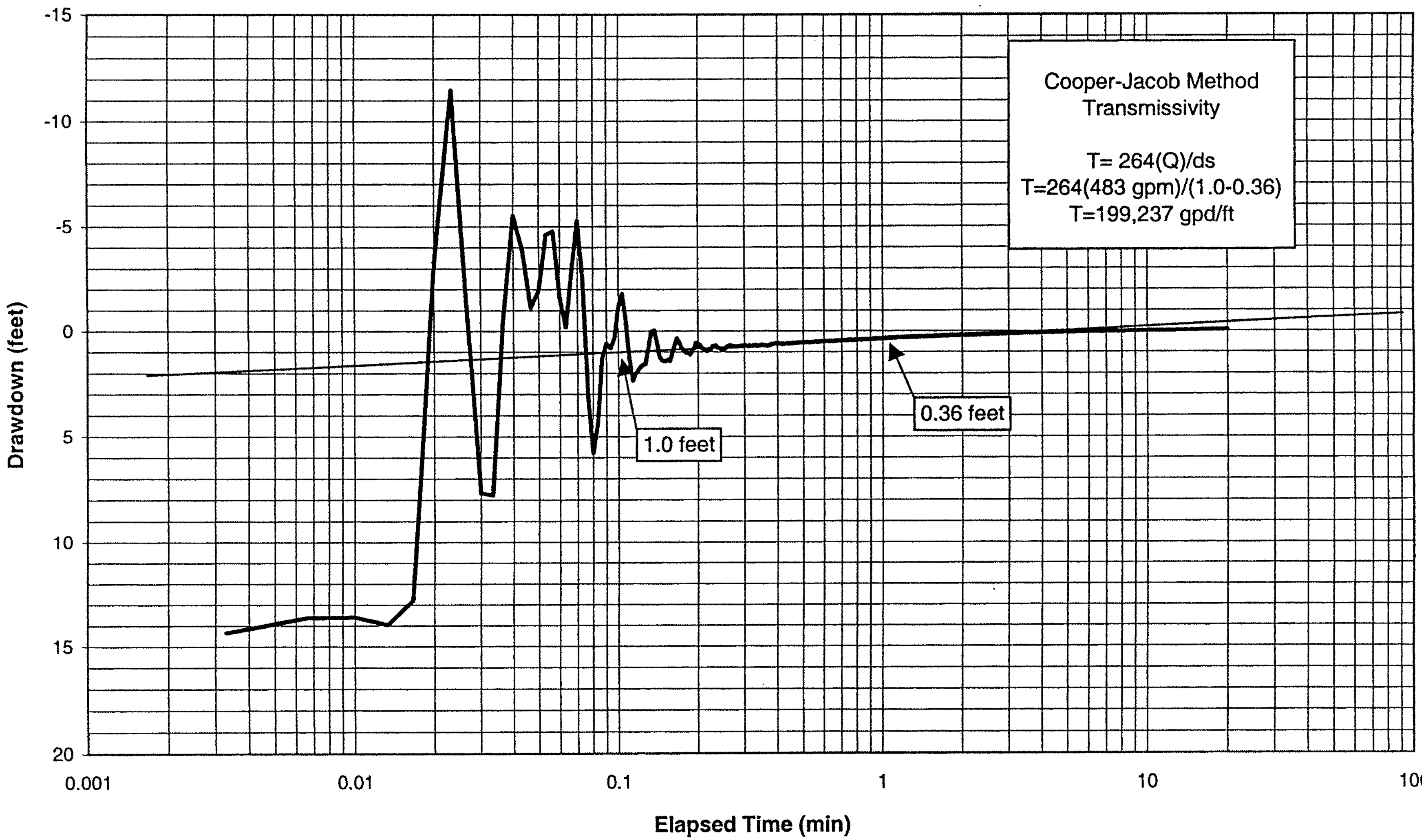

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FIGURE 4-3
ASR Packer Test Analysis 574.80 ft bls

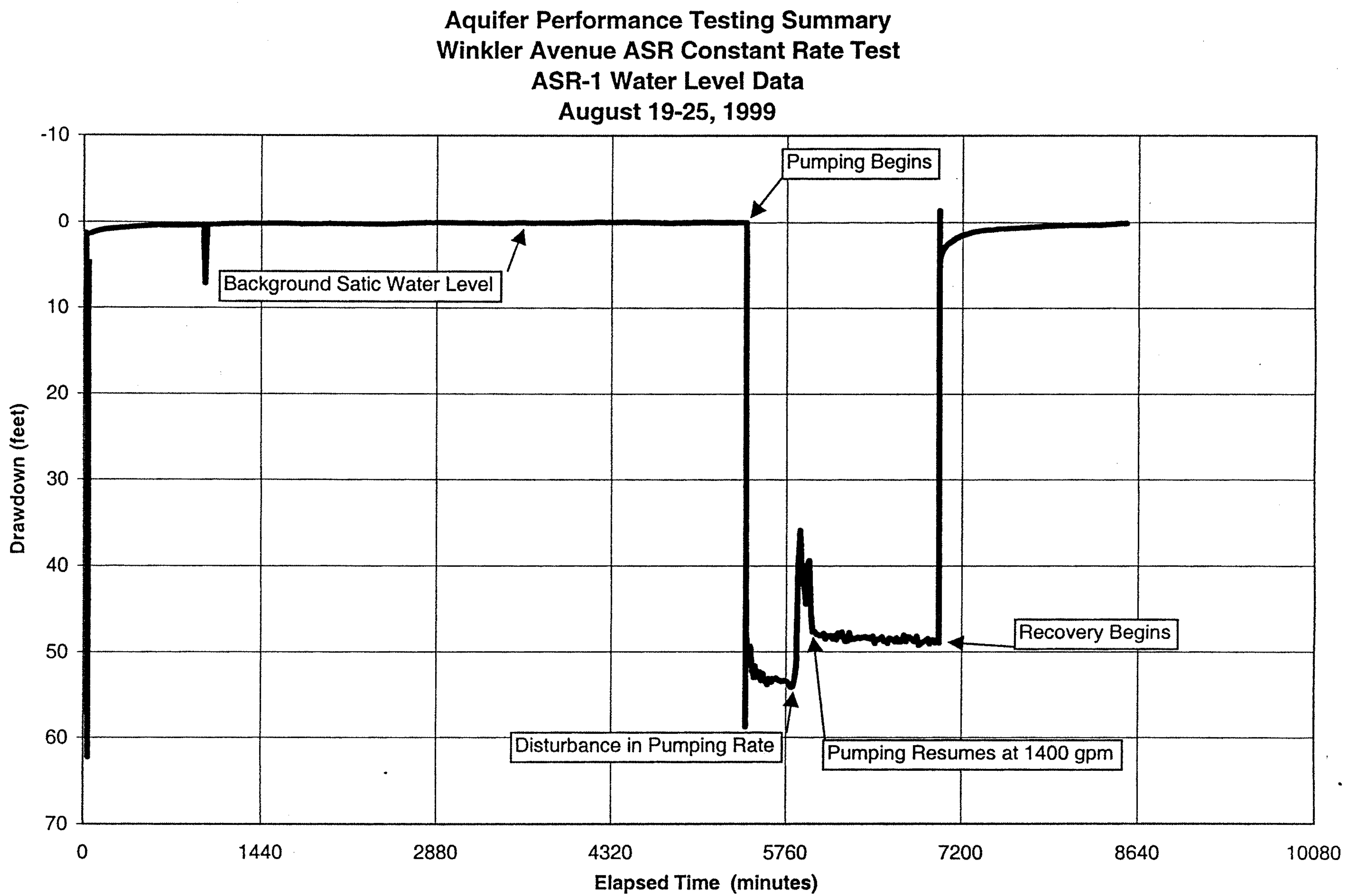

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FIGURE 4-4
ASR-1 Pumping Test Water Level Summary

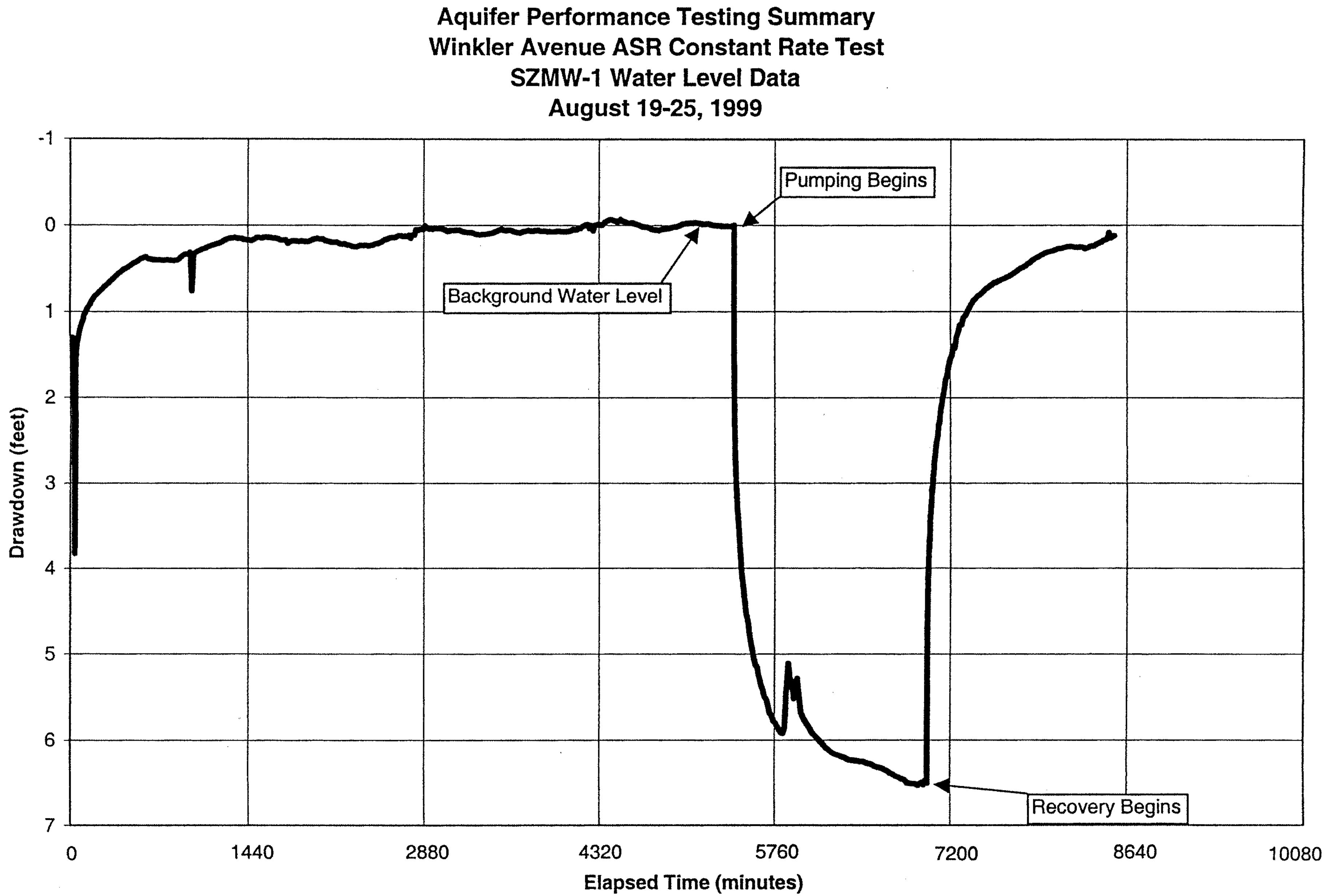

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FIGURE 4-5
SZMW-1 Pumping Test Water Level Summary

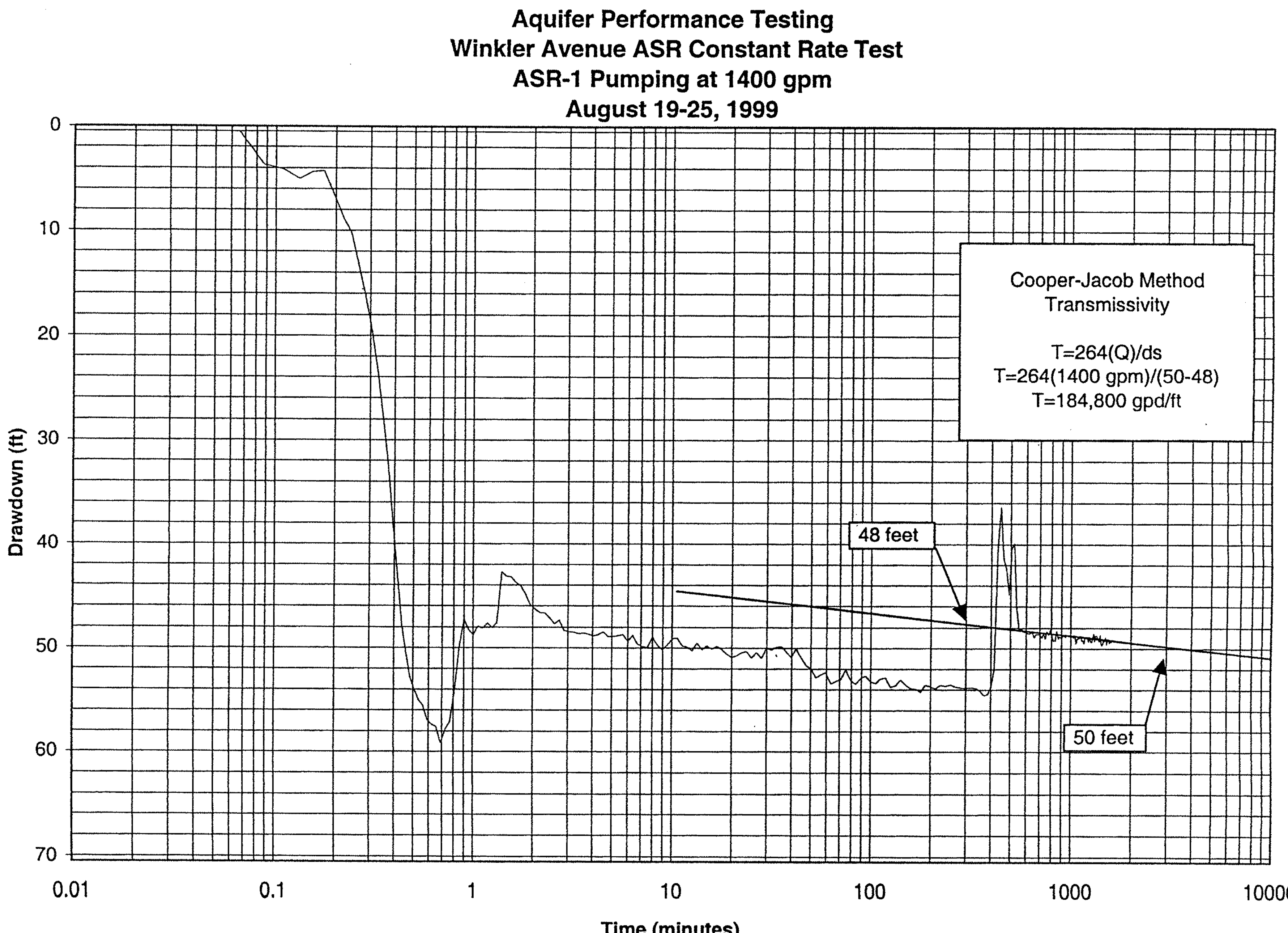

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FIGURE 4-6
ASR-1 Pumping at 1400 gpm

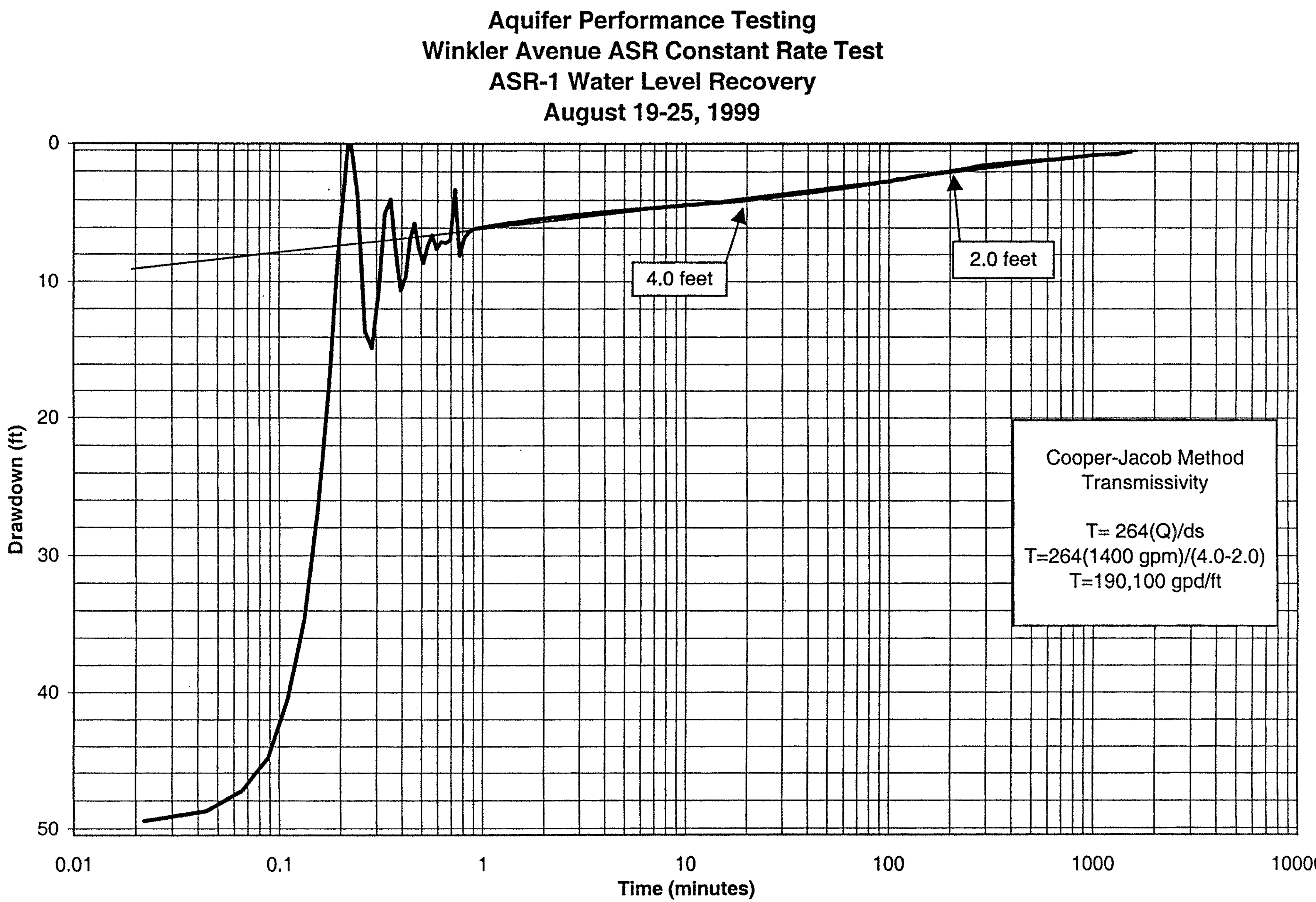

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FIGURE 4-7

Constant Rate Test - ASR-1 Water Level Recovery static conditions after approximately 13.7 hours. Using data collected from the recovery period, well ASR-1 was calculated to have a transmissivity value of approximately 190,100 gpd/ft.

Figure 4-8 presents the drawdown data recorded in well SZMW-1 during the pumping test. A value for aquifer transmissivity of approximately 205,300 gpd/ft was calculated for the pumping portion of the aquifer performance test. Figure 4-9 presents the recovery data for the test and shows that the water level in well SZMW-1 recovered to within 0.12 feet of the initial water level. The calculated aquifer transmissivity from the recovery data is approximately 217,400 gpd/ft.

Based on the analytical and hydraulic limitations of the data, the analyses from the storage zone monitor well (SZMW-1) data are the most accurate for depicting aquifer performance characteristics at the Winkler Avenue pumping station site.

Comparison of Pumping Test Results

The calculated aquifer characteristics summarized in Table 4-5, particularly those listed for the observation well SZMW-1, are consistent with the data available for the lower Hawthorn portion of the Intermediate aquifer system in Lee County. Typical transmissivity values for the lower Hawthorn aquifer in Lee County range from 6,000 gpd/ft to 350,000 gpd/ft (SFWMD 82-1).

Analytical results from the packer and constant rate pumping testing are generally in agreement for the pumping well and storage zone monitoring well. However, specific capacity testing results are lower than may be expected based on the calculated transmissivity values. The apparent dichotomy of these tests suggest that the portion of the aquifer immediately surrounding well ASR-1 has a lower transmissivity than the valves calculated for the extended aquifer potion influenced during the aquifer performance testing.

TABLE 4-5
Summary of Calculated Aquifer Characteristics
Winkler Avenue Pumping Station

	Pumping Test	Well Examined	Pumping Rate (gpm)	Transmissivity (gpd/ft)
Observation Well	Constant Rate	SZMW-1	1400	205,300
	Constant Rate	SZMW-1	Recovery	217,400
Pumped Well	Constant Rate	ASR-1	1400	184,800
	Constant Rate	ASR-1	Recovery	190,100
	Packer Test #1	ASR-1	Recovery	218,000
	Packer Test #2	ASR-1	Recovery	199,000

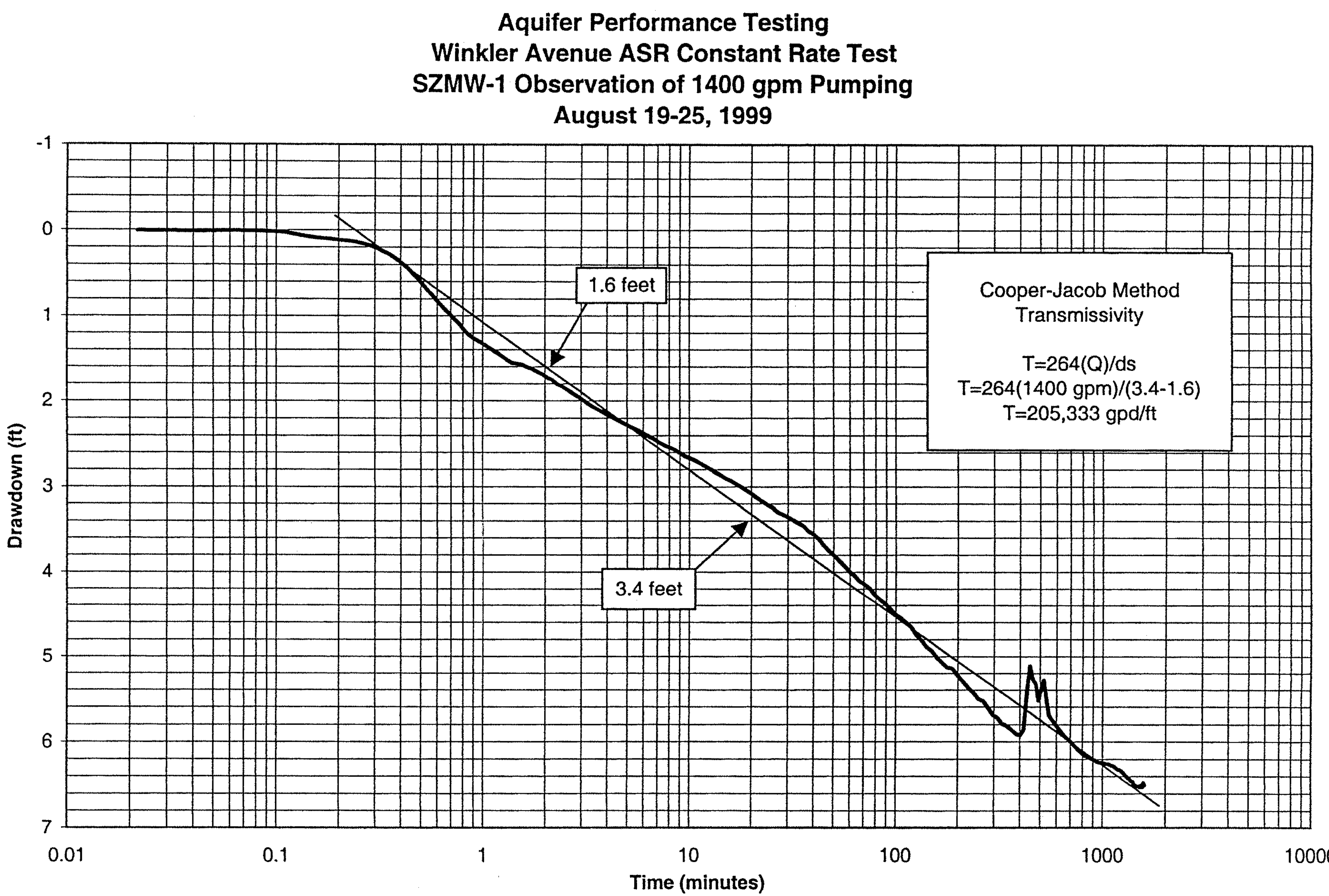

FIGURE 4-8
SZMW-1 Observation of ASR-1
Constant Rate Pumping at 1400 gpm

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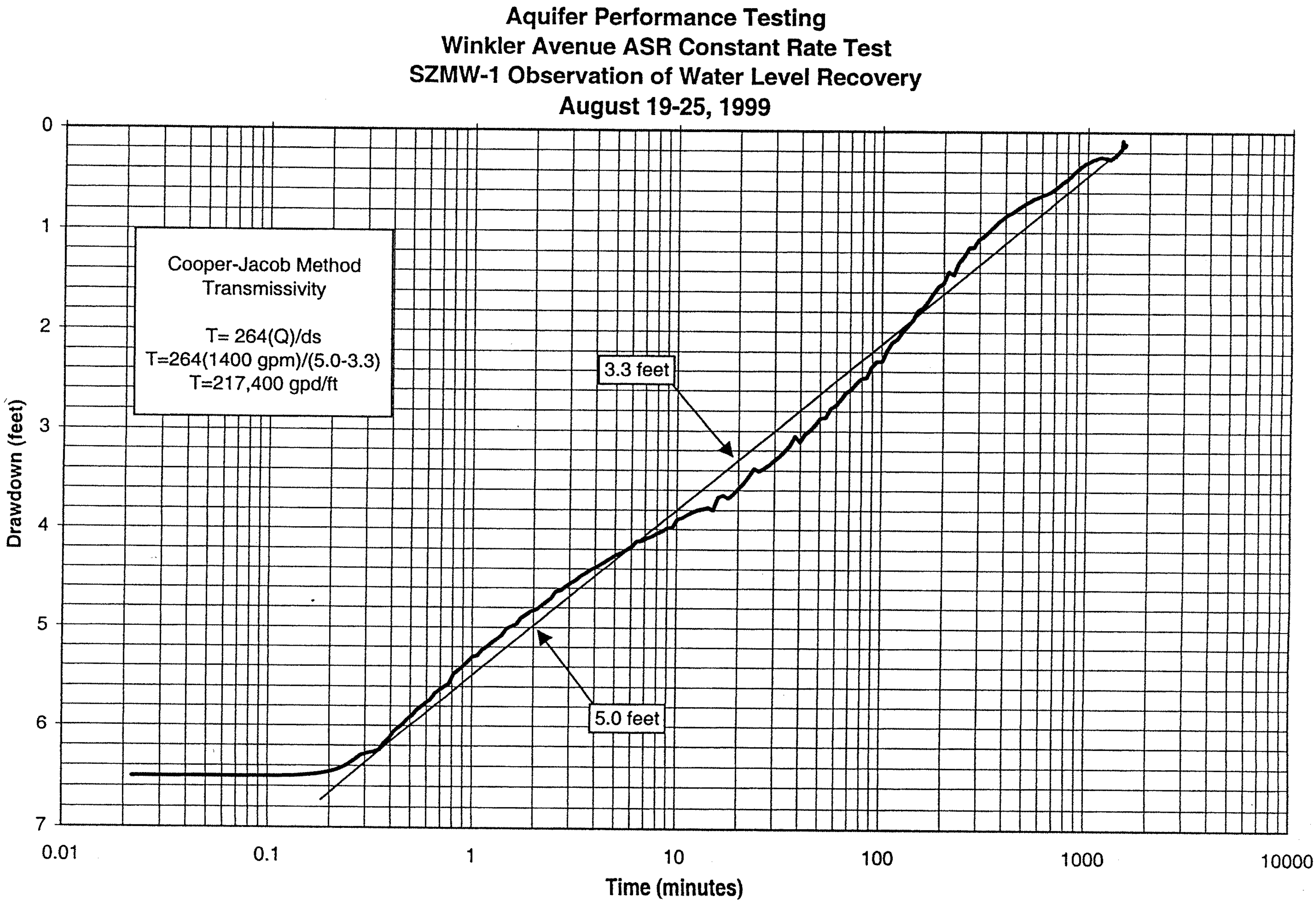

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FIGURE 4-9
SZMW-1 Observation of Water Level Recovery

SECTION 5

Water Quality Testing

Water samples were collected at various stages of construction and testing to provide data pertinent to decisions regarding the final design of the wells and to determine the background water quality of the proposed ASR storage zone. Results of the reverse-air pilot hole, packer test, pumping test, and background water quality sampling are discussed below. Final background water quality results are presented in Appendix J.

In addition to the water samples collected for ASR well design and optimization purposes, weekly water quality samples were collected from two water table monitoring wells located along the site perimeter. The purpose of these monitoring wells was to monitor for construction related impacts to the surficial aquifer. Data from these wells is presented and discussed at the end of this section.

Reverse-Air Pilot Hole Water Quality

Water samples were collected during reverse-air drilling of the pilot holes of wells ASR-1, SZMW-1, and MHMW-1 to provide a profile of water quality changes with respect to depth. Field samples from all three wells were analyzed for chloride and specific conductance while laboratory samples for well ASR-1 were analyzed for specific conductance, chloride, iron, sulfate, sodium, and total dissolved solids (TDS). Samples were collected in approximately 30-foot intervals in each of the wells during reverse air drilling. The pilot hole water quality samples reflect a mixture of formation fluids from the open hole interval from the base of the final casing to the depth that drilling had reached during the time of sample collection.

Table 5-1 and Figure 5-1 provide a summary of pilot hole water sample analytical results.

TABLE 5-1
Field Analysis of Reverse-Air Water Quality Samples from Well ASR-1
Winkler Avenue Pumping Station

Depth (feet bls)	Date	Time	Conductivity (μmhos/cm)	Temperature (°F)	Chloride (mg/l)
457	6/1/99	15:30	2550	29	600
492	6/3/99	8:00	2800	27	680
522	6/3/99	12:05	2860	28	625
554	6/3/99	15:05	3060	27.5	683
585	6/4/99	12:20	3000	28.5	678
616	6/4/99	15:15	3410	28.7	833
647	6/7/99	10:30	4080	28.6	1022

ASR-1 Pilot Hole Water Quality
Fort Myers Winkler Avenue ASR System
June 1999

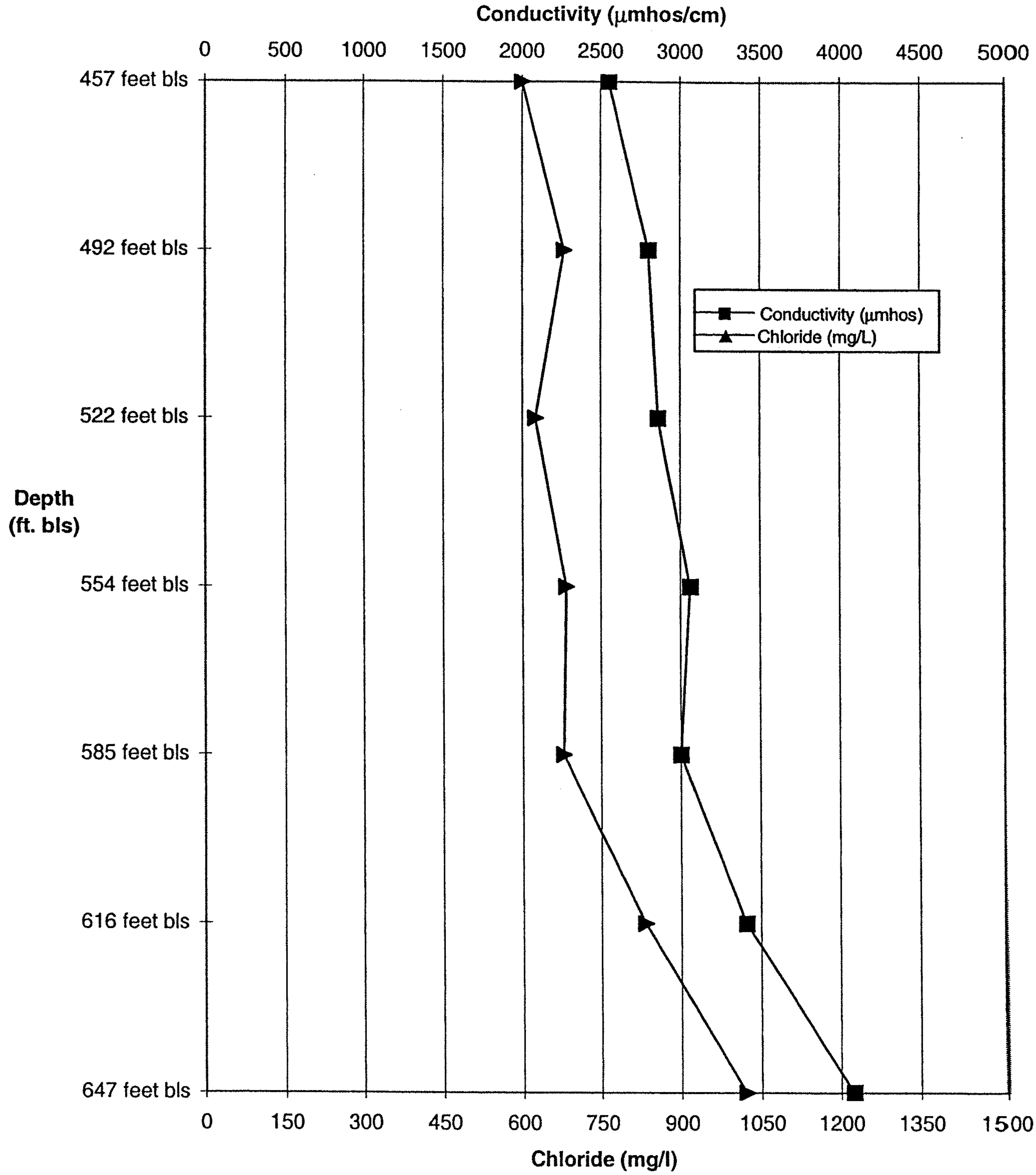

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FIGURE 5-1
ASR-1 Pilot Hole Water Quality

Figure 5-1 shows that pilot hole chloride concentration measurements in well ASR-1, ranging from 600 mg/l to 1022 mg/l, show a gradual increase with respect to depth, with no drastic deviations from expected water quality noted. The conductivity measurements, ranging from 2550 μmhos/cm to 4080 μmhos/cm, also show consistent results from 457 feet bls to 647 bls.

Table 5-2 presents the laboratory analysis of the reverse air water qaulity samples obtained from well ASR-1. These data are similar to those obtained in the field.

TABLE 5-2
Laboratory Analysis of Reverse-Air Water Quality Samples from Well ASR-1
Winkler Avenue Pumping Station

Depth (feet bls)	Specific Conductance (μmhos/cm)	Chloride (mg/l)	Iron (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	Total Dissolved Solids (mg/l)
457	2000	615	4.51	337	270	1740
492	2630	635	0.51	328	265	1640
522	3170	675	0.71	341	285	1680
554	2690	670	0.99	385	295	1800
585	3150	725	0.71	390	305	1650
616	2970	860	0.77	454	310	2050
647	4090	1022	0.82	540	300	2360

Table 5-3 presents the field analysis water quality data for the pilot hole of well SZMW-1. These results were collected in the same zone as the samples from well ASR-1 and reflect similar results. Although the values differ slightly, they are within the expected range for the ASR storage zone.

TABLE 5-3
Field Analysis of Reverse-Air Water Quality from Well SZMW-1
Winkler Avenue Pumping Station

Depth (feet bls)	Date	Time	Conductivity (μmhos/cm)	Chloride (mg/l)
480	8/3/99	16:30	2960	716
500	8/4/99	8:55	3350	860
520	8/4/99	9:40	3730	660
540	8/4/99	10:20	4660	1220
553	8/4/99	11:15	5950	1470

Table 5-4 presents water quality results of field analysis of samples collected from the pilot hole of well MHMW-1. Because the open hole interval of the well is from 150 feet to 200 feet bls, only two pilot hole water samples were collected, at 180 feet and 200 feet bls. These results are within the expected range of water quality of the mid-Hawthorn aquifer.

TABLE 5-4
Field Analysis of Reverse-Air Water Quality from Well MHMW-1
Winkler Avenue Pumping Station

Depth (feet bls)	Date	Time	Conductivity (µmhos/cm)	Chloride (mg/l)
180	7/30/99	12:30	3760	1032
200	7/30/99	13:50	3890	1106

Packer Test Water Quality

Water quality samples were taken during the packer tests conducted on well ASR-1. The results from these samples are presented in Table 5-5 and Table 5-6. Field analysis parameters included conductivity, pH, temperature, and chloride concentration. Laboratory analysis included the field parameters and iron, TDS, sulfate, and sodium. Conductivity and chloride measurements ranged from 3,220 to 3,860 mg/l and 804 to 972 mg/l, respectively, for the 455 feet to 574 feet bls interval. The field and laboratory results in Tables 5-5 and 5-6 are consistent with water quality observed during the pilot hole drilling of well ASR-1.

TABLE 5-5
Field Analysis of Packer Test Water Quality from Well ASR-1
Winkler Avenue Pumping Station

Interval Sampled (feet bls)	Date	Conductivity (µmhos/cm)	pH	Temperature (°C)	Chloride (mg/l)
0-573	6/16/99	3220	7.9	29.7	804
455 ~~0~~-573	6/16/99	3860	7.9	28.5	972
455 ~~0~~-574	6/17/99	3240	7.9	28.5	770

TABLE 5-6
Laboratory Analysis of Packer Test Water Quality from Well ASR-1
Winkler Avenue Pumping Station

Interval Sampled (feet bls)	Conductivity (µmhos/cm)	pH	Temp (°C)	Iron (mg/l)	TDS (mg/l)	Sulfate (mg/l)	Sodium (mg/l)	Chloride (mg/l)
0-573	3510	7.26	31	0.04	1850	295	402	820

Background Water Quality

Primary and secondary DWSs

Wells ASR-1, SZMW-1, and MHMW-1 were sampled for the parameters listed as State primary and secondary drinking water standards (Chapter 62-550, FAC) on November 11, 1999, September 17, 1999, and November 11, 1999, respectively. Results of the water quality sampling are presented in Appendix J.

Analytical results indicate that background samples from well ASR-1 met all primary water standards with the exception of sodium. Well ASR-1 exceeded the state maximum contaminant level (MCL) of 160 mg/l with a result of 331 mg/l. All secondary standards were passed with the exception of chloride , odor, sulfate, and TDS. Because the Winkler Avenue ASR system is designed as potable water ASR, the source water will meet all primary and secondary water standards, prior to injection. As a result, it is expected that the storage zone water quality will increase as more potable water is stored in the subsurface. Bacteriological samples were taken between October 11, 1999 and October 26, 1999. All twenty water samples returned satisfactory results as none of the samples contained any coliform counts.

Well MHMW-1 was sampled for primary and secondary water standards on November 11, 1999. Background water quality of well MHMW-1 exceeded the primary standard of 160 mg/l with a result of 545 mg/l. Well MHMW-1 did not meet the secondary water quality standards of chloride, sulfate, and TDS.

SZMW-1 was sampled for background water quality samples were taken on November 15, 1999 and September 16, 1999. All primary and secondary parameters were analyzed for in the first sample taken. As recorded in previous sampling, water quality samples collected from SZMW-1 showed slightly higher water quality than ASR-1. Samples collected from SZMW-1 met all primary standards. Secondary standards for chloride, sulfate, and TDS were not met during the background water quality sampling. As discussed above, injection of potable water into the storage zone should lead to an overall freshening of the aquifer.

There are no observed water quality problems observed in any of the three wells in the Winkler Avenue ASR system. Samples collected from ASR-1 and SZMW-1 that did not meet primary and/or secondary standards are expected to meet all requirements in the future, following injection of potable water as part of the ASR process.

Water Table Well Monitoring Wells Water Quality

Two water table monitoring wells were installed along the perimeter of the site near wells ASR-1 and SZMW-1. The purpose of these wells was to monitor the surficial aquifer for construction related impacts. Accordingly, the wells were sampled weekly for chlorides and conductivity during the construction of the two deep wells. Figure 5-2 presents field results for chloride and conductivity for WTMW-1 and WTMW-2.

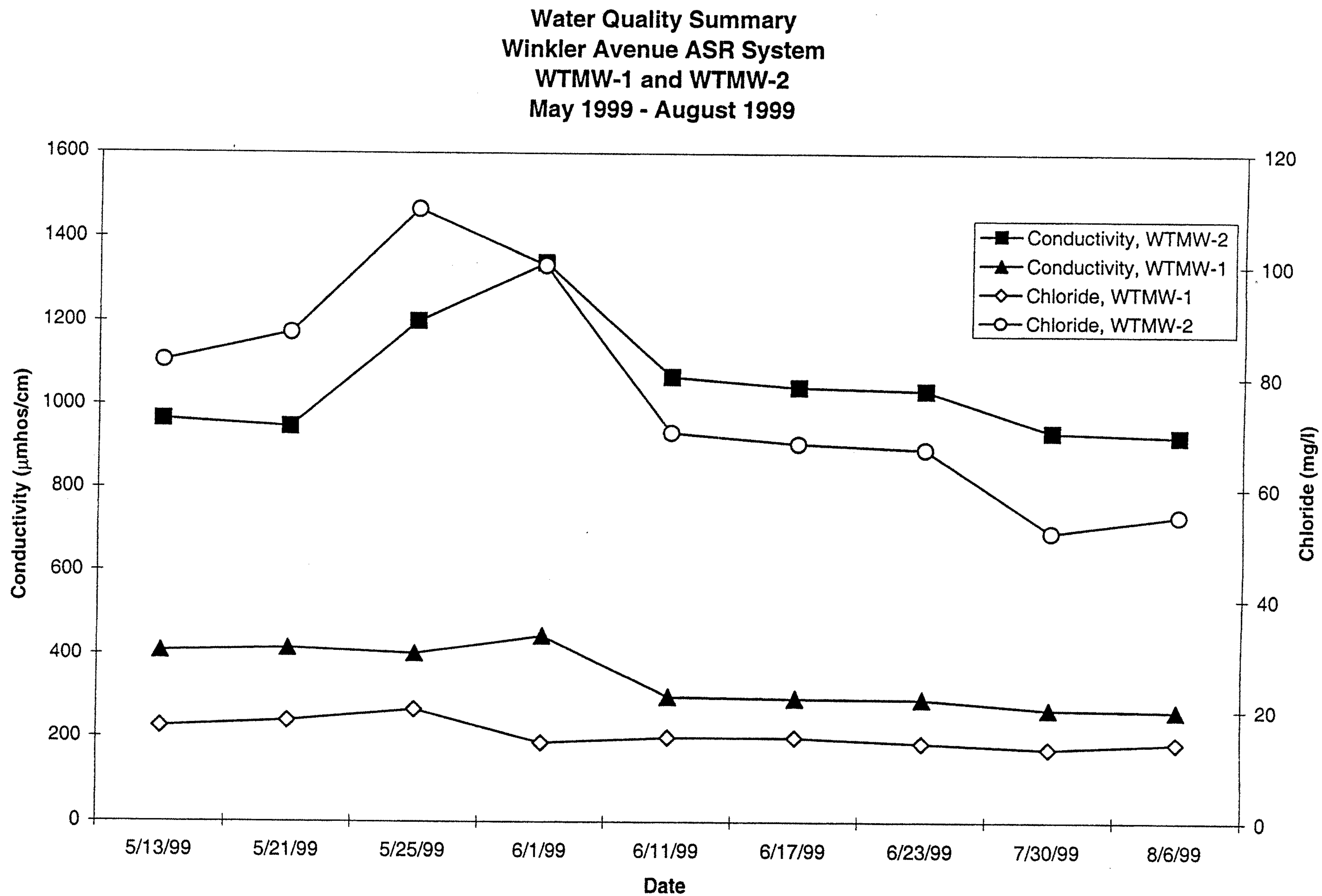

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FIGURE 5-2
WTMW-1 and WTMW-2 Water Quality Data

A slight short-term increase in chlorides and conductivity was observed in well WTMW-2 between May 21, 1999 and June 11, 1999 followed by a trend to background levels through August 1999. No other trends were noted. Boths wells were at or below background levels following construction activities.

Proposed ASR Cycle Testing

Table 6-1 presents the proposed ASR aquifer performance (cycle) test details. The initial ASR cycle test is proposed to begin with 10 days of injection into well ASR-1. The well will then be allowed to remain idle for 3 to 4 days prior to initiate the pump out test. Well ASR-1 will then be pumped at a rate of 700 gpm (1 mgd), approximately one-half of the estimated design capacity of well ASR-1. The treated drinking water produced from the well is proposed to be discharged to an adjacent storm sewer manhole.

TABLE 6-1
Proposed ASR Cycle Tests
Winkler Avenue Pumping Station

	Injection		Storage	Recovery	
Cycle	Duration (days)	Rate (gpm)	Duration (days)	Duration (days)	Rate (gpm)
Background [A]					
1	10	700	0-1 [B]	± 5 [C]	700
2	45	700 – 1,400	45-60 [D]	± 20 [E]	700 – 1,400
3	90	700 – 1,400	60-120 [D]	± 45-90 [E]	700 – 1,400

[A] Aquifer Performance Test completed in August 1999.
[B] Begin recovery to storm sewer.
[C] Recover water to upper limits of drinking water quality.
[D] Storage period dependant on distribution system demands. Water recovered to distribution system.
[E] Recovery water to upper limits of drinking water quality.
Note: This schedule will be adjusted as appropriate to reflect changing needs and conditions during the testing period and to incorporate experience from the previous cycle tests.

Proposed monitoring parameters during the planned cycle tests are shown in Table 6-2.

ASR Cycle Tests

A series of ASR cycle tests will be conducted at the site to determine the recoverability of the finished (potable) water stored in well ASR-1 and determine if the acceptable drinking water standards can be maintained in the recovered water.

Cycle test No. 1 consists of injecting potable water from the Fort Myers Membrane Water Treatment Plant (MWTP) for a period of 10 days. The recovery water will be discharged to the City's storm sewer system. Proposed Cycle Test No. 1 results in a volume of approximately 10 MG of water injected. After 10 days of recharge, flow to the well will be shut off and the water levels in the storage zone will be allowed to recover to near static conditions.

TABLE 6-2
Proposed Water Quality Sampling Schedule
Winkler Avenue Pumping Station

Parameter	ASR Well ASR-1 [A]		SZMW-1 and MHMW-1 [B]	
	Aquifer Performance Test	ASR Cycle Testing	Aquifer Performance Test	ASR Cycle Testing
Primary Drinking Water Parameters				
Complete Set (One time sample)	X		X	
Fluoride		X		X
Sodium		X		X
Turbidity		X		X
Microbiological		X		X
Radionuclides		X		X
Trihalomethanes		X		X
Secondary Drinking Water Standards				
Complete Set (One time sample)	X		X	
Chloride		X		X
Sulfate		X		X
Total Dissolved Solids		X		X
Color		X		
PH		X		X
Aluminum		X		
Unregulated Drinking Water Parameters				
Total Hardness	X	X	X	X
Noncarbonate Hardness	X	X	X	X
Alkalinity	X	X	X	X
Conductivity	X	X	X	X
Temperature	X	X	X	X
Calcium	X	X	X	X
Magnesium	X	X	X	X
Potassium	X	X		
Hydrogen Sulfide	X	X		
Dissolved Oxygen	X	X		

[A] Daily for first week; weekly for first month; monthly thereafter during recovery periods.
[B] Weekly for first month and monthly thereafter.

The recovery period will then begin, within approximately 24 hours, and water will be pumped from the well at a flow rate of 700 gpm. Recovery from the well will continue until conditions approaching drinking water standards are exceeded. This is anticipated to occur when either chloride concentration exceeds the secondary DWS of 250 mg/L or sulfate concentration exceeds the secondary DWS of 250 mg/L. Total dissolved solids concentration of 500 mg/L does not constitute a DWS violation if all other DWSs are met in the discharge from the well. Fluoride, chloride, TDS, sulfate, and several other monitoring parameters will be utilized as indicators with respect to the amount of mixing that occurs in the storage zone. Because some mixing in the storage zone is anticipated, the recovery period will most likely be less than the injection period by several days. Water quality of the recovered water will be monitored at least daily to determine when drinking water quality exceedences are approached.

Cycle Test No. 2 consists of injecting potable water from the MWTP into well ASR-1 at a rate of 700 to 1,400 gpm for approximately 45 days, for a total storage volume of approximately 45 MG to 90 MG of potable water. The storage period will depend on the City's need for the potable water and the results of the initial cycle test at the well. The recovery period will likely begin within 45 to 60 days following cessation of the recharge event. Water will be recovered at the same rate or until drinking water standards are exceeded or acceptable drinking water quality is no longer observed in the recovered water. It is anticipated that the recovered water will be utilized by the City's distribution system, however, this is contingent upon successful results obtained from the initial cycle test. Some excess may be discharged into the storm sewer system. Since the ambient quality of the storage zone is more brackish than the injected potable water, it is unlikely that full volumetric recovery will be attained.

Cycle Test No. 3 will be conducted at the design capacity of well ASR-1 to confirm a long-term reliable finished water supply is sustainable from the well. Approximately 60 MG to 120 MG of potable water will be injected over a 90-day period. The well will subsequently be shut-in for a period of approximately 60 to 120 days, depending on potable water demand during this time. After that period, water will be recovered at the same rate (700 to 1,400 gpm) or as otherwise needed, until any undesirable water quality standards are reached, or until any other criteria established during Cycle Tests No. 1 and 2 have been exceeded. The duration of the recovery period will depend on the amount of mixing that occurs in the storage zone and the recovered water quality produced from the well.

Subsequent cycle tests may be performed if additional data are required to thoroughly evaluate the ASR system prior to recommending or designing expansion of the ASR system. Appropriate regulatory agencies will be notified prior to performing additional cycle tests. It is the City's intent to collect sufficient data during the initial 2 to 3 cycle tests to support FDEP issuance of an "Authorization to Use" letter for future use of the well on an as-needed basis.

It may be necessary to adjust the duration of injection and recovery periods, as well as recharge and recovery rates during the cycle testing activities. Similarly, storage periods may also require modifications as appropriate based on potable water availability and other operational conditions. Changing needs and conditions may develop after the initial 5-day aquifer test and as each cycle test is evaluated. These changes will be incorporated into subsequent cycle tests.

Recharge Water Quality

The proposed recharge water for all cycle testing activities is finished water from the Fort Myers MWTP. The MWTP produces very high quality finished water, meeting all primary and secondary drinking water standards.

Cycle Test Monitoring

Extensive water quality and water level data will be collected during each cycle testing period. Flow rates and wellhead pressures will be monitored at well ASR-1 to determine if any hydraulic changes, such as borehole plugging, are occurring over time.

The majority of the data collected during the cycle tests will occur at ASR-1. Operational test data at wells ASR-1 will be collected at least daily for the initial week of recovery. Water quality data will be collected as frequently as twice per day during cycle No. 1, and at least weekly during cycles No. 2 and No. 3. Water level or wellhead pressure data and flow rates will be monitored at least daily throughout the injection and recovery periods.

Operational test data at wells SZMW-1 and MHMW-1 will be monitored at least weekly. Water quality and water level data will be collected, at a minimum, prior to and at the end of injection and recovery events at each of the monitoring wells at the site. This will provide substantial water quality and water level data to monitor any changes that result from operating the ASR system. If background conditions change significantly in any of the wells, the monitoring program may be intensified in subsequent cycles to provide insight into the cause of the changes.

A technical memorandum will be prepared and submitted to FDEP presenting the results of each cycle test.

Cycle Test Schedule

Construction of the final wellhead and yard piping is expected to begin in January 2000 and is scheduled to be completed by July 30, 1999.

A final report will be completed following Cycle Test No. 2 or No. 3, depending on the success of these cycle tests. This report may be delayed if additional cycle testing is required and the first three cycle tests do not fully support ASR development at the facility. The report will be prepared in support of FDEP authorization to use and a SFWMD water use permit for the potable water ASR system. Copies of this report will be provided to FDEP TAC members, SFWMD water use permitting staff, and other appropriate local agencies.

The final report will include the following:

- A detailed analysis of the cycle tests
- A detailed operation and maintenance protocol section
- Record drawings sealed by the engineer of record
- A discussion of typical operating scenarios
- Ultimate ASR capacity at the Winkler Avenue pumping station site

Members of the FDEP TAC, SFWMD WUP, and other agencies will be kept informed on the project progress throughout all testing activities.

SECTION 7

Summary and Recommendations

This report has been prepared to document the drilling and testing activities of the Winkler Avenue ASR system.

Summary

The City of Fort Myers' need for cost-effective short and long-term storage of potable water has led to the construction of an ASR well system at the Winkler Avenue pumping station. The ASR system consists of three wells, an ASR well (ASR-1), a storage zone monitoring well (SZMW-1), and a mid-Hawthorn monitoring well (MHMW-1).

Extensive hydrogeologic testing focused on identifying a storage zone adequate for potable water ASR during construction of wells ASR-1, SZMW-1, and MHMW-1. Lithologic sampling, packer tests, a pumping test, geophysical logging, and borehole water quality data were used to evaluate potential ASR storage zones at the Winkler Avenue pumping station.

The Winkler Avenue ASR system included construction of a 12-inch ASR well completed to 553 feet bls, a storage zone monitoring well completed to 553 feet bls, and a mid-Hawthorn aquifer monitoring well completed to 200 feet bls. Drilling and testing activities identified the optimal ASR storage zone to be a water producing zone in the lower Hawthorn aquifer located between 455 feet to 553 feet bls. The lower Hawthorn aquifer storage zone has suitable upper confinement from the approximately 200 feet thick low hydraulic conductivity sediments of the lower Hawthorn confining zone. Hydrogeologic test results of the limestones and interbedded clay lenses of the underlying lower Hawthorn system suggest adequate confinement beneath the storage zone.

A constant rate pumping test was conducted on the storage zone of well ASR-1 for 27 hours at a rate of 1400 gpm with a stabilized drawdown of 48.9 feet. Hydrogeologic testing results of the lower Hawthorn storage zone indicated aquifer transmissivity values of approximately 210,000 gpd/ft. These results indicate that well ASR-1 should be capable of recharge and recovery rates up to 2 mgd. Background water quality of the storage zone meets most primary and secondary drinking water standards. The parameters that were exceeded during testing (chloride, sodium, TDS, odor, and sulfate) should be met following future cycle testing of potable water into the storage zone.

Preliminary results indicate that this site will be suitable for developing and operating an ASR system following successful completion of cycle testing activities.

Recommendations

Data obtained during the drilling and testing of wells ASR-1, SZMW-1, and MHMW-1 suggest that a successful ASR system can be operated at the Winkler Avenue site following successful cycle testing. CH2M HILL recommends that the City of Fort Myers:

- Continue with preparation and construction of wellhead, piping, and other facilities for the ASR system
- Initiate cycle testing as presented in Section 6 upon completion of the ASR surface facilities
- Upon successful cycle testing and submittal of results to FDEP, submit Class V application for operation of an ASR system

SECTION 8
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Appendix D

Lithologic Description of Formation Samples

City of Ft. Myers Winkler Avenue ASR System
ASR Well
Lithologic Description

Date	Depth (ft. bsl) From	To	Observer's Description
05.19.99	0	10	Shell fragments (65%), unconsolidated; limestone (35%), pinkish gray (5 YR 8/1); fine sand grained, low porosity, well consolidated, phosphatic
	10	20	Same as above
	20	30	Same as above
	30	40	Same as above
	40	50	Same as above
	50	60	Same as above
	60	70	Clay (50%), light olive gray (5 Y 5/2), very low porosity, low plasticity; shell fragments (40%); limestone (10%), yellowish gray (5 Y 8/1), fine sand grained, low porosity
	70	80	Limestone (60%), yellowish gray (5 Y 8/1), fine sand grained, low porosity, well consolidated, shell fragments (40%)
	80	90	Same as above
	90	100	Same as above
	100	110	Limestone (50%), light gray (N7), fine sand grained, low porosity, well consolidated, shell fragments (50%), 5-20 mm
	110	120	Same as above
	120	130	Same as above
	130	140	Limestone (90%) yellowish gray (5 Y 8/1), fine sand grained, phosphatic, trace of quartz sand, low porosity, well consolidated, shell fragments (10%)
	140	150	Same as above
	150	160	Same as above, decrease limestone to 75%, increase phosphate to 15%
	160	170	Same as above, increase limestone to 90%, decrease phosphate to trace
	170	180	Same as above
	180	190	Same as above
	190	200	Same as above
	200	210	Same as above
	210	220	Same as above
	220	230	Same as above
	230	240	Same as above
	240	250	Same as above
	250	260	Same as above
	260	270	Limestone (30%), yellowish gray (5 Y 8/1), low porosity, moderate consolidation, fine sand grained; clay (30%), yellowish gray (5 Y 7/2), low porosity, medium plasticity, phosphate (30%), shell fragments (10%)
	270	280	Clay (90%), greenish gray (5 GY 6/1), low porosity, medium plasticity; limestone (5%), yellowish gray (5 Y 8/1), fine sand grained, well consolidated, low porosity, fine grained quartz sand (5%)
	280	290	Clay (80%), greenish gray (5 GY 6/1), low porosity, low plasticity; limestone (20%), yellowish gray (5 Y 8/1), fine sand grained, low porosity, well consolidated, phosphatic
	290	300	Limestone (90%), pinkish gray, (5 YR 8/1), fine sand grained, low porosity, well consolidated, phosphatic; shell fragments (10%)
	300	310	Limestone (60%), pinkish gray (5 YR 8/1), fine sand grained, low porosity, moderately consolidated, phosphatic; clay (30%), yellowish gray (5 Y 8/1), low porosity, medium plasticity; shell fragments (10%)

City of Ft. Myers Winkler Avenue ASR System
ASR Well
Lithologic Description

Date	Depth (ft. bsl) From	To	Observer's Description
	310	320	Same as above
	320	330	Same as above, increase limestone to 80%, decrease clay to 10%
	330	340	Same as above
	340	350	Same as above, decrease limestone to 60%, increase clay to 30%
	350	360	Clay (70%), light olive gray (5 Y 6/1), low porosity, high plasticity; limestone (30%), pinkish gray (5 YR 8/1), moderately consolidated, medium porosity
	360	370	Same as above, increase clay to 80%, medium plasticity, decrease limestone to 20%
	370	380	Same as above, decrease clay to 55%, increase limestone to 45%
	380	390	Same as above, increase clay to 90%, high plasticity, decrease limestone to 10%
	390	400	Clay (50%), dark greenish gray (5 GY 4/1), low porosity, high plasticity, phosphatic; limestone (50%), yellowish gray (5 Y 8/1) fine sand grained, medium porosity, moderate consolidation
	400	410	Clay (55%), light olive gray (5 Y 6/1), low porosity, medium plasticity; limestone (45%), pinkish gray (5 YR 8/1), fine sand grained, medium porosity, moderate consolidation
	410	420	Same as above
	420	430	Same as above, decrease clay to 40%, high plasticity, increase limestone to 60%
	430	440	Limestone (70%), yellowish gray (5 Y 8/1), fine sand grained, low porosity, moderately consolidated; fine grained sand (30%), phosphatic
	440	450	Clay (55%), light olive gray (5 Y 6/1), low porosity, high plasticity; limestone (45%), pinkish gray (5 YR 8/1), low porosity, moderately consolidated
	450	460	Limestone, yellowish gray (5 Y 8/1), medium porosity, moderately consolidated, phosphatic
	460	470	Same as above
	470	480	Same as above
	480	490	Same as above
	490	500	Same as above
	500	510	Same as above
	510	520	Same as above
	520	530	Same as above
	530	540	Same as above
	540	550	Same as above
06.07.99	555	560	Limestone, white (N9), very fine sand grained, abundant fine gravel sized fossil fragments, medium porosity, well consolidated
	560	570	Limestone (80%), very light gray (N8), fine sand grained, low porosity, trace of phosphate, well consolidated; clay (20%), very light gray (N8), calcareous, low plasticity
	570	580	Limestone, very light gray (N8), fine sand grained, moderate porosity, trace of phosphate, well consolidated
	580	590	Clay, medium dark gray (N4), low porosity, medium plasticity
	590	600	Limestone, white (N9), medium sand grained, high porosity, moderately consolidated
	600	610	Limestone, yellowish gray (5Y 8/1), medium sand grained, high porosity, medium to well consolidated

City of Ft. Myers Winkler Avenue ASR System ASR Well Lithologic Description			
Date	Depth (ft. bsl) From	To	Observer's Description
	610	620	Clay, yellowish gray, (5Y 8/1), low porosity, high plasticity
	620	630	Limestone, yellowish gray (5 Y 8/1), medium sand grained, high porosity, well consolidated
	630	640	Same as above
	640	645	Limestone, yellowish gray (5Y 8/1), very fine to medium sand grained, low to high porosity, well consolidated
ft. bsl = feet below surface level			

City of Ft. Myers Winkler Avenue ASR System
Storage Zone Monitoring Well
Lithologic Description

Date	Depth (ft. bsl) From	To	Observer's Description
07.30.99	250	260	Limestone (90%), yellowish gray (5 Y 8/1), fine sand grained, phosphatic, trace of quartz sand, low porosity, poorly consolidated; clay (15%), yellowish gray (5 Y 7/2), very low porosity, medium plasticity, phosphatic
	260	270	Clay, dark greenish gray (5 GY 4/1), low porosity, low plasticity, mottled
	270	280	Same as above
	280	290	Same as above, decrease clay to 80%, limestone (20%), yellowish gray (5 Y 8/1), fine sand grained, low porosity, poorly consolidated.
	290	300	Limestone, white (N9), fine sand grained, medium porosity, poorly consolidated, phosphatic
	300	310	Same as above, decrease limestone to 70%, Clay (30%), light olive gray (5 Y 6/1), low porosity, medium plasticity, phosphatic
	310	320	Same as above
	320	330	Same as above
	330	340	Same as above, increase limestone to 80%, decrease clay to 20%
	340	350	Same as above, decrease limestone to 65%, increase clay to 35%
	350	360	Same as above, decrease limestone to 30%, increase clay to 70%
	360	370	Sandy clay, light olive gray (5 Y 6/1), low porosity, medium plasticity, phosphatic
	370	380	Clay, dark greenish gray (5 G 4/1), low porosity, high plasticity
	380	390	Same as above, decrease clay to 85%, high plasticity; limestone (15%), pinkish gray (5 YR 8/1), fine sand grained, low porosity, well consolidated
	390	400	Same as above, decrease clay to 70%, increase limestone to 30%
	400	410	Same as above, decrease clay to 60%, increase limestone to 40%
	410	420	Same as above, decrease clay to 50%, increase limestone to 60%
	420	430	Limestone (80%), yellowish gray (5 GY 8/1), fine sand grained, low porosity, poorly consolidated; Clay (20%), dark greenish gray (5 G 4/1), low porosity, low plasticity
	430	440	Same as above, decrease limestone to 70%, increase clay to 30%
	440	450	Clay (55%), light olive gray (5 Y 6/1), low porosity, high plasticity; limestone (45%), pinkish gray (5 YR 8/1), low porosity, moderately consolidated
	450	458	Limestone, yellowish gray (5 Y 8/1), medium porosity, moderately consolidated, phosphatic
8.16.99	455	460	Same as above
	460	470	Same as above
	470	480	Same as above
	480	490	Same as above
	490	500	Same as above
	500	510	Same as above
	510	520	Same as above
	520	530	Same as above
	530	540	Same as above

ft. bsl = feet below surface level