ANNUAL GROUNDWATER MONITORING REPORT – 2007

BRUNSWICK NUCLEAR PLANT
STORM DRAIN STABILIZATION POND
SOUTHPORT, NORTH CAROLINA

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APRIL 2008

J-93

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TABLE OF CONTENTS

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

Silar Services Incorporated (SSi) has prepared this Annual Groundwater Monitoring Report to document the results of the quarterly groundwater monitoring program for the Storm Drain Stabilization Pond (SDSP) area of the Brunswick Nuclear Plant (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 this report is to provide technical information and verification with respect to the nature and extent of tritium impacts to groundwater including: documentation of the effectiveness of environmental monitoring systems, identification of site conditions that may affect mitigation efforts, and verification and modification of the Conceptual Site Model (CSM) presented in the Groundwater Investigation Report (March 2008). The work was performed in general accordance with Proposal for Quarterly Groundwater Monitoring Support and Reporting (SSi, January 2008) the "Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, 2001" (U.S. EPA), SSi and BNP Standard Operating Procedures, and the Site-Specific Health and Safety Plan.

The groundwater monitoring activities and 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 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 1800-feet northeast of the power generation plant, and occupies approximate 60 acres 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**. Note that this figure contains reference to both "true north" and "plant north". Plant north is a convention established at the time of design and construction of the facility and is the common means of reckoning used at the BNP. Therefore, this report will use "plant north" as the basis for discussion and the term north should be taken to mean "plant north" throughout.

The SDSP is surrounded by the following features:

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

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 1800 feet north of the power generating facility, and receives storm water from the BNP. Storm water is pumped from the storm drain collection basin (SDCB) within the plant area through a 12-inch HDPE pipe to the pond, where the water is naturally retained, biologically treated, and then discharged via a managed outfall under a current National Pollutant Discharge Elimination System (NPDES) Permit NC0007064. 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 southeastern 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 southern and western 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 southern edge of the SDSP promotes the flow of water to the west and then northeast 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 originally 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. 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 generating plant area to the SDSP via the storm water conveyance systems.

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.

1.3 SITE-SPECIFIC HYDROGEOLOGY

Site-specific hydrogeology at the Site was evaluated in the Groundwater Investigation Report (GIR) which discussed the three distinct 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 shallow surficial aquifer is an unconfined water-table aquifer;
- *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; and,
- *Deep Aquifer (Cretaceous Age):* The deep aquifer is a confined aquifer in the Peedee Formation.

1.3.1 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-NC-1 through ESS-NC-5, and ESS-GLB-1) were installed into the shallow surficial sand aquifer during the GIR 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 a low-permeability unit, which was encountered at all boreholes advanced at the Site. The low-permeability unit separates the shallow surficial aquifer and the intermediate aquifer that is below the low-permeability unit; however, there is some hydraulic and chemical exchange between the shallow and intermediate aquifers that occurs vertically through the low-permeability unit, as observed during well development/pumping (observed drawdown) and 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 and intermediate aquifer. 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.

1.3.2 Intermediate Aquifer

A network of seven (7) intermediate monitoring wells (ESS-18B through ESS-25B) was installed into the intermediate aquifer during the GIR to evaluate the direction of groundwater flow, hydraulic characteristics, and environmental conditions in the intermediate aquifer at the Site. The top of the sand unit in the intermediate aquifer is generally encountered at a depth of approximately -20 feet MSL, and extends to approximately -50 feet MSL. The intermediate aquifer also includes the underlying Castle Hayne Aquifer. Since there is no confining unit separating the Castle Hayne Aquifer and the overlying sand unit from a groundwater flow perspective, these two units behave as a single aquifer. 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.

1.3.3 Deep (Peedee) Aquifer

One monitoring well (ESS-24A) was installed in the Peedee Aquifer during the GIR 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 aquifer at the Site. 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 (USGS, 2003), and is a confined aquifer. The aquifer is confined by the overlying Peedee confining unit and underlying Black Creek Confining Unit.

1.3.4 Area Groundwater Use

One monitoring 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.

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.

2.0 GROUNDWATER MONITORING ACTIVITIES

A monthly groundwater monitoring and sampling program was initiated in August 2007 for the SDSP area. The program consists of collecting water level measurements and groundwater samples from a network of monitoring stations in the vicinity of the SDSP. The USEPA low-flow sampling methodology (EPA/540/S-95/504, April 1996) was selected for the SDSP monitoring program to provide consistent, highly representative groundwater samples. SSi performed groundwater sample collection in August 2007 using peristaltic pumps and submersible pumps and following the USEPA low-flow methodology. A Geosmart dedicated low-flow groundwater sampling system was installed in each SDSP monitoring well (except the "marsh" wells – see below) in September 2007 to facilitate the collection of high-quality, representative samples in general accordance with the low-flow sampling methodology. The Geosmart pump systems were specifically constructed for each well, and include a dedicated bladder pump (installed at the approximate mid-point between the static hydraulic head and the base of each well or at mid-screen) 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. SSi utilized these dedicated systems to collect groundwater samples from September through November 2007. Progress Energy (PE) and SSi developed a site-specific groundwater monitoring procedure (OE&RC-3250, Rev. 26) for the BNP and PE assumed responsibility for sample collection beginning in December 2007.

2.1 MONITORING NETWORK

Thirty-three (33) monitoring wells are utilized as part of the groundwater monitoring program for the SDSP. These include shallow, intermediate and deep groundwater monitoring networks as described below. Monitoring well locations for the shallow, intermediate and deep aquifers are depicted on **Figures 2-1 through 2-3**, respectively. Monitoring well construction details are provided in **Table 2-1**.

2.1.1 Shallow Groundwater Monitoring Well Network

The shallow groundwater monitoring well network consists of 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) installed in the vicinity of the SDSP; and, one (1) additional shallow permanent monitoring well, ESS-25C installed on the opposite site of the cooling water intake canal.

In addition to these sixteen (16) shallow monitoring wells installed near the SDSP, six (6) shallow wells (ESS-NC-1 through ESS-NC-5, and ESS-GLB-1) were installed along the edge of Nancy's Creek and Gum Log Branch in the tidal marsh locations depicted on **Figure 2-1**. The six "marsh wells" are evaluated separately to identify and characterize potential releases of tritium from the shallow aquifer into Nancy's Creek and Gum Log Branch.

2.1.2 Intermediate Groundwater Monitoring Well Network

The intermediate groundwater monitoring well network consists of seven (7) intermediate groundwater monitoring wells (ESS-18B through ESS-22B, ESS-24B, and ESS-25B) installed to evaluate groundwater conditions associated with the intermediate aquifer that is separated from the shallow aquifer by a low-permeability unit. The location of the intermediate monitoring well network is depicted on **Figure 2-2**.

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.

2.1.3 Deep Groundwater Monitoring Well Network

The deep monitoring well network consists of one deep monitoring well (ESS-24A), installed during the GIR, and 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). The three deep wells are constructed at an appropriate depth interval and spatially distributed to provide appropriate characterization of the groundwater conditions in the deep aquifer near the SDSP. Note that only groundwater elevation measurements and not analytical samples were collected from well ESS-13A as part of the investigation. The location of the deep monitoring wells is depicted on **Figure 2-3**.

2.1.4 Other Monitoring Points

Although not specifically included in the groundwater monitoring program, certain additional data that are periodically collected by Progress Energy are used to facilitate the discussion of the results of groundwater sampling. These include surface water samples collected from various waypoints within Nancy's Creek and Gum Log Branch as wells as samples collected of groundwater that has infiltrated into electrical manholes in the vicinity of the SDSP. These locations are shown on **Figure 2-1**. Data from these samples are not formally presented in this report since they were not collected as part of this program; however, as stated above, they are used for discussion purposes where appropriate. In addition, the BNP also collects meteorological and tide data at the facility and these data are also used where appropriate in the interpretation of groundwater data.

2.2 MONITORING PROCEDURES

This section describes the data collection activities.

2.2.1 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 in **Table 2-2**, and presented as potentiometric surface maps in Section 3.1.

2.2.2 Groundwater Sampling

The monthly groundwater monitoring and sampling activities were commenced in August, 2007. Five (5) rounds of monthly groundwater samples were collected for laboratory analyses from the SDSP monitoring wells between August and December 2007 as follows:

- Between August 2 and August 8, 2007 (SSi);

- Between September 12 and September 14, 2007 (SSi);
- Between October 16 and October18, 2007 (SSi);
- Between November 12 and November14, 2007 (SSi); and,
- Between December 10 and December 14, 2007 (PE).

The groundwater samples were analyzed for tritium by Progress Energy in the 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. Prior to installation of dedicated low-flow groundwater sampling systems in September 2007, samples were collected using submersible pumps and peristaltic pumps. The procedure for well purging and sampling was 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. A decontaminated submersible pump with dedicated Teflon tubing was lowered to the midpoint of the screened interval for intermediate and deep wells. For shallow wells (including marsh wells), dedicated sample tubing from the peristaltic pump was lowered to the midpoint of the screened interval.
3. The submersible pump was connected to a pump controller, the sample line was connected from the pump to the in-line water quality instrument (YSI MP556 with flow through cell), the pump was started, and purging of groundwater at the well was commenced.
4. An optimum pump rate was established and documented at each well on a well sampling form for each well. Groundwater quality parameters including pH, temperature, dissolved oxygen (DO), conductivity, and oxidation-reduction potential (ORP) and depth to water were monitored and recorded at prescribed time intervals to determine when the water quality parameters had stabilized to within 10%.

5. 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.

Sampling of the marsh wells followed the above procedure for all rounds. Following installation of the dedicated low-flow groundwater sampling systems in shallow, intermediate and deep wells, the procedure for well purging and sampling was 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 including temperature, conductivity and pH 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.

Purge water was collected in dedicated purge water containers and transported to the SDSP. Groundwater monitoring logs from each of the sampling rounds are included as **Appendix A**.

3.0 FINDINGS OF THE 2007 GROUNDWATER MONITORING PROGRAM

The following subsections present the results of groundwater samples collected during the initial five (5) months of the groundwater monitoring program (August through December 2007).

The United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL) for tritium is 20,000 pCi/L, which is a dose-based drinking water standard. The tritium MCL is generally used by State and Federal environmental regulators as the screening concentration for tritium identified in groundwater. The USEPA established a conservative groundwater radiological limit (standard) of 4 mrem (millirem) per year as a 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 to reflect 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 USEPA in the 1990s found that, based on improved intake models, the actual 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.

3.1 GROUNDWATER ANALYTICAL RESULTS SUMMARY

Groundwater samples were collected from all of the SDSP wells during each of the five (5) groundwater sampling events. **Tables 3-1 through 3-4** present analytical results from the five (5) groundwater sampling events for the shallow aquifer, marsh wells, intermediate aquifer, and deep aquifer, respectively. The nature and extent of tritium identified in groundwater samples is discussed below.

It should be noted that while trends are observed in the data to date, the sample set (five months of data at the tail end of a prolonged drought) is still quite small relative to the amount of time the SDSP has been in place (over 30 years). Key considerations in the evaluation of the data include the drought and the elimination of the air wash water from the SDCB. During the five (5) months of sampling at the Site, recorded rainfall at the site totaled 12.96 inches. According to the State Climate Office of North Carolina, normal rainfall for the five-month period from August through December is 28.1 inches. Only in October 2007 did the actual rainfall (4.42 inches) exceed the normal rainfall (3.87 inches). This drought condition would be expected to have several effects. The reduced rainfall would lower the overall quantity of water discharged to the SDSP, which would reduce the groundwater mounding effect within the SDSP, but would also reduce the dilution effect of the rainfall infiltrating within the SDSP. In June 2007, the BNP began directing the air wash water to rad waste rather than to the SDCB. This significantly reduced the tritium activity in the water discharged from the SDCB to the SDSP. **Figure 3-1** depicts the tritium activity measured in the SDCB during the period from July through December 2007. With the exception of one spike in early August 2007, average tritium activity in the SDCB has been less than 50,000 pCi/L during this period.

3.1.1 Shallow Surficial Aquifer - Groundwater Analytical Results

There are currently fifteen (15) permanent 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 2-1**. The shallow wells are distributed around the SDSP to provide an appropriate spatial distribution of data points to complete the monitoring objectives.

Groundwater samples were collected from each of the fifteen (15) shallow groundwater monitoring wells during each of the five (5) monthly sampling events in 2007. The analytical results of the groundwater samples are presented in **Table 3-1**, and are depicted on **Figures 3-2 through 3-6** for the months of August 2007 through December 2007, respectively.

Tritium was detected in 14 of the 15 wells at least once during the five (5) rounds of sampling. Tritium was not detected above the detection limit (roughly 300 pCi/L) in groundwater samples from shallow monitoring well ESS-25C, located across the cooling water intake canal, during any of the sampling rounds. Detected concentrations of tritium in the remaining shallow monitoring wells ranged from 306 pCi/L (ESS-28C in November 2007) to 787,800 pCi/L (ESS-22C in December 2007). Groundwater samples from seven (7) of the fifteen (15) shallow monitoring wells consistently exhibited tritium concentrations significantly above the USEPA MCL of 20,000 pCi/L indicated by **bold** text in **Table 3-1**. The highest concentrations of tritium in the shallow surficial aquifer are exhibited at ESS-18C, ESS-STAB, ESS-22C, ESS-26C and ESS-19C which are located to the immediate west and southwest of the SDSP. These data are supported by measurements taken of water samples collected from electrical manholes in the vicinity. Groundwater infiltrating these manholes is periodically sampled. Results from samples collected in December 2007, indicate that water in electrical manhole M.H. MW5 exhibited tritium at 213,000 pCi/L. This manhole is located near monitoring wells ESS-26C and ESS-27C. Water in electrical manhole M.H. MW6 exhibited tritium at 189,000 pCi/L. This manhole is located between monitoring wells ESS-23C and ESS-18C. It should be noted that the water sample collected from manhole M.H. MW3, located 600 feet southeast of M.H. MW-5, exhibited no detectable tritium activity.

Water level measurements were collected from the shallow monitoring wells as described in Section 2.2.1, above. 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.

Figure 3-7 and 3-8 illustrate the potentiometric surface of the shallow unconfined aquifer at the Site as measured during two events in October 2007. The direction of groundwater flow in the shallow unconfined aquifer is generally radial in the vicinity of the SDSP and is consistent between the rounds of water level measurements.

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 west and southwest 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 western 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 southwest and western area of the SDSP.

Figure 3-9 depicts concentrations trends in the shallow groundwater during the five months of sampling in 2007. In general, concentrations of tritium observed in the shallow groundwater monitoring well network were relatively consistent with a few exceptions. The tritium activity in groundwater at monitoring wells ESS-22C and ESS-19C each increased during the five-month period of sampling in 2007. Tritium in monitoring well ESS-22C increased from 556,100 pCi/L to 787,800 pCi/L and tritium in monitoring well ESS-19C increased from 355,000 pCi/L to 535,200 pCi/L. Further, tritium in monitoring well ESS-18C decreased from 750,500 pCi/L to 608,000 pCi/L. As shown on **Figure 3-9**, in August 2007, groundwater from monitoring well ESS-18C exhibited the highest tritium of all the shallow wells; however, by December 2007, the highest tritium was observed in groundwater from monitoring well ESS-22C and tritium in groundwater from monitoring well ESS-18C was less than that in monitoring wells ESS-26C and ESS-STAB.

3.1.2 Marsh Wells Groundwater Analytical Results

There are six (6) shallow monitoring wells installed along Nancy's Creek and Gum Log Branch at locations shown on **Figure 2-1**. 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 five (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. This is evidenced by the conductivity readings collected during groundwater purging activities, which were generally an order of magnitude higher in the marsh wells than the nearby shallow wells. 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 for the marsh wells are presented in **Table 3-2**. During the five (5) 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-NC-4 (ESS-NC-4-2) at a concentration of 314 pCi/L. ESS-NC-4 is located down gradient of monitoring wells ESS-19B/C. Based on the detection of tritium in this well, it is assumed that tritium is likely intermittently discharging to Nancy's Creek; however, due to the likelihood of dilution discussed above, the data collected in the marsh wells may be underestimating the concentration of tritium in groundwater that may be entering the creek. A number of waypoints along Nancy's Creek are periodically sampled by Progress Energy (**Figure 2-1**). Samples from several of these locations have intermittently exhibited tritium at levels just above the detection limit. These include Waypoints WP-52 (located at the mouth of Gum Log Branch/Nancy's Creek), WP-53, and WP-55 located near marsh well ESS-NC4). Tritium detected in these samples ranged from 251.5 pCi/L to 327.5 pCi/L.

3.1.3 Intermediate Aquifer - Groundwater Analytical Results

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

Groundwater samples were collected from all eight (8) intermediate groundwater monitoring wells during each of the five (5) monthly sampling events in 2007. The analytical results of the groundwater samples are presented in **Table 3-3**, and are depicted on **Figure 3-10**.

Tritium has been detected in three (3) of the eight (8) wells at least once during the first five (5) rounds of sampling (ESS-17B, ESS-19B and ESS-21B). None of the wells exhibited a concentration of tritium exceeding the drinking water standard. Tritium has not been detected in intermediate wells ESS-18B, ESS-20B, ESS-22B, ESS-24B, and ESS-25B (which is located across the cooling water intake canal).

Groundwater samples from monitoring wells ESS-17B and ESS-21B each exhibited tritium during only one event – September 2007 and October 2007, respectively. Groundwater samples from monitoring well ESS-19B exhibited detected concentrations of tritium during all five (5) monthly events with the detected concentrations ranging from 2,851 pCi/L (September 2007) to 7,195 pCi/L (December 2007).

Water level measurements were collected from the intermediate monitoring wells as described in Section 2.2.1, above. 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.

Figures 3-11 and 3-12 illustrate the potentiometric surface of the intermediate aquifer at the Site during the two events in 2007. 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 east toward the cooling water intake canal and the Atlantic Ocean. It is possible; however, that groundwater in the intermediate aquifer flows to the west in the area of ESS-18B and ESS-19B. No groundwater elevation data is present to the west of these monitoring points to refute or confirm this local flow direction. USGS information indicates a regional east groundwater flow in this unit.

Figure 3-13 depicts concentration trends in the intermediate groundwater during the five (5) months of sampling in 2007. Data for tritium in monitoring well ESS-19B are relevant. An increase in the concentration of tritium observed in ESS-19B is apparent. As shown in **Figure 3-9**, concentrations of tritium in shallow ground water observed in monitoring well ESS-19C also displayed an increasing (although less pronounced) trend. This data is consistent with the apparent downward vertical gradient between the shallow and intermediate aquifers. If this trend continues, it is possible that tritium levels at monitoring well ESS-19B could exceed the USEPA MCL in the future.

3.1.4 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 2-3.** 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 meet the monitoring objectives.

Groundwater samples were collected from each of the three (3) deep groundwater monitoring wells during each of the five (5) monthly sampling events in 2007. The analytical results of the groundwater samples are presented in **Table 3-4**.

Tritium was not detected in groundwater samples from any of the deep monitoring wells during the five (5) rounds of sampling in 2007.

Figure 3-14 and **Figure 3-15** illustrate the potentiometric surface of the deep aquifer on 10/02/2007 and 10/16/2007. The direction of groundwater flow is generally east toward the Atlantic Ocean. As shown in the figures, the direction of groundwater flow is very consistent between the two events. Additionally, there do not appear to be any hydrologic influences on the deep aquifer resulting from the SDSP.

4.0 CONCLUSIONS

The groundwater monitoring activities have provided sufficient data to confirm the conceptual site model (CSM) of the study area as described in the GIR. The source of tritium in groundwater in the study area 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 intermediate aquifer via migration in groundwater. Tritium is present above applicable regulatory standards in shallow groundwater around the SDSP and detected in certain surface water samples collected by Progress Energy from the marine estuary. Tritium has also been identified at concentrations below applicable regulatory standards in three intermediate wells, which are installed in the intermediate aquifer locally and regionally used as the source of drinking water.

Overall concentrations in the shallow aquifer have remained relatively constant; however, certain individual wells have exhibited apparent concentration increases over the reporting period. Tritium has exhibited increasing concentrations in groundwater collected from monitoring wells ESS-22C and ESS-19C and decreasing concentrations in groundwater collected from monitoring well ESS-18C. SSi recommends that the data for future rounds of sampling be used to evaluate these concentration patterns. Overall, the well network for the shallow aquifer is currently sufficient to meet the objectives of the monitoring program.

Sporadic and minimal impact has been observed to date in groundwater collected from the marsh wells and the sporadic observations of tritium at waypoint locations in Nancy's Creek sampled by Progress Energy are of concern. The marsh well data from future rounds should be evaluated carefully. SSi recommends that future rounds of sampling from both the shallow and marsh wells be coordinated with Progress Energy's sampling of the waypoints as well as with the tide cycle.

For the intermediate aquifer, the increase in tritium activity measured at ESS-19B is a concern. This data is consistent with the downward vertical gradient between the shallow and intermediate aquifers. If this trend continues, it is possible that tritium levels at monitoring well ESS-19B could exceed the USEPA MCL in the future. SSi recommends that Progress Energy consider expanding the network of intermediate wells in order to better monitor this trend and potential migration within the intermediate aquifer and to gain a better understanding of the hydrogeology of the intermediate aquifer.

No impact has been observed to date in the deep aquifer. This is consistent with the current understanding of the hydrogeology of the site. The deep aquifer monitoring network is believed to be sufficient at this time and SSi recommends continuing the monthly monitoring program.

Finally, the results of the monitoring conducted in 2007 support the conclusions of the GIR and the need to implement the recommendations of that report.

5.0 REFERENCES

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TABLES

FIGURES

APPENDIX A