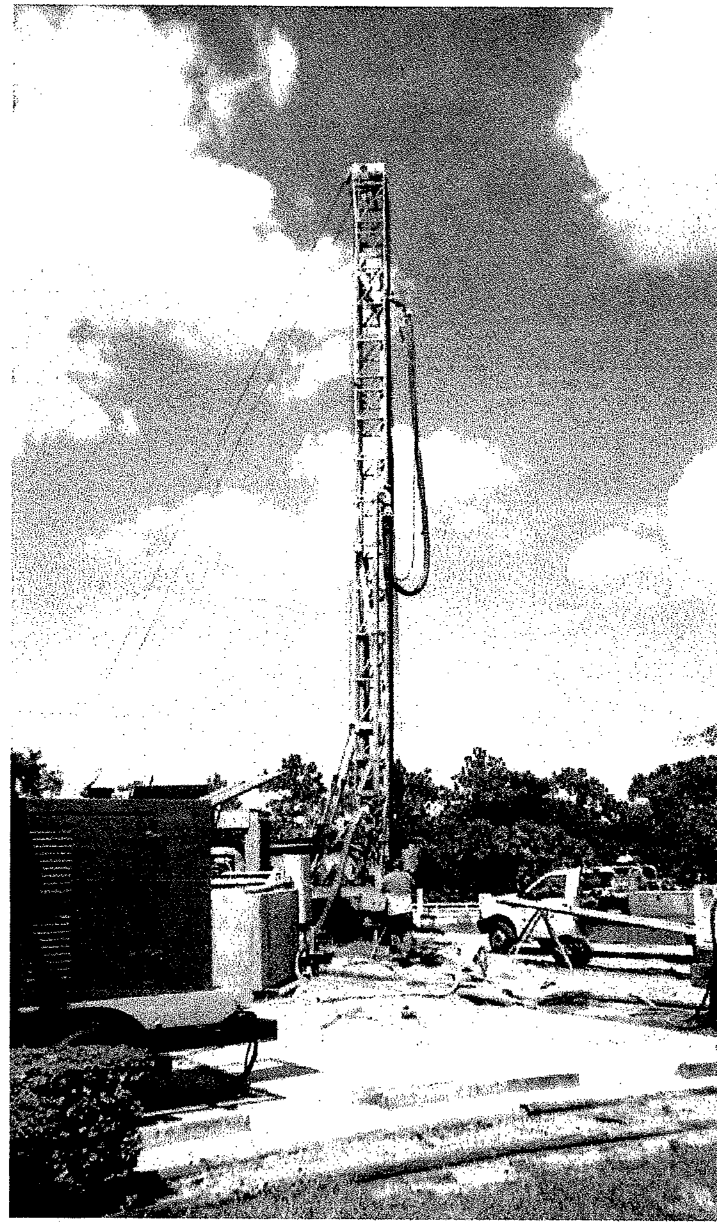
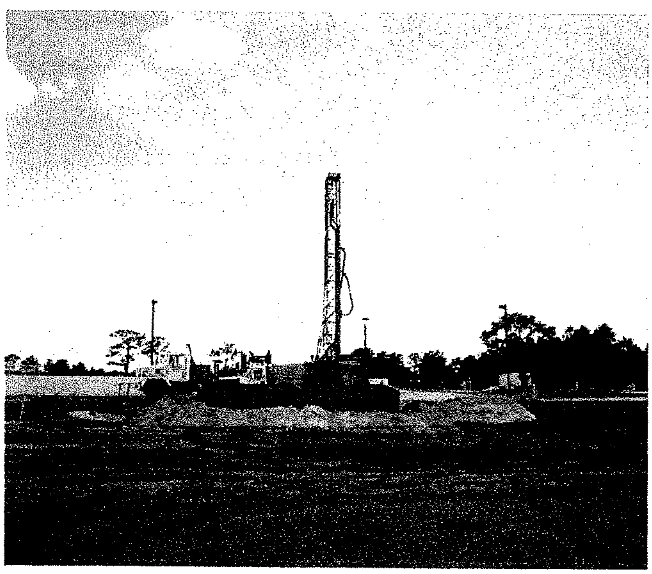
Station
CH-315 = ASR1
CH-316 = ASR2
CH-317 = ASR3

Interim Report on the Drilling and Testing of the Shell Creek Water Treatment Plant Expanded Aquifer Storage and Recovery (ASR) Well System





For

CITY OF PUNTA GORDA FLORIDA
PROSPERITAS IN SANITAT

By:

MWH
MONTGOMERY WATSON HARZA

June 2002

Interim Report on the Drilling and Testing of the Shell Creek Water Treatment Plant Expanded Aquifer Storage and Recovery (ASR) Well System

for:

The City of Punta Gorda

Submitted by:

Montgomery Watson Harza
1000 North Ashley Drive, Suite 400
Tampa, Florida 33602

June, 2002

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TABLES

FIGURES

Section 1
Introduction

BACKGROUND

The City of Punta Gorda (the City) is located in Charlotte County, Florida (**Figure 1-1**). The Shell Creek reservoir is utilized to supply the City's potable water needs. The City questioned Shell Creek's feasibility for future use and sustainability as a supplier of its long-term potable water needs. A feasibility study concluded that additional demands can be met by Shell Creek if additional storage is created, through increasing the reservoir volume or by implementation of an aquifer storage and recovery (ASR) system (Boyle, 1993). As a result, the City is implementing an ASR system at its water treatment plant (WTP) (**Figure 1-2**) to provide additional storage of potable water.

Construction of a successful ASR system will allow the City to meet increased future potable water demands, potentially increase the time between expansions of the WTP, and possibly allow for reduced dry season withdrawals from Shell Creek. The amount of excess potable water that can be stored through ASR during the wet season, when flows over the Shell Creek Reservoir Dam are greatest, will be increased. Recovery of the stored water from the wells will occur during the dry season when potable water demands are highest and Shell Creek flow is the lowest.

An initial exploratory ASR Well (ASR-1) was constructed at the WTP in 1997. Cycle testing of this well has been ongoing since completion of ASR-1 construction. This report summarizes the third phase of expansion involving the construction of 3 ASR wells and 3 monitor wells (**Figure 1-3**).

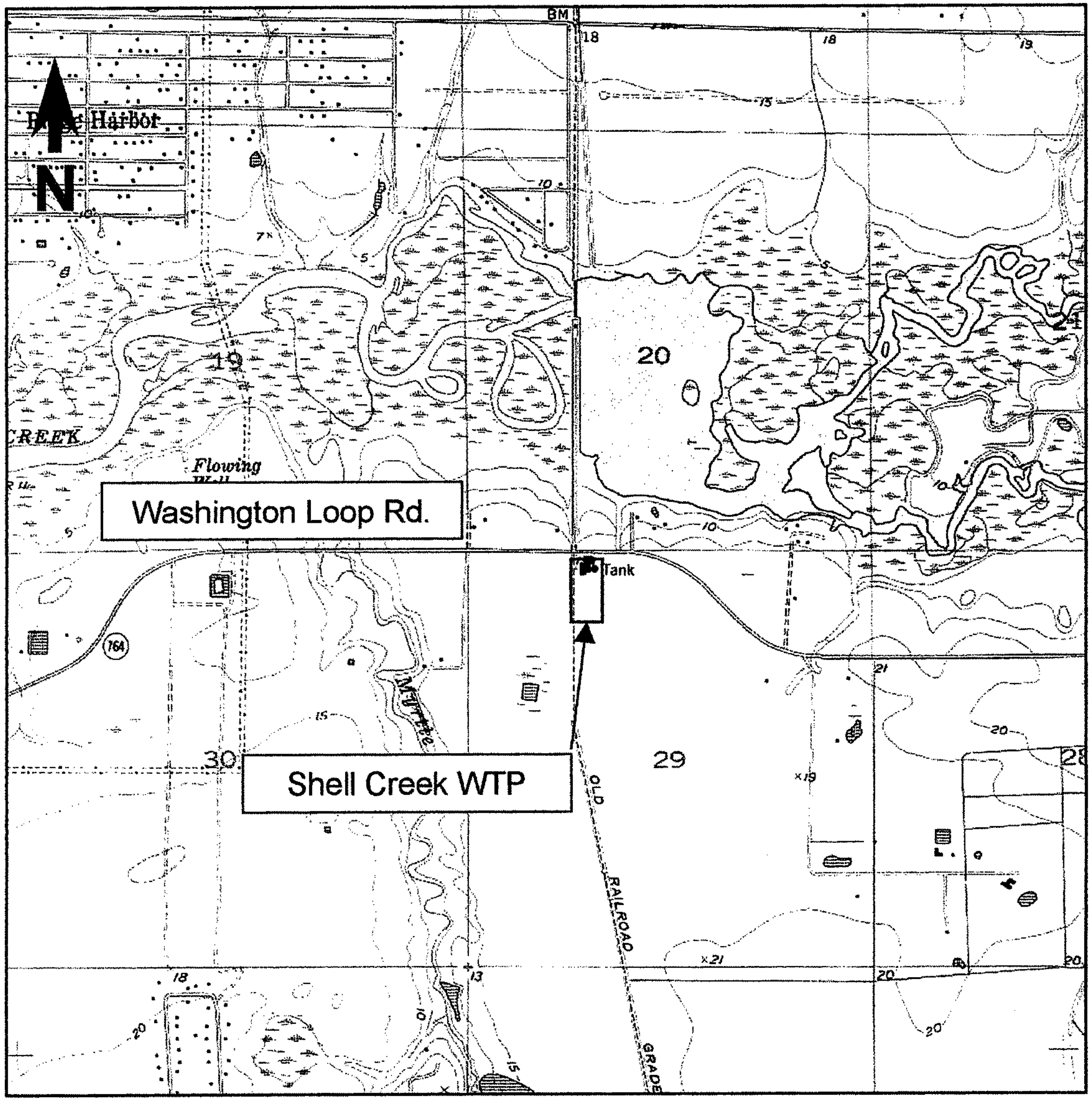
In the construction of ASR-1, MWH assisted the City in constructing the exploratory ASR well south of the solids contact unit (SCU) at the Shell Creek WTP. The siting of the ASR well is described in a memorandum titled *Technical Memorandum for the Basis of Design-City of Punta Gorda Shell Creek Water Treatment Plant Aquifer Storage and Recovery Exploratory Well* (July, 1996). Construction and testing of the exploratory well is described in a memorandum titled *Final Report on Exploratory ASR Well Drilling and Testing at the Shell Creek Water Treatment Plant* (March, 2000)

Regulatory approval from the Florida Department of Environmental Protection (FDEP) and the Southwest Florida Water Management District (SWFWMD) was required to construct and test the additional ASR and monitor wells. The permits required for construction and testing of the new ASR wells are contained in **Appendix A**. After obtaining the required permits, formal bids were received and the construction contract was awarded to the lowest qualified bidder. Diversified Drilling Corporation of Fort Myers, Florida was the selected contractor and construction of the wells began in August 2001.

SCOPE

Three additional ASR wells, two deep monitor wells and a shallow monitor well were constructed at the City's Shell Creek WTP. The purpose of these wells is to increase the effective capacity of the Shell Creek WTP and to monitor the water level and water quality effects on the Floridan aquifers.

This interim report summarizes the drilling and testing of the City of Punta Gorda's ASR expansion project, including all 6 additional wells, prior to operational (cycle) testing. Aquifer water quality, geology, and hydrogeology encountered during the drilling and testing are presented and discussed in this report. The proposed cycle testing program designed to develop the storage zone and to quantify the operational properties of the well is also included in this report.



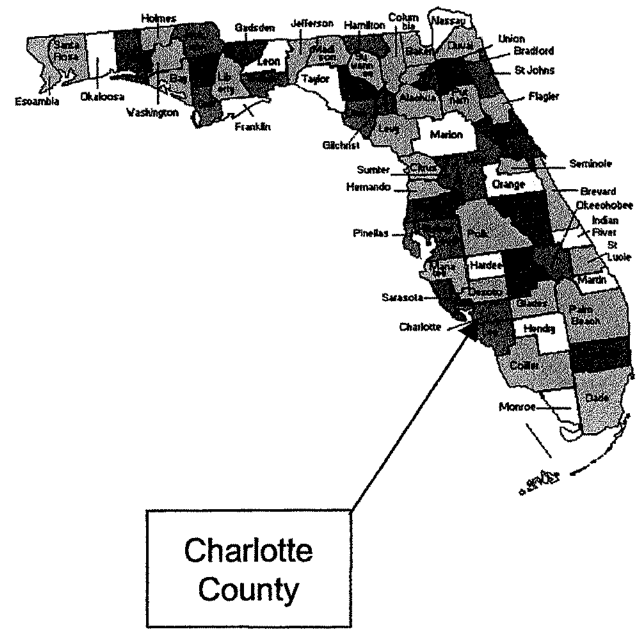


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Figure 1-1
Location Map

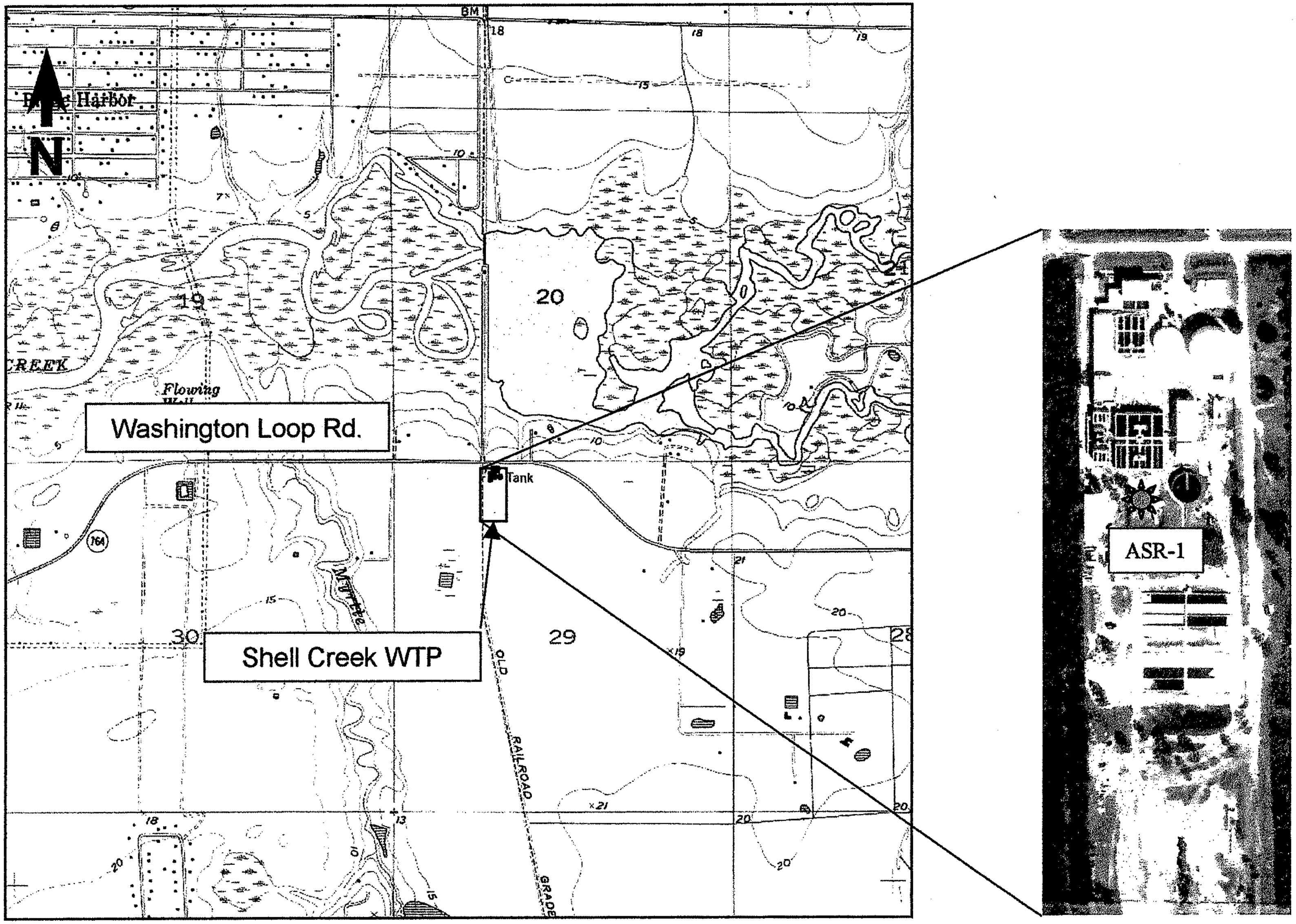

Figure 1-2
ASR-1 Location Map

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Figure 1-3
Expansion Well Location Map

970' S of ASR1
100' W

285636081561001

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Section 2
Hydrogeologic Setting

GEOLOGIC BACKGROUND

Florida lies on a carbonate platform, on the southeastern edge of the North American continent. The platform extends four hundred miles north to south and nearly four hundred miles east to west (at its widest point). More than half of the platform is presently under water, leaving a narrow peninsula of land extending from the mainland. A thick sequence of primarily carbonate rocks, several thousand feet thick (in south Florida), ranging in age from mid-Mesozoic to Recent, forms the Florida Platform (Scott, 1992). The stratigraphy and aquifer systems under discussion in this report range in age from Early Eocene to the Late Pleistocene.

Below is a summary of the generalized lithologic descriptions of the WTP site. Detailed lithologic descriptions of the cuttings obtained from the City of Punta Gorda ASR expansion wells, are located in **Appendix B**. During construction it became evident that the site geology is heterogenous. Lithologic units seen at one well are rarely encountered at the same position in nearby wells, and the geophysical logs also show large amounts of variation across the site. **Figure 2-1** shows the local lithologic features that were seen during the construction and testing of the ASR and monitor wells.

GEOLOGIC DESCRIPTIONS

Tamiami Formation

During drilling and testing of the ASR and monitor wells, Plio-Pleistocene aged limestone, sand, sandstone, clay, and variable amounts of whole and broken pelecypod and gastropod material were observed. These layers, from land surface to a depth ranging from approximately 90 to 132 feet below land surface (bls), comprise the equivalent of the Tamiami Formations (SWFWMD, 1988). These sediments unconformably overlie the Miocene-aged Hawthorn Group (Miller, 1986).

Hawthorn Group

At this site, the Hawthorn Group extends from an average depth of approximately 118 to 690 feet bls with a total thickness of approximately 570 feet. The Hawthorn Group is a complexly interbedded, highly variable sequence that consists of clay, silt, and sand beds, all of which contain scarce to abundant phosphate (Miller, 1986). Locally, the Hawthorn Group is segregated into two formations, an upper unit called the Peace River Formation and a lower unit called the Arcadia Formation (Miller, 1986). In this locality, determinations for the formation breaks could not be made due to the high variability in the interbedded layers.

Peace River Formation of the Hawthorn Group

The limestones of the Peace River Formation are generally light gray to white, poor to moderately indurated mudstones. Sandstones of this formation are poorly cemented, and show moderate amounts of historic transportation. Minor amounts of yellowish gray to olive clay are also present. The clay is plastic and interbedded with the light olive gray limestone. The clay contains quartz sand, silt, a minor percentage of pelecypoda material, and calcite and dolomite cement.

Arcadia Formation of the Hawthorn Group

Limestones of the Arcadia Formation are generally light gray to white, poor to moderately indurated mudstones. In contrast to the Peace River Formation, described above, the Arcadia Formation is composed predominantly of limestone.

Suwannee Limestone

Underlying the Hawthorn Group is the Suwannee Limestone. The top of this formation is at a depth of approximately 690 feet bls at the Punta Gorda well sites. The Suwannee Limestone is an Oligocene-aged formation comprised of white to medium gray, well indurated, highly fossiliferous packstones and grainstones. Some bioclasts are represented as moldic porosity, and high porosity and permeability are present. Locally the rock is recrystallized. Biotics include bryozoans, gastropods, and pelecypods. The Suwannee Limestone is approximately 270 feet thick at this site.

The shallowest significant water production that can be related to fracturing was identified in this formation. This formation has a high percentage of secondary porosity due to fossil molds, bedding planes, intergranular porosity, and some fractures. The moldic porosity is a result of the dissolution of aragonite from fossil shells (Zenger et al, 1980). Unfortunately, the large diameter and broken, irregular shape of the boreholes made precise measurements of fracture and bedding plane porosity impossible. The crumbling of the borehole wall during drilling relates the strongest evidence that fracturing is widespread in the formation.

Ocala Limestone

Below the Suwannee Limestone is the late-Eocene aged Ocala limestone. The top of this formation is located at approximately 960 feet bls at the site based on geophysical logs. It is composed of moderately soft, peloidal, white to very pale orange wackestones and packstones with 15-percent to 40-percent intergranular porosity. Locally, the unit is composed of thin layers of very hard micrite of low porosity and permeability. The total depth of the deepest well was 1,026 feet bls at the ASR-4r site, and the Ocala Limestone was not fully penetrated.

HYDROGEOLOGIC DESCRIPTION

Using composite information collected during drilling, and through geophysical logs, it is possible to determine the information about the hydrogeologic setting of the WTP site. Similar to other wells in the Charlotte County area, the porosity associated with some of the water producing intervals are the result of their depositional environment and do not appear to be a result of fracturing (Montgomery Watson, 1997). Other water producing intervals are clearly a result of secondary porosity, such as fracturing and dissolution. Many of the producing intervals within the aquifers at this location are a result of fracturing and dissolution of the formations.

Surficial Aquifer System

The surficial aquifer is present at these wells to an average depth of approximately 118 feet bls. This unconfined aquifer is found in the undifferentiated, post-Miocene sediments from land surface to the intermediate confining unit. The surficial aquifer is composed of alternating layers of poor to well consolidated, highly porous and permeable, sand, limestone, and shell material. Porosity in this aquifer is primary intergranular, moldic, and formed from fabric selective dissolution. Diagenesis, including dissolution and cementation, appears to have started to alter the interval, but a majority of the porosity is still primary and unreduced.

Intermediate Confining Unit

The intermediate confining unit is present at the site from an estimated 118 to 690 feet bls. This confining unit is composed of clay, sand, silt, and low porosity limestones, which are designated as part of the Hawthorn Group. This intermediate confining unit overlies the Floridan aquifer in west-central Florida, and was seen during other well construction projects in Charlotte County (Montgomery Watson, 1997). Productive intervals are sometimes seen in the sands and limestones of the Arcadia Formation of the Hawthorn Group. However, insufficient porosity and permeability restrict these intervals from being developed for extensive production.

Intermediate Aquifer System

Locally, the intermediate aquifer is located within the Hawthorn Group. A productive flow zone seen between approximately 364 and 372 feet bls was observed during the drilling of one of the wells. The unit produces water from sand, silt, and moderately porous limestones. This zone is generally comprised of sediments of the Peace River Formation of the Hawthorn Group. Porosity is from a mixture of primary intergranular, moldic, and fabric selective, and non-fabric selective dissolution processes, resulting in the formation of microscopic vugs, and the enlargement of bedding planes. Locally, this interval is penetrated by production wells for agricultural irrigation and domestic supply.

Floridan Aquifer System

Between approximately 690 and 1,026 feet bls the Floridan aquifer system was encountered. The Floridan aquifer system is a thick carbonate sequence which functions regionally as the most productive water-yielding hydraulic unit (FGS, 1986). Water in the Floridan aquifer system is under confined conditions in the area with a potentiometric surface of approximately 30 feet above mean sea level observed during drilling. Porosity in this part of the Upper Floridan aquifer is a mixture of primary intergranular, moldic, fabric selective, and non-fabric selective dissolution, resulting in the formation of vugs, and enlargement of bedding planes. At the ASR site, prior to the beginning of injection into ASR-1, the Upper Floridan aquifer contained water with total dissolved solids (TDS) concentration of approximately 2,000 mg/L and a chloride ion concentration of approximately 900 mg/L. During the drilling of the ASR system, the Floridan aquifer system was not fully penetrated.

Mid-Suwannee Confining Unit

Between approximately 770 and 800 feet bls, within the Suwannee Limestone, a low permeability layer comprised of clay, sand, silt, low porosity limestones, and crystaline dolostones was encountered. This unit comprises a semi-confining unit within the Upper Floridan aquifer. This semi-confining interval separates the Suwannee Limestone at the WTP site into upper and lower production intervals.

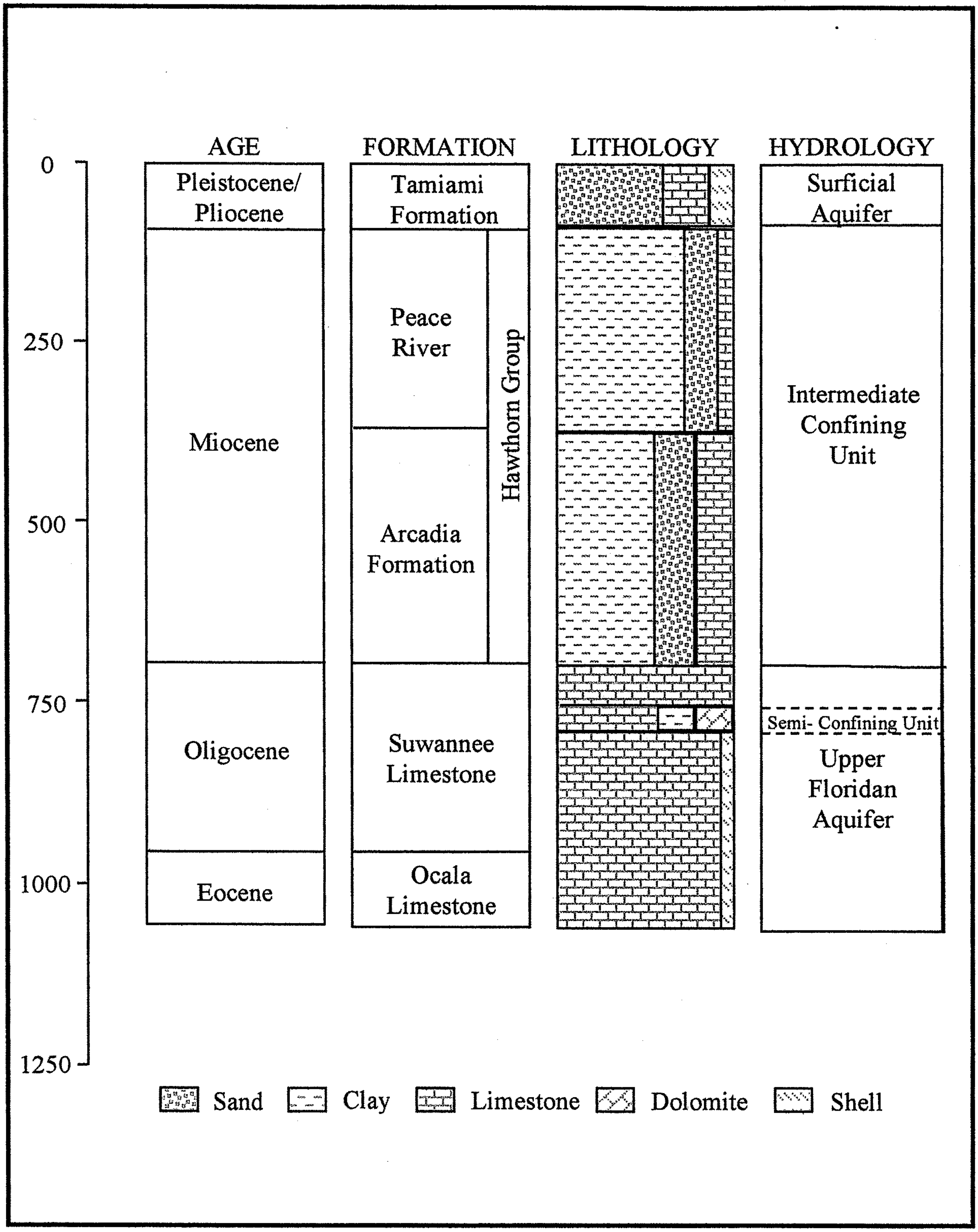

Figure 2-1
General Hydrology and Lithology at The City of Punta Gorda Shell Creek WTP

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Section 3
Well Construction

SITE DEVELOPMENT

The ASR Expansion Project well sites are located at the City of Punta Gorda Shell Creek WTP, on Washington Loop Road, in Charlotte County, Florida. The well locations on the property are as indicated in **Figure 1-3**. A drilling pad was laid and compacted at each site to provide support for the drilling equipment during construction. After construction was complete, each of the 6 work areas was filled and smoothed.

PAD MONITOR WELLS

Two temporary pad monitor wells were drilled at each of the three, new ASR locations on August 27, 2001. They were located at the north and south edges of each drilling pad, and were installed before the start of drilling the ASR wells. The 4-inch diameter pad monitor wells were constructed to 25 feet bls. Each well was constructed using 10 feet of 0.010-inch slot screen at the base of the well, and PVC casing from the top of screen to land surface. A well construction diagram for the wells is presented in **Figure 3-1**. **Figure 3-2** shows a plan view of the drilling pad locations and associated monitor wells.

Water quality samples were collected from the temporary pad monitor wells and analyzed for chloride concentration, specific conductivity and total dissolved solids concentration. Water quality analyses were conducted approximately once a week during the construction period. The results of these analyses are presented in **Appendix H**. Water quality fluctuations are evident over the construction period, but were not considered significant. At the end of the construction period, water quality was improved compared to the first sampling.

GENERALIZED ASR AND SZMW-2 CONSTRUCTION METHODS

Each of the ASR wells and SZMW-2 were constructed in a similar manner and with almost the same dimensions. Below is a summary of generalized construction details of the ASR wells and SZMW-2. See **Figures 3-3, 3-4, 3-6** and **3-9** for the specific construction details of ASR-2, ASR-3, ASR-4r, and SZMW-2 respectively.

Drilling

Each ASR well was drilled initially using mud-rotary method to a depth of approximately 350 feet bls. The drilling rig was then configured to use reverse-air drilling methods. This second method was used to drill to a total depth of approximately 1000 feet bls. Deviation surveys (sure shots) of the pilot boreholes and reamed boreholes were conducted, approximately every 60 feet of drilling, to track hole straightness and are presented in **Appendix D.**

Casing

All casings in the wells were centralized in the borehole using strap-type centralizers. The first group was located at the bottom of the casing, the second group was welded across the first joint, one group was placed every 100 feet and the final group was placed within 30 feet of the surface. Each group consists of four centralizers located at 0, 90, 180, and 270 degrees around the casing.

The surface casing is 36-inch OD, 0.375-inch wall thickness seamless steel casing, conforming to the standards of API 5L Grade B. The surface casing was set and cemented to a depth of approximately 40 feet bls in each well.

The first set of intermediate casing is 32-inch OD, set and cemented to a depth of approximately 120 feet bls. This steel casing conforms to the standards of API 5L Grade B and has a 0.375 inch wall thickness.

The second set of intermediate well casing is 26-inch OD, 0.375-inch wall thickness seamless steel casing, conforming to the standards of API 5L Grade B. The intermediate ASR casing is set and cemented to a depth of approximately 345 feet bls.

The final ASR well casing is 17.4-inch OD, SDR 17 (PVC) casing, conforming to the standards defined in ASTM D1784. This casing is set and cemented to a depth of approximately 780 feet bls in the wells. Casing joints were affixed using a spline and groove manufactured joint system. Mill certifications for all casings are found in **Appendix E.**

Welding

The factory beveled ends of the steel casings and tubing were arc welded by certified pipeline welders to standard pipeline certifications. They were welded with three welding passes.

Cementing

Casing was cemented using ASTM C 150, Type II sulfate-resistant cement. Cement mixed with 4 percent bentonite gel was used for the upper portion of the intermediate and final casings. Neat cement was used to cement the surface casing, intermediate casings and for approximately 70 feet of the bottom of the final casing.

The cementing of the final casing was completed in five stages (except in ASR-2 where only 4 stages were necessary). The first stage was pressure-grouted through a tremie pipe located inside the fluid-filled casing, near the bottom of the open hole. The remaining stages were cemented using a tremie pipe in the annulus between the casing and borehole wall. After each stage of cementing, the top of cement was located physically (tagged) with a tremie pipe, and by the performance of a temperature/gamma ray log inside the casing. This temperature log was conducted at least 5 to 8 hours after completion of each cement stage. A temperature/gamma ray log was not performed once the top of the cement was known to be located within the intermediate steel casing.

Geophysical Logging

Geophysical logging results are presented in **Appendix I.** The video survey of each completed borehole is presented in **Appendix J.**

ASR-2 WELL CONSTRUCTION

Construction Summary

The following paragraphs summarize the construction of ASR-2. A well construction diagram for the completed ASR-2 is presented as **Figure 3-3**, a summary of the casing is summarized in **Table 3-1,** and a list of the geophysical logs that were run are listed in **Table 3-2**.

Table 3-1
ASR-2 Casing Summary

Casing Name and Setting Depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 40 feet	36	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 120 feet	32	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 345 feet	26	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 780 feet	17.4	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-2
ASR-2 Geophysical Logging Summary

Interval (feet bls)	Hole Type	Logs Run
0 to 351	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
350	Reamed	Caliper log
350 to 780 780 to 998	Pilot and Completed	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)
350 to 780	Cased	Temperature Log
780 to 998	Completed	XY caliper Video

Construction of ASR-2 began on the morning of October 1, 2001, with the installation of the 36-inch outside diameter (OD), 0.375-inch wall thickness surface casing to a depth of 40 feet bls. A 40-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 40 feet bls. The annular space between the borehole and casing was pressure grouted with neat cement to pad level in one stage.

A 36-inch diameter borehole was drilled on October 9, 2001 to a depth of 139 feet bls using the mud-rotary drilling method. Due to the large amounts of sand encountered between 80 and 120 feet bls, a 32-inch OD intermediate casing was deemed necessary, set to 120 feet bls, and pressure grouted to surface.

Drilling of an 8-inch pilot hole commenced October 12, 2001. The pilot hole was drilled from the top of the neat cement at 119 feet bls and down to 351 feet bls. The following geophysical logs were performed in the pilot hole at this time: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. Following geophysical logging, the pilot hole was reamed with a 31-inch diameter bit to a depth of 350 feet bls. A steel, 26-inch OD casing, with a wall thickness of 0.375-inches was set to a depth of 345 feet bls. The annular space between the borehole and casing was pressure grouted to pad level in one stage, comprised of neat cement and 4 percent bentonite.

The 8-inch pilot hole drilling operations were resumed October 23, 2001 using reverse-air drilling methods. The pilot hole was drilled from the top of the neat cement, at a depth of 335 feet bls and down to 800 feet bls. While drilling on reverse air, specific capacity tests were performed and a water sample was taken, for water quality analysis, at 30-foot intervals. These specific capacity tests were performed by measuring the drawdown in the well and the discharge rate during reverse-air drilling. The discharge rate during these tests was typically 150-200 gpm. The specific capacity valves are expressed in units of gallons per minute per foot of drawdown. The results of these tests and analyses are presented in **Appendix H.** On November 6, 2001 a core was taken from 760 to 780 feet bls, of which 43 percent was recovered. The following geophysical logs were run at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic and caliper. The pilot hole was then reamed with a nominal 25-inch diameter reaming assembly from 350 to 785 feet bls.

A caliper log was performed prior to insertion of the final 17.4-inch OD final casing that was set and cemented into place November 30, 2001, to a depth of 780 feet bls. This casing was grouted in four stages. The first stage consisted of neat cement and the following three stages were composed of 4 percent gel cement. The first stage of cement was pressure grouted with neat cement followed by three additional stages of cement of 4 percent bentonite which were cemented by tremie into the annulus.

The final 15-inch borehole was drilled to a total depth of 998 feet bls from December 5, 2001 to December 17, 2001.

Upon completion of the drilling operations, the drilling rig was laid down and moved away from the pad. A temporary pump was installed and pump development was performed on the well from January 23, 2002 to January 28, 2002. A step-drawdown pump test was performed February 5, 2002. Final geophysical logs were run for the interval 780 to 998 feet bls February 8, 2002. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic, and caliper.

A constant rate pump test was performed on the entire ASR system from February 28 to March 5, 2002 and its effects were monitored in ASR-2. Finally, an additional video log was performed on March 20, 2002.

As required by the FDEP Class V Well Construction Permit, daily construction records were kept during the construction and testing of the ASR-2 (**Appendix C**).

Overview

Construction of ASR-2 began October 1, 2001. The sequence of drilling and testing of ASR-2 was as follows:

1. A 36-inch OD steel surface casing was set to 40 feet bls.
2. A 35-inch diameter borehole was drilled to a depth of 139 feet bls.
3. A 32-inch OD steel intermediate casing was set to 120 feet bls.
4. An 8-inch diameter pilot hole was drilled to a depth of 351 feet bls using mud rotary drilling techniques.
5. The pilot hole was geophysically logged.
6. The pilot hole was reamed to a nominal 31-inch diameter to 350 feet bls using mud-rotary drilling techniques.
7. A caliper log was performed on the reamed borehole.
8. A 26-inch OD steel casing was set and cemented into the reamed borehole.
9. An 8-inch diameter pilot hole was drilled to a depth of 760 feet bls using reverse-air drilling techniques.
10. A core barrel was installed on the drilling rod and a core was taken from depth of 760 to 780 feet bls.
11. The 8-inch diameter pilot hole was continued to a depth of 800 feet bls.
12. The pilot hole was geophysically logged.
13. The pilot hole was reamed to a nominal 25-inch diameter borehole, using reverse-air drilling techniques, to a depth of 785 feet bls.
14. A caliper log was performed on the reamed borehole.
15. A 17.4-inch OD SDR 17 PVC final casing was cemented in the reamed hole to a depth of 780 feet bls.
16. The cement plug at the bottom of the casing was drilled out and a nominal 15-inch diameter final borehole was drilled using reverse-air drilling techniques to a depth of 998 feet bls.
17. The final borehole was developed and geophysically logged.
18. A step-drawdown was conducted and the well was monitored during the constant rate test of the entire ASR system.

ASR-3 WELL CONSTRUCTION

Construction Summary

The following paragraphs summarize the construction of ASR-3. A well construction diagram for the completed ASR-3 is presented as **Figure 3-4**, a summary of the casing is summarized in **Table 3-3,** and a list of the geophysical logs that were run are listed in **Table 3-4**.

Table 3-3
ASR-3 Casing Summary

Casing Name and Setting depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 37 feet	36	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 140 feet	32	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 350 feet	26	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 810 feet	17.4	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-4
ASR-3 Geophysical Logging Summary

Interval (feet bls)	Hole Type	Logs Run
0 to 350	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
0 to 354	Reamed	Caliper log
350 to 810 810 to 1000	Pilot and Completed	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)
350 to 810	Cased	Temperature Log
810 to 1000	Completed	XY caliper Video

Construction of ASR-3 began on the morning of October 5, 2001, with the installation of the 36-inch OD, 0.375-inch wall thickness surface casing. A 40-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 39 feet bls. The annular space between the borehole and casing was pressure grouted with neat cement to pad level in one stage.

An additional 36-inch borehole was drilled on October 10, 2001 to a depth of 140 feet bls using mud-rotary drilling methods. Due to a large thickness of sand encountered between 80 and 120 feet bls a 32-inch OD intermediate casing was deemed necessary, set to 140 feet bls and pressure grouted to surface.

Drilling of the 8-inch pilot hole commenced October 16, 2001. The pilot hole was drilled from the top of the neat cement at 140 feet bls and down to 350 feet bls. The following geophysical logs were performed in the pilot hole: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. After geophysical logging, the pilot hole was reamed with a nominal 31-inch diameter bit to a depth of 354 feet bls. A steel, 26-inch OD, 0.375-inch wall thickness, casing was set to a depth of 350 feet bls. The annular space between the borehole and casing was pressure grouted to pad level in one stage comprised of neat cement and 4 percent bentonite.

The 8-inch pilot hole drilling operations were resumed November 6, 2001, using reverse-air drilling methods. The pilot hole was drilled from the top of the neat cement, at a depth at 345 feet bls and down to 810 feet bls. Specific capacity tests were performed and a water sample was taken for water quality analysis every 30 feet throughout this range to the total depth of the well (1000 feet bls). The results of these tests and analyses are presented in **Appendix H.** On November 14, 2001 a core was taken from 763 to 782 feet bls, of which 16 percent was recovered. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic and caliper. The pilot hole was reamed with a nominal 25-inch diameter reaming assembly from 350 to 815 feet bls. A caliper log was performed prior to insertion of the 17.4-inch PVC casing to 810 feet bls on December 12, 2001. The first stage of cement was pressure grouted with neat cement in the bottom followed by four additional stages of cement with 4 percent bentonite, cemented by tremie, into the annulus.

The 15-inch borehole was drilled from December 21, 2001 to January 3, 2001, to a total depth of 1000 feet bls. Final geophysical logs were performed for the interval 800 to 998 feet bls on January 8, 2002. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic and caliper.

Upon completion of the drilling operations, the drilling rig was laid down and moved away from the pad. A temporary pump was installed and pump development was performed on the well from January 14, 2002 to January 24, 2002. A step-drawdown pump test was performed January 31, 2002. The final caliper and video logs were performed February 6, 2002. A constant rate pump test was performed on this well from February 28 to March 5, 2002 and its effects were monitored.

As required by the FDEP Class V Well Construction Permit, daily construction records were kept during the construction and testing of the ASR well. These records are contained in **Appendix C.**

Overview

Construction of ASR-3 began on October 5, 2001. The sequence of drilling and testing of the ASR well was as follows:

1. A 36-inch OD steel surface casing was set to 37 feet bls.
2. A 35-inch diameter borehole was drilled to a depth of 140 feet bls.
3. A 32-inch OD steel intermediate casing was set to 140 feet bls.
4. An 8-inch diameter pilot hole was drilled to a depth of 350 feet bls using mud-rotary drilling techniques.
5. The pilot hole was geophysically logged.
6. The pilot hole was reamed to a nominal 31-inch diameter borehole to 354 feet bls using mud-rotary drilling techniques.
7. A caliper log was performed on the reamed borehole.
8. A 26-inch OD steel casing was cemented in the reamed borehole.
9. An 8-inch diameter pilot hole was drilled to a depth of 763 feet using reverse-air drilling techniques.
10. A core barrel was installed on the drilling rod and a core was taken from a depth of 763 to 782 feet bls.
11. The 8-inch diameter pilot hole was continued to a depth of 810 feet bls.
12. The pilot hole was geophysically logged.
13. The pilot hole was reamed to a nominal 25-inch diameter borehole using reverse-air drilling techniques to 815 feet bls.
14. A caliper log was performed on the reamed borehole.
15. A 17.4-inch OD SDR 17 PVC final casing was cemented in the reamed hole to 810 feet bls.
19. The cement plug at the bottom of the casing was drilled out and a nominal 15-inch diameter final borehole was drilled using reverse-air drilling techniques to a depth of 1000 feet bls.
20. The final borehole was developed and geophysically logged.
21. Both a step-drawdown test and a constant rate test were conducted on the well and completed March 13, 2002.

ASR-4 & ASR-4r WELL CONSTRUCTION

ASR 4 Construction Summary

Due to drilling complications, ASR-4 was drilled and abandoned before completion. A well plug and abandonment detail is presented as **Figure 3-5**. The details of construction for ASR-4 are approximately the same as those for the completed Well ASR-4r. The following is a summary of the events that occurred during ASR-4's construction and abandonment.

Drilling began on the morning of August 29, 2001, with the installation of the surface casing. A 40-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 41 feet bls. A 36-inch OD, 0.375-inch wall thickness surface casing was set to 40 feet bls. The annular space between the borehole and casing was pressure grouted with neat cement to pad level in one stage.

Drilling of the 8-inch pilot hole commenced August 31, 2001 and continued to a depth of 342 feet bls. The following geophysical logs were performed in the pilot hole at this time: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. Following geophysical logging, the pilot hole was reamed with a nominal 31-inch diameter bit to a depth of 128 feet bls. Due to a large occurrence of sand from 80 to 120 feet bls drilling slowed to a halt. Subsidence began to occur around the well, which spurred an attempt to stabilize ASR-4 with cement. These efforts were unsuccessful and the well was abandoned.

The drill rig was moved onto the site of ASR-4r, which was planned and drilled for use as a replacement for the unsuccessfully constructed ASR-4. Upon completion of the drilling operations on ASR-4r, the drilling rig returned to ASR-4 and the pilot hole was re-drilled to a depth of 340 feet. Final grouting of the abandoned ASR-4 was performed in one stage, to surface, February 4, 2002. The top of the well casing was cut off below land surface and buried.

ASR-4r Construction Summary

The following paragraphs summarize the construction of ASR-4r. A well construction diagram for the completed ASR-4r is presented as **Figure 3-6**, a summary of the casing is summarized in **Table 3-5,** and a list of the geophysical logs that were run are listed in **Table 3-6**.

Table 3-5
ASR-4 & ASR-4r Casing Summary

Casing Name and Setting Depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 40, 37 feet	36	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 124 feet	32	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 350 feet	26	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 800 feet	17.4	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-6
ASR-4 & ASR-4r Geophysical Logging Summary

Interval (feet bls)	Hole Type	Logs Run
0 to 342 (ASR-4) 0 to 350 (ASR-4r)	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
0 to 350	Reamed	Caliper log
350 to 800 800 to 1026	Pilot and Completed	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)
350 to 800	Cased	Temperature Log
800 to 1026	Completed	XY caliper Video

Drilling of ASR-4r, began on the morning of December 4, 2001, with the installation of surface casing. A 40-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 40 feet bls. A 36-inch OD, 0.375-inch wall thickness, surface casing was set to 36 feet bls. The annular space between the borehole and casing was pressure grouted with neat cement to pad level in one stage.

The 36-inch borehole was drilled December 6, 2001 to a depth of 137 feet bls. Due to the sand layer encountered between 80 and 120 feet bls a 32-inch, OD intermediate casing was deemed necessary, set at 124 feet bls and pressure grouted. A second stage of neat cement was necessary to bring the grouting to surface.

Drilling of the 8-inch pilot hole commenced December 10, 2001. The pilot hole was drilled from the top of the neat cement at 124 feet bls to depth of 350 feet bls. The following geophysical logs were performed in the pilot hole at this time: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. Following geophysical logging, the pilot hole was reamed with a nominal 31-inch diameter bit to a depth of 350 feet bls. A caliper log was then performed. A steel 26-inch OD, 0.375-inch wall thickness casing was set to a depth of 350 feet bls. The annular space between the borehole and casing was pressure grouted to pad level in one stage comprised of neat cement with 4 percent bentonite.

The 8-inch pilot hole drilling operations were resumed on December 26, 2001 using reverse-air drilling methods. The pilot hole was drilled from the top of the neat cement, at a depth of 340 feet bls to a depth of 810 feet bls. While drilling on reverse-air, a specific capacity test was performed and a water sample was taken for water quality analysis every 30 feet. The results of these tests and analyses are presented in **Appendix H.** On January 9, 2002 a core was taken from 760 to 780 feet of which 13 percent was recovered. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic and caliper. The pilot hole was then reamed with a nominal 25-inch diameter reaming assembly from 340 to 805 feet bls. A caliper log was performed prior to insertion of the 17.4-inch OD PVC casing to 800 feet bls January 21, 2002. The first stage of cement was pressure grouted with neat cement in the bottom followed by four additional stages of cement with 4 percent bentonice cemented by tremie into the annulus.

The final 15-inch borehole was drilled from December 21, 2001 to January 3, 2001 to a total depth of 1026 feet bls. Final geophysical logs were performed for the interval 800 to 1026 feet bls on January 30, 2002. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic, and caliper.

A temporary pump was installed and pump development was executed on ASR-4r from February 6, 2002 to February 11, 2002. A step-drawdown pump test was performed on February 13, 2002. The final caliper and video log were run on March 14, 2002. A constant rate pump test was performed on the entire ASR system from February 28, 2002 to March 5, 2002 and its effects were monitored from this well.

As required by the FDEP Class V Well Construction Permit, daily construction records were kept during the construction and testing of the ASR well. These records are contained in **Appendix C**

Overview

Construction of ASR-4 began on September 4, 2001. Upon abandonment, the construction of ASR-4r started December 4, 2001. The sequence of drilling and testing of the ASR wells was as follows:

1. A 36-inch OD steel surface casing was set to 36 feet bls in ASR-4.
2. An 8-inch diameter pilot hole was drilled to a depth of 342 feet bls using mud-rotary drilling techniques.
3. The ASR-4 pilot hole was geophysically logged.
4. The ASR-4 pilot hole was reamed to a nominal 31-inch diameter borehole to 128 feet bls using mud-rotary drilling techniques. Subsidence occurs around ASR-4.
5. A caliper log was performed on the reamed ASR-4 borehole.
6. ASR-4 is abandoned.
7. New location determined for ASR-4r.
8. A 36-inch OD steel surface casing was set to 37 feet bls in ASR-4r.
9. A 35-inch diameter borehole was drilled to a depth of 137 feet bls.
10. A 32-inch OD steel intermediate casing was set to 124 feet bls.
11. An 8-inch diameter pilot hole was drilled to a depth of 350 feet bls using mud-rotary drilling techniques.
12. The ASR-4r pilot hole was geophysically logged.
13. The ASR-4r pilot hole was reamed to a nominal 31-inch diameter borehole to a depth of 350 feet bls using mud-rotary drilling techniques.
14. A caliper log was performed on the reamed ASR-4r borehole.
15. A 26-inch OD steel casing was cemented in the reamed ASR-4r borehole.
16. An 8-inch diameter pilot hole was drilled to a depth of 760 feet bls using reverse-air drilling techniques.
17. A core barrel was installed on the drilling rod and a core was taken at a depth of 780 feet bls in ASR-4r.
18. The 8-inch diameter pilot hole was continued to a depth of 805 feet bls.
19. The ASR-4r pilot hole was geophysically logged.
20. The ASR-4r pilot hole was reamed to a nominal 25-inch diameter borehole using reverse-air drilling techniques to a depth of 800 feet bls.
21. A caliper log was performed on the reamed ASR-4r borehole.

22. A 17.4-inch OD SDR 17 PVC final casing was cemented in the reamed hole to 800 feet bls in ASR-4r.
22. The cement plug at the bottom of the casing of ASR-4 was drilled out and a nominal 15-inch diameter final borehole was drilled using reverse-air drilling techniques to a depth of 1026 feet bls.
23. The final ASR-4r borehole was geophysically logged.
24. ASR-4 was grouted and abandoned.
25. The final ASR-4r borehole was developed.
26. Both a step-drawdown test and a constant rate test were conducted on ASR-4r and completed February 28, 2002.
27. The final caliper and video logs were performed on ASR-4r, March 14, 2002

GENERALIZED SZMW-1 and SZMW-1r WELL CONSTRUCTION METHODS

SZMW-1 was begun and subsequently plugged and abandoned due to the loss of a bit and drilling rods at the bottom of the hole. SZMW-1r was constructed as a replacement. SZMW-1 and SZMW-1r were constructed to have slightly different dimensions than each of the ASR wells and SZMW-2. Below is a summary of generalized construction details that pertain to both SZMW-1 and SZMW-1r. See **Figure 3-7** for the plug and abandonment details of SZMW-1 and see **Figure 3-8** for the specific construction details of SZMW-1r.

Construction Methods

Drilling

SZMW-1 was initially drilled using mud-rotary drilling methods to a depth of approximately 354 feet bls. The drilling rig then was configured for reverse-air drilling methods. This second drilling method was used to drill to the total depth of 803 feet bls. Alternatively, SZMW-1r was drilled using mud-rotary drilling methods for the entire hole from surface to total depth of 815 feet bls. Deviation surveys (sure shots) of the pilot boreholes and reamed boreholes were conducted approximately every 60 feet of drilling to track hole straightness and are presented in **Appendix D.**

Casing

All casings in SZMW-1 and SZMW-1r were centralized in the borehole using strap-type centralizers. The first group at the bottom of the casing, the second across the first joint, one group every 100 feet and the final group within 30 feet of the surface. Each group consists of a centralizer at 0, 90, 180, and 270 degrees around the casing.

The surface casing for both wells is 24-inch OD, 0.375-inch wall thickness, seamless, steel casing, that conforms to the standards of API 5L Grade B. The surface casing was set and cemented to a depth of approximately 40 feet bls.

The intermediate casing is a 16-inch OD, 0.375-inch wall thickness, seamless, steel casing, that conforms to the standards of API 5L Grade B. The intermediate casing was set and cemented to a depth of approximately 350 feet bls.

The final casing is 8.625-inch OD, SDR 17 PVC casing, which conforms to the standards defined in ASTM D1784. The final casing was set and cemented to a depth of 780 feet bls in SZMW-1 and 764 feet in SZMW-1r. Casing joints were affixed using a spline and groove manufactured joint system. The mill certifications for the casing used in the construction of the wells are found in **Appendix E**.

Welding

The factory beveled ends of the casings and tubing were arc welded by certified pipeline welders to standard pipeline certifications. They were welded with three welding passes.

Cementing

Casing was cemented using ASTM C 150, Type II sulfate-resistant cement. Cement mixed with four percent bentonite gel was used for the upper portion of the final casing. Neat cement was used to cement the surface casing, intermediate casings and for the lower 70 feet of the final casing.

The cementing of the final casing was completed in six stages. The first stage was pressure-grouted through a tremie pipe located inside the fluid-filled casing, near the bottom of the open hole. The remaining stages were cemented with a tremie pipe in the annulus. After each stage of cementing, the top of cement was located physically (tagged) with a tremie pipe, and by performing a temperature/gamma ray log inside the casing. This temperature log was conducted at least 5 to 8 hours after completion of each cement stage. A temperature/gamma ray log was not performed after the cement could be seen from the top of the casing.

Geophysical Logging

The geophysical logging results from SZMW-1 and SZMW-1r are presented in **Appendix I**.

Construction Summary of SZMW-1

The following paragraphs summarize the construction of SZMW-1. A plug and abandonment detail for SZMW-1 is presented as **Figure 3-7**, the casing is summarized in **Table 3-7,** and a list of the geophysical logs that were run is in **Table 3-8**.

Table 3-7
SZMW-1 & SZMW-1r Casing Summary

Casing Name and Setting Depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 40 feet	24	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 350 feet	16	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 780,764 feet	8.625	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-8
SZMW-1 Geophysical Logging Summary

Interval (feet bls)	Hole Type	Logs Run
0 to 350	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
0 to 354	Reamed	Caliper log
350 to 803	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)
350 to 800	Cased	Temperature Log

Drilling of SZMW-1 began on the morning of December 5, 2001, with the installation of surface casing. A 32-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 45 feet bls. A 24-inch OD, 0.375-inch wall thickness surface casing was set to 40 feet bls. The annular space between the borehole and casing was pressure grouted with neat cement to pad level in one stage.

Drilling of the 8-inch pilot hole commenced December 11, 2001. The pilot hole was drilled from the top of the neat cement at 40 feet bls to a depth of 350 feet bls. The following geophysical logs were performed in the pilot hole at this time: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. Following geophysical logging, the pilot hole was reamed with a nominal 23-inch diameter bit to a depth of 350 feet bls. A steel 16-inch OD, 0.375-inch wall thickness casing was set to a depth of 350 feet bls. The annular space was pressure grouted to pad level in one stage comprised of neat cement.

The 8-inch pilot hole drilling operations were resumed January 16, 2002, using reverse-air drilling methods. The pilot hole was drilled from the top of the neat cement, at a depth of 344-feet bls, to a depth of 803 feet bls. A specific capacity test was performed and a water sample was taken for water quality analysis every 30 feet, while drilling on reverse-air. The results of these tests and analyses are presented in **Appendix H**. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic, and caliper. The pilot hole was then reamed with a nominal 15-inch diameter reaming assembly from 344 to 785 feet bls. A caliper log was performed prior to insertion of the 17.4-inch OD PVC casing to 780 feet bls January 31, 2002. The casing was cemented in place in seven stages. The first stage of cement was pressure grouted with neat cement in the bottom followed by six additional stages of cement with 4 percent bentonite cemented by tremie into the annulus.

February 12, 2002, after drilling to a depth of 794 feet bls, the rod twisted off, causing the drill bit and three drilling rods to be permanently lost at the bottom of the hole. As a result of the lost tools, the well was abandoned February 15, and the rig was moved to a new location, 40 feet to the west, where SZMW-1r was planned to be drilled.

Construction Summary of SZMW-1r

The following paragraphs summarize the construction of SZMW-1r. A well construction diagram for the completed ASR is presented as **Figure 3-8**, a summary of the casing is in **Table 3-9,** and a list of the geophysical logs that were run are listed in **Table 3-10**.

Table 3-9
SZMW-1 & SZMW-1r Casing Summary

Casing Name and Setting Depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 40 feet	24	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 350 feet	16	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 780,764 feet	8.625	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-10
SZMW-1 Geophysical Logging Summary

Interval (ft bls)	Hole Type	Logs Run
0 to 350	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
0 to 354	Reamed	Caliper log
350 to 803	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)
350 to 800	Cased	Temperature Log

Drilling of SZMW-1r began on the morning of February 15, 2002, with the installation of surface casing. A 32-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 42 feet bls. A 24-inch OD, 0.375-inch wall thickness, surface casing was set to 40 feet bls. The annular space was pressure grouted with neat cement to pad level in one stage.

Drilling of the 23-inch diameter nominal borehole commenced February 20, 2002. The borehole was drilled from the top of the neat cement at 40 feet bls to a depth of 355 feet bls. A steel 16-inch OD, 0.375-inch wall thickness, casing was set to a depth of 350 feet bls. The annular space between the borehole and casing was pressure grouted to pad level in one stage comprised of neat cement.

Drilling of the 15-inch diameter nominal borehole began February 21, 2002, using mud-rotary drilling methods. The pilot hole was drilled from the top of the neat cement at a depth of 350 feet bls, to a depth of 768 feet bls. A caliper log was performed, and verified a cavernous zone from 764 to 810 feet bls. This cavern had a diameter greater than the maximum reach of the caliper arms (51 inches) from 769 feet to 805 feet. The 8.625-inch OD, PVC casing was inserted to a depth of 764 feet bls and cemented into the 15-inch hole in six stages. All stages of cement were installed by tremie into the annulus. The first 70 feet consisted of neat cement and the remaining annulus was filled with a 4 percent bentonite mix.

A decision was made to stop drilling at this point. The cavernous zone, located between 764 to 810 feet bls, contained the water that is comparable to that injected into ASR-1. Final geophysical logs were not performed because the flow-rate of 2300 gpm made it difficult to insert the logging tools, and because a large loss of stored water from ASR-1 (currently undergoing cycle testing) would occur.

Upon completion of the drilling operations, the drilling rig was laid down and moved away from the pad. On March 22, 2002, a crane truck was mobilized to assist in plugging and abandonment grouting operations on SZMW-1. Tremie pipe was inserted to a depth of 726 feet bls. Grouting was completed to surface in one stage, after which the top of the well was trimmed below surface and buried.

As required by the FDEP Class V Well Construction Permit, daily construction records were kept during the construction and testing of SZMW1 and SZMW-1r. These records are contained in **Appendix C.**

Overview

Construction of SZMW-1 began on December 5, 2001. Construction of SZMW-1r began on February 15, 2002. The sequence of drilling and testing of SZMW-1 and SZMW-1r was as follows:

1. A 24-inch OD steel surface casing was set to 40 feet bls.
2. An 8-inch diameter pilot hole was drilled to a depth of 350 feet bls using mud-rotary drilling techniques.
3. The pilot hole was geophysically logged.
4. The pilot hole was reamed to a nominal 23-inch diameter borehole to 350 feet bls using mud-rotary drilling techniques.
5. A caliper log was performed on the reamed borehole.
6. A 16-inch diameter steel casing was cemented into the reamed borehole.
7. An 8-inch diameter pilot hole was drilled to a depth of 803 feet bls using reverse-air drilling techniques.
8. The pilot hole was geophysically logged.
9. The pilot hole was reamed to a nominal 15-inch diameter borehole using reverse-air techniques to 785 feet bls.
10. A caliper log was performed on the reamed borehole.
11. An 8.625-inch OD, SDR 17 PVC final casing was cemented in the reamed hole to 780 feet bls.
12. The 7-inch diameter final borehole was drilled to 794 feet bls.
13. The drill rod twisted off and the drill bit along with 90 feet of drilling rod were lost at the bottom of the hole

14. The well was abandoned. The drill rig was moved 40 feet west to SZMW-1r's location.
15. A 24-inch OD steel surface casing was set to 40 feet feet bls.
16. A 23-inch diameter hole was drilled to 350 feet bls.
17. A 16-inch OD steel casing was cemented in the reamed borehole.
18. A 15-inch diameter hole was drilled to 768 feet bls using mud rotary techniques where a cavern was encountered from 764 to 815 feet bls.
19. A caliper log was performed.
20. An 8.625-inch OD, SDR 17 PVC final casing was cemented in the reamed hole to 764 feet bls.

SZMW-2 WELL CONSTRUCTION

Construction Summary

The following paragraphs summarize the construction of SZMW-2. A well construction diagram for the completed ASR is presented as **Figure 3-9**, a summary of the casing is summarized in **Table 3-11,** and a list of the geophysical logs that were run are listed in **Table 3-12**.

Table 3-11
SZMW-2 Casing Summary

Casing Name and Setting Depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 40 feet	36	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 140 feet	32	0.375	Seamless Steel	API 5L, Grade B	Welded
Intermediate 350 feet	26	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 785 feet	17.4	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-12
SZMW-2 Geophysical Logging Summary

Interval (feet bls)	Hole Type	Logs Run
0 to 350	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
0 to 350	Reamed	Caliper log
350 to 790 790 to 1000	Pilot and Completed	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)
350 to 790	Cased	Temperature Log
790 to 1000	Completed	Video

Drilling of SZMW-2 began on the morning of January 9, 2002, with the installation of surface casing. A 40-inch diameter hole was drilled using mud-rotary drilling methods to a depth of 40 feet bls. A 36-inch OD, 0.375-inch wall thickness, surface casing was set to 40 feet bls. The annular space between the borehole and casing was pressure grouted with neat cement to pad level in one stage.

An additional 36-inch diameter borehole was drilled January 10, 2002, to a depth of 140 feet bls. Due to a large thickness of sand encountered between 80 and 120 feet bls a 32-inch intermediate casing was deemed necessary, set to 140 feet bls, and pressure grouted to surface.

Drilling of the 8-inch pilot hole commenced January 14, 2002. The pilot hole was drilled from the top of the neat cement at 134 feet bls to a depth of 350 feet bls. The following geophysical logs were performed in the pilot hole at this time: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. Following geophysical logging, the pilot hole was reamed with a nominal 31-inch diameter bit to a depth of 350 feet bls. A steel 26-inch OD, 0.375-inch wall thickness casing was set to a depth of 350 feet bls. The annular space between the borehole and casing was pressure grouted to pad level in one stage comprised of neat cement with 4 percent bentonite.

The 8-inch pilot hole drilling operations were resumed January 21, 2002, using reverse-air drilling methods. The pilot hole was drilled from the top of the neat cement, at a depth of 347 feet to a depth of 800 feet bls. A specific capacity test was performed and a water sample was taken for water quality analysis every 30 feet, during reverse-air drilling (347 to 1000 feet bls). The results of these tests and analyses are presented in **Appendix J.** The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic and caliper. The pilot hole was reamed with a nominal 25-inch diameter reaming assembly from 350 to 790 feet bls. A caliper log was performed prior to insertion of the 17.4-inch PVC casing to 785 feet bls February 7, 2002. The first stage of cement was pressure grouted with neat cement in the bottom, followed by four additional stages of cement with 4 percent bentonite cemented by tremie into the annulus.

Drilling of the final 15-inch borehole was continued February 15, 2002, to a total depth of 1000 feet bls. Final geophysical logs were performed for the interval 785 to 1000 feet bls February 18, 2002. The following geophysical logs were conducted at this time: static and dynamic temperature, static and dynamic fluid resistivity, static and dynamic flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic, caliper and video.

Upon completion of the drilling operations, the drilling rig was laid down and moved away from the pad. A constant rate pump test was performed on the site from February 28 to March 5, 2002, and its effects were monitored from SZMW-2.

As required by the FDEP Class V Well Construction Permit, daily construction records were kept during the construction and testing of SZMW-2. These records are contained in **Appendix C**.

Overview

Construction of SZMW-2 began January 9, 2002. The sequence of drilling and testing of SZMW-2 was as follows:

1. A 36-inch OD steel surface casing was set to 40 feet bls.
2. A 35-inch diameter borehole was drilled to a depth of 140 feet bls.
3. A 32-inch OD steel intermediate casing was set to 140 feet bls.
4. An 8-inch diameter pilot hole was drilled to a depth of 350 feet bls using mud-rotary drilling techniques.
5. The pilot hole was geophysically logged.
6. The pilot hole was reamed to a nominal 31-inch diameter borehole to a depth of 350 feet bls using mud-rotary drilling techniques.
7. A caliper log was performed on the reamed borehole.
8. A 26-inch OD steel casing was cemented in the reamed borehole.

9. An 8-inch OD pilot hole was drilled to a depth of 803 feet bls using reverse-air drilling techniques.
10. The pilot hole was geophysically logged.
11. The pilot hole was reamed to a nominal 25-inch diameter borehole using reverse-air drilling techniques to 790 feet bls.
12. A caliper log was performed on the reamed borehole.
13. A 17.4-inch diameter SDR 17 PVC final casing was cemented in the reamed hole to 785 feet bls.
14. The cement plug at the bottom of the casing was drilled out and a nominal 15-inch diameter final borehole was drilled using reverse-air techniques to a depth of 1000 feet.
15. The final borehole was developed and geophysically logged.
16. A step-drawdown test and monitoring during the constant rate test were conducted on the well.

IAMW-1 WELL CONSTRUCTION

Below is a summary of the generalized construction details for IAMW-1. See **Figure 3-10** for the construction details of IAMW-1.

Construction Methods

Drilling

IAMW-1 was drilled initially using mud-rotary drilling methods to a depth of 350 feet bls. The drilling rig then was configured for reverse-air drilling methods. This second method was used to drill to the bottom of the well at 400 feet bls.

Casing

All casings in IAMW-1 were centralized in the borehole using strap-type centralizers. The first group at the bottom of the casing, the second group across the first joint, one group every 100 feet and the final group within 30 feet of the surface. Each group consists of a centralizer at 0, 90, 180, and 270 degrees around the casing.

Surface casing was 16-inch OD, 0.375-inch wall thickness, seamless steel casing, conforming to the standards of API 5L Grade B. The surface casing was set and cemented to a depth of 40 feet bls in the monitor well.

The final IAMW-1 casing was 8.625-inch OD, SDR 17 PVC casing, conforming to the standards defined in ASTM D1784. This casing was set and cemented to a depth of 810 feet bls in IAMW-1. Casing joints were affixed using a spline and groove manufactured joint system. The mill certifications for the casing used in the construction of IAMW-1 are found in **Appendix E**.

Cementing

Casing was cemented using ASTM C 150, Type II sulfate-resistant cement. Four percent bentonite gel was used for the upper portion of the final casing. Neat cement was used to cement the surface casing and for the lower 70 feet of the final casing.

Cementing of the final casing was completed in two stages. The first stage was pressure-grouted through a tremie pipe located inside the fluid-filled casing, near the bottom of the open hole. The remaining stage was cemented using a tremie pipe in the annulus.

Geophysical Logging

Geophysical logging results are presented in **Appendix I.**

Construction Summary

The following paragraphs summarize the construction of IAMW-1. The construction diagram for the completed well is presented as **Figure 3-10**, a summary of the casing is in **Table 3-13,** and a list of the geophysical logs that were run are listed in **Table 3-14.**

Table 3-13
IAMW-1 Casing Summary

Casing Name and Setting Depth (feet)	Outside Diameter (inches)	Wall Thickness (Inches)	Casing Type	Grade	Joint Connection
Surface 40 feet	16	0.375	Seamless Steel	API 5L, Grade B	Welded
Final 350 feet	8.625	SDR 17	PVC	ASTM D1784	Spline and groove

Table 3-14
IAMW-1 Geophysical Logging Summary

Interval (ft bls)	Hole Type	Logs Run
0 to 350	Pilot	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic
0 to 350	Reamed	Caliper log
350 to 400	Completed	XY caliper Natural Gamma Ray Electric (long and short normal) Spontaneous potential Borehole compensated sonic Fluid Resistivity (static and dynamic) Temperature (static and dynamic) Flow Meter (static and dynamic)

Drilling of IAMW-1 began on the morning of September 6, 2001, with the installation of the surface casing. A 24-inch diameter hole was drilled using mud-rotary drilling techniques to a depth of 41 feet bls. A 16-inch OD, 0.375-inch wall thickness, surface casing was set to 40 feet bls. The annular space was pressure grouted with neat cement to pad level in one stage.

Drilling of the 8-inch pilot hole commenced September 10, 2001. The pilot hole was drilled from the top of the neat cement at 40 feet bls to a depth of 350 feet bls. The following geophysical logs were performed in the pilot hole at this time: caliper, gamma ray, spontaneous potential, resistivity, and borehole compensated sonic. Following geophysical logging, the pilot hole was reamed with a nominal 15-inch diameter bit to a depth of 350 feet bls. An 8.625 inch OD, SDR 17 PVC final casing was then set to a depth of 345 feet bls. The annular was grouted in two stages. The first stage was pressure grouted and was comprised of neat cement and neat cement with bentonite. The second stage included 4 percent bentonite and was cemented into the annulus by a tremie pipe and pumped to surface.

The 7-inch diameter final borehole drilling operations commenced September 25, 2001, using reverse-air drilling methods. The pilot hole was drilled from the top of the neat cement, at a depth of 343 feet bls to a depth of 400 feet bls.

The following final geophysical logs were conducted March 20, 2002: temperature, fluid resistivity, flowmeter, resistivity, gamma ray, spontaneous potential, borehole compensated sonic and caliper.

Upon completion of the drilling operations, the drilling rig was laid down and moved away from the pad. A temporary pump was installed and pump development was performed on the well March 20, 2002. A constant rate pump test was run from February 28 to March 5, 2002 and its effects were monitored at this IAMW-1.

As required by the FDEP Class V Well Construction Permit, daily construction records were kept during the construction and testing of IAMW-1. These records are contained in **Appendix C.**

Overview

Construction of IAMW-1 began on September 6, 2001. The sequence of drilling and testing of the monitor well was as follows:

1. A 16-inch OD steel surface casing was set to 40 feet bls.
2. An 8-inch diameter pilot hole was drilled to a depth of 350 feet bls using mud-rotary drilling techniques.
3. The pilot hole was geophysically logged.
4. The pilot hole was reamed to a nominal 15-inch diameter borehole to a depth of 350 feet bls using mud-rotary drilling techniques.
5. A caliper log was performed on the reamed borehole.
6. An 8.625-inch OD, SDR 17 PVC final casing was cemented in the reamed hole to 350 feet bls.
7. The cement plug at the bottom of the casing was drilled out and a nominal 7-inch diameter final borehole was drilled using reverse-air drilling techniques to a depth of 400 feet bls.
8. A constant rate test was conducted on the entire ASR system February 28, 2002. The effects of this test were monitored in IAMW-1.
9. The final borehole was developed and geophysically logged March 20, 2002.

PERMANENT ASR FACILITIES CONSTRUCTION

Prior to cycle testing of the ASR expansion wells, permanent wellheads and facilities will be completed. A new ductile iron pipeline from the existing high service pumps to the ASR wells will be constructed to supply potable water for recharge at an approximate rate of 725 gallons per minute (gpm). The permanent ASR wellhead will be constructed of 8-inch diameter ductile iron pipe and valves. Flow metering will be accomplished using a venturi meter on the recharge and recovery lines. The flows will be recorded by a new strip-chart recorder located in the electrical room of the filter building. A permanent vertical turbine pump will be installed to pump approximately 725 gpm from the well during recovery. Water recovered from the well will be discharged to the Solids Contact Unit trough via a new ductile iron and PVC pipeline.

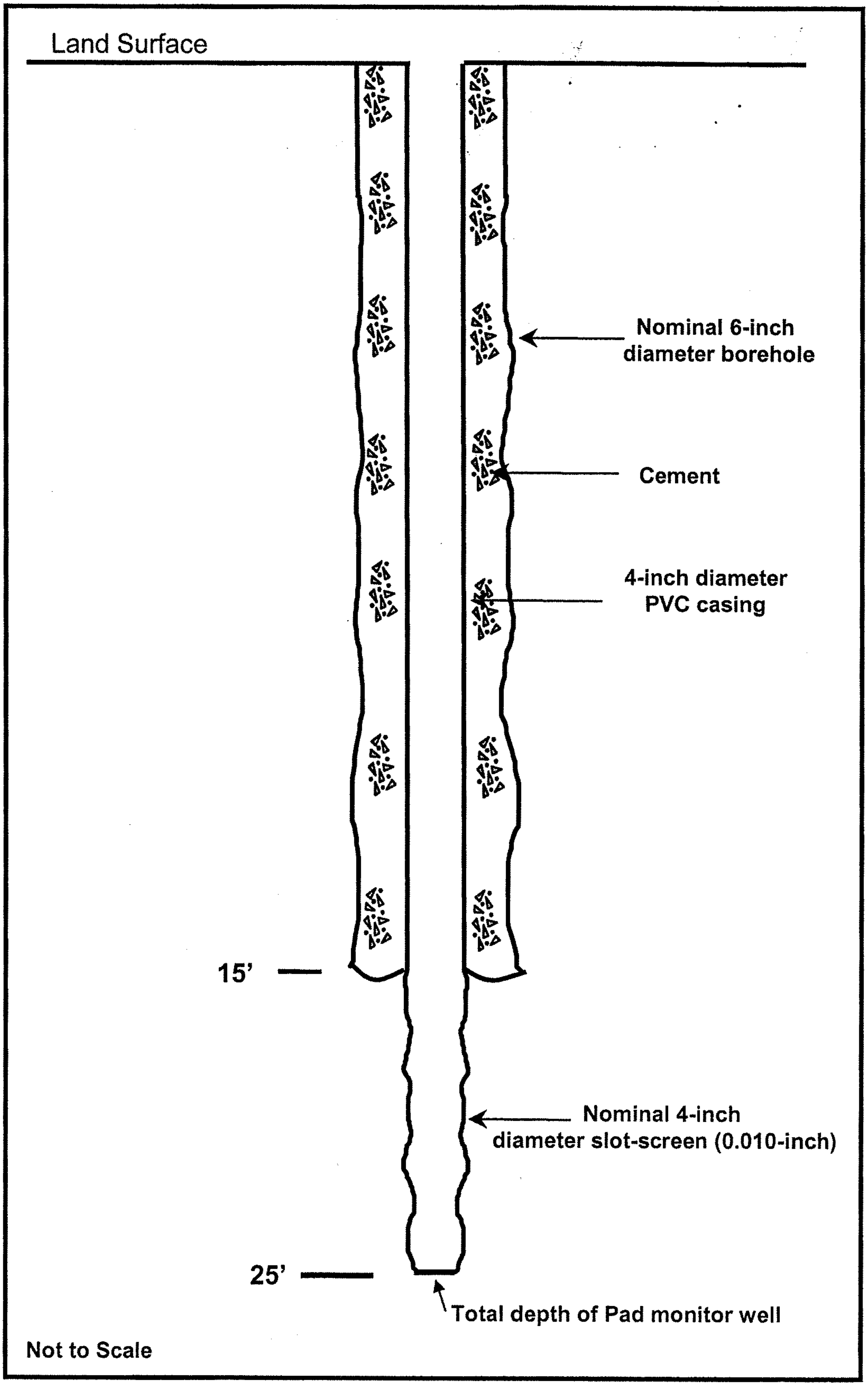
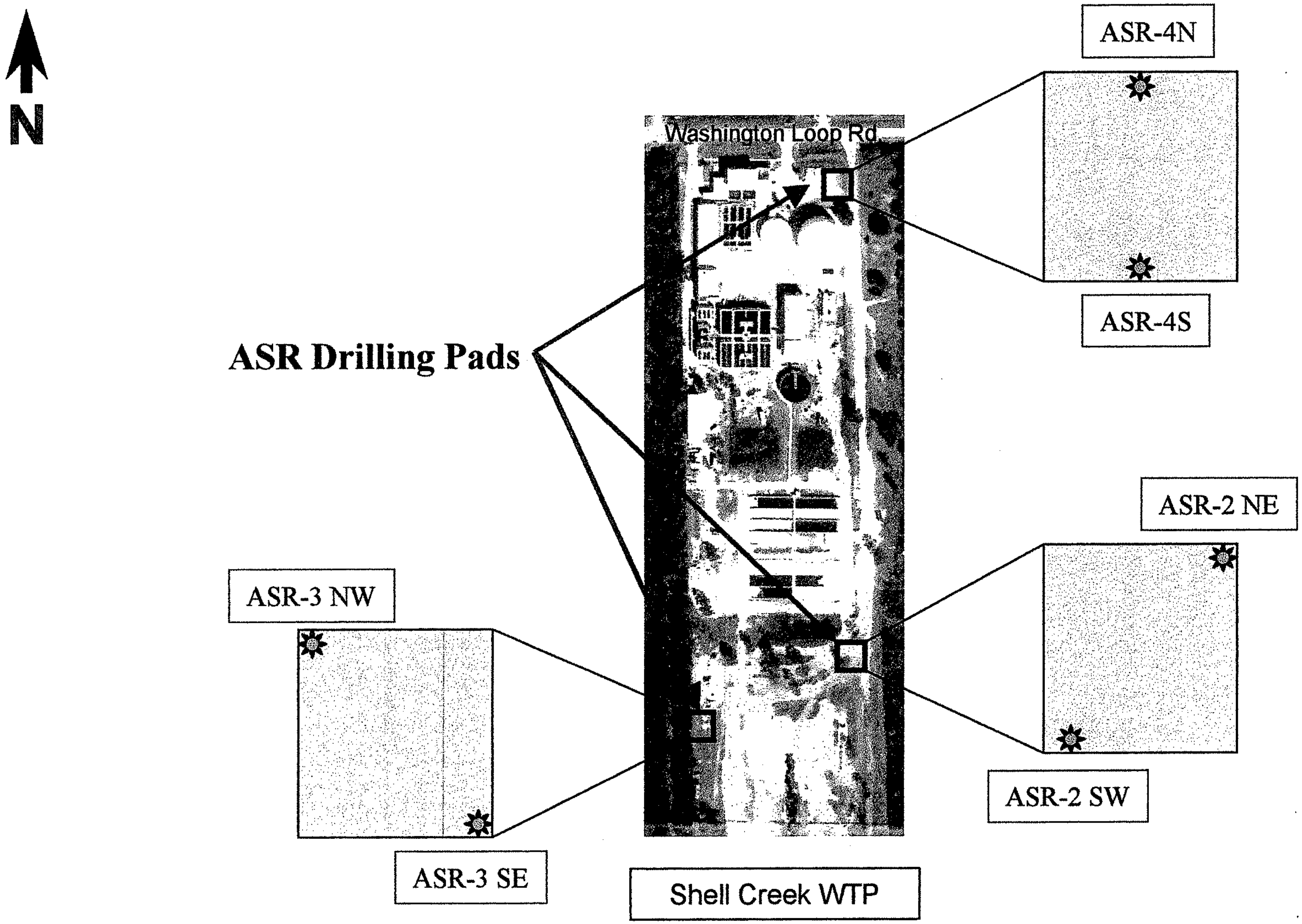


Figure 3-1
Pad Monitor Well Construction Details

MWH
MONTGOMERY WATSON HARZA



MWH
MONTGOMERY WATSON HARZA

Figure 3-2
Pad Monitor Well Location Map

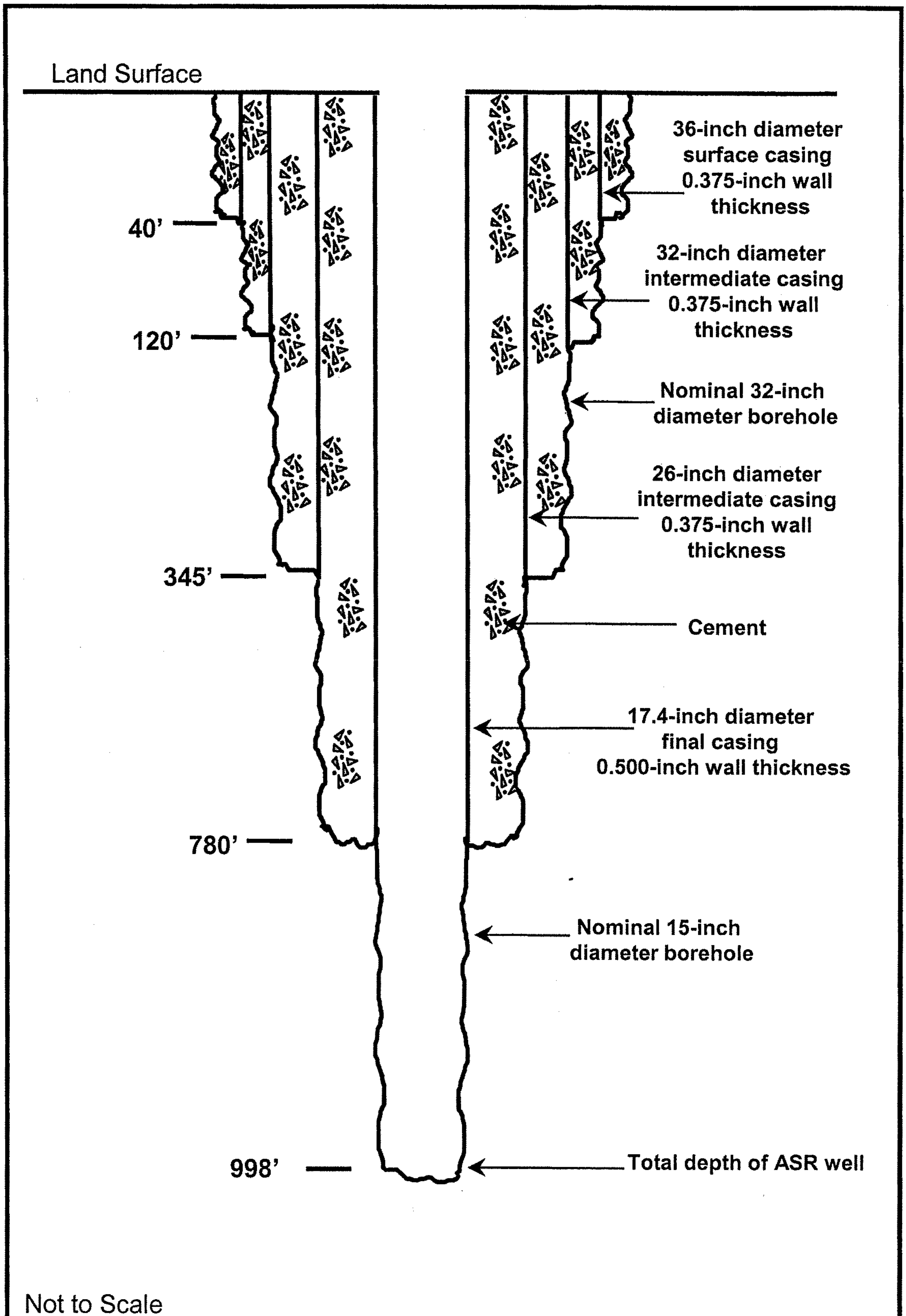


Figure 3-3
ASR-2 Construction Details

MWH
MONTGOMERY WATSON HARZA

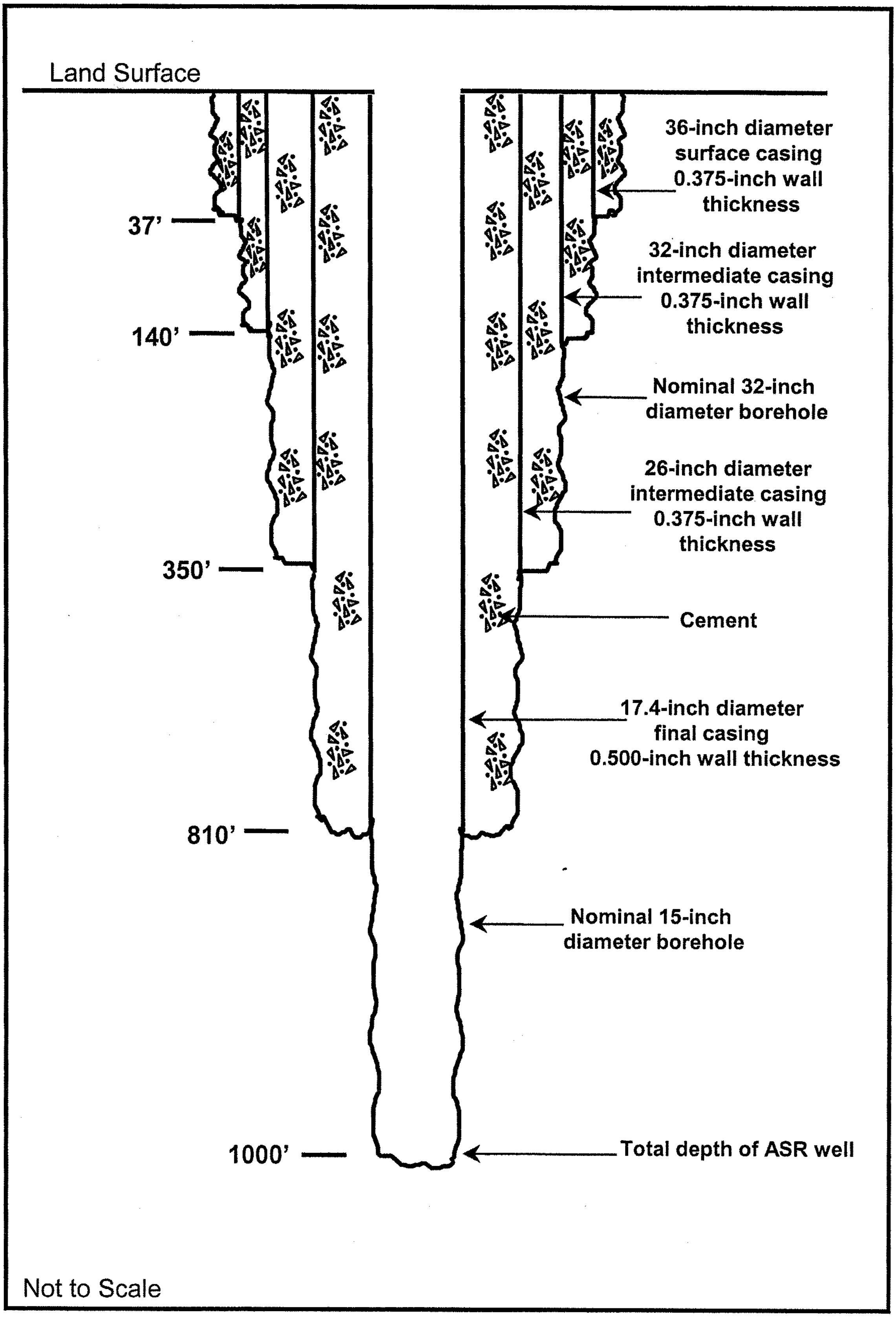


Figure 3-4
ASR-3 Construction Details

MWH
MONTGOMERY WATSON HARZA

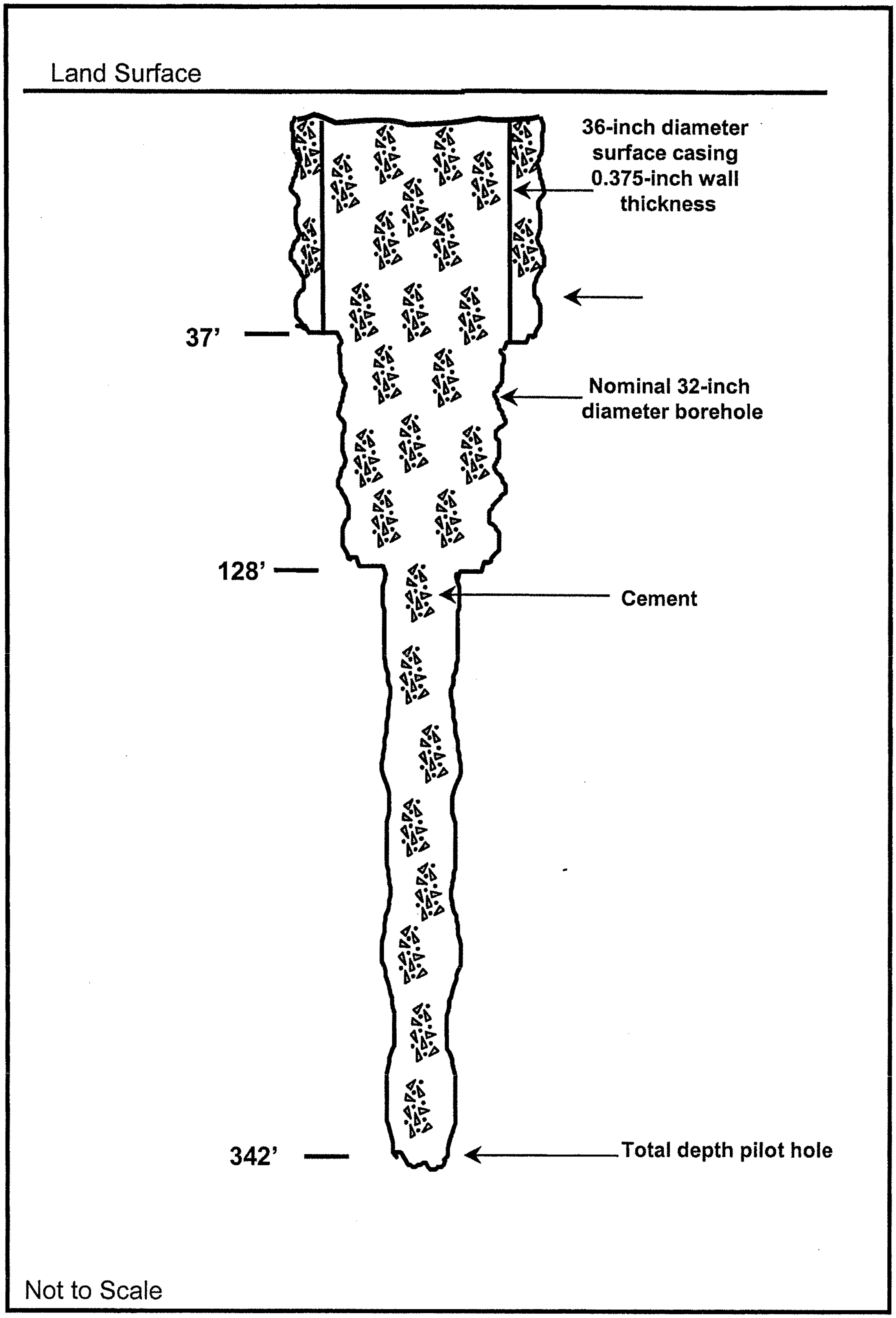


Figure 3-5
ASR-4 Plug and Abandonment Details

MWH
MONTGOMERY WATSON HARZA

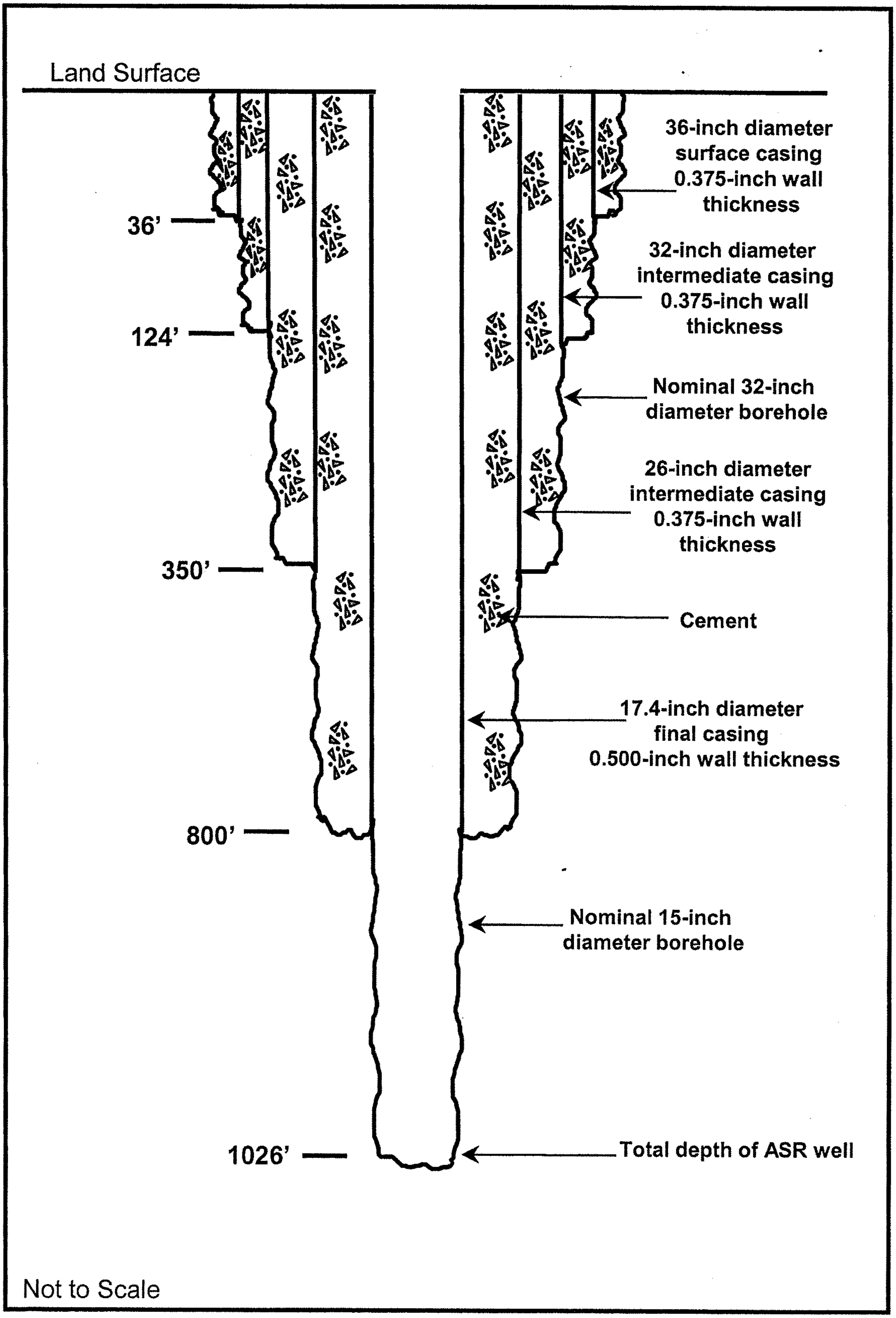


Figure 3-6
ASR-4r Construction Details

MWH
MONTGOMERY WATSON HARZA

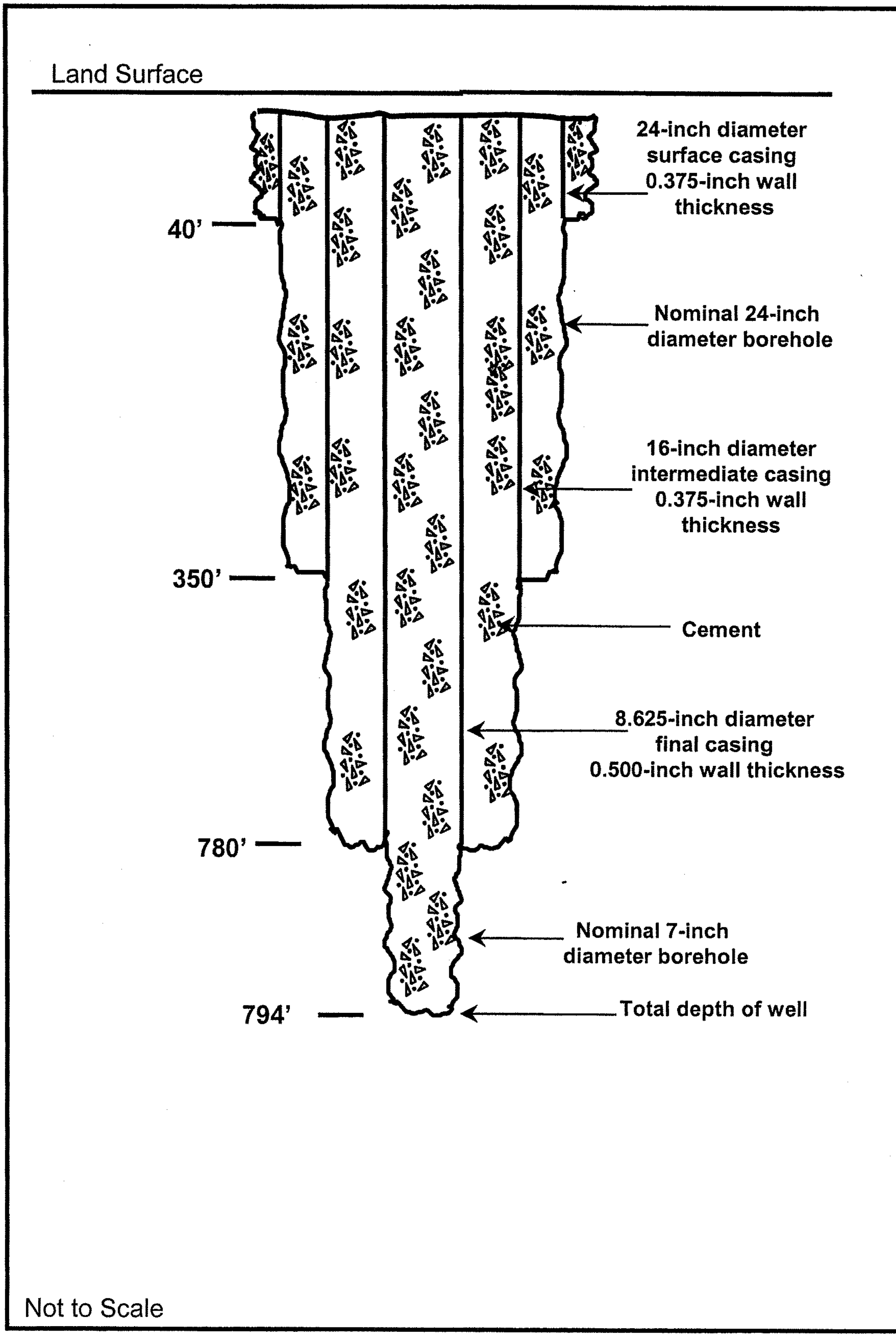


Figure 3-7
SZMW-1 Plug and Abandonment Details

MWH
MONTGOMERY WATSON HARZA

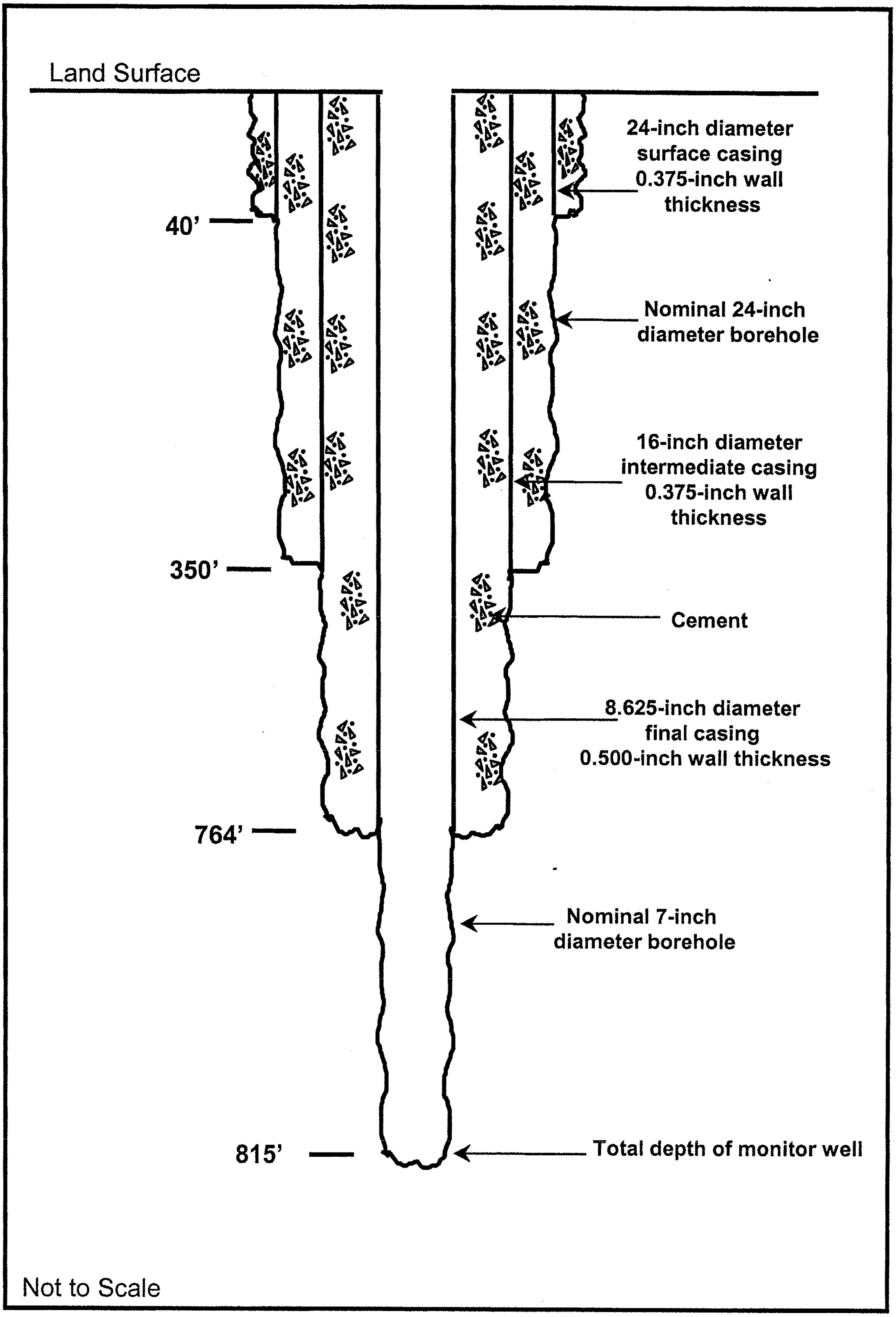


Figure 3-8
SZMW-1r Construction Details

MWH
MONTGOMERY WATSON HARZA

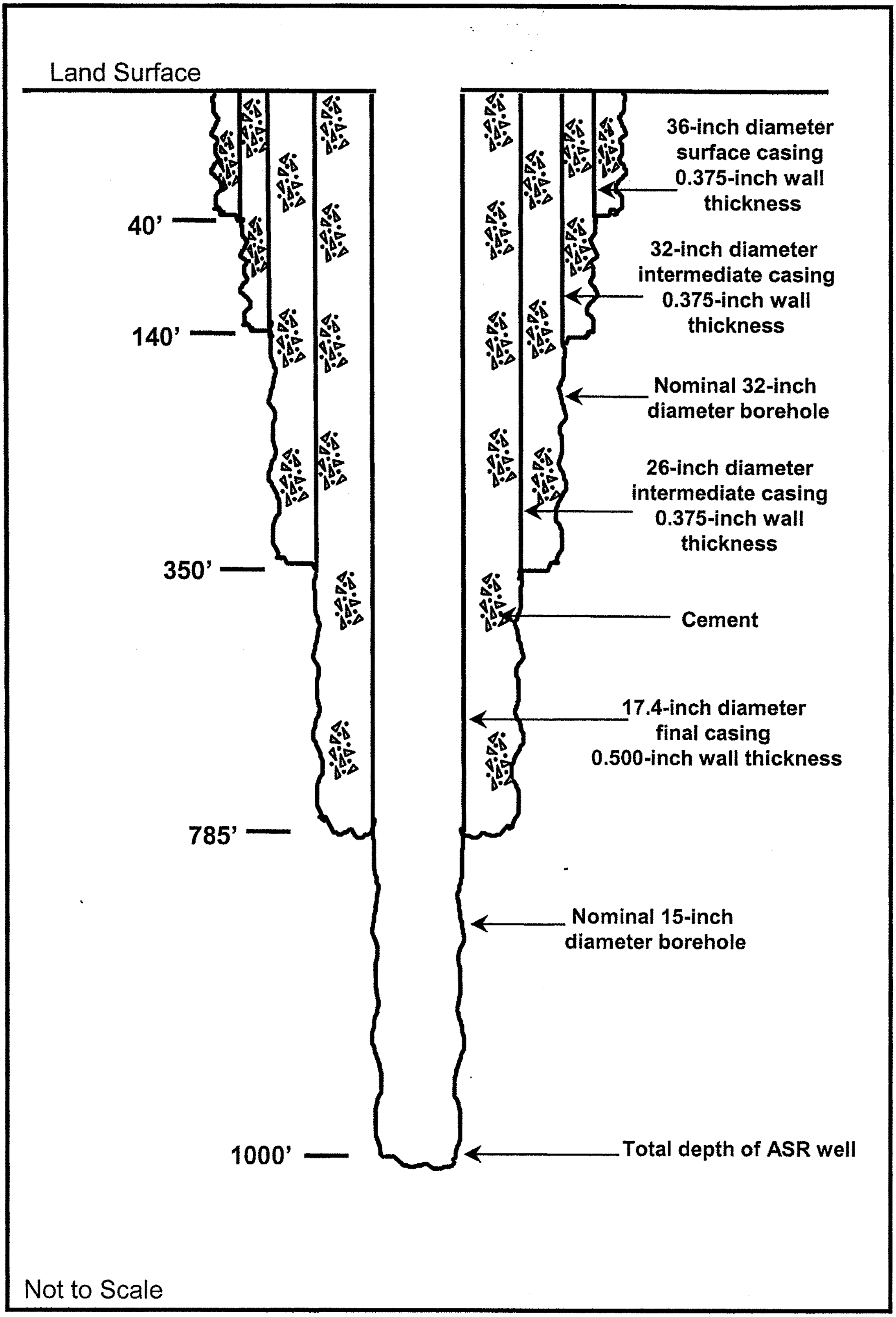


Figure 3-9
SZMW-2 Construction Details

MWH
MONTGOMERY WATSON HARZA

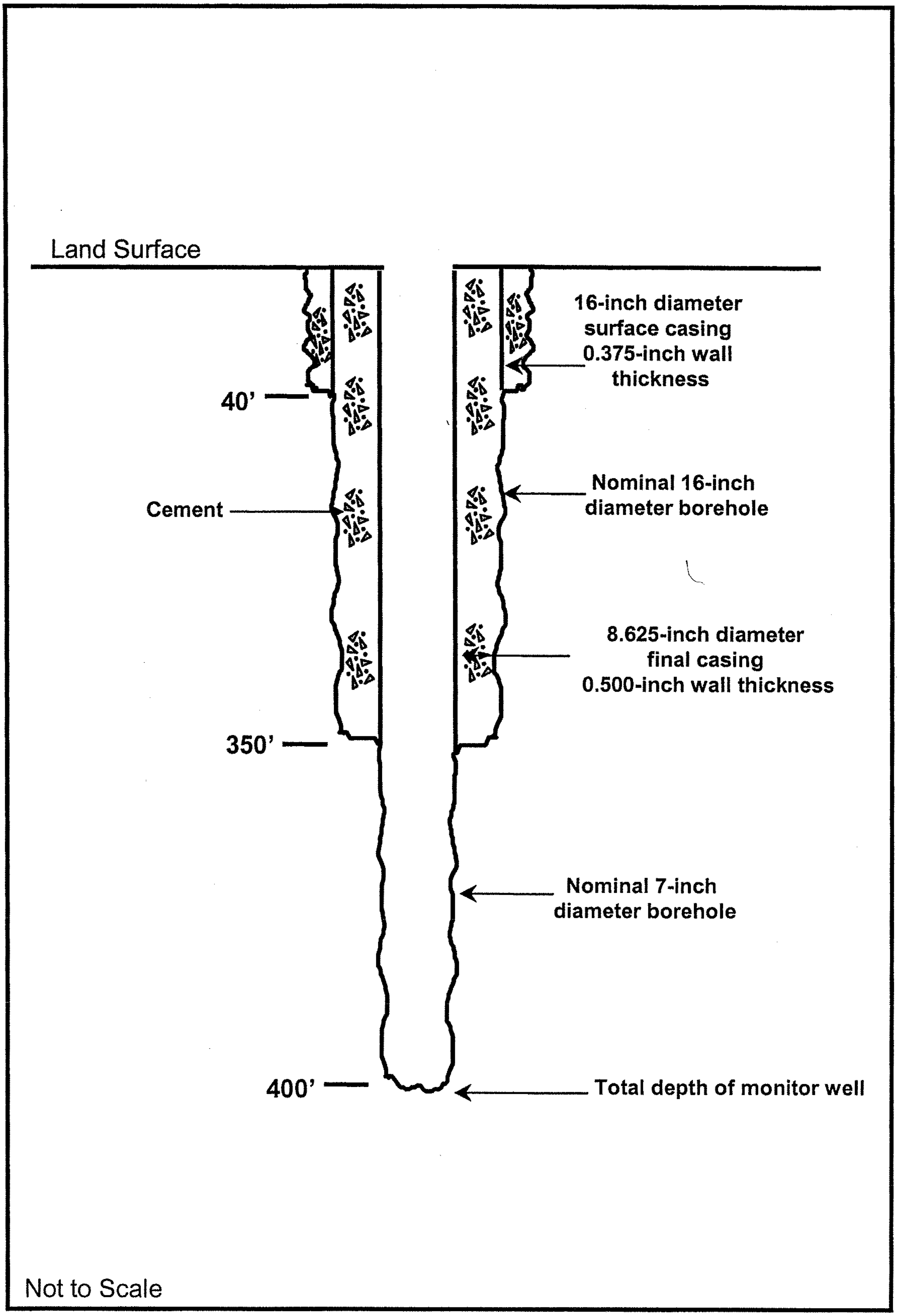


Figure 3-10
IAMW-1 Construction Details

MWH
MONTGOMERY WATSON HARZA

Section 4
Well Testing

INTRODUCTION

During construction of the ASR wells (ASR-2, ASR-3 and ASR-4) and monitor wells (IAMW-1, SZMW-1 and SZMW-2), extensive tests and geophysical logs were performed. The information that is collected is used to define the hydrogeology of the area, to determine drilling and casing setting depths and as information used for pump selection.

PILOT HOLE TESTING

Drill Stem Water Samples

Water samples were collected every 30 feet while the pilot holes were drilled using reverse-air drilling techniques. These samples were analyzed for chloride, total dissolved solids (TDS), and conductivity. The results from these analyses are presented in **Table 4-1** through **Table 4-5**. **Appendix H** presents the laboratory results and graphical analyses of the drill stem water quality.

Table 4-1
ASR-2 Water Samples Collected During Reverse-Air Drilling

Depth (ft)	Chloride (mg/L)	TDS (mg/L)	Conductivity (μmhos/cm)
380	783	1820	3100
410	783	1920	3030
440	825	1910	3000
470	750	1700	2630
500	850	1810	2950
530	850	1800	2920
560	775	1780	2870
590	850	1710	2890
620	800	1720	2900
650	800	1740	2910
680	800	1640	2750
715	800	1660	2830
745	750	1600	2830
780	775	1520	2750
800	800	1540	2780
842	925	1820	3160
873	950	1920	3200
904	950	1900	3190
934	950	1980	3190
967	900	1980	3190
998	875	1940	3170

The water quality data collected during construction of ASR-2 indicates there were no inversions in water quality. The values of chloride, TDS and conductivity generally increased with depth. A large increase occurred between 800 and 842 feet bls, which is likely to represent a flow zone.

Table 4-2
ASR-3 Water Samples Collected During Reverse-Air Drilling

Depth (ft)	Chloride (mg/L)	TDS (mg/L)	Conductivity (μmhos/cm)
394	925	1860	3000
425	850	1930	3010
457	850	1740	3000
487	800	1600	2740
519	675	1580	2720
550	425	1460	2540
580	625	1350	2410
611	500	1210	2120
641	550	1240	2210
673	400	1160	1880
703	550	1340	2340
733	675	1460	2500
763	650	1460	2590
782	800	1760	2870
835	875	2080	3220
866	900	1940	3200
898	875	2020	3220
928	875	1940	3200
959	900	1960	3190
991	775	1940	3120

The data collected during construction of ASR-3 identifies an inversion of the drill stem water quality at depths from 550 to 763 feet bls. The values of chloride, TDS and conductivity do not increase with depth through this interval, instead a decreasing trend is seen followed by an increase starting at approximately 675 feet bls.

Table 4-3
ASR-4r Water Samples Collected During Reverse-Air Drilling

Depth (ft)	Chloride (mg/L)	TDS (mg/L)	Conductivity (µmhos/cm)
435	680	1570	2600
466	660	1540	2630
498	670	1530	2640
528	600	1480	2430
560	620	1500	2470
590	640	1520	2490
620	680	1720	2450
650	660	1610	2570
680	630	1590	2430
715	690	1610	2560
746	730	1780	2780
760	710	1820	2800
775	720	1840	2840
805	750	1970	2930
836	500	1350	2280
868	590	1490	2430
900	640	1560	2530
930	640	1550	2570
960	640	1580	2550
993	770	1620	2620
1026	520	1510	2530

The data collected during construction of ASR-4r shows an inversion of the drill stem water quality from 836 feet bls to the base of the well. Chloride, TDS and conductivity values slowly increase to a depth of approximately 805 feet bls, where a sharp decrease is seen, followed by a general increasing trend from that depth to the base of the well. The freshening in water quality below 805 feet bls is most probably associated with injection of water at ASR-1 during cycle test OP-3

Table 4-4
SZMW-1 Water Samples Collected During Reverse-Air Drilling

Depth (ft)	Chloride (mg/L)	TDS (mg/L)	Conductivity (µmhos/cm)
383	610	1620	2480
423	620	1650	2410
443	720	1960	2680
483	480	1300	2030
523	600	1430	2050
563	420	1120	1900
583	590	1450	2400
623	780	1760	2960
663	750	1750	2880
703	690	1690	2680
743	780	1820	2930
783	670	1560	2590
803	730	1730	2850

The data collected during construction of SZMW-1 indicates inversions of the drill stem water quality from 483 and 583 feet bls. A sharp decrease in the values of chloride, TDS and conductivity begins at a depth of approximately 443 feet bls. This trend stops at approximately 563 feet bls, where an increasing trend in chloride, TDS and conductivity is seen until approximately 743 feet bls. A slight decrease in the values of chloride, TDS and conductivity is seen at the base of the well.

Table 4-5
SZMW-2 Water Samples Collected During Reverse-Air Drilling

Depth (ft)	Chloride (mg/L)	TDS (mg/L)	Conductivity (µmhos/cm)
402	740	1760	2830
433	750	1840	2720
464	720	1670	2790
495	650	1550	2690
527	650	1610	2580
558	720	1410	2560
590	675	1480	2480
620	630	1420	2440
650	530	1180	2060
682	600	1440	2400
710	500	1260	2050
745	500	1230	2020
775	530	1240	2030
800	530	1160	2030

The data collected during construction of SZMW-2 indicates inversions of drill stem water quality from 650 to 800 feet bls. There is a general decreasing trend in chloride, TDS and conductivity from 402 feet bls to the base of the hole.

Specific Capacity Measurements

Drawdown and flow rate were measured every 30 feet during reverse-air drilling of the pilot holes. These measurements allowed specific capacity to be calculated, and a summary of the results is presented in **Table 4-6**.

Table 4-6
Specific Capacity Results (gpm/ft drawdown)

Approximate Depth (ft bls)	ASR-2	ASR-3	ASR-4	SZMW-1	SZMW-2	IAMW-1
380	5.93	2.50	-	1.43	-	0.77
410	7.07	4.26	6.30	1.85	2.13	
440	6.76	4.25	7.30	2.27	4.26	
470	8.72	6.30	-	2.60	4.30	
500	9.12	6.05	4.84	3.64	5.02	
530	8.77	10.30	4.00	3.50	5.66	
560	8.61	-	4.30	4.90	5.88	
590	9.53	12.10	4.16	-	5.87	
620	9.46	12.90	4.83	12.70	10.80	
650	10.42	12.28	5.52	9.45	10.70	
680	11.03	17.57	5.56	10.35	13.80	
710	12.31	19.98	6.50	-	14.47	
740	12.62	16.40	9.00	15.34	14.60	
770	12.24	19.90	11.5	15.14	15.50	
800	13.60	35.10	17.12	15.40	16.57	
830	1.61	6.10	7.35		5.80	
860	2.40	9.45	7.53		10.50	
890	2.86	10.16	8.07		10.80	
920	9.26	11.30	8.54		11.10	
950	7.10	14.90	8.52		12.80	
980	11.50	15.60	9.22		-	
1000	11.37	15.80	9.86		12.80	

Primary and Secondary Drinking Water Analyses

At the completion of the well construction, each well was sampled for primary and secondary drinking water standards. Those values that exceeded the Florida Department of Environmental Protection's (FDEP) standards are indicated in **Table 4-7**. Copies of the laboratory reports are included in **Appendix H**.

Table 4.7
Primary and Secondary Drinking Water Analyses

Unit MCL	**Chloride** mg/L 250	**Sulfates** mg/L 250	**TDS** mg/L 500	**Gross Alpha** Pci/l 15	**Sodium** mg/L 160	**Odor** TON 3
ASR-2	746	344	2020	-	448	100
ASR-3	745	339	1860	22.8 ± 4.2	415	100
ASR-4r	585	293	1640	-	322	8
SZMW-1r	-	-	760	-	-	-
SZMW-2	694	303	1860	19.0 ± 4.0	405	35
IAMW-1	687	298	1730	28.4 ± 4.9	411	200

Coring

Coring at each of the ASR wells was attempted, with varying rates of success. On November 6, 2001, a 20-foot core was taken in the ASR-2 well from 760 to 780 feet bls of which approximately 8.5 feet of material, or 43%, was recovered. The material ranged from light tan sandy limestone to light gray clayey silt.

On November 14, 2001, a 20-foot core was taken in ASR-3 from 763 to 782 feet bls of which approximately 3 feet, or 16%, was recovered. The material ranged from brown crypto-crystaline dolomite to light tan fossiliferous limestone.

On January 9, 2002, a 20-foot core was taken in ASR-4r from 760 to 780 feet bls of which approximately 2.5 feet, or 13%, was recovered. The material ranged from grayish-yellow fossiliferous limestone to light gray sandy clay.

These core samples from the ASR wells were tested for permeability, specific gravity, total porosity, and unconfined compression strength. **Table 4-8** displays a summary of the testing results. Descriptions of the cores and the laboratory results are presented in **Appendix H**.

Table 4-8
Laboratory Results from Core Intervals

Sample	ASR-2	ASR-3	ASR-4r
Depth of tested section (ft)	773	778	779
Orientation	Vertical	Vertical	Vertical
Specific Gravity	2.71	2.71	2.72
Initial Dry Density (lb/ft^3)	127.9	109.3	119.4
Initial Porosity	0.24	0.35	0.30
Hydraulic Conductivity (ft/day)	4.1×10^{-7}	1.7×10^{-6}	9.7×10^{-8}

The vertical hydraulic conductivity associated with each of the core sections are consistent with the expected hydraulic conductivity of clay (Das, 1990). The low hydraulic conductivity values insinuate the presence of a semi-confining unit above the storage zone.

GEOPHYSICAL LOGGING

The geophysical logging program should help to define formation characteristics such as water quality and flow zones. Each type of log that was run is defined below with the different information that it provides.

Geophysical Log Definitions

Geophysical logs were conducted in each pilot hole in accordance with the FDEP Class V Injection Well Construction Permit. These logs were performed to confirm the formation characteristics and depths recorded by the geologist from the lithologic cuttings and estimate the relative rate of fluid movement within the borehole. A complete set of geophysical logs is contained in **Appendix I**. The following is a description of the uses and interpretation of the geophysical logs performed.

- **Caliper**: This log measures the diameter of the borehole, is useful in identifying fractures and solution features, and provides indirect evidence concerning the mechanical strength of the formation material.

- **Dual Induction/Spontaneous Potential (SP)**: The Dual Induction/SP log is used to measure the electrical properties of the formation. The electrical resistivities of the formation are affected by porosity and water quality. These logs provide important information concerning water quality transitions, the porosity of the formation, possible producing and confining zones, and the mixing of formation water with the drilling fluid in the borehole. The log consists of four traces:

- **ILD**: Measures the resistivity of the formation material with a wide receiver spacing that penetrates deep into the formation.

- **ILM**: Measures the resistivity of the formation with a medium receiver spacing that examines the formation material close to the borehole, where drilling fluids may have invaded the formation.

- **LL3**: This log reads the lateral resistivity with closely spaced electrodes that measure primarily within the borehole and on the borehole wall.

- **SP**: Measures potential differences within the borehole and in the formation. This trace is strongly affected by water quality changes and formation differences.

- **Borehole Compensated Sonic (BHCS) with Variable Density Log (VDL)**: The BHCS log measures the acoustic properties of the formation material. This log is strongly affected by the mechanical strength of the formation and by porosity. The VDL provides important information about fractures and solution features.

- **Gamma Ray**: The gamma ray log measures the natural gamma radiation produced by the formation material. The sources of gamma radiation contained in the formation are mostly associated with clays, phosphates, and uranium compounds. These components are important in identifying geologic formations and give clues about the origins of the formational layers.

- **Temperature and Fluid Resistivity**: This log measures the temperature and resistivity of the fluid filling the borehole. These logs are used to measure the characteristics of the formation fluid under static and dynamic flow conditions and provide information about the movement of the fluids within the borehole.

- **Flowmeter Survey**: The fluid velocity log measures the rate of fluid movement in the borehole and detects the entry of water into the borehole as the well is pumped.

ASR-2, ASR-3, and ASR-4 Geophysical Logging

The geophysical logs run for each stage of pilot hole drilling in the ASR wells are listed below. Logging was performed to estimate formation competency, estimate composition, porosity and permeability, identify water quality changes, and locate zones of flow and fractures within the borehole. Detailed descriptions of the logs are presented below by pilot hole stages.

The following logs were performed following completion of the first stage of pilot hole drilling to approximately 350 feet bls:

- Natural Gamma Ray
- Caliper
- Dual Induction

- Spontaneous Potential
- Borehole Compensated Sonic

These logs were performed to determine the boundaries of the Peace River Formation of the Hawthorn Group and to identify competent formation layers at which to set the intermediate casing. The caliper log showed a relatively gauge borehole from 50 to 365 feet bls with minor washouts below the surface casing from 50 to 70 feet bls. Additional washout zones were identified between 120 and 150 feet bls and between 160 and 245 feet bls. The gamma ray log showed intermittent zones of increased natural radiation below 60 feet bls. These increases are typically found within the Hawthorn Group sediments due to the presence of clay and phosphate. The dual-induction log showed increases in formation resistivity corresponding to the phosphatic shell beds present within the clays of the Peace River Formation. The BHCS log confirmed these intervals, showing decreases in travel time corresponding with the shell beds.

Following the second phase of pilot hole drilling from 350 to 800 ft bls, the following geophysical logs were performed:

- Natural Gamma Ray
- Caliper
- Dual Induction
- Spontaneous Potential
- Temperature (static and pumping)
- Flow (static and pumping)
- Fluid Resistivity (static and pumping)
- Borehole compensated sonic

The primary objective of this logging suite was to identify the base of the Mid-Suwannee confining unit under which we expect the suitable storage zone for the well system. The flowmeter logs identified one distinct flow zone present in the lower Suwannee Limestone. This flow zone was located between 800 and 850 feet bls. The caliper and BHCS logs indicated that a competent zone for setting the casing existed from 780 to 800 feet bls.

Temperature logs were also performed to verify the top of cement following completion of the first stage of cementing when two or more stages were needed.

Following completion of an ASR well, a final suite of logs was performed including the following:

- Natural Gamma Ray
- Caliper
- Video

The intent of these logs was to evaluate the integrity of the final casing and record the final condition of the well as a baseline for future activities.

IAMW-1 Geophysical Logging

Upon completion of drilling the pilot hole from 0 to 350 ft bls, the following geophysical logs were completed:

- Caliper
- Natural Gamma Ray
- Dual Induction
- Spontaneous Potential
- Borehole Compensated Sonic

These logs were used to verify the depths of formation boundaries. This suite of logs correlated with the findings from the previously drilled ASR-1,(*The Interim Report on Exploratory ASR Well Drilling and Testing at the Shell Creek WTP,* MW, 1998).

After reaming the pilot hole from 350 to 400 ft bls, the following geophysical logs were completed:

- Caliper
- Natural Gamma Ray
- Dual Induction
- Spontaneous Potential
- Temperature (static and pumping)
- Flow (static and pumping)
- Fluid Resistivity (static and pumping)
- Borehole compensated sonic

These logs were used to evaluate the hydrologic properties of the intermediate aquifer monitor zone located within the Peace River formation.

SZMW-1 and SZMW-2 Geophysical Logging

Upon completion of drilling the pilot hole from 0 to 350 ft bls, the following geophysical logs were completed:

- Caliper
- Natural Gamma Ray
- Dual Induction
- Spontaneous Potential
- Borehole Compensated Sonic

The purpose of these logs was to verify the depths of formation boundaries and determine suitable formation zones to set casing. This suite of logs correlated generally with the findings from ASR-1 and IAMW-1.

After drilling the pilot hole from to 800 ft bls, the following geophysical logs were completed:

- Caliper
- Natural Gamma Ray
- Spontaneous Potential
- Temperature (static and pumping)
- Flow (static and pumping)
- Fluid Resistivity (static and pumping)
- Borehole compensated sonic
- Video

The logs will provide a record of the initial well completion parameters for future activities.

AQUIFER PUMP TESTING

Step-rate and constant-rate pumping tests were run to quantify the hydraulic characteristics of the ASR well system. The goals of the tests included:

- Quantifying the hydraulic performance of each well for the design of the permanent well pump, motor, and wellhead
- Estimating aquifer characteristics (transmissivity)
- Collecting a background water quality sample

A temporary vertical turbine pump capable of producing a flow of up to 700 gpm was installed in ASR-2, ASR-3 and ASR-4r for the step-rate testing. A discharge line conveyed the pumped water approximately 100 feet to a discharge line. A totalizing flow meter was installed onto the discharge pipe to allow the flow rate to be measured accurately. Water levels were recorded both by hand and automatically with a pressure transducer and data logger.

The pump was installed in ASR-3 for a constant rate test of the entire ASR system. Water levels were recorded with a pressure transducer and data logger in ASR-2, ASR-3, ASR-4r, SZMW-2 and IAMW-1 during the constant-rate test. A discharge line conveyed the pumped water approximately 100 feet to a discharge line. A totalizing flow meter was installed onto the discharge pipe to allow the flow rate to be measured accurately. The data collected allowed drawdown and recovery curves to be generated.

Step Rate Test

ASR-2

A step-rate test was run February 2, 2002. The pump was first run at 400 gpm for 170 minutes. The rate was then increased to 500 gpm for 110 minutes. The rate was then increased to 600 gpm for 170 minutes. Finally, the rate was increased to 700 gpm for another 150 minutes. The maximum drawdown and specific capacity for each step is presented in **Table 4-9**.

Table 4-9
ASR-2 Step-Rate Pump Test Flowrate, Drawdown and Specific Capacity

Step	Flowrate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)
1	400	40.0	10.0
2	500	51.5	9.7
3	600	63.5	9.4
4	700	77.5	9.0

ASR-3

A step-rate test was run on January 31, 2002. The pump was first run at 500 gpm for 225 minutes. The rate was then increased to 600 gpm for 110 minutes. The rate was then increased to 700 gpm for 170 minutes. Finally, the rate was increased to 800 gpm for another 170 minutes. The maximum drawdown and specific capacity for each step is presented in **Table 4-10**

Table 4-10
ASR-3 Step-Rate Pump Test Flowrate, Drawdown and Specific Capacity

Step	Flowrate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)
1	500	38.5	13.0
2	600	47.5	12.6
3	700	59.0	11.8
4	800	71.0	11.3

ASR-4r

A step-rate test was run on February 13, 2002. The pump was first run at 400 gpm for 210 minutes. The rate was then increased to 500 gpm for 100 minutes. The rate was then increased to 600 gpm for 80 minutes. Finally, the rate was increased to 700 gpm for another 200 minutes. The maximum drawdown and specific capacity for each step is presented in **Table 4-11**.

Table 4-11
ASR-4r Step-Rate Pump Test Flowrate, Drawdown and Specific Capacity

Step	Flowrate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)
1	400	47.0	8.5
2	500	59.5	8.4
3	600	72.2	8.3
4	700	88.0	8.0

Constant Rate Test

A 120-hour constant-rate discharge pumping test was performed from February 28, 2002, to March 5, 2002. Water level recording continued until the morning of March 13, 2002. Graphs of drawdown and recovery versus time in **Appendix H** present the water level variations in ASR-2, ASR-4, and SZMW-2 caused by the pumping of ASR-3 for 120 hours at a rate of 760 gpm. The maximum drawdown in ASR-3 was approximately 65 feet with a resultant specific capacity of 11.7 gpm/ft.

Evaluation of Aquifer Performance Testing

The transmissivity of the storage zone was calculated based on the data collected during the constant-rate pump test using the Hantush-Jacob Method, which assumes a leaky aquifer and, therefore, allows for the calculation of leakage as well as transmissivity and storativity. The data from SZMW-2 and ASR-2 were suitable for analysis, but the data from the other wells could not be used due to the small amount of drawdown. Interference from other wells was also observed at these locations. These effects were seen at some wells, ASR-4r in particular, but not in others, possibly indicative of the highly heterogenous lithology observed at the site. Calculations were made using both the drawdown and the recovery data. **Table 4-12** summarizes the results of the calculations.

Table 4-12
Transmissivity Calculation Results for Storage Zone

Method	Transmissivity (gpd/ft)	Transmissivity (ft^2/day)	Storativity	Leakage (day^-1)
ASR-2 Drawdown	44,708	5,977	0.00028	0.0050
ASR-2 Recovery	32,284	4,316	0.00024	0.0060
SZMW-2 Drawdown	49,570	6,627	0.00016	0.0021
SZMW-2 Recovery	41,170	5,504	0.00015	0.0025
Average Values	41,933	5,606	0.00021	0.0039

These values are similar to those reported for the Suwannee zone at the Peace River ASR facility, where transmissivity was calculated to be approximately 6,000 ft^2/day, storativity approximately 0.0001, and leakage roughly 0.0085/day (Pyne, 1995).

Video Log

A video log is a direct method of viewing the formation, porosity, and the casing details in the borehole. Changes in lithology and porosity, and details about the casing are documented in a visual format for easy interpretations. The date and depth of these logs is presented below in **Table 4-12**. SZMW-1r was not logged because of the high flow rate of the well, which would have resulted in a large loss of stored water from the bubble at ASR-1. Copies of the video logs are contained in **Appendix J**.

Table 4-13
Video Logs Performed

Well	Date	Depth
ASR-2	March 20, 2002	998
ASR-3	February 6, 2002	1000
ASR-4	March 14, 2002	1026
SZMW-2	February 18, 2002	1000

Plumbness and Alignment

Throughout drilling activities at 60 foot intervals, plumbness and alignment tests were run on the wells. These tests confirmed that the well and casing were straight in each of the tested wells and suitable for the proposed use. The results of this testing are presented in **Appendix D.**

Section 5
Operational Testing Program

INTRODUCTION

The permanent Aquifer Storage and Recovery (ASR) facilities are presently under construction. The permanent ASR facilities are to include the recharge and recovery pipelines, wellhead facilities, and permanent well pumps. Operational testing of the wells will be conducted to determine the recoverability of finished water from the ASR wells.

OPERATIONAL TESTING PROGRAM

In order to assure the ASR wells and facilities are fully functional, a testing program will be conducted with Florida Department of Environmental Protection (FDEP) approval. This testing program will consist of an operational test of the expanded ASR system at the Punta Gorda's Shell Creek Water Treatment Plant (WTP). The program will simultaneously test wells ASR-1, ASR-3, and ASR-4.

Operational testing cannot begin until construction is completed at each well and adequate amounts of water are available for the recharge of the system. Assuming that excess potable water is available, and the ASR wells and facilities are functional, the proposed operational testing program for the Shell Creek WTP's ASR system will be as presented in **Table 5-1**.

Some of the water that is injected during operational tests (especially at ASR Wells 3 and 4r) will not be recovered. This water will be emplaced to start forming a "buffer zone". The "buffer zone" is a mixing zone between native aquifer water and usable recovered water from the ASR well. The formation of an adequate "buffer zone" is essential to development of a fully operational ASR Well System.

It is recommended that injection begin once excess potable water is available at a chloride concentration at the wellhead less than 150 mg/L. This injection should continue until approximately 100 million gallons have been injected into each well. At this point recovery could begin immediately or be deferred until the City wishes to utilize the recovered water.

The timing of the operational testing of the new ASR wells needs to be coordinated with the completion of the wellhead and piping facilities at ASR Wells 3 and 4r. During the operational testing of the new ASR wells, it is recommended that ASR-1 be injected into and recovered from concurrently with the new wells.

Table 5-1 is the recommended initial operational test program for ASR wells 1, 3, and 4r.

TABLE 5-1
Operational Test Schedule for Entire ASR System
Shell Creek WTP – ASR Expansion

Cycle	Injection			Storage	Recovery		
	Duration (a) (days)	Rate (b) (gpm)	Volume Injected (MG)	Duration (days)	Duration (a) (days)	Rate (b) (gpm)	Volume Recovered (MG)
1	100	725	100	0	6	725	23.1

(a) Water will be injected and recovered from the ASR wells 24 hours per day.
(b) Rate for ASR-1 is 500 gpm, and the rate for ASR-3 and ASR-4 is 725 gpm
(c) Chlorides of injection water, as measured at ASR wellhead shall be less than 150 mg/L.

Operational testing will consist of injection of potable water for approximately 100 days at a rate of approximately 500 gpm for ASR-1, and 725 gpm for ASR-3 and ASR-4. The injected volume will be approximately 300 million gallons (MG) for the system, 100 MG each for well. After approximately 100 days, injection will stop and water levels in the well will be allowed to stabilize. Recovery from the wells will begin at a rate of approximately 500 gpm for ASR-1, and 600 to 650 gpm for ASR-3 and ASR-4. Pumping from the wells will continue until the chloride concentration in the water recovered equals 250 mg/L.

Subsequent operational testing will be based on the results of the first operational test of the expanded ASR System. However, subsequent cycles are targeted to be 100 mg with recovery to a chloride level of 250 mg/L.

Water recovered from ASR-1 during testing of the new wells will be directed to the solids contact unit for treatment and potable use. The remaining ASR wells will discharge to the existing ditch outfall location, which ultimately drains into Shell Creek downstream of the reservoir. This location has been approved for discharge of operational testing waters, after monitoring for a short list of chemical constituents.

Upon approval from the FDEP, subsequent cycles will be discharged directly to the solids contact unit for treatment and distribution to potable water customers. At the completion of the operational testing, a final report that incorporates these test results will be submitted to the FDEP and the Southwest Florida Water Management District (SWFWMD).

DATA COLLECTION PLAN

During operational testing, flow rates and injection pressures will be collected for the ASR wells. The maximum, minimum, and average values on a daily and monthly basis will be reported. The total volume recharged and recovered will also be recorded.

For the monitor wells, water levels and/or pressures will be collected. The maximum, minimum, and average values on a daily and weekly basis will be reported.

WATER QUALITY SAMPLING PLAN

Required water quality analysis, specified in the Class V Well Construction Permit, will be performed during the testing. The parameters, as listed in **Table 5-2**, will be sampled from ASR-2, ASR-3, and ASR-4 during recharge and recovery of the test. Testing for ASR-1 will follow the existing permit.

TABLE 5-2
Water Quality Parameters to be Monitored During Operational Testing
City of Punta Gorda ASR Expansion

Parameter	Frequency
Gross Alpha	+
Total Trihalomethanes	Weekly
Chloride	Weekly
Dissolved Oxygen	Weekly
Magnesium	Weekly
pH	Weekly
Specific Conductivity	Weekly
Sulfate	Weekly
Temperature	Weekly
Total Alkalinity	Weekly
Total Dissolved Solids	Weekly
Total Iron	Weekly
Turbidity	Weekly
Arsenic	Weekly

Note: + Beginning of recharge cycle; beginning and end of each recovery cycle.

Table 5-3 presents the parameters to be sampled from monitor wells SZMW-1, SZMW-2, and IAMW-1 during operational testing.

TABLE 5-3

Water Quality Parameters to be Monitored in SZMW-1, SZMW-2, and IAMW-1 During Operational testing
City of Punta Gorda ASR Expansion

Parameter	Frequency
Gross Alpha+	monthly
Total Trihalomethanes+	weekly
Chloride	weekly
Dissolved Oxygen	weekly
Magnesium	weekly
pH	weekly
Specific Conductivity	weekly
Sulfate	weekly
Temperature	weekly
Total Alkalinity	weekly
Total Dissolved Solids	weekly
Total Iron	weekly
Turbidity	weekly
Arsenic	weekly

Note: + Monthly during operational testing and for a minimum of one year, then annually with FDEP approval.

TRAVEL DISTANCE ESTIMATION

The estimated radial travel distance of water for various injection periods and their associated volumes has been calculated based on estimated storage zone volumes. The estimated radial travel distances for injection periods of 6, 12, 20 30, 60, 100, 120 and 200 days are presented in **Table 5-4**.

TABLE 5-4
Calculated Radial Travel Distance of Injected Water
City of Punta Gorda ASR Expansion

Injection Period (Days)	Injection Rate (gpm)	Storage Volume (MG)	Calculated Travel Distance (feet)
6	725	6.26	94
12	725	12.53	134
20	725	20.88	172
30	725	31.32	211
60	725	62.64	299
100	725	104.40	385
120	725	125.28	422
200	725	208.80	545

Figure 5-1 presents a map showing the estimated travel distance for selected injection volumes.

The calculations are volumetric and assume a homogeneous medium, a sharp mixing front and no vertical movement of injected water. The assumed aquifer parameters are as follows:

- Storage Zone Porosity = 0.2
- Storage Zone Thickness = 150 feet
- Injection Rate = 725 gpm

The travel distance calculations are preliminary, but the results of operational testing on ASR-1 suggest that the calculations are reasonable estimations. Actual travel distances will be different depending on storage zone heterogeneity and *in situ* porosity. The operational testing program will provide some additional information on storage zone properties to better define the movement of injected water.

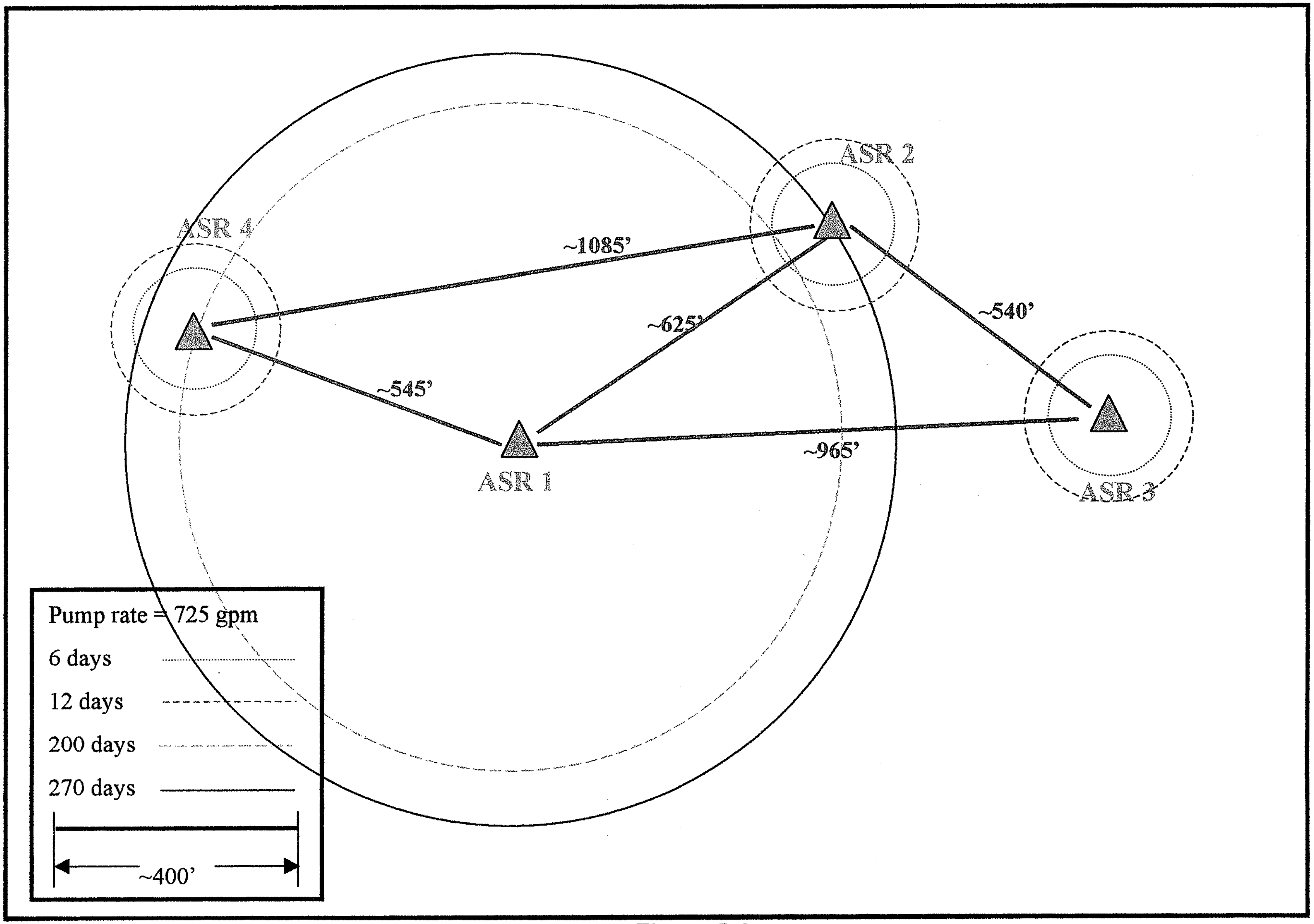


Figure 5-1

Estimated Travel Distance of Injected Water

MWH
MONTGOMERY WATSON HARZA