GROUNDWATER INVESTIGATION REPORT

BRUNSWICK NUCLEAR PLANT

STORM DRAIN STABILIZATION POND

SOUTHPORT, NORTH CAROLINA

PREPARED FOR:

Progress Energy

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INTRODUCTION

Silar Services Incorporated (SSi) has prepared this Groundwater Investigation Report (GIR) for Progress Energy to document the results of groundwater characterization activities performed at the Brunswick Nuclear Plant (BNP), located in Southport, Brunswick County, North Carolina. This study was commenced in response to the detection of tritium in a water sample collected from inside of an onsite subsurface structure (manway) that is located near the Storm Drain Stabilization Pond (SDSP) area of the BNP (the Site). Progress Energy suspected the source of the tritium identified in the manway sample to be groundwater seepage originating from the SDSP area, which suggested the SDSP was leaching tritium into the shallow groundwater aquifer onsite. The SDSP was suspected as the source because it receives process water containing tritium and other radiological materials from the BNP.

The groundwater investigation activities and subsequent evaluations presented in this report were conducted in a manner generally consistent with industry guidance documents associated with the protection of groundwater resources from radiological materials, including the following:

- Guideline for Implementing a Groundwater Protection Program at Nuclear Power Plants [Electric Power Research Institute, Final Report, November 2007]; and,
- Industry Ground Water Protection Initiative – Final Guidance Document [Nuclear Energy Institute (NEI), August 2007].

The SDSP is considered one of the "systems, structures, and components" (SSCs) of the BNP, as defined in *Guidance Statement 2.2a* in the EPRI Guidance. As such, the evaluation of the SDSP has been completed in general accordance with the EPRI [November 2007] and NEI [August, 2007] guidance documents, which are referenced throughout this report.

SITE BACKGROUND

The SDSP is a constructed surface feature that was originally designed to serve as a permeable sediment dewatering basin during the construction of the cooling water intake canal. After the construction of the intake canal was complete, the dewatering basin was permitted for use as a storm water retention pond to receive and provide natural treatment of storm water collected from the storm drainage system installed within and around the BNP power generating facility. The storm water in the SDSP is periodically discharged via a controlled release to the intake canal in accordance with a NPDES permit.

During the operational history of the plant, occasional releases of radiological materials within the nuclear power facility, including tritium and other radiological materials, resulted in the transport of radiological material from the BNP to the SDSP via the storm water conveyance systems. These materials are transported as either suspended sediments (i.e. gamma nuclides) in water, or, as in the case of tritium, dissolved or condensed chemical constituents present in the process water from the plant or storm water. According to facility personnel, solid materials (soil and/or sediments) containing radiological materials that were generated during the initial cleanup of these historical releases within the plant were often physically transported to the SDSP and staged within the pond area. As such, other radionuclides are generally known to be present in solids within the sediment in the SDSP.

As a result of the detection of tritium in a nearby man-way in April, 2007, tritium was suspected to be leaching into the groundwater from the SDSP.

As described in Section 2.2 of the EPRI guidance, nuclear power generation facilities should complete a comprehensive evaluation of "systems, structures, and components containing liquid radioactive material" (SSC) that may have a plausible potential for releasing radioactive liquid to soils or groundwater. This report summarizes the evaluation of groundwater quality in the SDSP area, which is considered one of the SSCs present at the BNP facility, and presents potential remedial action objectives, an initial screening of remedial technologies, and an evaluation of possible remedial alternatives.

The initial field activities performed during the groundwater investigation work were performed in accordance with the Proposal to Perform Hydrogeologic Assessment (SSi, May 2007), and all field activities were completed in general accordance with "Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, 2001" (U.S. EPA), SSi's Standard Operating Procedures, and the Site-Specific Health and Safety Plan.

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The storm drain stabilization pond (SDSP) is located at the Brunswick Nuclear Plant (BNP) in Southport, North Carolina. The Site is located within the secured access area of the BNP, and is approximately 2.5 miles north-northeast of the City of Southport, North Carolina. The approximate geographic coordinates of the SDSP are 35° 06' 18.6'' north latitude and 78° 02' 32.8" west longitude. The SDSP encompassed a total of approximately 60 acres. According to the 1985 Geologic Map of North Carolina, prepared by the North Carolina Geological Survey Section of the North Carolina Department of Environment and Natural Resources (NC DENR), the Site is located in the North Carolina Coastal Plain Physiographic Province. The Site is located approximately 7,000 feet west of the Cape Fear River.

The SDSP consists of a constructed sediment dewatering pond that has been converted for use as a storm water retention/treatment facility, and includes an elevated earthen berm that surrounds the 60-acre pond. Significant surface features surrounding the SDSP include a marine estuary to the north and east, a constructed recovery pond to the southeast, an intake canal to the south which provides cooling water to the BNP, and a power transmission corridor and the BNP to the west.

The site-specific geology consists of approximately 70 feet of unconsolidated materials overlying limestone bedrock. The site-specific geology generally consists of gently sloping, horizontally-oriented units including the following (from shallowest to deepest): an upper sand unit (~25 feet thick); a low permeability silt/clay unit (~5-10 feet thick); a lower sand unit (~30 feet thick); a limestone unit (the Castle Hayne Formation, ~10 feet thick); a low permeability confining unit (Peedee confining unit, ~30 feet thick); and, a sandy limestone unit (the Peedee Formation, ~430 feet thick).

Three distinct groundwater aquifers are identified at the study area, and include the Upper Sand (shallow) aquifer, the Lower Sand/Castle Hayne (intermediate) aquifer, and the Peedee (deep) aquifer. The intermediate and deep aquifers are locally and regionally used as the sole source of potable water supply for domestic, commercial, industrial, and municipal use. No other sources of fresh water exist in the study area due to the brackish and saline conditions in deeper groundwater and the tidally-influenced surface water. Groundwater from the SDSP exhibits a radial (in all horizontal directions) flow pattern, and discharges into the tidal estuary and creeks to the north and east which drain into the Cape Fear River, into the intake canal to the south (which discharges to the discharge canal and to the Atlantic Ocean). To the west, groundwater is eventually drawn into the cooling water pump system and subsequently discharged to the discharge canal.

One significant low-permeability unit is present in the study area between the Upper Sand and Lower Sand that has helped to reduce the vertical extent of groundwater impacts associated with the release of radiological materials at the SDSP. The low permeability unit bisects the two sand units beneath the

SDSP and provides an important barrier (aquitard) that reduces the vertical transport of groundwater and radiological materials between the shallow sand aquifer and the potable water supply aquifer in the Castle Hayne; however, three monitoring wells in the intermediate aquifer have exhibited evidence of radiological impacts.

FIELD INVESTIGATION ACTIVITIES

The groundwater investigation activities at the SDSP commenced on June 4, 2007 and continued through October 2007. The major field activities included:

- Preliminary identification of surface features and surface hydrology in the vicinity of the SDSP;
- Advancing soil borings onsite to complete a detailed geologic characterization of the subsurface stratigraphy;
- Installation of a groundwater monitoring well network in the shallow, intermediate, and deeper aquifers to evaluate the physical and chemical characteristics of groundwater in the vicinity of the SDSP;
- Collection of soil samples in the SDSP; and,
- Implementation of a preliminary groundwater monitoring program and collection of groundwater monitoring data and hydraulic data to evaluate groundwater movement in the vicinity of the SDSP.

FIELD INVESTIGATION FINDINGS

The groundwater monitoring activities have provided sufficient data to prepare a conceptual site model (CSM) of the study area and characterize the nature and extent of tritium in groundwater near the SDSP. The source of tritium in groundwater is confirmed to be an ongoing, uncontrolled release from the SDSP. The uncontrolled release occurs through the direct leaching of tritiated surface water in the SDSP to the underlying shallow groundwater, which in turn transports tritium into the adjacent wetlands, surface water, and deeper potable supply aquifer via migration in groundwater. Tritium is present above applicable regulatory standards in the shallow groundwater around the SDSP. Tritium has also been detected in groundwater samples collected from the intermediate aquifer. Other radiological materials (i.e. gamma radionuclides) are present within the SDSP area, but are not the focus this evaluation.

FEASIBILITY STUDY

A feasibility study was performed to evaluate alternatives for the remediation of tritiated ground water at the Site. Remedial Action Objectives (RAOs) were developed based on environmental concerns and compliance with applicable regulations and include:

Reduce the continual migration of tritium in groundwater on-site and off-site to protect human health and the environment.

Control future releases of tritiated water through the SDSP.

Address ARARs relating to historic disposal practices at the SDSP.

The proposed remedial goal (RG) for tritium in groundwater is based on the federal MCL of 20,000 pCi/L.

The area of attainment was selected as:

Contaminated groundwater within the berm of the SDSP.

Contaminated groundwater outside the berm of the SDSP with tritium concentrations greater than the RG of 20,000 pCi/l.

Based on this, the following General Response Actions were identified;

- No Action
- Limited Action
- Containment
- Active Restoration

Based on the GRAs, remedial technologies were identified and screened with respect to effectiveness, implementability and cost. Technologies passing the screening were then assembled into the following six (6) remedial alternatives:

Alternative 1 – Monitored Natural Attenuation (MNA)

Alternative 2 – Containment (Barrier Wall) with MNA

Alternative 3 – Containment (Impoundment) with MNA

Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA

Alternative 5 – Site-wide Groundwater Extraction with MNA

Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA

The remedial alternatives were then evaluated against effectiveness, implementability and cost criteria.

All Alternatives assume that the major source of tritiated water discharge to the SDSP will be eliminated through process changes within the BNP. Alternative 1 - MNA includes no active remediation and provides no additional protection of human health and the environment other than that offered by the early warning of off-site migration provided through monitoring. However discharges of tritiated storm water at concentrations greater than the RG (20,000 pCi/L) are anticipated to continue. Based on this practice Alternative 1 would not achieve the RAOs or RGs in the long-term. It is anticipated that current concentrations of tritium in groundwater would decrease via natural attenuation processes; however, the RGs would not be achieved and decommissioning costs associated with the remaining groundwater impacts may be significant. Alternative 2 would reduce the horizontal migration of tritiated groundwater through implementation of a barrier wall. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. Alternative 2 does not control future releases of tritiated storm water from the SDSP and the barrier wall may increase the vertical gradient and potential vertical migration. Alternative 2 would not be expected to achieve the RGs in the long term. Alternative 3 would reduce the migration of tritiated groundwater by controlling (eliminating) the continual source of tritiated storm water from the SDSP by directing it to an impoundment. Existing tritiated groundwater within and in the vicinity of the SDSP would continue to migrate although at a slower rate since the groundwater flow gradient would be expected to decrease due to the elimination of flow from the SDSP. Monitoring would provide an early warning of potential off-site migration. Alternative 3 would not be expected to achieve the RGs in the long term. Alternative 4 would reduce the migration of tritiated groundwater through implementation of a barrier wall. Alternative 4 would control the future release of tritiated storm water from the SDSP by directing it to an impoundment. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. Alternative 4 would not be expected to achieve the RGs in the long term. Alternative 5 reduces the migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to the SDSP. Alternative 5 does not control future releases of tritiated storm water from the SDSP. Alternative 5 would not be expected to achieve the RGs in the long term. Alternative 6 reduces migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to an impoundment. Alternative 6 also controls future releases of tritiated storm water from the SDSP by directing it to the impoundment. Because Alternative 6 removes the continual source of tritiated storm water and captures and removes existing tritiated groundwater, this alternative would be expected to achieve the RGs in the long term.

Of the six alternatives, Alternative 1 – MNA is the easiest to implement. The major elements of Alternative 1 (groundwater/surface water sampling and analysis) are already in place at the site and would continue for up to 30-years. Alternative 2 through 6 involve widely available, contractor-installed services and would be readily implementable. Implementation of any of these alternatives could be completed within a year. Alternatives 2 through 6 would result in a reduction of the annual monitoring efforts currently associated with Alternative 1. Since Alternative 5 and 6 involve groundwater extraction there would be greater operations and maintenance concerns. Additional evaluations would need to be conducted before design and construction of Alternatives 2 through 6.

Alternative 1 is the low cost alternative with a present value of $4,954,399, but this alternative would not meet the RAOs in the long-term. Alternatives 2, 3 and 5 would meet some of the RAOs but would not be expected to meet the RGs in the long-term. Alternatives 4 and 6 would meet the RAOs, but only Alternative 6 would be expected to meet the RGs in the long term. Present value costs for the alternatives are as follows:

Alternative 1 – Monitored Natural Attenuation, $4,954,399

Alternative 2 – Containment (Barrier Wall) with MNA, $5,897,482;

Alternative 3 – Containment (Impoundment) with MNA, $7,478,082 (RCRA type liner) and $6,150,228 (non-RCRA type liner);

Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA, $10,686,740;

Alternative 5 – Site-wide Groundwater Extraction with MNA, $9,786,218; and,

Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA, $9,418,406.

1 INTRODUCTION

1.1 Purpose of Report

Silar Services Incorporated (SSi) has prepared this GIR to document the results of the groundwater investigation performed for the SDSP area of the BNP located in Southport, North Carolina. As a result of the detection of tritium in a nearby man-way in May, 2007, tritium was suspected to be leaching into the groundwater from the SDSP. The purpose of the investigation was to determine the nature and extent of tritium impacts to groundwater in the vicinity of the SDSP and to evaluate alternatives to remediate the impacts. The work was performed in general accordance with Proposal to Perform Hydrogeologic Assessment, Storm Drain Stabilization Pond (SSi, May, 2007), the "Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, 2001" (U.S. EPA), SSi's Standard Operating Procedures, and the Site-Specific Health and Safety Plan.

The groundwater investigation activities and subsequent evaluations presented in this report were generally conducted with the intent to meet the intent of industry guidance documents associated with the protection of groundwater resources from radiological materials, including the following:

Guideline for Implementing a Groundwater Protection Program at Nuclear Power Plants [Electric Power Research Institute, Final Report, November 2007]; and,

Industry Ground Water Protection Initiative – Final Guidance Document [Nuclear Energy Institute (NEI), August 2007].

As such, these documents are used to provide a basis for the evaluation of the SDSP area, and referenced throughout this report.

1.2 Site Background

This section includes information on the location, description and history of the Site.

1.2.1 Site Location

The Brunswick Nuclear Plant Site is located approximately 1.6-miles north of the City of Southport, Brunswick County, North Carolina, and is situated on approximately 1,200 acres of land. The SDSP is located approximately 800-feet east of the power generation plant, and occupies an approximate 60-acre area of land. The general location of the SDSP is shown in **Figure 1-1**. A depiction of the layout of the SDSP is presented on **Figure 1-2**.

The SDSP is surrounded by the following features:

- **North**: Nancy's Creek marine estuary; and single-family residential properties to the north of Nancy's Creek;
- **East**: Gum Log Branch marine estuary (a tributary to Nancy's Creek), and further to the east are additional made lands associated with the BNP including additional sediment dewatering basins;
- **South**: A recovery pond (southeast), and the cooling water intake canal (south); and,
- **West**: BNP lands, including an active power transmission line corridor, several materials storage buildings, a communications tower (northwest), and grassy and wooded areas (northwest) associated with the BNP.

Site features are discussed in greater detail in Section 3.

1.2.2 Current Description of the Storm Drain Stabilization Pond

The SDSP consists of an unlined storm water retention pond that is used to retain, treat, and discharge surface water runoff originating from the BNP facility. The SDSP is located approximately 800 feet east of the power generating facility, and receives storm water from the BNP via a subsurface storm drain. Storm water is pumped from the plant area through the storm drains and into the pond, where the water is naturally retained, biologically treated, and then discharged via a managed outfall under a current NPDES permit. The NPDES permit allows for the use of the pond to retain and treat surface water runoff to remove oil and grease and suspended solids. The treated water is periodically discharged to the cooling water intake canal through a monitored outfall system at the southwestern corner of the SDSP.

The geographic area of the SDSP is defined by the presence of an elevated earthen berm. The topographic relief of the earthen berm is 12 to 15 feet higher than the surrounding topography on its south, west, and northwestern sides, and approximately 15 to 22 feet higher in relief than areas to the north and east of the SDSP. The approximate surface area of the interior of the SDSP area is approximately 60 acres. The interior of the SDSP is approximately 5 to 10 feet deeper than the surrounding earthen berm, which provides significant water storage and retention capacity.

The interior area of the SDSP is generally a flat, open, vegetated area. A finger dike present near the discharge pipe on the western edge of the SDSP promotes the flow of water to the north and then east within the SDSP. Vegetation in the SDSP consists of a thick vegetated monoculture consisting of phragmites, although there are several areas within the SDSP where open water is consistently present. The interior edge of the SDSP and exterior slope of the earthen berm is generally covered by woody vegetation, which provides a visual buffer from the surrounding area.

A maintained dirt access road is present along the centerline of the earthen berm, which provides access for security and visual inspections of the SDSP area. The top of the earthen berm is generally a minimum of 15 feet wide around the perimeter of the SDSP.

1.2.3 History of SDSP Operations and Radiological Input

The SDSP is a constructed surface feature that was designed and constructed to serve as a permeable sediment dewatering basin during the construction of the cooling water intake canal. After its use as a dewatering basin for the construction of the intake canal in the early 1970s, the dewatering basin was permitted for use as a storm water retention pond to receive and provide natural treatment of storm water collected from the storm drainage system installed within and around the BNP power generating facility. The storm water in the SDSP is periodically discharged via a controlled release to the intake canal in accordance with a NPDES permit.

During the operational history of the plant, occasional releases of radiological materials within the nuclear power facility, including tritium and other radiological materials, resulted in the transport of radiological material from the BNP to the SDSP via the storm water conveyance systems. These materials were transported as either suspended sediments (i.e. gamma nuclides) in water, or, as in the case of tritium, dissolved or condensed chemical constituents present in the process water from the plant or storm water. According to facility personnel, solid materials (soil and/or sediments) containing radiological materials that were generated during the initial cleanup of these historical releases within the plant were often physically transported to the SDSP and staged within the pond area. As such, other radionuclides are generally known to be present in solids within the sediment in the SDSP.

As a result of the detection of tritium in a nearby man-way in May, 2007, tritium was suspected to be leaching into the groundwater from the SDSP.

1.2.4 Summary of Previous Investigations

Although the SDSP has not been the focus of environmental investigation, a number of sources of relevant site-specific information were reviewed, including, but not limited to, the following:

Site Assessment Report, Unit 2 Radwaste Effluent Line, Brunswick Nuclear Plant (D'Appolonia, June 1995);

Well Construction Records, CP&L Brunswick Plant, Letter from Richard Catlin and Associates, Inc., to NCDEM, Groundwater Section (May 23, 1995);

An Evaluation of Ground-Water Conditions in the Vicinity of the Intake and Discharge Canals at the Brunswick Steam Electric Plant, CP&L, November 10, 1082;

Groundwater Monitoring Program, OE&RC-3250, Rev. 25, Progress Energy; and,

Report, Production Well No. 2 Pumping Tests, Brunswick steam electric Plant, E. D'Appolonia Consulting Engineers, Inc., June 1974;

Not all sources of information provided by Progress Energy and reviewed by SSi were able to be formally documented. Various historical plant drawings, well construction records, aerial photographs, and files and information were made available to SSi by Progress Energy throughout the execution of the groundwater investigation. A number of important observations and findings are documented in this report that conflict with previous information presented in plant-related documents.

1.3 EPRI Site Priority Index Scoring

The nuclear power industry developed a numeric site scoring system, as outlined in detail in the *Guideline for Implementing a Groundwater Protection Program at Nuclear Power Plants* [Electric Power Research Institute, Final Report, November, 2007] to be used to guide the implementation of appropriate response actions required to evaluate and monitor soil and groundwater conditions at nuclear power facilities. The scoring system develops a Priority Index (PI) based on a likelihood factor (L) and a consequence factor (C), which are derived from objectively defined indices.

The priority index is determined by the following equation:

Priority Index (PI) = Likelihood (L) x Consequence (C) x Normalization Factor (N)

The indices associated with the likelihood and consequence factors are summarized in Section 1.3.1 and Section 1.3.2, respectively. Each index is given a score from 1 to 3, which is based on site-specific information. After determining the likelihood and consequence factors, the priority index (PI) is determined by multiplying the likelihood, consequence, and normalization factors. The normalization factor is 11.11, which is based on the following normalization equation:

$$N = 100 \div 9 = 11.11$$

where 9 is the maximum possible non-normalized priority index value.

Based on the value of the priority index resulting from the screening process, a Site is categorized to one of three priority levels, as listed below.

1. Program Level 1 – $0 < PI \leq 50$
2. Program Level 2 - $50 < PI \leq 75$
3. Program Level 3 – $75 < PI$

Based on the program level achieved by the scoring of the Site, a specified degree of investigation activities are required, which are qualitatively defined in the EPRI Guideline.

The results of the scoring for the SDSP area are discussed in the following subsections.

1.3.1 Site-Specific Likelihood Indices

The Likelihood (L) index is based on site-specific history, conditions, design, and detection systems that are associated with the release of the radiological materials, according to the following formula:

$$L = \frac{H_L + C_L + D_L + P_L}{4} = 3$$

The site-specific likelihood factor for the SDSP area of the BNP is 3. The basis for scoring each of the four indices comprising the likelihood factor, as defined in the EPRI Guideline, is listed below.

H_L	History	**3** (known recurring spill or ongoing leak from SSC)
C_L	Condition	**3** (Unknown conditions that can lead to real or potential leaks)
D_L	Design	**3** (High probability for soil or groundwater contamination following initial leak or spill)
P_L	Pre-Release Detection	**3** (Potential Release would not be detected until in the environment).

1.3.2 Site-Specific Consequence Indices

The Consequence (C) factor is based on site-specific inventory (I_c), hazard (H_c), mobility (M_c), and post-release detection (P_c) criteria, and are used to determine the consequence index, according to the following formula:

$$C = \frac{I_C + H_C + M_C + P_C}{4} = 2.5$$

The site-specific consequence factor for the SDSP area of the BNP is 2.5. The basis for scoring each of the four indices comprising the consequence factor, as defined in the EPRI Guideline, is listed below.

I_C	Inventory	**3** (high volume/high concentration/high flow rate)
H_C	Hazard	**1** (by definition tritium is listed as a low hazard)
M_C	Mobility	**3** (High mobility)
P_C	Post-Release Detection	**3** (Release first detected near the site boundary)

1.3.3 Priority Index Score

As previously mentioned, the priority index is determined by the following equation:

Priority Index (PI) = Likelihood (L) x Consequence (C) x Normalization Factor (N)

The resulting priority index for the SDSP is as follows:

Priority Index (PI) = 3 (L) x 2.5 (C) x 11.11 (N) = 83

Based on this score, the SDSP achieves Program Level 3 status.

1.4 Report Organization

The organization and content of the remainder of this report are described below.

Section 2.0 - Investigation Objectives, Activities and Findings

The objectives of the groundwater investigation are summarized. Activities completed during planning and executing the investigation are described. Results of the sampling and analysis program are presented. Included are data to evaluate the nature and extent of contamination observed in soil and groundwater.

Section 3.0 - Physical Characteristics of the Study Area

A description of the Site including: surface features, geology and soils, surface water hydrology, groundwater hydrology, and demography and climate.

Section 4.0 - Conceptual Site Model

A narrative summary of the conceptual site model (CSM) is presented which conveys what is known or suspected about the source(s), releases, release mechanisms, contaminant fate and transport, possible exposure pathways, potential receptors, and potential risks. The CSM is based on information available at the time this report was prepared, and may further evolve as more information becomes available.

Section 5.0 - Development of Remedial Action Objectives and General Response Actions

A discussion regarding applicable rules and regulations is provided followed by presentation of the remedial action objectives. Quantities of contaminated material volumes are presented and general response actions are identified.

Section 6.0 - Identification of Screening Technologies, Types, and Process Options

Potential remedial technologies, suitable for achieving the remedial action objectives are initially identified and screened based on general applicability to site contaminants, media and conditions.

Section 7.0 - Evaluation of Remedial Alternatives

Remedial technologies are assembled into alternatives and evaluated against the primary criteria of effectiveness, implementability and cost. The potential alternatives are compared to each other based on these criteria.

Section 8.0 - Summary and Conclusions

The results of the investigation and the remedial alternatives evaluation are summarized and an alternative is recommended.

Section 9.0 - References

A list of references utilized during the preparation of this Report.

2 INVESTIGATION ACTIVITIES AND FINDINGS

The groundwater investigation activities included intrusive and non-intrusive activities. The objectives of the groundwater investigation activities are as follows:

- Characterize the subsurface stratigraphy in the vicinity of the SDSP;
- Identify groundwater aquifers that may potentially be affected by the release of tritium from the SDSP;
- Characterize the physical and chemical conditions in groundwater aquifers adjacent to the SDSP;
- Estimate the vertical and lateral extent of tritium in groundwater associated with the release from the SDSP;
- Identify potable and non-potable users of groundwater that could potentially be affected by a release at the SDSP, and evaluate whether an offsite release of radiological materials has or could potentially occur;
- Develop and refine the conceptual site model (CSM) for the study area; and,
- Develop and implement a preliminary groundwater monitoring program to regularly monitor the SDSP.

These activities are summarized in the following subsections. The field investigation portion of the groundwater investigation was performed in multiple phases spanning approximately 5 months.

This section also summarizes the results of chemical analyses performed on groundwater samples collected during three monthly groundwater monitoring events completed from August through October, 2007 from the SDSP monitoring wells. The analytical results are presented in tabular form and in figures.

Throughout this section, groundwater data are compared and discussed with respect to the USEPA drinking water standard of 20,000 pCi/L (picocuries per liter).

2.1 Soil Investigation

2.1.1 Methods

Figure 2-1 depicts the location of the soil boring locations, all of which were subsequently completed as groundwater monitoring wells.

A total of sixteen (16) soil borings were advanced using hollow-stem auger drilling techniques. These borings were completed as shallow groundwater monitoring wells, as discussed in Section 2.2, and are generally denoted by a "**C**" in the last digit of the investigation location nomenclature (e.g. ESS-18**C**). Seven (7) soil borings were completed using mud-rotary drilling techniques. These eight borings were advanced into the intermediate depth aquifer, and are denoted by a "**B**" in the last digit of the investigation location nomenclature (e.g. ESS-18**B**). One soil boring (ESS-24**A**) was completed using a combination of air-rotary and mud-rotary drilling techniques to penetrate resistant geologic units encountered.

Continuous soil sampling and standard penetration tests were completed in general accordance with ASTM D-1586 at each boring in order to provide detailed information to support the development of geologic and hydrogeologic cross sections in the vicinity of the SDSP. Additionally, the continuous soil sampling program was strictly maintained to ensure that the investigation activities did not cause or contribute to the migration of contaminants in the subsurface by providing additional conduits or pathways for contaminant migration.

Borehole logs were recorded by a Professional Geologist licensed in the State of North Carolina for all borings advanced during the drilling program. The boring logs were recorded to document the results of the soil sampling activities and support an interpretation of the subsurface stratigraphy and geologic framework at the Site. Interpretation of borehole logs and soil cores provide tools that aid in understanding the geologic and hydrogeologic framework of the Site. The borehole logs (**Appendix A**) describe soil units/lithologies encountered, depths of various strata, results of standard penetration tests, moisture content, and other pertinent data. **Section 3.2** (Geology) and **Section 3.5** (Groundwater Hydrology) describe additional details regarding the physical site settings.

At the request of Progress Energy, a total of three (3) soil samples (SB-SPDA-1, SB-SPDA-2 and SB-SPDA-3) were collected for radiological analysis from a suspected disposal area within the SDSP. All three of the soil samples were collected from the unsaturated zone and composited from approximately zero to five (5) feet below grade.

2.1.2 Findings

The general purpose of the soil investigation program was to characterize the subsurface stratigraphy in the vicinity of the SDSP. As mentioned in Section 2.1.1, the findings of the soil boring investigation with respect to the geology and hydrology of the site are discussed in **Section 3.2** (Geology) and **Section 3.4** (Groundwater Hydrology). Borehole logs for each of the soil borings are included as **Appendix A**.

Several soil samples were collected to evaluate the presence of gamma radionuclides and to evaluate geotechnical characteristics, as described in the following subsections.

2.1.2.1 Radiological Results – Soil Samples

A total of three (3) soil samples were collected for purposes of evaluating the presence of radiological materials at a location within the SDSP. The three samples were analyzed for gamma-emitting isotopes. The locations of the three soil samples are within the SDSP basin in an area specifically used to dispose of radiological material that originated at the BNP. The results are presented in **Table 2-1**. As indicated, Cobalt-60 was identified in two (2) of three (3) samples and Cesium-137 was identified in all three (3) samples.

It is important to note that the soil investigation activities were generally not performed with the intent of determining the nature and extent of radiological materials in the SDSP sediments or underlying soils; however, as discussed later in this report, tritium and other gamma-emitting isotopes associated with documented and/or undocumented releases at the BNP are generally known to have been discharged via the storm water system to the SDSP. As such, additional study of the soil and sediments in the SDSP is warranted with respect to characterizing the nature of radiological materials in the SDSP sediment and to develop an appropriate, long-term remedy associated with the presence of radiological material in the SDSP, as required by the NEI Industry Groundwater Protection Initiative 07-07 (NEI, August 2007):

NEI Objective 1.4: "Establish a remediation protocol to prevent migration of licensed material off-site and to minimize decommissioning impacts."

The EPRI Guidance (November 2007) may also require the sediments in the SDSP to be evaluated:

Guidance Statement 2.2b: "...the contents of the SSCs shall be sampled and analyzed for plant-related radionuclides. Gamma-emitters and tritium shall be analyzed for, as a minimum."

It may be prudent to evaluate the sediments in the pond prior to selecting a long-term groundwater remedy. For example, should the nature and extent of radiological materials in the SDSP sediment warrant a response action as part of the decommissioning process, there may be a technical and financial incentive to evaluate combined remedial approaches to mitigating soil and groundwater components of the SDSP from a decommissioning perspective.

2.1.2.2 Geotechnical Soil Samples

Two undisturbed soil samples were collected from boring ESS-STAB for geotechnical analyses. The samples were collected from the sandy fill material that comprises the SDSP berm 8-10 feet bgs (Sample #1) and the Upper Sand Unit 26-28 feet bgs (Sample #2). Samples were analyzed for moisture content (ASTM D2216), organic content (ASTM D2974), particle size (ASTM D422), permeability and porosity (US Army Corps of Engineers EM 1110-2-1906). The results are as follows:

Sample moisture content ranged from 19.66% to 21.76%;

Organic content was less than 1% and ranged from 0.74% to 0.98%;

The particle size analysis indicates that the soil samples are composed primarily of very fine grain sand and silt;

Permeability testing indicates that the soils have a relatively low permeability ranging from 2.35E-07 cm/sec to 6.55E-08 cm/sec and a porosity range of 36.7% to 37.3%.

The geotechnical results as received from the laboratory are included in **Appendix B.**

2.2 Hydrogeologic Investigation

The objectives of the hydrogeologic investigation were to provide sampling points to define the magnitude and extent of groundwater impacts potentially attributable to the SDSP, and assess the associated potential impacts to groundwater receptors. Throughout the implementation of the hydrogeologic investigation field activities, the scope of the hydrogeologic investigation was increased, and project objectives were expanded in order to meet the intent of the recently developed EPRI (November 2007) and NEI (August, 2007) guidance initiatives. As such, the following objectives of the hydrogeologic investigation were developed:

Identify groundwater aquifers that may potentially be affected by the release of tritium from the SDSP;

Characterize the physical and chemical conditions in groundwater aquifers adjacent to the SDSP; and,

Estimate the vertical and lateral extent of tritium in groundwater associated with the release from the SDSP.

To accomplish the objectives of the study, a network of monitoring wells was installed to characterize the hydrostratigraphy and provide groundwater monitoring points in the relevant hydrogeologic units at the site. The hydrogeologic units identified at the site consist of a shallow unconfined aquifer, an intermediate semi-confined aquifer, and deep unconfined groundwater aquifer. A sufficient number of groundwater monitoring wells were installed in each of the three hydrogeologic units to characterize each aquifer and estimate the extent of impacts associated with the SDSP.

The following subsections summarizes the methods used to install the groundwater monitoring well network, and the analytical results of groundwater samples collected during the initial 3 months of the groundwater monitoring program (August through October 2007). The results of aquifer testing and hydrogeologic characterization are presented in Section 3.5.

2.2.1 Monitoring Well Installation

All drilling activities were performed by Geologic Exploration, Inc. and overseen by SSi. A number of drilling methods were employed to complete the installation of the groundwater monitoring well network, including hollow-stem auger (shallow wells), mud-rotary (intermediate wells), a combination of mud-rotary and air-rotary (deep well), and hand-auger (shallow wells located in the marine estuary along Nancy's Creek and Gum Log Branch). The drilling activities are described in the following sections. Monitoring well construction details are presented in Section 3 and Appendix A.

2.2.1.1 Shallow Groundwater Monitoring Well Network

During the investigation, fourteen (14) shallow permanent monitoring wells (ESS-17C through ESS-24C, ESS-26C through ESS-28C, ESS-30C, ESS-31C and ESS-STAB) and one (1) temporary monitoring well (STR-6) were installed in the vicinity of the SDSP. One additional shallow permanent monitoring well, ESS-25C, was installed on the opposite site of the cooling water intake canal. All sixteen shallow monitoring wells were installed using 4 ¼-inch I.D. hollow-stem auger drilling techniques in locations depicted on **Figure 2-2**. Monitoring wells were constructed using 2-inch I.D. Schedule 40 PVC well casing and 0.010-slotted 2-inch diameter Schedule 40 PVC well screen. The terminal depth of the shallow wells ranged from approximately fifteen (15) feet bgs (below ground surface) to thirty-one (31) feet bgs. In general, the shallow wells were installed to fully-penetrate the vertical extent of the shallow aquifer.

In addition to these sixteen shallow monitoring wells installed near the SDSP, six (6) shallow wells (ESS-NC-1 through ESS-NC5, and ESS-GLB1) were installed along the edge of Nancy's Creek in the tidal marsh locations depicted on **Figure 2-2**. The six marsh wells were installed along the creek in order to identify and characterize a possible release of tritium from the shallow aquifer into Nancy's Creek. These six wells were installed using a 4-inch diameter hand-auger to advance the boreholes, which were generally advanced to a terminal depth of approximately eight (8) feet bgs. Monitoring wells were constructed using 2-inch I.D. Schedule 40 PVC well casing and 5-feet of 0.010-slotted 2-inch diameter Schedule 40 PVC well screen. In general, the marsh wells were installed in the clayey wetland sediments, although sand was encountered at the base of several of the boreholes.

2.2.1.2 Intermediate Groundwater Monitoring Well Network

Seven (7) intermediate groundwater monitoring wells (ESS-18B through ESS-22B, ESS-24B, and ESS-25B) were installed to evaluate groundwater conditions associated with a discrete water bearing zone that is hydraulically isolated from the shallow aquifer by a low-permeability aquitard (dark grey silt/clay). The location of the intermediate monitoring well network is depicted on **Figure 2-3**.

The shallow and intermediate wells in each cluster were installed in separate boreholes to eliminate the possibility of cross-contamination between aquifers. Additionally, surface casings were installed into the low-permeability unit and tremie-grouted in place in order to provide an appropriate seal and eliminate the vertical migration of groundwater between the two aquifers. End caps were fitted to the bottom of the surface casings to keep shallow groundwater from filling the casing as the casing was being installed, further preventing the potential for cross-contamination between aquifers. The low permeability unit was generally observed in all of the soil borings advanced during the project at a depth ranging from approximately 5 to 10 feet bgs.

One existing intermediate well, ESS-17B (formerly referred to as ESS17), was selected for inclusion in the groundwater monitoring program for the SDSP area since its location and construction specification supported the evaluation of the intermediate aquifer.

2.2.1.3 Deep Groundwater Monitoring Well Network

One deep monitoring well (ESS-24A) was installed during the field investigation. The deep well was installed in the hydrogeologic unit present beneath the intermediate depth aquifer. The depth of the ES-24A was selected based on the presence of a low-permeability unit that separated the intermediate aquifer from the deep aquifer at ESS-24A. Two surface casings were installed in ESS-24A. The initial surface casing was installed in the low-permeability unit between the shallow and intermediate aquifers. The second surface casing was installed into the low-permeability unit between the intermediate and deep aquifer. Each casing was tremie-grouted in place and given 24 hours to cure prior to advancing the borehole deeper into the subsurface in order to provide an appropriate seal and eliminate the vertical migration of groundwater between the aquifers. End caps were fitted to the bottom of the surface casings during installation to keep potentially impacted groundwater from filling the casing as the casing was being installed, further preventing the potential for cross-contamination between aquifers. The low permeability unit between the intermediate and deep aquifer was observed between 77 and 107 ft bgs.

Three (3) existing deep wells, ESS-13A (formerly referred to as C33A1), ESS-27A (formerly referred to as CT1), and ESS-17A (formerly referred to as C27A3) were selected for inclusion in the deep groundwater monitoring well network for the SDSP area since their locations and construction specifications supported the evaluation of the deep aquifer, which is used as a potable water supply aquifer for the City of Southport and nearby Town of Oak Island. The three deep wells are constructed at an appropriate depth interval and spatially distributed to provide appropriate characterization of the groundwater conditions in the potable supply aquifer near the SDSP. Note that groundwater samples were not collected from well ESS-13A as part of the investigation.

The location of the deep monitoring wells is depicted on **Figure 2-4**. Geologic boring logs are included in **Appendix A**. Sections 3.2 (Geology) and Section 3.5 (Groundwater Hydrology) describe the physical nature of the subsurface materials encountered.

2.2.1.4 Monitoring Well Installation

The general monitoring well installation procedures are summarized below. The six (6) shallow marsh wells were installed by hand as described in Section 2.2.1.1

1. The field Geologist selected the well depth for the shallow wells based on depth of the first low-permeability unit (dark grey silt/clay) at each well location. The screened interval for the intermediate-depth monitoring wells was selected during drilling with the objective of establishing a groundwater monitoring network in the water bearing zone that is immediately below the shallow aquifer (isolated from the shallow zone by the dark grey silt/clay).
2. The shallow wells (Type I) were installed using 4¼-inch inner diameter (I.D.) hollow stem augers with the bottom of the well screen placed at or immediately above the aquitard (dark gray silt/clay units) that separates the shallow aquifer from the intermediate aquifer.
3. The intermediate wells (Type II) were completed by installing a 6-inch I.D. surface casing into the low-permeability unit. End caps were fitted onto the casing prior to lowering the casing into the borehole to keep potentially impacted shallow groundwater out of the casing during the installation. The casings were tremie-grouted in place and given 24 hours to cure prior to advancing the borehole deeper into the subsurface. The screened interval of each intermediate well was selected to intersect the lower sand unit (intermediate aquifer) that is underlying the low-permeability unit.
4. The deep well (Type III) was completed by installing a 10-inch I.D. surface casing into the initial low-permeability unit. End caps were fitted onto the casing prior to lowering the casing into the borehole to keep potentially impacted shallow groundwater out of the casing during the installation. The casing was tremie-grouted in place and given 24 hours to cure prior to advancing the borehole deeper into the subsurface. The borehole was subsequently advanced through the intermediate aquifer to the underlying Peedee confining unit (tight black silt/clay). A 6-inch I.D. PVC casing was installed into the Peedee confining unit. The 6-inch

casing was tremie-grouted in place and given 24 hours to cure prior to advancing the borehole deeper into the Peedee aquifer. The screened interval of the deep well was selected to be consistent with other deep wells installed in the vicinity of the SDSP.

5. Shallow monitoring wells were installed using conventional hollow-stem auger (HSA) methods. The deeper monitoring wells were installed using conventional mud-rotary drilling technologies. Mud rotary was determined to be necessary due to the instability of the soil and weathered rock matrix upon disturbance.

6. Rock coring was conducted during the advancement of the deep monitoring well (ESS-24A) in order to obtain core samples of a hard, consolidated unit encountered in the boring at 70 feet bgs.

7. The monitoring well installation program was coordinated in conjunction with the soil boring program, which utilized soil sampling techniques to collect samples for geologic interpretation and description of each stratigraphic unit encountered within the borehole. Core samples were obtained from the surface to designated depths of each boring. These samples were logged by the Site Geologist.

8. Formation water and drill cuttings generated during the construction of monitoring wells were collected and containerized in Department of Transportation (DOT) approved shipping containers (1A2, 55-gallon steel drums). Solid and liquid materials from the drilling program were subsequently transported to the SDSP for disposal.

9. At least ten feet of 2-inch-ID, Schedule 40 PVC, machine cut, well screen with 0.010-inch-slot size was set at the bottom of each Type I well. A sufficient length of Schedule 40 PVC riser pipe was coupled to the screen to allow the PVC riser pipe to extend above the ground surface. Well screens were fitted with a nominal 2-inch solid (unslotted) bottom sediment trap.

10. Type II wells were constructed with the same construction defined in Item 9 above except that a 6-inch I.D. PVC surface casing was installed into the low-permeability aquitard to prevent the possibility that the monitoring well could serve as a conduit between the overburden aquifer and intermediate zones.

11. The annular space around the well screen was back-filled with clean uniform sand (filter pack sieve #2). The filter pack was placed from the bottom of the well to approximately 2 to 3 feet above the top of the well screen. A seal consisting of a minimum of a 2-foot-thick bentonite seal was placed above the sand and allowed to hydrate. The remaining annular space was then tremie-grouted with a bentonite-to-

cement grout mixture ratio selected to fill the annular space and control shrinkage while hardening.

12. All wells (except as those noted in Item 13, below) were completed as stick-up wells, with a lockable protective steel cover, in order to facilitate ease in locating the wells. Each well was secured with a lockable expansion plug.
13. Monitoring wells ESS-27C, ESS-25C, and ESS-25B were completed flush to grade with steel well box/traffic protectors and secured with a lockable expansion plug.
14. A concrete pad was installed around the security casing and mounded in such a way as to direct surface runoff away from the casing.
15. Monitoring well construction sketches (**Appendix A**) were prepared for each monitoring well.
16. Dedicated groundwater sampling equipment, including a stainless-steel bladder pump, Teflon® tubing, and an integrated well cap, was installed in each of the SDSP monitoring wells to facilitate the anticipated future monitoring program.

2.2.2 Aquifer Testing

Aquifer tests (slug tests) were conducted on monitoring wells and a short-term pumping test was conducted on monitoring well ESS-18C. The tests provided a means of estimating the hydraulic conductivity of the aquifer deposits. This data was later used with other relevant site-specific data (groundwater levels, and gradient derived water potentiometric surface maps) to evaluate ground water flow rates. The results of the aquifer tests and subsequent calculations are provided in Section 3.4, Appendix C, and Appendix D.

The aquifer tests were conducted using an In-Situ® Troll® Model SP4000 digital data logger with electronic pressure transducer probe. The Troll® was placed into the well at the beginning of the test, allowed to equilibrate, and the static water level was monitored with the data logger via a laptop computer during the tests. The water level data recorded electronically in the memory of the data logger and was later analyzed by the groundwater software AquiferTest® version 2.56 developed by Waterloo Hydrogeologic, Inc

2.2.3 Water Level Measurements

Two complete rounds of depth-to-water measurements were recorded from all existing SDSP monitoring wells on October 2, 2007 and October 16, 2007. Measurements were collected using a Keck ET Model 122 Water Level Indicator Probe capable of measuring depth to water within 0.01-foot accuracy. These measurements were used to provide data to map the potentiometric surface of the shallow, intermediate, and deep aquifer and the direction of groundwater flow in the water-bearing zones at the Site. The results are summarized on **Table 2-2**, and presented as potentiometric surface maps in Section 3.5.

2.2.4 Groundwater Monitoring Program

Following the installation of the monitoring wells, a monthly groundwater monitoring and sampling program was initiated for all SDSP monitoring wells. A Geosmart dedicated low-flow groundwater sampling system was installed into SDSP monitoring wells to facilitate the collection of high-quality, representative samples in general accordance with the US EPA low-flow sampling methodology (EPA/540/S-95/504, April, 1996). The low-flow groundwater sampling method was selected for the SDSP monitoring program to provide consistent, highly representative groundwater samples. Each Geosmart pump system was specifically constructed for each well, and includes a dedicated bladder pump (installed at the approximate mid-point between the static hydraulic head and the base of each well) and associated hardware. The dedicated bladder pumps were outfitted with a heavy duty Teflon® bladder, Teflon® sample and air-line tubing, and an integrated well cap, to facilitate ease of sample collection.

2.2.5 Groundwater Sampling

The monthly groundwater monitoring and sampling activities were commenced in August, 2007. Three (3) rounds of monthly groundwater samples were collected for laboratory analyses from the SDSP monitoring wells between August and October, 2007, as follows:

The first round of groundwater sampling was conducted between August 2 and August 8, 2007;

The second round of groundwater sampling was conducted between September 12 and September 14, 2007; and,

The third round of groundwater sampling was conducted between October 16 and October18, 2007.

The groundwater samples were analyzed for tritium by Progress Energy during all three rounds of groundwater monitoring in a chemical laboratory at the Site.

A consistent naming convention was established to ensure that all samples collected throughout the SDSP groundwater monitoring program would be given unique sample identification, as follows:

> **[ESS] – [Well I.D.] – [# (Sampling Round)]** As an example, the sample collected from monitoring well ESS-19B during the third monthly groundwater monitoring is named ESS-19B-3.

Prior to sampling, each well was purged using a low flow sampling technique to assure collection of a representative groundwater sample. Water quality measurements were collected during the purging activities. The procedure for well purging and sampling is generally as follows:

1. First, the security cap was removed, and the depth to water in the well was determined by sounding the well with a water level meter (Keck ET). The depth to water was recorded on a groundwater sample form.
2. The portable air compressor was connected to the air line port on the top of the well, the sample line was connected from the sample port on the well to the in-line water quality instrument (YSI MP556 with flow through cell), the air compressor was started, and purging of groundwater at the well was commenced.
3. An optimum pump rate was established and documented at each well on a well sampling form for each well. The groundwater quality parameters and depth to water were monitored and recorded at prescribed time intervals to determine when the water quality parameters had stabilized to within 10%.
4. Following the stabilization of the groundwater quality parameters, groundwater samples were collected from the wells and the sampling time was recorded on the groundwater sampling form.
5. Purge water was collected in dedicated purge water containers and transported to the SDSP.

2.2.6 Groundwater Regulatory Standard for Tritium

The US EPA maximum contaminant level (MCL) for tritium is 20,000 pCi/L, which is a dose-based drinking water standard. As such, the tritium MCL is generally used by State and Federal environmental regulators as the screening concentration for tritium identified in groundwater. The US EPA established a conservative groundwater radiological limit (standard) of 4 mrem (millirem) per year as means to avoid future contamination of public water supplies due to controllable human activities. The MCL of 20,000 picocuries per liter (pCi/L) for tritium was thereby established in the 1970s that reflected the concentration of tritium that, if present in the drinking water consumed daily by humans throughout a calendar year, would result in an annual dose of tritium of 4 mrem/year. If other radioactive materials are present in the drinking water, the sum of the annual dose from all radionuclides is not permitted to exceed 4 mrem/year. The tritium standard assumes that no other radiological materials are present in the groundwater.

Updated intake calculations used by US EPA in the 1990s found that, based on improved intake models, the concentration of tritium in drinking water that, if consumed, would result in a dose of 4 mrem/year, is over 60,000 pCi/L. However, the drinking water standard remains unchanged.

2.2.7 Groundwater Analytical Results Summary

Groundwater samples were collected from all of the SDSP wells during each of the three groundwater sampling events. **Table 2-3, Table 2-4, Table 2-5,** and **Table 2-6** present analytical results from the three groundwater sampling events for the shallow aquifer, marsh wells, intermediate aquifer, and deep aquifers, respectively. The nature and extent of tritium identified in groundwater samples is presented below.

2.2.7.1 Shallow Surficial Aquifer - Groundwater Analytical Results

There are currently fifteen (15) shallow groundwater monitoring wells installed in the shallow surficial aquifer that are included in the groundwater monitoring program for the SDSP, as shown on **Figure 2-2**. In addition, well STR6 was installed as a temporary well but not sampled during any rounds of groundwater sampling. The shallow wells are distributed around the SDSP to provide an appropriate spatial distribution of data points to complete the study objectives.

Groundwater samples were collected from each of the fifteen (15) shallow groundwater monitoring wells during each of the first three monthly sampling events. The analytical results of the groundwater samples are presented on **Table 2-3**, and are depicted on map **Figure 2-5** (August), **Figure 2-6** (September), and **Figure 2-7** (October).

Tritium was detected in 14 of the 15 wells at least once during the first three rounds of sampling. Concentrations of Tritium range from 750,700 pCi/L at ESS-18C to below the detection limit (300 pCi/L) at ESS-25C, which is located across the cooling water intake canal. The highest concentrations of tritium in the shallow surficial aquifer are exhibited at ESS-STAB, ESS-19C, ESS-18C, ESS-26C, and ESS-27C, which are located to the immediate north and northwest of the SDSP.

The spatial distribution of tritium in the shallow surficial aquifer indicates tritium is migrating radially (in all directions) from the SDSP in the shallow groundwater. The majority of tritium is being released from the SDSP to the north and northwest of the SDSP. This condition is believed to be caused by the configuration of the finger dyke, which directs water discharged into the SDSP to the north rim of the pond. Since a relatively small quantity of process water is discharged into the pond in comparison to the total volumetric capacity of the SDSP, the discharged water is believed to preferentially infiltrate the northwest and northern area of the SDSP. Additional discussion regarding the distribution of tritium in shallow groundwater is discussed in Section 4.0.

In general, concentrations of tritium observed in the shallow surficial monitoring well network were relatively consistent at each well.

2.2.7.2 Marsh Wells Groundwater Analytical Results

Six (6) shallow wells were installed along Nancy's Creek and Gum Log Branch at locations shown on **Figure 2-2**. The intent of the installation of the marsh wells was to install groundwater data points into the surficial sand aquifer sufficiently close to the creek to evaluate the potential discharge of "tritiated" groundwater to the creek. Each marsh well was installed in the tidal wetlands approximately 5 feet from the edge of the creek.

Because the installation of these wells was completed by hand to minimize impact to the wetland, the maximum depth the wells were able to be installed was approximately eight (8) feet bgs. As a result, limited penetration (approximately 6-inches) into the surficial sand aquifer was accomplished, and the majority of the screened interval of the marsh wells intersects the silty marsh sediments, which are saturated by the brackish tidal water of Nancy's Creek and Gum Log Branch. Therefore, groundwater in these wells is likely diluted by the infiltration of surface water that saturates the marsh sediments. As a result, the data from these wells is used primarily as a screening indicator to estimate the probability that a discharge of tritium to the creek may be occurring.

The groundwater analytical results are presented on **Table 2-4**. During the three rounds of groundwater monitoring, tritium was not detected in any of the marsh wells except for one. During the second round of groundwater monitoring completed in September 2007, tritium was detected in ESS-NC4 (ESS-NC4-2) at a concentration of 314 pCi/L. ESS-NC4 is located down gradient of ESS-19B/C. Based on the detection of tritium in this well, it is assumed that tritium is likely discharging to Nancy's Creek. However, due to likelihood of dilution discussed above, the data collected in the marsh wells may be underestimating the concentration/dose of tritium that may be entering the creek.

2.2.7.3 Intermediate Aquifer - Groundwater Analytical Results

There are currently eight (8) intermediate-depth groundwater monitoring wells installed in the intermediate aquifer that are included in the groundwater monitoring program for the SDSP, as shown on **Figure 2-3**. The intermediate wells are located around the SDSP to provide an appropriate spatial distribution of data points to complete the study objectives.

Groundwater samples were collected from each of the eight (8) shallow groundwater monitoring wells during each of the first three monthly sampling events. The analytical results of the groundwater samples are presented on **Table 2-5**, and are depicted on map **Figure 2-8**.

Tritium has been detected in 3 of the 8 wells at least once during the first three rounds of sampling. None of the wells exhibited a concentration of tritium exceeding the drinking water standard. The detected concentrations of tritium range from 3,226 pCi/L at ESS-19B (October 2007) to 391 pCi/L at ESS-21B (October 2007). Tritium has not been detected in the intermediate wells ESS-18B, ESS-20B, ESS-22B, ESS-24B, and ESS-25B (which is located across the cooling water intake canal).

Unlike the shallow aquifer, which exhibits a radial groundwater flow pattern in the vicinity of the SDSP, the intermediate aquifer appears to flow in a relatively linear direction to the southeast toward the cooling water intake canal. Groundwater flow is discussed in detail in Section 3.

2.2.7.4 Deep Aquifer - Groundwater Analytical Results

There are currently three (3) relatively deep groundwater monitoring wells included in the SDSP monthly monitoring program. The location of these wells is depicted on **Figure 2-4.** These wells are installed in the Peedee aquifer, which is a source of potable water to portions of Southport and Oak Island. The deep wells are located around the SDSP to provide an appropriate spatial distribution of data points in this aquifer to the study objectives.

Groundwater samples were collected from each of the three (3) deep groundwater monitoring wells during each of the first three monthly sampling events. The analytical results of the groundwater samples are presented on **Table 2-6**.

Tritium has not been detected in any of the deep wells during the first three rounds of sampling.

2.3 Surveying and Mapping

A site survey was conducted to include pertinent Site features, structures, and existing monitoring wells. Surveying activities were performed and certified by a North Carolina Registered Land Surveyor (McKim and Creed). The surveyor reviewed existing site maps and other maps that encompassed the project area prior to mobilization. The surveyor ascertained the locations and conditions of all horizontal and vertical controls available for the project utilizing benchmark descriptions, maps, and listings provided by Progress Energy, as well as other documents. The survey was georeferenced using two local monuments of known northing and easting as defined by the North Carolina Geological Survey.

A survey map was produced that includes scale, benchmarks, North arrow, dimensions and locations of property boundaries, the locations of existing monitoring wells and sample locations. Existing structures were located, including the rim of the SDSP. The survey map provided the information required to produce a site basemap on which all of the site maps presented in this report have been based.

2.4 Data Validation

Data analysis and validation was performed in accordance with BNP requirements. The laboratory data associated with this investigation was not validated according to procedures based on the U.S. EPA Functional Guidelines (U.S. EPA 1994). The EPRI Guidance (EPRI, November 2007) requires the establishment, documentation, and implementation of data quality objectives (DQOs). The DQOs include the development of a quality assurance/quality control (QA/QC) program and data validation activities to be documented in advance and implemented for all associated groundwater investigation activities. The relevant guidance is included in Section 7, *Establishing a Groundwater Sampling and Analysis Process*. Based on the general absence of a DQO program, it is highly recommended that these items be reviewed and addressed in order to establish a consistent means of verifying the usability and general adherence to quality standards set forth by EPRI and the Functional Guidelines of the US EPA.

3 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section summarizes the physical characteristics of the Site including surface features, geology, soils, surface water hydrology, groundwater hydrology, climate, and demographics.

3.1 Surface Features

The storm drain stabilization pond (SDSP) is located at the Brunswick Nuclear Plant (BNP) in Southport, North Carolina. The Site location is shown in **Figure 1-1**. The surface layout and features discussed in this section are depicted on **Figure 3-1**. The Site is located within the secured access area of the BNP, and is approximately 2.5 miles north-northeast of the City of Southport, North Carolina. Access to the SDSP is limited to workers and visitors of the BNP facility, and is accomplished by entering the BNP from River Road (State Route 87). The approximate geographic coordinates of the SDSP are 35° 06' 18.6'' north latitude and 78° 02' 32.8" west longitude. The SDSP encompasses approximately 59 acres.

The SDSP is located approximately 880 feet east of the BNP power generating facility and consists of a constructed sediment dewatering pond that has been converted for use as a storm water retention/treatment facility. The SDSP was constructed above the pre-construction surface topography and includes an earthen berm that surrounds the 59-acre pond. The earthen berm is approximately ten (10) feet higher in elevation than the surrounding land surface to the west and south, and approximately twenty (20) feet higher in elevation than the land surface to the north and east. The berm consists of a wooded upland habitat that is densely vegetated by varieties of gymnosperm (pine) and other trees that provide a visual barrier as well as soil stability on the slopes of the berm. The interior of the pond is generally covered by vegetation including phragmites and similar vegetation suitable for wet habitats. Organic silts and other sediments that have accumulated as a result of the industrial use of the pond are assumed to be the predominant sediment/soil materials present within the interior of the pond.

Significant surface features adjacent to the pond that are highlighted on **Figure 3-1** are referenced in bold in the following Section.

Nancy's Creek: Approximately 100 feet to the north of the SDSP, a marine estuary is present that consists of Nancy's Creek and associated tidal wetland habitats. The creek and wetlands drain to the east during the outward flow of the tides into the **Cape Fear River**. Water in Nancy's Creek is brackish (low tide) to saline (high tide).

Gum Log Branch: To the east/northeast of the SDSP, Gum Log Branch and associated tidal wetlands are present. Gum Log Branch generally flows to the north during outward tidal flows and is a tributary to Nancy's Creek. Gum Log Branch is a natural surface drainage feature, but also receives water from a constructed **recovery pond** that is used to facilitate the return of marine life that was captured/impinged on the cooling water intake screens adjacent to the BNP generating facility. A constructed drainage system (referred to as the "slide for life") feeds water and marine life recovered from the intake structure to the recovery pond, where the wildlife can "recover" and return to the marine environment. Further to the east of Gum Log Branch, a larger dredge pond is present that was used during the construction of the intake canal, and has been used to periodically provide a sediment dewatering basin for dredged intake canal sediments.

Intake Canal: The cooling water intake canal is located adjacent to the SDSP to the south. The intake canal is approximately 18 feet deep and is designed to provide a constant source of water from the **Cape Fear River** to the BNP to cool the nuclear reactors. The design of the intake canal permits flow into the plant area, and cannot be reversed by tides or other hydraulic conditions. As such, the water elevation in the canal is relatively consistent and presents a shallow hydraulic boundary to the south of the SDSP. To the south of the intake canal, a dredge pond is present that was used during the construction of the intake canal, and has been used to periodically provide a sediment dewatering basin for dredged intake canal sediments.

3.2 Geology

3.2.1 Regional Geology and Hydrogeology

According to the 1985 Geologic Map of North Carolina, prepared by the North Carolina Geological Survey Section of the North Carolina Department of Environment and Natural Resources (NC DENR), the Site is located in the North Carolina Coastal Plain Physiographic Province. The geology of this area is characterized by an easterly thickening wedge of unconsolidated sediments underlain by limestone aquifers. According to the United States

Geologic Survey (USGS) *Water Resources Investigations Report 03-4051* (USGS, 2003), the SDSP is located in the Coastal Lowlands subregion of the coastal plain, which consists of sediments deposited in estuarine and near-shore environments. However, close to the north is the interpreted boundary with the middle-coastal plain subregion, which is characterized by variable sediment conditions laterally and vertically, and includes coarse sands associated with shoreline deposits to silts and clays associated with estuaries and lagoons deposited during the Pleistocene.

Based on the *Water Resources Investigations Report,* the geologic formations in the area, from most recent to oldest include the following:

the quaternary-aged surficial sand deposits;
the undifferentiated Pleistocene and Pliocene deposits of the quaternary and later tertiary system;
the Tertiary-aged Castle Hayne Formation;
the Tertiary-aged Beaufort Formation (Peedee Confining Unit); and,
the Cretaceous-aged Peedee Formation.

According to the North Carolina Geologic Survey, the Site area is underlain by the Waccamaw Formation, which is generalized as a fossiliferous bluish-gray to tan loosely consolidated sand with silt and clay. The Waccamaw Formation straddles the Pleistocene-Pliocene boundary, and generally correlates with the data provided by US Geologic Survey.

These units are described in the USGS report as follows:

Surficial Sand Deposits: Light yellow to grey fine to medium sands with traces of clay, coarse-grained sand, pebbles, and minerals. These deposits are part of the *surficial aquifer*, which is a shallow groundwater aquifer in the uppermost strata in Brunswick County.

Pleistocene and Pliocene Deposits: An undifferentiated, variable unit that does not have sufficient to divide into discrete formations, this unit is characterized by shelly quartz sands with well preserved shell material or shell hash, and shelly carbonates consisting of shell hash and sandy marls or sandy moldic limestone. An important fact relevant to the SDSP stratigraphy is indicated by USGS is as follows:

> "In areas where the Castle Hayne...confining unit is missing, the surficial aquifer is in direct contact with the Castle Hayne Aquifer..." (Pg. 14, USGS, 2003).

Clays and silts in these deposits are generally thin, discontinuous, and lack lateral continuity. However, the USGS points out that, at Sunny Point Military Terminal (SPMT), located approximately two-miles northeast of the SDSP, a clay unit separates the surficial aquifer into a surficial aquifer and a deeper tertiary sand aquifer, which is directly underlain by the Castle Hayne aquifer at SPMT.

Castle Hayne Formation: The Castle Hayne Formation consists primarily of limestone and sand deposited in a marine environment (Winner and Coble, 1996). The elevation of the top of the Castle Hayne in the vicinity of the Site is documented to be approximately 45 feet below sea level, as documented on the hydrogeologic cross section provided as Plate G of the USGS Water Resources Report (USGS, 2003). **Figure 3-2** presents a portion of this cross section and indicates the location of the SDSP on the cross section. Notably, the elevation of the interpreted top of the Castle Hayne Limestone as observed while drilling ESS-24A is 54 feet below sea level. The importance of this information is discussed later in this report. The Castle Hayne aquifer is the principal source of potable water supply for the City of Southport (USGS, 2003).

Peedee Confining Unit: The Peedee confining unit is generally the closest clay or silt beds that occur near the top of the Peedee Formation. Where it is present, the Peedee confining unit is part of the Beaufort Formation in southeastern Brunswick County (Lautier, 1998). The elevation of the top of the Peedee confining unit is documented to be approximately 65 feet below sea level, as documented on the hydrogeologic cross section depicted on **Figure 3-2** and provided as Plate G of the USGS Water Resources Report (USGS, 2003). The elevation of the top of the Peedee confining unit as interpreted from core samples collected from ESS-24A is 60 feet below sea level. The importance of this information is discussed later in this report.

Peedee Formation: The composition of the Peedee Formation in southeastern Brunswick County is described as the Rocky Point Member of the Upper Peedee Formation consisting of gray, sandy, moldic limestone that grades downward to a calcareous sandstone. The upper part of the Peedee aquifer is an important source of water for domestic and commercial use, and is used in combination with the Castle Hayne aquifer as the source of municipal water supply by Brunswick County (USGS, 2003).

3.2.2 Site-Specific Geology

Site-specific geology near the SDSP is relatively complex, and is very consistent with the regional geology represented by state and federal resources. In general, the site-specific geology consists of approximately 70 feet of unconsolidated materials overlying limestone. The unconsolidated materials generally consist of an upper sand unit, a low permeability silt/clay unit, a lower sand unit, a limestone unit, a low permeability confining unit, and a sandy limestone unit. Two site-specific geologic cross sections have been prepared that depict the geologic units encountered at the site. **Figure 3-3** presents a Cross Section Location Map that shows the areas transected by **Figure 3-4** (Geologic Cross Section A-A') and **Figure 3-5** (Geologic Cross Section B-B').

As exhibited in the two cross sections, the geologic strata that were identified at the Site during the groundwater investigation include the following:

Upper Sand Unit (S_U): A fine to medium grained sand unit was generally observed around the perimeter of the SDSP to a depth of approximately 20 feet below ground surface (or approximately 5 feet below mean sea level or -5 feet MSL). The sand was generally observed as a loose tan to light grey fine sand, with varying amounts of silt. Towards the middle to bottom of the Upper Sand, silt and clay lenses were often observed, although the depth of the silt and clay lenses were not generally consistent between borings. In some borings, clay and silt lenses were not observed. The Upper Sand was typically observed to be saturated at a depth of approximately five to ten feet below grade. Towards the base of the Upper Sand, shelly layers were often encountered in thin lenses of silt, and the contact with the underlying low-permeability unit was typically characterized by interlayered sandy silts, silty sands, and clayey silts. This unit correlates with the *Surficial Deposits* described by USGS (USGS, 2003).

A groundwater aquifer is observed in the Upper Sand and is referred to in Section 2 and later in this report as the Shallow Aquifer. The shallow aquifer is the groundwater unit that has been impacted by the release of tritium in the SDSP, as described in Section 2.2.7 (Groundwater Analytical Results) and Section 3.4.3 (Site-Specific Hydrogeology). This aquifer correlates with the *Surficial Aquifer* described by USGS (USGS, 2003).

Low-Permeability Unit (LP): Below the Upper Sand Unit, a low permeability unit was encountered at each of the investigation locations. The low permeability unit consists of cohesive dark grey silt with varying amounts of clay. As described above, the contact with the overlying Upper Sand is typically gradational until the competent dark grey silt and clay unit is encountered. The vertical thickness of the low permeability unit is approximately 4 to 15 feet thick, and exhibits shelly layers and occasional thin laminates of very fine grained sand within the low to medium moist silt and clay. In some borings (i.e. ESS-STAB), plant casings were observed within the silty clay matrix at the uppermost portion of the unit. The low permeability unit hydraulically separates the Shallow Aquifer and the Intermediate Aquifer, as shown on the geologic cross sections presented on **Figure 3-4** and **Figure 3-5**.

Lower Sand Unit (S_L): Below the low permeability unit, a layer of fine to medium grey sand was observed. The Lower Sand generally consists of quartz sands and silty limey sands (sandy carbonates) with occasional shells, shell hash, clayey sands, clayey silt, and sandy silt layers. The lower portion of this sand unit generally grades to a limey sand/sandy carbonate. The thickness of the Lower Sand is generally 30 to 35-feet thick. This unit correlates with the *Undifferentiated Pleistocene and Pliocene Deposits* described by USGS (USGS, 2003)

The Lower Sand exhibits saturated conditions generally throughout the vertical thickness of the unit. A groundwater aquifer is observed in the Lower Sand and is referred to in Section 2 and later in this report as the Intermediate Surficial Aquifer. This aquifer correlates with the *Tertiary Sand Aquifer* described by USGS (USGS, 2003). Except for conditions near ESS-19B, the intermediate aquifer has generally been protected from the impacted groundwater in the shallow aquifer by the low permeability unit, as described in Section 2.2.7 (Groundwater Analytical Results) and Section 3.4.3 (Site-Specific Hydrogeology).

Castle Hayne Unit (CH): Only one boring (ESS-24A) was completed into the Castle Hayne limestone during the groundwater investigation. The Castle Hayne Limestone was observed as a very hard, consolidated sandy limestone. Rock core samples were obtained of the limestone which was observed to be present at ESS-24A from a depth of 70 to 77 feet below grade. The top of the Castle Hayne Limestone was observed to be 54 feet below sea level. It is important to note that the Lower Sand Unit and the Castle Hayne Unit are generally considered one hydrostratigraphic unit (aquifer) since there is no confining layer that hydraulically separates the two distinct geologic units. This condition has been documented at the nearby SPMT by Crabtree (1983), who determined that the tertiary sand aquifer and the Castle Hayne aquifer have similar hydraulic characteristics and can be considered one aquifer (USGS, 2003). The Castle Hayne aquifer is the principal source of potable water supply for the City of Southport (USGS, 2003). The interpretation of the rock cores and other core samples obtained during drilling at ESS-24A were reviewed and confirmed by Jim Lautier of the North Carolina Department of Environment and Natural Resources. Jim Lautier is the lead technical resource responsible for characterizing the geologic framework in Brunswick County provided in the USGS *Water Resources Investigation Report* (USGS, 2003), according to co-author Stephen Harding of the USGS.

Review of Historical Information – Castle Hayne Limestone

Subsequent to the identification of the Castle Hayne Limestone at ESS-24A, a review of historical drilling documents and borehole logs for groundwater monitoring wells installed prior to the SDSP groundwater investigation was completed. In the 1974 drillers report (Carolina Well and Pump Company, Driller's Logs, Production Well No.2), geologic correlations were reviewed, and two incorrect geologic correlations were identified. "Hard rock" was identified at a depth of 70 to 79 feet bgs (the general depth and thickness of the Castle Hayne unit observed in ESS-24A). However, the driller assigned the Castle Hayne Formation to the "Soft rock" and "rock with sand" observed from 84-101 ft bgs and 101-181bgs, respectively (the depth and general consistency of the Peedee Formation). As a result, it appears that subsequent drilling activities assumed the top of the Castle Hayne to be approximately 100 feet below the surface. In any event, the approximate depth of the boundaries between units and unit thicknesses presented in the drillers report correlate closely with the units and thicknesses characterized during the groundwater investigation of the SDSP, but the *formations were improperly assigned.* It is important to note that the historical drilling records for the deep wells do not indicate the drilling was observed by a geologist, and no core samples were collected, which suggests that the geologic interpretations were generally based on the drillers' interpretation of drill cuttings based on general driller "knowledge", and historical non-scientific interpretation.

The well completion reports for two deep wells located near the SDSP (ESS-13A, and ESS-17A) were specifically evaluated. The previous identification of these wells was C33A1, and C27-AA, respectively. The interpreted depth of the Castle Hayne was similarly prescribed to be the top of the Peedee Formation at approximately 110 feet below grade at each location. Because the slope of the top of the Castle Hayne has been documented to be approximately 9 feet per mile in the vicinity of the Site (USGS, 2003), it is further concluded that previous drillers interpretations of the Castle Hayne unit should have been assigned as Peedee Formation.

Peedee Confining Unit (PC): The Peedee confining unit was observed at ESS-24A in core samples collected during drilling at a depth of 77 feet bgs to 107 feet bgs. The unconsolidated unit consisted of tight, cohesive and soft dark grey clayey silt with very low moisture. The confining unit was consistent in texture and appearance throughout the interval. The elevation of the top of the Peedee confining unit is documented to be approximately 65 feet below sea level, as documented on the hydrogeologic cross section depicted on **Figure 3-2** and provided as Plate G of the USGS Water Resources Report (USGS, 2003). The elevation of the top of the Peedee confining unit as interpreted from core samples collected from ESS-24A is 60 feet below sea level.

Peedee Formation (PF): The Peedee Formation was observed during drilling ESS-24A in core samples collected during drilling at a depth of 107 feet bgs to 140 feet bgs (the terminal depth of the boring). The unit consists of a grey, sandy argillaceous limestone ("dirty" limestone) with moldic features. The material is generally cohesive and relatively hard.

3.3 Surface Water Hydrology

3.3.1 Regional Surface Water Hydrology

Surface water hydrology in vicinity of the SDSP and within the Coastal Plain of North Carolina is characterized by estuarine conditions with relatively low energy, meandering drainage patterns. The total precipitation, which is generally the total inflow of water to the hydrologic system, is estimated to be approximately 55 inches per year. Approximately 9 inches/year of the precipitation results in runoff to streams, 35 inches per year results in evapotranspiration, and 11 inches/year provides recharge (infiltration) to the water table. Of the 11 inches/year of total infiltration to the water table, 10 inches/year is estimated to discharge from the water table aquifer (unconfined surficial aquifers) to local streams (USGS, 2003, and Giese et. al., 1997). The remaining 1 inch/year is estimated to percolate through a confining unit into a deeper, confined Castle Hayne or Peedee aquifers, where it either seeps back into overlying surficial aquifers, larger river basins, or into the ocean.

Many of the local rivers and streams in Brunswick County are tidally influenced due to the proximity to the Atlantic Ocean. As such, the local streams and creeks in the eastern portion of Brunswick County are influenced by the tidal cycles of Cape Fear River, which provides a continual source of brackish to saline water to the estuaries that generally characterize the near coast stream environments in the region.

3.3.2 Site-Specific Surface Water Hydrology

The SDSP is generally a surface water body, much like a pond or lake, and therefore receives the total annual rainfall that falls during a calendar year. Two conditions make the SDSP different from a typical pond or lake: the SDSP is designed to naturally drain down into the subsurface; and, the SDSP receives storm water and other industrial discharges. Therefore, the total annual input to the pond is the sum of the annual precipitation (inches/year) and the total annual discharge of storm water and industrial process water (gallons).

The majority of the land surface near the SDSP consists of pervious surfaces. However, there are a number of man-made and natural drainage features that are present around the SDSP. These systems generally do not contain free standing water since the surface sediments exhibit a relatively high permeability, allowing precipitation to readily infiltrate into the surficial aquifer. Some of the surface drainage features to the northeast of the SDSP drain to monitored outfalls that drain to Nancy's Creek under an NPDES permit.

A storm water collection system was installed along the access road to the south of the SDSP. The system consists of large permeable conduit connected to a series of manholes fitted with float-activated sumps. The system collects surface water runoff and shallow water that infiltrates into the soil, which is conveyed via gravity drainage to a sump and pumped from the manholes into the SDSP. The intent of the system was to ensure that tritiated surface water did not collect in the former storm ditch, presenting the potential for an uncontrolled exposure to tritium.

Gum Log Branch and Nancy's Creek receive a constant source of baseflow from the local surficial aquifers around the SDSP, specifically the shallow surficial aquifer. The amount (volume) of baseflow these surface features receive can be assumed to be the total volume of groundwater in the shallow surficial aquifer that migrates to the associated surface water feature. These features include:

The recovery pond located to the southeast of the SDSP;
Gum Log Branch and associated wetlands;
Nancy's Creek and associated wetland; and
The cooling water intake canal.

Of these surface water features, all of them drain to the Cape Fear River with the exception of the cooling water intake canal, which passes though the BNP facility and discharges to the cooling water discharge canal.

3.4 Groundwater Hydrology

3.4.1 Regional Groundwater Resources

The Site lies in the Coastal Plain Physiographic Province. According to USGS, the following list of regional groundwater aquifers are identified in the study area, and are listed from youngest (shallow) to oldest (deep).

The Quaternary Age Aquifer System, including:
- The shallow Quaternary Age surficial aquifer, and
- The Quaternary-Tertiary Age surficial aquifer (intermediate aquifer).

The Tertiary Age Castle Hayne Aquifer System (part of the intermediate aquifer in the study area); and,

The Cretaceous Age Peedee Aquifer.

There are other regional groundwater aquifers identified by USGS present beneath the Peedee Aquifer, but are generally not discussed since they are generally not viewed as relevant to the SDSP investigation.

The surficial aquifer system is used as a source of agricultural and domestic water supply in Brunswick County (USGS, 2003). Groundwater in the Castle Hayne and Peedee Formations is the principal source for potable water in the region (municipal supply, commercial, and domestic use). This is generally due to poor (brackish) water quality in the lower portion of the Peedee aquifer and deeper geologic formations beneath the Peedee Formation resulting from natural saltwater intrusion. Based on the USGS evaluation of groundwater samples collected in the region, the chemical conditions in the surficial, Castle Hayne, and Peedee aquifers are suitable for use as drinking water. Groundwater is obtained by withdrawing water from groundwater aquifer(s) that exhibit sufficient quality and storage to yield a sufficient supply for its intended purpose.

The Castle Hayne is recharged primarily from the overlying surficial aquifers and where it is exposed or unconfined. The Castle Hayne is also prone to the development of sinkholes, and, where their occurrence is prevalent, the aquifer can be recharged through the development and collapse of sinkholes. A minor amount of recharge (~1-inch) is provided through seepage from the shallow surficial aquifer into the deeper intermediate aquifer directly through infiltration from precipitation, and from the underlying Peedee Aquifer.

The Peedee Aquifer receives recharge generally from the overlying Castle Hayne, as well as from upward leakage from the underlying Black Creek Aquifer.

In general, groundwater quality in the Castle Hayne and Peedee formations is viewed as susceptible to saltwater intrusion caused by "up-coning" of the sodium-chloride type water present in the Lower Peedee and deeper aquifers in the region. Up-coning of deeper groundwater into shallow groundwater aquifers is often caused when groundwater is pumped from the shallower aquifer intervals. As such, the USGS and NCDENR closely monitor groundwater elevations in the region.

3.4.2 Area Groundwater Use

Groundwater in the area is the only source of potable water, and is used for municipal, domestic, and commercial purposes. The City of Southport withdraws groundwater for potable water supply and municipal use from the Castle Hayne and Peedee aquifers from a network of groundwater supply wells located in Southport, within two miles of the SDSP area. The location of several of these wells is depicted on **Figure 3-13**.

Additional groundwater wells are used in the area for commercial and domestic purposes. Although these wells are not identified in the EDR GeoCheck® Report completed for the Site (EDR, Inc., May 31, 2007), these wells have been identified through other resources including USGS, state, county, and information provided by nearby residents. For example, domestic water wells located on residential properties to the north of the Site (on the north side of Nancy's Creek) were identified during discussions with local residents, who reportedly use the wells for non-potable domestic purposes. An additional wellfield is identified at a coal-fired electric generating facility, located approximately 1.25-miles south-southwest from the SDSP. This wellfield allegedly is used for industrial purposes at the facility, and withdraws water from the Castle Hayne and Peedee aquifers.

Progress Energy owns a number of formerly used groundwater supply wells and groundwater monitoring wells at and in the vicinity of the Site. The supply wells are no longer used; however, supply wells in the vicinity of the BNP present a potential future groundwater hazard should the borehole provide a conduit for downward leakage of radiological materials.

3.4.3 Site-Specific Hydrogeology

Site-specific hydrogeology in the unconsolidated materials at the Site was evaluated during the groundwater investigation activities through the installation and monitoring of a network of groundwater monitoring wells in three discrete aquifers in the study area. Hydrogeological evaluation was completed to characterize the horizontal and vertical groundwater flow system between three aquifers in the vicinity of the SDSP, which include the following:

Shallow Surficial Aquifer: The upper portion of the Quaternary Age aquifer described in Section 3.4.1, the shallow surficial aquifer is an unconfined water-table aquifer. The matrix characteristics of the shallow surficial aquifer is discussed in section 3.2.2, Upper Sand Unit;

Intermediate Aquifer (Quaternary/Tertiary Age): The intermediate aquifer is a semi-confined aquifer unit that consists of the Quaternary-Tertiary Age aquifer and the Tertiary Age Castle Hayne Aquifer described in Section 3.4.1. The matrix characteristics of the intermediate aquifer are described in Section 3.2.1 and Section 3.2.2., Lower Sand Unit and the Castle Hayne Unit; and,

Deep Aquifer (Cretaceous Age): The deep aquifer is a confined aquifer in the Peedee Formation, which is described in Section 3.4.1. The matrix characteristics of the Peedee Formation are described in Section 3.2.1 and Section 3.2.2, Peedee Formation.

A summary of the monitoring well construction details is included in **Table 3-1**. The hydrogeological evaluation included the collection of synoptic water elevation measurements at each monitoring well, the completion of a pumping test, the completion of slug tests, the evaluation of horizontal and vertical flow gradients, and a one-month synoptic water elevation study using pressure transducers.

The findings of these studies and the general characteristics of the three aquifers are discussed in the following sections.

3.4.3.1 Shallow Surficial Aquifer

A network of twenty-two (22) shallow monitoring wells (ESS-17C through ESS-28C, ESS-30C, ESS-31C, ESS-STAB, STR6, ESS-NC1 through ESS-NC5, and ESS-GLB1) were installed into the shallow surficial sand aquifer to evaluate the direction of groundwater flow, hydraulic characteristics, and environmental conditions in the shallow surficial aquifer at the Site. The shallow aquifer, which is generally encountered at a depth of approximately seven to ten feet bgs, extends to approximately -5 feet MSL and is approximately 15 feet thick. The aquifer exhibits unconfined, water table conditions, and is recharged directly through infiltration from precipitation.

The shallow aquifer is generally underlain by the low-permeability unit, which was encountered at all boreholes advanced at the Site. The low permeability unit can be considered as a vertical hydraulic boundary between the shallow surficial aquifer and the intermediate aquifer that is below the low-permeability unit, as shown in the cross sections provided on **Figure 3-4** and **Figure 3-5**. However, there is likely a relatively small degree of hydraulic and chemical exchange between the shallow and intermediate aquifers that occurs vertically through the clay, as observed during well development/pumping (observed drawdown), in chemical analytical results (tritium detections at ESS-17B, ESS-19B, and ESS-21B).

It is noted that the constructed depth of the bottom of the intake canal and the BNP foundation are deeper than the base of the low permeability unit. At these areas, hydraulic separation does not exist between the shallow aquifer, intermediate aquifer, and intake canal. As such, the hydraulic head (static water level elevation) in each unit is an important factor that determines the fate and transport of water and chemical constituents to and from these units.

The vertical gradient between the shallow surficial aquifer and underlying intermediate aquifer is in the downward direction, which is generally consistent with previous work conducted at the BNP by others.

The slope of the top of the low permeability unit often plays an important role in determining the direction of groundwater movement in a water table aquifer. A surface contour of the top of the low-permeability unit is presented on **Figure 3-6** relative to mean sea level elevation. The contour is developed using the lithologic description at each borehole and the surveyed elevation of the ground surface at each borehole to develop a general interpretation of the surface gradient(s) associated with the top of the silt/clay unit. As depicted on **Figure 3-6**, the elevation of the top of the clay appears to be highest beneath the SDSP, and generally slopes in a radial direction away from the pond, similar to the observed groundwater flow direction discussed later in this section.

Groundwater Flow Direction in the Shallow Aquifer

Interpretations regarding groundwater flow direction at the Site are based on water level measurements collected from the shallow wells. These data are presented in **Table 2-2** and provided the basis for the interpretation of horizontal flow in the shallow aquifer and vertical groundwater flow between the shallow aquifer and deeper aquifers at the Site. An average groundwater flow rate has been calculated based on water level measurements at each shallow well and the development of a potentiometric surface contour of the shallow water table, an average horizontal hydraulic gradient calculated using the potentiometric surface contour, and the calculated hydraulic conductivity. Hydraulic conductivity was derived primarily from pump test data collected at ESS-18C. The average linear seepage velocity (V_s) for groundwater flow as defined by the Darcy equation is calculated by:

$$V_s = -K \frac{(dh/dl)}{n_e}$$

Where:

K	=	hydraulic conductivity
dh/dl	=	hydraulic gradient
n_e	=	effective porosity

Figure 3-7 and **Figure 3-8** illustrate the potentiometric surface of the shallow unconfined aquifer at the Site on 10/02/2007 and 10/16/2007, respectively. The direction of groundwater flow in the shallow unconfined aquifer is generally radially in the vicinity of the SDSP and is consistent between the two rounds of water level measurements.

Groundwater flow estimates were calculated using the water level measurements. The horizontal gradient in the shallow aquifer during the October groundwater monitoring events was calculated for flow to the north from ESS-STAB to the drainage feature in the wetland adjacent to Nancy's Creek (250 feet horizontal distance) using the groundwater flow maps presented on **Figure 3-7** and **Figure 3-8**, respectively. The hydraulic conductivity (12.7 feet/day) in the aquifer was calculated using the pumping test results from ESS-18C. The results of the pump test analyses are included in **Appendix C**.

Groundwater flow velocities were calculated using the Darcy equation. A value of 33% was assumed for the effective porosity of the water table aquifer material. A summary of the resulting linear velocities is provided below.

Date	**Shallow Surficial Aquifer**
10/02/07	North (ESS-STAB to Drainage feature in Nancy's Creek) Horizontal Gradient Vs 0.0676 ft/ft 0.147 ft/day
10/16/07	North (ESS-STAB to Drainage feature in Nancy's Creek) Horizontal Gradient Vs 0.068 ft/ft 0.148 ft/day
Average	**0.1475 ft/day**

The resulting average horizontal groundwater flow velocity is 2.615 feet/day or 54 feet/year.

3.4.3.2 Intermediate Aquifer

A network of seven (7) intermediate monitoring wells (ESS-18B through ESS-25B) was installed into the intermediate aquifer to evaluate the direction of groundwater flow, hydraulic characteristics, and environmental conditions in the intermediate aquifer at the Site. The top of the tertiary sand unit in the intermediate aquifer is generally encountered at a depth of approximately -20 feet MSL, and extends to approximately -50 feet MSL. However, the intermediate aquifer also includes the underlying Castle Hayne Aquifer since there is no confining unit separating the Castle Hayne Formation and the overlying lower tertiary sand aquifer, and, from a groundwater flow perspective, these two units behave as a single aquifer (USGS, 2003). The combined thickness of the intermediate aquifer is approximately forty (40) feet thick, and extends to a depth of approximately -60 feet MSL. The aquifer exhibits semi-confined to confined conditions, and is recharged locally.

The intermediate aquifer is generally underlain by the low-permeability Peedee confining unit, which was encountered at ESS-24A at a depth of -60 feet MSL. The Peedee confining unit is considered a vertical hydraulic boundary between the intermediate (Tertiary Age Castle Hayne) aquifer and the deep (Peedee) aquifer that is below the low-permeability unit, as shown in the cross sections provided on **Figure 3-4** and **Figure 3-5**.

It is noted that the constructed depth of the bottom of the intake canal and the BNP are deeper than the base of the low permeability unit (LP) in the shallow surficial deposits, as depicted in **Figure 3-4** and **Figure 3-5**. At these areas, the hydraulic separation does not exist between the shallow aquifer, intermediate aquifer, and intake canal. As such, the hydraulic head (static water level elevation) in each unit is an important factor that determines the fate and transport of water and chemical constituents to and from these units.

Vertical Groundwater Flow Direction in the Intermediate Aquifer

The intermediate aquifer exhibits confined conditions in the vicinity of the SDSP, as exhibited by the elevation of the groundwater surface above the top of the overlying low-permeability unit (**Figure 3-4** and **Figure 3-5**); however, the net vertical gradient between the intermediate aquifer and the shallow surficial aquifer is in the downward direction since the elevation of the overlying shallow aquifer is generally higher than in the intermediate aquifer. Constituents in the shallow aquifer may enter the intermediate aquifer either through seepage through the overlying low-permeability unit or directly into the intermediate aquifer where the low permeability unit is either not present of has been physically breached. One such area is discussed below.

It is noted that an area north of ESS-18B is allegedly an area previously used to dispose of large equipment and other materials near the time the BNP was constructed. Based on the alleged size of the excavation, the excavation may have penetrated the low permeability unit (LP) separating the shallow surficial aquifer from the intermediate aquifer. The specific location and depth of this alleged activity has not been verified or confirmed.

The vertical gradient between the intermediate aquifer and the underlying deep aquifer is similarly in the downward direction at each of the three well clusters evaluated (ESS-13B/ESS-13A, ESS-17B/ESS-17A, and ESS-24B/ESS-24A).

Horizontal Groundwater Flow Direction in the Intermediate Aquifer

Interpretations regarding groundwater flow direction at the Site are based on water level measurements collected from the intermediate wells. These data are presented in **Table 2-2** and provided the basis for the interpretation of horizontal flow in the intermediate aquifer and vertical groundwater flow between the intermediate aquifer and deeper aquifers at the Site. An average groundwater flow rate has been calculated based on water level measurements at each intermediate well and the development of a potentiometric surface contour of the intermediate water table, an average horizontal hydraulic gradient calculated using the Potentiometric surface contour, and the calculated hydraulic conductivity. Hydraulic conductivity was derived primarily from slug tests conducted on the intermediate wells. The average linear seepage velocity (V_s) for groundwater flow as defined by the Darcy equation is calculated by:

$$V_s = -K \frac{(dh/dl)}{n_c}$$

Where:

K	=	hydraulic conductivity
dh/dl	=	hydraulic gradient
n_c	=	effective porosity

Figure 3-9 and **Figure 3-10** illustrate the potentiometric surface of the shallow unconfined aquifer at the Site on 10/02/2007 and 10/16/2007, respectively. The direction of groundwater flow in the intermediate semi-confined aquifer is generally to the southeast in the vicinity of the SDSP and is consistent between the two rounds of water level measurements. It is possible; however, that groundwater in the intermediate aquifer flows to the north in the area of ESS-18B and ESS-19B. This

possibility is hypothesized based on the apparent groundwater mound that occurs in the vicinity of ESS-18B. No groundwater elevation data is present to the north of these monitoring points to refute or confirm this. However, a variable flow pattern is present in this unit particularly near the northwest and eastern side of the SDSP, which suggests an additional source of groundwater may be infiltrating (from above or below) into the intermediate aquifer near ESS-18B. USGS information indicates a regional southeast groundwater flow in this unit.

Groundwater flow estimates were calculated using the water level measurements. The horizontal gradient in the intermediate aquifer during the October groundwater monitoring events was calculated for flow to the south perpendicular to the direction of flow from ESS-20B to ESS-17B using the groundwater flow maps presented on **Figure 3-9** and **Figure 3-10**, respectively. The hydraulic conductivity (37.2 feet/day) in the aquifer was calculated using the average test results from slug tests performed at ESS-22B. An alternative hydraulic conductivity (80.4 ft/day) was also presented based on hydraulic conductivity values published from a pump test performed on a nearby well BR-163, which has a similar depth (60 feet bgs) as ESS-22B and was screened in the Castle Hayne formation (USGS, 2003). The Cooper-Bredehoeft-Papadopulos analysis method was used to evaluate the slug tests due to the confined nature of the aquifer. The results of the slug test analyses are included in **Appendix D**.

Groundwater flow velocities were calculated using the Darcy equation. A value of 32% was assumed for the effective porosity of the sand aquifer material (Mcwartor and Sunata, 1977). The resulting linear velocities are summarized below.

Date	**Intermediate / Lower Sand / Castle Hayne Aquifer**
10/02/07	South (ESS-22B to ESS-17B) Horizontal Gradient Vs 0.00042 ft/ft **4.8 x 10^{-2} ft/day**
10/02/07 (based on BR-163)	South (ESS-22B to ESS-17B) Horizontal Gradient Vs 0.00042 ft/ft **1.05 x 10^{-1} ft/day**
10/16/07	South (ESS-22B to ESS-17B) Horizontal Gradient Vs 0.00054 ft/ft **6.3 x 10^{-2} ft/day**
10/16/07 (based on BR-163)	South (ESS-22B to ESS-17B) Horizontal Gradient Vs 0.00054 ft/ft **1.36 x 10^{-1}ft/day**
Average	**8.8 x 10^{-2} ft/day**

The resulting average groundwater flow velocity is 8.8 x 10^{-2} feet/day or 32 feet/year.

3.4.3.3 Deep (Peedee) Aquifer

One Type III bedrock monitoring well (ESS-24A) was installed in the Peedee Aquifer to evaluate (in conjunction with existing monitoring wells completed in the Peedee aquifer) the direction of groundwater flow, hydraulic characteristics, and environmental conditions in the deep water supply aquifer at the Site. The well was constructed using 10-inch PVC surface casing to prevent the vertical exchange of groundwater between the shallow aquifer and the intermediate aquifer. An additional 6-inch surface casing was installed to prevent the vertical exchange of groundwater into the Peedee Formation. The Peedee confining unit is approximately thirty (30) feet thick at ESS-24A and limits the exchange of groundwater between the intermediate and deep aquifers. The Peedee aquifer, which was encountered at a depth of approximately 107 feet bgs, is estimated to be approximately 440 feet thick (**Figure 3-2**, USGS, 2003), and is a confined aquifer. The aquifer is confined by the overlying Peedee confining unit and underlying Black Creek Confining Unit.

Three (3) existing deep wells (ESS-13A, ESS-17A, and ESS-27A) were retained for evaluation and two (ESS-17A and Ess-27A) are included in the monthly tritium monitoring program of the deep aquifer due to their close proximity to the SDSP and since the screened interval of the wells are at a similar depth in the Peedee Formation as in the newly-installed ESS-24A.

Vertical Groundwater Flow Direction in the Deep Aquifer

The deep aquifer exhibits confined conditions in the vicinity of the SDSP, as exhibited by the elevation of the groundwater surface above the top of the overlying Peedee confining unit (**Figure 3-4** and **Figure 3-5**). However, according to USGS, the Peedee confining unit is not consistently observed in Brunswick County, as exhibited in **Figure 3-2**.

The vertical gradient between the intermediate aquifer and the underlying deep aquifer is similarly in the downward direction at each of the three well clusters evaluated (ESS-13B/ESS-13A, ESS-17B/ESS-17A, and ESS-24B/ESS-24A). Constituents in the intermediate aquifer may migrate vertically into the deep aquifer in three ways: 1) gradual seepage through the overlying through the Peedee confining unit; 2) where the confining unit is not present; or, 3) through a breach in the confining unit (i.e. man-made conduit). Investigations to date have not indicated that any of these conditions currently exist at the Site.

Groundwater Flow Direction in the Deep Aquifer

Interpretations regarding groundwater flow direction at the Site are based on water level measurements collected from on-site wells. These data are presented in **Table 2-2** and provided the basis for the interpretation of horizontal and vertical groundwater flow at the Site. Groundwater flow rates are based on water level measurements (hydraulic gradient) and hydraulic conductivity. The average linear seepage velocity (V_s) for groundwater flow as defined by the Darcy equation is calculated by:

$$V_s = -K \frac{(dh/dl)}{n_e}$$

Where:

K	=	hydraulic conductivity
dh/dl	=	hydraulic gradient
n_e	=	effective porosity

Figure 3-11 and **Figure 3-12** illustrate the potentiometric surface of the deep aquifer on 10/02/2007 and 10/16/2007. As shown in the figures, the direction of groundwater flow is very consistent between the two events. Additionally, there does not appear to be any hydrologic influences on the deep aquifer resulting from the SDSP.

Groundwater flow estimates were calculated by using the water level measurements. Horizontal gradients between wells were determined by dividing the difference in groundwater elevation in each well by the distance between the wells. The average hydraulic conductivity in the deep aquifer was estimated from slug test data and derived (9.28 ft/day) from the published transmissivity value (T=4,000 ft^2/day) and aquifer thickness (431 feet) in the nearby BR-209 (USGS, 2003). The results of slug test analyses are included in **Appendix D**. Groundwater flow velocities were calculated for the two October groundwater monitoring events using the Darcy equation. A value of 39% was assumed for the effective porosity of the water table aquifer material. The horizontal gradients and resulting linear velocities are summarized below.

Date	
10/02/07	Southeast (ESS-27A – ESS-24A) Horizontal Gradient Vs 0.0023 ft/ft 1.37×10^{-2} ft/day
10/02/07 (BR-209)	Southeast (ESS-27A – ESS-24A) Horizontal Gradient Vs 0.0023 ft/ft 5.4×10^{-2} ft/day
10/16/07	Southeast (ESS-27A – ESS-24A) Horizontal Gradient Vs 0.0023 ft/ft 1.37×10^{-2} ft/day
10/16/07 (BR-209)	Southeast (ESS-27A – ESS-24A) Horizontal Gradient Vs 0.0023 ft/ft 5.4×10^{-2} ft/day
Average	**3.4×10^{-2} ft/day**

The resulting average groundwater flow velocity is 3.4×10^{-2} feet/day or 12.41 feet/year.

3.4.4 Tidal Influences on the Shallow, Intermediate, and Deep Groundwater Aquifers

A 30-day synoptic water level monitoring evaluation was completed at the SDSP area to evaluate the hydraulic relationships between the shallow, intermediate, and deep groundwater aquifers at the site and also determine whether tidal fluctuations affected the groundwater at the Site. To accomplish this objective, Waterloo Diver pressure transducers were calibrated for the synoptic study and installed in selected wells near the SDSP. Wells were selected across the SDSP area based on their proximity to the SDSP and other hydrologic units in order to provide a broad range of data from the three aquifers. The selected wells included the following:

ESS-19C/B (adjacent to Nancy's Creek);
ESS-STAB (adjacent to the SDSP);
ESS-24A/B/C (between the SDSP and the intake canal); and,
ESS-25B/C (on the south side of the intake canal).

4 CONCEPTUAL SITE MODEL

The purpose of the conceptual Site model (CSM) is to identify potential sources of constituents of interest, migration routes for these constituents, and human and ecological receptors and their associated exposure pathways. The CSM provides a basis for establishing remedial goals that are designed to be both protective of human health and the environment, and, consistent with short and long term regulatory objectives. The remedial goals are often developed and evaluated through the completion of a site-specific risk assessment, as necessary.

An important consideration in this process is the future, post-decommissioned use of the BNP property, including the SDSP area. Because the future use of the Site has not been identified or restricted, future receptors and exposure routes could include onsite residential, commercial, industrial, and recreational uses and exposure scenarios. If these possible future uses cannot or may not be restricted at this time, they and their associated potential exposures could significantly affect the remedial goals and the decommissioning costs associated with the SDSP and surrounding BNP Site.

4.1 Site Setting

Several features of the Site are important in developing the CSM. The SDSP area is relatively large area (approximately 60 acres) and includes an additional area of approximately 20 acres that exhibits impacted groundwater. The Site is bordered primarily by marine estuary and surface water bodies to the north, east, and south, and by the Brunswick Nuclear Plant facility to the west. Further to the north are residential properties. Selection of appropriate receptors and potential exposure pathways depends on the current and future use of the Site and adjacent areas.

Surface water bodies (e.g., the SDSP, recovery pond, intake canal, and surface drainage features) are present onsite. These surface water bodies eventually discharge into Nancy's Creek and Gum Log Branch, which drain into the Cape Fear River, located approximately 7,000 feet east of the Site. The intake canal eventually drains (via the discharge canal) into the Atlantic Ocean to the south of Caswell Beach and may provide some recharge to the underlying groundwater aquifers along the discharge canal.

The selected well locations coincide with the wells included in geologic cross section B-B' presented on **Figure 3-5**.

Water level data was recorded at 5-minute intervals to provide sufficient resolution to evaluate anomalies and temporal trends, as necessary. The elevation data is presented on **Figure 3-14** which presents a graph of the recorded water elevation at each well included in the evaluation. The data was not compensated for barometric pressure since barometric pressure during the evaluation was reasonably consistent. As such the water elevations exhibited in the graph represent the total pressure in each well (water pressure + barometric pressure). In conjunction with the transducer data, tidal data was obtained from the NOAA tide monitoring station 8659084 located in Southport, North Carolina to provide a comparison of the tidal signature with the signatures of the hydrographs at each monitoring well. The NOAA tidal data is presented on **Figure 3-15**.

The results are of the survey are as follows:

Intermediate and Deep Aquifers: As exhibited by the symmetry in the elevation signatures, the intermediate aquifer and deep aquifer are strongly influenced by the tide cycles.

Shallow Aquifer: As indicated by the minimal fluctuation in the water elevation recorded in the shallow wells, the shallow aquifer is generally less affected by the tide, primarily since the elevation of the water table in the shallow aquifer is above sea level. However, ESS-19C and ESS-24C exhibit some tidal affects. As is best observed at ESS-19C, the outgoing tide causes a decline in the water elevation in the well, which is due to an increase in the hydraulic gradient between ESS-19C and Nancy's Creek. This change results in a temporal increase in groundwater seepage velocity and ultimately a higher rate of groundwater discharge into Nancy's Creek.

Based on the results of this evaluation, surface water sampling conducted in the adjacent wetlands, Nancy's Creek, Gum Log Branch, and the Cape Fear River at periods of low tide would likely maximize the groundwater contribution.

Potential future use of SDSP area and surrounding BNP property and the offsite property is expected to change after the power plant is decommissioned, and could result in a residential use, public recreational use, or industrial use. Decommissioning of the plant is anticipated to occur in approximately 30 years. However, the offsite property use is not expected to change. As discussed in Section 3.4.2, groundwater is used in the vicinity of the SDSP and BNP facility, although there is no current use of groundwater on the Site. However, depending on the future use of the SDSP area and surrounding BNP Site, the use of onsite groundwater is a possibility.

4.2 Source Media and Transport Mechanisms

Based on the results of the groundwater investigation conducted at the Site, the primary source area onsite is the SDSP. Concentrations of tritium are present within the SDSP and decrease in a radial direction around the SDSP. Concentrations of other radiological materials, such as gamma radionuclides, are generally considered to be present in the sediment within the SDSP. Therefore, the sediments and surface water in the SDSP have been identified as the source media for the SDSP Site. They are also potential exposure media.

Radiological constituents in source media have the potential for direct contact with certain receptors or to migrate to additional environmental media, where they may be contacted by a receptor. Groundwater transport via leaching of constituents in surface water, soils, or sediments into groundwater from the SDSP is identified as a primary transport mechanism for radiological constituents from the SDSP source media. Radiological constituents in groundwater can also migrate to outdoor air via evaporation or transpiration,

Radiological materials attached to soil particles can migrate to ambient air via fugitive dust generation (wind erosion, vehicle traffic, or excavation). As such, radiological materials in soil, sediment, or water can migrate to outdoor air via evaporation and transpiration and be transported downwind to human and ecological receptors.

4.3 Potential Receptors and Complete Exposure Pathways

Potential receptors and potentially complete exposure pathways have been identified based on current and potential future land use. The current potential receptors identified include the following:

- Onsite workers;
- Onsite visitors;
- Onsite construction and utility workers;
- Ecological receptors; and,
- Offsite human receptors (groundwater users, recreational users of Nancy's Creek, nearby residents);

It is possible for ecological receptors to be exposed to tritium and other radionuclides (i.e. gamma) in surface water and sediments in the SDSP. Additionally, both human and ecological receptors may be exposed to tritium in the marine estuary and wetlands associated with Nancy's Creek, Gum Log Branch, the recovery pond, and the intake canal. Where groundwater is shallow, certain plants may be potential receptors to tritium in groundwater. Ecological receptors include plants, aquatic invertebrates and wildlife, and terrestrial and avian species that may forage in the vicinity of the aquatic habitats.

As discussed in Section 3.2, Section 3.3, and Section 3.4, the groundwater use pathway is considered to be complete due to the current and anticipated future potable use of groundwater from aquifers present at the Site in the vicinity of the BNP. The long-term groundwater use pathway is a critical pathway since freshwater resources in Brunswick County are limited to the surficial, Castle Hayne, and Upper Peedee aquifers, and are relied upon for all domestic, municipal, industrial, and commercial water supply.

It is possible for onsite workers, construction workers, and utility workers to be exposed to tritium and other radionuclides (i.e. gamma) present in surface water and sediments in the SDSP. Construction and utility workers could be exposed to tritium or other radionuclides in groundwater around the SDSP during intrusive construction activities. It is not currently known whether tritium or other radionuclides are present in surface soils around the SDSP.

It is possible for human receptors to be exposed to tritium in ambient air resulting from evaporation and transpiration of tritium from the SDSP area; however, this pathway may also include additional sources of airborne tritium originating from the BNP.

4.4 Remediation Standard Selection

Remedial action objectives (RAOs) must take into account Applicable or Relevant and Appropriate Requirements (ARARs) and other guidelines To Be Considered (TBCs, as described in Section 5. This section identifies constituents of interest (COI) in Site media that may not meet an applicable standard, and, therefore, should consider COI for the SDSP area and retained for further evaluation.

4.4.1 Soil and Sediments - Onsite

Limited biased soil sampling was completed during the groundwater investigation. The soils and sediments in the vicinity of the SDSP include soil and sediment inside the berm of the SDSP, and soils and sediments outside the berm that may come into contact with radiological materials. Based on the information collected during the groundwater investigation, tritium and gamma radionuclides are considered to be constituents of interest (COI) for soil and sediment in the SDSP area as well as for soils in contact with impacted groundwater.

Consideration regarding the long-term presence of these radionuclides in soil and sediments near the pond should be considered with respect to the following:

possible current/future exposures;

future (decommissioned) use of the SDSP Area;

minimum decommissioning requirements of the SDSP Area following plant shut-down;

possible current and future transport of these materials to areas not affected by radiological contamination, and ARARs and TBCs.

4.4.2 Groundwater

Groundwater has been demonstrated to be impacted by tritium originating from the SDSP (the source area). This source area also has received sediments and other wastes impacted by gamma radionuclides. The groundwater conditions should be characterized for gamma radionuclides in order to substantiate or refute the possibility of gamma emitting isotopes as COI in groundwater and substantiate the comprehensive evaluation of ARARs and TBCs discussed in Section 5.

Groundwater impacts are identified in the shallow surficial aquifer and in an isolated area in the intermediate aquifer. The concentration of COI at these locations may not meet applicable standards. Additionally, the ongoing release of COI to offsite locations may not meet ARARs and TBCs.

Consideration regarding the short and long-term presence of these radionuclides in groundwater should be considered with respect to the following:

possible current/future exposures;

future (decommissioned) use of the SDSP Area;

the minimum decommissioning requirements of the SDSP Area following plant shut-down;

possible current and future transport of these materials to areas not affected by radiological contamination;

how changes in future site use may affect the fate and transport of COI including consideration of possible transport to areas currently unaffected; and,

Compliance with ARARs and TBCs.

4.4.3 Air

SSi has not evaluated possible tritium or other radiological constituents in ambient air. Air monitoring is conducted by Progress Energy for the BNP Site, which may adequately address possible airborne impacts associated with evaporation and transpiration of radiological materials form the SDSP area.

4.4.4 Surface Water and Offsite Sediments

Surface water samples are collected by Progress Energy on a routine basis. Relatively few surface water samples have exhibited concentrations of tritium above the detection limit of 300 pCi/L. The source of tritium is demonstrated to be due to the transport of groundwater that is impacted with radiological materials, specifically tritium. Surface water data should continue to be collected and evaluated with respect to compliance with ARARs and TBCs. ARARs and TBCs should be determined in order to evaluate compliance.

Sediments along Gum Log Branch and Nancy's Creek and the associated wetlands are a potential receptor of groundwater impacted by radionuclides from the SDSP area. The accumulation of radionuclides in the sediment should be considered with respect to ARARs and TBCs.

The remaining sections of this GIR present a Focused Feasibility Study to address groundwater at the Site that has been impacted by tritium released from the SDSP. The selected remediation standard or remediation goal (RG) for tritium in groundwater is the USEPA MCL of 20,000 pCi/L.

5 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

The purpose of this section is to develop remedial action objective (RAOs) and develop general response actions (GRAs) for the groundwater contamination found at the BNP. The following is the three-step process for the developing GRAs.

Remedial action objectives are developed based on environmental concerns (contaminant characterization, risk evaluation) and compliance with Applicable or Relevant and Appropriate Requirements (ARARs) and other guidelines to be considered (TBCs).

Volume and/or area estimates for contaminated groundwater are described.

General response actions are identified that will satisfy the remedial action objectives.

Each step of the GRA development process is discussed in the following subsections

5.1 Summary of ARARs and Proposed Remedial Action Objectives

In this section, site-specific remedial action objectives are developed. Remedial action objectives are based on environmental concerns and on ARARs. The environmental concerns (i.e. nature and extent of tritium impact in groundwater) were described in previous sections of this report. ARARs for the site are presented below.

5.1.1 ARARs and TBCs

ARARs may include the following:

Any standard, requirement, criterion, or limitation under Federal environmental law.

Any promulgated standard, requirement, criterion or limitation under a State environmental or facility-siting law.

Law that is more stringent than the associated Federal standard, requirement, criterion or limitation.

A requirement may be either "applicable" or "relevant and appropriate," but not both.

Applicable Requirements are those cleanup standards, control standards and other environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at BNP.

Relevant and Appropriate Requirements are those cleanup standards, control standards and other environmental protection requirements, criteria or limitations promulgated under Federal or State law that, while not "applicable" to a pollutant, contaminant, remedial action, location or other circumstances at BNP, address problems or situations sufficiently similar (relevant) to those encountered at BNP that their use is well-suited (appropriate) to the site. Requirements must be both relevant and appropriate to be ARARs.

The relevance and appropriateness of a requirement can be judged by comparing a number of factors including the characteristics of the site of the remedial action, the contaminant in question or the physical circumstances of the site with those addressed in the requirement. The objective and origin of the requirement is also considered. A requirement that is judged to be relevant and appropriate must be complied with to the same degree as if it were applicable. However, there is more discretion in this determination; i.e., it is possible for only part of a requirement to be considered relevant and appropriate, the rest being dismissed.

To-Be Considered (TBCs) Materials are non-promulgated, non-enforceable advisories, guidelines or criteria issued by Federal/State government or advisory organizations that are not legally binding and do not have the status of potential ARARs, but are considered during evaluation of potential remedial alternatives.

ARARs and TBCs fall into three broad categories based on the manner in which they are applied at a site. These categories are as follows:

Chemical-Specific – These ARARs govern the extent of site cleanup. Such ARARS may be actual concentration-based cleanup levels, or they may provide the basis for calculating such levels. Examples of chemical-specific ARARs are Maximum Contaminant Levels (MCLs).

Location-Specific – These ARARs are considered in view of natural or man-made site features. Examples of natural site features include wetlands, scenic rivers and flood plains. Man-made features could include, for example, the presence of constructed wetlands. ARARs based on aquifer designations are also location-specific ARARs.

Action-Specific – These ARARs pertain to the implementation of a given remedy. Examples of action-specific ARARs include monitoring requirements, effluent discharge limitations, waste manifesting requirements and occupational health and safety requirements.

ARARs and TBCs pertaining to both contaminant levels and to performance or design standards should generally be attained at all points of potential exposure, or at the point specified by the ARAR itself. At sites where a TBC value is used to set a protective level of cleanup, or where the ARAR does not specify the point of compliance, there is discretion to determine where the requirement should be attained to ensure protectiveness. For groundwater, cleanup goals should generally be attained throughout the contaminated plume or at the edge of the waste management area when waste is left in place. For surface water, cleanup goals should generally be attained at the point or points where the release enters the surface water. For air, cleanup goals should generally achieved at the maximum exposed individual, considering the reasonably expected uses of the site and surrounding area.

For the BNP, chemical-specific, location-specific and action-specific ARARs and TBCs are summarized below.

5.1.1.1 Chemical-Specific ARARs and TBCs

In this section, a summary of Federal and State chemical-specific ARARs and TBCs is presented. All of these ARARs or TBCs provide some specific guidance on "acceptable" or "permissible" concentrations of contaminants in environmental medial.

<u>ARARs</u>

The Clean Water Act (CWA) as amended governs point-source discharges through the National Pollution Discharge Elimination System (NPDES), discharges of dredge or fill material, and oil and hazardous waste spills to United States waters. NPDES requirements (40 CFR 122) may be applicable if the direct discharge of pollutants into navigable waters is part of the remedial action. Compliance with Federally approved State Water Quality Standards may also be required. The use of best available technology economically achievable is required to control toxic and non-conventional pollutants. The use of best conventional pollution control technology is required to control conventional pollutants. Technology-based limitations may be determined on a case-by-case basis.

The Clean Air Act (CAA) of 1977 (amended in 1990) governs air emissions resulting from remedial actions. The CAA promulgated the National Ambient Air Quality Standards (NAAQS) (40 CFR, Part 50). NAAQS are available for six criteria pollutants, including airborne particulates. The source of the contaminant, human health, and route of exposure were considered in the formulation of the standards. These standards do not consider the cost of achievement or feasibility of implementation. The NAAQS allow for a margin of safety to account for unidentified hazards and effects. The CAA amendments of 1990 contained 11 titles that address a variety of subjects including the following: attainment of NAAQS, mobile sources, hazardous air pollutants, permit provisions, stratospheric ozone protection, enforcement and clean air research. The amendment that could serve as an ARAR for the potential remedial activities is the Title III-Hazardous Air Pollutants. This title establishes a system of setting technology-based source standards for 189 hazardous air pollutants. Maximum achievable control technology (MACT) standards could be ARARs for potential remedial activities.

United States Nuclear Regulatory Commission (10 CFR Part 20 and 51) provide standards for the protection against radiation (Part 20) including requirements for: dose limits for radiation workers and members of the public; monitoring and labeling radioactive materials; posting radioactive areas; and, reporting the theft or loss of radioactive material. Part 51 includes environmental protection regulations for domestic plants.

North Carolina Regulations for Protection Against Radiation (NC Code, Title 15A, Chapter 11) provides regulations for the management of radioactive materials.

The rules relate "to the manufacture, production, transportation, use, handling, servicing, installation, storage, sale, lease, or other disposition of radioactive materials and machines…" and "…provide by rule and regulation for an electronic product safety program to protect the public health and safety, which program may authorize regulation and inspection of source of non-ionizing radiation throughout the state

North Carolina Surface Water Quality Standards (NC Code, Title 15A, Chapter 2B) have been promulgated as standards to protect lakes, rivers, streams, and other surface water bodies from pollutants. The rules contain: beneficial use designations, water quality criteria that are protective of the use designation, and procedures for applying the water quality criteria to wastewater discharges and other sources of pollution. North Carolina Water Quality Standards may be ARARs for the actions involving discharge of contaminants to surface water.

North Carolina Groundwater Quality Standards (NC Code, Title 15A, Chapter 2L) have been promulgated as standards to protect groundwater of the State. These rules are applicable to all activities or actions, intentional or accidental, which contribute to the degradation of groundwater quality, regardless of any permit issued by a governmental agency authorizing such activity. North Carolina Groundwater Quality Standards may be ARARs for the BNP.

North Carolina Ambient Air Quality Standards (NC Code, Title 15A, Chapter 2D) have been promulgated as standards to protect the air quality of the State. North Carolina Ambient Air Quality Standards may be ARARs for the BNP.

<u>TBCs</u>

The Safe Drinking Water Act (SDWA) promulgated National Primary Drinking Water Standard Maximum Contaminant Levels (MCLs) (40 CFR Part 141). MCLs are enforceable standards for contaminants in public drinking water supply systems. They consider not only health factors, but also the economic and technical feasibility of removing a contaminant from groundwater. Maximum Contaminant Level Goals (MCLGs) are non-enforceable guidelines that do not consider the technical feasibility of contaminant removal. Secondary MCLs (40 CFR Part 143) are not enforceable, but are intended as guidelines to protect the public welfare. Contaminants covered are those that may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance; and may deter public acceptance of drinking water provided by public water systems. MCLs are often considered to be "relevant and appropriate" when groundwater at a site is, or could reasonably be, used for drinking water, because this constitutes a situation sufficiently similar that their use is well-suited to the site. For the BNP, MCLs are considered TBCs since on-site groundwater is not used for drinking water. Secondary MCLs may also be TBCs for remedial actions involving groundwater.

USEPA Ambient Water Quality Criteria (AWQC) are non-enforceable guidelines that were developed for pollutants in surface waters pursuant to Section 304(a)(1) of the Clean Water Act. Although AWQC are not legally enforceable, they have been used by many states to develop enforceable water quality standards. AWQC are available for the protection of human health from exposure to contaminants in drinking water as well as from ingestion of aquatic biota and for the protection of freshwater and saltwater aquatic life. AWQC may be considered for actions that involve groundwater treatment and/or discharges to surface water.

North Carolina Water Quality Standards (NC Code, Title 15A, Chapter 1B) have been promulgated as standards to protect drinking water of the State. For the BNP, drinking water standards are considered TBCs since on-site groundwater is not used for drinking water.

(Draft) North Carolina Risk Analysis Framework has been developed but not promulgated to provide a mechanism to establish risk-based remedial strategies for soil and groundwater at impacted sites. The framework is considered a TBC for the site.

5.1.1.2 Location-Specific ARARs and TBCs

In this section, a summary of Federal and State location-specific ARARs and TBCs is presented.

<u>ARARs</u>

Dredged and Fill Material Disposal under the Clean Water Act (Section 404, 40 CFR Part 230 and 33 CFR Parts 320-330) provide that the degradation or destruction of wetlands and other special aquatic sites should be avoided to the extent possible. Under the Section 404(b)(1) guidelines, no discharge or dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. For the BNP, most wetland areas are removed from areas of historic waste disposal and most likely would not be affected by potential remedial actions.

The Endangered Species Act of 1978 (16 USC 1531) provides for consideration of the impacts on endangered and threatened species and their critical habitats. This act requires Federal agencies, in consultation with the Secretary of the Interior, to ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or adversely affect its critical habitat. If it is determined that such a species may be present, the Federal agency must conduct a biological assessment to identify an endangered or threatened species likely to be affected by the agency's action. The Endangered Species Act may be an ARAR for the site.

The Fish and Wildlife Coordination Act (16 USC 661) was enacted to protect fish and wildlife when Federal actions result in the control or structural modification of a natural stream or body of water. The statute requires Federal agencies to take into consideration the effect that water-related projects would have upon fish and wildlife and then take action to prevent loss or damage to these resources. Such action should be viewed in the context of obtaining maximum overall project benefits, i.e., cleaning up the site. Under Section 662 of the Act, consultation is required with the U.S. Fish and Wildlife Service or National Marine Fishery Service and the Wildlife Resources Agency of the State if alteration of the water resource would occur as a result of off-site remedial activities. Consultation is strongly recommended for on-site actions. The purpose of consultation is to develop measures to prevent, mitigate or compensate for project-related losses to fish and wildlife. For the BNP, it is unlikely that any alternative would modify a stream or other water body.

The Fish and Wildlife Improvement Act (16 USC 742a) and Fish and Wildlife Conservation Act (16 USC 2901) provides for consideration of the impacts on wetland and protected habitats.

North Carolina Coastal Area Management Act (NC Code, Title 15A, Chapter 7) provides guidelines and regulations for areas of environmental concern within the coastal management zone including estuarine waters and shorelines.

North Carolina Endangered Species Act (NCGS 113-331 10 113-337) requires action to avoid impacting the continued existence of listed endangered species, State special concern species, State significant rare species, and the State watch list.

North Carolina Solid Waste Management Rules (NCGS 130A, Article 9) establishes rule for the management, excavation, storage and/or treatment of solid (non-hazardous) waste on site.

<u>TBCs</u>

Federal Protection of Wetlands and Management of Floodplains Executive Orders (Executive Order Nos. 11990 and 11988) provide for consideration of wetlands and floodplains during remedial actions. These executive orders are implemented by USEPA's policy set forth in 40 CFR Part 6 Appendix A, which may be an ARAR for remedial activities. The procedures substantively require that Federal agencies conduct their activities to avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction or modification of wetlands and the occupation or modification of floodplains. The procedures also require Federal agencies to avoid direct or indirect support of new construction in wetlands, or floodplain development, wherever there are practicable alternatives, and to minimize potential harm to floodplains or wetlands whenever there are no practicable alternatives. For the BNP, most wetland areas are removed from areas of historic waste disposal and most likely would not be affected by potential remedial actions.

USEPA Groundwater Protection Strategy provides guidance for the protection of groundwater for its highest use.

5.1.1.3 Action-Specific ARARs and TBCs

In this section, a summary of Federal and State action-specific ARARs and TBCs is presented.

<u>ARARs</u>

Resource Conservation and Recovery Act (RCRA) (PL 94-580) Subtitle C regulates the treatment, storage and disposal of hazardous waste. RCRA Subtitle C requirements may be ARARs for BNP because they regulate the same or similar wastes, cover many of the same activities and address releases and threatened releases similar to those found at BNP.

In general RCRA Subtitle C requirements for the treatment, storage or disposal of hazardous waste could be applicable if the following conditions are met:

1. The waste is a listed hazardous waste or has the specified characteristics of a hazardous waste as defined by RCRA; <u>and</u> either:

2(a). The waste was treated, stored or disposed after the effective date of the particular RCRA requirements under consideration (RCRA Subtitle C regulations that established the hazardous waste management system were effective on November 19, 1980), or

2(b). The activity at the site constitutes placement/disposal. Placement/disposal occurs when:

- ✓ Wastes from different units are consolidated into one unit (other than a land disposal unit within an area of contamination);
- ✓ Waste is removed and treated outside a unit and redeposited into the same or another unit (other than a land disposal unit within an area of contamination); or,
- ✓ Waste is picked up from the unit and treated within the area of contamination in an incinerator, surface impoundment, or tank and then redeposited into the unit (does not include in-situ treatment).

The RCRA Subtitle C regulations that may be applicable to the BNP involve the disposal of hazardous wastes include 40 CFR Part 264: Subpart F regarding groundwater protection; Subpart N regarding landfill standards; and Subpart G regarding closure and post-closure.

Groundwater protection standards under Subpart F establish three categories of groundwater protection standards: background concentrations, RCRA Maximum Concentration Limits (MCLs), and Alternate Concentration Limits (ACLs). In complying with Safe Drinking Water Act MCLs, cleanup will also be consistent with RCRA MCLs. The procedure for establishing site-specific ACLs under RCRA requires a finding that the hazardous constituent in the groundwater will not pose a substantial present or potential hazard to human health or the environment as long as the ACL is not exceeded.

There are three general types of groundwater monitoring outlined in 40 CFR Part 264 Subpart F which are TBCs for the BNP:

Detection monitoring;

Compliance monitoring; and

Corrective action monitoring.

RCRA establishes minimum technology requirements for land disposal units. If new landfills or surface impoundments are constructed, or if replacements or lateral expansions of existing landfills or surface impoundments are used, they must satisfy these minimum technical requirements. Minimum technology requirements include two or more liners and a leachate collection system between the liners. In addition, for landfills, another leachate collection system must be placed above the top liner.

RCRA provides two basic closure options: clean closure and landfill closure. The clean closure option requires removal and/or detoxification of all hazardous constituents from the RCRA unit. Clean closure requirements, which assume no further management of the RCRA unit, require that levels of contamination remaining in the unit are at acceptable levels for ingestion of soils and groundwater (i.e., edible soils and drinkable leachate). Landfill closure, where all or part of the contaminated material is left in the unit, requires a final impermeable cover, or cap, and a post-closure plan that protects human health and the environment. In addition to the clean closure and landfill closure options, a third closure option, hybrid closure, was proposed to the National Contingency Plan (NCP) (53 FR 51446) as an amendment to the landfill closure. Because the rules for hybrid closure are proposed regulations, they may not be used (without a waiver) where RCRA closure requirements are applicable, but may be considered when the closure requirements are relevant and appropriate (USEPA, October 1989). There are two hybrid closure approaches: 1) hybrid-clean closure; and 2) hybrid-landfill closure, which combines elements of clean closure and closure with waste in place, as described below:

- *Hybrid-Clean Closure:* Used when leachate will not impact the groundwater (even though residual contamination and leachate are above health-based levels) and contamination does not pose a direct contact threat.

  - ✓ No covers or long-term management are required;
  - ✓ Fate and transport modeling and model verification are used to ensure that groundwater is usable; and
  - ✓ A property deed notice is used to indicate the presence of hazardous substances.

Hybrid-Landfill Closure: Used when residual contamination poses a direct contact threat, but does not pose a groundwater threat.

  - ✓ Covers, which may be permeable, are used to address the direct contact threat;
  - ✓ Limited long-term management includes site and cover maintenance and minimal groundwater monitoring; and
  - ✓ Institutional controls (e.g., land-use restrictions or deed notices) are used as necessary.

North Carolina Water Pollution Control Regulations (*NC Code, Title 15A, Chapter 2B and 2H*) govern point-source discharges to North Carolina waters. The rules include requirements for permits, permit applications, and permit conditions and monitoring. These rules may be applicable to remedial actions involving a discharge to surface water.

North Carolina Sedimentation Control Regulations (*NC Code, Title 15A, Chapter 4B)* govern erosion and sedimentation control resulting from the remediation actions that may involve earth moving activities. The purpose of the regulation is to control accelerated erosion and the resulting sedimentation in surface waters and thus to prevent pollution of water from sediment and polluting substances carried by sediment.

North Carolina Well Construction Standards (NC Code, Title 15A, Chapter 2C) established rules and requirement for the construction and abandonment of well.

TBCs

OSWER No. 9295.8-06 Memorandum of Understanding between the Environmental Protection Agency and the Nuclear Regulatory Commission which identifies the interaction of the two agencies for the decommissioning and decontamination of NRC-licensed sites. The memorandum indicates that it is not applicable to NRC-Agreement State licensed facilities or facilities decommissioned by such states. Since North Carolina is a NRC-Agreement State this guidance is considered a TBC.

Electric Power Research Institute - Groundwater Monitoring Guidance for Nuclear Power Plants Final Report September 2005, and *Guidelines for Implementing a Groundwater Protection Program at Nuclear Power Plants Final Report, November 2007* provides guidance to the nuclear industry for the assessment and monitoring of radiological impacts in groundwater.

Nuclear Energy Institute Industry Groundwater Protection Initiative Final Guidance Document, August 2007 identifies actions to improve the nuclear industry response to accidental releases of radioactive substances to the environment. This guidance also provides some direction on establishing remediation protocol to prevent the migration of radioactive material off-site and to minimize decommissioning impacts. Acceptance criteria include the following:

Establish written procedures outlining the decision making process for remediation of leaks and spills or other instances of inadvertent releases. The process is site specific and shall consider migration pathways.

Evaluate the potential for detectible levels of licensed material resulting from planned releases of liquids and/or airborne materials.

Evaluate and document, as appropriate, decommissioning impacts resulting from remediation activities or the absence thereof.

The National Environmental Policy Act (NEPA) of 1969 promotes consideration of environmental concerns by Federal agencies. NEPA declares national environmental policy and goals and provides a method for accomplishing these goals. Fund-financed Federal remedial actions are exempt from NEPA requirements for an Environmental Impact Statement provided that: 1) standards exist that ensure adequate consideration of environmental issues and 2) opportunity for public comment is provided prior to selection of a remedial alternative.

5.1.2 Proposed Remedial Action Objectives

Based on the results of the groundwater investigation and considering the requirements for risk reduction, and the ARARs, the Remedial Action Objectives (RAOs) specifically developed for the site are presented below.

Reduce the continual migration of tritium in groundwater on-site and off-site to protect human health and the environment.

Control future releases of tritiated water through the SDSP.

Address ARARs relating to historic disposal practices at the SDSP.

The proposed remedial goal (RG) for tritium in groundwater is based on the federal MCL of 20,000 pCi/L. However, it should be noted that the applicable NCDENR RG for tritium in groundwater is non-detect.

5.2 Area of Attainment

The estimated area and volume of contaminated groundwater are discussed below. To facilitate the discussion of general response actions and remedial technology screening, the area and volume of groundwater requiring remedial action have been grouped as follows:

Contaminated groundwater within the berm of the SDSP.

Contaminated groundwater outside the berm of the SDSP with tritium concentrations greater than the RG of 20,000 pCi/l.

Each of these is described below.

The area of the SDSP as measured from the approximate centerline of the dike is approximately 2,572,650 square feet or approximately 59 acres. Assuming a saturated thickness of 35' and effective porosity of 30% there is over 202 million gallons of tritiated groundwater in the SDSP area.

The area outside the SDSP with tritium concentrations greater than the RG is approximately 888,601 square feet of approximately 20 acres. Assuming a saturated thickness of 20' and effective porosity of 30% there is approximately 40 million gallons of tritiated groundwater in the area of attainment outside the SDSP area.

5.3 General Response Actions

General response actions are those actions that will satisfy the RAOs identified in Section 5.1.2. General response actions have been developed for contaminated groundwater at the BNP and include the following:

No Action

Limited Action

Containment

Active Restoration

Technologies applicable to each general response are identified and screened in Section 6.

6 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND SELECTION OF PROCESS OPTIONS

The screening of the remedial technologies is performed in two steps: (1) the identification and screening of technology types and process options for each general response action, and (2) the preliminary evaluation and selection of representative process options. The following section discusses the results of each step.

6.1 Identification and Screening of Technology Types and Process Options

The remedial technology types associated with each of the GRAs considered for corrective action of groundwater at the site were developed based on experience at other sites, knowledge of new technologies and professional judgment. Remedial technology types associated with each GRA are presented in **Table 6-1**. Most of these remedial technology types include several different process options that could apply to the Site. The potential applicable technologies and process options were screened based on technical implementability considering site-specific conditions. The process options retained in the screening process are also identified in **Table 6-1** are carried through to the evaluation and selection process.

6.2 Preliminary evaluation and selection of representative process options

Retained process options were preliminarily evaluated on the basis of overall effectiveness, technical implementability and cost relative to site-specific conditions.

Process option effectiveness focused on: 1) ability to address the estimated quantity of material and to meet contaminant reduction/control goals; 2) effectiveness at protecting human health and the environment during the construction and implementation phase; and, 3) reliability of the technology with respect to contaminants and Site conditions.

Process option implementability refers to how easy it will be to employ the process option based on Site conditions and contaminant characteristics.

Process option cost evaluation is preliminary and relied upon professional judgment and experience to generate a relative cost of process options within a given technology type.

The initially retained process options were evaluated qualitatively, based on effectiveness, implementability and cost, as described above. Comparisons were made within each technology type by assessing the effectiveness, implementability and cost of each process option as either low, moderate, or high relative to other process options within the technology type. Based on the evaluation, specific process options were selected for development of site-specific remedial alternatives. Process options that were not selected were still technically feasible and may be substituted for the selected process option during remedial design. The results of the process option evaluation and selection are presented in **Table 6-2**.

Table 6-2 presents a summary of the technology screening for groundwater. Each technology is rated according to a qualitative designation low, moderate or high. For effectiveness and implementability, a high rating indicates that evaluation criteria are favorable for this technology. A moderate rating is neither favorable nor unfavorable, but indicates potential unknowns and/or uncertainties. A low rating is sufficient basis for eliminating the technology from further consideration.

With respect to cost, the ratings provided are relative to the full range of technologies. Qualitative designations of low, moderate or high correspond to relative cost: low referring to a low cost to implement the process option. A high rating for cost is sufficient to eliminate a technology if technologies within the same response category still remain. Technologies and process options are designated as retained or eliminated from consideration in the conclusion column of the summary table.

7 EVALUATION OF REMEDIAL ALTERNATIVES

The following section identifies and evaluates potential corrective actions for the site.

7.1 Assembly of Potential Remedial Alternatives

Based on the evaluation discussed in the proceeding sections, the following alternatives have been assembled for the Site:

Alternative 1 – Monitored Natural Attenuation (MNA)
Alternative 2 – Containment (Barrier Wall) with MNA
Alternative 3 – Containment (Impoundment) with MNA
Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA
Alternative 5 – Site-wide Groundwater Extraction with MNA
Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA

It must be noted that all of the alternatives assume that certain operational changes will be made to the BNP. Specifically, the plant will be reconfigured such that tritiated condensate will no longer be discharged to the SDSP. This eliminates the most significant source of tritiated water to the SDSP. Storm water discharges containing tritium in excess of the RG will still be directed to the SDSP.

Each alternative will be evaluated against the primary criteria of effectiveness, implementability, and cost as discussed in the following section.

7.2 Evaluation Criteria

Each alternative is evaluated based on the primary criteria of effectiveness, implementability and cost in order to identifying the merit of each potential corrective action. Elements of each evaluation criteria are discussed below.

7.2.1 Effectiveness

The elements considered to evaluate effectiveness include the following.

Protection of human health and the environment; reduction in toxicity, mobility and volume; and permanence of solution.

Ability of the technology to handle the estimated areas or volumes of contaminated media.

Ability of the technology to meet the remediation goals identified in the remedial action objectives.

Technical reliability (innovative versus well proven) with respect to contaminants and site conditions.

7.2.2 Implementability

The elements considered to evaluate implementability include the following.

Overall technical feasibility at the site.

Availability of vendors, resources, storage and disposal services, etc.

Administrative feasibility.

Special long-tem operation and maintenance requirements.

7.2.3 Cost

The elements considered to evaluate cost include the following.

Capital cost.

Operation and maintenance (O&M costs).

Cost have been developed using cost estimating references such as RS Means Environmental Remediation Cost Data – Assemblies, 2005, subcontractor estimates, and professional judgment. Typically these study estimate costs made during the preliminary evaluation/conceptual design stage are expected to provide an accuracy of +50% to -30%.

Screening evaluations at this stage focus mainly on effectiveness and implementability. Less emphasis is placed on cost evaluations so that technologies of different categories are not eliminated solely on cost. Each alternative presented in the following section is not necessarily intended to stand alone and may be combined with other technologies now or in the future, in whole or in-part, to form the optimal corrective action alternative.

7.3 Evaluation of Alternatives

In the following subsections, each potential alternative is summarized then evaluated against the primary evaluation criteria.

7.3.1 ALTERNATIVE 1 - Monitored Natural Attenuation (MNA)

Alternative 1 – Monitored Natural Attenuation (MNA) is evaluated in the following section. A technical summary of the alternative is presented followed by an evaluation against the primary criteria of effectiveness, implementability and cost.

7.3.1.1 Technical Description

The term MNA as used by the USEPA, refers to the reliance on natural processes to achieve site-specific remediation objectives. Natural attenuation processes include a variety of physical, chemical, and biological processes that act to reduce the volume, toxicity, mobility, and concentration of contaminants in the groundwater. These processes include biodegradation, decay, dilution, absorption, volatilization, and chemical reactions with natural materials.

Determining whether MNA may be an appropriate technology for a site requires answers to the following questions:

Are the contaminants of interest amendable to degradation?

Will physical processes (e.g., decay) contribute significantly to the attenuation of contaminants?

Will contaminant degradation result in more toxic compounds or compounds that are less degradable?

Does the Site's hydrogeologic profile or conceptual model support the use of MNA (e.g., location of potential receptors, complexity of site geology)?

Given that answers to the above questions are favorable, data from a groundwater monitoring program are needed to further document that MNA will achieve the RAOs. Physical, chemical, and biological data collected from a groundwater monitoring program would be evaluated to determine if: 1) there is an observed trend of declining contaminant concentrations over time, and 2) the estimated rate of attenuation will exceed the rate of contaminant transport resulting in an unacceptable exposure to groundwater.

In relation to the site, MNA has been retained for analysis as a potential groundwater remedial alternative based on the following:

The groundwater investigation data indicated that the chemical of concern in the groundwater is tritium. The half-life of tritium is 12.32 years, therefore natural decay is occurring. In addition, biodegradation/bioremediation of tritium via phytoremediation has been documented at similar sites and this process option could be utilized to enhance the MNA process.

The ultimate breakdown product of tritium is helium. Therefore unlike the biodegradation of chlorinated hydrocarbons that produce more toxic intermediaries such as vinyl chloride, the decay of tritium results in no adverse affects.

An element of the corrective action for the Site will be the future source control of tritiated groundwater. As discussed previously, the removal of tritiated water (condensate) stream from plant operations will eliminate the majority of the future source material contributing to the groundwater conditions although storm water containing tritium above the RG will still be discharged to the SDSP and the existing tritiated groundwater within the SDSP will continue to act as a continual source, Combining source removal with MNA remedies is a key component of EPA's approach to natural attenuation as outlined in OSWER Directive 9200.4-17 (*Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites*).

The groundwater in the area is not used for drinking water purposes.

The MNA alternative will consist of groundwater monitoring of tritium concentration trends throughout the site area. Surface water sampling and analysis will also be required as part of this alternative to evaluate potential groundwater to surface water impacts. Monitoring will be performed on a monthly basis until the remedial goal of 20,000 pCi/L is achieved throughout the site area. It is assumed that a total of 40 groundwater and surface water samples will be collected on a monthly basis to support the MNA Alternative. Existing monitoring wells will be utilized for groundwater sample collection. The duration of timeframe for implementation of this alternative is expected to be 30+ years since there would be no action to control the input of tritiated water, at a concentration greater than 20,000 pCi/L, into the SDSP.

7.3.1.2 Effectiveness

Monitored Natural Attenuation (MNA) provides no additional protection of human health and the environment except that afforded by monitoring which would provide an early warning as to the migration of tritiated groundwater off site. Tritium contaminants present in the groundwater will naturally attenuate primarily through dilution and decay over time. Although the primary source of the highly concentrated tritium discharges to the SDSP, tritiated water stream from plant operations, will be eliminated, since the on-going discharge of storm water to the pond is generally in excess of the RG, it is anticipated that the groundwater concentrations will not approach the RG (20,000 pCi/L) in the foreseeable future. Migration of tritium-impacted groundwater would continue and concentrations exceeding the RG may extend off-site; however, this would be mitigated by the use of monitoring that would provide an early warning of such an occurrence so that additional actions could be implemented. Because groundwater in this area is not used for potable purposes, there would be no receptors for groundwater ingestion during the natural attenuation remediation period.

Regulatory agencies accept monitored natural attenuation as a viable remedial alternative for addressing dissolved groundwater plumes. Acceptance is generally contingent on some demonstration of source removal or control. With source removal and/or control, monitored natural attenuation should meet the RAO of protecting human health and the environment.

This alternative would not provide long-term effectiveness and permanence. Tritium concentrations in groundwater would be reduced via natural attenuation mechanisms, specifically dilution and decay, and this degradation is permanent and effective; however, because a continual discharge of tritiated storm water would exist, the RGs would not be achieved in the foreseeable future.

The monitored natural attenuation alternative reduces the toxicity and volume of tritium present in the groundwater as it decays.

7.3.1.3 Implementability

The monitored natural attenuation alternative is easily implemented. The remediation processes are naturally occurring and require no construction activities directly related to implementation of the corrective action. The groundwater and surface water would be monitored long-term to evaluate the effectiveness of the remedial alternative.

It must be noted that the primary assumption of all of the alternatives evaluated is that highly concentrated tritiated water from the plant will no longer be disposed in the SDSP. The implementability and costs for plant engineering and construction to achieve this assumption is unknown and beyond the scope of this evaluation.

7.3.1.4 Cost

The estimated cost to implement Alternative 1 – Monitored Natural Attenuation (MNA), for a period of 30 years, is approximately $9,394,145, with a total present worth cost of $4,954,399. A breakdown of major cost components is shown on **Table 7-1**. Costs for activities described in this alternative include direct and indirect capital cost. Operation and maintenance cost are included in the annual cost. An allowance for hazardous waste/nuclear site work has been added along with a 10% contingency. The cost assumes:

Sampling would be conducted monthly for 30 years.

30 groundwater samples from existing monitoring wells and 10 surface water samples would be collected each month.

Sample collection and analyses would be performed by in-house environmental specialists.

An Update Report would be prepared on a quarterly basis and a Monitoring Report would be prepared on an annual basis to evaluate the groundwater and surface water monitoring results, water quality trends, and, provide recommendations for future activities. This report would be prepared by a third party independent consultant.

A present worth analysis was performed on the total 30-year cost. A discount rate of 5 percent before taxes and after inflation was assumed. The estimated present worth for 30-years is $4,954,399 as shown on **Table 7-1A**. The final costs for Alternative 1 - MNA would depend on the long-term groundwater monitoring program and the ability to adjust (reduce) the sampling frequency based on data supporting a decreasing concentration trend over time.

7.3.2 ALTERNATIVE 2 -Containment (Barrier Wall) with MNA

Alternative 2 – Containment (Barrier Wall) with MNA is evaluated in the following section. A technical summary of the alternative is presented followed by an evaluation against the primary criteria of effectiveness, implementability, and cost.

7.3.2.1 Technical Description

Alternative 2 -Containment (Barrier Wall) with MNA would involve the installation of a non-structural low permeability vertical barrier to stop the horizontal flow of impacted groundwater from the area of the SDSP. The barrier wall would be constructed using fairly standard construction equipment (long-stick excavator) by excavating a trench under bentonite slurry. The bentonite slurry stabilizes the excavation and prevents it from collapsing, even below the water table. As small segments of the excavation are completed the trench is backfilled with an impervious mixtures, usually a blend of soil and bentonite; soil, cement, and bentonite; or cement and bentonite. A soil-bentonite slurry wall is proposed for the site that would have an effective permeability of $1x10^{-7}$ cm/sec permeability.

In addition, MNA as discussed in Section 7.3.1 would be included as an element of this alternative.

Based on the existing conceptual site model the barrier wall would be constructed around the majority of the perimeter of the SDSP. The barrier wall would be located along the approximate centerline of the existing dike on the northern, eastern and western sides of the SDSP. The barrier wall in the southern side of the pond would extend toward the intake canal and be open to the canal in-part in a funnel and gate type configuration. This configuration would allow the natural discharge of shallow groundwater to the intake canal. A series of three (3) monitoring wells would be installed in the gate area to monitor groundwater quality and flow rate to document the dose of tritium released to the intake canal. Total length and width of the barrier wall would be approximately 6,400 feet and 3 feet, respectively. Nominal depth of the barrier wall along the dike would be 45 feet bgs or elevation of approximately -10 feet MSL. The total depth of the barrier wall would decrease from the dike area to the intake canal. The bottom of the barrier wall would be keyed, a minimum of 3 feet, into the low permeable layer. The general barrier wall layout and cross section is illustrated in **Figure 7-1**.

Additional study and design efforts would be required prior to construction of the barrier wall. Objectives of these efforts include the following:

Evaluate what effects containing the existing SDSP would have on the downward vertical groundwater flow gradients from the impacted shallow surficial aquifer to the much lesser impacted intermediate aquifer. Downward vertical flow gradients are significant in the area of the pond as illustrated by water level measurements collected from EES-19B and ESS-19C but they are equally strong away from the influence of the pond as illustrated by water level measurements collected from EES-3B and ESS-3C. This data would provide information to assist with the final wall design and would aid in determining if a groundwater gate would be required or if the barrier wall could be a complete enclosure.

Additional soil borings would be advanced along the path of the wall to confirm the depth of the low permeability zone.

Samples representing the vertical profile of the wall (ground surface to 45 feet bgs) would be collected at several locations to perform material compatibility testing and develop the final design mix.

A geotechnical evaluation of the dike would be conducted to ensure that the dike would support the construction equipment required for barrier wall installation.

Results of these additional activities would provide the necessary information for the final design and construction of the barrier wall.

7.3.2.2 Effectiveness

Containment in the form of a vertical barrier wall with MNA provides protection of human health and the environment. Groundwater with elevated concentrations of tritium within the SDSP would be contained and prevented from migrating horizontally. This alternative would not control the future release of tritiated storm water to the SDSP. Tritiated groundwater outside the containment area would naturally attenuate over time. With containment of the source area (SDSP), tritium concentrations in groundwater outside of the containment area might approach the GR (20,000 pCi/L) over time (30 years). Migration of tritium-impacted groundwater outside the containment would continue and concentrations exceeding the RG may extend off-site; however, this would be mitigated by the use of monitoring that would provide an early warning of such an occurrence so that additional actions could be implemented. It is also possible that the containment would increase the downward vertical groundwater flow gradient, which could lead to further impact to the intermediate surficial aquifer. Again, this would be mitigated by the use of monitoring that would provide an early warning of such an occurrence so that additional actions could be implemented.

The groundwater in this area is not used for potable purposes and, therefore, there would be no receptors for groundwater ingestion outside the containment area during the natural attenuation remediation period.

This alternative would provide long-term effectiveness and permanence. Tritium in groundwater would be contained within the SDSP area and concentrations reduced via natural attenuation mechanisms outside of the containment area. Over the long-term (i.e. several decades), this alternative would be effective as containment would prevent the continual migration of tritiated groundwater from the SDSP. Because a continual discharge of tritiated storm water would exist, the RGs would not be achieved within the SDSP in the foreseeable future outside the containment area natural attenuation would be allowed to occur and concentrations of tritium in groundwater would be reduced.

The containment with a barrier wall with monitored natural attenuation alternative would reduce the toxicity, mobility, and volume of tritium present in the groundwater.

7.3.2.3 Implementability

The containment via barrier wall and monitored natural attenuation alternative is implementable using fairly typical construction equipment and methods. Additional hydrogeologic and engineering evaluations would be conducted to evaluate the long-term effects of the barrier wall on tritiated groundwater migration and finalize the wall design and construction methods. Installation of the barrier wall could be completed within a relatively short time period, six months to a year. Typical drilling equipment would be used for the installation of monitoring wells included in this alternative.

The remedial processes associated with MNA are naturally occurring and require no construction activities. The groundwater and surface water would be monitored long-term to evaluate the effectiveness of the remedial alternative.

7.3.2.4 Cost

The estimated cost to implement Alternative 2 – Containment (Barrier Wall) with MNA, for a period of 30 years, is approximately $6,835,203, with a total present worth cost of $5,897,482. A breakdown of major cost components is shown on **Table 7-2**. Costs for activities described in this alternative include direct and indirect capital cost. Operation and maintenance cost are included in the annual cost. An allowance for hazardous waste/nuclear site work has been added along with a 10% contingency. The cost assumes:

Additional assessments would be conducted to evaluate the long-term effects of the barrier wall on groundwater flow and develop the final barrier wall design and construction methods.

The barrier wall would be constructed of a soil-bentonite mix and be approximately 6,400' long by 45' deep by 3' wide.

The wall would be installed with a gate which would allow shallow groundwater to naturally discharge to the intake canal thereby alleviating the mounding of shallow groundwater behind the wall which would create an increased downward vertical groundwater flow gradient. Three (3) monitoring wells would be constructed in the gate area to allow for the monitoring of groundwater flow and quality discharging to the intake canal.

Sampling for MNA purposes would be conducted monthly for the first year and quarterly thereafter for 30 years.

30 groundwater and 10 surface water samples would be collected the first year and 10 groundwater and 5 surface water samples would be collected thereafter.

Sample collection and analyses would be performed by in-house environmental specialists.

A Monitoring Report would be prepared on an annual basis to evaluate the groundwater and surface water monitoring results, water quality trends, and, provide recommendations for future activities. This report would be prepared by a third party independent consultant.

A present worth analysis was performed on the total 30-year cost. A discount rate of 5 percent before taxes and after inflation was assumed. The estimated present worth for 30-years is $5,897,482 as shown on **Table 7-2A**. The final costs for Alternative 2 – Containment (Barrier Wall) with MNA would depend on the final design of the barrier wall and the long-term groundwater monitoring program specifically the ability to reduce the sampling frequency or completely eliminate the monitoring program based on data supporting the effectiveness of the corrective action.

7.3.3 ALTERNATIVE 3 - Containment (Impoundment) with MNA

Alternative 3 – Containment (Impoundment) with MNA is evaluated in the following section. A technical summary of the alternative is presented followed by an evaluation against the primary criteria of effectiveness, implementability, and cost.

7.3.3.1 Technical Description

Alternative 3 -Containment (Impoundment) with MNA would involve the construction of a new low permeability impoundment within the SDSP to stop the percolation of tritiated water into groundwater. The impoundment would be located in the western portion of the SDSP. The existing dike wall in the western portion of the SDSP would be used to the extent practical for the impoundment. This location minimizes relocation requirements of the current inlet to the pond from the plant and discharge to the intake canal. As with all the alternatives, the removal of the tritiated water (condensate) stream from plant operations will eliminate the majority of the future source material contributing to the groundwater conditions. Storm water containing tritium above the RG will still be discharged to the newly constructed impoundment and subsequently discharged to the intake canal. It is estimated that the pond will cover approximately 350,000 square feet (8 acres) and be approximately 5' deep. Total volume of the impoundment would be approximately 1.75 million cubic feet or 13.65 million gallons. The impoundment would meet the functional requirements of the SDSP for oil and grease removal. The impoundment would discharge to the intake canal. The general impoundment layout is illustrated in **Figure 7-2**.

Two potential impoundment liner designs are evaluated. The first liner design is equivalent to a RCRA hazardous waste landfill liner design and consists from top to bottom the following: a one-foot thick soil protective layer, a 30 mil PVC geomembrane, a geosynthetic clay layer, a one-foot thick granular leak detection/recovery layer, a 30 mil PVC geomembrane and, prepared natural material. This configuration is very protective and includes the ability to monitor for leaks through the primary liner. The second design is a non-RCRA type liner and is equivalent to a municipal waste landfill liner. The liner consists from top to bottom the following: a one-foot thick soil protective layer, a 30 mil PVC geomembrane, and prepared natural material. The impoundment will be constructed using standard construction equipment. In addition, MNA as discussed in Section 7.3.1 will be included as an element of this alternative.

Additional study and design efforts would be required prior to construction of the impoundment. Objectives of these efforts include the following:

Conduct additional evaluations to optimize the size and location of the impoundment. The size and location of the impoundment would be designed to ensure that the NPDES permit requirements are met.

Determine final design of the liner system based on risk management objectives.

Determine if there are any other water inputs to the impoundment, potentially from plant operations or groundwater withdrawal as part of the corrective action.

An evaluation of the dike would be conducted in the area of the impoundment to ensure that the dike would support the construction equipment require for impoundment installation and long-term operation.

Results of these additional activities would provide the necessary information for the final design and construction of the impoundment.

7.3.3.2 Effectiveness

Containment in the form of an impoundment with MNA provides protection of human health and the environment. Future storm water with elevated concentrations of tritium would be contained thereby controlling future releases to the SDSP and prevented from migrating while tritiated groundwater outside the impoundment will naturally attenuate over time. Migration of tritium-impacted groundwater outside the impoundment would continue and concentrations exceeding the RG may extend off-site; however, this would be mitigated by the use of monitoring that would provide an early warning of such an occurrence so that additional actions could be implemented. With containment of the ongoing source, groundwater outside of the impoundment might approach the RG (20,000 pCi/L) over time (30 years), although this is not likely since the tritiated groundwater within the remainder of the SDSP would remain a continual source.

The groundwater in this area is not used for potable purposes and, therefore, there would be no receptors for groundwater ingestion during the natural attenuation remediation period.

This alternative would provide long-term effectiveness and permanence. The continual source of tritium would be contained in an impoundment within the SDSP and natural attenuation mechanisms would occur in groundwater outside of the impoundment area. Over the long-term (i.e. several decades), this alternative would be effective as containment would prevent the continual source of tritiated groundwater from reaching the SDSP. Outside the containment area attenuation would occur and concentrations of tritium in groundwater would be reduced. Elimination of the storm water flow into the SDSP would reduce the hydraulic head in the SDSP thereby reducing the migration rate of tritiated groundwater and potentially restoring the natural groundwater flow regime resulting in shallow groundwater flow discharging to the intake canal.

The containment with an impoundment with monitored natural attenuation alternative reduces the toxicity, mobility, and volume of tritium present in the groundwater.

7.3.3.3 Implementability

The containment via impoundment and monitored natural attenuation alternative is implementable using fairly typical construction equipment and methods.

Additional engineering evaluations would need to be conducted to finalize the impoundment design and construction methods. Installation of the impoundment can be completed within a relatively short time period, six months to a year.

The remedial processes associated with MNA are naturally occurring and require no construction activities. The groundwater and surface water would be monitored long-term to evaluate the effectiveness of the remedial alternative.

7.3.3.4 Cost

The estimated cost to implement Alternative 3 – Containment (Impoundment) with MNA, has been developed for the two impoundment liner systems discussed above. The estimated cost to implement Alternative 3 with the RCRA type impoundment liner for a period of 30 years is approximately $8,415,804, with a total present worth cost of $7,478,082. A breakdown of major cost components is shown on **Table 7-3**. The estimated cost to implement Alternative 3A with the non-RCRA type impoundment liner for a period of 30 years is approximately $7,087,950, with a total present worth cost of $6,150,228. A breakdown of major cost components is shown on **Table 7-4**. Costs for activities described in this alternative include direct and indirect capital cost. Operation and maintenance cost are included in the annual cost. An allowance for hazardous waste/nuclear site work has been added along with a 10% contingency. The cost assumes:

Additional assessments would be conducted to evaluate the final impoundment design (size and liner system) and construction methods.

The impoundment would be approximately 8 acres and have a nominal depth of 5' for a total volume of 1.75 million cubic feet or 13.65 million gallons.

The RCRA type liner would include: a one-foot thick soil protective layer, a 30 mil PVC geomembrane, a geosynthetic clay liner, a one-foot thick granular leak detection layer, a 30 mil PVC geomembrane and, prepared natural material.

The non-RCRA type liner would include: a one-foot thick soil protective layer, a 30 mil PVC geomembrane and, prepared natural material.

Sampling for MNA purposes would be conducted monthly for the first year and quarterly thereafter for 30 years.

30 groundwater and 10 surface water samples would be collected the first year and 10 groundwater and 5 surface water samples would be collected thereafter.

Sample collection and analyses would be performed by in-house environmental specialists.

A Monitoring Report would be prepared on an annual basis to evaluate the groundwater and surface water monitoring results, water quality trends, and, provide recommendations for future activities. This report would be prepared by a third party independent consultant.

A present worth analysis was performed on the total 30-year cost. A discount rate of 5 percent before taxes and after inflation was assumed. The estimated present worth for 30-years of Alternative 3 with the RCRA type liner is $7,478,082 as shown on **Table 7-3A**, while the estimated present worth for 30-years of Alternative 3A with the non-RCRA type liner is $6,150,228 as shown on **Table 7-4A**. The final costs for Alternative 3 – Containment (Impoundment) with MNA would depend primarily on the final design (size and liner type) of the impoundment and to lesser extend the long-term groundwater monitoring program specifically the ability to reduce the sampling frequency or completely eliminate the monitoring program based on data supporting the effectiveness of the corrective action.

7.3.4 ALTERNATIVE 4 - Containment (Barrier Wall and Impoundment) with MNA

Alternative 4– Containment (Barrier Wall and Impoundment) with MNA is evaluated in the following section. A technical summary of the alternative is presented followed by an evaluation against the primary criteria of effectiveness, implementability, and cost.

7.3.4.1 Technical Description

Alternative 4 -Containment (Barrier Wall and Impoundment) with MNA combines the primary elements of Alternative 2 and Alternative 3 to provide containment of tritiated groundwater and prevent the continual migration of impacted groundwater.

This alternative would include the installation of a soil-bentonite barrier wall as discussed in Section 7.3.2 and an impoundment (non-RCRA) as discussed in Section 7.3.3. In addition, MNA as discussed in Section 7.3.1 will be included as an element of this alternative. The containment with barrier wall and impoundment alternative layout is illustrated in **Figure 7-3**.

7.3.4.2 Effectiveness

Containment in the form of a barrier wall and impoundment with MNA provides protection of human health and the environment. Groundwater with elevated concentrations of tritium within the SDSP would be contained and prevented from migrating while tritiated groundwater outside the impoundment would naturally degrade over time. With containment of the source area (SDSP) concentrations of tritium in groundwater outside of the containment area might approach the RG (20,000 pCi/L) over time (30 years). Migration of tritium-impacted groundwater outside the containment would continue and concentrations exceeding the RG may extend off-site; however, this would be mitigated by the use of monitoring that would provide an early warning of such an occurrence so that additional actions could be implemented. It is also possible that the containment would increase the downward vertical groundwater flow gradient, which could lead to further impact to the intermediate surficial aquifer. This is less likely than in Alternative 2 because the continual tritiated storm water discharge to the SDSP would be eliminated, reducing both the concentration and hydraulic gradient. If vertical migration were to occur, it would be mitigated by the use of monitoring that would provide an early warning of such an occurrence so that additional actions could be implemented. The groundwater in this area is not used for potable purposes and, therefore, there would be no receptors for groundwater ingestion during the natural attenuation remediation period.

This alternative would provide long-term effectiveness and permanence. The continual source of tritium would be contained in an impoundment within the SDSP and natural attenuation mechanisms would occur in groundwater outside of the impoundment area. Over the long-term (i.e. several decades), this alternative would be effective as the impoundment would prevent the continual source of tritiated groundwater from reaching the SDSP and tritiated groundwater within the SDSP would be contained within the barrier wall. Outside the containment area attenuation would occur and concentrations of tritium in groundwater would be reduced. Elimination of the storm water flow into the SDSP would reduce the hydraulic head in the SDSP thereby potentially reducing the need for the gate system. Over the long-term (i.e. several decades), this alternative is effective as containment will prevent the continual migration of tritiated groundwater from the SDSP area to non-impacted areas.

The containment (barrier wall and impoundment) with monitored natural attenuation alternative reduces the toxicity, mobility, and volume of tritium present in the groundwater.

7.3.4.3 Implementability

The containment via barrier wall and impoundment and monitored natural attenuation alternative is implementable using fairly typical construction equipment and methods. Additional hydrogeologic and engineering evaluations would need to be conducted to evaluate the long-term effects of the barrier wall on tritium migration in groundwater, optimize the impoundment size, location and liner design and finalize the alternative design and construction methods. Installation of the barrier wall and impoundment can be completed within a relatively short time period, approximately one year. Typical drilling equipment would be used for the installation of monitoring wells included in this alternative.

The remedial processes associated with MNA are naturally occurring and require no construction activities. The groundwater and surface water would be monitored long-term to evaluate the effectiveness of the remedial alternative.

7.3.4.4 Cost

The estimated cost to implement Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA, for a period of 30 years, is approximately $10,686,740, with a total present worth cost of $11,624,460. A breakdown of major cost components is shown on **Table 7-5**. Costs for activities described in this alternative include direct and indirect capital cost. Operation and maintenance cost are included in the annual cost. An allowance for hazardous waste/nuclear site work has been added along with a 10% contingency. The cost assumes:

Additional assessments would be conducted to evaluate the long-term effects of the barrier wall on groundwater flow and develop the final barrier wall design, evaluate the final impoundment design (size, location, and liner system), and alternative construction methods.

The barrier wall would be a soil-bentonite mix approximately 6,400’ long by 45’ deep by 3’ wide.

The wall would be installed with a gate which would allow shallow groundwater to naturally discharge to the intake canal thereby alleviating the mounding of shallow groundwater behind the wall which would create an increased downward vertical groundwater flow gradient. Three monitoring well would be constructed in the gate to allow for the monitoring of groundwater flow and quality discharging to the intake canal.

The impoundment would be approximately 8 acres and have a nominal depth of 5’ for a total volume of 1.75 million cubic feet or 13.65 million gallons.

The non-RCRA type liner would include: a one-foot thick soil protective layer, a 30 mil PVC geomembrane, and, prepared natural material.

Sampling for MNA purposes would be conducted monthly for the first year and quarterly thereafter for 30 years.

30 groundwater and 10 surface water samples would be collected the first year and 10 groundwater and 5 surface water samples would be collected thereafter.

Sample collection and analyses would be performed by in-house environmental specialists.

A Monitoring Report would be prepared on an annual basis to evaluate the groundwater and surface water monitoring results, water quality trends, and, provide recommendations for future activities. This report would be prepared by a third party independent consultant.

A present worth analysis was performed on the total 30-year cost. A discount rate of 5 percent before taxes and after inflation was assumed. The estimated present worth for 30-years is $10,686,740 as presented on **Table 7-5A**. The final costs for Alternative 4 (Containment, Barrier Wall and Impoundment with MNA) would depend on the final design of the barrier wall and impoundment as well as the long-term groundwater monitoring program specifically the ability to reduce the sampling frequency or completely eliminate the monitoring program based on data supporting the effectiveness of the corrective action.

7.3.5 ALTERNATIVE 5 – Site-Wide Groundwater Extraction with MNA

Alternative 5 – Site-wide Groundwater Extraction with MNA is evaluated in the following section. A technical summary of the alternative is presented followed by an evaluation against the primary criteria of effectiveness, implementability, and cost.

7.3.5.1 Technical Description

This alternative involves extracting groundwater in sufficient volume and at appropriate locations to capture the area of tritium impacts in groundwater at concentrations greater than the RG of 20,000 pCi/L. Groundwater would be captured via a system of extraction wells. Extraction wells would be screened in the shallow aquifer. Based on the hydrogeologic data presented herein the estimated sustained yield of each extraction well in the shallow zone is approximately 0.5 gpm or 720 gpd. With a sustained yield of 0.5 gpm the effective capture zone diameter of each well is approximately 80'. Based on the hydrogeologic data and the area of attainment (area of groundwater with tritium concentrations greater than 20,000 pCi/L) it is estimated that approximately 214 extraction wells would be required to capture tritium impacted groundwater in the area. The general layout of the extraction wells is illustrated in **Figure 7-4**. Once the groundwater is extracted it would be conveyed directly to the SDSP. Total groundwater discharge to the pond would be approximately 107 gpm or 154,000 gpd. Groundwater in the SDSP would be periodically discharged to the intake canal and infiltrate back into the groundwater for re-collection through the groundwater extraction wells in-lieu of containment. In addition, MNA as discussed in Section 7.3.1 will be included as an element of this alternative.

Groundwater extraction would continue until the groundwater concentrations either achieve the remedial goals, or the extracted groundwater concentrations have been reduced significantly such that the extraction system could be turned off, and the remedial goals achieved via natural attenuation.

Some additional study and design efforts would be required prior to construction of the site-wide groundwater extraction alternative. Objectives of these efforts include the following:

Evaluate the effect of the groundwater discharge at an approximate rate of 150,000 gpd to the existing SDSP.

Finalize the final well spacing and withdrawal rates by conducting pumping tests at various extraction well locations.

Results of these additional activities would provide the necessary information for the final design and construction of the site-wide groundwater extraction system.

7.3.5.2 Effectiveness

Site-wide groundwater extraction with MNA provides protection of human health and the environment by preventing potential off-site migration of tritiated groundwater. Groundwater with tritium concentrations greater than 20,000 pCi/L would be captured and prevented from migrating off-site; however, without containment of the SDSP the extracted groundwater once discharged to the pond would percolate back into the subsurface. In addition, because tritiated storm water would continue to be discharged to the SDSP, concentrations would not be expected to attenuate to the point of attaining the RG within the foreseeable future.

Therefore, this alternative would have limited effectiveness in the long term. The groundwater in this area is not used for potable purposes and, therefore, there would be no receptors for groundwater ingestion during the natural attenuation remediation period.

7.3.5.3 Implementability

The Site-wide groundwater extraction and monitored natural attenuation alternative is implementable using fairly typical construction equipment and methods. Additional hydrogeologic and engineering evaluations would need to be conducted to evaluate optimal well spacing and withdrawal rates. Installation of the Site-wide groundwater extraction system could be completed within a year. Typical drilling and trenching equipment would be used for the installation of extraction wells and piping included in this alternative.

The remedial processes associated with MNA are naturally occurring and require no construction activities. The groundwater and surface water would be monitored long-term to evaluate the effectiveness of the remedial alternative.

7.3.5.4 Cost

The estimated cost to implement Alternative 5 – Site-wide Groundwater Extraction with MNA, for a period of 30 years, is approximately $14,859,943, with a total present worth cost of $9,786,218. A breakdown of major cost components is shown on **Table 7-6**. Costs for activities described in this alternative include direct and indirect capital cost. Operation and maintenance cost are included in the annual cost. An allowance for hazardous waste/nuclear site work has been added along with a 10% contingency. The cost assumes:

Additional assessments would be conducted to evaluate optimal well spacing and withdrawal rates.

214 extraction wells with low flow pumps with controller and telemetry would be installed.

Wells would be constructed of 4" diameter PVC with approximately 25' of continuously wound screen and 20' of riser.

The groundwater conveyance system would consist of three zones each with a pump station.

Sampling for MNA purposes would be conducted monthly for the first year and quarterly thereafter for 30 years.

30 groundwater and 10 surface water samples would be collected the first year and 10 groundwater and 5 surface water samples would be collected thereafter.

Sample collection and analyses would be performed by in-house environmental specialists.

A Monitoring Report would be prepared on an annual basis to evaluate the groundwater and surface water monitoring results, water quality trends, and, provide recommendations for future activities. This report would be prepared by a third party independent consultant.

A present worth analysis was performed on the total 30-year cost. A discount rate of 5 percent before taxes and after inflation was assumed. The estimated present worth for 30-years is $9,786,218 as shown in **Table 7-6A**. The final costs for Alternative 5 – Site-wide Groundwater Extraction with MNA would depend on the final number of extraction wells and the long-term groundwater monitoring program, specifically the ability to reduce the sampling frequency or completely eliminate the monitoring program based on data supporting the effectiveness of the corrective action.

7.3.6 ALTERNATIVE 6 – Focused Groundwater Extraction with Containment (Impoundment and MNA

Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA is evaluated in the following section. A technical summary of the alternative is presented followed by an evaluation against the primary criteria of effectiveness, implementability, and cost.

7.3.6.1 Technical Description

This alternative includes elements of Alternative 3 – Containment (Impoundment) with MNA and Alternative 5 – Site-wide Groundwater Extraction with MNA. In this alternative an impoundment would be constructed in the area of the SDSP as described in Section 7.3.3. In addition, groundwater with elevated concentrations of tritium would be captured via a system of extraction wells. Extraction wells details (construction, spacing and withdrawal rates) would be similar to those described in Section 7.3.5. It is estimated that approximately 50 extraction wells would be required to capture groundwater with significant tritium impacts and control potential off-site migration of tritiated groundwater. The general layout of the extraction well system is illustrated in **Figure 7-5**. Once the groundwater is extracted it would be conveyed directly to the impoundment constructed within the existing SDSP. The design of the impoundment would be similar to those presented in Section 7.3.3. The total groundwater discharge to the impoundment would be approximately 25 gpm or 36,000 gpd. Groundwater discharged to the impoundment (approximately 1 million gallons per month) would be contained and periodically discharge to the intake canal. In addition, MNA as discussed in Section 7.3.1 would be included as an element of this alternative.

Groundwater extraction would continue until the groundwater either achieves the RG, or the extracted groundwater concentrations have been reduced significantly such that the extraction system could be turned off, and the remedial goals achieved via monitored natural attenuation.

Some additional study and design efforts would be required prior to construction of the focused groundwater extraction with containment alternative. Objectives of these efforts include the following:

Conduct additional evaluations to optimize the size and location of the impoundment. The size and location of the impoundment would be designed to ensure that the NPDES permit requirements are met. The impacts of groundwater discharge at an approximate rate of 36,000 gpd on the size of the impoundment would also be considered.

Determine final design of the liner system based on risk management objectives.

Determine if there are any other water inputs to the impoundment, potentially from plant operations.

An evaluation of the dike would be conducted in the area of the impoundment to ensure that the dike would support the construction equipment require for impoundment installation and long-term operation.

Additional pumping tests would be performed at various extraction well locations to finalize the final well spacing and withdrawal rates.

Results of these additional activities would provide the necessary information for the final design and construction of the focused groundwater extraction with containment (impoundment) and MNA alternative.

7.3.6.2 Effectiveness

Focused groundwater extraction with containment (impoundment) and MNA provides protection of human health and the environment. Groundwater with elevated concentrations of tritium would be captured at strategic locations and prevented from migrating off-site. Conveyance of the groundwater to an impoundment would prevent the re-infiltration of tritiated water. This combined with controlling the discharge of tritiated storm water by directing it to the impoundment would make this alternative effective in the long-term with respect to restoring groundwater quality to the RG. The groundwater in this area is not used for potable purposes and, therefore, there would be no receptors for groundwater ingestion during the natural attenuation remediation period.

This alternative would reduce the toxicity, mobility, and volume of tritium present in the groundwater.

7.3.6.3 Implementability

The focused groundwater extraction with containment and monitored natural attenuation alternative is implementable using fairly typical construction equipment and methods. Additional hydrogeologic and engineering evaluations would need to be conducted to evaluate optimal well spacing and withdrawal rate as well as impoundment design. Installation of the focused groundwater extraction system and impoundment can be completed within a year. Typical construction equipment would be used for the installation of the groundwater extraction system and impoundment included in this alternative.

The remedial processes associated with MNA are naturally occurring and require no construction activities. The groundwater and surface water would be monitored long-term to evaluate the effectiveness of the remedial alternative.

7.3.6.4 Cost

The estimated cost to implement Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA, for a period of 30 years, is approximately $11,343,053, with a total present worth cost of $9,418,406. A breakdown of major cost components is shown on **Table 7-7**. Costs for activities described in this alternative include direct and indirect capital cost. Operation and maintenance cost are included in the annual cost. An allowance for hazardous waste/nuclear site work has been added along with a 10% contingency. The cost assumes:

Additional assessments would be conducted to evaluate optimal well spacing and withdrawal rates and evaluate the final impoundment design (size and liner system) and construction methods.

The impoundment would be approximately 8 acres and have a nominal depth of 5' for a total volume of 1.75 million cubic feet or 13.65 million gallons.

The RCRA type liner would include: a one-foot thick soil protective layer, a 30 mil PVC geomembrane, a geosynthetic clay liner, a one-foot thick granular leak detection layer, a 30 mil PVC geomembrane and, prepared natural material.

50 extraction wells with low flow pumps with controller and telemetry would be installed.

Wells would be constructed of 4" diameter PVC with approximately 25' of continuously wound screen and 20' of riser.

Sampling for MNA purposes would be conducted monthly for the first year and quarterly thereafter for 30 years.

30 groundwater and 10 surface water samples would be collected the first year and 10 groundwater and 5 surface water samples would be collected thereafter.

Sample collection and analyses would be performed by in-house environmental specialists.

A Monitoring Report would be prepared on an annual basis to evaluate the groundwater and surface water monitoring results, water quality trends, and, provide recommendations for future activities. This report would be prepared by a third party independent consultant.

A present worth analysis was performed on the total 30-year cost. A discount rate of 5 percent before taxes and after inflation was assumed. The estimated present worth for 30-years is $9,418,406 as shown on **Table 7-7A**. The final costs for Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA would depend on the impoundment design (liner system), final number of extraction wells and the long-term groundwater monitoring program specifically the ability to reduce the sampling frequency or completely eliminate the monitoring program based on data supporting the effectiveness of the corrective action.

7.4 Comparison of Alternatives

The results of the evaluation of each alternative with respect to the evaluation criteria were presented in the previous section. This section provides a comparative analysis which evaluates the relative performance of each alternative in relation to each specific evaluation criteria. This comparative analysis identifies advantages and disadvantages of each alternative so that tradeoffs between the alternatives can be determined.

Table 7-8 presents a summary of the comparative analysis. A discussion of the comparative analysis is presented below.

7.4.1 Effectiveness

All Alternatives assume that the major source of tritiated water discharge to the SDSP will be eliminated through process changes within the BNP. Alternative 1 - MNA includes no active remediation and provides no additional protection of human health and the environment other than that offered by the early warning of off-site migration provided through monitoring. However discharges of tritiated storm water at concentrations greater than the RG (20,000 pCi/L) are anticipated to continue. Based on this practice Alternative 1 would not achieve the RAOs or RGs in the long-term. It is anticipated that current concentrations of tritium in groundwater would decrease via natural attenuation processes; however, the RGs would not be achieved and decommissioning costs associated with the remaining groundwater impacts may be significant. Alternative 2 would reduce the horizontal migration of tritiated groundwater through implementation of a barrier wall. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. Alternative 2 does not control future releases of tritiated storm water to the SDSP and the barrier wall may increase the vertical gradient and potential vertical migration. Alternative 2 would not be expected to achieve the RGs in the long term. Alternative 3 would reduce the migration of tritiated groundwater by controlling (eliminating) the continual source of tritiated storm water to the SDSP by directing it to an impoundment. Existing tritiated groundwater within and in the vicinity of the SDSP would continue to migrate although at a slower rate since the groundwater flow gradient would be expected to decrease due to the elimination of flow to the SDSP. Monitoring would provide an early warning of potential off-site migration. Alternative 3 would not be expected to achieve the RGs in the long term. Alternative 4 would reduce the migration of tritiated groundwater through implementation of a barrier wall. Alternative 4 would control the future release of tritiated storm water to the SDSP by directing it to an impoundment. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. Alternative 4 would not be expected to achieve the RGs in the long term. Alternative 5 eliminates the migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to the SDSP. Alternative 5 does not control future releases of tritiated storm water to the SDSP. Alternative 5 would not be expected to achieve the RGs in the long term. Alternative 6 reduces migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to an impoundment. Alternative 6 also controls future releases of tritiated storm water to the SDSP by directing it to the impoundment. Because Alternative 6 removes the continual source of tritiated storm water and captures and removes existing tritiated groundwater, this alternative would be expected to achieve the RGs in the long term.

7.4.2 Implementablity

Of the six alternatives, Alternative 1 – MNA is the easiest to implement. The major elements of Alternative 1 (groundwater/surface water sampling and analysis) are already in place at the site and would continue for up to 30-years. Alternative 2 through 6 involve widely available, contractor-installed services and would be readily implementable. Implementation of any of these alternatives could be completed within a year. Alternatives 2 through 6 would result in a reduction of the annual monitoring efforts currently associated with Alternative 1. Since Alternative 5 and 6 involve groundwater extraction there would be greater operations and maintenance concerns. Additional evaluations would need to be conducted before design and construction of Alternatives 2 through 6.

7.4.3 Costs

Alternative 1 is the low cost alternative with a present value of $4,954,399, but this alternative would not meet the RAOs in the long-term. Alternatives 2, 3, and 5 would meet some of the RAOs but would not be expected to meet the RGs in the long-term. Alternatives 4 and 6 would meet the RAOs, but only Alternative 6 would be expected to meet the RGs in the long term.

Present value costs for the alternatives are as follows:

Alternative 1 – Monitored Natural Attenuation, $4,954,399;

Alternative 2 – Containment (Barrier Wall) with MNA, $5,897,482;

Alternative 3 – Containment (Impoundment) with MNA, $7,478,082 (RCRA type liner) and $6,150,228; (non-RCRA type liner);

Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA, $10,686,740;

Alternative 5 – Site-wide Groundwater Extraction with MNA, $9,786,218; and,

Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA, $9,418,406.

8 SUMMARY AND CONCLUSIONS

8.1 Summary

Silar Services Incorporated (SSi) has prepared this Groundwater Investigation Report (GIR) for Progress Energy to document the results of groundwater characterization activities performed at the Brunswick Nuclear Plant (BNP), located in Southport, Brunswick County, North Carolina. This study was commenced in response to the detection of tritium in a water sample collected from inside of an onsite subsurface structure (manway) that is located near the Storm Drain Stabilization Pond (SDSP) area of the BNP (the Site). Progress Energy suspected the source of the tritium identified in the manway sample to be groundwater seepage originating from the SDSP area, which suggested the SDSP was leaching tritium into the shallow groundwater aquifer onsite. The SDSP was suspected as the source because it receives process water containing tritium and other radiological materials from the BNP.

The groundwater investigation activities and subsequent evaluations presented in this report were conducted in a manner generally consistent with industry guidance documents associated with the protection of groundwater resources from radiological materials, including the following:

Guideline for Implementing a Groundwater Protection Program at Nuclear Power Plants [Electric Power Research Institute, Final Report, November 2007]; and,

Industry Ground Water Protection Initiative – Final Guidance Document [Nuclear Energy Institute (NEI), August 2007].

Three distinct groundwater aquifers are identified at the study area, and include the Upper Sand (shallow surficial) aquifer, the Lower Sand/Castle Hayne (intermediate) aquifer, and the Peedee (deep) aquifer. The intermediate and deep aquifers are locally and regionally used as the sole source of potable water supply for domestic, commercial, industrial, and municipal use. No other sources of fresh water exist in the study area due to the brackish and saline conditions in deeper groundwater and the tidally-influenced surface water. Groundwater from the SDSP exhibits a radial (in all horizontal directions) flow pattern, and discharges into the tidal estuary and creeks to the north and east which drain into the Cape Fear River, into the intake canal to the south (which discharges to the discharge canal and to the Atlantic Ocean). To the west, groundwater is eventually drawn into the cooling water pump system and subsequently discharged to the discharge canal.

The groundwater investigation activities at the SDSP commenced on June 4, 2007. The major field activities included:

- Preliminary identification of surface features and surface hydrology in the vicinity of the SDSP;
- Advancing soil borings onsite to complete a detailed geologic characterization of the subsurface stratigraphy;
- Installation of a groundwater monitoring well network in the shallow, intermediate, and deeper aquifers to evaluate the physical and chemical characteristics of groundwater in the vicinity of the SDSP;
- Collection of soil samples in the SDSP; and,
- Implementation of a preliminary groundwater monitoring program and collection of groundwater monitoring data and hydraulic data to evaluate groundwater movement in the vicinity of the SDSP.

The groundwater monitoring activities have provided sufficient data to prepare a conceptual site model (CSM) of the study area and characterize the nature and extent of tritium in groundwater near the SDSP. The source of tritium in groundwater is confirmed to be an ongoing, uncontrolled release from the SDSP. The uncontrolled release occurs through the direct leaching of tritiated surface water in the SDSP to the underlying shallow groundwater, which in turn transports tritium into the adjacent wetlands, surface water, and deeper potable supply aquifer via migration in groundwater. Tritium is present above applicable regulatory standards in shallow groundwater around the SDSP and detected in certain surface and sediment samples collected by Progress Energy from the marine estuary. Tritium has also identified at concentrations below the applicable state groundwater standard in three intermediate wells, which are installed in the intermediate aquifer locally and regionally used as the source of drinking water. Other radiological materials (i.e. gamma radionuclides) are present within the SDSP area, but are not the focus this evaluation.

A feasibility study was performed to evaluate alternatives for the remediation of tritiated ground water at the Site. Remedial Action Objectives (RAOs) were developed based on environmental concerns and compliance with ARARs and TBCs and include:

- Reduce the continual migration of tritium in groundwater on-site and off-site to protect human health and the environment.
- Control future releases of tritiated water through the SDSP.
- Address ARARs relating to historic disposal practices at the SDSP.

The proposed remedial goal (RG) for tritium in groundwater is based on the federal MCL of 20,000 pCi/L.

The area of attainment was selected as:

- Contaminated groundwater within the berm of the SDSP.
- Contaminated groundwater outside the berm of the SDSP with tritium concentrations greater than the RG of 20,000 pCi/l.

Based on this, the following General Response Actions were identified;

- No Action
- Limited Action
- Containment
- Active Restoration

Based on the GRAs, remedial technologies were identified and screened with respect to effectiveness, implementability and cost. Technologies passing the screening were then assembled into the following six (6) remedial alternatives:

- Alternative 1 – Monitored Natural Attenuation (MNA)
- Alternative 2 – Containment (Barrier Wall) with MNA
- Alternative 3 – Containment (Impoundment) with MNA
- Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA
- Alternative 5 – Site-wide Groundwater Extraction with MNA
- Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA

The remedial alternatives were then evaluated against effectiveness, implementability and cost criteria.

All Alternatives assume that the major source of tritiated water discharge to the SDSP will be eliminated through process changes within the BNP. Alternative 1 - MNA includes no active remediation and provides no additional protection of human health and the environment other than that offered by the early warning of off-site migration provided through monitoring. However discharges of tritiated storm water at concentrations greater than the RG (20,000 pCi/L) are anticipated to continue. Based on this practice Alternative 1 would not achieve the RAOs or RGs in the long-term. Alternative 2 would reduce the horizontal migration of tritiated groundwater through implementation of a barrier wall. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. Alternative 2 does not control future releases of tritiated storm water to the SDSP and the barrier wall may increase the vertical gradient and potential vertical migration. Alternative 2 would not be expected to achieve the RGs in the long term. Alternative 3 would reduce the migration of tritiated groundwater by controlling (eliminating) the continual source of tritiated storm water to the SDSP by directing it to an impoundment. Existing tritiated groundwater within and in the vicinity of the SDSP would continue to migrate although at a slower rate since the groundwater flow gradient would be expected to decrease due to the elimination of flow to the SDSP. Monitoring would provide an early warning of potential off-site migration. Alternative 3 would not be expected to achieve the RGs in the long term. Alternative 4 would reduce the migration of tritiated groundwater through implementation of a barrier wall. Alternative 4 would control the future release of tritiated storm water to the SDSP by directing it to an impoundment. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. Alternative 4 would not be expected to achieve the RGs in the long term. Alternative 5 eliminates the migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to the SDSP. Alternative 5 does not control future releases of tritiated storm water to the SDSP. Alternative 5 would not be expected to achieve the RGs in the long term. Alternative 6 reduces migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to an impoundment. Alternative 6 also controls future releases of tritiated storm water to the SDSP by directing it to the impoundment. Because Alternative 6 removes the continual source of tritiated storm water and captures and removes existing tritiated groundwater, this alternative would be expected to achieve the RGs in the long term.

Of the six alternatives, Alternative 1 – MNA is the easiest to implement. The major elements of Alternative 1 (groundwater/surface water sampling and analysis) are already in place at the site and would continue for up to 30-years. Alternative 2 through 6 involve widely available, contractor-installed services and would be readily implementable. Implementation of any of these alternatives could be completed within a year. Alternatives 2 through 6 would result in a reduction of the annual monitoring efforts currently associated with Alternative 1. Since Alternative 5 and 6 involve groundwater extraction there would be greater operations and maintenance concerns. Additional evaluations would need to be conducted before design and construction of Alternatives 2 through 6.

Alternative 1 is the low cost alternative with a present value of $4,954,399, but this alternative would not meet the RAOs in the long-term. Alternatives 2, 3 and 5 would meet some of the RAOs but would not be expected to meet the RGs in the long-term. Alternatives 4 and 6 would meet the RAOs, but only Alternative 6 would be expected to meet the RGs in the long term. Present value costs for the alternatives are as follows:

- Alternative 1 – Monitored Natural Attenuation, $4,954,399

- Alternative 2 – Containment (Barrier Wall) with MNA, $5,897,482;
- Alternative 3 – Containment (Impoundment) with MNA, $7,478,082 (RCRA type liner) and $6,150,228; (non-RCRA type liner);
- Alternative 4 – Containment (Barrier Wall and Impoundment) with MNA, $10,686,740;
- Alternative 5 – Site-wide Groundwater Extraction with MNA, $9,786,218; and,
- Alternative 6 – Focused Groundwater Extraction with Containment (Impoundment) and MNA, $9,418,406.

8.2 Conclusions

Tritium is present above applicable regulatory standards in shallow groundwater around the SDSP and in certain surface and sediment samples collected by Progress Energy from the marine estuary. Tritium has also been identified at concentrations significantly below the applicable state groundwater standard in three intermediate wells, which are installed in the intermediate aquifer locally and regionally used as the source of drinking water. Of the six (6) remedial alternatives developed and evaluated to address the presence of tritium in groundwater, only one alternative is capable of meeting the RAOs and the achieving the RGs in the long term.

Alternative 1 – Monitored Natural Attenuation is the easiest to implement and the lowest cost; however, it fails to achieve the RAOs of reducing migration of tritiated groundwater or controlling future releases of tritiated groundwater and it would not meet the RGs. Alternative 2 significantly reduces the migration of tritiated groundwater from the SDSP through the use of a barrier wall but fails to control future releases of tritiated storm water to the SDSP and would not meet RGs in the long term. Alternative 3 controls future discharges of tritiated storm water to the SDSP by directing it to a new impermeable impoundment; however, this alternative does nothing to address the existing tritium impacts within the SDSP and would not meet the RGs in the long term. By effectively combining Alternatives 2 and 3, Alternative 4 would meet the RAOs of reducing migration of tritiated groundwater and controlling future releases of tritiated storm water to the SDSP. Alternative 4 would not, however, meet the RGs in the long term. Alternative

5 would eliminate migration of tritiated groundwater by capturing it through the use of extraction wells; however, because the extracted groundwater would be returned to the SDSP, no actual reduction in concentrations would be achieved beyond that due to MNA. Further, this alternative would do nothing to control future releases of tritiated storm water to the SDSP and would not meet RGs in the long term. Alternative 6 combines the impermeable impoundment from Alternative 3 with a modified groundwater extraction system from Alternative 5 to meet the RAOs of controlling future releases of tritiated storm water to the SDSP and eliminating migration of tritiated groundwater.

Reducing migration of tritiated groundwater is the most significant RAO with respect to human health and the environment and this RAO can be achieved by several of the alternatives; however, it is important to understand the significance of meeting the RGs. If RGs are addressed prior to decommissioning, it will significantly reduce the cost of decommissioning. If not, the costs to address groundwater may be significantly higher as tritiated groundwater continues to migrate and additional contaminant loading takes place over time. To achieve the RGs, it is necessary to control future releases of tritiated water to the SDSP as well as reduce migration. Only Alternative 6 achieves this and is therefore the recommended alternative.

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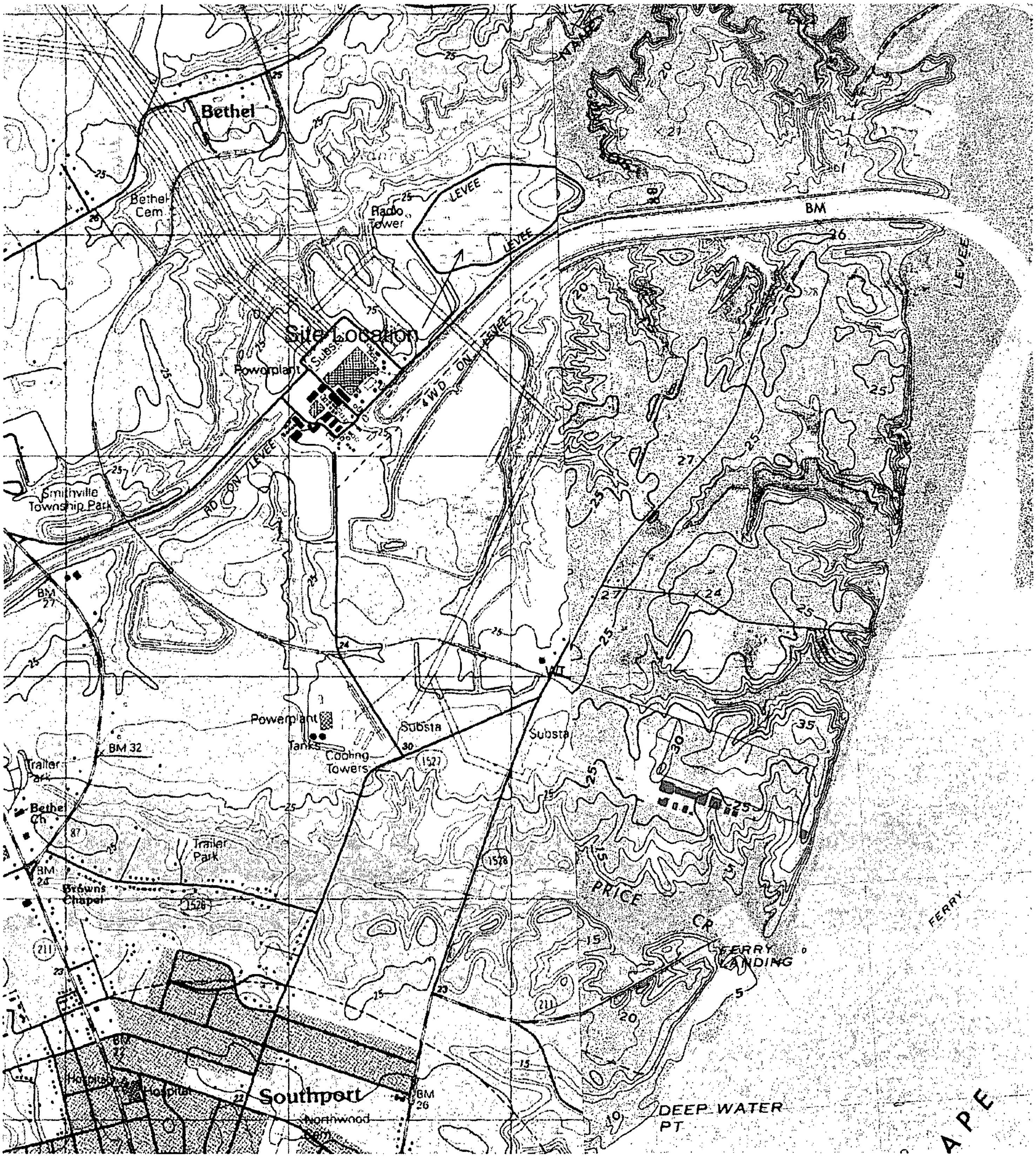
FIGURES

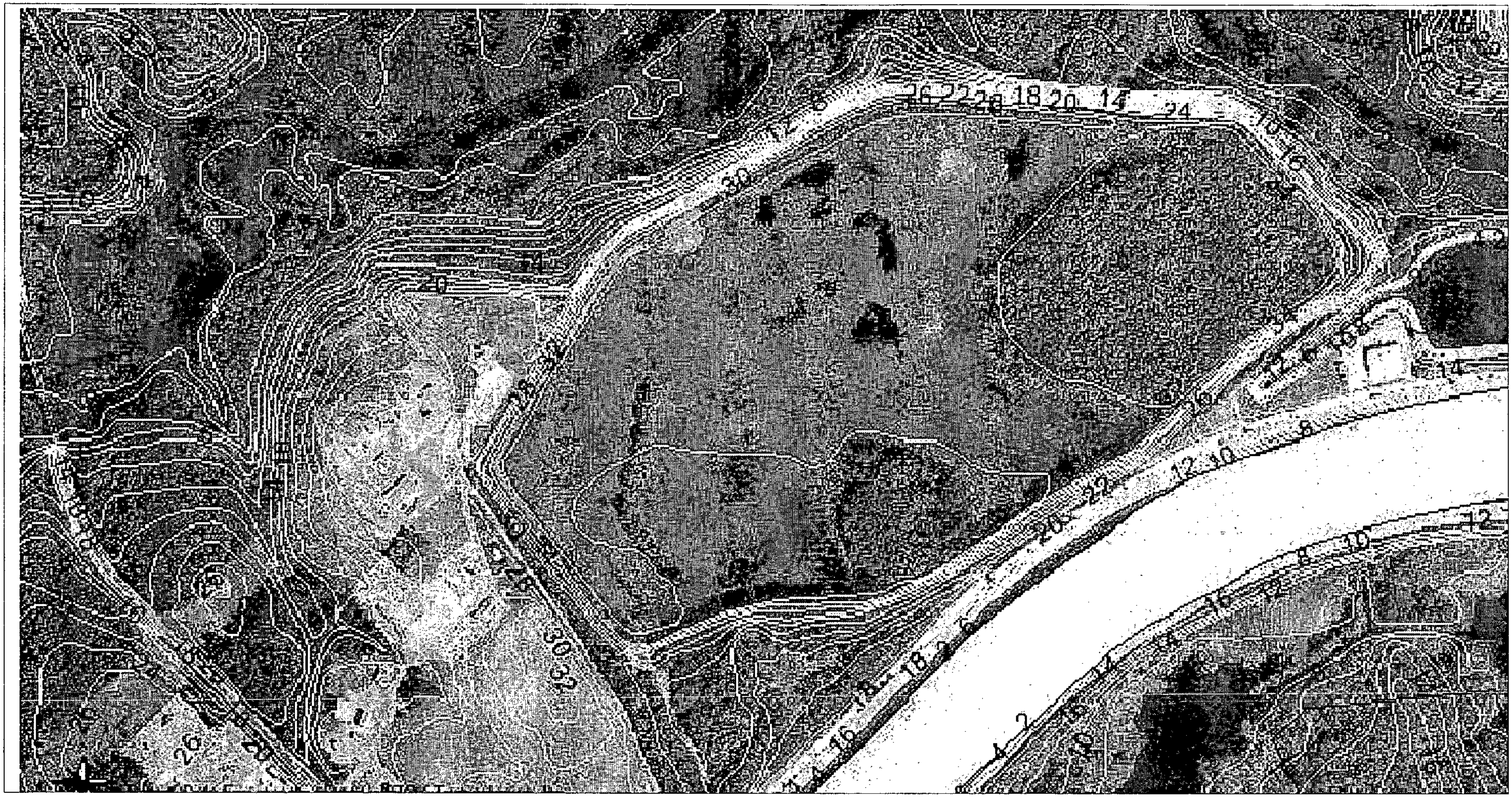


Source: U.S.G.S. Topographic Map (7.5 minute)
Southport & Kure Beach, NC quadrangles

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 1–1
Site Location Map

SSi Silar Services Inc.



Approximate scale: 1" = 600'

Source: Brunswick County GIS

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 1–2

Site Layout Map

SSi **Silar Services Inc.**

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

SCALE 1" = 500'

0 250 500 1000 1500

LEGEND:

SHALLOW WELL

INTERMEDIATE WELL

DEEP WELL

RED = SHALLOW WELL – NEW
BLUE = INTERMEDIATE WELL – NEW
GREEN = DEEP WELL – NEW
YELLOW = PLANT MONITORING WELL – EXISTING

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2–1
Monitoring Well Network –
Storm Drain Stabilization Pond

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

SCALE 1" = 500'

0 250 500 1000 1500

LEGEND:

SHALLOW WELL

EXISTING SHALLOW WELL

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2–2
Shallow Monitoring Well Location Map

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

SCALE 1" = 500'

0 250 500 1000 1500

LEGEND:

INTERMEDIATE WELL

EXISTING INTERMEDIATE WELL

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2–3

Intermediate Monitoring Well Location Map

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.
NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

SCALE 1" = 500'

0 250 500 1000 1500

LEGEND:

DEEP WELL

EXISTING DEEP WELL

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2-4

Deep Monitoring Well Location Map

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.
3. RESULTS ARE pCi/L

LEGEND:

ISOCONCENTRATION CONTOUR OF TRITIUM IN pCi/L

SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2-5
Shallow Aquifer Groundwater Results
August 2007

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.
3. RESULTS ARE pCi/L

LEGEND:

ISOCONCENTRATION CONTOUR OF TRITIUM IN pCi/L

SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2-6
Shallow Aquifer Groundwater Results
September 2007

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. *COORDINATES ARE BASED ON NC GRID NAD83*
2. *ELEVATIONS ARE BASED ON NGVD29.*
3. *RESULTS ARE pCi/L*

LEGEND:

ISOCONCENTRATION CONTOUR OF TRITIUM IN pCi/L

SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2-7
Shallow Aquifer Groundwater Results
October 2007

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

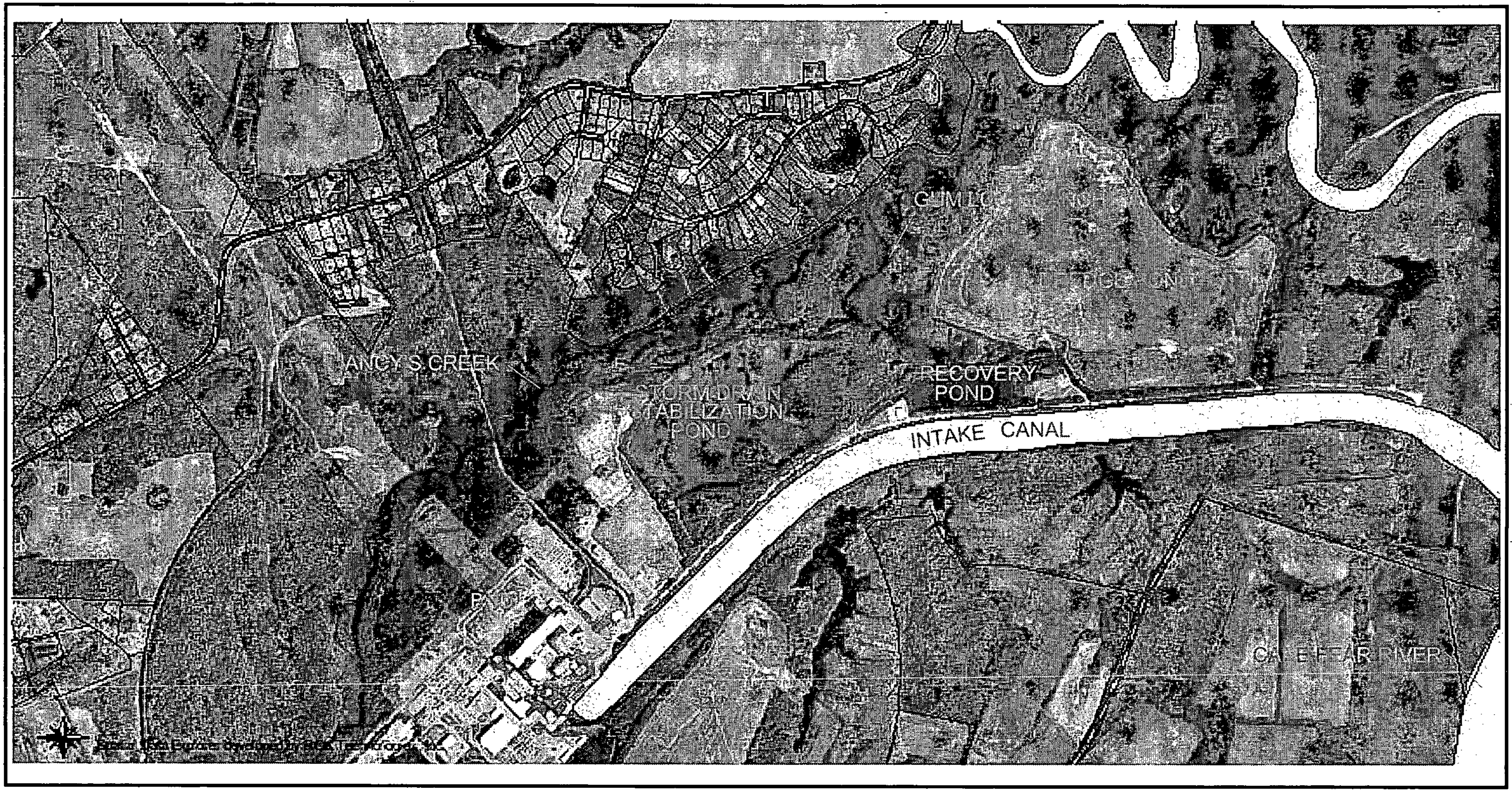
LEGEND:
RESULTS OF TRITIUM IN pCi/L
△ *INTERMEDIATE WELL – NEW* ▲ *INTERMEDIATE WELL – EXISTING*

SCALE 1" = 500'
0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 2–8
Intermediate Aquifer Groundwater Results

SS Silar Services Inc.

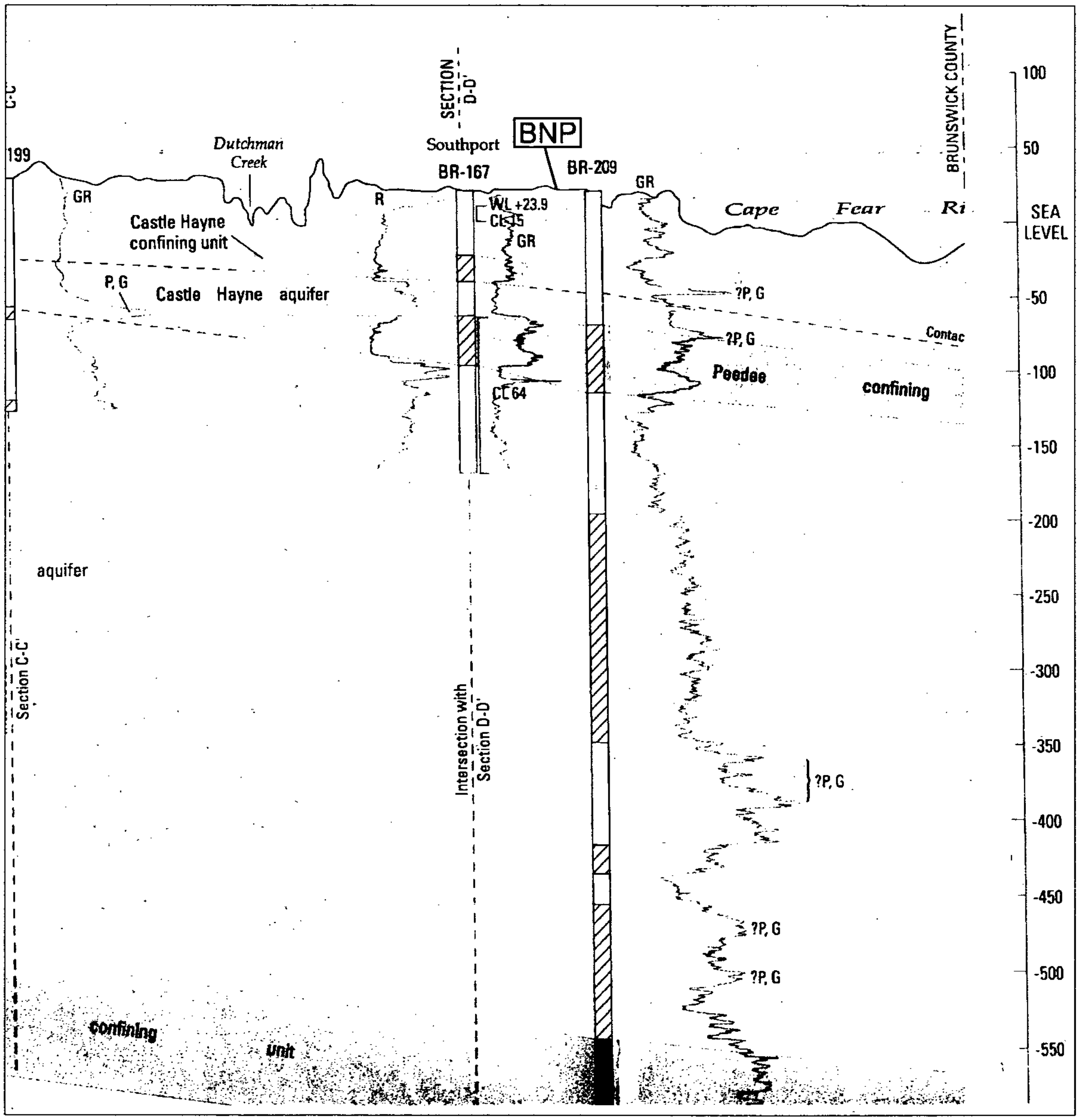


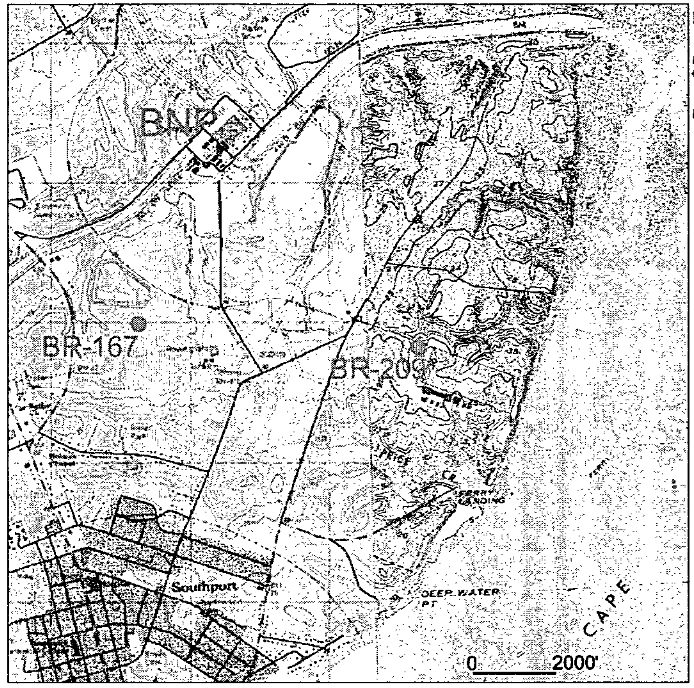
Approximate scale: 1" = 1650'

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-1
Surface Features

SSi **Silar Services Inc.**





Key Map

Source: U.S.G.S. WATER-RESOURCES INVESTIGATION REPORT 03-4051
HYDROLOGIC SECTION G-G' PLATE 7 OF 9
HYDROGEOLOGY AND GROUND-WATER QUALITY OF BRUNSWICK COUNTY, NC

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-2
Regional Geologic Section

Silar Services Inc.

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SOURCE:
McKim & Creed, June 15, 2007.
NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

SCALE 1" = 500'

0 250 500 1000 1500

LEGEND:

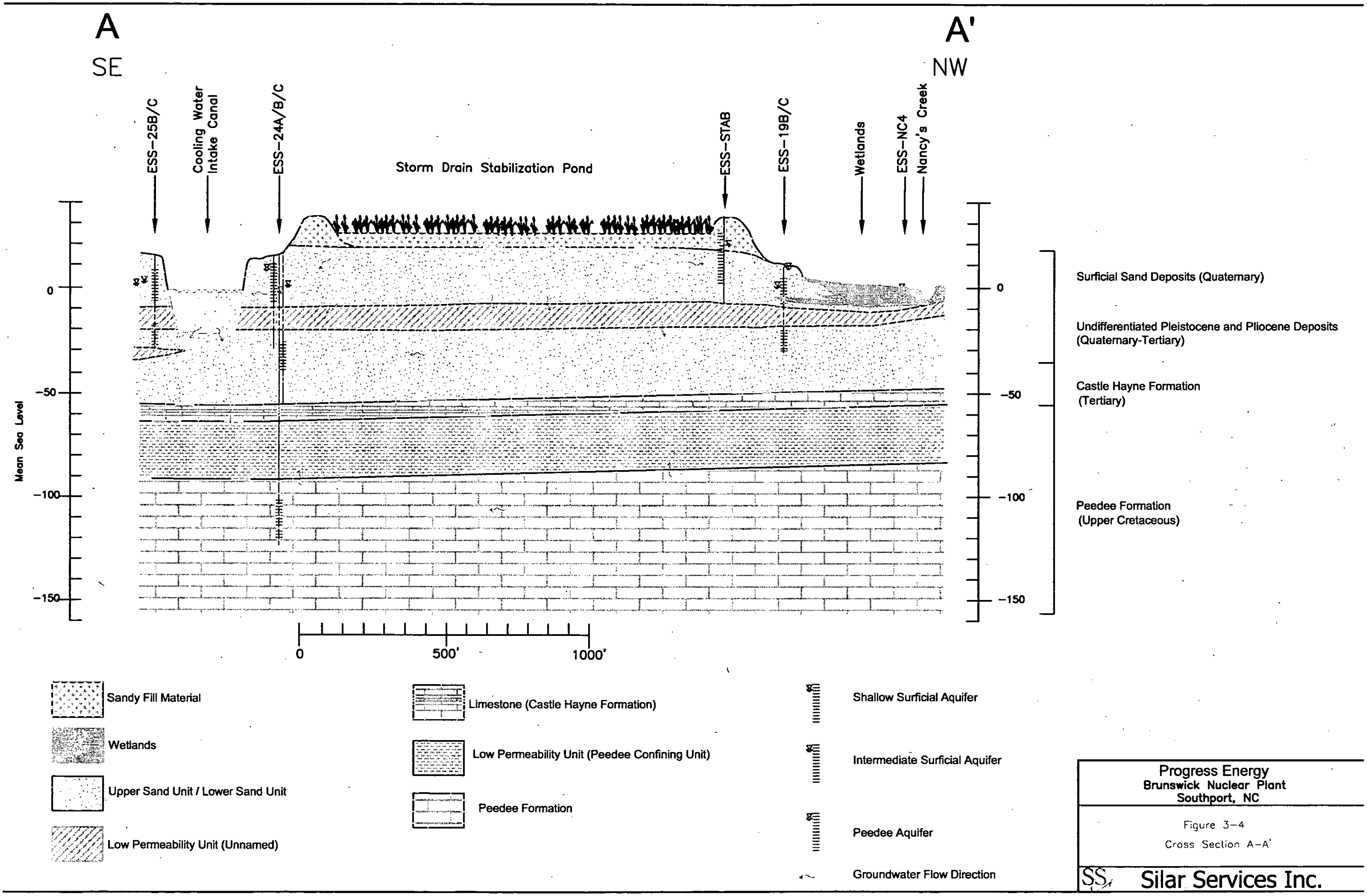
- *SHALLOW WELL*
- *INTERMEDIATE WELL*
- *DEEP WELL*

RED = SHALLOW WELL – NEW
BLUE = INTERMEDIATE WELL – NEW
GREEN = DEEP WELL – NEW
YELLOW = PLANT MONITORING WELL – EXISTING

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3–3
Cross Section Location Map

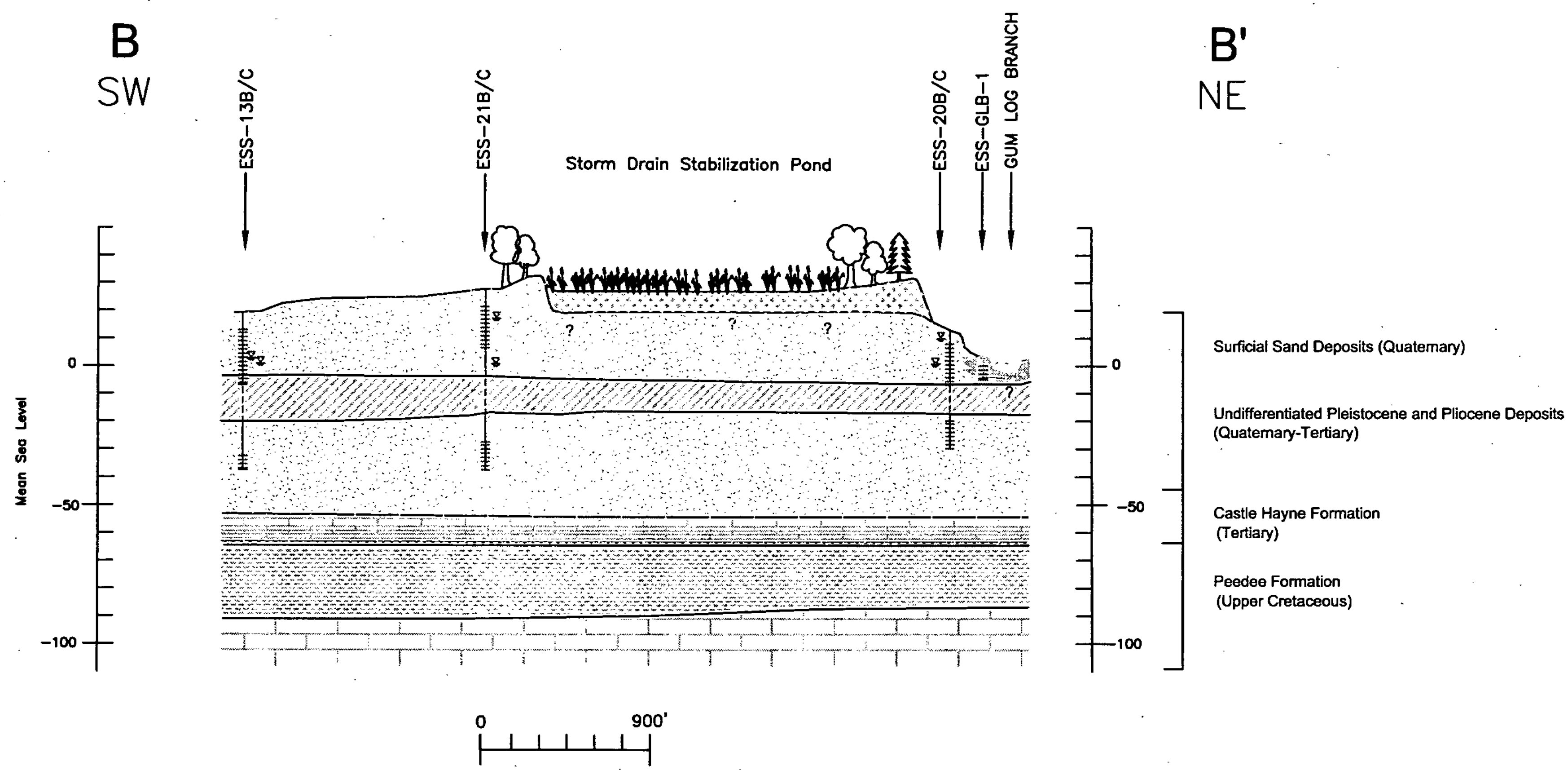
SS Silar Services Inc.



Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-4
Cross Section A-A'

SS Silar Services Inc.



Sandy Fill Material

Wetlands

Upper Sand Unit / Lower Sand Unit

Low Permeability Unit (Unnamed)

Limestone (Castle Hayne Formation)

Low Permeability Unit (Peedee Confining Unit)

Peedee Formation

Shallow Surficial Aquifer

Intermediate Surficial Aquifer

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-5
Cross Section B-B'

SS Silar Services Inc.

MAP SOURCE:
McKim & Creed, June 15, 2007.
NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

SCALE IN FEET

0 250 500 1000 1500

LEGEND:

——— ***INTERPOLATED SURFACE CONTOUR WITH ELEVATION (AMSL)***

— — — ***INFERRED SURFACE CONTOUR***

NOTE:
ALL ELEVATIONS ARE REPRESENTED IN FEET RELATIVE TO MEAN SEA LEVEL

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3–6
Elevation of the Top of Low Permeability Unit

SS Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

LEGEND:

SHALLOW WELL – NEW

SHALLOW WELL – EXISTING

GROUNDWATER FLOW DIRECTION

GROUNDWATER CONTOUR LINE (DASHED WHERE INFERRED)

2.1 ELEVATION MEAN SEA LEVEL

SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-7
Potentiometric Surface Map
Shallow Aquifer– October 2, 2007

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

LEGEND:

SHALLOW WELL - NEW
SHALLOW WELL - EXISTING
GROUNDWATER FLOW DIRECTION
GROUNDWATER CONTOUR LINE (DASHED WHERE INFERRED)
2.1 *ELEVATION MEAN SEA LEVEL*

SCALE 1" = 500'
0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-8
Potentiometric Surface Map
Shallow Aquifer– October 16, 2007

SSi Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

LEGEND:

- INTERMEDIATE WELL – NEW
- INTERMEDIATE WELL – EXISTING
- GROUNDWATER FLOW DIRECTION
- GROUNDWATER CONTOUR LINE (DASHED WHERE INFERRED)
- **2.1** ELEVATION MEAN SEA LEVEL

SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3–9
Potentiometric Surface Map
Intermediate Aquifer– October 2, 2007

SSi Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

LEGEND:
- INTERMEDIATE WELL - NEW
- INTERMEDIATE WELL - EXISTING
- GROUNDWATER FLOW DIRECTION
- GROUNDWATER CONTOUR LINE (DASHED WHERE INFERRED)
- **2.1** ELEVATION MEAN SEA LEVEL

SCALE 1" = 500'
0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-10
Potentiometric Surface Map
Intermediate Aquifer- October 16, 2007

Silar Services Inc.

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

LEGEND:

DEEP WELL – NEW

DEEP WELL – EXISTING

GROUNDWATER FLOW DIRECTION

GROUNDWATER CONTOUR LINE (DASHED WHERE INFERRED)

2.1 ELEVATION MEAN SEA LEVEL

SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3–11
Potentiometric Surface Map
Deep Aquifer– October 2, 2007

SS Silar Services Inc.

LEGEND:

DEEP WELL - NEW

DEEP WELL - EXISTING

GROUNDWATER FLOW DIRECTION

GROUNDWATER CONTOUR LINE (DASHED WHERE INFERRED)

2.1 ELEVATION MEAN SEA LEVEL

SOURCE:
McKim & Creed, June 15, 2007.

NOTES:
1. COORDINATES ARE BASED ON NC GRID NAD83
2. ELEVATIONS ARE BASED ON NGVD29.

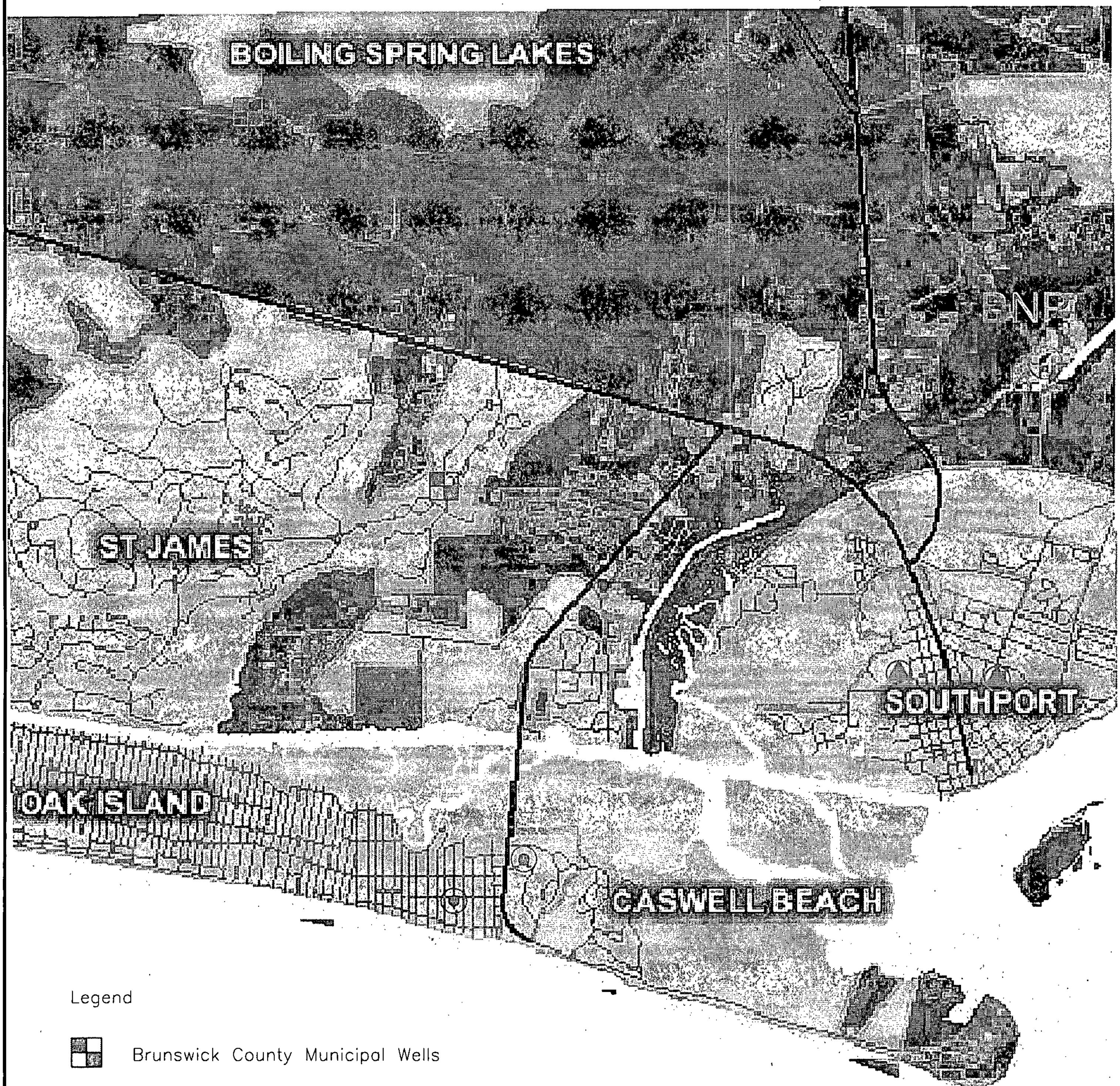
SCALE 1" = 500'

0 250 500 1000 1500

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-12
Potentiometric Surface Map
Deep Aquifer— October 16, 2007

SS Silar Services Inc.



Legend

- Brunswick County Municipal Wells
- Southport Municipal Wells
- Oak Island Municipal Wells

0 1 mile

N

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 3-13
Public Water Supply Well Location Map

SSi Silar Services Inc.

Figure 3-14
Synoptic Groundwater Elevation Data
Extended Hydrologic Monitoring
Brunswick Nuclear Plant, Southport, NC

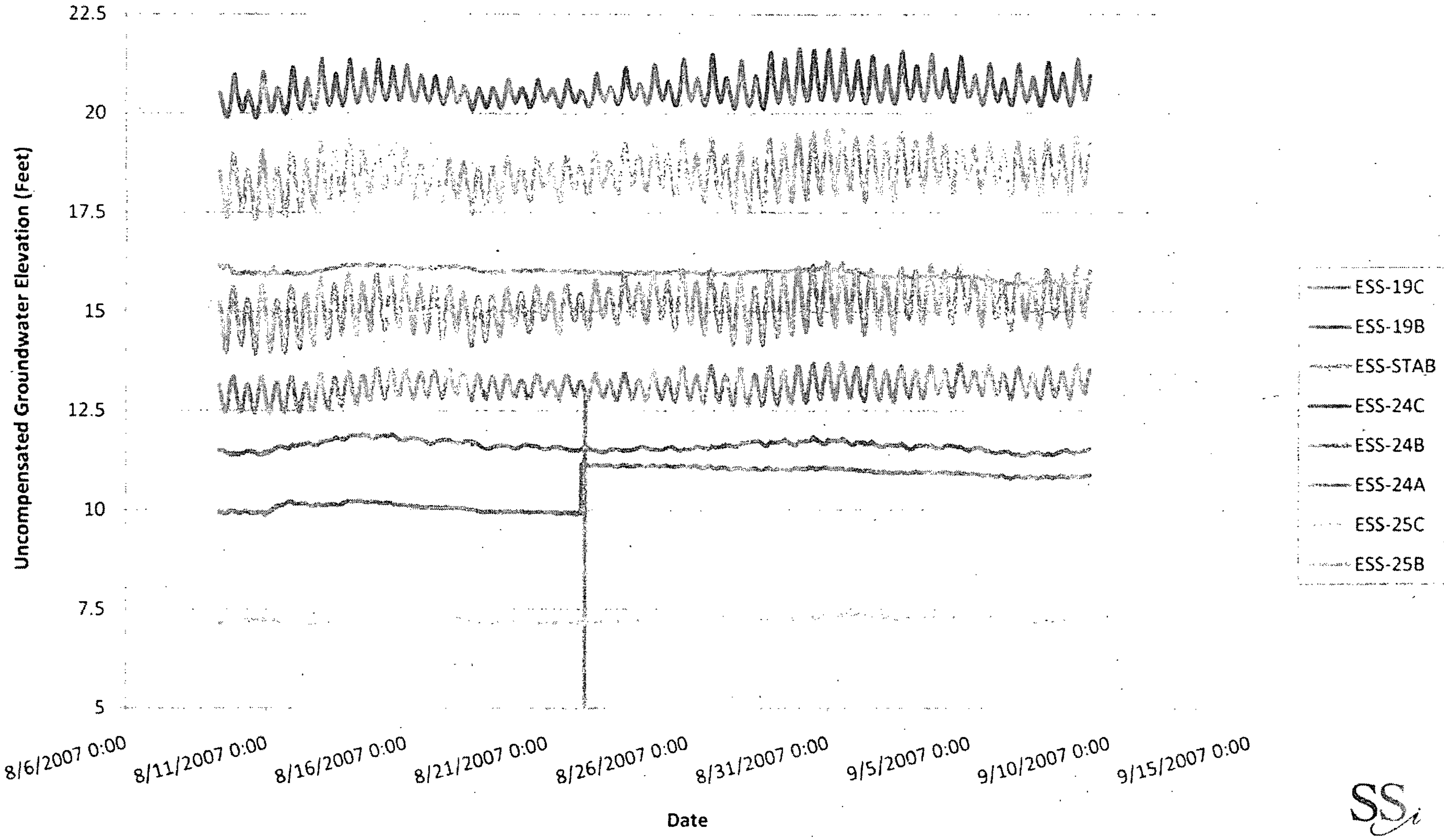
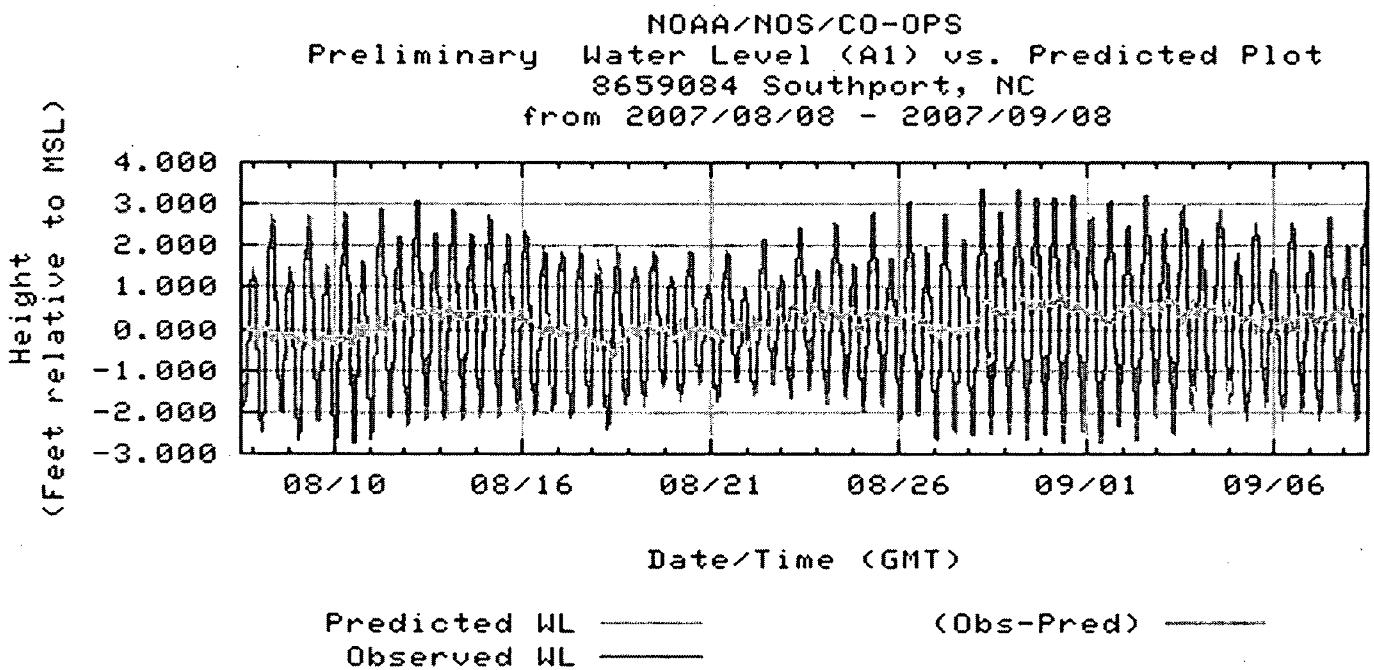
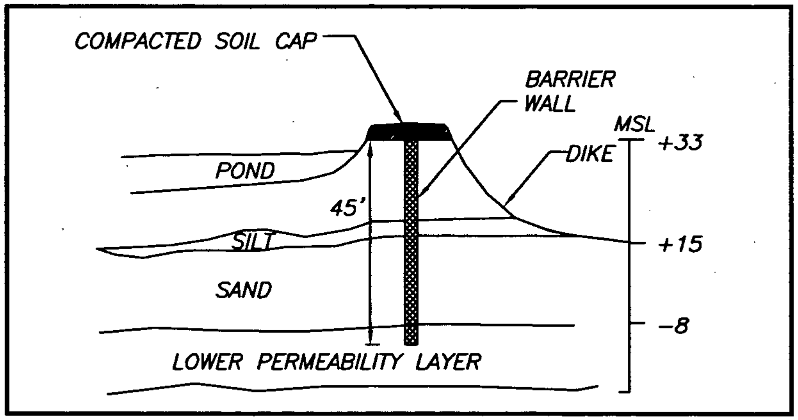


Figure 3-15

Tidal Graph – Southport, NC





BARRIER WALL CROSS-SECTION

LEGEND:

BARRIER WALL

COMPLIANCE MONITORING WELL

GRAPHIC SCALE IN FEET

0 250' 500' 1000'

SOURCE:
McKim & Creed, October 9, 2007.

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 7-1
Alternative 2 - Containment
(Barrier Wall) with MNA

SS*i* **Silar Services Inc.**

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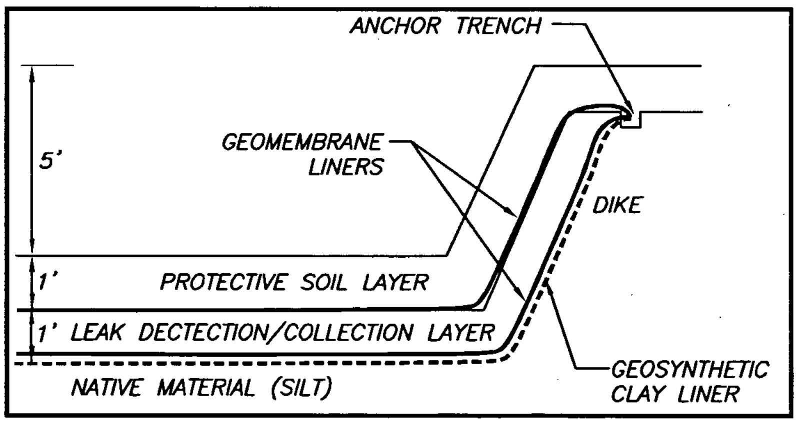

LINER CROSS-SECTION

LEGEND:

BORDER OF LINED STABILIZATION POND

GRAPHIC SCALE IN FEET

0 150' 300' 600'

SOURCE:

McKim & Creed, October 9, 2007.

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 7–2
Alternative 3 – Containment (Impoundment) with MNA

Silar Services Inc.

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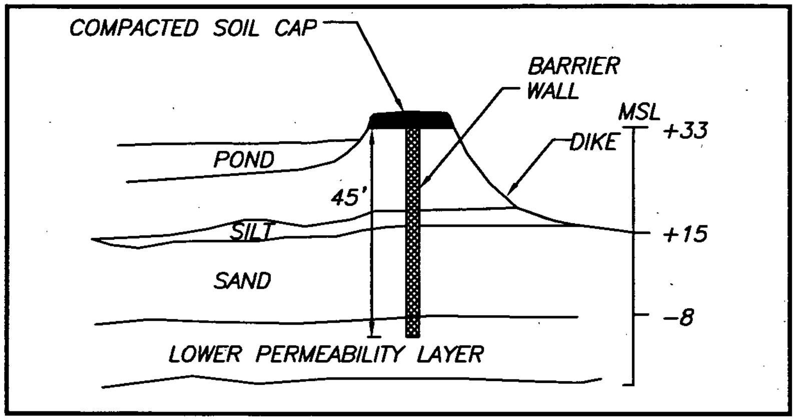
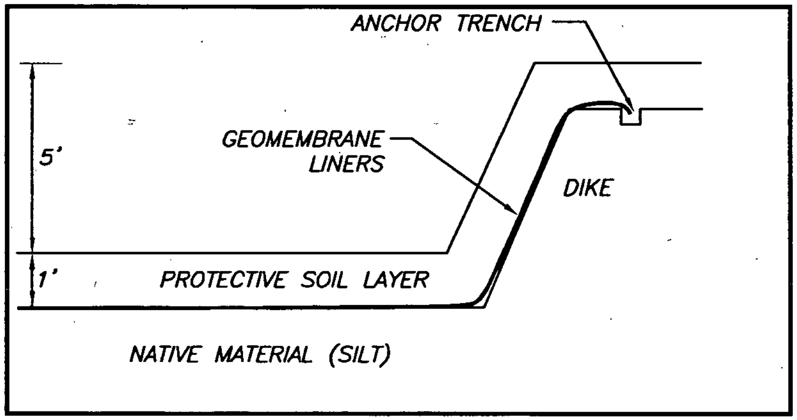


BARRIER WALL CROSS-SECTION



(NON-RCRA) LINER CROSS-SECTION

LEGEND:

- BORDER OF LINED STABILIZATION POND
- BARRIER WALL
- COMPLIANCE MONITORING WELL

SOURCE:
McKim & Creed, October 9, 2007.

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 7-3
Alternative 4 Containment
(Barrier Wall and Impoundment) with MNA

Silar Services Inc.

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LEGEND:

● ● ● EXTRACTION WELLS AT 64 FT. SPACING

▬▬ EXTRACTION WELLS AT 100 FT. SPACING

GRAPHIC SCALE IN FEET

0 250' 500' 1000'

SOURCE:

McKim & Creed, October 9, 2007.

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 7–4
Alternative 5 Site–Wide
Groundwater Extraction with MNA

SSi Silar Services Inc.

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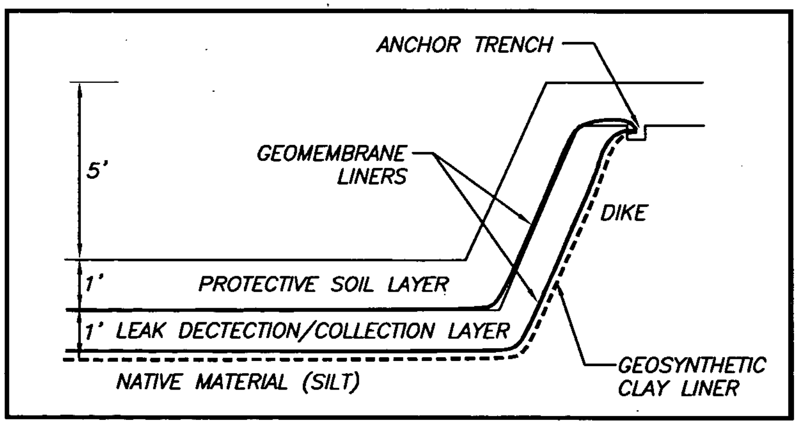
LEGEND:

BORDER OF LINED STABILIZATION POND

EXTRACTION WELLS AT 64 FT. SPACING



LINER CROSS-SECTION

GRAPHIC SCALE IN FEET

0 250' 500' 1000'

SOURCE:

McKim & Creed, October 9, 2007.

Progress Energy
Brunswick Nuclear Plant
Southport, NC

Figure 7-5
Alternative 6 Focused Groundwater Extraction with Containment (Impoundment) and MNA

SSi Silar Services Inc.

F:\Brunswick\GW ANALYSIS\FINAL\BNP 7-5_ALT 6 FINAL.dwg

TABLES

Table 2-1
Progress Energy - Brunswick Nuclear Plant
Storm Drain Stabilization Pond
Soil Analytical Results
July 2007

Sample ID	SB-SPDA-3	SB-SPDA-2	SB-SPDA-1
Sample Date	7/20/2007	7/20/2007	7/20/2007
	Analytical Results (uCi/g)		
Cobalt-60	1.361E-07	1.293E-07	ND
Cesium-137	1.370E-06	1.308E-06	3.599E-07

1. All samples analyzed by Progress Energy

uCi/g = microcuries per gram

NS = Not sampled

Table 2-2
Water Elevation Measurements - October 2007
Groundwater Investigation Report
Brunswick Nuclear Plant, Southport, NC

Monitoring Well Identification	Depth of Well[1] (feet)	Top of Casing (TOC) Elevation[2] (feet above MSL)	10/2/2007		10/16/2007	
			Depth to Water (feet from TOC)	Groundwater Elevation (feet above MSL)	Depth to Water (feet from TOC)	Groundwater Elevation (feet above MSL)
Shallow Wells						
ESS-3C	14.3	22.61	9.44	13.17	9.6	13.01
ESS-12C	14.94	24.14	8.01	16.13	8.18	15.96
ESS-13C	24.8	21.26	18.35	2.91	18.48	2.78
ESS-17C	26	20.35	10.61	9.74	10.54	9.81
ESS-18C	20	25.65	5.20	20.45	5.3	20.35
ESS-19C	20	14.44	4.42	10.02	4.47	9.97
ESS-20C	20	15.41	4.66	10.75	4.82	10.59
ESS-21C	20	30.16	11.02	19.14	11.29	18.87
ESS-22C	20	30.58	6.79	23.79	6.91	23.67
ESS-23C	23	26.57	14.49	12.08	14.57	12
ESS-24C	18	18.36	7.65	10.71	7.81	10.55
ESS-25C	22	16.14	-	-	-	-
ESS-26C	15	29.54	6.17	23.37	6.26	23.28
ESS-27C	15.5	28.45	10.00	18.45	10.06	18.39
ESS-28C	23	19.36	11.98	7.38	12.02	7.34
ESS-30C	15	26.28	7.64	18.64	7.91	18.37
ESS-31C	15	22.82	8.85	13.97	9.18	13.64
ESS-STAB	31	38.16	17.17	20.99	17.27	20.89
ESS-GLB-1	8	6.04	-	-	-	-
ESS-NC-1	7.5	5.02	-	-	-	-
ESS-NC-2	8	4.95	-	-	-	-
ESS-NC-3	8	4.93	-	-	-	-
ESS-NC-4	8	4.68	-	-	-	-
ESS-NC-5	8	3.64	-	-	-	-
Intermediate Wells						
ESS-3B	52.4	23.03	21.04	1.99	20.8	2.23
ESS-13B	56.5	21.53	19.95	1.58	19.41	2.12
ESS-17B	53	19.83	17.74	2.09	17.67	2.16
ESS-18B	63	25.84	23.00	2.84	22.91	2.93
ESS-19B	42	15.36	12.77	2.59	12.62	2.74
ESS-20B	43	16.61	14.19	2.42	14	2.61
ESS-21B	67	29.11	27.15	1.96	26.98	2.13
ESS-22B	76	30.82	28.81	2.01	28.67	2.15
ESS-24B	53	19.98	17.76	2.22	17.75	2.23
ESS-25B	43	16.18	13.21	2.97	13.39	2.79
Deep Wells						
ESS-13A (C33A1)	>100	22.07	22.71	-0.64	22.42	-0.35
ESS-17A (C27A3)	150	19.58	19.18	0.40	19.28	0.3
ESS-24A	140	19.59	20.05	-0.46	19.98	-0.39
ESS-27A (CT-1)	150	32.13	29.39	2.74	29.31	2.82

Notes:

1 - TOC reflects top of gray cap insert in well head for wells fitted with dedicated bladder pump assemblies.

Table 2-3
Progress Energy - Brunswick Nuclear Plant
Storm Drain Stabilization Pond
Summary of Tritium Concentrations - Shallow Groundwater Aquifer
August - October 2007

Well I.D. Sample Date	Analytical Results (pCi/L)		
	Aug-07	**Sep-07**	**Oct-07**
ESS-17C	3,871	3,292	5,099
ESS-18C	**750,700**	NA	**668,900**
ESS-19C	**355,000**	**356,000**	**445,900**
ESS-20C	14,070	17,200	17,640
ESS-21C	617	ND	391
ESS-22C	**556,100**	**493,000**	**556,100**
ESS-23C	**191,100**	**204,000**	**231,800**
ESS-24C	3,055	3,878	3,639
ESS-25C	ND	ND	ND
ESS-26C	**625,700**	**615,800**	**562,200**
ESS-27C	**301,600**	**239,100**	**279,400**
ESS-28C	ND	ND	328
ESS-STAB	**685,500**	**594,800**	**668,200**
ESS-30C	**23,030**	3,724	2,408
ESS-31C	4,055	4,780	4,871

1. All samples analyzed by Progress Energy
pCi/L = picocuries per liter
NS = Not sampled
Bold indicates the analytical result exceeds the drinking water standard (20,000 pCi/L) for tritium.

Table 2-4

Progress Energy - Brunswick Nuclear Plant

Storm Drain Stabilization Pond

<u>Summary of Tritium Concentrations - Marsh Wells</u>

August - October 2007

Well I.D.	Analytical Results (pCi/L)		
Sample Date	Aug-07	Sep-07	Oct-07
ESS-NC-1	ND	ND	ND
ESS-NC-2	ND	ND	ND
ESS-NC-3	ND	ND	ND
ESS-NC-4	ND	314	ND
ESS-NC-5	ND	ND	ND
ESS-GLB-1	ND	ND	ND

1. All samples analyzed by Progress Energy

pCi/L = picocuries per liter

NS = Not sampled

Bold indicates the analytical result exceeds the drinking water standard (20,000 pCi/L) for tritium.

Table 2-5

Progress Energy - Brunswick Nuclear Plant

Storm Drain Stabilization Pond

Summary of Tritium Concentrations - Intermediate Groundwater Aquifer

August - October 2007

Well I.D. Sample Date	Analytical Results (pCi/L)		
	Aug-07	Sep-07	Oct-07
ESS-17B	ND	795	ND
ESS-18B	ND	ND	ND
ESS-19B	3,128	2,851	3,226
ESS-20B	ND	ND	ND
ESS-21B	ND	ND	391
ESS-22B	ND	ND	ND
ESS-24B	ND	ND	ND
ESS-25B	ND	ND	ND

1. All samples analyzed by Progress Energy

pCi/L = picocuries per liter

NS = Not sampled

Bold indicates the analytical result exceeds the drinking water standard (20,000 pCi/L) for tritium.

Table 2-6

Progress Energy - Brunswick Nuclear Plant

Storm Drain Stabilization Pond

Summary of Tritium Concentrations - Deep Groundwater Aquifer

August - October 2007

Well I.D. Sample Date	Analytical Results (pCi/L)		
	Aug-07	Sep-07	Oct-07
ESS-24A	ND	ND	ND
ESS-17A	ND	ND	ND
ESS-27A	ND	ND	ND

1. All samples analyzed by Progress Energy

pCi/L = picocuries per liter

NS = Not sampled

Bold indicates the analytical result exceeds the drinking water standard (20,000 pCi/L) for tritium.

Table 3-1
Monitoring Well Construction Summary
Groundwater Investigation - Storm Drain Stabilization Pond
Brunswick Nuclear Plant, Southport, North Carolina

Well ID.	Well Depth (TOC)	Surface Casing Depth (bgs)	TOC (MSL)	Ground Surface Elevation (MSL)	Annular Fill Material			
					Screen Interval (feet bgs)	Sand Interval (feet bgs)	Seal Interval (feet bgs)	Concrete Interval (feet bgs)
Shallow Wells								
ESS-STAB	31	NA	38.12	35.31	31 - 6	31.5 - 4	4 - 2	1 - 0
ESS-17C	25	NA	20.3	17.63	20-5	20-3	3-1	1 - 0
ESS-18C	20	NA	25.61	23.2	20 - 5	20 - 3	3 - 1	1 - 0
ESS-19C	20	NA	14.37	12.37	20 - 5	20 - 3	3 - 1	1 - 0
ESS-20C	20	NA	15.36	13.28	20 - 5	20 - 3	3 - 1	1 - 0
ESS-21C	20	NA	30.12	27.41	20 - 5	20 - 3	3 - 1	1 - 0
ESS-22C	20	NA	30.51	28.12	20 - 5	20 - 3	3 - 1	1 - 0
ESS-23C	23	NA	26.53	23.91	20 - 5	20 - 3	3 - 1	1 - 0
ESS-24C	18	NA	18.31	16.37	18 - 3	18 - 2	2 - 1	1 - 0
ESS-25C	22	NA	16.1	16.49	22 - 7	22 - 5	5 - 3	3 - 0
ESS-26C	15	NA	29.49	27.31	15 - 5	15 - 3	3 - 1.5	1.5 - 0
ESS-27C	15.5	NA	28.75	29.1	15.5 - 5.5	15.5 - 4	4 - 2	2 - 0
ESS-28C	23	NA	19.31	17.84	23 - 8	23 - 6	6 - 4	4 - 0
STR6	17	NA	30.65	28.24	17 - 7	17 - 5	5 - 3	3 - 0
ESS-30C	15	NA	26.23	23.55	15 - 5	15 - 3	3 - 1.5	1.5 - 0
ESS-31C	15	NA	22.78	23.16	15 - 5	15 - 3	3 - 1.5	1.5 - 0
Intermediate Wells								
ESS-18B	63	26	25.79	22.48	63 - 53	63 - 50	50 - 40	40 - 0
ESS-19B	42	23	15.30	12.55	42 - 32	42 - 30	30 - 25	25 - 0
ESS-20B	43	25	16.55	14.23	43 - 33	43 - 30	30 - 25	25 - 0
ESS-21B	67	42	29.79	29.06	67 - 57	67 - 54	54 - 45	45 - 0
ESS-22B	76	31	30.76	28.01	76 - 66	76 - 63	63 - 50	50 - 0
ESS-24B	53	23	19.94	17.13	53 - 43	53 - 41	41 - 35	35 - 0
ESS-25B	43	24	16.12	16.62	43 - 33	43 - 31	31 - 25	25 - 0
Deep Wells								
ESS-24A	140	(10"-35')(6"-70')	19.54	15.91	140 - 110	140 - 108	108 - 95	95 - 0
Marsh Wells								
ESS-NC1	7.5	NA	5.02	1.64	7.5 - 2.5	7.5 - 1	1 - 0	NA
ESS-NC2	8	NA	4.95	2.07	8 - 3	8 - 1	1 - 0	NA
ESS-NC3	8	NA	4.93	2.04	8 - 3	8 - 1	1 - 0	NA
ESS-NC4	8	NA	4.68	1.35	8 - 3	8 - 1	1 - 0	NA
ESS-NC5	8	NA	3.64	-0.98	8 - 3	8 - 1	1 - 0	NA
ESS-GLB1	8	NA	6.04	2.95	8 - 3	8 - 1	1 - 0	NA

Notes:
bgs - Below Ground Surface
TOC - Top of Well Casing

TABLE 6-1
SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

General Response Actions	Remedial Technology Type	Process Options	Technical Feasibility
No Action	Site Reviews	Not Applicable	Not Retained
Limited Action	Institutional Controls	Deed Restrictions	Retained
		Access Restrictions	Retained
		Area Work Plans and Health and Safety Plan	Retained
	Monitoring of Natural Attenuation	Groundwater Monitoring	Retained
Containment	Impoundment	Clay	Retained
		Multi-Media	Retained
	Barrier Wall	Soil-Bentonite	Retained
		Sheet Pile	Retained
		Waterloo Barrier	Retained
	Hydraulic Control	Interception Trench	Not Retained
		Extraction Wells	Retained
Active Restoration	Removal	Extraction Wells (site wide)	Retained
		Extraction Wells (select areas)	Retained
	In-situ Treatment	None	Not Retained
	Ex-situ Treatment	None	Not Retained
	Off-site Discharge	None	Not Retained
	On-site Discharge	Stabilization Pond/Intake Canal	Retained

TABLE 6-2 EVALUATION AND SELECTION OF PROCESS OPTIONS							
General Response Action	**Technology**	**Process Option**	**Description**	**Effectiveness**	**Implement-ability**	**Cost**	**Conclusion**
No Action	No Action	No Action	No Corrective Action taken	Low	High	Low	Not Retained (1)
Limited Action	Institutional Controls	Deed Restrictions	Administrative action used to restrict future site activities, post decommissioning	Low	High	Low	Retained (2)
	Institutional Controls	Access Restrictions	Administrative action used to restrict future site activities, post decommissioning	Low	High	Low	Retained (2)
	Institutional Controls	Area Work Plans and Health and Safety Plan	Provides awareness of the potential of future potential migration of tritium to currently non-impacted areas caused by site activities/construction and worker safety during future work activities	Moderate	Moderate	Low	Retained (2)
	Monitoring of Natural Attenuation	Groundwater Monitoring	Monitoring of groundwater and surface water to evaluate tritium fate and transport and natural attenuation due to on-going natural processes (i.e decay)	Low	Moderate	Moderate	Retained

TABLE 6-2
EVALUATION AND SELECTION OF PROCESS OPTIONS

General Response Action	Technology	Process Option	Description	Effectiveness	Implement-ability	Cost	Conclusion
Containment	Surface Impoundment	Clay Liner	Source of current and future groundwater impacts (stabilization pond) will be reconfigured and the bottom will be lined with a low permeable clay liner	Moderate	Moderate	Moderate to High	Not Retained
	Surface Impoundment	Multi-Media Liner	Source of current and future groundwater impacts (stabilization pond) will be reconfigured and the bottom will be lined with a multi-media geo-textile liner	High	Moderate	Moderate to High	Retained
	Barrier Wall	Soil-Bentonite	Source of current and future groundwater impacts (stabilization pond) will be surrounded by a low-permeability soil-bentonite wall keyed into the low permeability zone thereby reducing the lateral migration of groundwater.	High	Moderate	Moderate	Retained

TABLE 6-2
EVALUATION AND SELECTION OF PROCESS OPTIONS

General Response Action	Technology	Process Option	Description	Effectiveness	Implement-ability	Cost	Conclusion
Containment (cont'd)	Barrier Wall	Sheet Pile	Source of current and future groundwater impacts (stabilization pond) will be surrounded by a low-permeability soil-bentonite wall keyed into the low permeability zone thereby reducing the lateral migration of groundwater.	High	High	High	Not Retained
	Barrier Wall	Waterloo Barrier	Source of current and future groundwater impacts (stabilization pond) will be surrounded by a low-permeability soil-bentonite wall keyed into the low permeability zone thereby reducing the lateral migration of groundwater.	High	High	High	Not Retained
	Hydraulic Control	Interception Trench	Horizontal interceptor trenches would be installed around the perimeter of the stabilization pond to collect impacted shallow groundwater. Deeper groundwater would continue to migrate beyond the interceptor trenches.	Low	Moderate	Moderate	Not Retained

TABLE 6-2
EVALUATION AND SELECTION OF PROCESS OPTIONS

General Response Action	Technology	Process Option	Description	Effectiveness	Implement-ability	Cost	Conclusion
Containment (cont'd)	Hydraulic Control	Extraction Wells	Extraction wells would be installed around the perimeter of the stabilization pond to collect impacted shallow groundwater. Groundwater would be discharged back to the stabilization pond.	Low	High	Moderate to High	Not Retained
Active Restoration	Removal	Extraction Wells (site-wide)	Extraction wells would be installed throughout the area of impacts at concentrations greater than 20,000 pCi/L. Groundwater would be discharged back to the stabilization pond.	Moderate	High	High	Retained
	Removal	Extraction Wells (select areas)	Extraction wells would be installed around the perimeter of the stabilization pond to collect impacted shallow groundwater. Groundwater would be discharged back to the stabilization pond.	Moderate	High	Moderate	Retained

TABLE 6-2
EVALUATION AND SELECTION OF PROCESS OPTIONS

General Response Action	Technology	Process Option	Description	Effectiveness	Implement-ability	Cost	Conclusion
Active Restoration (cont'd)	In-situ Treatment	None	Based on a review of existing data there is no proven in-situ treatment technology for tritiated groundwater. Phytoremediation has shown to be somewhat effective in some cases	Not Applicable	Not Applicable	Not Applicable	Not Retained
	Ex-situ Treatment	None	Based on a review of existing data there is no know ex-situ treatment technology for tritiated groundwater.	Not Applicable	Not Applicable	Not Applicable	Not Retained
	Off-site Discharge	Permitted Facility	Extracted groundwater will be disposed off-site at a licensed facility.	High	Moderate	High	Not Retained
	On-site Discharge	Stabilization Pond/Intake Canal	Extracted groundwater will be disposed on-site in the stabilization pond.	High	High	Low	Retained

1) No Action has not been retained because site conditions and ARARs indicate that this option is not applicable.
2) Retained for combination with other technologies/process options.

TABLE 7-1
Alternative 1 - Monitored Natural Attenuation (MNA)
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Investigation and Feasibility Study	1	LS	$200,000	$200,000	1.18	$236,000
Study Subtotal						$236,000
Contingency	1	LS	10%			$23,600
Study Total Cost						**$259,600**
II. REMEDY Year 1						
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Quarterly/Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$276,120**
Contingency	1	LS	10%			$27,612
Remedy Year 1 Total Cost						**$303,732**
III. REMEDY Year 2-30						
Groudwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Quarterly/Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Pump, sampling equipment (O&M)	1	yr	$100	$100	1.18	$118
Wells (O&M)	1	yr	$500	$500	1.18	$590
Remedy Year 2-30 Annual Subtotal						**$276,828**
Contingency	1	LS	10%			$27,683
Remedy Year 2-30 Total Annual Cost						**$304,511**
Year 1 Total Costs						**$563,332**
Year 2-30 Total Costs						**$8,830,813**
Total Alternative Costs						**$9,394,145**
Total Cost - Present Value						**$4,954,399**

TABLE 7-1A
Alternative 1- Monitored Natural Attenuation (MNA)
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$259,600	$303,732	563,332	563,332
2009		$304,511	304,511	276,200
2010		$304,511	304,511	263,048
2011		$304,511	304,511	250,522
2012		$304,511	304,511	238,592
2013		$304,511	304,511	227,231
2014		$304,511	304,511	216,410
2015		$304,511	304,511	206,105
2016		$304,511	304,511	196,290
2017		$304,511	304,511	186,943
2018		$304,511	304,511	178,041
2019		$304,511	304,511	169,563
2020		$304,511	304,511	161,489
2021		$304,511	304,511	153,799
2022		$304,511	304,511	146,475
2023		$304,511	304,511	139,500
2024		$304,511	304,511	132,857
2025		$304,511	304,511	126,531
2026		$304,511	304,511	120,505
2027		$304,511	304,511	114,767
2028		$304,511	304,511	109,302
2029		$304,511	304,511	104,097
2030		$304,511	304,511	99,140
2031		$304,511	304,511	94,419
2032		$304,511	304,511	89,923
2033		$304,511	304,511	85,641
2034		$304,511	304,511	81,563
2035		$304,511	304,511	77,679
2036		$304,511	304,511	73,980
2037		$304,511	304,511	70,457
Subtotal =	$259,600	$9,134,545	$9,394,145	$4,954,399
Costs to Date				
Total Cost	$259,600	$9,134,545	$9,394,145	$4,954,399

TABLE 7-2
Alternative 2 - Containment (Barrier Wall) with MNA
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Pre-design Investigation/Design	1	LS	$300,000	$300,000	1.18	$354,000
Study Subtotal						**$354,000**
Contingency	1	LS	10%			$35,400
Study Total Cost						**$389,400**
II. REMEDY Year 1						
Mobilization	1	LS	$50,000	$50,000	1.18	$59,000
Site Preparation	1	LS	$350,000	$350,000	1.18	$413,000
Soil-bentonite slurry wall (installed)	288,000	Sq Ft	$10	$2,880,000	1.18	$3,398,400
Monitoring Wells	3	wells	$5,000	$15,000	1.18	$17,700
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$4,164,220**
Contingency	1	LS	10%			$416,422
Remedy Year 1 Total Cost						**$4,580,642**
III. Remedy Year 2-30						
Groundwater/Surface Water Monitoring	4	rounds	$4,000	$16,000	1.18	$18,880
Analysis	4	rounds	$2,000	$8,000	1.18	$9,440
Data Analysis/Reporting	4	rounds	$1,000	$4,000	1.18	$4,720
Sampling Supplies/Equipment	4	rounds	$300	$1,200	1.18	$1,416
Annual Review	4	rounds	$5,000	$20,000	1.18	$23,600
Pump, sampling equipment (O&M)	1	yr	50.00	$50	1.18	$59
Wells (O&M)	1	yr	300.00	$300	1.18	$354
Remedy Year 2-30 Annual Subtotal						**$58,469**
Contingency	1	LS	10%			$5,847
Remedy Year 2-30 Total Annual Cost						**$64,316**
Year 1 Total Costs						**$4,970,042**
Year 2 - 30 Cost						**$1,865,161**
Toatal Cost						**$6,835,203**
Total Costs -Present Value						**$5,897,482**

TABLE 7-2A
Alternative 2 - Containment (Barrier Wall) with MNA
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$389,400	$4,580,642	4,970,042	4,970,042
2009		$64,316	64,316	58,336
2010		$64,316	64,316	55,558
2011		$64,316	64,316	52,913
2012		$64,316	64,316	50,393
2013		$64,316	64,316	47,994
2014		$64,316	64,316	45,708
2015		$64,316	64,316	43,532
2016		$64,316	64,316	41,459
2017		$64,316	64,316	39,484
2018		$64,316	64,316	37,604
2019		$64,316	64,316	35,813
2020		$64,316	64,316	34,108
2021		$64,316	64,316	32,484
2022		$64,316	64,316	30,937
2023		$64,316	64,316	29,464
2024		$64,316	64,316	28,061
2025		$64,316	64,316	26,725
2026		$64,316	64,316	25,452
2027		$64,316	64,316	24,240
2028		$64,316	64,316	23,086
2029		$64,316	64,316	21,986
2030		$64,316	64,316	20,939
2031		$64,316	64,316	19,942
2032		$64,316	64,316	18,993
2033		$64,316	64,316	18,088
2034		$64,316	64,316	17,227
2035		$64,316	64,316	16,407
2036		$64,316	64,316	15,625
2037		$64,316	64,316	14,881
Subtotal =	$389,400	$6,445,803	$6,835,203	$5,897,482
Costs to Date				
Total Cost	$389,400	$6,445,803	$6,835,203	$5,897,482

TABLE 7-3
Alternative 3 - Containment (Impoundment) with MNA
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Pre-design Investigation/Design	1	LS	$200,000	$200,000	1.18	$236,000
Study Subtotal						**$236,000**
Contingency	1	LS	10%			$23,600
Study Total Cost						**$259,600**
II. REMEDY Year 1						
Mobilization	1	LS	$200,000	$200,000	1.18	$236,000
Site Preparation	8	acres	$40,000	$320,000	1.18	$377,600
Excavation	193,600	cb yds	$7.10	$1,374,560	1.18	$1,621,981
Berm construction	900	ln ft	$45	$40,500	1.18	$47,790
Subgrade preparation	350,000	sq ft	$1.15	$402,500	1.18	$474,950
Geomembrane liner (30 mil PVC)	350,000	sq ft	$2.15	$752,500	1.18	$887,950
Leak detection/collection layer	8	acres	$50,000	$400,000	1.18	$472,000
Geosynthetic Clay Liner	350,000	sq ft	$0.38	$133,000	1.18	$156,940
Geomembrane liner (30 mil PVC)	350,000	sq ft	$1.40	$490,000	1.18	$578,200
Protective Soil Layer	13,000	cb yds	$13.82	$179,660	1.18	$211,999
Revegatation	8	acres	$40,000	$320,000	1.18	$377,600
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$5,719,130**
Contingency	1	LS	10%			$571,913
Remedy Year 1 Total Cost						**$6,291,043**
III. Remedy Year 2-30						
Groundwater/Surface Water Monitoring	4	rounds	$4,000	$16,000	1.18	$18,880
Analysis	4	rounds	$2,000	$8,000	1.18	$9,440
Data Analysis/Reporting	4	rounds	$1,000	$4,000	1.18	$4,720
Sampling Supplies/Equipment	4	rounds	$300	$1,200	1.18	$1,416
Annual Review	4	rounds	$5,000	$20,000	1.18	$23,600
Pump, sampling equipment (O&M)	1	yr	$50	$50	1.18	$59
Wells (O&M)	1	yr	$300	$300	1.18	$354
Remedy Year 2-30 Annual Subtotal						**$58,469**
Contingency	1	LS	10%			$5,847
Remedy Year 2-30 Total Annual Cost						**$64,316**
Year 1 Total Costs						**$6,550,643**
Year 2 - 30 Cost						**$1,865,161**
Toatal Cost						**$8,415,804**
Total Costs -Present Value						**$7,478,082**

TABLE 7-3A
Alternative 3 - Containment (Impoundment) with MNA
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$259,600	$6,291,043	6,550,643	6,550,643
2009		$64,316	64,316	58,336
2010		$64,316	64,316	55,558
2011		$64,316	64,316	52,913
2012		$64,316	64,316	50,393
2013		$64,316	64,316	47,994
2014		$64,316	64,316	45,708
2015		$64,316	64,316	43,532
2016		$64,316	64,316	41,459
2017		$64,316	64,316	39,484
2018		$64,316	64,316	37,604
2019		$64,316	64,316	35,813
2020		$64,316	64,316	34,108
2021		$64,316	64,316	32,484
2022		$64,316	64,316	30,937
2023		$64,316	64,316	29,464
2024		$64,316	64,316	28,061
2025		$64,316	64,316	26,725
2026		$64,316	64,316	25,452
2027		$64,316	64,316	24,240
2028		$64,316	64,316	23,086
2029		$64,316	64,316	21,986
2030		$64,316	64,316	20,939
2031		$64,316	64,316	19,942
2032		$64,316	64,316	18,993
2033		$64,316	64,316	18,088
2034		$64,316	64,316	17,227
2035		$64,316	64,316	16,407
2036		$64,316	64,316	15,625
2037		$64,316	64,316	14,881
Subtotal =	$259,600	$8,156,204	$8,415,804	$7,478,082
Costs to Date				
Total Cost	$259,600	$8,156,204	$8,415,804	$7,478,082

TABLE 7-4
Alternative 3A - Containment (Impoundment) with MNA
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Pre-design Investigation/Design	1	LS	$200,000	$200,000	1.18	$236,000
Study Subtotal						**$236,000**
Contingency	1	LS	10%			$23,600
Study Total Cost						**$259,600**
II. REMEDY Year 1						
Mobilization	1	LS	$200,000	$200,000	1.18	$236,000
Site Preparation	8	acres	$40,000	$320,000	1.18	$377,600
Excavation	193,600	cb yds	$7.10	$1,374,560	1.18	$1,621,981
Berm construction	900	ln ft	$45	$40,500	1.18	$47,790
Subgrade preparation	350,000	sq ft	$1.15	$402,500	1.18	$474,950
Geomembrane liner (30 Mil PVC)	350,000	sq ft	$2.15	$752,500	1.18	$887,950
Protective Soil Layer	13,000	cb yds	$13.82	$179,660	1.18	$211,999
Revegatation	8	acres	$40,000	$320,000	1.18	$377,600
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$4,511,990**
Contingency	1	LS	10%			$451,199
Remedy Year 1 Total Cost						**$4,963,189**
III. Remedy Year 2-30						
Groundwater/Surface Water Monitoring	4	rounds	$4,000	$16,000	1.18	$18,880
Analysis	4	rounds	$2,000	$8,000	1.18	$9,440
Data Analysis/Reporting	4	rounds	$1,000	$4,000	1.18	$4,720
Sampling Supplies/Equipment	4	rounds	$300	$1,200	1.18	$1,416
Annual Review	4	rounds	$5,000	$20,000	1.18	$23,600
Pump, sampling equipment (O&M)	1	yr	$50	$50	1.18	$59
Wells (O&M)	1	yr	$300	$300	1.18	$354
Remedy Year 2-30 Annual Subtotal						**$58,469**
Contingency	1	LS	10%			$5,847
Remedy Year 2-30 Total Annual Cost						**$64,316**
Year 1 Total Costs						**$5,222,789**
Year 2 - 30 Cost						**$1,865,161**
Toatal Cost						**$7,087,950**
Total Costs -Present Value						**$6,150,228**

TABLE 7-4A
Alternative 3A - Containment (Impoundment) with MNA
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$259,600	$4,963,189	5,222,789	5,222,789
2009		$64,316	64,316	58,336
2010		$64,316	64,316	55,558
2011		$64,316	64,316	52,913
2012		$64,316	64,316	50,393
2013		$64,316	64,316	47,994
2014		$64,316	64,316	45,708
2015		$64,316	64,316	43,532
2016		$64,316	64,316	41,459
2017		$64,316	64,316	39,484
2018		$64,316	64,316	37,604
2019		$64,316	64,316	35,813
2020		$64,316	64,316	34,108
2021		$64,316	64,316	32,484
2022		$64,316	64,316	30,937
2023		$64,316	64,316	29,464
2024		$64,316	64,316	28,061
2025		$64,316	64,316	26,725
2026		$64,316	64,316	25,452
2027		$64,316	64,316	24,240
2028		$64,316	64,316	23,086
2029		$64,316	64,316	21,986
2030		$64,316	64,316	20,939
2031		$64,316	64,316	19,942
2032		$64,316	64,316	18,993
2033		$64,316	64,316	18,088
2034		$64,316	64,316	17,227
2035		$64,316	64,316	16,407
2036		$64,316	64,316	15,625
2037		$64,316	64,316	14,881
Subtotal =	$259,600	$6,828,350	$7,087,950	$6,150,228
Costs to Date				
Total Cost	$259,600	$6,828,350	$7,087,950	$6,150,228

TABLE 7-5
Alternative 4 - Containment (Barrier Wall and Impoundment) with MNA
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Pre-design Investigation/Design	1	LS	$400,000	$400,000	1.18	$472,000
Study Subtotal						**$472,000**
Contingency	1	LS	10%			$47,200
Study Total Cost						**$519,200**
II. REMEDY Year 1						
Mobilization	1	LS	$250,000	$250,000	1.18	$295,000
Site Preparation (Barrier wall)	1	LS	$350,000	$350,000	1.18	$413,000
Soil-bentonite slurry wall (installed)	288,000	SQ	$10	$2,880,000	1.18	$3,398,400
Monitoring Wells	3	wells	$5,000	$15,000	1.18	$17,700
Site Preparation	8	acres	$40,000	$320,000	1.18	$377,600
Excavation	193,600	cb yds	$7.10	$1,374,560	1.18	$1,621,981
Berm construction	900	ln ft	$45	$40,500	1.18	$47,790
Subgrade preparation	350,000	sq ft	$1.15	$402,500	1.18	$474,950
Geomembrane liner	350,000	sq ft	$2.15	$752,500	1.18	$887,950
Protective Soil Layer	13,000	cb yds	$13.82	$179,660	1.18	$211,999
Revegatation	8	acres	$40,000	$320,000	1.18	$377,600
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$8,400,090**
Contingency	1	LS	10%			$840,009
Remedy Year 1 Total Cost						**$9,240,099**
III. REMEDY Year 2-30						
Groundwater/Surface Water Monitoring	4	rounds	$4,000	$16,000	1.18	$18,880
Analysis	4	rounds	$2,000	$8,000	1.18	$9,440
Data Analysis/Reporting	4	rounds	$1,000	$4,000	1.18	$4,720
Sampling Supplies/Equipment	4	rounds	$300	$1,200	1.18	$1,416
Annual Review	4	rounds	$5,000	$20,000	1.18	$23,600
Pump, sampling equipment (O&M)	1	yr	$50	$50	1.18	$59
Wells (O&M)	1	yr	$300	$300	1.18	$354
Remedy Year 2-30 Annual Subtotal						**$58,469**
Contingency	1	LS	10%			$5,847
Remedy Year 2-30 Total Annual Cost						**$64,316**
Year 1 Total Costs						**$9,759,299**
Year 2-30 Total Costs						**$1,865,161**
Total Costs						**$11,624,460**
Total Cost - Present Value						**$10,686,740**

TABLE 7-5A

Alternative 4 - Containment (Barrier Wall and Impoundment) with MNA
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$519,200	$9,240,099	9,759,299	9,759,299
2009		$64,316	64,316	58,337
2010		$64,316	64,316	55,559
2011		$64,316	64,316	52,913
2012		$64,316	64,316	50,393
2013		$64,316	64,316	47,994
2014		$64,316	64,316	45,708
2015		$64,316	64,316	43,532
2016		$64,316	64,316	41,459
2017		$64,316	64,316	39,484
2018		$64,316	64,316	37,604
2019		$64,316	64,316	35,814
2020		$64,316	64,316	34,108
2021		$64,316	64,316	32,484
2022		$64,316	64,316	30,937
2023		$64,316	64,316	29,464
2024		$64,316	64,316	28,061
2025		$64,316	64,316	26,725
2026		$64,316	64,316	25,452
2027		$64,316	64,316	24,240
2028		$64,316	64,316	23,086
2029		$64,316	64,316	21,986
2030		$64,316	64,316	20,939
2031		$64,316	64,316	19,942
2032		$64,316	64,316	18,993
2033		$64,316	64,316	18,088
2034		$64,316	64,316	17,227
2035		$64,316	64,316	16,407
2036		$64,316	64,316	15,625
2037		$64,316	64,316	14,881
Subtotal =	$519,200	$11,105,263	$11,624,463	$10,686,740
Costs to Date				
Total Cost	$519,200	$11,105,263	$11,624,463	$10,686,740

TABLE 7-6
Alternative 5 - Site-wide Groundwater Extraction with MNA
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Pre-design Investigation/Design	1	LS	$300,000	$300,000	1.18	$354,000
Study Subtotal						**$354,000**
Contingency	1	LS	10%			$35,400
Study Total Cost						**$389,400**
II. REMEDY Year 1						
Mobilization	1	LS	$50,000	$50,000	1.18	$59,000
Site Preparation	1	LS	$200,000	$200,000	1.18	$236,000
Extraction Wells	214	each	$4,500	$963,000	1.18	$1,136,340
2" PVC piping	21,400	ln ft	$6.37	$136,318	1.18	$160,855
4" PVC piping	9,800	ln ft	$14.40	$141,120	1.18	$166,522
Low flow pump and controller	214	each	$3,500	$749,000	1.18	$883,820
Tranfer Stations	3	each	$200,000	$600,000	1.18	$708,000
Electric installation	1	LS	$300,000	$300,000	1.18	$354,000
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$3,980,657**
Contingency	1	LS	10%			$398,066
Remedy Year 1 Total Cost						**$4,378,723**
III. Remedy Year 2-30						
Groundwater/Surface Water Monitoring	4	rounds	$4,000	$16,000	1.18	$18,880
Analysis	4	rounds	$2,000	$8,000	1.18	$9,440
Data Analysis/Reporting	4	rounds	$1,000	$4,000	1.18	$4,720
Sampling Supplies/Equipment	4	rounds	$300	$1,200	1.18	$1,416
Annual Review	4	rounds	$5,000	$20,000	1.18	$23,600
Pumps, sampling equipment (O&M)	1	yr	$74,900	$74,900	1.18	$88,382
Extraction System/Wells (O&M)	1	yr	$144,000	$144,000	1.18	$169,920
Remedy Year 2-30 Annual Subtotal						**$316,358**
Contingency	1	LS	10%			$31,636
Remedy Year 2-30 Total Annual Cost						**$347,994**
Year 1 Total Costs						**$4,768,123**
Year 2 - 30 Cost						**$10,091,820**
Toatal Cost						**$14,859,943**
Total Costs -Present Value						**$9,786,218**

TABLE 7-6A
Alternative 5 - Site-wide Groundwater Extraction with MNA
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$389,400	$4,378,723	4,768,123	4,768,123
2009		$347,994	347,994	315,641
2010		$347,994	347,994	300,610
2011		$347,994	347,994	286,295
2012		$347,994	347,994	272,662
2013		$347,994	347,994	259,678
2014		$347,994	347,994	247,313
2015		$347,994	347,994	235,536
2016		$347,994	347,994	224,320
2017		$347,994	347,994	213,638
2018		$347,994	347,994	203,465
2019		$347,994	347,994	193,776
2020		$347,994	347,994	184,549
2021		$347,994	347,994	175,761
2022		$347,994	347,994	167,391
2023		$347,994	347,994	159,420
2024		$347,994	347,994	151,829
2025		$347,994	347,994	144,599
2026		$347,994	347,994	137,713
2027		$347,994	347,994	131,155
2028		$347,994	347,994	124,910
2029		$347,994	347,994	118,962
2030		$347,994	347,994	113,297
2031		$347,994	347,994	107,902
2032		$347,994	347,994	102,764
2033		$347,994	347,994	97,870
2034		$347,994	347,994	93,210
2035		$347,994	347,994	88,771
2036		$347,994	347,994	84,544
2037		$347,994	347,994	80,518
Subtotal =	$389,400	$14,470,543	$14,859,943	$9,786,218
Costs to Date				
Total Cost	$389,400	$14,470,543	$14,859,943	$9,786,218

TABLE 7-7
Alternative 6 - Focused Groundwater Extraction with Containment (Impoundment) and MNA
Total Cost Summary

Cost Item	Quantity /Size	Units	Unit Cost	Extended Unit Cost	Allowance	Total Cost
I. STUDY						
Pre-design Investigation/Design	1	LS	$300,000	$300,000	1.18	$354,000
Study Subtotal						**$354,000**
Contingency	1	LS	10%			$35,400
Study Total Cost						**$389,400**
II. REMEDY Year 1						
Mobilization	1	LS	$50,000	$50,000	1.18	$59,000
Site Preparation (well installation)	1	LS	$50,000	$50,000	1.18	$59,000
Extraction Wells	50	each	$4,500	$225,000	1.18	$265,500
2" PVC piping	5,000	ln ft	$6.37	$31,850	1.18	$37,583
4" PVC piping	2,500	ln ft	$14.40	$36,000	1.18	$42,480
Low flow pump and controller	50	each	$3,500	$175,000	1.18	$206,500
Tranfer Stations	1	each	$200,000	$200,000	1.18	$236,000
Electric installation	1	LS	$75,000	$75,000	1.18	$88,500
Site Preparation	8	acres	$40,000	$320,000	1.18	$377,600
Excavation	193,600	cb yds	$7.10	$1,374,560	1.18	$1,621,981
Berm construction	900	ln ft	$45	$40,500	1.18	$47,790
Subgrade preparation	350,000	sq ft	$1.15	$402,500	1.18	$474,950
Geomembrane liner (30 mil PVC)	350,000	sq ft	$2.15	$752,500	1.18	$887,950
Leak detection/collection layer	8	acres	$50,000	$400,000	1.18	$472,000
Geosynthetic Clay Liner	350,000	sq ft	$0.38	$133,000	1.18	$156,940
Geomembrane liner (30 mil PVC)	350,000	sq ft	$1.40	$490,000	1.18	$578,200
Protective Soil Layer	13,000	cb yds	$13.82	$179,660	1.18	$211,999
Revegatation	8	acres	$40,000	$320,000	1.18	$377,600
Groundwater/Surface Water Monitoring	12	rounds	$8,000	$96,000	1.18	$113,280
Analysis	12	rounds	$4,000	$48,000	1.18	$56,640
Data Analysis/Reporting	12	rounds	$2,000	$24,000	1.18	$28,320
Sampling Supplies/Equipment	12	rounds	$500	$6,000	1.18	$7,080
Annual Review	12	rounds	$5,000	$60,000	1.18	$70,800
Remedy Year 1 Subtotal						**$6,477,693**
Contingency	1	LS	10%			$647,769
Remedy Year 1 Total Cost						**$7,125,462**
III. Remedy Year 2-30						
Groundwater/Surface Water Monitoring	4	rounds	$4,000	$16,000	1.18	$18,880
Analysis	4	rounds	$2,000	$8,000	1.18	$9,440
Data Analysis/Reporting	4	rounds	$1,000	$4,000	1.18	$4,720
Sampling Supplies/Equipment	4	rounds	$300	$1,200	1.18	$1,416
Annual Review	4	rounds	$5,000	$20,000	1.18	$23,600
Pumps, sampling equipment (O&M)	1	yr	$17,500	$17,500	1.18	$20,650
Extraction System/Wells (O&M)	1	yr	$35,000	$35,000	1.18	$41,300
Remedy Year 2-30 Annual Subtotal						**$120,006**
Contingency	1	LS	10%			$12,001
Remedy Year 2-30 Total Annual Cost						**$132,007**
Year 1 Total Costs						**$7,514,862**
Year 2 - 30 Cost						**$3,828,191**
Toatal Cost						**$11,343,053**
Total Costs -Present Value						**$9,418,406**

TABLE 7-7A
Alternative 6 - Focused Groundwater Extraction with Containment (Impoundment) and MNA
Present Value Cost Summary

Years	Studies and Investigations	REMEDY	Actual Cost (in 2008 dollars)	Present Value of Cost
2008	$389,400	$7,125,462	7,514,862	7,514,862
2009		$132,007	132,007	119,734
2010		$132,007	132,007	114,032
2011		$132,007	132,007	108,602
2012		$132,007	132,007	103,431
2013		$132,007	132,007	98,505
2014		$132,007	132,007	93,815
2015		$132,007	132,007	89,347
2016		$132,007	132,007	85,093
2017		$132,007	132,007	81,041
2018		$132,007	132,007	77,182
2019		$132,007	132,007	73,506
2020		$132,007	132,007	70,006
2021		$132,007	132,007	66,672
2022		$132,007	132,007	63,497
2023		$132,007	132,007	60,474
2024		$132,007	132,007	57,594
2025		$132,007	132,007	54,851
2026		$132,007	132,007	52,239
2027		$132,007	132,007	49,752
2028		$132,007	132,007	47,383
2029		$132,007	132,007	45,126
2030		$132,007	132,007	42,978
2031		$132,007	132,007	40,931
2032		$132,007	132,007	38,982
2033		$132,007	132,007	37,126
2034		$132,007	132,007	35,358
2035		$132,007	132,007	33,674
2036		$132,007	132,007	32,071
2037		$132,007	132,007	30,543
Subtotal =	$389,400	$10,953,653	$11,343,053	$9,418,406
Costs to Date				
Total Cost	$389,400	$10,953,653	$11,343,053	$9,418,406

TABLE 7-8
SUMMARYOF THE COMPARISON OF REMEDIAL ALTERNATIVES

Criteria	Alternative 1 Monitored Natural Attenuation (MNA)	Alternative 2 Containment (Barrier Wall) with MNA	Alternative 3 Containment (Impoundment) with MNA	Alternative 4 Containment (Barrier Wall and Impoundment) with MNA	Alternative 5 Site-wide Ground water Extraction with MNA	Alternative 6 Focused Ground water Extraction with Containment (Impoundment) and MNA
Effectiveness	Natural attenuation processes would be allowed to reduce concentrations over time. Groundwater and surface water monitoring would be conducted to continually evaluate site conditions and the affect of natural attenuation processes on water quality. These actions would not achieve the RAOs or RGs in the long term as the migration and release of tritiated groundwater would not be controlled; however, monitoring would provide an early warning of off-site migration of tritiated groundwater This	This alternative would reduce the horizontal migration of tritiated groundwater through implementation of a barrier wall. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site migration. This alternative 2 would not control future releases of tritiated storm	This alternative would reduce the migration of tritiated groundwater by controlling (eliminating) the continual source of tritiated storm water to the SDSP by directing it to an impoundment. The impoundment liner can be design to various specifications based on risk management decisions. Existing tritiated groundwater within and in the vicinity of the SDSP would continue to migrate although at a slower rate since the groundwater flow gradient would be expected to	This alternative would reduce the migration of tritiated groundwater through implementation of a barrier wall and would control the future release of tritiated storm water to the SDSP by directing it to an impoundment. Tritiated groundwater outside the SDSP would naturally attenuate, but would continue to migrate albeit at a slower rate. Monitoring would provide an early warning of potential off-site	Alternative 5 eliminates the migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to the SDSP. Alternative 5 does not control future releases of tritiated storm water to the SDSP. This alternative would not be expected to achieve the RGs in the long term. A significant area of impacted groundwater would need to be addressed during decommissioning. This alternative is	This alternative reduces migration of tritiated groundwater by capturing groundwater exceeding the RGs and discharging it to an impoundment. Alternative 6 also controls future releases of tritiated storm water to the SDSP by directing it to the impoundment. This alternative has the potential to meet the RGs prior to decommissioning. This alternative is

TABLE 7-8
SUMMARYOF THE COMPARISON OF REMEDIAL ALTERNATIVES

Criteria	Alternative 1 Monitored Natural Attenuation (MNA)	Alternative 2 Containment (Barrier Wall) with MNA	Alternative 3 Containment (Impoundment) with MNA	Alternative 4 Containment (Barrier Wall and Impoundment) with MNA	Alternative 5 Site-wide Ground water Extraction with MNA	Alternative 6 Focused Ground water Extraction with Containment (Impoundment) and MNA
	alternative is protective of human health and the environment as there are no potable drinking water wells within the area of attainment.	water to the SDSP and the barrier wall may increase the vertical gradient and potential vertical migration. Alternative 2 would not be expected to achieve the RGs in the long term.	decrease due to the elimination of flow to the SDSP. Monitoring would provide an early warning of potential off-site migration. Alternative 3 would not be expected to achieve the RGs in the long term. This alternative is protective of human health and the environment as there are no potable drinking water wells within the area of attainment.	migration. Alternative 4 would not be expected to achieve the RGs in the long term. This alternative is protective of human health and the environment as there are no potable drinking water wells within the area of attainment.	protective of human health and the environment as there are no potable drinking water wells within the area of attainment.	protective of human health and the environment as there are no potable drinking water wells within the area of attainment.
Implementability	Easy to implement; elements of the alternative are in place and currently implemented with in-house staff and thirty-party consultation; however	Fairly easy to implement; additional evaluations would be required prior to final design and implementation. MNA implementation	Fairly easy to implement; additional evaluations would be required prior to final design and implementation. MNA implementation would be reduced from the level	Fairly easy to implement; additional evaluations would be required prior to final design and implementation. MNA implementation	Implementable with moderate difficulty due to the number of extraction wells. Additional evaluations would be required prior to final design and implementation.	Fairly easy to implement; additional evaluations would be required prior to final design and implementation. Some long-term operation and

TABLE 7-8
SUMMARYOF THE COMPARISON OF REMEDIAL ALTERNATIVES

Criteria	**Alternative 1 Monitored Natural Attenuation (MNA)**	**Alternative 2 Containment (Barrier Wall) with MNA**	**Alternative 3 Containment (Impoundment) with MNA**	**Alternative 4 Containment (Barrier Wall and Impoundment) with MNA**	**Alternative 5 Site-wide Ground water Extraction with MNA**	**Alternative 6 Focused Ground water Extraction with Containment (Impoundment) and MNA**
	implementation would require significant resources for decades.	would be reduced from the level anticipated in Alternative 1.	anticipated in Alternative 1 .	would be reduced from the levels anticipated in Alternative 1.	Significant long – term operation and maintenance would be required. MNA implementation would be reduced from the level anticipated in Alternative 1 .	maintenance would be required. MNA implementation would be reduced from the level anticipated in Alternative 1 .
Costs						
Year 1	$563,332	$4,970,042	$6,550,643 (RCRA) $5,222,789 (non-RCRA)	$9,759,299	$4,768,123	$7,514,862
Year 2-30	$8,830,813	$1,865,161	$1,865,161 (RCRA) $1,865,161 (non-RCRA)	$1,865,161	$10,091,820	$3,828,191
Total Costs	$9,394,145	$6,835,203	$8,415,804 (RCRA) $7,087,950 (non-RCRA)	$11,624,460	$14,859,943	$11,343,053
Present Value	$4,954,399	$5,897,482	$7,478,082 (RCRA) $6,150,228 (non-RCRA)	$10,686,740	$9,786,218	$9,418,406

Appendix A
Boring Logs / Well Construction Diagrams

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Borehole Log Report

Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: **ESS-17C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments
0.0–3.0	SP (Poorly Graded Sand)	Grassy surface over loose SAND	brown	Low	
3.0–4.5	SP (Poorly Graded Sand)	Light Brown SAND, trace Silt	brown	Low	
4.5–5.0	SM (Silty Sand)	Dark Grey Silty SAND, trace clay	grey	Medium	
5.0–6.0	SP (Poorly Graded Sand)	Grey Fine SAND	grey	Low	
6.0–8.0	SM (Silty Sand)	Dark grey-Black Sandy SILT, root material	grey	Low	
8.0–8.5	OL (Organic Clay/Silt of low plasticity)	Light Brown Clay	brown	Low	
8.5–9.0	SP (Poorly Graded Sand)	Brownish Grey Fine SAND	grey	Low	
10.0–11.0	SW (Well-graded Sand)	Brown to Greyish Sandy Silty CLAY, root material	grey	Medium	
11.0–17.0	CL (Lean Clay)	Mottled CLAY, trace sand,	brown	Low	
17.0–18.5	SW (Well-graded Sand)	Grey Fine SAND with silt, trace clay	grey	Saturated	
18.5–24.0	SW (Well-graded Sand)	Clayey SAND, very wet.	grey	Saturated	
24.0–25.0	CL (Lean Clay)	Mottled Sandy CLAY	grey	Medium	
25.0–25.5	SP (Poorly Graded Sand)	Dark Grey SAND	grey	Saturated	
25.5–		Dark Grey Silty CLAY, some	grey	Low	

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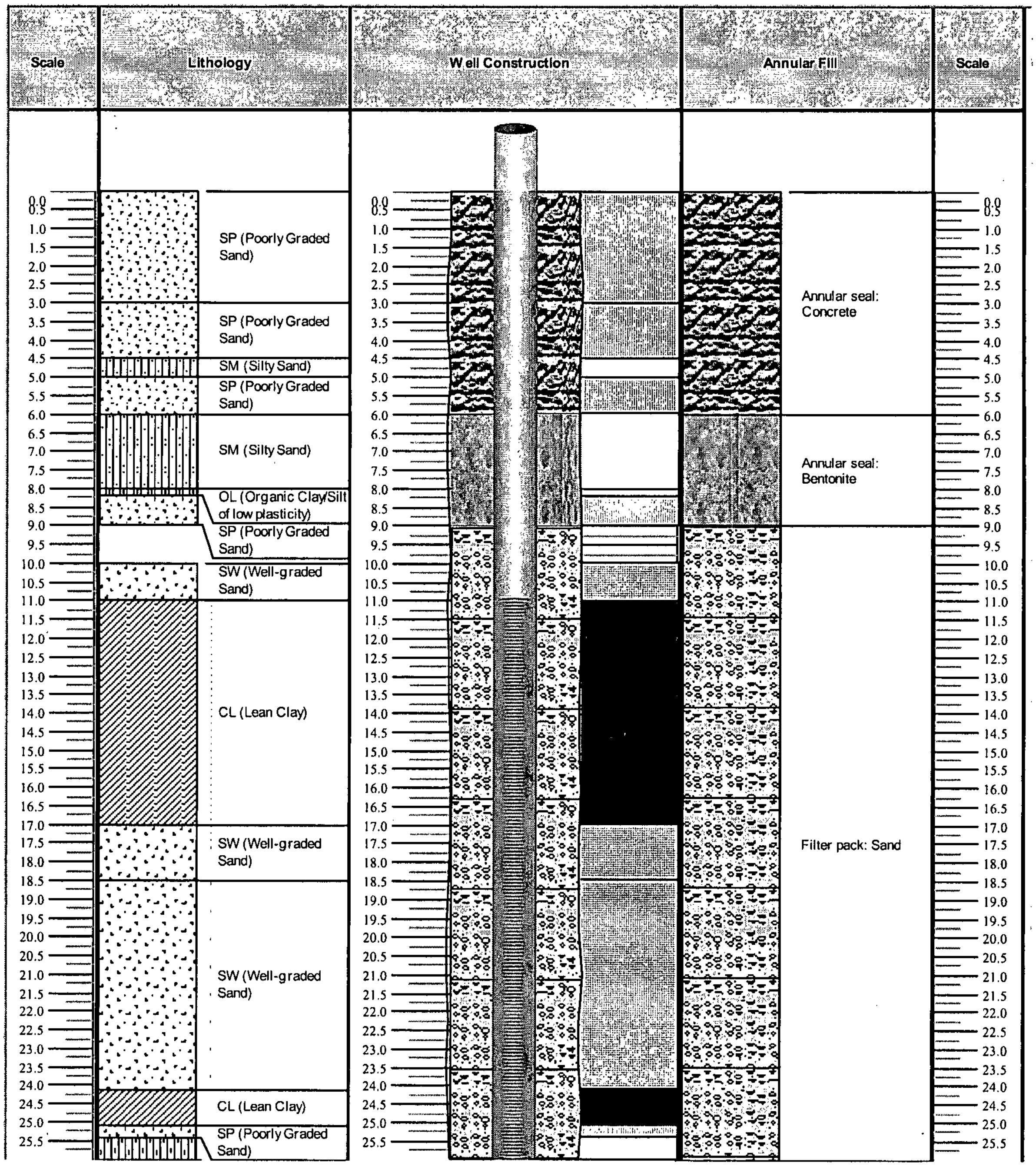
Monitoring Well I.D.: ESS-17C

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-18C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–0.5	SM (Silty Sand)	Grass, organic silt and fine sand	brown	Low		0.0–0.5
0.5–3.5	SM (Silty Sand)	Dark Grey Silty SAND	grey	Medium		0.5–3.5
3.5–4.5	SM (Silty Sand)	Brown Silty SAND, woody material at 4.5 ft bgs	brown	Medium		3.5–4.5
4.5–5.5	OL (Organic Clay/Silt of low plasticity)	Dark Grey Clayey SILT	grey	Medium		4.5–5.5
5.5–8.5	SP (Poorly Graded Sand)	Light Brown Fine SAND	brown	Medium		5.5–8.5
8.5–13.5	SM (Silty Sand)	Light Brown and Grey Silty SAND	Other	Saturated		8.5–13.5
13.5–14.5	SW (Well-graded Sand)	Light Brown Clayey Silty Sand	brown	Saturated		13.5–14.5
14.5–19.5+	OL (Organic Clay/Silt of low plasticity)	Light Brown sandy Clayey SILT	brown	Medium		14.5–19.5+

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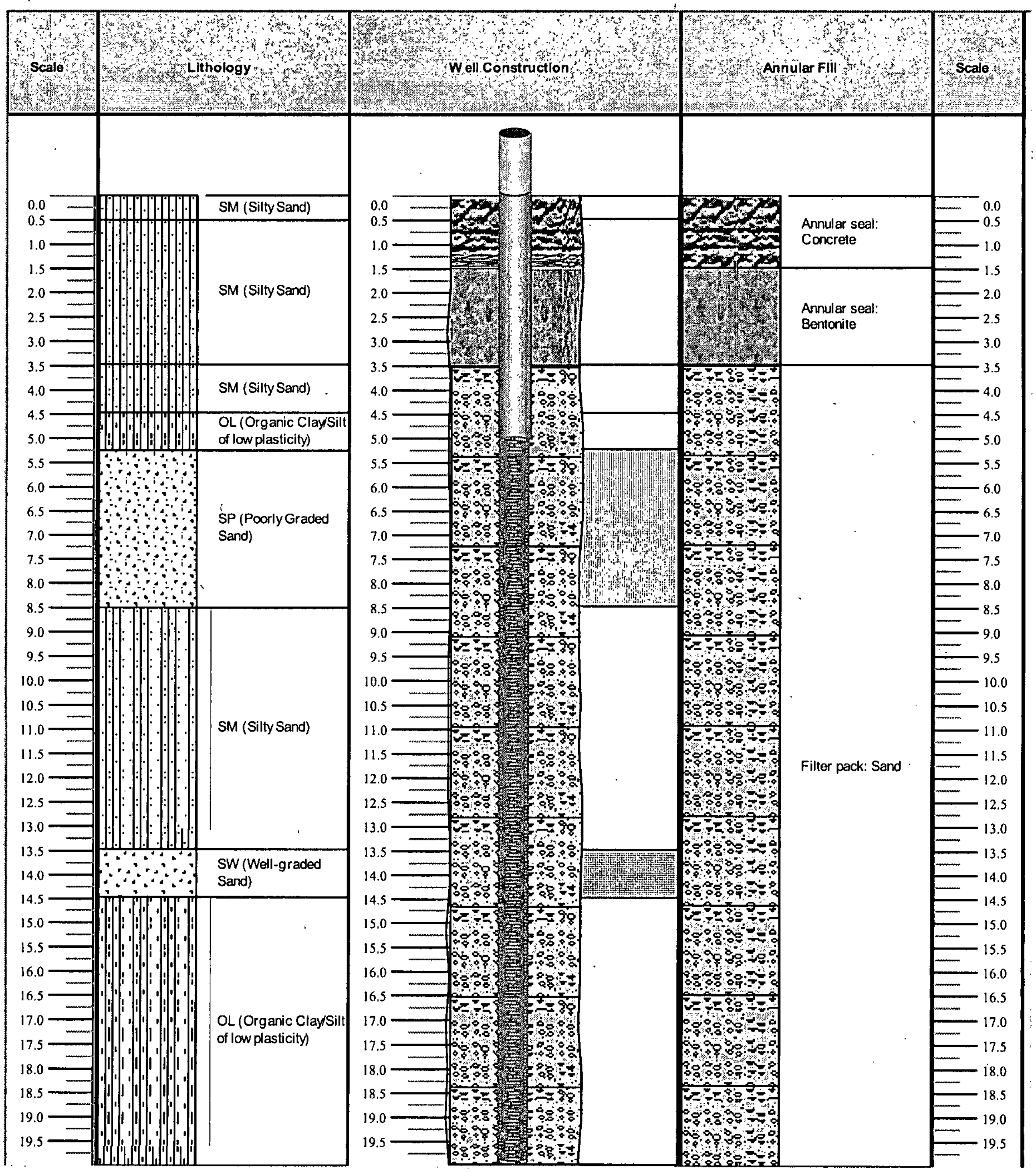
Monitoring Well Construction Report

Date: December, 2007



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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-18B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–20		See ESS-18C				0–20
20–24	ML (Silt)	Dark Grey SILT with fine to very fine sand	grey	Saturated		20–24
24–26	ML (Silt)	Dark Grey Clay with thin layers of v. fine sandy silt	grey	Low		24–26
26–28	ML (Silt)	Dark Grey Silty Clay with trace shells	grey	Low	Trace Shells	26–28
28–33	ML (Silt)	Dark Grey Silty CLAY, shelly	grey	Medium	Shelly	28–33
33–40	OL (Organic Clay/Silt of low plasticity)	Dark Grey CLAY	grey	Low		33–40
40–45	OL (Organic Clay/Silt of low plasticity)	Dark Grey CLAY, shelly, bivalves up to 3/4	grey	Medium	Shelly	40–45
45–48	OL (Organic Clay/Silt of low plasticity)	Dark Grey Silty CLAY, gravelly	grey	Medium	Shelly	45–48
48–63	GW (Well-graded Gravel)	Whitish Limey Gravel and Limey Sand	white	Saturated		48–63

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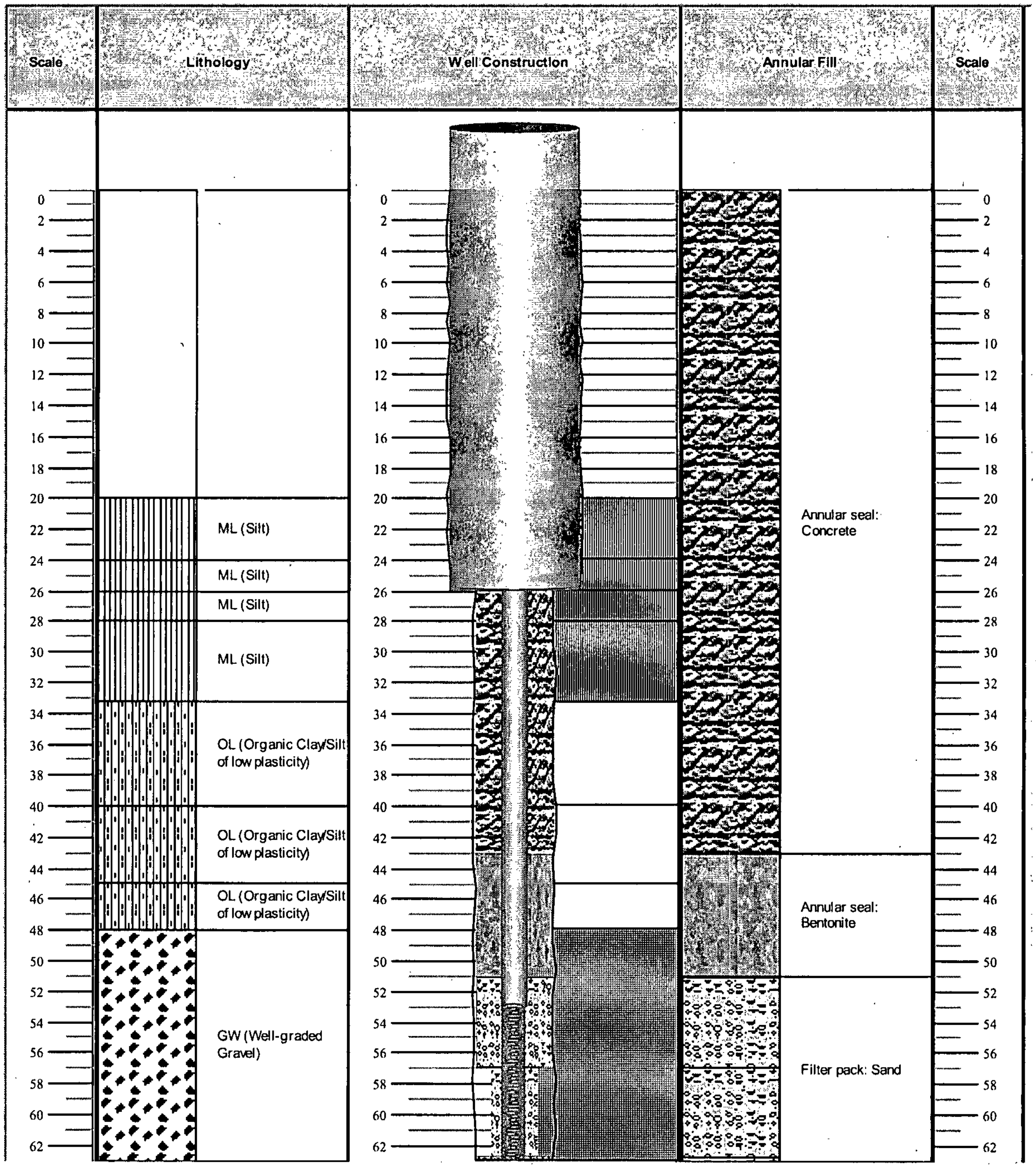
Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-19C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 3.5	SM (Silty Sand)	Dark Grey Silty Fine SAND, moderate organic content	grey	Low		0.0 – 3.5
3.5 – 4.0	SM (Silty Sand)	Dark Grey sandy SILT, trace clay.	grey	Low		3.5 – 4.0
4.0 – 5.0	SW (Well-graded Sand)	Silty, clayey SAND, woody material encased in matrix	grey	Medium		4.0 – 5.0
5.0 – 10.0	SM (Silty Sand)	Grey Silty SAND	grey	High		5.0 – 10.0
10.0 – 11.0	SW (Well-graded Sand)	Clayey SAND	Other	Low		10.0 – 11.0
11.0 – 14.7	SP (Poorly Graded Sand)	Tan and red Fine SAND, trace silt	Other	High		11.0 – 14.7
14.7 – 16.0	ML (Silt)	Grey SILT, trace clay, marsh-like sediments.	grey	Saturated		14.7 – 16.0
16.0 – 19.5	SM (Silty Sand)	Silty SAND	Other	Saturated		16.0 – 19.5
19.5 –	MH (Elastic Silt)	Grey SILT, fossiliferous at top	grey	Medium	Shelly	19.5 –

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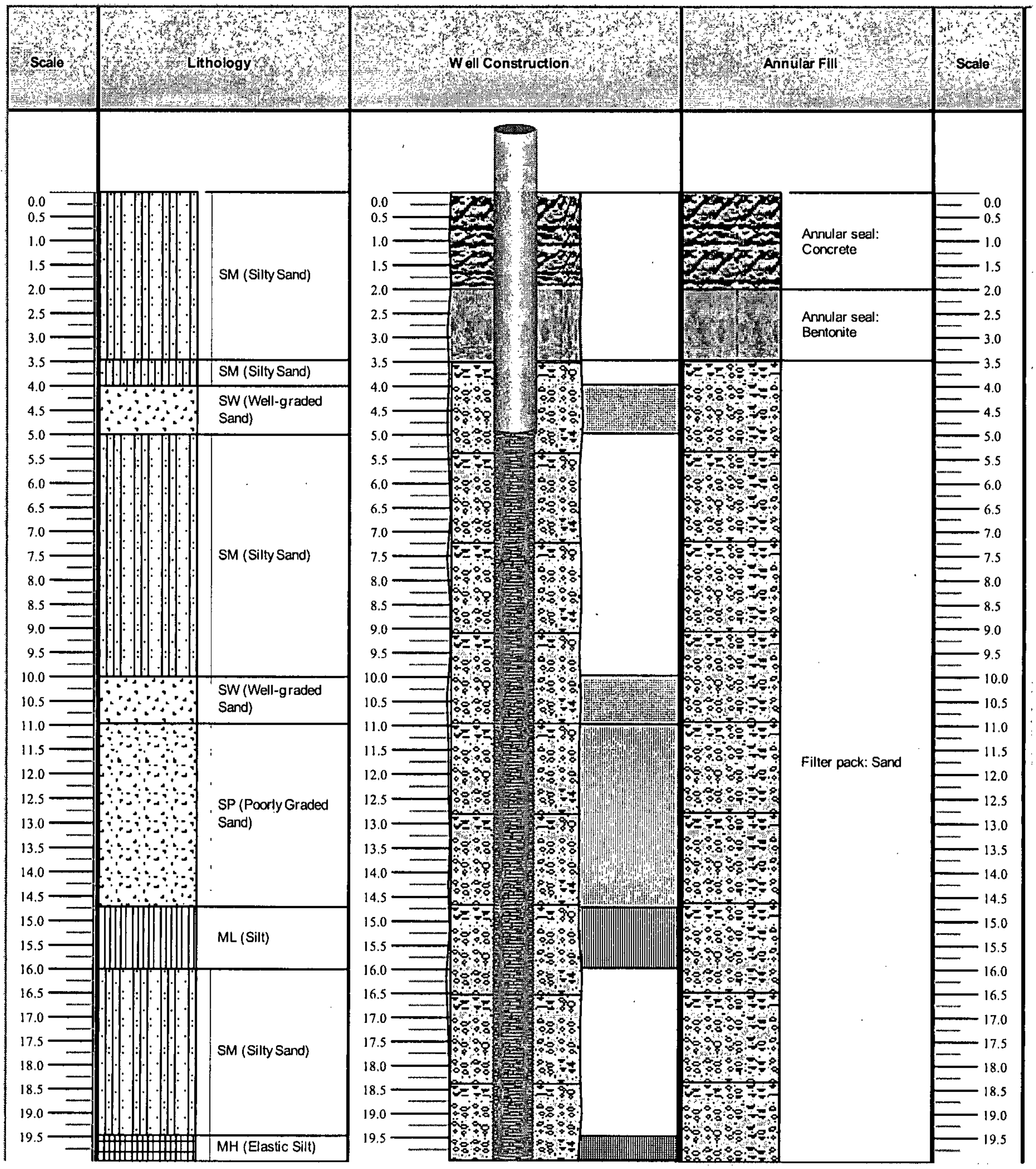
Monitoring Well I.D.: ESS-19C

Date: December, 2007



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Borehole / Monitoring Well I.D.: **ESS-19B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–19		See ESS-19C				0–19
20–21	ML (Silt)	Dark Grey Clayey SILT, shelly from 20-20.5, no shells below 21 ft bgs	grey	Medium	Shelly	20–21
22–23	ML (Silt)	Dark grey Clayey SILT	grey	Low		22–23
24	ML (Silt)	Dark Grey SILT, grassy organic material	grey	Low	Trace Shells	24
25–28	ML (Silt)	Dark Grey Clayey SILT	grey	Low	Trace Shells	25–28
29	ML (Silt)	Light Grey-off-white Shell Hash	white	Saturated	Shelly	29
29–30	ML (Silt)	Dark Grey Clayey SILT	grey	Medium	Shelly	29–30
30–31	ML (Silt)	Interlayered Dark Grey Silt with trace fine sand and shell hash	grey	Medium		30–31
31–33	GP (Poorly Graded Gravel)	Off-white Shell Hash	white	High		31–33
33–34	GP (Poorly Graded Gravel)					33–34
34–35	SW (Well-graded Sand)	Medium SAND, shells	white	High	Shelly	34–35
35–37	SW (Well-graded Sand)	Fine to Course SAND, trace shells	grey	Saturated		35–37
37–39	SW (Well-graded Sand)	Med. fine SAND	grey	High		37–39
39–41	SW (Well-graded Sand)	Med. SAND, tace gravel	grey	High		39–41
41–42		Layers of LIMESTONE	white	High		41–42
42–43		Sandy Limestone	grey	Saturated		42–43

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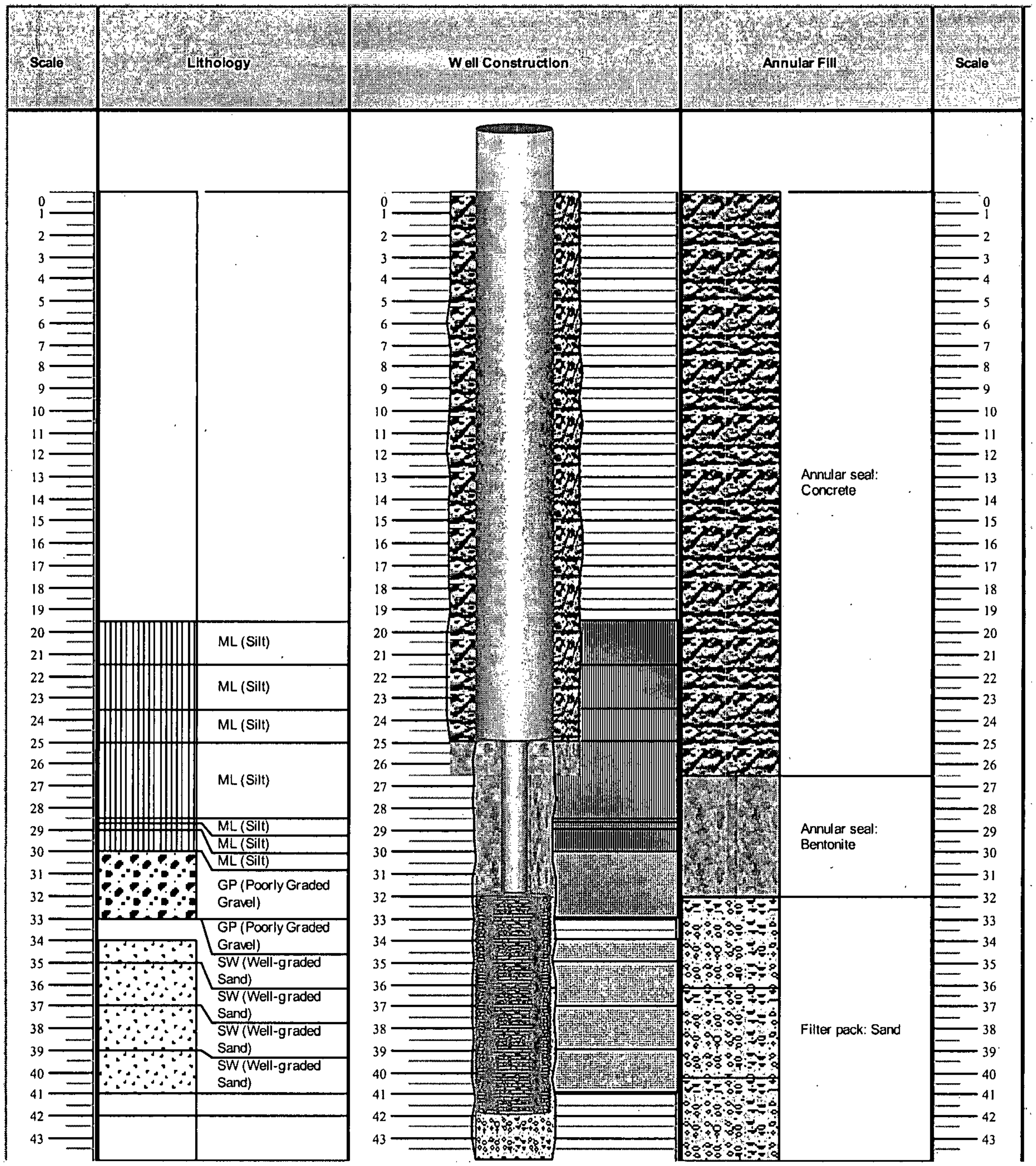

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Borehole Log Report

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Borehole / Monitoring Well I.D.: **ESS-20C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–4.5	SW (Well-graded Sand)	Green-Grey Clayey Silty Fine SAND	Other	Medium		0.0–4.5
4.5–8.5	SM (Silty Sand)	Light Brown Silty Fine SAND	brown	Medium		4.5–8.5
8.5–9.0	SW (Well-graded Sand)	Light reddish Brown Silty sandy Clay,	brown			8.5–9.0
9.0–10.3	SM (Silty Sand)	Light Brown Sandy SILT, woody material within matrix	brown			9.0–10.3
10.3–14.5	SM (Silty Sand)	Light Brown to Whitish Silty SAND	Other	Saturated		10.3–14.5
14.5–15.5	ML (Silt)	Dark Grey SILT	grey	Saturated		14.5–15.5
15.5–19.5	SM (Silty Sand)	Light Brown Silty SAND	brown	Saturated		15.5–19.5
19.5–20.5	ML (Silt)	Dark Grey SILT, high shell content, molluscs and bivalves.	grey	Medium	Shelly	19.5–20.5

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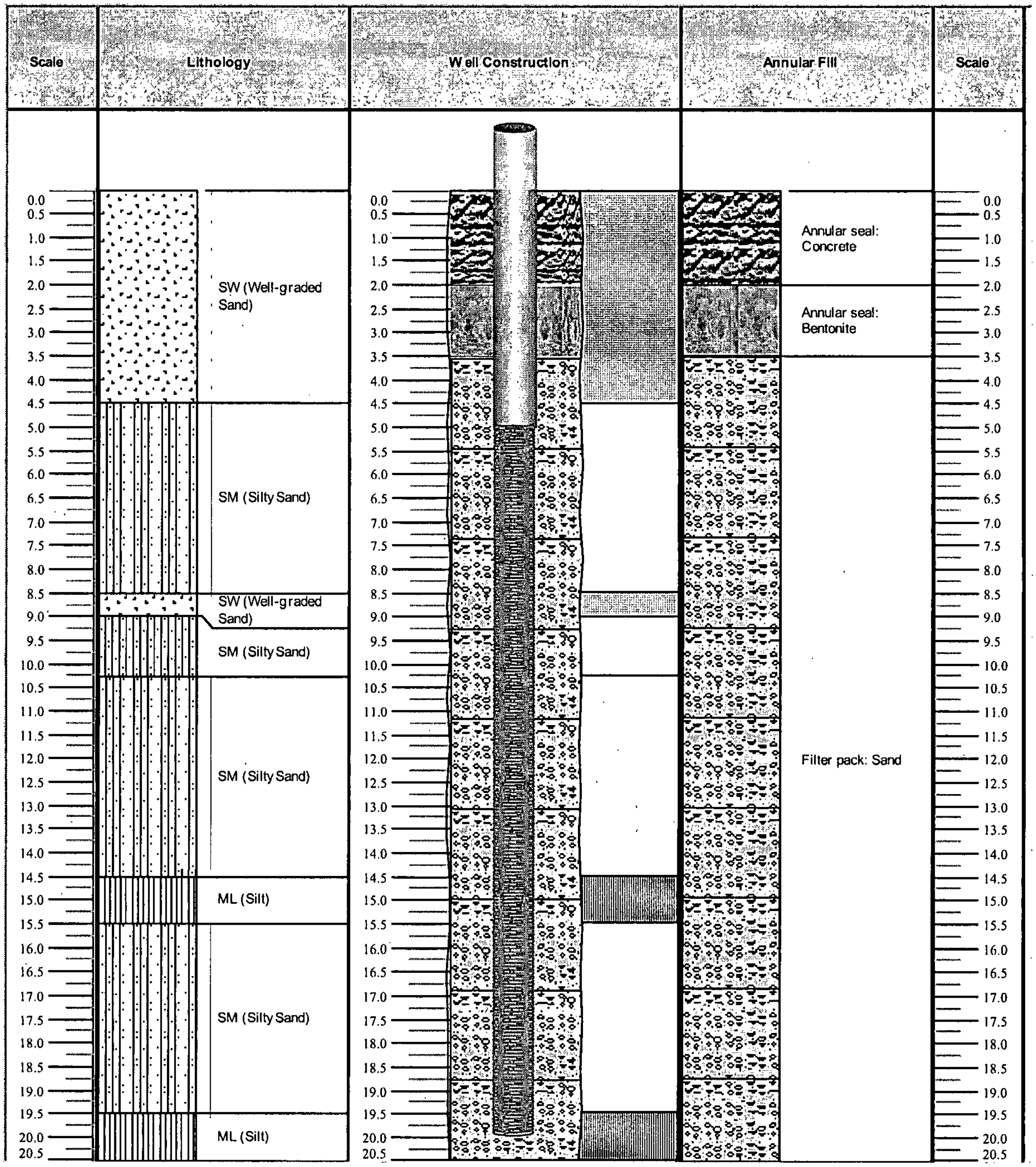
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-20C

Date: December, 2007



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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-20B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–21		See ESS-20C				0–21
21–22	ML (Silt)	Dark Grey Clayey SILT, trace sand	grey	Medium	Shelly	21–22
22–23	ML (Silt)	Dark grey Clayey SILT	grey	Low	Trace Shell	22–23
23–24	ML (Silt)	Dark Grey Clayey SILT	grey	Medium		23–24
24–25	ML (Silt)	Dark Grey Clayey SILT	grey	Low		24–25
25–27	ML (Silt)	Greenish Grey CLAY with thin laminates of Silt	grey	Low		25–27
27–30	ML (Silt)	Greenish grey Clay/Silt, less lamination	grey	Low		27–30
30–31	ML (Silt)	A-A with shells	grey	Medium	Shelly	30–31
31–33	GW (Well-graded Gravel)	Sandy SHELL HASH	grey	Saturated	Shelly	31–33
33–35	SW (Well-graded Sand)	Medium SAND and Shells	white	Saturated	Shelly	33–35
35–37	SW (Well-graded Sand)	Med. SAND, some fine and course grains, trace clay	white	Saturated		35–37
37–39	GW (Well-graded Gravel)	SHELL HASH with Med. Fine Sand	white	Saturated	Shelly	37–39
39–41	GP (Poorly Graded Gravel)	SHELL HASH	white	Saturated	Shelly	39–41
41–43	GP (Poorly Graded Gravel) / SW (Well-graded	Med. Course SAND, some shells	grey	Saturated	Shelly	41–43

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Monitoring Well Construction Report

Monitoring Well I.D.: ESS-20B

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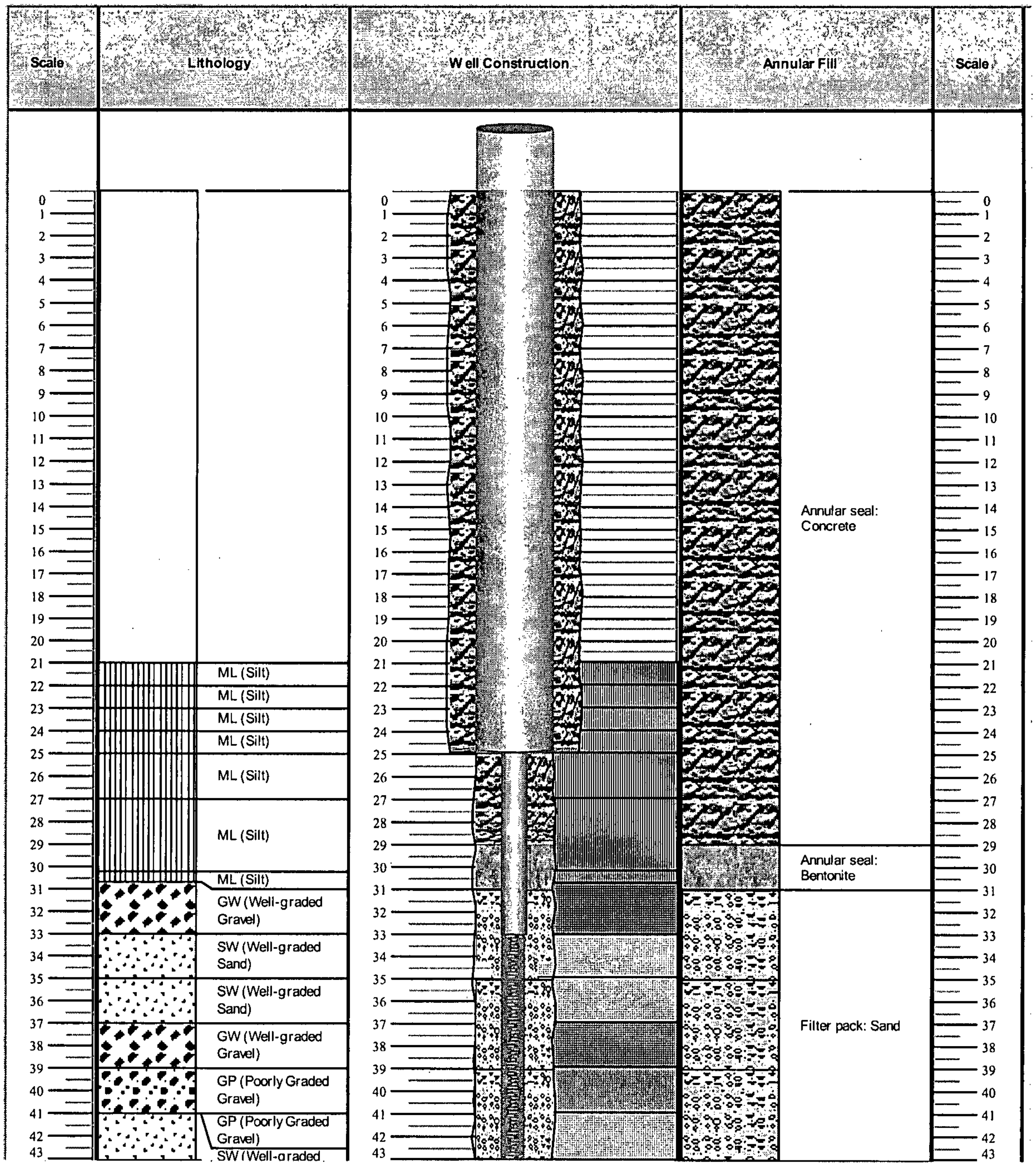

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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-21C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 3.5	ML (Silt)	FILL: Dark Grey Black SILT	black	Low		0.0 – 3.5
3.5 – 14.0	ML (Silt)	FILL: Silt, Sand, Concrete, root material.	grey	Medium		3.5 – 14.0
14.0 – 15.0	SM (Silty Sand)	Silty Fine SAND	brown	Medium		14.0 – 15.0
15.0 – 16.0	OL (Organic Clay/Silt of low plasticity)	Green Clayey SILT, abundant broken shell material, very sandy at base.	Other	Medium		15.0 – 16.0
16.0 – 20.0	SM (Silty Sand)	Brown Silty SAND	brown	Medium		16.0 – 20.0
20.0 – 21.0	SP (Poorly Graded Sand)	Dark grey Fine SAND, shelly at 20.25 ft bgs, no shells at base.	grey	Saturated		20.0 – 21.0

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Monitoring Well Construction Report

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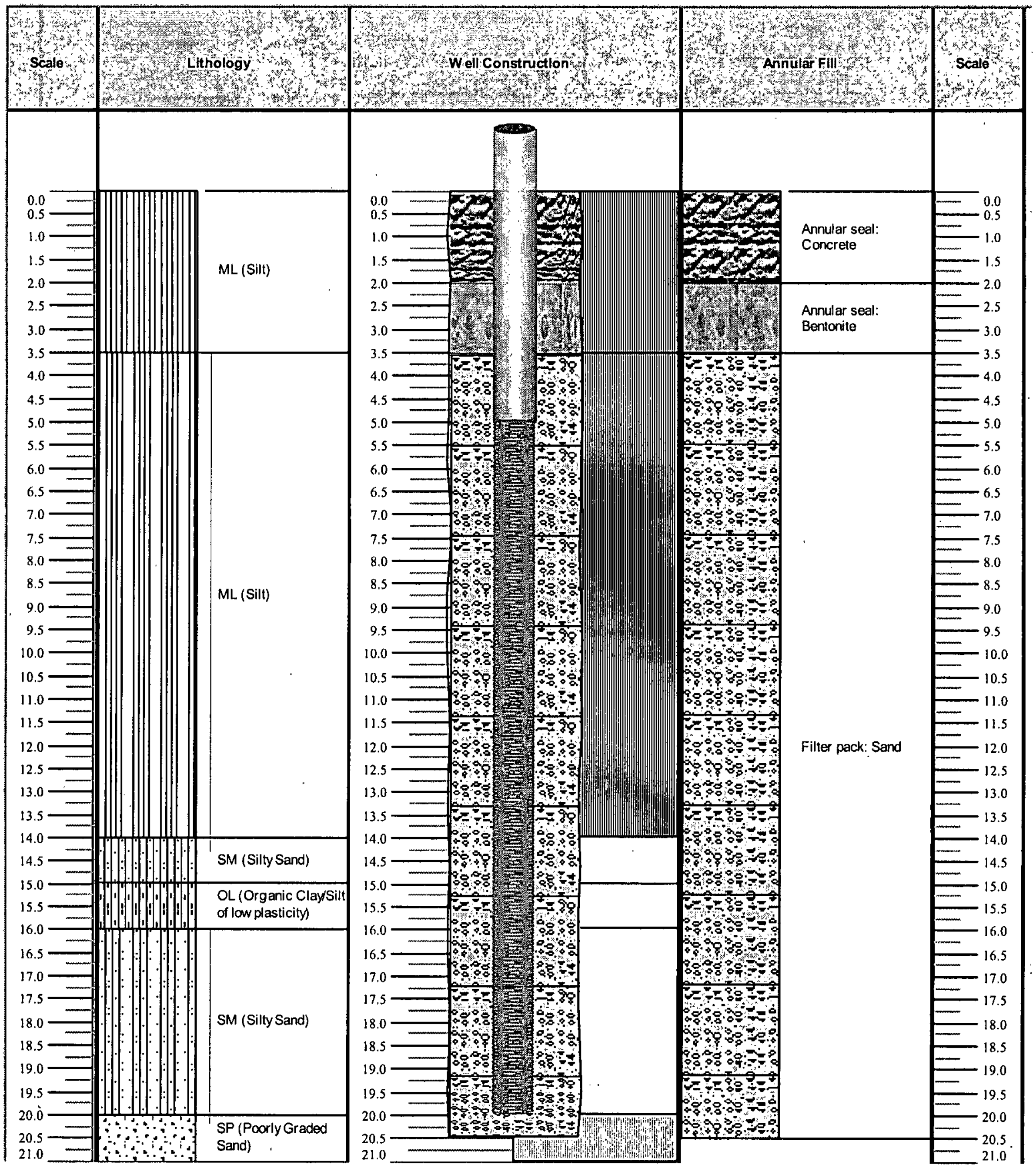
Date: December, 2007



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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: ESS-21B

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–20		See ESS-21C				0–20
20–22	SP (Poorly Graded Sand)	Fine SAND	brown			20–22
22–24	SM (Silty Sand)	Fine Sand and silt, thin (<2) lenses of clayey silt	grey			22–24
24–27	SP (Poorly Graded Sand)	Fine SAND	grey			24–27
28	SM (Silty Sand)	Silty SAND	grey			28
28–32	SP (Poorly Graded Sand)	Fiine SAND	grey			28–32
32	ML (Silt)	Grey Clayey Silt, shelly, bivalves	grey	Saturated	Shelly	32
33–35	SP (Poorly Graded Sand)	Silty to Fine SAND, trace shells	grey	Saturated	Trace Shells	33–35
35–41	SP (Poorly Graded Sand)	Fine SAND	grey	Saturated		35–41
41–45	ML (Silt)	Dark grey Silty Clay	grey	High		41–45
45–46	SP (Poorly Graded Sand)	Fine SAND	grey			45–46
46–56	SP (Poorly Graded Sand)	Dark Grey Med. SAND	grey	High		46–56
56–57	PT (Highly Organic Soil/Peat)	Wood layer	brown			56–57
57–67	GW (Well-graded Gravel)	Limey Sand and shellls	white	High		57–67

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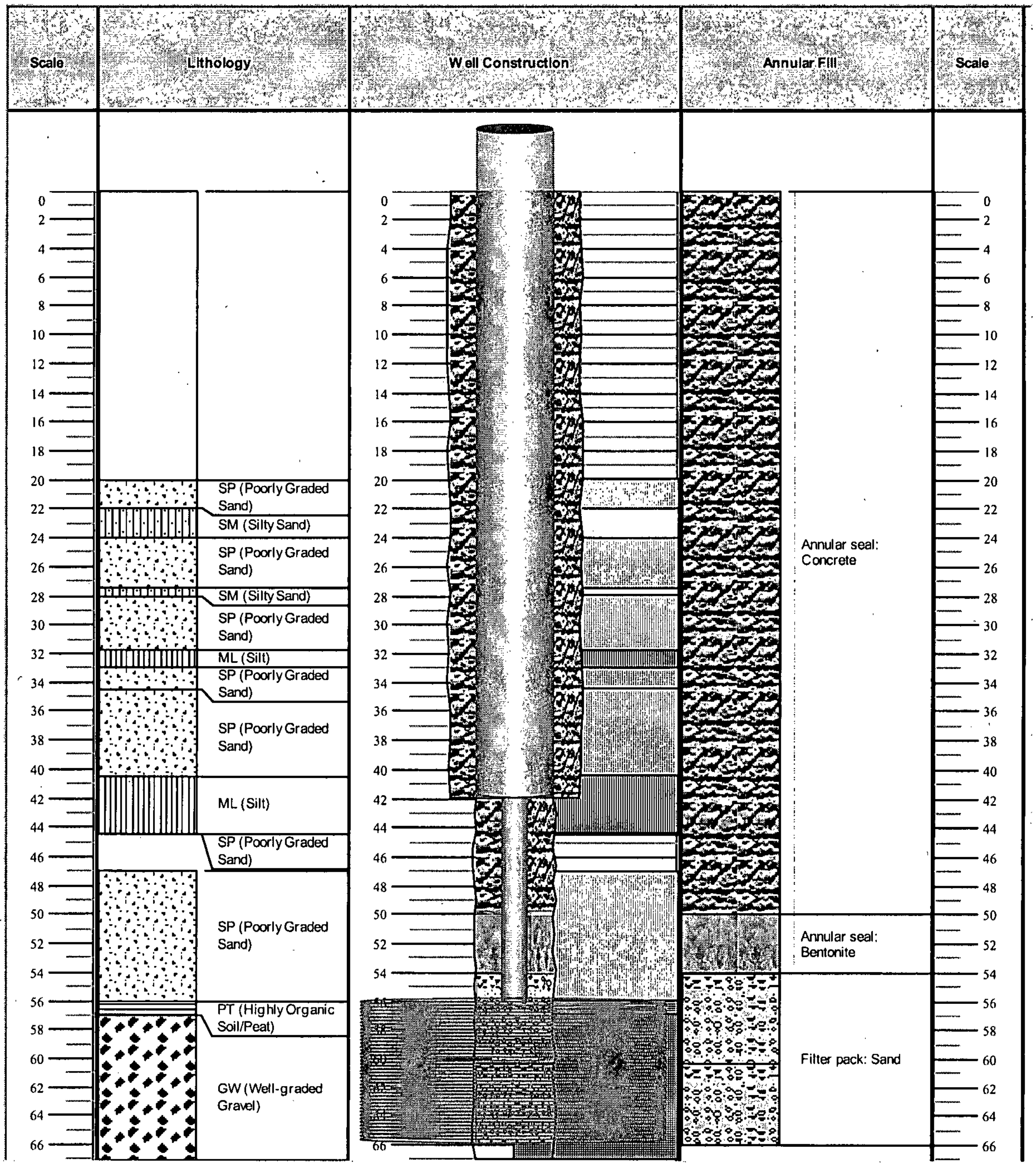
Monitoring Well I.D.: ESS-21B

Date: December, 2007



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Borehole / Monitoring Well I.D.: ESS-22C

Date: December, 2007

Lithology	Field Description	Color	Moisture	Comments
SM (Silty Sand)	Brown Silty Fine SAND	brown	Low	Low Moisture
SM (Silty Sand)	Dark Grey Fine Sandy SILT	grey	Medium	Med. Moisture
SP (Poorly Graded Sand)	Grey Fine SAND	grey	Low	Low Moisture
SP (Poorly Graded Sand)	Grey Clayey Fine SAND	grey	Low	Low Moisture
SM (Silty Sand)	Light Brown Silty SAND	brown	High	High Moisture to Wet
CH (Fat Clay)	Mottled Grey CLAY	grey	Low	Low Moisture
SP (Poorly Graded Sand)	Light Brown SAND	brown	High	High Moisture
SW (Well-graded Sand)	Light Brown Clayey Sandy SILT	brown	Saturated	Wet
ML (Silt)	Dark Grey SILT	grey	Medium	Med. Moisture
SP (Poorly Graded Sand)	Light Brown Fine-Med. SAND, trace silt	grey	Saturated	Wet
SP (Poorly Graded Sand)	Grey to Dark Grey Fine SAND	grey	Medium	Med. Moisture
SW (Well-graded Sand)	Grey-Green Silty Clayey SAND	Other	Medium	Med. Moisture
SW (Well-graded Sand)	Brown Silty SAND, increasing clay content	brown	Low	Low Moisture

Scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0, 20.5

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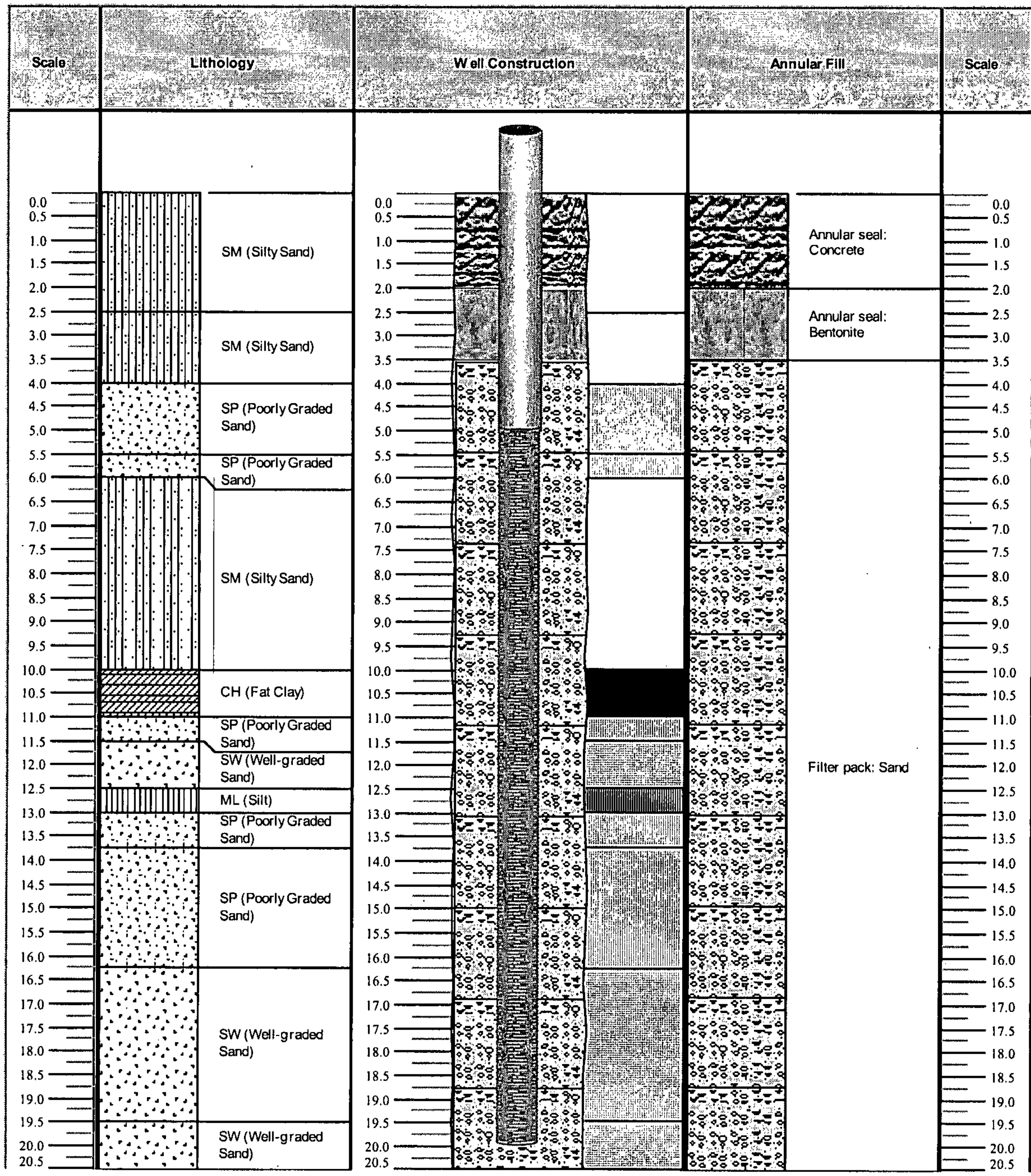
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-22C

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: **ESS-22B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments
0–19		See ES-22C			
20–58	SM (Silty Sand)	Dark Grey Silty Fine Sand, sandy silt, more sandy at base of sample.	grey	Saturated	
	GP (Poorly Graded Gravel)	Brown Silty Shell Hash.	brown	Saturated	Shelly
	GP (Poorly Graded Gravel)	Dark Grey SAND, grading to Dark Grey SILT to Dark Grey Silty SAND.	grey	High	Trace shells
	SM (Silty Sand)	Dark Grey Silty SAND, trace bivalve shells at bottom of interval.	grey	Saturated	Shelly
	SM (Silty Sand)	Dark Grey Silty SAND with trace clay, abundant bivalve shells.	grey	Medium	Shelly
	SW (Well-graded Sand)	Dark Grey SILT, trace sand and clay.	grey	Medium	Shelly
	ML (Silt)	Shell Layer, matrix A-A	grey	Medium	Trace shells
	GM (Silty Gravel)	Dark Grey SILT, trace clay, bivalves in matrix.	grey	Low	Shelly
	ML (Silt)	Dark Grey Silty Clay, bivalves.	grey	Low	Trace shells
	ML (Silt)	Shell Layer	grey	Low	Trace shells
	GP (Poorly Graded Gravel)	Dark Grey Clayey SILT, shelly at base of interval.	grey	Low	Woody material
	GP (Poorly Graded Gravel)	Dark Grey CLAY, trace silt, trace bivalve shells	grey	Low	
	ML (Silt)	Dark Grey SILT and CLAY.	grey	Low	
	OL (Organic Clay/Silt of low plasticity)				
	OL (Organic Clay/Silt of low plasticity)				
60–64	SP (Poorly Graded Sand)	Grey Fine-Med. SAND	grey	Medium	
64–70	SP (Poorly Graded Sand)	Grey Fine-Med. SAND	grey	Saturated	
70–77	SP (Poorly Graded Sand)	Grey Med.-Course SAND, trace silt.	grey	Saturated	
78	SM (Silty Sand)	Dark Grey-Black Silty Fine SAND	grey	Low	
	ML (Silt)	Dark Grey SILT with Fine sand	grey	Low	

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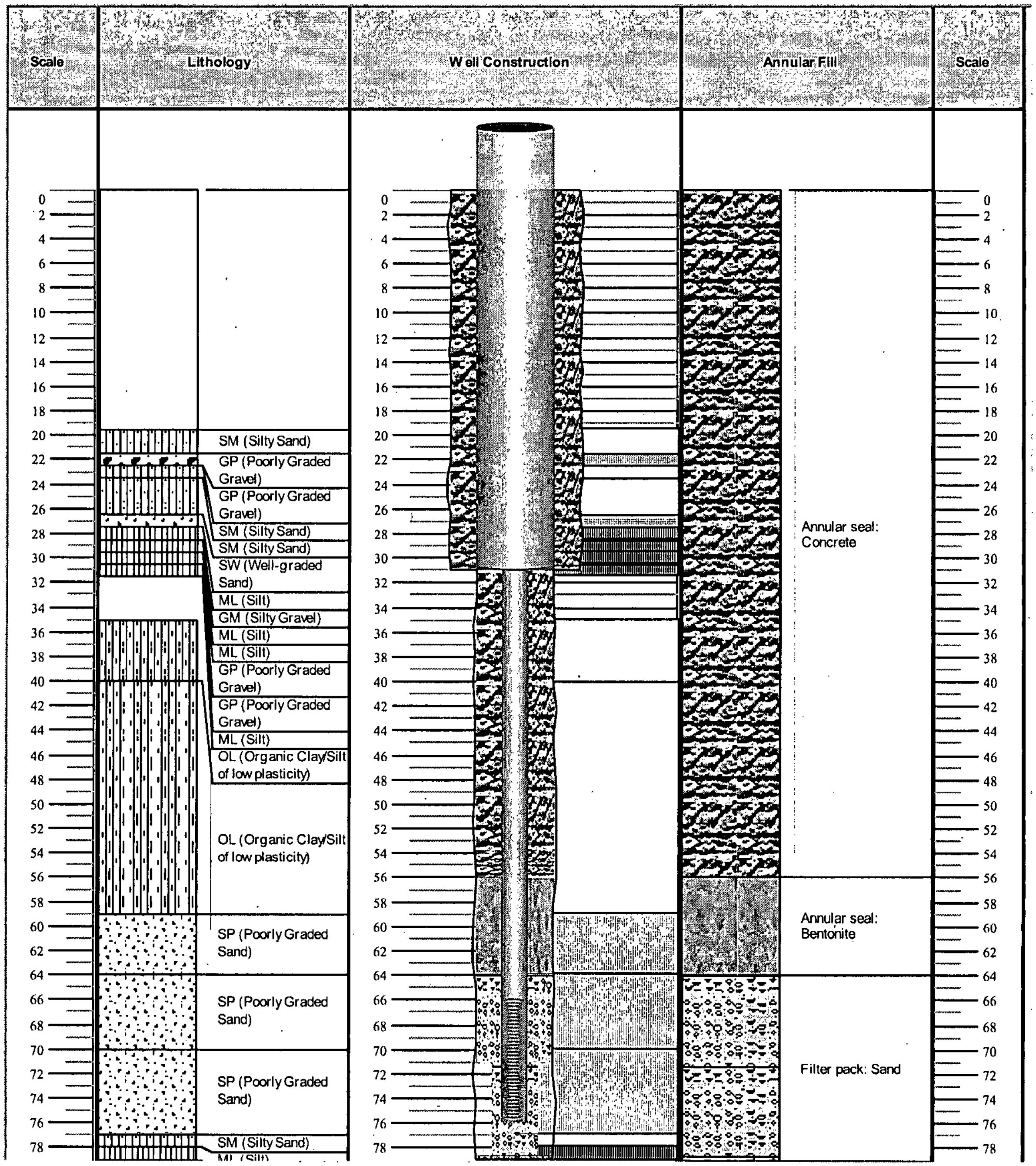
Monitoring Well I.D.: ESS-22B

Date: December, 2007



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Borehole / Monitoring Well I.D.: **ESS-23C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 3.0	SM (Silty Sand)	Reddish brown Silty SAND	brown	Low		0.0 – 3.0
3.0 – 10.0	SM (Silty Sand)	Brown to Reddish Brown Silty SAND	brown	Medium		3.0 – 10.0
10.0 – 12.0	SW (Well-graded Sand)	Reddish Brown and Grey Sandy Clayey SILT	Other	Medium		10.0 – 12.0
12.0	SM (Silty Sand)	Reddish Brown Silty Clayey SAND				12.0
12.0 – 19.0	SM (Silty Sand)	Light Brown and reddish Brown Silty SAND	brown	Saturated		12.0 – 19.0
19.0 – 23.5	SM (Silty Sand)	Grey Silty Fine SAND	grey	Saturated		19.0 – 23.5
23.5	SM (Silty Sand)	Grey Sandy SILT	grey	High		23.5
24.0 – 24.5	ML (Silt)	Dark Grey SILT	grey	Medium		24.0 – 24.5

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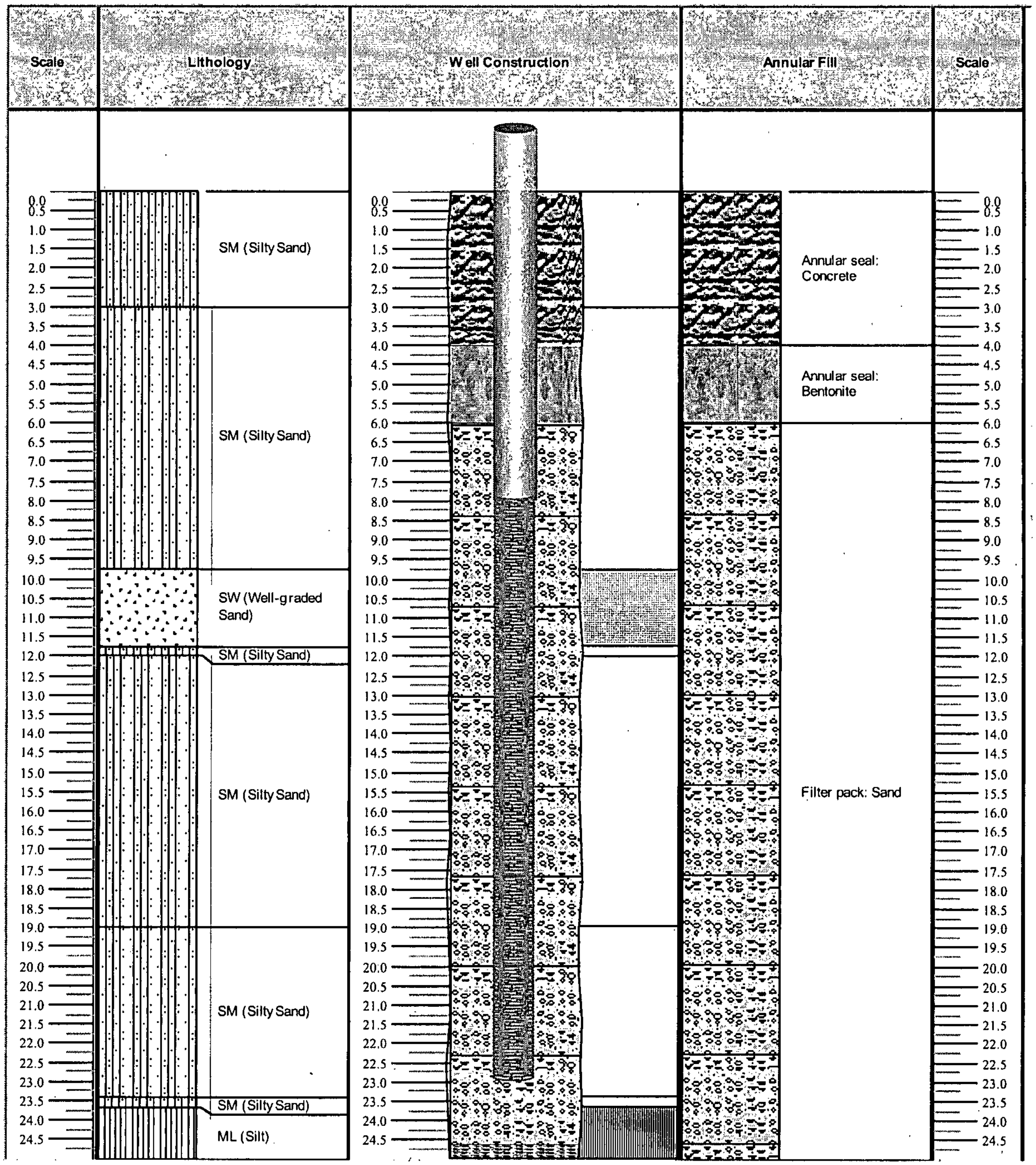
Monitoring Well I.D.: ESS-23C

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: ESS-24C

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–2.0	SP (Poorly Graded Sand)	Sandy organic soil, root material and detritis.	brown	Low		0.0–2.0
2.0–6.0		FILL: Concrete and debris.				2.0–6.0
6.0–11.0	SM (Silty Sand)	Dark Grey Silty SAND, root material at base of interval.	grey	Medium		6.0–11.0
11.0–11.8	SM (Silty Sand)	Dark grey Silty SAND	grey	Saturated		11.0–11.8
11.8–12.8	SM (Silty Sand)	Grey-Green Silty SAND, trace clay,.	Other	High		11.8–12.8
12.8–13.1	SM (Silty Sand)	Grey Green Sandy SILT	Other	High		12.8–13.1
13.1–14.0	SM (Silty Sand)	Brown Silty SAND	brown	Saturated		13.1–14.0
14.0–15.0	ML (Silt)	Dark Grey SILT, trace sand at base of interval.	grey	Medium		14.0–15.0
15.0–17.0	SM (Silty Sand)	Dark Grey Sandy SILT and Silty SAND, sandy at base of interval.	grey	Saturated		15.0–17.0
17.0–19.0	SM (Silty Sand)	Dark Grey Silty SAND grading to Dark grey SILT, trace bivalves at base of interval.	grey	High	Trace shells	17.0–19.0
19.0–19.8						19.0–19.8
19.8–20.1	GP (Poorly Graded Gravel)	SHELL Layer.	grey			19.8–20.1
20.1–21.0	GP (Poorly Graded Gravel)	Dark Grey Clayey SILT, trace bivalve shells.	grey	Low	Trace shells	20.1–21.0

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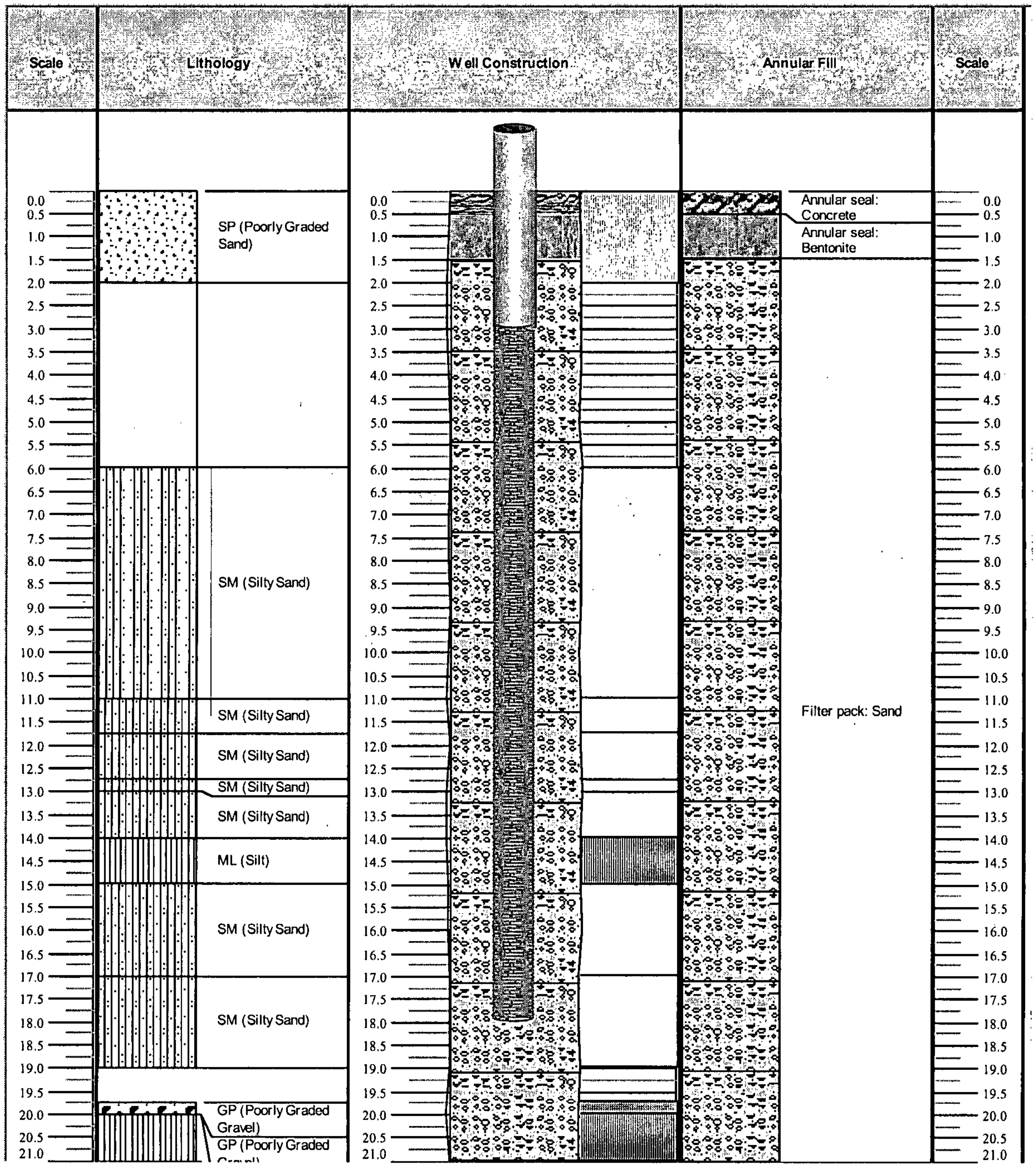
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-24C

Date: December, 2007



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Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: **ESS-24B**

Date: December, 2007

Scale: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72

Lithology	Field Description	Color	Moisture	Comments
	See ESS-24C			
ML (Silt)	Dark Grey Clayey SILT	grey	Low	
OL (Organic Clay/Silt of low plasticity)	Grey-Green Silty CLAY	Other	Low	Shelly
GP (Poorly Graded Gravel)	SHELL Layer	grey	Low	Shelly
GP (Poorly Graded Gravel)	Dar Grey-Green Silty CLAY	Other	Low	
OL (Organic Clay/Silt of low plasticity)	A-A, abundant shell material.	Other	Low	
OL (Organic Clay/Silt of low plasticity)	Dark Grey Silty SAND	grey	Medium	
SM (Silty Sand)	Interlayered Silty SAND and Clayey SILT	grey	Low	
SM (Silty Sand)	Dark Grey Clayey SILT, interlayered with thin sandy lenses	grey	Medium	
MH (Elastic Silt)				
SM (Silty Sand)	Dark Grey Silty SAND, trace clay	grey	Saturated	
MH (Elastic Silt)	Dark Grey Clayey SILT	grey	Medium	
SW (Well-graded Sand)	Dark Grey Silty SAND	grey	Saturated	
SW (Well-graded Sand)	Dark Grey Clayey SAND	grey	High	
SP (Poorly Graded Sand)	Dark Grey Med. Fine SAND, trace to some silt	grey	Saturated	
SW (Well-graded Sand)	Dark Grey SAND and GRAVEL	grey	Saturated	
SP (Poorly Graded	Whitish Fine to med. SAND	white	Saturated	
	Lithology Change, no recovery			

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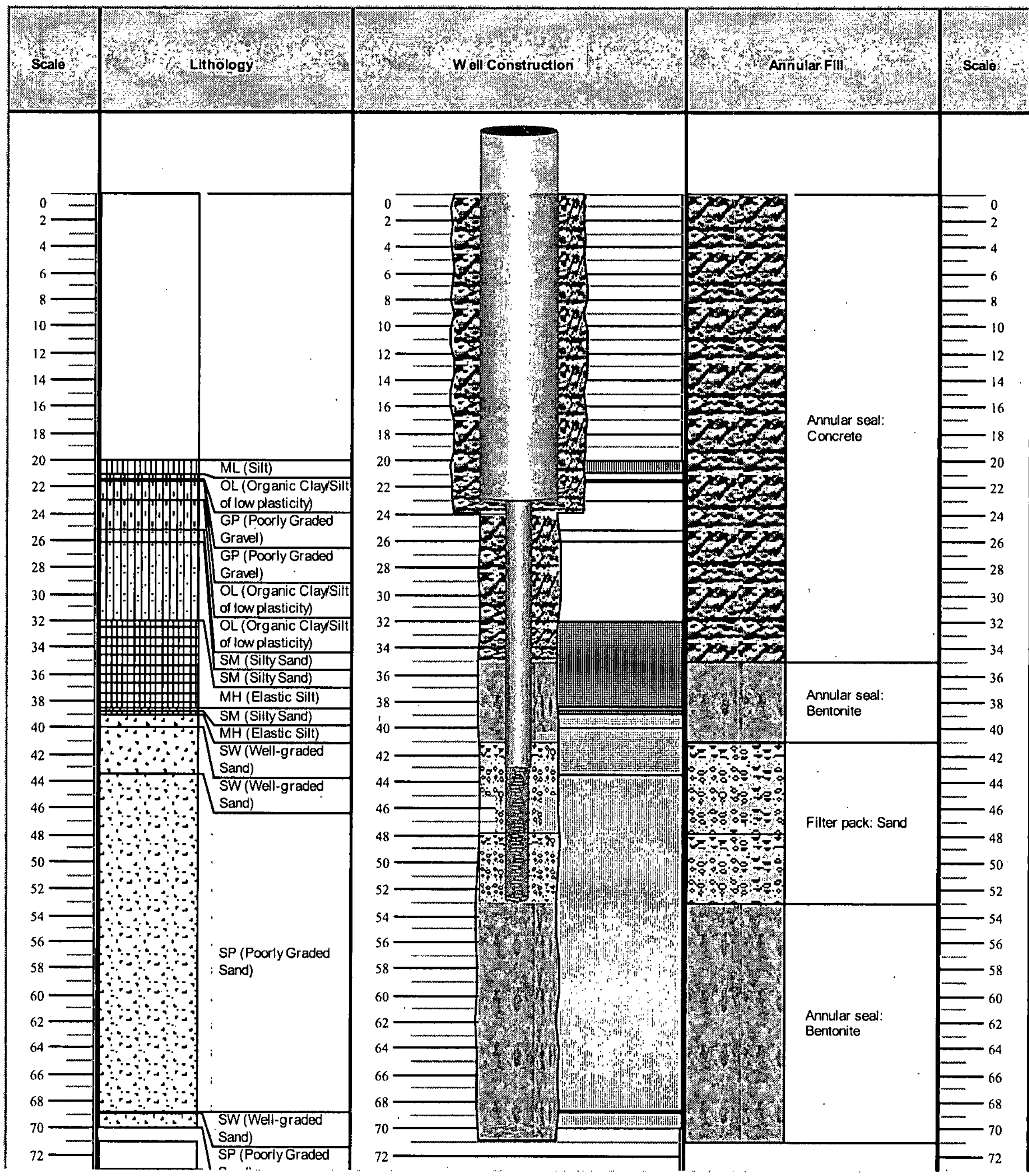
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-24B

Date: December, 2007



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Borehole / Monitoring Well I.D.: ESS-24A

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–20		See ESS-24C				0–20
20–70		See ESS-24B				20–70
70–76	Sandy Limestone	Sandy Shelly LIMESTONE, whitish grey, glauconitic, small voids at 70.5. Hard upper 6, fractured and broken from 71-74.	white	High	Shelly	70–76
76–108	ML (Silt)	Dark Grey Clayey SILT, Very tight.	black	Low		76–108
108–140		Gray, sandy LIMESTONE, moldic features, wet.	grey	High		108–140

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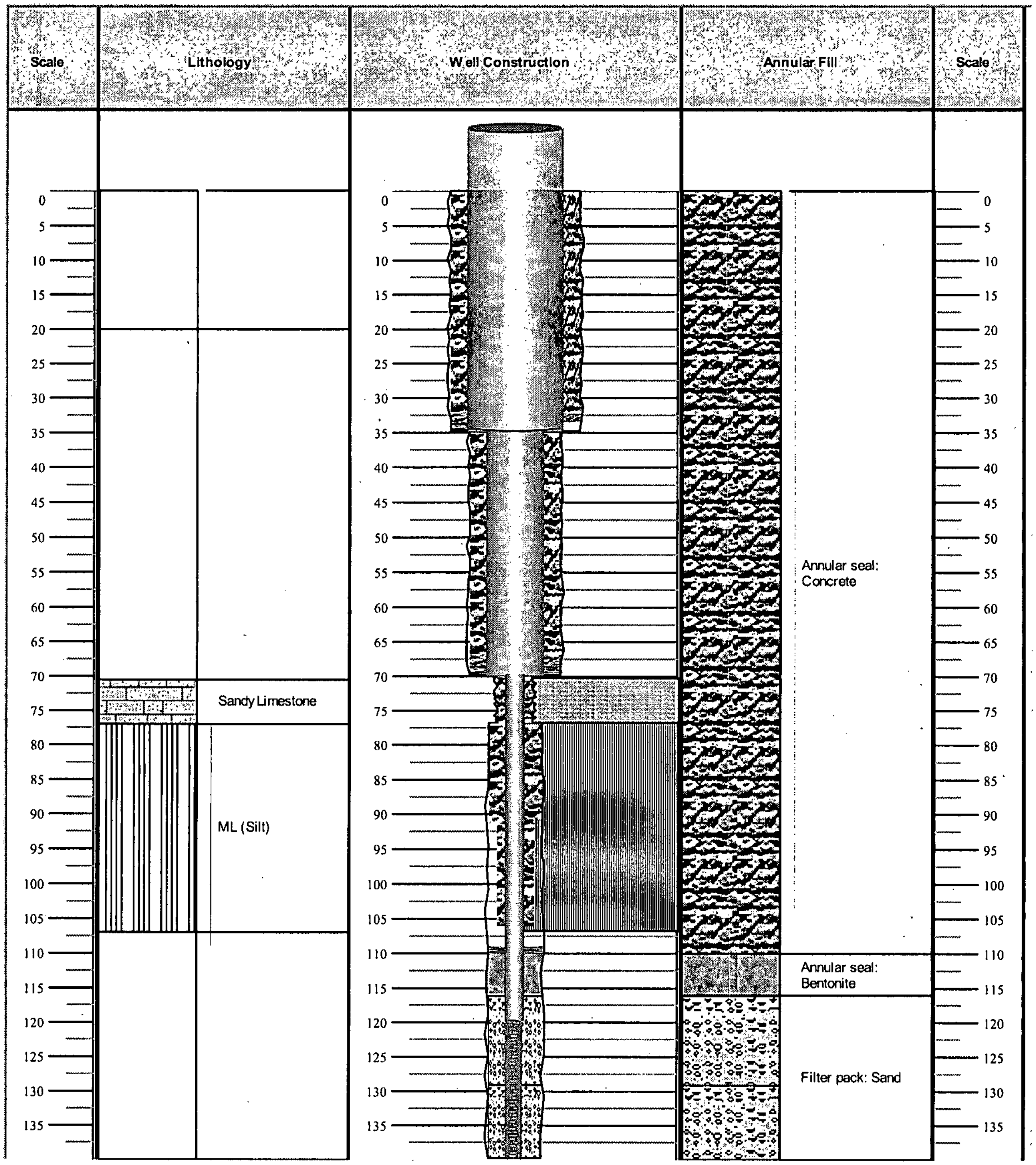
Monitoring Well I.D.: ESS-24A

Monitoring Well Construction Report

Date: December, 2007



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Borehole / Monitoring Well I.D.: **ESS-25C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 5.0	ML (Silt)	Light Brown to Dark Grey SILT	brown	Low		0.0 – 5.0
5.0 – 7.0	SM (Silty Sand)	Grey Silty Fine SAND	grey	Medium		5.0 – 7.0
7.0 – 8.0	SW (Well-graded Sand)	grey Clayey Fine SAND	grey	Medium		7.0 – 8.0
8.0 – 9.5	SM (Silty Sand)	Reddish Brown Silty Finie SAND	brown	Low		8.0 – 9.5
9.5 – 11.5	SM (Silty Sand)	Light Brown-Tan Silty Fine sAND	brown	Medium		9.5 – 11.5
11.5 – 12.75	SW (Well-graded Sand)	Light Brown Silty Clayey Fine SAND	brown	Medium		11.5 – 12.75
12.75 – 14.0	SM (Silty Sand)	Light Brown Silty Fine SAND	brown	Medium		12.75 – 14.0
14.0 – 17.0	SP (Poorly Graded Sand)	Layered Light Brown-Grey Fine SAND, layers 1/2-inch thick	Other	High		14.0 – 17.0
17.0 – 19.0	SP (Poorly Graded Sand)	Pale Grey Fine-Med. SAND	grey	Saturated		17.0 – 19.0
19.0 – 23.5	CL (Lean Clay)	Pale grey Sandy CLAY, variable moisture, root material @19 ft bgs	grey	Medium		19.0 – 23.5
23.5 – 24.0	CH (Fat Clay)	Pale Grey CLAY	grey	Low		23.5 – 24.0
24.0 – 25.5	ML (Silt)	Dark Grey Clayey SILT, very small shells in matrix	grey	Low		24.0 – 25.5

Scale: 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0 18.5 19.0 19.5 20.0 20.5 21.0 21.5 22.0 22.5 23.0 23.5 24.0 24.5 25.0 25.5

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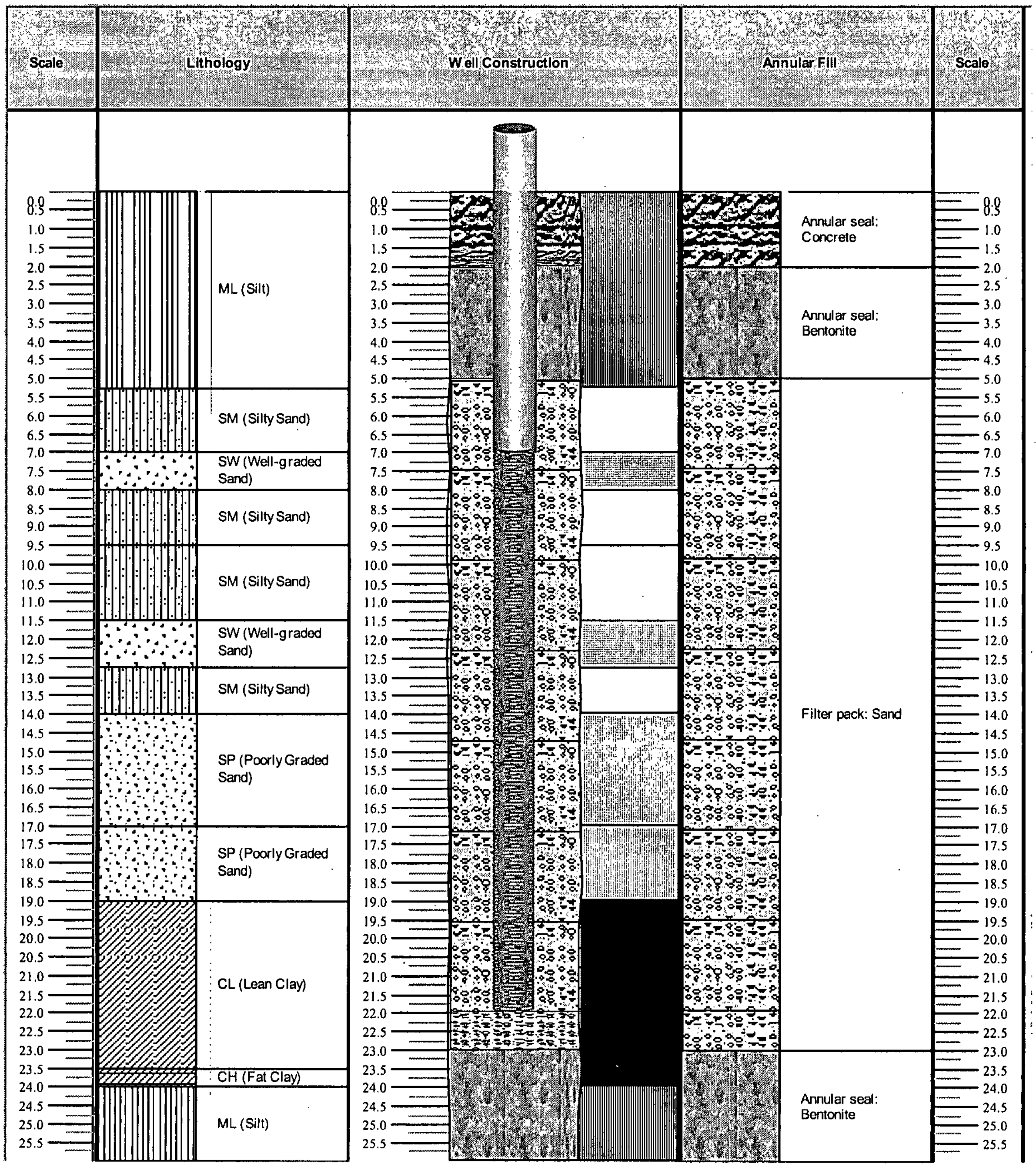
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-25C

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: **ESS-25B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–26		See ESS-25C				0–26
26–34	OL (Organic Clay/Silt of low plasticity)	Dark Grey Silty CLAY, shelly, with less shells at base of interval	grey	Low	Shelly	26–34
34–36	MH (Elastic Silt)	Dark Grey Clayey SILT with layered sand lenses (<1mm) throughout interval	grey	Low		34–36
36–40.5	SP (Poorly Graded Sand)	LAYERED Fine SAND and Clayey SILT beds, approx 1.5-inches thick throughout interval	grey	Saturated		36–40.5
40.5–42	SP (Poorly Graded Sand)	Grey Fine to Med. SAND	grey	Saturated		40.5–42
42–43	SP (Poorly Graded Sand)	Med. to Course SAND, shells	grey	Saturated	Shelly	42–43
43–43.5	SM (Silty Sand)	Light Grey Silt and SAND	grey	High		43–43.5
43.5–44.5		Dark Grey Silty CLAY, layered	grey	Low		43.5–44.5
44.5–45	OH (Organic Clay/Silt of high	dark Grey Silty CLAY	grey	Low		44.5–45

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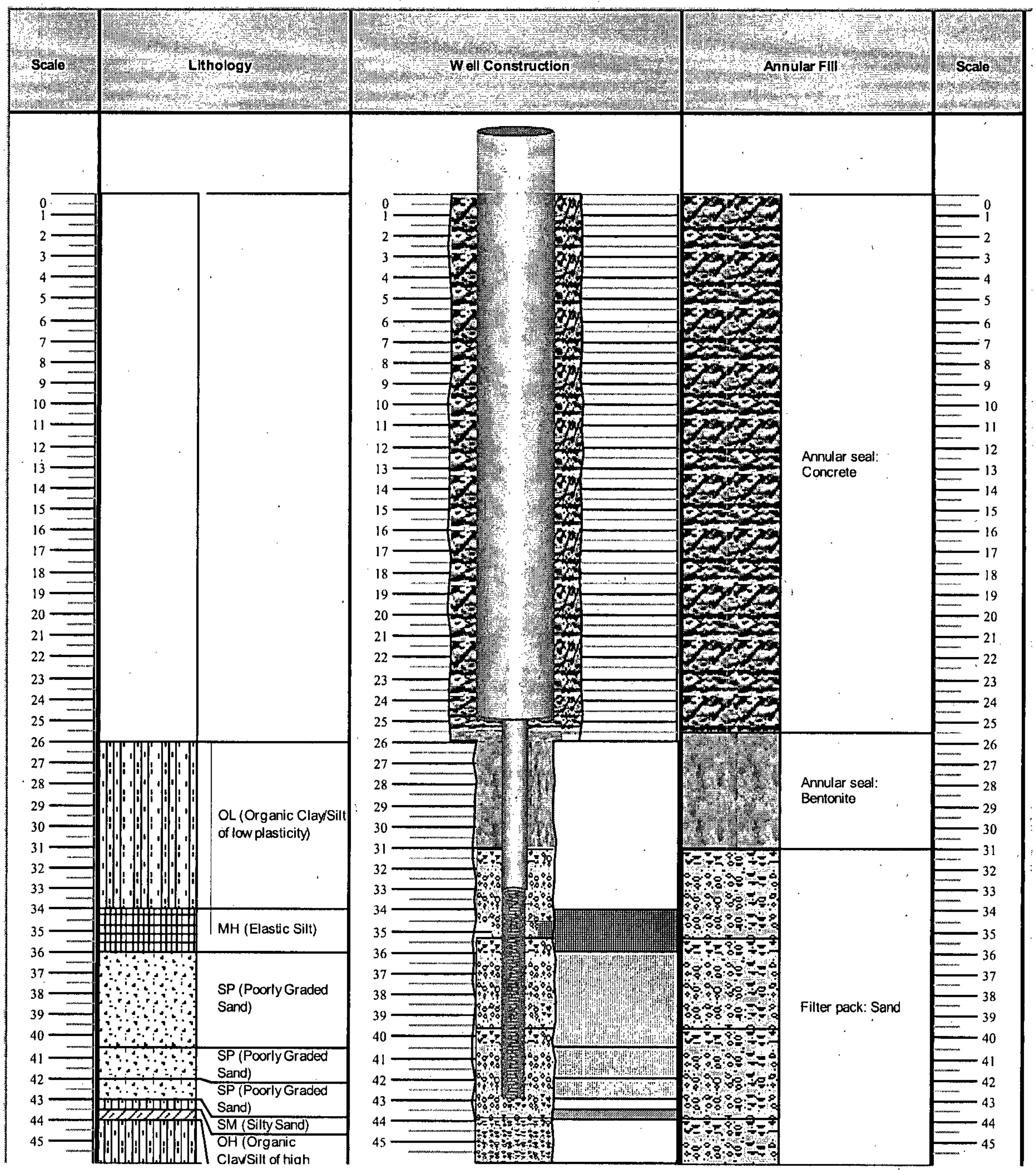
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-25B

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant

Groundwater Investigation, 2007 Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: ESS-26C

Logged by: B. Sladky
Driller: Geologic Exploration, Inc.
Date: July, 2007

Scale	Lithology	Field Description	Color	Moisture	Standard Penetratio Test (ASTM D1586-99)	Scale
0.0 – 4.0	SP (Poorly Graded Sand)	Fine to med. Sand	brown	Low		0.0 – 4.0
4.0 – 5.5	SM (Silty Sand)	Silty Fine Sandy FILL	grey	Low		4.0 – 5.5
5.5 – 8.0	SM (Silty Sand)	Silty Fine SAND, non-cohesive	brown	Medium		5.5 – 8.0
8.0 – 9.25	SP (Poorly Graded Sand)	Medium SAND	grey	Saturated		8.0 – 9.25
9.25 – 17.5	SC (Clayey Sand)	Fine Sandy Silty Clay, large and small shells	dark grey	Medium		9.25 – 17.5
17.5 –	SP (Poorly Graded Sand)	Silty Fine SAND	grey	Medium		17.5 –

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Monitoring Well Construction Report

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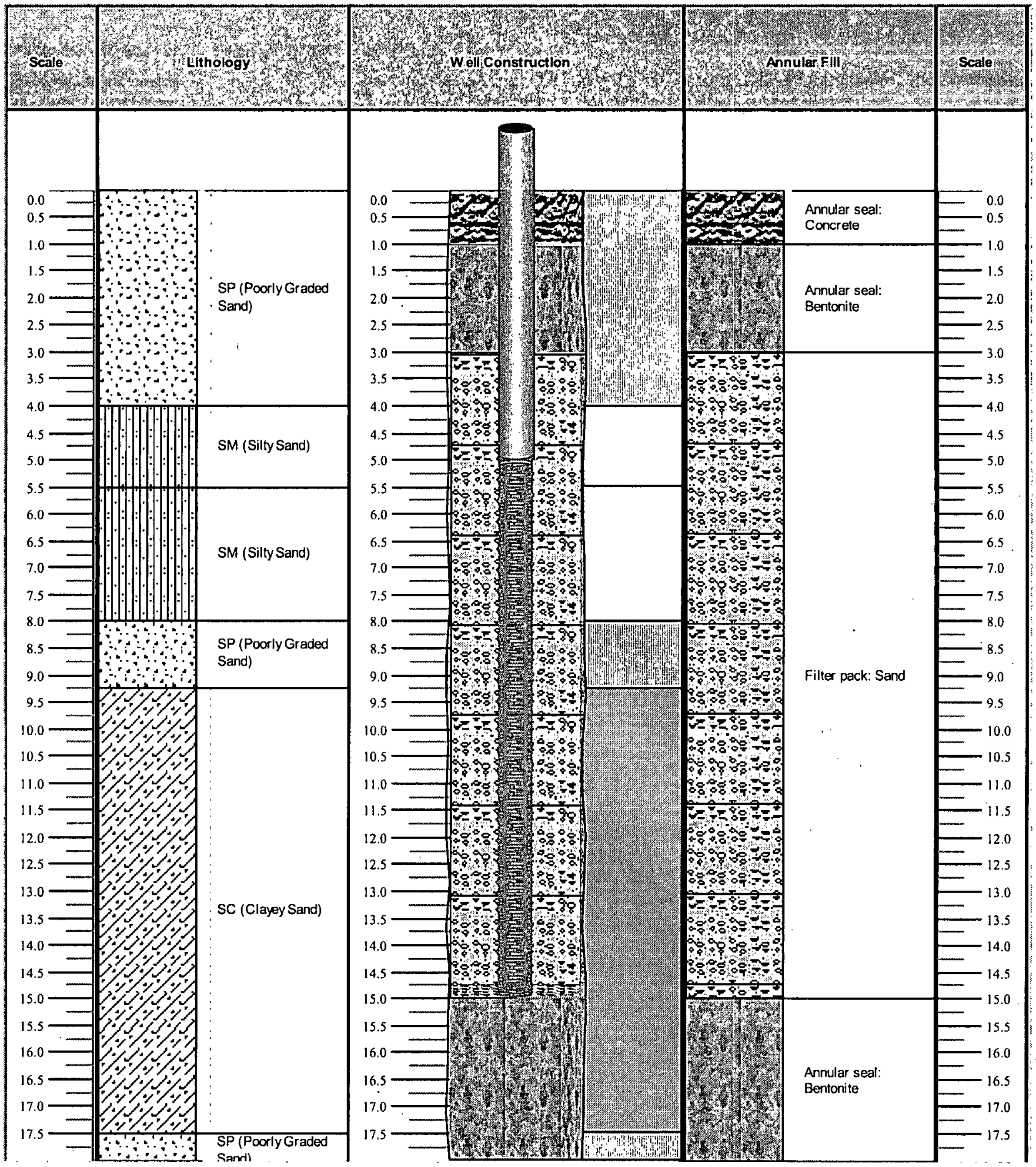
Monitoring Well I.D.: ESS-26C

Logged by: B. Sladky
Drilled by: Geologic Exploration, Inc.
Date: July, 2007



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Borehole / Monitoring Well I.D.: **ESS-27C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–2.0	SM (Silty Sand)	asphalt, Subbase, Lt. Brown Silty SAND	brown	Low		0.0–2.0
2.0–3.0	SM (Silty Sand)	Brown Sandy SILT	brown	Low		2.0–3.0
3.0–5.0		FILL: Clay and sand		Low		3.0–5.0
5.0–7.0	SM (Silty Sand)	Brown Silty SAND	brown	Low		5.0–7.0
7.0–9.2	SP (Poorly Graded Sand)	V. Fine to Fine Light Brown and Light Grey SAND	Other	Medium		7.0–9.2
9.2–13.7	SM (Silty Sand)	Light Reddish Brown Silty Fine SAND, tace clay from 11-12 ft bgs	brown	Saturated		9.2–13.7
13.7–15.9	ML (Silt)	Dark Grey Clayey SILT, trace sand	grey	Low		13.7–15.9

Scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5

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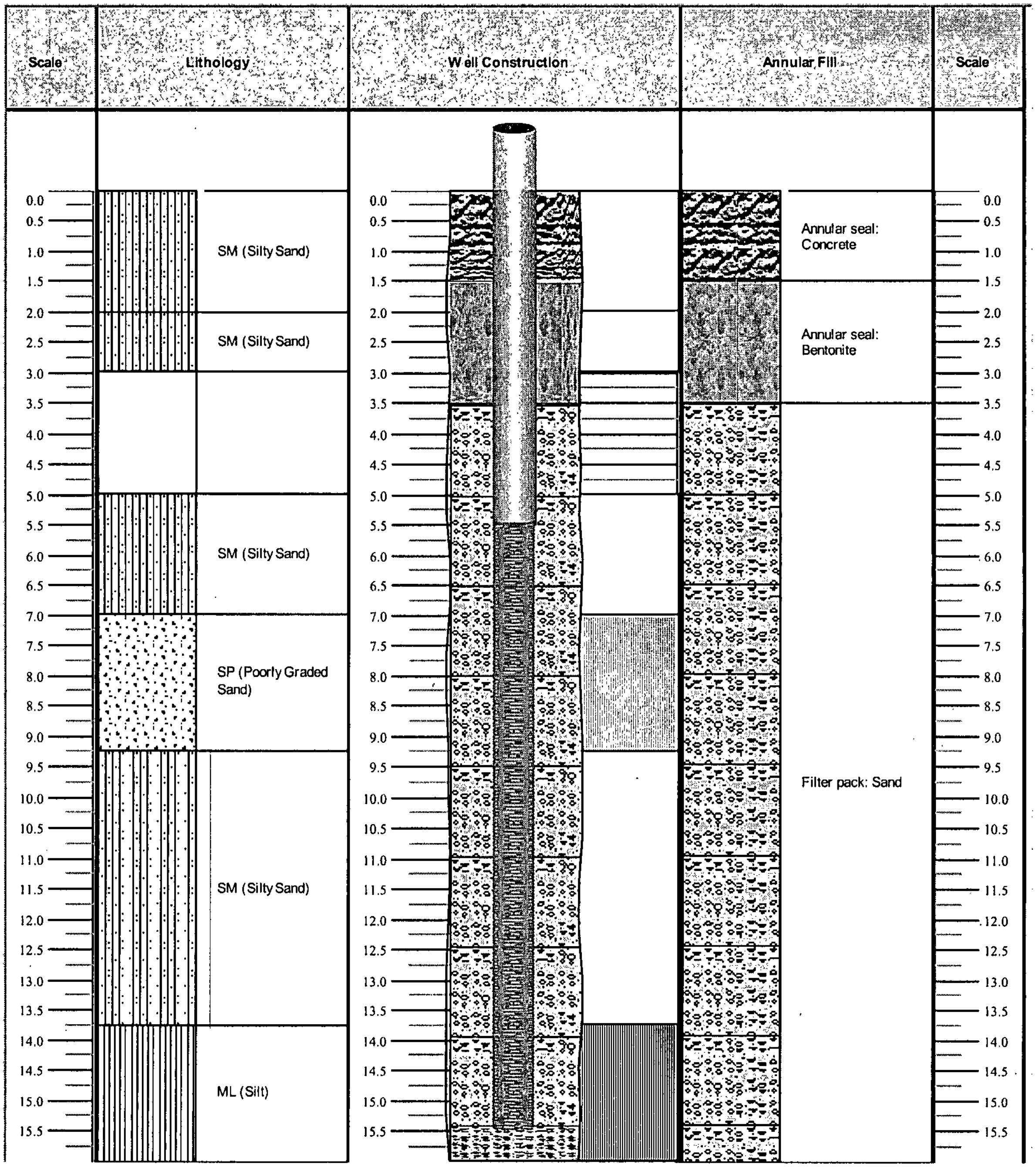
Monitoring Well I.D.: ESS-27C

Monitoring Well Construction Report

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-28C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 2.5	SM (Silty Sand)	Reddish brown Silty SAND	brown	Low		0.0 – 2.5
2.5 – 8.0	SM (Silty Sand)	Brown to Reddish Brown Silty SAND	brown	Medium		2.5 – 8.0
8.0 – 9.75	SW (Well-graded Sand)	Reddish Brown and Grey Sandy Clayey SILT	Other	Medium		8.0 – 9.75
9.75 – 17.0	SM (Silty Sand)	Light Brown to Reddish Silty SAND	brown	High		9.75 – 17.0
17.0 – 22.5	SM (Silty Sand)	Grey Silty Fine SAND	grey	Saturated		17.0 – 22.5
22.5 – 25.0	ML (Silt)	Dark Grey SILT	grey	Low		22.5 – 25.0

Scale (ft): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0, 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0, 24.5

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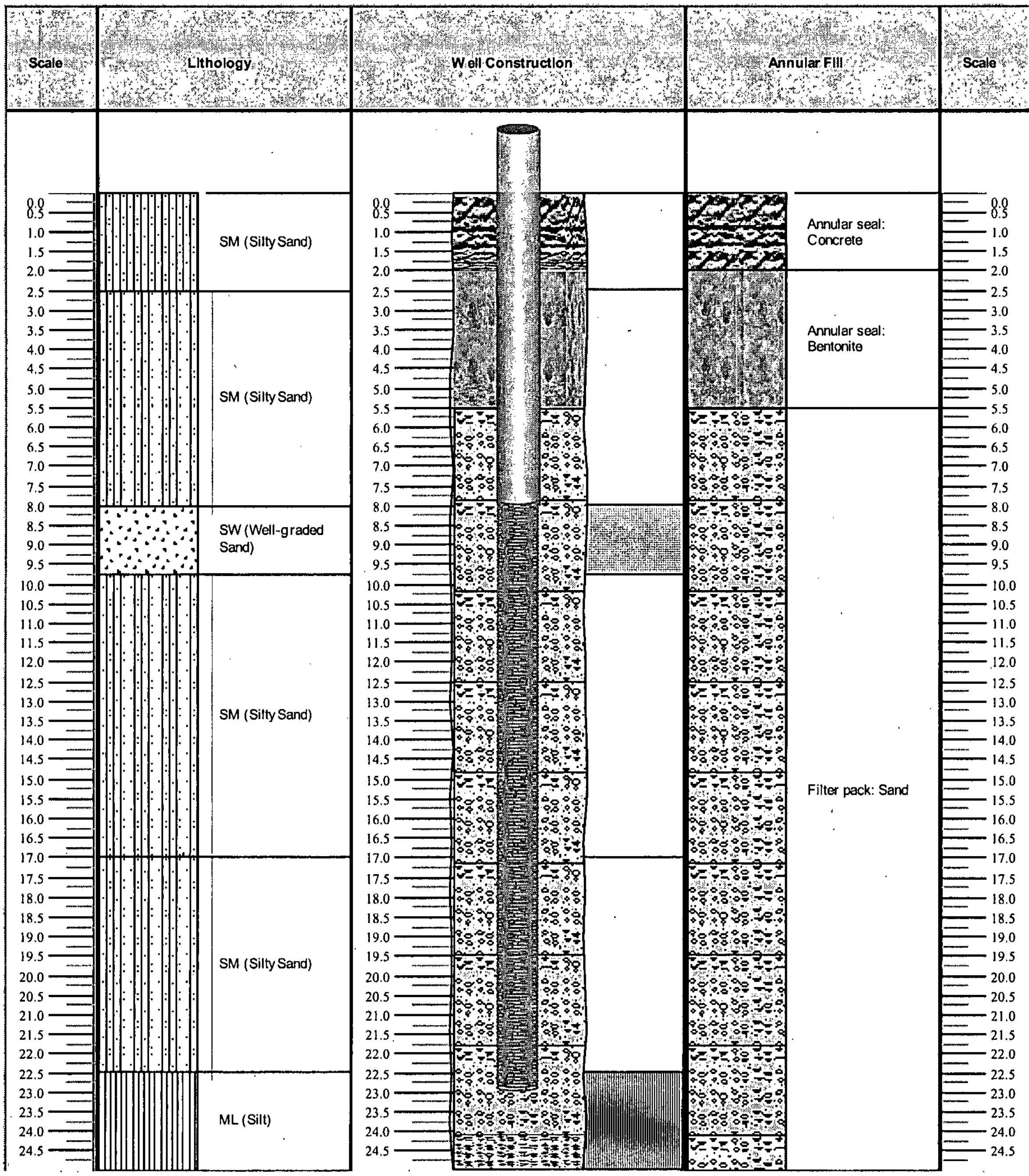
Drilled by: Geologic Exploration, Inc.

Monitoring Well Construction Report

Monitoring Well I.D.: ESS-28C

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: ESS-30C

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–2.0	PT (Highly Organic Soil/Peat)	wood chips and roots	brown	Low		0.0–2.0
2.0–2.5	SM (Silty Sand)	Concrete FILL	Other	Low		2.0–2.5
2.5–7.0	SM (Silty Sand)	Sand, trace clay	grey	Medium		2.5–7.0
7.0–13.0	SM (Silty Sand)	Sandy silt	brown	High		7.0–13.0
13.0–15.0	SP (Poorly Graded Sand)	Fine SAND	grey	Saturated		13.0–15.0

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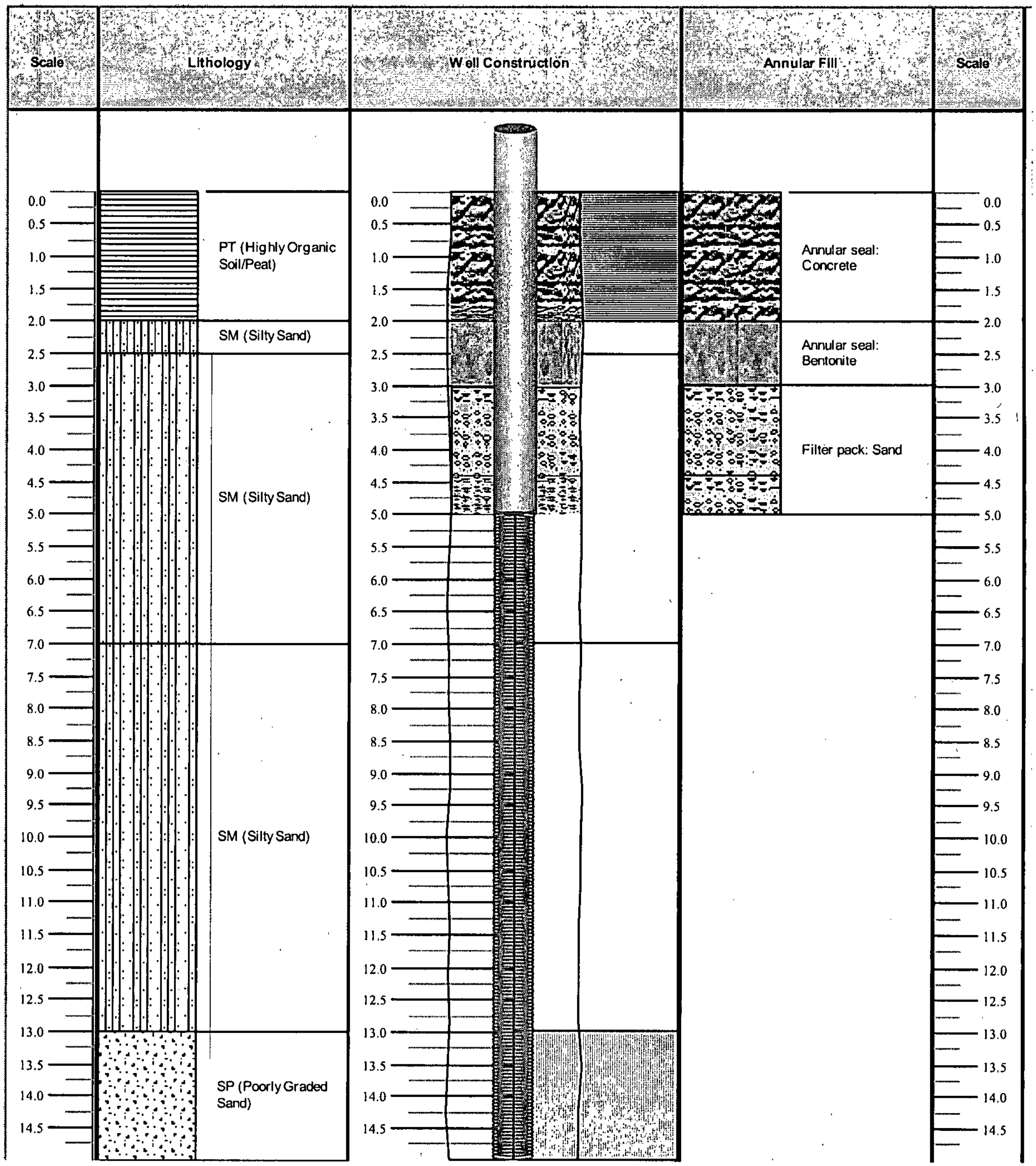
Monitoring Well I.D.: ESS-30C

Monitoring Well Construction Report

Date: December, 2007



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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: ESS-31C

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 5.0	SM (Silty Sand)	Sand	brown	Low		0.0 – 5.0
5.0 – 12.0	SM (Silty Sand)	Sandy Silt	grey	High		5.0 – 12.0
12.0 – 14.5	SM (Silty Sand)	Sandy silt	grey	Saturated		12.0 – 14.5

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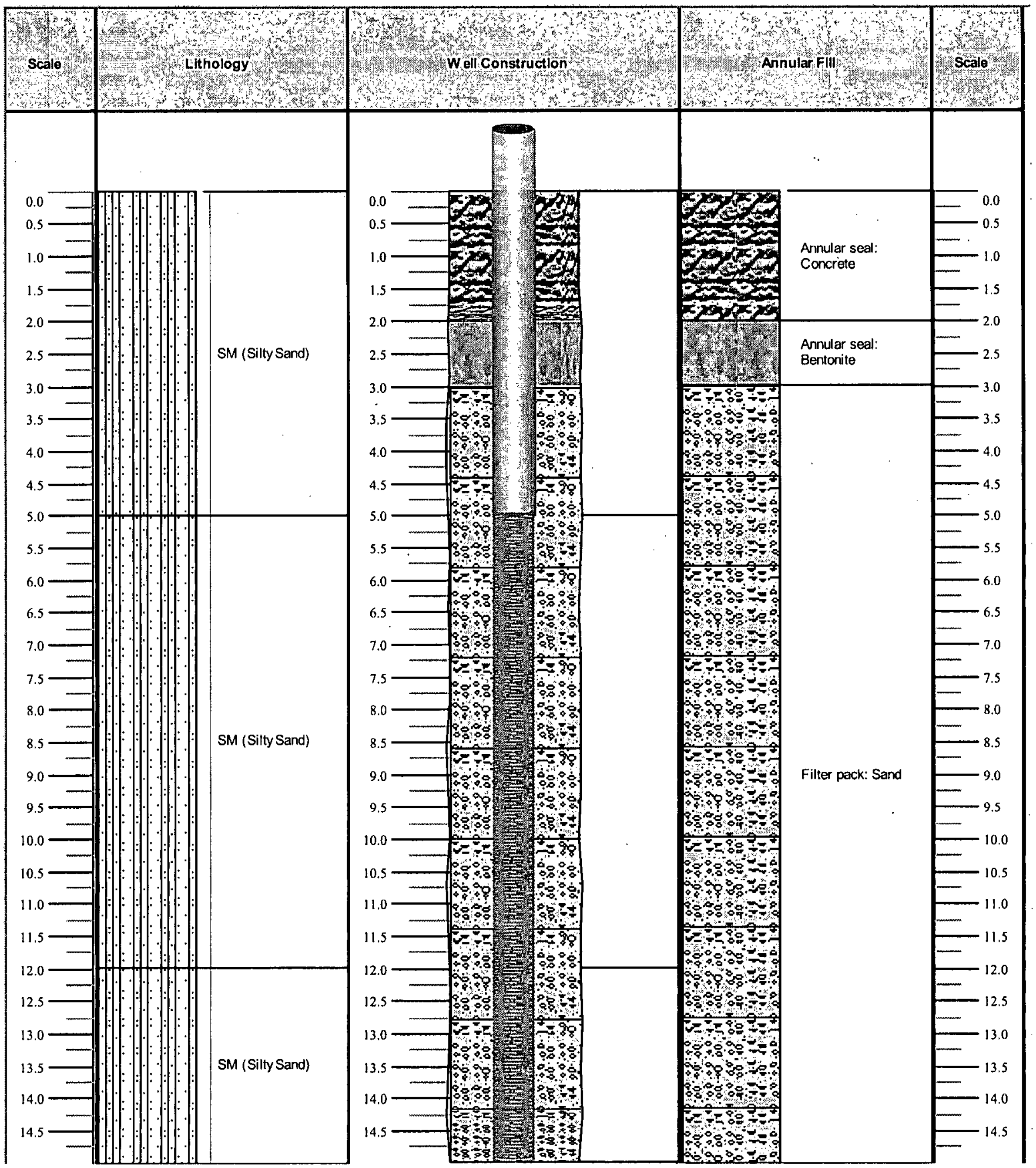
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-31C

Date: December, 2007



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Borehole / Monitoring Well I.D.: **ESS-STAB**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0	SP (Poorly Graded Sand)	Light Borwn SAND, poor recovery	brown	Low		0
6	ML (Silt)	Dark Grey Sandy SILT	grey	High		6
11	SP (Poorly Graded Sand)	Dark Grey Silty Fine SAND, shelly at 11 ft bgs. layered	grey	High		11
12		No recovery		Saturated		12
14	SM (Silty Sand)	Dark Grey and Light Grey Silty SAND, trace clay, root fragments	grey	Saturated		14
15	ML (Silt)	Dark Grey SILT, grading to sandy silt, shelly.	grey	Saturated	Shelly	15
16	SM (Silty Sand)	Dark Grey Silty SAND, shelly at 19.5 ft bgs,some root material	grey	Saturated	Shelly	16
21	ML (Silt)	Dark Grey Clayey SILT, trace sand, shells	grey	Medium		21
22	SM (Silty Sand)	Dark Grey Silty SAND	grey	Saturated		22
25	SP (Poorly Graded Sand)	Light Brown Fine Sand, trace silt	grey			25
26	SM (Silty Sand)	Dark Grey to Grey Silty Fine SAND	grey	Saturated		26
29	SW (Well-graded Sand)	Grey Clayey Fine SAND	grey	Low		29
30	SW (Well-graded Sand)	Light Grey-White Clayey SAND, root material, phosphoritic	white	High		30
34	SM (Silty Sand)	Dark Grey Sandy SILT, tracxe clay	grey	Medium		34
35	SM (Silty Sand)	Light Grey to whitish Silty SAND	white	High		35
37	ML (Silt)	Dark Grey SILT, sea grass encased in matrix	grey	Low		37

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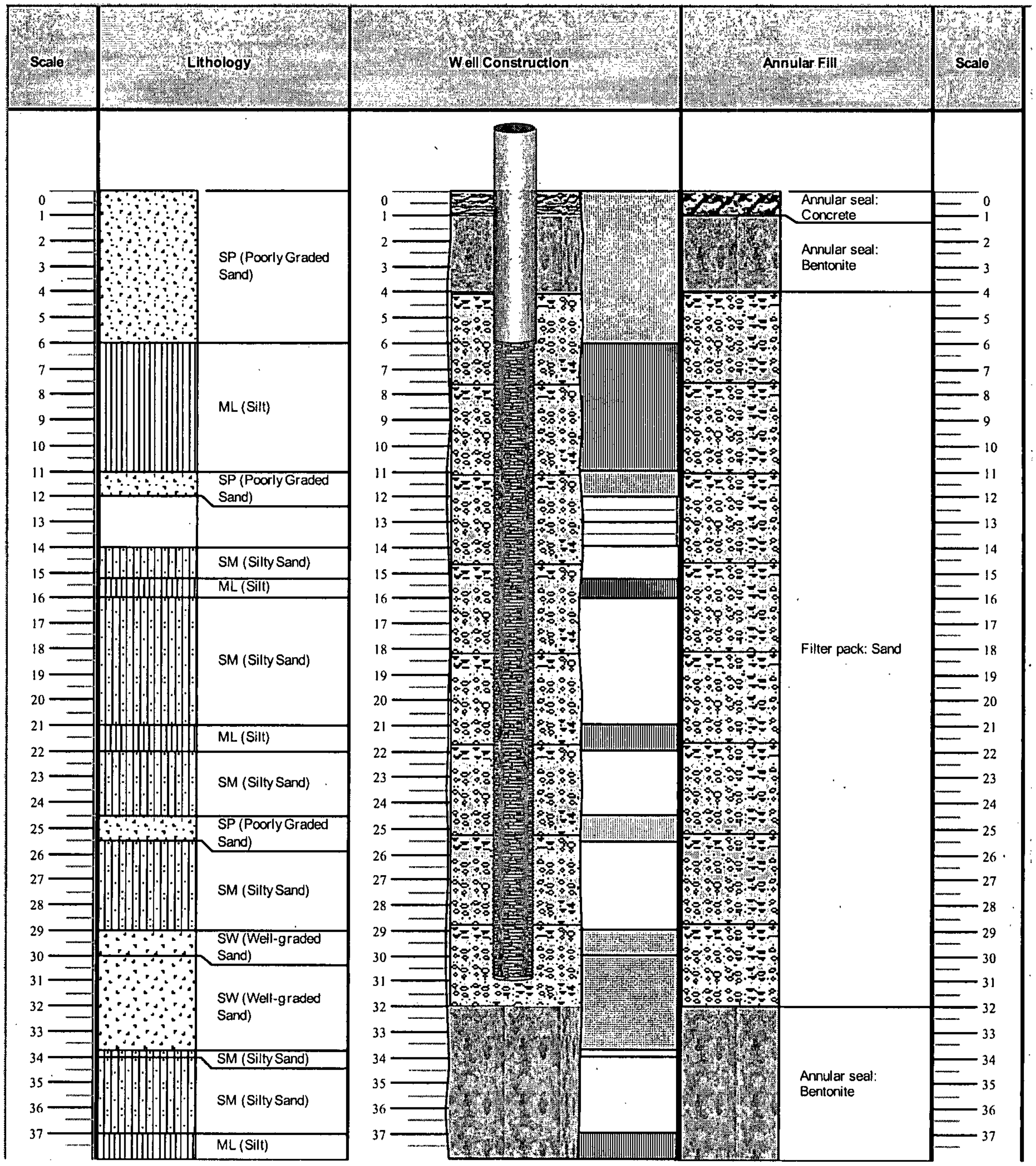
Monitoring Well Construction Report

Monitoring Well I.D.: ESS-STAB

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-NC1**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–7.0	ML (Silt)	Dark Grey Clay and SILT, wetland sediments	grey	High		0.0–7.0
7.0–7.4	SP (Poorly Graded Sand)	SAND	grey	High		7.0–7.4

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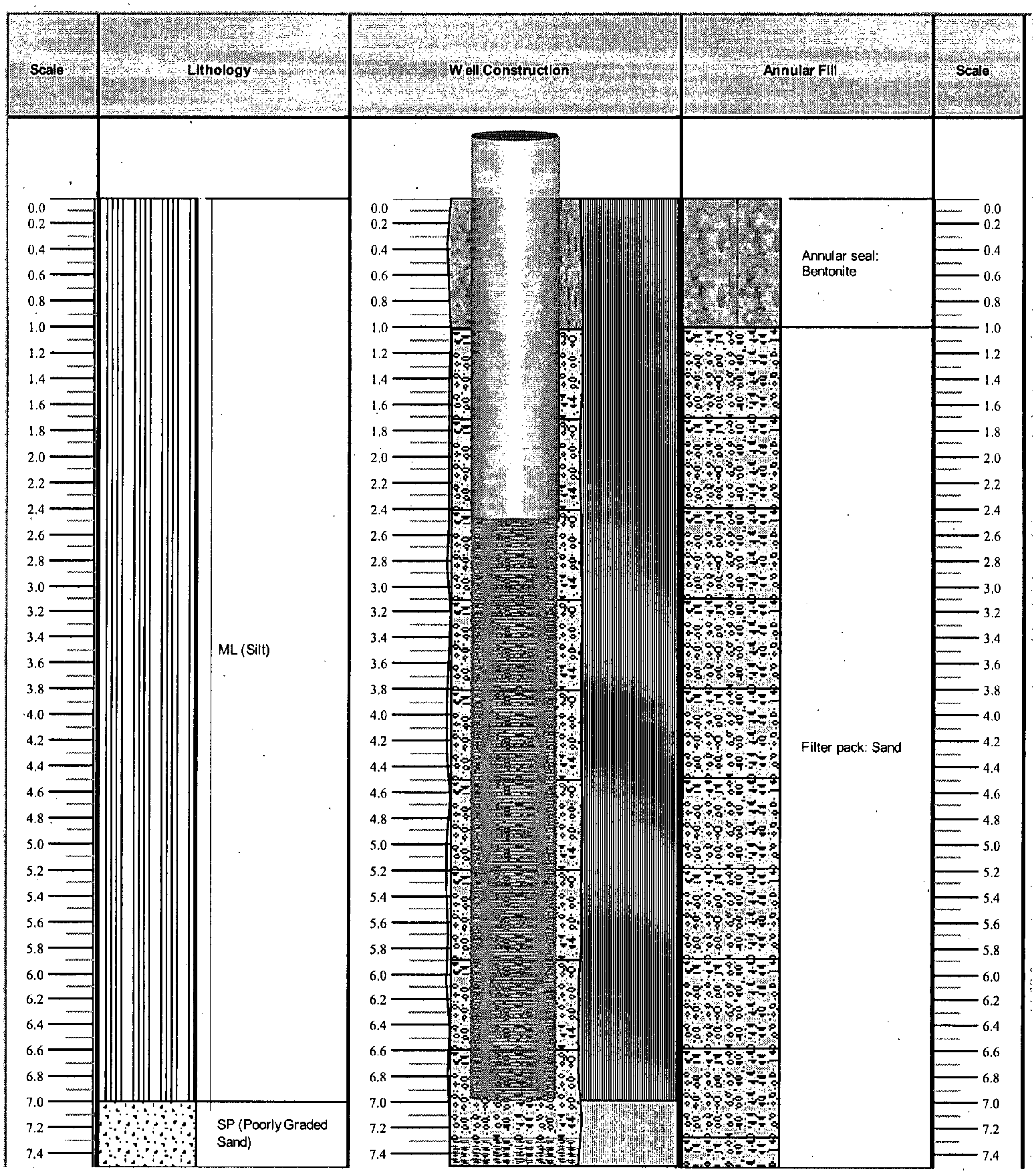
Monitoring Well I.D.: ESS-NC1

Monitoring Well Construction Report

Date: December, 2007



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Borehole / Monitoring Well I.D.: **ESS-NC2**

Date: December, 2007

Scale	Lithology		Field Description	Color	Moisture	Comments	Scale
0.0–7.0		ML (Silt)	Dark Grey Clay and SILT, wetland sediment	grey	High		0.0–7.0
7.0–7.8		SP (Poorly Graded Sand)	Grey Fine SAND	grey	Saturated		7.0–7.8

Scale: 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, 5.2, 5.4, 5.6, 5.8, 6.0, 6.2, 6.4, 6.6, 6.8, 7.0, 7.2, 7.4, 7.6, 7.8

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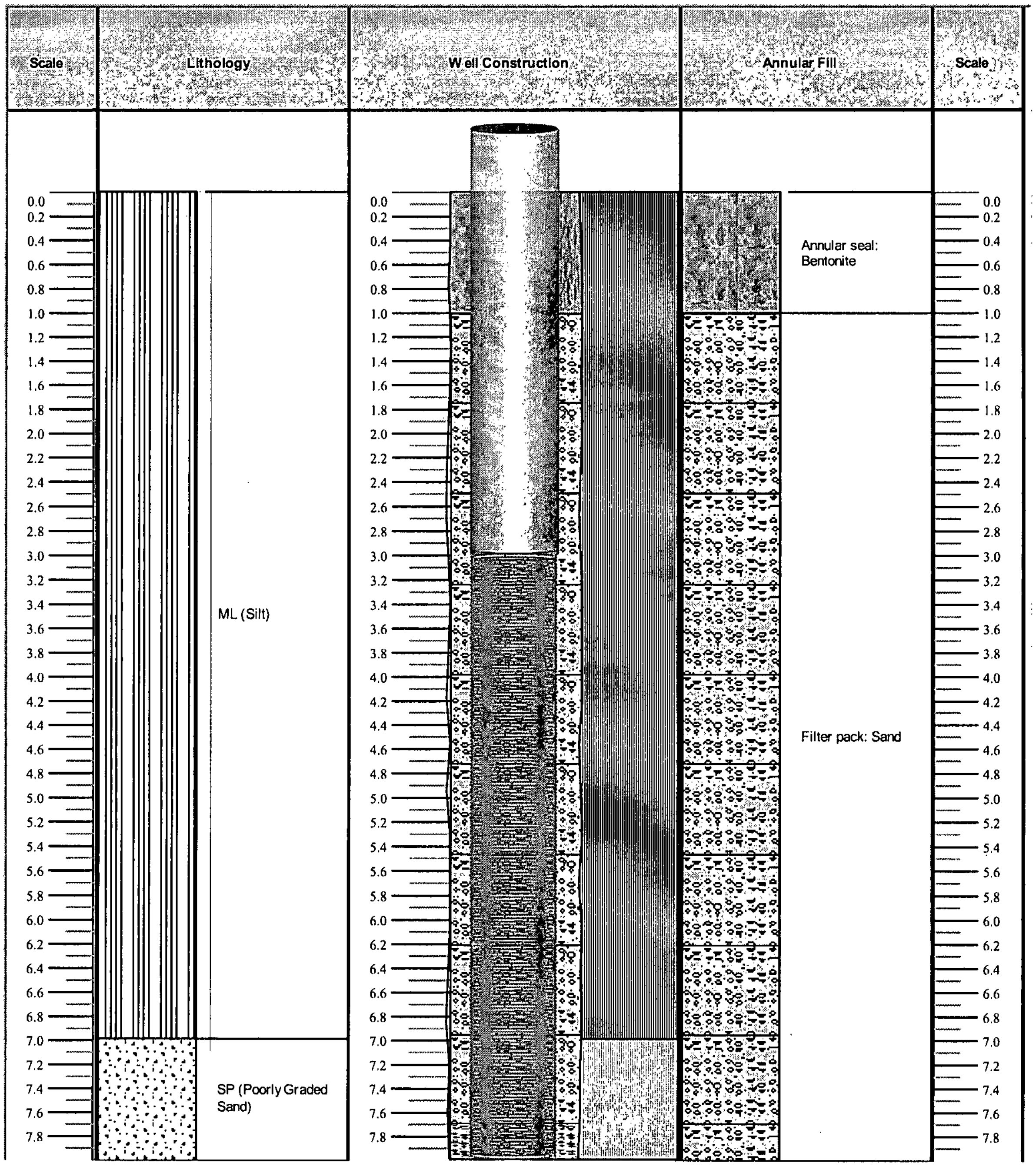
Drilled by: Geologic Exploration, Inc.

Monitoring Well I.D.: ESS-NC2

Monitoring Well Construction Report

Date: December, 2007



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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-NC3**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 7.0	ML (Silt)	Dark Grey Clay and Silt, wetland sediments	grey	High		0.0 – 7.0
7.0 – 7.8	SP (Poorly Graded Sand)	Grey Fine SAND	grey	Saturated		7.0 – 7.8

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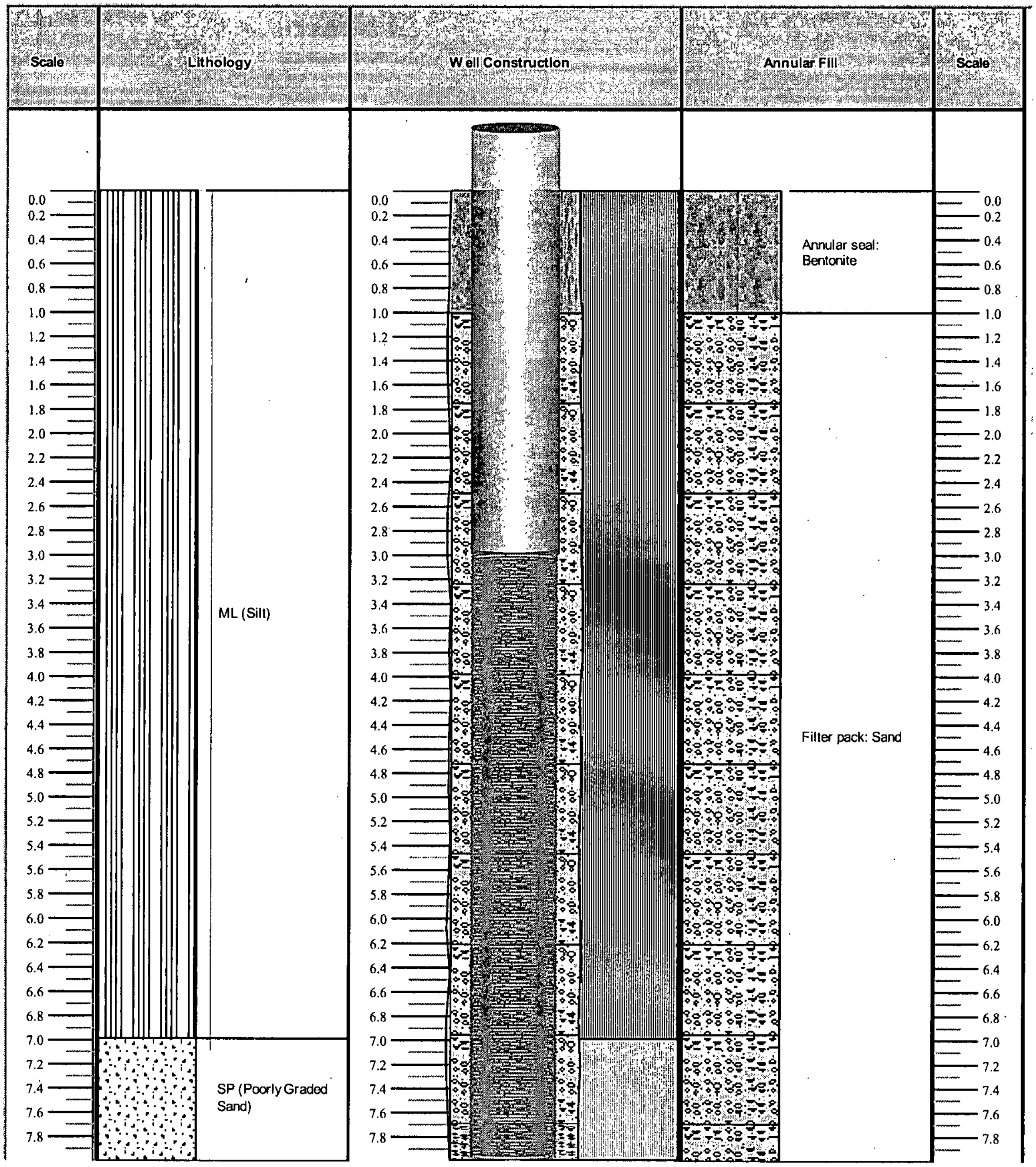
Drilled by: Geologic Exploration, Inc.

Monitoring Well I.D.: **ESS-NC3**

Date: December, 2007



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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-NC4**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0 5.2 5.4 5.6 5.8 6.0 6.2 6.4 6.6 6.8	ML (Silt)	Dark Grey Clay and Silt, wetland sediments	grey	High		0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0 5.2 5.4 5.6 5.8 6.0 6.2 6.4 6.6 6.8
7.0 7.2 7.4 7.6 7.8	SP (Poorly Graded Sand)	Whitish Med. SAND	white	High		7.0 7.2 7.4 7.6 7.8

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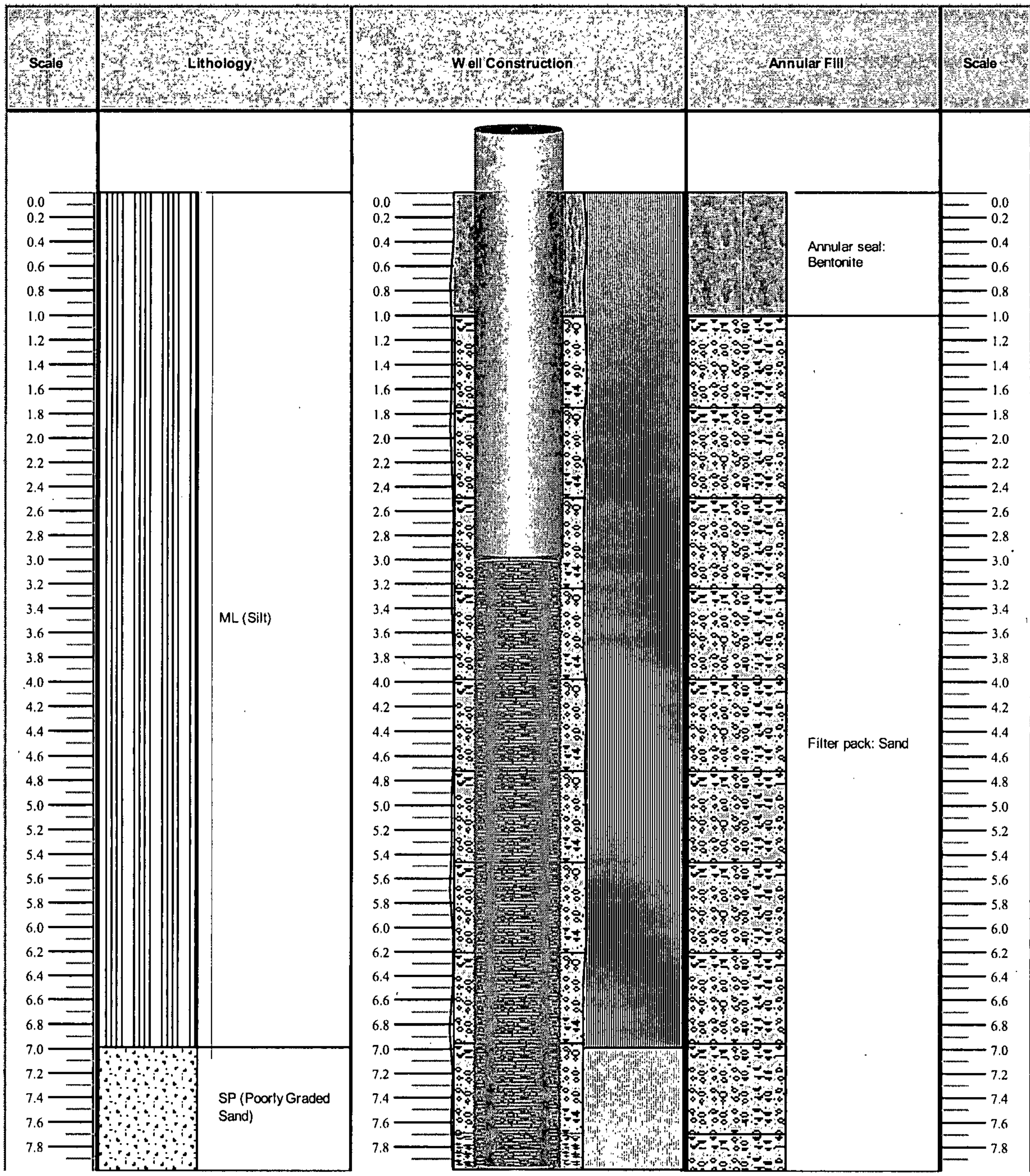
Monitoring Well I.D.: ESS-NC4

Monitoring Well Construction Report

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-NC5**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 7.5	ML (Silt)	Dark Grey Clay and Silt, wetland sediments	grey	High		0.0 – 7.5
7.5 – 7.6	SP (Poorly Graded Sand)	Dark Grey Fine Sand	grey	Saturated		7.5 – 7.6

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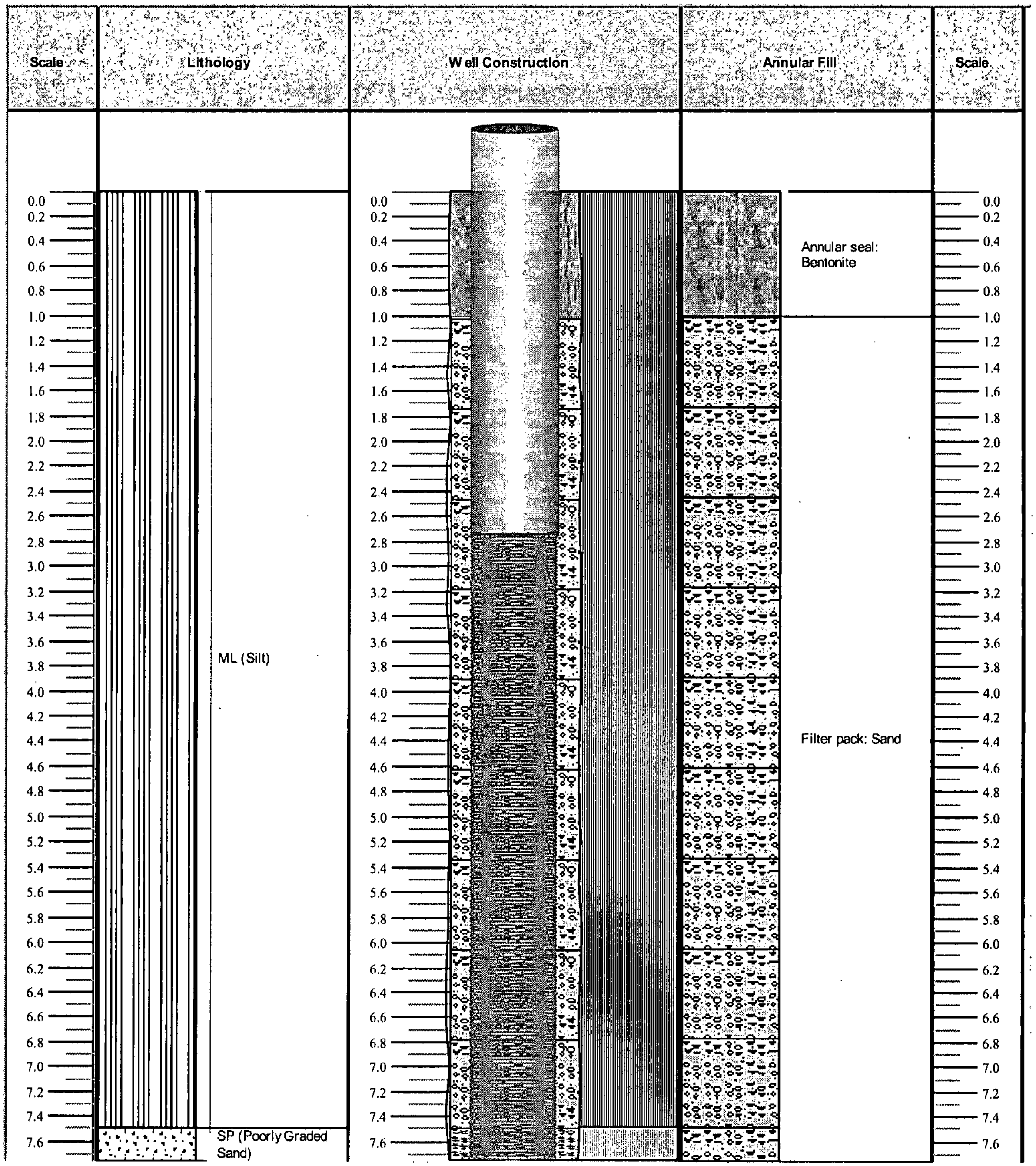
Drilled by: Geologic Exploration, Inc.

Monitoring Well I.D.: ESS-NC5

Monitoring Well Construction Report

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: **ESS-GLB1**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 7.5	ML (Silt)	Dark Grey Clay and Silt, wetland sediments	grey	Medium		0.0 – 7.5
7.5 – 8.0	SP (Poorly Graded Sand)	Dark Grey Fine Sand	grey	Saturated		7.5 – 8.0

Scale: 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, 5.2, 5.4, 5.6, 5.8, 6.0, 6.2, 6.4, 6.6, 6.8, 7.0, 7.2, 7.4, 7.6, 7.8

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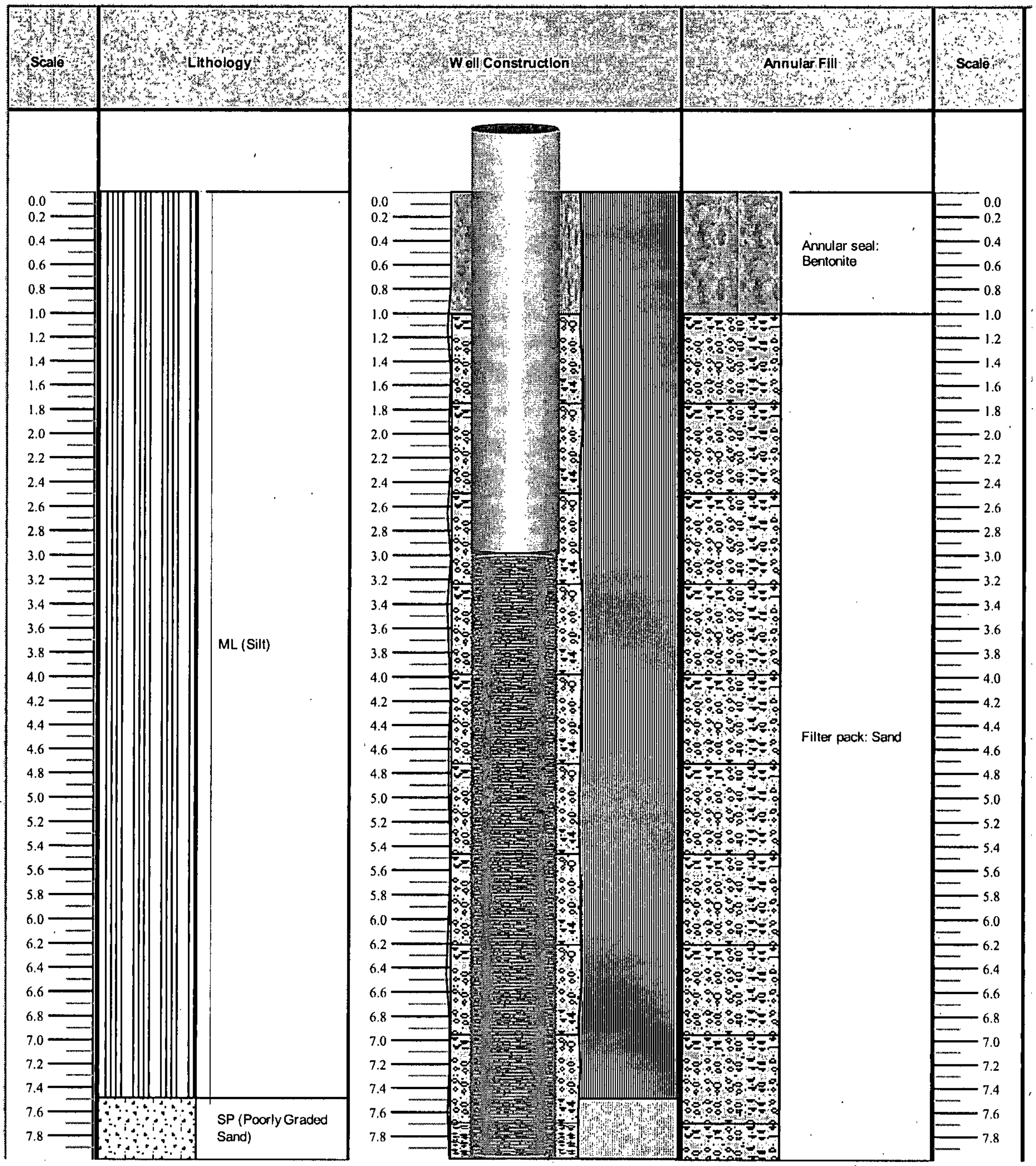
Drilled by: Geologic Exploration, Inc.

Monitoring Well Construction Report

Monitoring Well I.D.: ESS-GLB1

Date: December, 2007



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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-17B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
4–5	SC (Clayey Sand)	Olive green-dark Grey Fine to Med. Clayey SAND, glauconitic	Other	Low		4–5
9–10	SC (Clayey Sand)	Brownish Grey Clayey Fine SAND, organics on top of fat glauconitic clay with organics	grey			9–10
14–15	OH (Organic Clay/Silt of high plasticity)	Light Brown to Grey CLAY	grey			14–15
19–20	OH (Organic Clay/Silt of high plasticity)	Grey CLAY	grey	High		19–20
24–25	OH (Organic Clay/Silt of high plasticity)	Grey Clay	grey	High	Shelly	24–25
29–30	OH (Organic Clay/Silt of high plasticity)	Grey Clay, trace v. fine sand, shell fragments	grey	Medium	Trace shells	29–30
34–35	OH (Organic Clay/Silt of high plasticity)	Grey CLAY, increasing v. fine sand content, trace shells	grey		Trace Shells	34–35
39–40	OH (Organic Clay/Silt of high plasticity)	Interlayerred Grey CLAY, with v. fine sandy clay layers and shell fragments	grey	Medium	Trace shells	39–40
44–45	SC (Clayey Sand)	Interlayered Sandy Clay and Clayey Sand, shell fragments	grey	Medium	Trace shells	44–45
49–50	SP (Poorly Graded Sand)	Interlayered Course sand and Clay	grey	Medium		49–50
54–55	SP (Poorly Graded Sand)	Light Grey Med. Course SAND	grey			54–55

Scale: 0–55

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Borehole Log Report

Project: Brunswick Nuclear Plant
Groundwater Investigation, Storm Drain Stabilization Pond

Borehole / Monitoring Well I.D.: **ESS-17A**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0						0
5						5
10						10
15						15
20						20
25						25
30						30
35						35
40						40
45						45
50						50
55						55
60						60
65						65
70						70
75						75
80						80
85						85
90						90
95						95
100						100
105						105
110						110
115						115
120						120
125						125
130	Sandy Limestone	Peedee				130
135						135
140						140
145						145

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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-3B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–5	SP (Poorly Graded Sand)	Tan Sand with Shale fragments	brown			0–5
5–7	ML (Silt)	Dark Grey SILT	grey			5–7
7–15	SM (Silty Sand)	Green-Grey silty SAND, some clay	grey			7–15
15–30	SM (Silty Sand)	Interbedded dark Grey Green Silty SAND with shells and laminated silty clay	grey	Saturated		15–30
30–40	SM (Silty Sand)	Interbedded Grey Green Silty SAND with shells and laminated silty clay	grey	Saturated		30–40
40–43	OL (Organic Clay/Silt of low plasticity)	Dark Grey Green Laminated Silty CLAY with thin interbeds of fine med. grained sand	grey			40–43
43–54	SP (Poorly Graded Sand)	Grey Med. fine SAND	grey			43–54

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Borehole / Monitoring Well I.D.: **ESS-3C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 5.0	SP (Poorly Graded Sand)	tan SAND, some gravel and rock fragments, darkens with depth	brown	Medium		0.0 – 5.0
5.0 – 6.5	ML (Silt)	Dark Grey Sandy SILT	grey	Medium		5.0 – 6.5
7.0 – 15.5	SM (Silty Sand)	Green Grey Silty SAND and interbedded dark grey green silty clay and shell hash	grey	Saturated		7.0 – 15.5

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Borehole Log Report

Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: ESS-13

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0 – 14.5	SM (Silty Sand)	Interlayered Brown, Tan, and Grey Sandy Silt FILL	Other	Medium		0.0 – 14.5
14.5 – 15.5	SM (Silty Sand)	Light Grey sandy SILT	grey			14.5 – 15.5
15.5 – 18.5	ML (Silt)	dark Grey SILT, coarser below	grey	Saturated		15.5 – 18.5

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Project: Brunswick Nuclear Plant
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Borehole / Monitoring Well I.D.: **ESS-13B**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0–30						0–30
30–40	SM (Silty Sand)	Grey Silty Fine-Med. SAND grading to grey silt and fine sand		Saturated		30–40
40–45	SC (Clayey Sand)	Grey Clayey Fine SAND to Sandy Clay		Medium		40–45
45–56	SW (Well-graded Sand)	Grey Fine to Coarse SAND and some gravel		Saturated		45–56

Scale: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56

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Borehole / Monitoring Well I.D.: **ESS-13C**

Date: December, 2007

Scale	Lithology	Field Description	Color	Moisture	Comments	Scale
0.0–10.0	SM (Silty Sand)	Brown, Tan, and Grey Silty SAND and sandy Silt, interlayered	Other	Medium		0.0–10.0
10.0–15.0	SM (Silty Sand)	Tan to Brown Silty Fine SAND		Medium		10.0–15.0
15.0–20.0	SM (Silty Sand)	Grey Silt and Fine Sand	grey	Saturated		15.0–20.0
20.0–25.0	SM (Silty Sand)	Grey Fine Sandy Silt and shells	grey	Saturated		20.0–25.0
25.0–26.5	SM (Silty Sand)	Grey Fine Sandy Silt with shell fragments	grey	Saturated		25.0–26.5