2.4 HYDROLOGIC ENGINEERING

This section of the U.S. EPR FSAR is incorporated by reference with the following departures and supplements.

2.4.1 Hydrologic Description

The U.S. EPR FSAR includes the following COL Item for Section 2.4.1:

> A COL applicant that references the U.S. EPR design certification will provide a site-specific description of the hydrologic characteristics of the plant site.

This COL Item is addressed as follows:

{This section identifies the interface of CCNPP Unit 3 with the hydrosphere. It also identifies the hydrologic causal mechanisms that will establish the design basis with respect to floods and water supply requirements. Information on surface water and ground water uses that may be affected by plant operation is also included in this section.

References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.1.1 through 2.4.1.3 are added as a supplement to the U.S. EPR FSAR.

2.4.1.1 Site and Facilities

The CCNPP site covers an approximate area of 2,057 acres (832 hectares). It is located on the western shore of the Chesapeake Bay in Calvert County, MD near Maryland State Highway (MD) 2/4, approximately 110 mi (177 km) north from the Chesapeake Bay entrance.

The topography at the CCNPP site is gently rolling with steeper slopes along stream banks. Local relief ranges from the sea level up to an approximate elevation of 130 ft (39.6 m), with an average relief of approximately 100 ft (30.5 m). Along the northeastern perimeter of the CCNPP site, the Chesapeake Bay shoreline consists mostly of steep cliffs with a narrow beach area. The CCNPP site is well drained by short, ephemeral streams. A drainage divide, which is generally parallel to the shoreline, extends across the CCNPP site. The area to the northeast of the divide, which lies within Maryland Western Shore Watershed, comprises about 20% of the CCNPP site property and drains into the Chesapeake Bay. The southwestern area within the Patuxent River Watershed is drained by tributaries of Johns Creek, which flow into St. Leonard Creek, located west of (MD) 2/4, and subsequently flow into the Patuxent River. The Patuxent River empties into the Chesapeake Bay approximately 10 mi (16.1 km) to the southeast from the mouth of St. Leonard Creek. All streams that drain the CCNPP 3 site that are located east of (MD) 2/4 are non-tidal. Figure 2.4-1 shows the topography of the site, the local drainage routes near the CCNPP site and the drainage divide. The characteristics of the watersheds are described in Section 2.4.1.2.1.

Southeast of the existing CCNPP Units 1 and 2 is an abandoned recreational area known as Camp Conoy that was used by CCNPP employees and their families. The Calvert Cliff State Park is located further to the southeast outside of the CCNPP property boundary. The Flag Ponds Nature Park is located northwest of the CCNPP site.

CCNPP Unit 3 will be located southeast of and adjacent to CCNPP Units 1 and 2 as shown in Figure 2.4-1 and Figure 2.4-2. In the western shore, Maryland's Critical Area Commission law requires a 1,000 ft (305 m) critical area along the Chesapeake Bay shoreline (CAC, 2006). The CCNPP Unit 3 power block will be located outside the critical area.

CCNPP Unit 3 will use a hybrid mechanical draft cooling tower for plant non-safety-related Circulating Water System (CWS) cooling and the makeup water will be supplied from the Chesapeake Bay. The CWS makeup water intake will be located approximately 500 ft (152.5 m) southeast of the existing CCNPP Units 1 and 2 intake structure as shown in Figure 2.4-2. Four safety-related Essential Service Water System (ESWS) cooling, mechanical draft cooling towers will also be used. The makeup water for the ESWS cooling towers will normally be supplied from the non-safety-related raw water system (i.e., desalinization plant).

ESWS cooling tower basins will also provide storage for the Ultimate Heat Sink (UHS) cooling water for use during design basis accidents (DBA). The ESWS tower basin inventory will provide cooling water for safety-related heat removal for the first 72 hours during a DBA. UHS makeup water after the first 72 hours of the DBA will be supplied directly from the Chesapeake Bay. The CCNPP Unit 3 safety-related UHS makeup water intake structure will be located southeast of the CCNPP Units 1 and 2 intake structure, as shown in Figure 2.4-2. The Unit 3 intake forebay will have an invert elevation of -22.5 ft (-6.9 m) and vertical side walls with a top elevation of approximately 11.5 ft (3.5 m) to provide water to the UHS makeup water intake structure. Makeup water will be conveyed to the Unit 3 forebay by two safety-related buried pipes that will withdraw water from the Chesapeake Bay at an inlet area located adjacent to the Units 1 and 2 intake forebay. The inlet area will be sheltered from the Chesapeake Bay by the Units 1 and 2 forebay baffle wall and a sheet pile wall. The sheet pile wall will extend from the shore to the southern corner of the baffle wall, as shown in Figure 2.4-49. The UHS makeup water intake structure will share the forebay with the nonsafety-related CWS makeup water intake structure. The deck of the UHS intake structure will be at approximately elevation 11.5 ft (3.5 m).

The UHS makeup water will be pumped to the safety-related ESWS (UHS) cooling tower basins via buried safety-related piping.

At the CCNPP Unit 3 power block site, the existing elevations will be re-graded for safety-related structures, systems and components (SSCs). Safety-related SSCs for CCNPP Unit 3 include the following: nuclear island (consisting of the reactor building, safeguard buildings, and the fuel building), two emergency diesel generator buildings, and the ESWS (UHS) cooling towers. The safety-related SSCs in the power block area will be contained within the protected area boundary, which is shown in Figure 2.4-2. Access to safety-related SSCs within the protected area boundary will be located at or above the elevation of 84.6 ft (25.8 m).

The CCNPP Unit 3 power block will be located in the Maryland Western Shore Watershed, as shown in Figure 2.4-1 and Figure 2.4-2. The CWS cooling tower and the CCNPP Unit 3 switchyard will be located in the Patuxent River watershed. The CCNPP Unit 3 power block area will affect the headwaters of the unnamed branch, Branch 2, as shown in Figure 2.4-1 and Figure 2.4-2. To the southeast of the CCNPP Unit 3, an area including the headwaters of Branch 1 and portions of the Camp Conoy Pond will be re-graded for use as construction laydown. The CWS cooling tower and the CCNPP Unit 3 switchyard will affect the unnamed branch, Branch 3, in the Patuxent River Watershed. Post-construction drainage from the CCNPP Unit 3 power block area will be directed towards the Chesapeake Bay, while drainage from the CWS cooling towers and the CCNPP Unit 3 switchyard will be directed to Johns Creek, as discussed in Section 2.4.2.3. Details of the post-construction site drainage design will be developed during the detailed design phase.

The critical flood elevation at the CCNPP Unit 3 power block area results from flooding due to local probable maximum precipitation (PMP). The maximum computed PMP water elevation in the power block area is discussed in Section 2.4.2. The elevations of safety-related SSC entrances and openings will be at or above 84.6 ft (25.8 m). This will be higher than the local PMP elevation; thus, flooding of the safety-related SSCs in the CCNPP Unit 3 power block area is precluded.

Probable maximum surge and seiche flooding on the Chesapeake Bay constitutes the design basis flood elevation for the safety-related UHS makeup water intake structure. The probable maximum storm surge (PMSS) water level is estimated to be 17.6 ft (5.35 m) in Section 2.4.5. Coincidental wind-wave action will produce a maximum water level of 33.2 ft (10.11 m). Because the deck elevation of the UHS intake structure will be about 11.5 ft (3.5 m) and the roof elevation of the entire first level of the UHS makeup water pump house building will be at about 26.5 ft (8.1 m), the intake deck and the first level of the UHS makeup water pump house building will be submerged. The CCNPP Unit 3 UHS makeup water intake structure will include protection measures against flooding and wind-wave impact as discussed in Section 2.4.10.

The design low water level in the Chesapeake Bay at the inlet of the intake pipes is estimated to be -6.0 ft (-1.8 m) as discussed in Section 2.4.11. The general arrangement of the UHS makeup water intake structure is described in Section 9.2.5. The invert elevation of the UHS makeup water intake pump sump will be set at -22.5 ft (-6.9 m) to ensure that the available water depth under the minimum design water level will be adequate to satisfy the pump submergence and the net positive suction head requirements, taking into account the head losses in the intake pipes and screens.

2.4.1.2 Hydrosphere

2.4.1.2.1 Hydrological Characteristics

The CCNPP Unit 3 site is located on the Calvert peninsula within the Chesapeake Bay watershed. The Chesapeake Bay constitutes the main water body influencing the siting of CCNPP Unit 3. The Chesapeake Bay, having a watershed area in excess of 64,000 mi2 (165,700 km^2), is the largest estuary in the U.S.

The Calvert peninsula is formed by the Chesapeake Bay to the east and the Patuxent River to the west. It has a width of approximately 5 mi (8 km) near the CCNPP site. The Patuxent River flows near the CCNPP site from the northwest to the southeast direction. Drainage in the vicinity of the CCNPP site includes several small streams and creeks, which fall within two sub-watersheds of the Chesapeake Bay with the drainage divide running nearly parallel to the shoreline. These sub-watersheds include the Patuxent River Watershed and the Chesapeake Bay Sub-watershed (CBP, 2006). Figure 2.4-3 (USGS, 2005) shows the Chesapeake Bay watershed and sub-watersheds along with the CCNPP site location.

2.4.1.2.1.1 Maryland Western Shore Watershed

The Maryland Western Shore Watershed has a total area of approximately 1,670 mi2 (4,325 km2) (CBP, 2006), most of which is located in the northern part of the watershed, as shown in Figure 2.4-3. In the southern part, the watershed becomes a narrow strip along the Chesapeake Bay shoreline, referred to as the Lower Western Shore Basin, which drains water directly to the Chesapeake Bay from approximately 305 mi2 (790 km2) (MDNR, 2006a) of land. Large water bodies in the lower basin include the Magothy, Severn, South, West, and Rhode Rivers. The Lower Western Shore Basin is a varied landscape that includes the highly developed areas of Annapolis and the Route 2 corridor, along with miles of Chesapeake Bay shoreline and farmland that stretches into Calvert County. At the CCNPP site, this part of the watershed includes steep cliffs along the Chesapeake Bay shoreline. It is drained by two unnamed creeks, Branch 1 and Branch 2, located east of CCNPP Unit 3 as shown in Figure 2.4-1.

2.4.1.2.1.2 Patuxent River Watershed

The Patuxent River is the largest river completely contained in Maryland, draining an approximate area of 932 mi^2 (2,414 km^2) as shown in Figure 2.4-3. This area includes portions of St. Mary's, Calvert, Charles, Anne Arundel, Prince George's, Howard, and Montgomery Counties (MDNR, 2006b). The Patuxent River watershed is divided into four sub-watersheds:

- Upper Patuxent River watershed
- Western Branch Patuxent River watershed
- Middle Patuxent River watershed
- Lower Patuxent River watershed

The Lower Patuxent River watershed, which includes a portion of the CCNPP site, lies entirely in the Coastal Plain physiographic province.

The river basin is situated between the two large metropolitan areas of Baltimore and Washington, DC. Consequently, the watershed has gone through significant suburban development in the past few decades. Present land use in the basin is approximately 44% forest, 30% urban, and 26% agriculture (MDNR, 2006b).

The Lower Patuxent River Watershed within Calvert County is approximately 174 mi^2 (451 km^2) in area. It covers over 50% of land in the county. The major rivers and creeks contributing to the watershed are the Patuxent River, Hunting, Hall, St. Leonard, and Battle Creeks (CWP, 2004). The main stem of the Patuxent River is influenced by tidal fluctuation in the Chesapeake Bay. The tidal influence is observed over nearly the entire length of the river in the lower watershed with the head of tide located south of Bowie, MD.

The U.S. Geological Survey (USGS) maintains a network of stream gauging stations on the rivers draining to the Chesapeake Bay, including the Patuxent River. The USGS gauging station on the Patuxent River that is closest to the site is located at Bowie, MD (USGS Station No. 01594440), approximately 60 mi (96.6 km) upstream from the river mouth (USGS, 2006a). The drainage area at the gauging station is 348 mi2 (901 km2), which is approximately 37% of the total drainage area of the Patuxent River. The station is located in the non-tidal reach of the river. The Patuxent River contributes slightly over one percent of the total streamflow delivered annually from the catchment of the Chesapeake Bay Basin (USGS, 1968). USGS records streamflow data on a water year basis, which starts on October 1st and ends on September 30th of the next year (water year). The nearest dam and reservoir, the Rocky Gorge Dam and Howard Duckett Reservoir, is located approximately 21 mi (33.8 km) upstream of the gauging station, and the streamflow may have been affected by this water control structure. A description of the reservoirs and associated dams is provided in Section 2.4.1.2.2.

The gauge at Bowie, MD has recorded continuous streamflow data from June 27, 1977 to date. The highest daily flow at this station was estimated to be 8,860 cfs on January 27, 1978. The lowest daily flow of 56 cfs (1,586 lps) was observed between September 17, 18, and 19, 1986, and an instantaneous low flow of 32 cfs (0.9 cms) was observed at this location on August 9, 1966 (USGS, 2006c). The lowest recorded 7 day flow is 57 cfs (1.6 cms), as reported on September 15, 1986 (USGS, 2006c).

Monthly streamflows and mean, maximum and minimum daily streamflows at Bowie, MD are presented in Table 2.4-1 through Table 2.4-4. Mean monthly streamflow discharges are also presented in Figure 2.4-4 along with the maximum and minimum monthly values. While the mean of monthly values show highest flow discharge in March, the maximum values indicate that maximum monthly streamflows may arrive in any month between December and June. The maximum mean monthly streamflow shows an upper limit of approximately 1,350 cfs (38.2 cms) consistently for several months.

The Lower Patuxent River Watershed in Calvert County, MD is further subdivided into 13 sub-watersheds (CWP, 2004), as shown in Figure 2.4-5. Part of the CCNPP site is located within the St. Leonard Creek sub-watershed, which has an area of approximately 35.6 mi^2 (92.2 km^2) (CWP, 2004). Streams and water courses in the sub-watershed include St. Leonard Creek and its tributaries, including the Perrin Branch, Woodland Branch, Planters Wharf Creek, Johns Creek and its tributaries, Grovers Creek, Rollins Cove, and Grapevine Cove. The combined flow from these streams discharges to the Patuxent River through St. Leonard Creek. The other notable streams in this sub-watershed are Mears Creek and Helen Creek, which directly discharge to the Patuxent River.

The USGS had a gauging station on St. Leonard Creek (USGS Station No. 01594800), which operated from 1957 to 1968 and from 2000 to 2003 (USGS, 2006c). The gauging station has a drainage area of 6.73 mi^2 (17.4 km^2) comprising approximately 19% of the St. Leonard Creek sub-watershed area. The highest peak flow at this station was recorded as 288 cfs (8.1 cms) on July 30, 1960. The maximum daily flow was recorded to be 140 cfs (3.9 cms) on August 25, 1958 (USGS, 2003a). The station recorded no flow several times during 1966, 2002, and 2003 with the minimum daily and instantaneous low flow of 0 cfs (0 cms) (USGS, 2003a). The lowest recorded 7-day flow is 0 cfs (0 cms), as reported on August 24, 1966 (USGS, 2003a).

Monthly streamflows and mean, maximum and minimum daily streamflows near St. Leonard, MD are presented in Table 2.4-5 through Table 2.4-8. Mean monthly streamflow discharges are also presented in Figure 2.4-6 along with the maximum and minimum monthly values. It shows that the maximum monthly discharge at this location occurs in April and May.

2.4.1.2.1.3 The Chesapeake Bay Estuary

The Chesapeake Bay is one of the largest and most productive estuarine systems in the world. The Chesapeake Bay main stem, defined by tidal zones, is approximately 195 mi (314 km) long from its entrance at the Atlantic Ocean near Norfolk, VA to the mouth of the Susquehanna River near Havre de Grace, MD. At the northern end, the estuary is connected to the Delaware Bay through the Chesapeake Bay and Delaware Canal. The Chesapeake Bay varies in width from about 3.5 mi (5.6 km) near Aberdeen, MD to 35 mi (56.3 km) at the widest point near the mouth of the Potomac River, with an approximate width of 6 mi (9.7 km) near the CCNPP site. It has an open surface area of nearly 4,480 mi^2 (11,603 km^2), and including its tidal estuaries, has approximately 11,684 mi (18,804 km) of shoreline (USGS, 2003b) (CBP, 2004a).

On average, the Chesapeake Bay holds more than 18 trillion gallons (6.8E+13 liters) of water (CBP, 2004a). Although the bay's length and width are dramatic, the average depth, including tidal tributary channels, is only about 21 ft (6.4 m). The Chesapeake Bay is shaped like a shallow tray, except for a few deep troughs believed to be paleo channels of the Susquehanna River. The troughs form a deep channel along much of the length of the Chesapeake Bay. This channel allows passage of large commercial vessels. Because it is so shallow, the Chesapeake Bay is far more sensitive to temperature fluctuations and wind than the open ocean. The Chesapeake Bay is irregular in shape and is long enough to accommodate one complete tidal wave cycle at all times.

The main stem of the bay is entirely within Maryland and Virginia. Nearly 50 rivers, with thousands of tributary streams and creeks, drain an area in excess of 64,000 mi^2 (165,759 km^2) forming the Chesapeake Bay Basin (CBP, 2004a). The basin contains more than 150,000 stream miles in the District of Columbia and parts of six states: New York, Pennsylvania, Maryland, Virginia, West Virginia, and Delaware as shown in Figure 2.4-3. Nine rivers, including the Susquehanna, Patuxent, Potomac, Rappahannock, York (including its Mattaponi and Pamunkey tributaries), James, Appomattox, and Choptank, contribute over 90% of the Chesapeake Bay's mean annual freshwater inflow (USGS, 2003b). The Susquehanna River, the largest river entering the Chesapeake Bay, drains nearly 43% of the basin and normally contributes about 50% of the freshwater reaching the Chesapeake Bay. Approximately 80% to 90% of the freshwater entering the Chesapeake Bay comes from the northern and western portions of the basin. The remaining 10% to 20% is contributed by the eastern shore (CBP, 2004b). Although the Chesapeake Bay lies totally within the Atlantic Coastal Plain Physiographic Province, the watershed includes portions of the Piedmont Province and the Appalachian Province, which provide a mixture of waters to the bay with variable geochemical and sediment origins.

Flow circulation in the Chesapeake Bay is mainly governed by astronomical tides entering the bay through the bay mouth near Norfolk, VA; gravitational flow due to freshwater inflow from the rivers; and wind-driven and atmospheric pressure-driven circulation. The effect of these physical processes is further impacted by the irregular Chesapeake Bay shape and bathymetry variation. The combined interaction of these physical processes also causes a varying degree of tidal water mixing to produce different salinity zones over the Chesapeake Bay length.

The USGS provides estimates of monthly freshwater inflow to the Chesapeake Bay based on a methodology (USGS, 1968) that uses index stream gauging data from the Susquehanna, Potomac, and James Rivers (USGS, 2007). Estimated monthly freshwater inflow to the bay for a period from 1951 to 2000 is provided in Table 2.4-9. An average annual freshwater inflow to the Chesapeake Bay for the period of record is estimated to be approximately 77,500 cfs (2,200 cms).

Tides enter the Chesapeake Bay primarily through the southern entrance from the Atlantic Ocean and propagate upstream. The modifications of tidal characteristics and tidal circulation within the bay are dependent on the width, depth, and configuration of the estuarine basins and tributaries. In the Chesapeake Bay, the mean tidal range in the bay varies from approximately 2.55 ft (0.78 m) near the Atlantic Ocean entrance (Chesapeake Bay Bridge Tunnel, VA), decreasing to approximately 1.04 ft (31.7 cm) near Cove Point, MD near the CCNPP site, and increasing to nearly 1.9 ft (57.9 cm) near the northern head waters (Havre De Grace, MD) (NOAA, 2007). Due to the effects of Coriolis force, the tidal range is higher on the eastern shore than the western shore. The tidal range generally increases as the tidal wave propagates through the tributary rivers. The mean tidal range near the entrance of the Patuxent River (Solomons Island, MD) is about 1.17 ft (35.7 cm), while the range at the upstream stations Lower Marlboro, MD is 1.79 ft (54.6 cm) (NOAA, 2007). Tides in the Chesapeake Bay are mainly semidiurnal with two nearly equal tide peaks and two troughs each over a day. However, in the upper part of the Chesapeake Bay, mixed-type tides are also observed with unequal tide peaks and troughs. Also, freshwater flow from the Susquehanna River can considerably modify the tidal behavior in the upper reach of the Chesapeake Bay.

Tidal currents in the bay follow a distribution similar to that of the mean tidal ranges. The spring tidal current, as estimated by the National Oceanic and Atmospheric Administration (NOAA) at the entrance of the Chesapeake Bay, is about 1.7 knots (3.1 km/hr). At the entrance of Baltimore Harbor, the current magnitude reduces to approximately 1.1 knots (2.0 km/hr), but increases in the Chesapeake and Delaware Canal near Chesapeake City to about 2.5 knots (4.6 km/hr) (NOAA, 2007). The tides and tidal currents in the bay can be significantly affected by local meteorological conditions, including wind storms and barometric pressure changes.

Recorded data in the Chesapeake Bay show a strong seasonal dependence on the spatial and vertical distribution of water temperature. Water temperature near the CCNPP site, as obtained from two Chesapeake Bay Program (CBP) stations (CB4.2C and CB5.2) whose location is shown in Figure 2.4-3, varies within a range of about 32°F to 85.5°F (0°C to 29.7°C) over a period from 1984 to 2006 (NOAA, 2007).

In the Chesapeake Bay and its tributaries, salinities range from less than 0.5 parts per thousand (ppt) in non-tidal and tidal fresh water areas to about 30 ppt at the mouth of the Chesapeake Bay. Salinities are higher on the eastern side of the Chesapeake Bay than on the western side, due in part to the Coriolis effect of the earth's rotation and in part because more freshwater is discharged from rivers along the western shore of the Chesapeake Bay (CBP, 2004b). Near the CCNPP site, vertical salinity distribution at the CBP stations shows that the typical halocline is located between 5 ft (1.5 m) and 15 ft (4.6 m) of water depth, similar to the range of a typical thermocline. The surface salinity at the stations varies approximately between 2.0 ppt and 21.8 ppt, while the salinity near the bottom varies within the range of approximately 11.3 to 25.8 ppt for the period from 1984 to 2006 (NOAA, 2007). Salinities are generally highest after dry weather periods and lowest after wet weather or snowmelt periods. Thus, salinities are usually lowest in April and May, after the spring rains, and increase in August and September, after the drier summer months.

The Chesapeake Bay is periodically affected by storm surges generated in the Atlantic Ocean. Between 1851 and 2005, eleven hurricanes affected the Chesapeake Bay region that had intensities greater than Category I in the Saffir-Simpson Hurricane scale (NOAA, 2006). Three typical storm tracks can be identified for the hurricanes affecting the Chesapeake Bay:

- Storms that landfall in Georgia or South Carolina coast and progress over land west of and away from the Chesapeake Bay generally produce high rainfall
- Lower outer bank hurricanes with landfall in southern North Carolina that progress along the Virginia eastern shoreline east of the Chesapeake Bay
- Upper outer bank hurricanes with landfall in northern North Carolina that progress following a path nearly parallel to and west of the Chesapeake Bay

The outer bank hurricanes produce the most severe storm surge heights and storm-induced low water levels in the middle and upper part of the Chesapeake Bay. Further details of hurricane characteristics and their impact on Chesapeake Bay hydrology are provided in Section 2.4.5.

Although the east coast of the U.S. is generally believed to be free from tsunamis generated in the Atlantic Ocean, historical records establish that tsunamis and tsunami-like events have occurred in this area. One of the most notable tsunamis originating on the east coast of North America occurred due to an earthquake off the Burin Peninsula of Newfoundland, Canada in November 1929. The tsunami was recorded on tide gauges along the east coast of the U.S. The other notable tsunami in the Atlantic Ocean was generated off the coast of Portugal on November 1, 1755. Model prediction showed a tsunami with an amplitude of approximately 10 ft (3 m) reaching the U.S. east coast (Lockridge, 2003). The impact of tsunamis on the CCNPP site is discussed in Section 2.4.6.

Ice sheets may form on the upper reach of the Chesapeake Bay, including the CCNPP site, however, historical ice formation in the Chesapeake Bay has not caused any instances of ice jams or ice induced flooding at the CCNPP site. Section 2.4.7 provides a detailed discussion on ice formation and its impact on the CCNPP site.

2.4.1.2.2 Dams and Reservoirs

There are no dams or reservoirs on St. Leonard Creek or its tributaries. There are two dams on the Patuxent River. These are Rocky Gorge Dam and Brighton Dam, located approximately 75 and 85 mi (121 and 137 km) from the mouth of the Patuxent River, respectively. Details of the dams are provided in Table 2.4-10 (USACE, 2006). Potential failure of these dams would have no influence on conditions at the CCNPP site, which is discussed further in Section 2.4.4.

2.4.1.2.3 Surface Water Users

Use of surface water near the CCNPP site is mainly non-consumptive involving the Chesapeake Bay and the Patuxent River. Several communities are located within 6 mi (9.7 km) of the CCNPP site. None of them use surface water either from the Chesapeake Bay or from streams of St. Leonard Creek for domestic water supply. Near the CCNPP site, major consumptive uses of surface water include Chesapeake Bay water used for once-through cooling of CCNPP Units 1 and 2 and Dominion Cove Point liquefied natural gas (LNG) facility, which uses water for hydrostatic testing and pipeline drilling. Most of the water used by CCNPP Units 1 and 2 is returned to the Chesapeake Bay. Other consumptive surface water users include the Morgan State University Estuarine Research Center (ERC), Calvert County Commissioners for Calvert Marine Museum, and the Chesapeake Biological Laboratory (CBL) of the University of Maryland. These facilities withdraw surface water from the Patuxent River for institutional use. Surface water users within Calvert County, as obtained from the Maryland Department of Environment, are shown in Table 2.4-11. The nearest surface water withdrawal locations as listed in Table 2.4-11 include the Morgan State University ERC, located approximately 4 mi (6.4 km) northwest of the site, and Dominion Cove Point LNG facility, located approximately 4 mi (6.4 km) to the south-southeast of the site.

2.4.1.2.4 Ground Water Characteristics

The local and regional ground water characteristics are described in Section 2.4.12. A detailed list of current ground water users, ground water well locations, and the withdrawal rates in the vicinity of the CCNPP site is presented in Section 2.4.12.2.

The proposed water source to meet the water demand requirements during the operation of CCNPP Unit 3 is a desalinization plant utilizing water from the Chesapeake Bay. An additional source of water will be required during construction activities until the desalinization plant is operational. Construction water needs are expected to be satisfied by appropriating water from CCNPP Units 1 and 2 using the established ground water permits. Additional information regarding the use of ground water at the CCNPP site is presented in Section 2.4.12.1.4.

2.4.1.3 References

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2.4.2 Floods

The U.S. EPR FSAR includes the following COL Item in Section 2.4.2:

> A COL applicant that references the U.S. EPR design certification will identify site-specific information related to flood history, flood design considerations, and effects of local intense precipitation.

This COL Item is addressed as follows:

{This section identifies historical flooding at the site and in the region of the site. It summarizes and identifies individual flood types and combinations of flood producing phenomena in establishing the flood design basis for safety-related plant features. This section also covers the potential effects of local intense precipitation. Although topical information is discussed in Section 2.4.3 through Section 2.4.7 and Section 2.4.9, the types of events considered and the controlling event are reviewed in this section.

References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.2.1 through 2.4.2.4 are added as a supplement to the U.S. EPR FSAR.

2.4.2.1 Flood History

The CCNPP site is subject to flooding from the Chesapeake Bay, Johns Creek and two small unnamed streams identified on Figure 2.4-1 as Branch 1 and Branch 2. There are no stream gauges or flood records for Johns Creek or any of the unnamed branches that collect drainage from undeveloped wooded areas. Flood potential for Johns Creek is discussed in Section 2.4.3

and flooding potential for the unnamed branches is discussed in Section 2.4.2.3. As discussed in Section 2.4.1, stream gauges are located on St. Leonard Creek and the Patuxent River. However, St. Leonard Creek at the confluence with Johns Creek and the Patuxent River at the confluence with St Leonard Creek are both under tidal influence and stream flows do not significantly influence flooding water surface elevations at these locations. Thus, peak stream flow records for St. Leonard Creek and the Patuxent River are not presented in this section. Daily maximum stream flow records are presented and discussed for both water courses in Section 2.4.1.

Tide level data have been recorded on the Chesapeake Bay at Baltimore, Maryland from 1902 to present and at Annapolis, Maryland from 1928 to present. Tide level data have been recorded on the Patuxent River at Solomons Island, Maryland from 1979 to present. The five highest recorded water levels at Baltimore and Annapolis are presented in Table 2.4-22 (NOAA, 2004). Each of these high water levels is associated with surges from tropical storm events. The water levels presented in Table 2.4-22 have been adjusted for sea level rise and are presented as though they would have been measured with the current sea level datum (epoch 1983-2001) (NOAA, 2004). The high water level data at Solomons Island is not presented as water level data is missing from some high water level events and thus, the maximum recorded water level does not reflect the actual highest water level at the gauge. Since the construction and operation of CCNPP Units 1 and 2 there have been no instances of flooding of the CCNPP Units 1 and 2 grade area surrounding the pump intake area at Elevation 10.0 ft (3.0 m).

As discussed in Section 2.4.7, ice sheets have formed on the Chesapeake Bay on more than one occasion. Despite the formation of ice on the Chesapeake Bay, there have been no instances of ice jams or ice induced flooding at the CCNPP site. As discussed in Section 2.4.7.8 there have been small ice jams that have occurred on tributaries to the Patuxent River. However, they have had no flooding impact on the CCNPP site. Further details of historic ice sheets and ice effects are discussed in Section 2.4.7.

There are no records of any landslide (submarine or subaerine) or distant tsunami source induced flooding events at the CCNPP site. Historical Tsunami events are discussed in Section 2.4.6.

2.4.2.2 Flood Design Considerations

The design basis flood elevation for the CCNPP site is determined by considering a number of different flooding possibilities. The possibilities applicable and investigated for the site include the probable maximum flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami, and ice effect flooding. Each of these flooding scenarios was investigated in conjunction with other flooding and meteorological events, such as wind generated waves, as required in accordance with guidelines presented in ANSI/ANS 2.8-1992 (ANS, 1992). Detailed discussions on each of these flooding events and how they were estimated are found in Section 2.4.3 through Section 2.4.7.

The estimation of the PMF water level on Johns Creek, located just west of the CCNPP Unit 3 substation/switchyard area is discussed in detail in Section 2.4.3. The maximum PMF water level for Johns Creek is Elevation 65.0 ft (19.8 m). All safety-related facilities for CCNPP Unit 3 are located in the Maryland Western Shore watershed. The low point of the drainage divide between the Maryland Western Shore watershed and the Johns Creek watershed is at Elevation 98.0 ft (29.9 m) and passes through the CCNPP Unit 3 switchyard as shown on

Figure 2.4-7. Since the maximum PMF water level is 33 ft (10.1 m) below the drainage divide, the Johns Creek PMF does not pose a flooding risk to the CCNPP Unit 3 safety-related facilities.

Section 2.4.4 presents a detailed discussion on potential flood elevations on Johns Creek from dam failures on the Patuxent River. The resulting water level increase in the tidal portions of Johns Creek and St. Leonard Creek would be about 2.0 ft (0.6 m). This water level increase poses no risk to the CCNPP site.

Probable maximum surge and seiche flooding on the Chesapeake Bay as a result of the probable maximum hurricane (PMH) is discussed in Section 2.4.5. The probable maximum storm surge (PMSS) water level is estimated to be at Elevation 17.6 ft (5.35 m). Wave action from coincident winds associated with the storm surge produce a wave run-up height of 16.3 ft (4.96 m) above the PMSS resulting in a maximum flood level of Elevation 33.9 ft (10.31 m) on the slope to the CCNPP Unit 3 power block. The grade elevation of the Ultimate Heat Sink (UHS) makeup intake structure area is at Elevation 10.0 ft (3.0 m) and the UHS makeup water intake building will experience flooding as a result of the PMH as described in Section 2.4.5. The PMSS and coincident wave run-up water level at the CCNPP Unit 3 site produce the highest potential water levels on the Chesapeake Bay and become the design basis flood elevation for the CCNPP Unit 3 UHS makeup intake structure area. The UHS makeup intake structure will be provided with flood protection measures such as water tight doors, roof vents, and piping and conduit penetrations. Flood protection measures are discussed in Section 2.4.10. The CCNPP Unit 3 power block site grade is at nominal Elevation 85.0 ft (25.9 m) and all safety-related facilities other than the UHS makeup intake structure are located above the PMSS and wave run-up water level.

Section 2.4.6 describes the derivation of the probable maximum tsunami (PMT) water level. The maximum water level associated with a PMT at the CCNPP site is 3.8 ft (1.2 m). This is much lower than the flood level due to the PMH and thus, the PMT does not pose a flood risk to the CCNPP site.

The maximum water level due to local intense precipitation or the local probable maximum precipitation (PMP) is estimated and discussed in Section 2.4.2.3. The maximum water level in the CCNPP Unit 3 power block area, due to a local PMP, is at Elevation 81.5 ft (24.8 m). This water level becomes the design basis flood elevation for all safety-related facilities in the power block area. All safety-related building entrances in the power block are located above this elevation. The effects of local intense precipitation at the UHS makeup water intake are not estimated since the design basis flood elevation from the PMH will completely submerge this area.

2.4.2.3 Effects of Local Intense Precipitation

The design basis for the local intense precipitation is the all season 1 square mile or point PMP as obtained from the U.S. National Weather Service (NWS) Hydro-meteorological Report Number 52 (NOAA, 1982). Table 2.4-18 presents the 1 square mile PMP for various durations at the CCNPP site.

As described in Section 2.4.1, CCNPP Unit 3 is located adjacent to the existing CCNPP Units 1 and 2. The site layout and drainage system are shown in Figure 2.4-7. The site grade completely fills in the upper reaches of the two unnamed branches (Branch 1 and Branch 2) shown on Figure 2.4-1 such that the streams will now begin just east of the CCNPP Unit 3 plant boundary area. Additionally, the drainage area for these streams, at the headwater, consists of only the CCNPP Unit 3 power block area. Since the power block area is at a much higher elevation than the existing streams, flood flows in these streams will not affect the CCNPP Unit 3 power block area. Thus, local PMP analysis on these two streams was not performed.

As indicated on Figure 2.4-7, the containment, fuel and safeguards buildings are located in the center and along the high point of the CCNPP Unit 3 power block area. From the high point, site grading falls at a 1% slope to bio-retention drainage ditches located along the northern and southern edges of the CCNPP Unit 3 area. There are four bio-retention ditches which drain the power block and the Turbine Building areas. Three of them run in the east-west direction; one north of CCNPP Unit 3 (North Ditch), one south of CCNPP Unit 3 and between CCNPP Unit 3 and the area reserved for equipment laydown (Center Ditch) and one south of the equipment laydown area (South Ditch). The fourth ditch (East Ditch) is located along the eastern edge of CCNPP Unit 3 and the equipment laydown area. It collects flows from the other three ditches. The East Ditch is divided into two sections, to allow passage of the CCNPP Unit 3 security fence. Flows in the South Ditch and the southern half of the East Ditch do not have an impact on the PMP flood levels in CCNPP Unit 3 and are not discussed in this section. The dimensions of the center, north, and east bio-retention ditches are provided in Table 2.4-17.

The bio-retention ditches are constructed with base materials that promote infiltration of runoff from low intensity rainfall events. However, for large storms, the infiltration capacity of the base materials would be exceeded and overflow pipes are provided to direct the runoff to the stormwater basin located to the east of the CCNPP Unit 3 power block. For the assessment of the local PMF levels, the overflow pipes and culverts in the drainage system are assumed to be clogged as a result of ice or debris blockage. In that case, PMP storm runoff from the area collected in the North and East Ditches would overflow along the northern and eastern edges (top of berm at Elevation 79 ft (24.1 m)), spilling out to the areas north and east of the CCNPP Unit 3 power block down the bluff to Chesapeake Bay. Channels and diversion walls will be provided on the north side of the site to direct North Ditch overflows to the east and eventually to the Chesapeake Bay. Flows from the Center Ditch will discharge into the East Ditch before overflowing the eastern edge of the East Ditch.

Grading in the vicinity of the safety-related structures slopes away from the individual structures such that PMP ground and roof runoff will sheet flow away from each of these structures towards the collection ditches. Thus, sheet flows are prevented from entering the structures.

The effect of potential ice and debris blockage of storm drains, roof drains, culverts, and outlet pipes has been considered in the site PMP runoff analyses. As mentioned previously, all storm drains, outlet pipes, and culverts are considered blocked for the PMP runoff analysis. Since roof drains are considered blocked, runoff from roofs is assumed to be sheet flow over the edge of the roofs and contributing to the sheet flow runoff from each sub-basin. The runoff model does not consider any detention or storage for roof runoff. All runoff from roofs is included as direct runoff from the sub-basin drainage areas.

Peak water levels in the CCNPP Unit 3 power block area were determined by performing a hydrologic runoff analysis. The U.S. Army Corps of Engineers (USACE) computer program HEC-HMS (USACE, 2006a) was used to develop the hydrologic model and determine peak discharges in the site drainage ditches. Ground cover in the power block consists of primarily two types of surface characteristics, namely: 1) developed impervious area and 2) gravel surface on compacted fills. The drainage areas for the North, Center, and East Ditches are subdivided into 6 sub-basins for the site drainage evaluations. The drainage areas for these sub-basins are shown in Figure 2.4-1 and presented in Table 2.4-12.

The methodologies suggested by the U.S. National Resources Conservation Service (NRCS) as given in TR-55 Manual (USDA, 1986) were used to estimate the times of concentration (Tc) for the various sub-basins. To account for non-linearity effects during extreme flood condition, the computed Tc was reduced by 25% in accordance with guidance from EM-1110-2-1417 (USACE, 1994). The lag time, estimated as 60% of Tc, (USACE, 2006b) and the local intense precipitation presented in Table 2.4-18 were input to the USACE Computer program HEC-HMS (USACE, 2006a). A runoff curve number of 98, representing impervious surfaces (USDA, 1986), is conservatively used for the entire drainage area and also input into the HEC-HMS computer model. The NRCS dimensionless unit hydrograph option for the developments of the peak discharges from the various sub-basins in HEC-HMS was utilized. A schematic of the HEC-HMS model is given in Figure 2.4-8 and resulting peak discharges are presented in Table 2.4-13.

The computer program HEC-RAS, also developed by the USACE (USACE, 2005), was used in estimating the peak water levels in the CCNPP Unit 3 power block area. The water level in all ditches is assumed to be at Elevation 79.0 ft (24.1 m), corresponding to a ditch full condition, at the commencement of the PMP storm event. With the ditches full, nearly all of the runoff flowing into the North Ditch is assumed to overflow the North Ditch before entering the East Ditch. This assumption is confirmed with the HEC-RAS results. The runoff from the Center Ditch then flows into the East Ditch along with the East Ditch runoff (sub-basins East 1 and East 2). Cross-sections were developed along the ditches at locations as shown in Figure 2.4-9 using the topographic information shown in the figure. The cross section data was input into the HEC-RAS model assuming steady-state flow conditions.

The inflow peaks given in Table 2.4-14 were also input into the HEC-RAS model at the locations indicated. The discharges were developed from the HEC-HMS peak discharges in Table 2.4-13. Inflows from sub-basins North 2, Center 2, and East 1 were added to the North, Center, and East ditches as evenly distributed flows at each successive cross section as shown in Table 2.4-14.

Flow out of the bio-retention ditches during the PMP event was modeled by the use of the lateral weir option in HEC-RAS (USACE, 2005) to determine the overflow discharges from the North and East ditches. Also, the momentum of the incoming flow to the 90° confluence of the Center and East Ditches was analyzed with the momentum junction option in HEC-RAS. A Manning's "n" value of 0.035 was assumed for the ditches and over bank areas representing rip-rap lining for the ditches and gravel cover in the over banks (Chow, 1959).

The hydraulics of the East and North ditch junction require that the water level at the downstream (east) end of the North Ditch and the downstream (north) end of the East Ditch have the same starting water level and that the remaining flow in each ditch be close to zero (all flows have exited over the lateral weirs). The starting water level (Elevation 79.7 ft (24.3 m)) and hydraulic condition was determined by trial and error. The water levels at the various cross-sections along the North and Center Ditches during the local PMP are shown in Table 2.4-15.

Two adjacent lateral weirs were used to model the overflow out of the East ditch. The upstream weir between cross sections 1200 and 600 is about 575 feet in length and the downstream weir between cross sections 600 and 0 is about 600 feet in length. The flow out of the North ditch is modeled with a third lateral weir about 600 feet in length between cross sections 600 and 0. The flows entering the East and North ditches pass over the lateral weirs in the local PMP flood analysis.

The flow depths over the upstream East ditch lateral weir range from 1.1 ft (0.34 m) to 0.7 ft (0.21 m) with an average velocity over the weir of 2.4 ft/s (0.73 m/s) during the peak flow condition. The flow depths over the downstream lateral weir on the East ditch are fairly constant at about 0.7 ft (0.21m) with an average velocity of about 2.2 ft/s (0.67 m/s). The overflow from the lateral weirs will sheet flow down the eastern power block fill slope with a gradient of 3 (horizontal) to 1 (vertical) and continue as sheet flow before discharging to existing drainage into the Chesapeake Bay.

The flow depths over the North ditch lateral weir range from 0.8 ft (0.24 m) to 0.7 ft (0.21 m) with an average velocity of about 2.2 ft/s (0.67 m/s) during the peak flow condition. Once the flow from the North ditch passes over the lateral weir it will sheet flow down the northern power block fill slope and continue as sheet flow towards the north and east, eventually discharging to existing drainage to the Chesapeake Bay. The northern and eastern power block fill slopes are provided with rip rap protection sufficient to resist the local PMP-generated peak flow velocities, which are estimated to be on the order of 10 ft/s (3 m/s), assuming normal depth condition and using a Manning's n of 0.035 to represent the rip rap surface.

Overflows from the East ditch and North ditch lateral weirs will not be intercepted by any building or structure related to CCNPP Unit 3.

The safety-related structures in the CCNPP Unit 3 power block consist of two UHS cooling towers located in the northwest corner, two UHS cooling towers located in the southeast corner, diesel generator buildings located north and south of the reactor complex and the reactor complex, which consists of the containment building, fuel building, and safeguards buildings. The locations of the buildings are shown on Figure 2.4-7. The entrances to each of these structures are located at or close to the grade slab elevation (Elevation 84.6 ft (25.8 m)) for each structure, with the exception of the UHS cooling towers, where the entrances are located 14 ft (4.3 m) above the grade slab elevation. Table 2.4-16 gives the entrance elevations at the various safety-related facilities and compares them with the PMP water levels near those facilities. The maximum computed PMP water level in the power block area is Elevation 81.5 ft (24.8 m). However, the maximum PMP water level associated with a safety-related structure is Elevation 81.5 ft (24.8 m) which is 3.1 ft (0.95 m) below the reactor complex grade slab at Elevation 84.6 ft (25.8 m).

Based on the CCNPP Unit 3 power block grading, entrance locations, and peak PMP water levels in the site ditches, all safety-related facility entrances, except for the UHS makeup intake structure, are located above peak PMP ditch water levels and PMP sheet flows are prevented from reaching safety-related entrances.

Flood protection measures are required for the CCNPP Unit 3 UHS makeup water intake structure. The grade level at the UHS makeup water intake structure location is at Elevation 10.0 ft (3.0 m). The maximum flood level at the intake location is Elevation 33.2 ft (10.11 m) as a result of the surge, wave heights, and wave run-up associated with the probable maximum hurricane (PMH) as discussed in Section 2.4.5. Thus, the UHS makeup water intake structure would experience flooding during a PMH and flood protection measures are required.

The general arrangement of the UHS makeup water intake area is described in Section 9.2.5. Flood protection for the UHS makeup water intake structure, as described in Section 2.4.10, will consist of structural measures to withstand the static and dynamic flooding forces as well as water proofing measures to prevent the flooding of the interior of the structures where pump motors and electrical or other equipment associated with the operation of the intake are located.

2.4.2.4 References

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USACE, 2006b. HEC-HMS User's Manual, U.S. Army Corps of Engineers, Hydrologic Engineering Center, April 2006.

USDA, 1986. Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Soil Conservation Service, June 1986.}

2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers

The U.S. EPR FSAR includes the following COL Item in Section 2.4.3:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information to describe the probable maximum flood of streams and rivers and the effect of flooding on the design.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

The CCNPP site is located on the western shore of the Chesapeake Bay as shown on Figure 2.4-10. Sources of potential flooding at the proposed site are the Chesapeake Bay to the east, Johns Creek to the west, and local intense precipitation directly over the site. This section discusses the probable maximum flood (PMF) on streams and rivers as a result of the probable maximum precipitation (PMP) over the watershed.

The Chesapeake Bay is the largest estuary on the east coast of the United States. The surface area of the Chesapeake Bay and its tidal tributaries is approximately 4,480 square miles (CPB, 2004). Many tributaries discharge into the Chesapeake Bay, including the Susquehanna, Patapsco, Patuxent, Potomac, Rappahannock, York and James Rivers. The Chesapeake Bay empties into the Atlantic Ocean near Norfolk, Virginia about 90 mi (145 km) south of the CCNPP site.

Since the Chesapeake Bay is connected to the Atlantic Ocean, water levels at a coastal site, including flood levels, are largely influenced by tide levels, storm surges, wind-generated waves, and tsunamis. Although, river discharge into the Chesapeake Bay can have some effect on water levels in the Chesapeake Bay, the effect is minimal in comparison with flood water levels generated by the events listed above. Thus, the water levels in the Chesapeake Bay due to the PMF on streams and rivers that are tributaries to the Chesapeake Bay are not assessed in this section. Flood elevations on the Chesapeake Bay due to the events listed above are addressed in Section 2.4.5 and Section 2.4.6. The effects of local intense precipitation are addressed in Section 2.4.2.

Three streams are identified to have potential impacts on the flood level at the CCNPP site. The first is Johns Creek located southwest of the CCNPP site. The PMF analysis for Johns Creek is discussed in this section. The other two are unnamed creeks located north and southeast of CCNPP Unit 3. The flood analyses for these two creeks are discussed in Section 2.4.2 as part of local intense precipitation discussion.

Johns Creek is a tributary to St. Leonard Creek, which is a tributary to the Patuxent River, as shown in Figure 2.4-11. St. Leonard Creek is tidally influenced at the mouth of Johns Creek and is an extension of the Chesapeake Bay, as is the Patuxent River. The CCNPP site is located far enough away from the limit of the tidally influenced areas that flood flows on these water courses have no influence on the water levels near the site. Thus, neither St. Leonard Creek nor the Patuxent River is analyzed for the PMF on streams or rivers for the CCNPP site.

A portion of Johns Creek, upstream of the tidally influenced reach, is located immediately west of the switchyard area for the site. Thus, a PMF analysis is performed on Johns Creek to determine the PMF water levels near the site.

The results of the analysis indicate a maximum PMF water surface elevation of 65 ft (20 m) on Johns Creek at the CCNPP site. All safety-related structures, systems, and components of CCNPP Unit 3 will be located outside the Johns Creek watershed in the Maryland Western Shore watershed. Flood water from Johns Creek could only flow into the Maryland Western Shore watershed and pose a risk to Unit 3 structures, systems, and components should the water level in Johns Creek exceed the low point in the drainage divide boundary at Elevation 98.0 ft (30 m), which passes through the CCNPP Unit 3 switchyard. The drainage divide boundary is about 33.0 ft (10 m) above the maximum PMF elevation on Johns Creek.

Sections 2.4.3.1 through 2.4.3.7 are added as a supplement to the U.S. EPR FSAR.

2.4.3.1 Probable Maximum Precipitation

The PMP was developed according to procedures outlined in the Hydro Meteorological Report (HMR) Numbers 51, 52, and 53 (NOAA, 1978) (NOAA, 1980) (NOAA, 1982). The values are presented in Table 2.4-18. They have been estimated based on the size and shape of the Johns Creek watershed drainage area in accordance with the procedures outlined in HMR Number 52 (NOAA, 1982). The 2.3 mi2 (5.9 km2) Johns Creek watershed drainage area, upstream of the Maryland State Highway MD 2/4 culvert crossing, is shown on Figure 2.4-11. The drainage area is divided into four sub-basins. The topography for each sub-basin is variable with elevations ranging from about 10 ft (3.0 m) to about 120 ft (37 m). There are few level areas in the drainage area. Ground cover for all four sub-basins primarily consists of dense woods with a few open space areas. The drainage area for each sub-basin is listed in Table 2.4-19. A schematic of the watershed sub-basins is shown in Figure 2.4-11.

Sensitivity analysis indicates that Johns Creek water levels at the CCNPP site are not affected by different tail water levels downstream of the MD 2/4 crossing. Thus, the crossing is used as the downstream control point for the watershed and water surface modeling.

Since the watershed drainage area is less than 10 square miles, the all-season point (1.0 mi2 (2.6 km2)) PMP depths are used for the analysis. The all-season point PMP depths represent the maximum PMP depths that could occur at the site location at any time of the year. Since estimated point PMP values occur at the center of the storm, there is no need to analyze storm orientations with respect to the drainage area. Additionally, the site is located in the coastal plain, orographic effects do not contribute to precipitation formation and are not considered in the PMP depth estimations.

The distribution of the PMP storm is determined using the frequency-based hypothetical storm procedure as outlined in the HEC-HMS Technical Reference Manual (USACE, 2000). In this procedure, the values listed in Table 2.4-18 are input into the HEC-HMS computer model (USACE, 2006a) and an incremental time step of five minutes is selected for the Johns Creek model. Rainfall depths for durations that are integer multiples of the selected time interval are produced by interpolating the PMP depths in Table 2.4-18. Successive differences in the cumulative depths are then determined to compute a set of incremental precipitation depths. The maximum incremental depth is placed at the middle of the storm duration, with the remaining incremental depths arranged in descending order, alternating before and after the central incremental depth.

For the runoff analysis, an antecedent storm condition is assumed as indicated in ANSI/ANS-2.8-1992 (ANS, 1992). This condition assumes a rainstorm equivalent to 40% of the PMP, followed by three days with no precipitation, and then the full PMP storm is modeled.

Based on the historical snowfall information for the CCNPP site region in Section 2.3, snowmelt does not make a significant contribution to flooding situations. Therefore, antecedent snow-pack conditions have not been considered in the PMF analysis.

2.4.3.2 Precipitation Losses

Precipitation losses for the Johns Creek watershed are determined using the Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Service, runoff methodology (USDA, 1986). For this method, a composite runoff curve number (RCN) is assigned to each drainage sub-basin in the watershed. The RCN is used to describe the sub-basin’s capacity to absorb and retain precipitation or produce runoff. Runoff curve numbers range from about 30 to 100, with higher numbers producing more runoff. Each composite RCN is determined based on the sub-basin's surface soils, land cover, and antecedent moisture condition (dry, average, or wet).

Even after development of CCNPP Unit 3, most of the Johns Creek watershed will consist of wooded areas. As a measure of conservatism and to reflect the presence of saturated soils that would exist with a PMP storm following a 40% PMP the entire watershed drainage area is conservatively assumed to be impervious for determining precipitation losses and runoff. The RCN for impervious surfaces is 98 regardless of the soil type (USACE, 1994) and thus soil classifications for the watershed have not been determined for runoff determination purposes. An RCN of 100 is used for determining runoff over a water body. Using an RCN of 98 results in very little precipitation losses. Thus, nearly all of the precipitation is converted to runoff.

2.4.3.3 Runoff Model

ANSI/ANS-2.8-1992 (ANS, 1992) requires that all culverts and underground drainage facilities be considered clogged during the PMP event to account for accumulation of debris. For the PMP analysis, the MD 2/4 culvert is assumed to be blocked. Thus, the area behind the culvert becomes a large detention/storage area up to the top of the road crossing. A schematic of the HEC-HMS computer model for the watershed is shown in Figure 2.4-12. As shown in this figure, the runoff hydrographs from Sub-basins 3 and 4 are combined in Johns Creek upstream of the water storage area behind the MD 2/4 culvert. Runoff hydrographs from Sub-basins 1 and 2 discharge directly to the portion of Johns Creek under the influence of the storage area upstream of the MD 2/4 culvert and are added to the combined Sub-basin 3 and 4 hydrograph. After combining all sub-basin hydrographs, the combined hydrograph is routed through the MD 2/4 culvert storage area and an outflow hydrograph over the culvert crossing is determined.

The NRCS unit hydrograph method (USDA, 1986) in the computer program HEC-HMS (USACE, 2006a) is used to transform the runoff calculated to a discharge hydrograph for Johns Creek. There are no stream gauges or historical flood records for Johns Creek or any of its tributaries. Thus, there are no historical records available to verify the results of the runoff analysis. However, the NRCS curve number and unit hydrograph methods are accepted in many regions of the United States, including the Mid-Atlantic Region, to estimate basin runoff and peak discharges from precipitation events and are known to have reliable results. The high RCN used in the analysis adds conservatism to the results.

The steps involved in the NRCS methodology are summarized below:

- The runoff volume over each sub-basin is computed for each individual time increment (5 minutes) of the computation duration, using the incremental precipitation depths described in Section 2.4.3.1 and the RCN.

- The incremental peak discharges for each sub-basin are computed for each time step using the runoff volume calculated in the step above, the NRCS unit hydrograph, and a time of concentration value calculated for each sub-basin.

- The incremental discharges are then used to create a discharge hydrograph for each sub-basin.

- The time of concentration value for each sub-basin is estimated using methods developed by the NRCS (USDA, 1986). To account for nonlinear basin response to high rainfall rates, the time of concentration values have been reduced by 25% (USACE, 1994). For the NRCS transformation option, HEC-HMS requires the input of "lag time" rather than the time of concentration. Lag time can be estimated as 0.6 times the time of concentration (USACE, 2006b).

- Once the hydrographs for each sub-basin are determined, HEC-HMS combines the hydrographs at the storage area created upstream of the MD 2/4 culvert.

With the MD 2/4 culvert clogged, runoff will accumulate in the area behind the culvert crossing until water overtops the crossing. Because the elevation at the low point of the top of the road (Elevation 45.5 ft (13.9 m)) is more than 37 feet above the stream bed elevation (Elevation 7.9 ft (2.4 m)), a significant amount of storage is provided behind the culvert crossing. Thus, the level pool storage option in HEC-HMS is used to route the combined hydrographs through the culvert crossing. This is done by determining a stage-storage relationship based on the topography shown on the U.S. Geological Survey (USGS) topographic map (USGS, 1987). Additionally, a stage-discharge relationship is also developed for the weir flow over the road. HEC-HMS uses the geometry of the road crossing and the standard broad crest weir equation to determine the discharge relationship and thereby determine the water levels in the storage area behind the culvert crossing.

The inflow hydrograph is then routed through the culvert crossing and based on the stage-storage-discharge relationship, the outflow hydrograph over the MD 2/4 culvert is computed in the HEC-HMS model. With the assumption of a 40% PMP event 3 days prior to the PMP event, the starting water level in the storage area upstream of the culvert is set at the top of the road elevation (Elevation 45.5 ft (13.9 m)). The resulting hydrographs at the culvert outlet and for each sub-basin for the PMP event are shown in Figure 2.4-13 through Figure 2.4-17. In addition to the outflow hydrograph, Figure 2.4-13 also displays the inflow hydrograph to the culvert storage area as well as the storage volume and water surface elevation curve. Figure 2.4-14 through Figure 2.4-17 also shows the precipitation hyetograph in addition to the runoff hydrograph for each sub-basin.

Base flow for each sub-basin was estimated based on bank full condition for Johns Creek and its tributaries. The base flow for each sub-basin is also shown on Figure 2.4-14 through Figure 2.4-17. However, the flow is small enough compared to the PMF flows that the base flow has no impact on the calculated flood water levels.

There are no upstream or downstream dams or reservoirs on Johns Creek; thus, there are no effects from dam breach or upstream reservoir storage considered in the PMP runoff analysis.

2.4.3.4 Probable Maximum Flood Flow

The PMP peak flood flow rates as calculated in HEC-HMS are summarized in Table 2.4-19. The highest Johns Creek water levels occur in the upper reaches of the creek, thus, the controlling flood hydrograph for the site is the flood hydrograph for Sub-basin 4 depicted in Figure 2.4-17.

As shown in Table 2.4-19, the peak flow rates for the various sub-basins occur at different times. Backwater levels from the MD 2/4 culvert crossing also influence water levels in the upstream cross sections. Thus, in order to determine the maximum PMF water levels at the CCNPP Unit 3 location, six steady-state water surface profiles are analyzed. The first water surface profile is based on flow rates for each sub-basin at the time corresponding to the peak flow in Sub-basin 4 (Hour 0:50), which is the most upstream sub-basin. The next four profiles reflect the discharges at 5 minute time intervals beginning at Hour 0:55 and ending at Hour 1:10. The sixth water surface profile represents the flow rates when the peak flow occurs at the

MD 2/4 culvert outlet (Hour 1:15), i.e., when the culvert crossing backwater level is the highest. The flow rates for each profile are obtained from the printed hydrographs in the HEC-HMS output and are summarized in Table 2.4-20. Discharges in Table 2.4-20 are represented as inflow at the indicated cross sections, which are located just downstream of the confluence of tributaries to Johns Creek.

2.4.3.5 Water Level Determination

Maximum water levels along Johns Creek above the MD 2/4 culvert crossing are determined utilizing the standard step backwater method for natural channels as implemented in the HEC-RAS computer program developed by the U.S. Army Corps of Engineers (USACE, 2005). Required input for HEC-RAS includes geometric cross section data, flow rates, roughness data, and boundary conditions.

Since no historic flood information is available for Johns Creek and calibration of the standard step backwater model is not possible, conservative values are estimated for roughness and weir coefficients.

The cross section data is obtained from topographic maps developed for the site and USGS topographic maps (USGS, 1987). The HEC-RAS computer model cross section locations are shown on Figure 2.4-18.

Manning's roughness coefficients for the stream channel and floodplain are estimated based on visual observations and procedures outlined by the USGS (USGS, 1990). Roughness coefficient values of 0.035 for the main channel and 0.142 for the floodplain areas are used in the HEC-RAS model.

Although the downstream control point for the HEC-RAS computer model is the MD 2/4 culvert crossing, HEC-RAS requires at least 2 cross sections downstream of a culvert or inline weir structure. One cross section is required at the downstream face of the culvert and the first section is located a few hundred feet downstream of the face. Thus, in the HEC-RAS model, the first cross section is located about 800 ft (244 m) downstream of the culvert crossing. Since the culvert opening at MD 2/4 is considered blocked, the road crossing is modeled as an inline weir in the HEC-RAS computer program. A weir coefficient of 2.6 is used to model the flow over the road.

The normal depth option, which computes the normal depth water level based on the cross section dimensions, flow rate, and a user defined channel slope, is used to determine the downstream boundary condition at the first cross section. As indicated in Section 2.4.3.1, sensitivity analysis performed indicated that water levels at CCNPP Unit 3 were unaffected by differing water levels at the downstream control point.

The PMF flow rates for the six profiles listed in Table 2.4-20 are input into the HEC-RAS model at the indicated cross section locations. The entire length of the Johns Creek HEC-RAS model covers portions of the creek that are upstream of the tidal reach. Thus, the normal depth option in HEC-RAS is used to estimate the downstream starting water level. The mixed flow option, which computes both sub-critical and super-critical flow regimes, is used to model the flood profiles.

The computed water surface elevations for each profile are summarized in Table 2.4-21 and are depicted in Figure 2.4-19. The maximum PMF water surface elevation for each cross section is highlighted in bold in Table 2.4-21.

From Table 2.4-21, the maximum water level during the PMP event in Johns Creek near CCNPP Unit 3 is Elevation 65.0 ft (20 m) at Cross Section 17. This is 33.0 ft (10 m) below the drainage divide at Elevation 98.0 ft (30 m) in the switchyard.

2.4.3.6 Coincident Wind Wave Activity

The HEC-RAS output (Attachment 4) indicates that the top width of the peak water surface is about 200 ft (61 m) at Cross Section 17. Given the narrow water surface width and the elevation difference between the drainage divide and the PMF water level, the opportunity for significant wave height development does not exist. Thus, wave height estimation is not performed for the PMF elevations on Johns Creek.

2.4.3.7 References

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USACE, 2005. HEC-RAS, River Analysis System, Version 3.1.3, U.S. Army Corps of Engineers, Hydrologic Engineering Center, May 2005.

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USACE, 2006b. HEC-HMS User's Manual, U.S. Army Corps of Engineers, Hydrologic Engineering Center, April 2006.

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USGS, 1990. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains, Water Supply Paper 2339, U.S. Department of Interior, U.S. Geological Survey, July 1990.}

2.4.4 Potential Dam Failures

The U.S. EPR FSAR includes the following COL Item for Section 2.4.4:

> A COL applicant that references the U.S. EPR design certification will verify that the site-specific potential hazards to safety-related facilities due to the failure of upstream and downstream water control structures are within the hydrogeologic design basis.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

As mentioned in Section 2.4.1, the Calvert Cliffs Nuclear Power Plant (CCNPP) site property is located on the western shore of the Chesapeake Bay in Lusby, Maryland. Flooding sources for the site include the Chesapeake Bay east of the site and Johns Creek west of the site and local intense precipitation. Johns Creek is a tributary to St. Leonard Creek, which is a tributary to the Patuxent River, which is a tributary to the Chesapeake Bay. Both St. Leonard Creek and the Patuxent River are extensions of the Chesapeake Bay near the CCNPP site. Figure 2.4-10 shows the locations of these surface water features relative to the site. The water levels in these water bodies are essentially the same as the water levels in the Chesapeake Bay and are influenced by tides, storm surges, waves, and tsunamis in the Chesapeake Bay and Atlantic Ocean.

There are no dams on Johns Creek or St. Leonard Creek. There are two dams on the Patuxent River. Rocky Gorge Dam is located about 65 mi (104 km) upstream of the mouth of St. Leonard Creek. Brighton Dam is located about 78 mi (124.8 km) upstream of the mouth of St. Leonard Creek. Figure 2.4-20 shows the location of both dams. The combined maximum storage capacity for both of these dams is approximately 49,000 acres-ft (6,044 hectares-m) (USACE, 2006). The surface area of the tidal reach of the Patuxent River, as measured from U.S. Geological Survey topographic maps, is approximately 40.9 mi2 (105.9 km2) (USGS, 1974) (USGS, 1983) (USGS, 1984) (USGS, 1986) (USGS, 1987a) (USGS, 1987b). The tidal reach, shown on Figure 2.4-20, extends from the mouth of Patuxent River to a point about 32 mi (51.2 km) upstream. If the total volume of these two reservoirs were to be instantly added to the tidal region of the Patuxent River and not allowed to escape into the Chesapeake Bay, the water level increase in the tidal river reach would be approximately 2 ft (0.6 m). This would create a backwater condition for St. Leonard Creek and possibly Johns Creek. If this backwater condition were uniformly translated up Johns Creek, flood levels in the upper reaches of Johns Creek and near the CCNPP site would not be affected for events such as the Probable Maximum Floods (PMF) discussed in Section 2.4.3. Water levels in this reach are controlled by the Maryland State Highway 2/4 crossing and the channel slope.

Flood water levels from dam breaches for both the Brighton Dam and Rocky Gorge Dam would be less than that estimated above due to flood attenuation over the 65 mi (104 km) reach of the river and due to the flood wave discharging directly into the Chesapeake Bay and not creating a backwater condition for St. Leonard Creek and Johns Creek.

Several other dams are located on other tributaries to the Chesapeake Bay upstream of the CCNPP site. However, dam failures from these other dams would have negligible flooding effect to the CCNPP site as the flood waves would discharge directly into the Chesapeake Bay far upstream of the CCNPP site. Once the flood wave reaches the Chesapeake Bay, water levels would be attenuated by the size and storage volume available in the Chesapeake Bay.

2.4.4.1 References

Section 2.4.4.1 is added as a supplement to the U.S. EPR FSAR.

USACE, 2006. National Inventory of Dams, Brighton Dam (MD00005) and Rocky Gorge Dam (MD00020), U.S. Army Corps of Engineers, 2006.

USGS, 1974. 7.5 Minute Series Topographic Maps, Scale 1:24,000 Mechanicsville MD, U.S. Geological Survey, 1974.

USGS, 1983. 7.5 Minute Series Topographic Maps, Scale 1:24,000 Benedict MD, U.S. Geological Survey, 1983.

USGS, 1984. 7.5 Minute Series Topographic Maps, Scale 1:24,000 Hollywood MD, U.S. Geological Survey, 1984.

USGS, 1986. 7.5 Minute Series Topographic Maps, Scale 1:24,000 Broomes Island MD, U.S. Geological Survey, 1986.

USGS, 1987a. 7.5 Minute Series Topographic Maps, Scale 1:24,000 Cove Point MD, U.S. Geological Survey, 1987.

USGS, 1987b. 7.5 Minute Series Topographic Maps, Scale 1:24,000 Solomons Island MD, U.S. Geological Survey, 1987.}

2.4.5 Probable Maximum Surge and Seiche Flooding

The U.S. EPR FSAR includes the following COL Item for Section 2.4.5:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information on the probable maximum surge and seiche flooding and determine the extent to which safety-related plant systems require protection. The applicant will also verify that the site-specific characteristic envelope is within the design maximum flood level, including consideration of wind effects.

This COL Item is addressed as follows:

Sections 2.4.5.1 through 2.4.5.6 are added as a supplement to the U.S. EPR FSAR.

2.4.5.1 Probable Maximum Winds and Associated Meteorological Parameters

The meteorological events that can cause severe coastal flooding at the CCNPP Unit 3 site fall into two categories: hurricanes and northeasters. Historical water level data from National Oceanic and Atmospheric Administration (NOAA) tide gauges at Baltimore MD, Annapolis MD, and Sewells Point VA, where water level records are available for at least 78 years, show that the top five maximum water levels at these locations occurred mostly during passage of hurricanes near the Chesapeake Bay area (NOAA, 2004). Although the third highest water level at Sewells Point VA occurred during a winter storm, the highest water level at this location was due to the passage of the August 1933 hurricane (NOAA, 2004).

Northeasters move along the Atlantic coast with winds blowing from the northeast, off the Atlantic Ocean, onto the shoreline, typically producing winds ranging from 30 to 40 mph (48 to 64 km/h) with gusts that can exceed 74 mph (119 km/h). Winds of northeasters are typically below hurricane force, in terms of sustained surface wind speed as used in the Saffir-Simpson Hurricane Scale, but can persist for several days to a week, generating large waves and enhanced storm surges. In comparison, hurricanes are more severe in terms of wind speed and storm surge elevations, and their shoreline effects tend to be more localized, generally confined to stretches of coastline of about 65 mi (105 km) or less. In addition to having lower wind intensities and forces than hurricanes, the general wind direction of the northeasters in the Chesapeake Bay region will produce a water level decrease (set-down) in the northern (or upper) part of the Chesapeake Bay where the CCNPP Unit 3 site is located. Thus, it is postulated that the highest water level at the CCNPP Unit 3 site will be controlled by hurricane-induced storm surges.

The NOAA National Weather Service (NWS) Technical Report NWS 23 defines the probable maximum hurricane (PMH) as a hypothetical steady-state hurricane with a combination of meteorological parameters that will give the highest sustained wind speed that can probably occur at a specified coastal location (NOAA, 1979). The meteorological parameters that define the PMH wind field include the hurricane peripheral pressure (p_n), central pressure (p_o), radius of maximum winds (RMW), forward speed (T), and track direction (Θ).

The PMH parameters on the Atlantic coast near the Chesapeake Bay entrance are obtained from the Technical Report NWS 23 (NOAA, 1979). The PMH parameter values in NWS 23 were based on data from historical hurricanes from 1851 to 1977 and were presented for multiple locations along the Gulf of Mexico and Atlantic Ocean coastlines corresponding to their milepost distances from the U.S.-Mexico border. The entrance to Chesapeake Bay is located approximately at latitude 37° 00' North corresponding to a distance of approximately 2,300 nautical miles (4,260 km) from the U.S.-Mexico border. The characteristic parameters of the PMH at the entrance of the Chesapeake Bay, as obtained from the Technical Report NWS 23 (NOAA, 1979), are summarized below:

- Peripheral pressure is 30.12 in Hg (102 kPa)
- Central pressure is 26.49 in Hg (89.7 kPa)
- Radius of maximum wind is 10.0 to 26.0 nautical miles (18.5 to 48.2 km)
- Forward speed is 17.0 to 38.0 knots (31.5 to 70.4 km/h)

The pressure difference between the hurricane peripheral and central pressures, Δp, is identified as the most important meteorological parameter in defining the hurricane wind field (NOAA, 1979). The Technical Report NWS 23 provides single values of PMH peripheral and central pressures along the mileposts, thereby giving single values for Δp. However, a range of values (i.e., lower and upper bounds) is provided for other PMH parameters. As can be seen from the PMH parameters above, the Δp at this location is 3.63 inches of mercury or 12.3 kPa.

2.4.5.2 Surge and Seiche Water Levels

2.4.5.2.1 Historical Surges

Between 1851 and 2005, 281 hurricanes have been reported to hit the coast of the continental U.S. Only twelve hurricanes, with intensities equal to or stronger than Category I in the Saffir-Simpson Hurricane Scale, have passed through Maryland and Virginia, including the Chesapeake Bay Area (Blake, 2007).

The surge mechanism that significantly impacts the Chesapeake Bay is characterized by two hurricane paths. One of the storm paths is the southerly hurricane path that passes by the eastern side of the Chesapeake Bay in the open ocean. These hurricanes cause an interaction of the initial primary surge wave that propagates through the Chesapeake Bay entrance and the water level induced by the northerly wind of the hurricane. The resulting water levels show a water level increase (set-up) in the lower Chesapeake Bay and a set-down in the upper Chesapeake Bay areas.

The other storm path is the southeasterly hurricane path. When the storm path passes by the western side of the Chesapeake Bay on the land, the primary surge wave in the Chesapeake Bay interacts with the water level induced by the southerly wind. This results in a set-down in the lower Chesapeake Bay and a set-up in the upper Chesapeake Bay. The water surface set-up in the upper Chesapeake Bay, which also includes the CCNPP Unit 3 site, is attributed to the combination of the primary surge propagating northward and a wind setup due to cross wind of the hurricane. This storm path will produce a higher storm surge height at the CCNPP Unit 3 site than that produced by a southerly hurricane path that passes by the eastern side of the Chesapeake Bay.

The hurricanes that generated the five highest water levels at the Baltimore and Annapolis tidal stations are listed in Table 2.4-22 (NOAA, 2004). The observed water level records at these two major stations represent the storm surge patterns for the upper Chesapeake Bay where the CCNPP site is located. Data presented in Figure 2.4-26 indicate that, with the exception of Hurricane Connie, the highest water levels at Baltimore and Annapolis were generated by hurricanes passing by the west side of the Chesapeake Bay. While the highest water level at Baltimore was due to the August 1933 Hurricane, the highest water level at Annapolis was due to Hurricane Isabel of 2003. These two hurricanes also resulted in the highest recorded water levels at several other tidal gages in the Chesapeake Bay, and caused roughly equivalent storm surges in the upper Chesapeake Bay (Baltimore and Annapolis) (NOAA, 2004).

The maximum storm surge height recorded in history at Baltimore (after correction for sea level rise) was 7.4 ft (2.26 m) during the passage of the August 1933 hurricane. At Annapolis, the maximum storm surge height was 6.3 ft (1.93 m) recorded during Hurricane Isabel of 2003. The second highest storm surge height recorded in history at Baltimore was 7.3 ft (2.21 m) during Hurricane Isabel of 2003. At Annapolis, the second highest storm surge was 6 ft (1.82 m) during the August 1933 hurricane (NOAA, 2004). The storm surge heights at different locations in the Chesapeake Bay during Hurricane Isabel in 2003 are presented in Figure 2.4-25.

2.4.5.2.2 Estimation of Probable Maximum Storm Surge

2.4.5.2.2.1 Antecedent Water Level

According to RG 1.59 (NRC, 1977), the 10% exceedance high spring tide including initial rise should be used to represent the PMSS antecedent water level. RG 1.59 defines the 10% exceedance high spring tide as the high tide that is equaled to or exceeded by 10% of the maximum monthly tides over a continuous 21-year period. For locations where the 10% exceedance high spring tide is estimated from observed tide data, RG 1.59 indicates that a separate estimate of initial rise (or sea level anomaly) is not necessary.

The 10% exceedance high spring tide at the site is estimated to be 2.05 ft (0.62 m) mean low water (MLW) or 1.53 ft (0.47 m) mean sea level (MSL), following the procedures described in ANSI/ANS 2.8-1992 (ANS, 1992). It is the average of the 10% exceedance high spring tides at the Long Beach and Cove Point tide stations. The two stations are second order tide stations of Baltimore and are located on either side (upcoast and downcoast) of the CCNPP Unit 3 site. The MLW and MSL tidal datum are based on the 1983 to 2001 National Tidal Datum Epoch (NOAA, 2006a). The initial rise or sea level anomaly of 1.1 ft (0.34 m) at Sewells Point (ANS, 1992) is adopted for the CCNPP Unit 3 site.

In addition to the 10% exceedance high spring tide and initial rise, the long-term trend observed in tide gage measurements is also considered to account for the expected sea level rises over the design life of the plant. Based on measured tide levels from 1902 to 1999 at Baltimore MD, NOAA reported a long-term sea level rise trend of 1.02 ft/century or 3.12 mm/year. At Solomons Island MD the rate of rise in the mean sea level between 1937 and 2006 is 1.12 ft/century or 3.41 mm/year. Assuming that the sea level at the site would continue to rise at the average rate of the two stations, a nominal long-term sea level rise of 1.07 ft/century (3.26 mm/yr) is estimated for the site. To account for potential global warming effects, the entire 1.07 ft (0.33 m) is assumed even though the end of the plant license is expected to be reached in about 50 years.

At the NOAA gage station located about 3 mi (4.8 km) from the CCNPP Unit 3 site at Cove Point MD the MSL is 0.64 ft (0.20 m) above the NGVD 29. Applying the tidal datum relationship to the 10% exceedance high spring tide, and adding the initial rise and the long-term sea level rise, the antecedent water level is 4.4 ft (1.34 m) NGVD 29.

2.4.5.2.2.2 Empirical Method for Estimating Probable Maximum Storm Surge

Based on USACE Hurricane Surge Predictions for Chesapeake Bay (USACE, 1959) and USACE Coastal Engineering Manual (USACE, 2008), storm surge in the open ocean due to a PMH can be estimated by empirical methods. The probable maximum surge on the open ocean is composed of the wind setup and pressure setup.

The USACE published the results of hurricane surge study specific to the Chesapeake Bay which is based on the August 1933 hurricane (USACE, 1959) because it caused the highest surge within the Chesapeake Bay. The storm surge in the open ocean due to the PMH just outside of the entrance to the Chesapeake Bay is calculated using the value given in Regulatory Guide 1.59 (NRC, 1977). The primary component of the surge just inside the mouth of the Chesapeake Bay is calculated according to the relationship between the surge at this point and the open ocean surge provided in Figure 15 of USACE (1959). The primary component of the surge is defined as the wave of water which enters through the mouth of the Chesapeake Bay and travels up the bay. Once the surge height just inside the Chesapeake Bay is known, the surge hydrographs provided in Table II of USACE (1959) are used to proportion the surge at the mouth of the Chesapeake Bay to obtain the surge height closest to CCNPP Unit 3 site. The effect (i.e., setup) of local cross-winds is added to this primary surge height, along with the 10% exceedence high spring tide, sea level anomaly (i.e., initial rise), and long term-rise to the primary component of the surge at CCNPP Unit 3 site to obtain the probable maximum storm surge (PMSS). The PMSS closest to CCNPP Unit 3 was computed by this approach to be 20.4 ft (6.22 m) NGVD 29.

2.4.5.2.2.3 SLOSH Model

PMSS at the site can also be predicted by using the NOAA computer model Sea, Lake, and Overland Surges from Hurricane (SLOSH) version 3.94 (Jelesnianski, 1992; Glahn et al, 2009).

SLOSH

The SLOSH computer model was developed to forecast real-time hurricane storm surge levels on continental shelves, across inland water bodies and along coastlines, including inland routing of water levels. SLOSH is a depth-averaged two-dimensional finite difference model on curvilinear polar, elliptical, or hyperbolic grid schemes. Modification of storm surges due to the overtopping of barriers (including levees, dunes, and spoil banks), the flow through channels and floodplains, and barrier cuts/breaches are included in the model. The effects of local bathymetry and hydrography are also included in the SLOSH simulation. Details of model formulation and application can be found in Jelesnianski (1992).

The NOAA SLOSH model requires the hurricane pressure difference (Δp), hurricane track description including landfall location, forward speed, and size, given as the radius of maximum wind, as input to define the physical attributes of a hurricane in performing a storm surge simulation (Jelesnianski, 1992). The SLOSH Chesapeake Bay basin model extent includes CCNPP Unit 3 site. The model is set up using a curvilinear polar grid system (NOAA, 2006b). The basin bathymetry and water levels in the model input and output are referenced to NGVD 29.

The time sequence of hurricane movement or the hurricane track is a required input to the SLOSH model represented by a series of successive locations of the center of hurricane. The hurricane track is derived as a function of the hurricane direction (angle), forward speed, and landfall location (defined as the location where the hurricane crosses the shoreline). Model simulations are performed for different combinations of the PMH parameters to obtain the maximum surge water level at the site. The model results are processed using the NOAA SLOSH Display Program (NOAA, 2009). The CCNPP Unit 3 is located in the SLOSH model grid cell (31, 59) and the simulated time histories of water levels are extracted from this grid cell for the PMSS evaluation. The model grid for the Chesapeake Bay basin and the location of CCNPP Unit 3 site are shown in Figure 2.4-21.

Comparison of SLOSH Results with Observations

The SLOSH model predictions have been validated against observed hurricane surge levels at several locations (Jelesnianski, 1992; Jarvinen, 1985). The errors of the SLOSH model predictions, defined by subtracting the observed surge water levels from model predictions, were evaluated for ten storms in eight SLOSH model basins, 90 percent of which were in the Gulf of Mexico. Based on a comparison of the SLOSH simulated surge heights against 523 observations, a mean error of -0.09 m (-0.3 ft) was reported. The range of errors was from -2.16 m (-7.1 ft) to 2.68 m (8.8 ft) with a standard deviation of 0.61 m (2 ft) (Jarvinen, 1985).

NOAA Technical Report NWS 48 (Jelesnianski, 1992) also provides a comparison of SLOSH model results with observations for well-documented hurricanes. A total of 570 observations from 13 significant hurricanes in nine SLOSH basins were evaluated. NOAA concludes that the model results generally stayed within ± 20% for significant surges (Jelesnianski, 1992). i.e., if the model calculates a peak storm surge of 10 ft (3 m) for the event, the observed peak could range from 8 to 12 ft (2.4 to 3.7 m).

SLOSH model simulation of the August 1933 hurricane was performed to facilitate a comparison with observed data in the Chesapeake Bay. The comparisons at Baltimore, MD, Annapolis, MD, and Sewells Point, VA indicate that model results underestimate observed surge elevations by a maximum of approximately 7%.

Comparison with RG 1.59

RG 1.59 provides estimates of the PMSS elevation along the U.S. Gulf and Atlantic Coasts (NRC, 1977). At the entrance of the Chesapeake Bay, RG 1.59 provides a PMH surge height (including wind and pressure setup) of 17.30 ft (5.3 m). By comparison, the surge height simulated by the SLOSH model at the entrance of the Chesapeake Bay (model grid cell 45, 15) for the PMH parameters provided in Table 2.4-23 is higher at 19.9 ft (6.1 m) or 23.9 ft (7.3 m) accounting for the 20% uncertainty. Consequently, it is concluded that the PMSS elevation obtained from the SLOSH model is conservative with respect to RG 1.59.

Sensitivity of PMH Parameters on Storm Surge Elevation

SLOSH model runs were performed to investigate the effects of the PMH forward speed, size, direction, and track distances from the site and Chesapeake Bay entrance on the storm surge elevation. The ranges of the parameters used in the simulations include two steady state PMH forward speeds (the lower and upper bounds), three PMH radiuses of maximum wind (the mean, the lower bound and upper bound), nine PMH directions and thirteen track distances. Based on the results of the SLOSH model sensitivity runs, it was concluded that the PMSS at the site would be generated by a PMH that:

1. has the lower bound forward speed of 17 knots (19.6 mph or 31.5 km/h);
2. has the upper bound size (radius of maximum wind of 26 nautical miles (29.9 mi 48.2 km);
3. approaches the Atlantic Ocean shoreline with a westward direction (270 degrees from the north), and with a track distance of approximately 1.5 times the upper bound radius of maximum wind south of the Chesapeake Bay entrance; and
4. passes by the west of the site with a distance of approximately 0.25 times the upper bound PMH size and is directed towards north (360 degrees from north).

Application of SLOSH for CCNPP Unit 3

Based upon the above studies a PMH track was developed. The selected PMH track direction and the envelope of simulated maximum surge elevation for the SLOSH Chesapeake Bay basin is shown on Figure 2.4-22. The PMH parameters (e.g., Radius of Maximum Winds and Central Pressure) were computed for 16 points (1 hour intervals) along the PMH track. This information is provided in Table 2.4-22 and is used to compute surge height using the SLOSH model.

The methodology in Technical Report NWS 23 (NOAA, 1979) was utilized to compute the wind field at the site accounting for the reduction in wind speed after landfall. The maximum 10 meters 10-minute wind speed at the point of landfall was computed as 152.6 mph (245.6 km/h). The CCNPP Unit 3 site is located near point 8 of the 16 point path (Table 2.4-22). The 10 minute maximum wind speed at point 8 is 116.4 mph (187.3 km/h) after 8 hours from landfall. Point 8 is located inland; therefore, the PMH wind speed will further decay due to friction. At the site, the estimated 10-meter 10 minute maximum wind speed is 111.7 mph (179.8 km/h) by accounting the decay in the wind field due to landfall at Point 8.

The simulated storm track contains the defined 16 points the PMH track. The SLOSH model was initialized with a water level of 0.0 ft (0.0 m), to allow the maximum possible antecedent water level, the sea level anomaly, 10% exceedence high spring tide and long term sea level rise to be addressed separately.

2.4.5.2.2.4 Probable Maximum Storm Surge Elevation at CCNPP Unit 3

The SLOSH model predicted a maximum surge elevation at the site of 11.0 ft (3.35 m) from a water level of 0.0 NGVD 29. The simulated surge height was then adjusted to take into account the 20% margin (SLOSH model uncertainties) suggested in Technical Report NWS 48 (Jelesnianski, 1992) and the antecedent water level of 4.4 ft (1.34 m) NGVD 29. The surge over time is shown in Figure 2.4-23. The final PMSS elevation thus obtained is 17.6 ft (5.35 m) NGVD 29.

Using the empirical method, the PMSS was computed to be 20.4 ft (6.22 m) NGVD 29 indicating that the empirical method is over-predicting the storm surge when compared to the SLOSH model results. The High PMSS value can be attributed to the fact that the USACE method is based upon the one hurricane of 1993. See Table 2.4-24 for comparison of results between SLOSH and empirical method.

2.4.5.3 Wave Action

With the exception of the intake structures, CCNPP Unit 3 is approximately at 85 ft (26 m) NGVD 29 and beyond 1,000 ft (305 m) from the shoreline and is not expected to be affected by the PMSS including wave action. The safety-related forebay and UHS Makeup Water Intake Structure (MWIS), shown inFigure 2.4-25are affected by the PMSS and by wind waves generated during a PMH event.

2.4.5.3.1 Hurricane Maximum Wind Speed

The hurricane wind direction at the CCNPP Unit 3 site will change clockwise from southwestward to southeastward, as the PMH passes by the western side of the Chesapeake Bay moving in the composite direction from landfall to a location north of the CCNPP Unit 3 site as shown in Figure 2.4-25. The hurricane wind speed will decrease as the PMH moves closer to the site after landfall. As discussed in Section 2.4.5.2.2.3, the wind speed corresponding to the PMH conditions is 111.7 mph (179.8 km/h).

2.4.5.3.2 Wave Height and Run-up

As described in Section 2.4.5.2, the PMH will cause the highest surge height at the CCNPP Unit 3 site when it travels north following a track on the west side of the Chesapeake Bay. The SLOSH simulation results show that the highest sustained wind speed of a PMH to generate the maximum wave height at the CCNPP Unit 3 site will come from the east or southeast and will occur when the eye of the hurricane is southwest of the CCNPP Unit 3 site at a distance equal the radius of maximum wind. Because the peak surge and the maximum wind speed from the PMH are active at the site for a relatively short duration compared to the total duration of the PMH (Figure 2.4-23 and Figure 2.4-24), the growth of wind- induced waves at the site would be limited by duration instead of the large fetch length. The wind-induced wave height and period at the CCNPP Unit 3 site is calculated following the procedure described in the USACE Coastal Engineering Manual (USACE, 2008). The significant wave height (Hmo) is 10.8 ft (3.31 m) and the 1% wave height (1.67 times Hmo) is 18.1 ft (5.52 m).

During the passage of the PMH event at the CCNPP Unit 3 site, the elevation of the storm surge is 17.6 ft (5.35 m) NGVD 29. The grade elevation surrounding the intake structures is 10 ft (3.05 m), leaving the grade inundated with 7.6 ft (2.30 m) of water. Since the storm surge is above grade, some waves will propagate unimpeded around the intake structure to a graded slope farther inland, while other waves will directly impact the intake structure façade.

The maximum sustainable unbroken wave height in 7.6 ft (2.30 m) of water was calculated to be 5.9 ft (1.79 m). Waves larger than this value will break and diminish in size while waves 5.9 ft (1.79 m) or smaller may strike the intake structures without breaking. The maximum wave runup on the intake structure was computed to be 15.6 ft (4.76 m). This runup, combined with the PMSS, will reach an elevation of 33.2 ft (10.11 m) NGVD 29 as shown on Figure 2.4-26.

Waves that travel past the intake structure will break on a smooth 3H:1V slope farther inland. The runup in this location was calculated to be 16.3 ft (4.96 m), which combined with the PMSS reaches an elevation of 33.9 ft (10.31 m) NGVD 29.

2.4.5.3.3 Effect on Safety-Related Structures

Because the grade elevation of the CCNPP Unit 3 power block is approximately 85 ft (26 m) NGVD 29 and the power block is located approximately 1,000 ft (305 m) from the shoreline, the CCNPP Unit 3 power block will not be impacted by the PMH-induced flood events.

The safety-related UHS MWIS will be flooded during the PMSS and is designed to meet the requirements of Regulatory Guide 1.27 (NRC, 1976b). Access into the UHS MWIS below the maximum water level during the PMH is designed to be watertight to prevent the internal flooding of the structures. The design of the UHS MWIS is discussed in Section 3.8 and Section 9.2.5.

2.4.5.4 Resonance

No significant oscillations appear in the historical storm surge records of the Chesapeake Bay. Recorded surge hydrographs at different locations in the Chesapeake Bay during the passage of Hurricane Isabel in 2003 are shown in Figure 2.4-27. The figure shows that the storm surge gradually rises to its peak and then gradually reverts back to the normal water level when the influence of the hurricane is diminished.

When the storm surge due to a hurricane traveling in a northerly direction enters the Chesapeake Bay, the water level at the lower Chesapeake Bay will increase (set-up) due to the passage of the surge wave. At the same time the water level at the upper Chesapeake Bay is likely to decrease (set-down) due to the counterclockwise pattern of the wind field. Similarly, when the storm surge approaches the upper Chesapeake Bay combined with a southerly wind, the water level in the upper Chesapeake Bay will increase and the water level in the lower Chesapeake Bay will eventually decrease.

Except for this variation in water level during the passage of a hurricane, historical records in the Chesapeake Bay do not show any significant oscillations affecting the storm surge levels in the Chesapeake Bay. Once the hurricanes move beyond the Chesapeake Bay region, small oscillations have been observed. However, these oscillations did not amplify the water level during the passage of the peak storm surges.

Sustained wind speed along the axis of the Chesapeake Bay (north-south) may trigger a seiche event in the Chesapeake Bay. The period of these oscillations along the north-south axis of the Chesapeake Bay is reported to be between 2 and 3 days. Because the effects of seiche oscillation are eliminated by a change in sustained wind direction, any existing seiche oscillation in the Chesapeake Bay prior to the arrival of any hurricane will be eliminated by the strong and changing wind field of the hurricane. Hence, resonance of seiche oscillation with PMSS is precluded.

2.4.5.5 Protective Structure

The shoreline near the UHS makeup water intake structure will be protected against the PMH and coincident wind-wave conditions. The design crest elevation of the shore protection structure will be 10 ft (3 m) NGVD 29. Flood protection measures for the UHS MWIS are discussed in Section 2.4.10.

2.4.5.6 References

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2.4.6 Probable Maximum Tsunami Flooding

The U.S. EPR FSAR includes the following COL Item in Section 2.4.6:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information and determine the extent to which the plant safety-related facilities require protection from tsunami effects, including Probable Maximum Tsunami Flooding.

This COL Item is addressed as follows:

{This section develops the geohydrological design basis to ensure that any potential hazards to the structures, systems, and components important to safety due to the effects of a probable maximum tsunami are considered in the plant design.

Sections 2.4.6.1 through 2.4.6.12 are added as a supplement to the U.S. EPR FSAR.

2.4.6.1 Probable Maximum Tsunami

Tsunami events that could affect the CCNPP Unit 3 would be caused by local or distant geo-seismic activities. While local tsunamigenic source mechanisms could include submarine or subaerial landslides in the Chesapeake Bay, distant tsunami sources would include submarine fault displacements, submarine landslides, or volcanic eruptions in the Atlantic Ocean. Because the CCNPP site is most likely to be affected by tsunamis generated in the Atlantic Ocean, potential tsunami sources in the Atlantic Ocean were considered when tsunami effects on the CCNPP site were evaluated.

The potential of a subaerial landslide near the site was assessed with geological maps, topographic maps, and CCNPP site reconnaissance. Along the western shoreline of the Chesapeake Bay, slope failure has occurred and appears to be caused by erosion of the base of the cliffs that reach an Elevation of about 100 ft (30.5 m) NGVD 29 (National Geodetic Vertical Datum of 1929), as described in Section 2.4.9. Two additional cliff failure scenarios, sliding and toppling along a failure plane, are hypothesized in Section 2.5.5.2.2. However, they are not supported by geologic and hydrogeologic evidence and are not expected to occur. Combined with the shallow water depth in the near shore area of the cliffs, it is not credible that the safety-functions of the plant would be affected as a result of tsunamis generated from these hypothetical cliff failure mechanisms. Across from the CCNPP site, the eastern shore of the Chesapeake Bay, as shown on USGS topographical maps (USGS, 1982a) (USGS, 1982b), consists of nearly flat terrain, primarily of low and wide tidal flats with a maximum topographic elevation near the eastern shoreline of approximately 7.5 ft (2.3 m) NGVD 29. It is therefore evident that the eastern shore of the Chesapeake Bay, opposite the CCNPP site, would not be subject to slope failure. If subaerial landslides near the site were to happen, they would not trigger local tsunami-like waves in the Chesapeake Bay.

Several tsunami studies identify tsunamigenic sources in the Atlantic Ocean and estimate tsunami impacts on the east coast of the U.S. Based on these studies and historical tsunami events recorded along the east coast of the U.S., discussed in Section 2.4.6.2, potential tsunamigenic sources that could affect the coastal region near the entrance of the Chesapeake Bay are identified as:

- A potential submarine landslide off the coast of Norfolk VA. Submarine landslides in this area along the Virginia and North Carolina continental shelf could produce tsunami amplitudes of 6.6 to 13 ft (2 to 4 m) along beaches from North Carolina to New York (Driscoll, 2000) (Ward, 2001a).
- Large tsunamis in the Atlantic Ocean generated by submarine landslides and volcanic flank failure near La Palma in the Canary Islands, which could be triggered by volcanic eruptions. Such tsunamis could propagate across the Atlantic Ocean and reach the U.S. east coast with tsunami amplitudes less than 10 ft (3 m) (Pararas-Caravannis, 2002) (Mader, 2001a).
- Tsunamis due to submarine fault displacement or volcanic activities near the Caribbean Islands. This area has a subduction zone where the North American Plate (moving west) meets the Caribbean Plate (moving east) (Maine, 2007). The maximum tsunami amplitude predicted near Newport News, Virginia from the Caribbean sources is about 3.1 ft (1 m) (NRC, 1979).

Other potential far-field tsunami sources in the Atlantic Ocean include an active subduction zone near the South Sandwich Islands in the South Atlantic Ocean (Maine, 2007), and earthquake zones off the coast of Newfoundland, Canada. Small tsunami amplitude of approximately 0.2 ft (0.06 m) near Newport News VA is predicted from the south Atlantic sources (NRC, 1979). Observations at Atlantic City NJ indicated a tsunami amplitude of about 2.2 ft (0.7 m) due to the 1929 earthquake near Grand Banks, Canada (NOAA, 2006a). Tsunami sources from these other areas were excluded when the Probable Maximum Tsunami (PMT) was estimated because of their small intensity.

The PMT amplitude and drawdown at the CCNPP site were computed for the three potential tsunami sources using the maximum and minimum tsunami-induced water surface elevations. The maximum simulated amplitude and drawdown at the CCNPP site were obtained from the postulated submarine landslide at the Virginia-North Carolina continental shelf off the coast of Norfolk VA. The PMT amplitude was estimated to be 1.6 ft (0.5 m) above the antecedent water level. The PMT drawdown was estimated to be 1.6 ft (0.5 m) below the antecedent water level.

Because the maximum and the minimum water levels at the CCNPP site would be affected by storm surges, as discussed in Section 2.4.5, the maximum and minimum water levels from the PMT did not represent limiting flood or low water design bases for the CCNPP site.

2.4.6.2 Historical Tsunami Record

All recorded historical tsunamis in the eastern U.S. and Canada from 1755 to 2006 are shown in Table 2.4-25 (NOAA, 2006a). Figure 2.4-28 shows the location of geo-seismic tsunami source generators in the Atlantic Ocean. From Figure 2.4-28 and Table 2.4-25, five potential tsunamigenic sources could be identified that could affect the CCNPP site. These sources are:

- A submarine landslide in the continental shelf along the east coast of the U.S.;
- Tsunamigenic sources along the Atlantic east coast including those near the Portuguese coast and Canary Islands;

- A marginal boundary subduction zone near the Caribbean Islands;
- Earthquake zones in the northern Atlantic Ocean primarily near Newfoundland, Canada; and
- A subduction zone near the South Sandwich Islands in the southern Atlantic Ocean.

Historical records and published studies indicate that the greatest severity of tsunami waves in the central east coast of the U.S. including the entrance of the Chesapeake Bay would be due to the first three sources. Regional records and eyewitness reports are part of the historical record, as appropriate. Note that historical records do not contain detailed earthquake source parameters. Estimates of such parameters as displacement volume, focal depth, and fault dimension and orientation are estimated based on eye witness accounts and resulting impacts on shorelines and coastal populations.

A submarine landslide from the continental shelf along the east coast of the U.S. is known to have occurred in the late Pleistocene era. This slide is known as the Albemarle-Currituck slide with an estimated volume displacement of 36 mi^3 (150 km^3). It is estimated the size of the generated tsunami wave was several meters at the coast line roughly equivalent to the height of a storm surge associated with a Category 3 or Category 4 hurricane. However, a large submarine landslide from the continental shelf off the east coast of the U.S. is a rare event on a human time scale (Driscoll, 2000).

The Chesapeake Bay bolide impact that was found in an exploration of the Chesapeake Bay area by the USGS (USGS, 1998) likely generated a paleo-tsunami about 35 million years ago. No estimate is available as to the size of the generated tsunami wave and no tsunami deposits attributable to this tsunami have been found. Also, information gathered during a literature search and geologic reconnaissance indicates that there is no evidence of a paleo-tsunami or paleo-tsunami deposits due to geo-seismic events in the CCNPP site region. A literature search reveals no historical or geologic evidence of seismically-generated seiches in Chesapeake Bay. Resonance frequencies of wind-induced seiches are described in Section 2.4.5.4.

No tsunami-specific monitoring program exists for the Atlantic Ocean. However, the U.S. National Seismograph Network (USNSN), operated by the U.S. Geological Survey, is part of a Global Seismic Network that monitors seismic (earthquake) activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by the seismographs, and beamed to a satellite and to the USNSN home base in Colorado, where it is analyzed and warnings (if needed) are issued (Maine, 2007).

The most notable historic tsunamis in the Atlantic Ocean that could affect the coastal region at the entrance of the Chesapeake Bay are summarized in the following sections. These tsunamis were generated from the tsunami source generators described above.

2.4.6.2.1 Tsunami from 1755 Lisbon, Portugal Earthquake

The most notable Atlantic Ocean tsunami that affected the east coast of the U.S. was generated off the coast of Portugal in 1755. The tsunami was generated at the Gorringe Bank, approximately 124 mi (200 km) from the Portuguese coast, due to a displacement in the submarine fault. The highest run up from this tsunami was estimated to be approximately 100 ft (30.5 m) near Lagos, Portugal. At Lisbon, Portugal a run up height of 40 ft (12.2 m) was reported (NOAA, 2006a). The maximum tsunami amplitude along the east coast of the U.S. was estimated to be approximately 10 ft (3 m) by numerical simulation (Mader, 2001b).

2.4.6.2.2 Tsunami from 1918 Puerto Rico Earthquake

The 1918 earthquake near Puerto Rico had a magnitude of 7.3 in the moment magnitude scale (Mw). It triggered a tsunami with run up height ranging between 13 ft (4 m) and 20 ft (6.1 m) along the Puerto Rico coast. The earthquake epicenter was located 9.4 mi (15.1 km) off the northwest coast of the island within the Puerto Rican Trench and the tsunami was caused by submarine fault displacement. Tsunami amplitude of approximately 0.2 ft (0.06 m) was recorded at Atlantic City NJ, located northeast of the CCNPP site (NOAA, 2006a).

2.4.6.2.3 Tsunami due to 1929 Earthquake at Grand Banks, Newfoundland, Canada

The 1929 earthquake had a moment magnitude of 7.4 M and generated one of the most devastating tsunamis in the northern part of the North American east coast. However, destruction due to this tsunami was mostly confined within the Newfoundland coast. The epicenter of the earthquake was located near the mouth of Laurentian Channel, south of the Burin Peninsula and on the south coast of Newfoundland. The earthquake triggered an underwater landslide that generated a tsunami with a run up height of 88.6 ft (27 m) at the Burin Peninsula. Water level records at Atlantic City NJ show that the maximum tsunami amplitude at this location from the 1929 Grand Banks tsunami was 2.2 ft (0.7 m) (NOAA, 2006a).

2.4.6.3 Tsunami Source Generator Characteristics

The tsunami analysis for the CCNPP site was performed in the Chesapeake Bay using tsunami propagation models that considered both nonlinear shallow water equations, including bottom friction and linear shallow water equations without bottom friction. The tsunami waves at the entrance of the Chesapeake Bay were characterized based on the results from published studies on the Atlantic Ocean tsunamis.

Three potential tsunami-generating sources were selected to estimate tsunami heights at the CCNPP site. These sources are selected based on the historical tsunami sources discussed in Section 2.4.6.2, using the locations shown in Figure 2.4-28, and from published studies. The hypothetical characteristics of the tsunami-generating sources and the tsunami wave characteristics at the entrance of the Chesapeake Bay are as follows:

2.4.6.3.1 Norfolk Canyon Submarine Landslide, Virginia

- Source: Submarine landslide of continental shelf off the coast of southern Virginia and North Carolina (Driscoll, 2000) (Ward, 2001a).
- Sliding Scenario: 36 mi^3 (150 km^3) of material running out at a speed of 49 to 115 ft/s (15 to 35 m/s) for 55 minutes (Ward, 2001a) (Driscoll, 2000).
- Tsunami Parameters: Maximum tsunami amplitude of 13 ft (4 m) at the Chesapeake Bay entrance with a period of 3,600 seconds.

It is suggested (Driscoll, 2000) that the presence of a system of en echelon cracks along the edge of the continental shelf, just north of the Pleistocene Albemarle-Currituck landslide, likely indicates an initial stage of a large scale slope failure. Because large magnitude earthquakes do not occur in the east coast of the U.S. or in the vicinity of the Norfolk Canyon, gas hydrate release and interglacial changes are possible triggering mechanisms for the landslide (Driscoll, 2000). Ward (Ward, 2001a) estimated the landslide parameters of the

Norfolk Canyon landslide based on assumptions that the size and volume of a potential landslide would be the same as the mapped debris field of the Pleistocene Albemarle-Currituck landslide. The slide front would advance at the same speed as that of the Storegga landslide in the northern Atlantic Ocean. Ward (Ward, 2001a) used these landslide parameters to perform model simulation for the submarine landslide-induced tsunami. While tsunami amplitude at the entrance of the Chesapeake Bay is selected from the model simulation results, of Ward (Ward, 2001a) the tsunami period is estimated based on recorded tsunami periods along the east coast of the U.S. The longest wave period recorded from the 1929 Grand Banks submarine landslide-generated tsunami was 40 min, recorded at Halifax, Nova Scotia, Canada (NOAA, 2006a). Considering the proximity of the Chesapeake Bay entrance to the tsunami source location, similar to that of Halifax to the Burin Peninsula, a tsunami wave period of similar time span could be approximated. However, because the shallow and wide continental shelf would likely cause the short-period component waves to dissipate before reaching the Chesapeake Bay entrance, the tsunami wave period at the entrance of the Chesapeake Bay was conservatively selected to be 60 min (3,600 sec).

2.4.6.3.2 La Palma in Canary Islands

- Source: Lateral collapse of flank of Cumbre Vieja Volcano on La Palma in Canary Islands (Pararas-Carayannis, 2002) (Mader, 2001a) (Ward, 2001b).
- Sliding Scenario: 120 mi^3 (500 km^3) of material running out 37.3 mi (60 km) at a mean speed of 328 ft/s (100 m/s) (Ward, 2001b).
- Tsunami Parameters: Maximum tsunami amplitude of 10 ft (3 m) at the Chesapeake Bay entrance with a period of 3,600 seconds.

Ward (Ward, 2001b) postulated the sliding scenario and the tsunami source parameters of the Cumbre Vieja volcanic flank failure based on geological evidence of the area, shape of the previous La Palma slide, and past collapses of similar volume elsewhere in the Canaries.

Although Mader and Ward used the same source and sliding scenarios for the Cumbre Vieja volcano flank failure, they obtained vastly different tsunami amplitude distribution along the east coast of the U.S. While Mader suggests wave amplitude of 10 ft (3 m) along the east coast of the U.S., Ward suggests a maximum tsunami amplitude of between 10 ft (3 m) and 25 ft (7.6 m). Pararas-Carayannis indicated that parameters for initial tsunami generation from the postulated landslide and the initial wave properties are incorrectly addressed in Ward, thereby greatly exaggerating the tsunami amplitude along the U.S. coast.

Pararas-Carayannis also pointed out that the initial tsunami period for the postulated landslide scenario would be small producing an intermediate wave condition rather than a shallow water wave condition. The tsunami database of the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center reveals that the maximum tsunami wave period (period of the first wave cycle) ever recorded along the U.S. coast was 100 min at Sitka, Alaska resulting from the 1938 Shumagin Island, Alaska earthquake tsunami (NOAA, 2006a). Along the east coast of the U.S., the maximum wave period of 30 min was recorded at Charleston, SC from the 1929 Grand Banks tsunami. Considering that the La Palma tsunami is postulated for a landslide generated tsunami and the tsunami wave would travel across the Atlantic Ocean where the short-period wave components would be dissipated, the selected wave period of 3,600 seconds is considered conservative.

The selected tsunami amplitude for this tsunami is nearly the same as the simulated tsunami amplitude from the 1755 Lisbon tsunami (Mader, 2001b). The selected wave period of 3,600 seconds also would provide a representative tsunami condition at the entrance of the Chesapeake Bay for a tsunami event of similar magnitude from this source.

2.4.6.3.3 Haiti in Caribbean Islands

- Source: Earthquake induced fault displacement (NRC, 1979)
- Displacement Scale: Length of 662 mi (1066 km), width of 298 mi (480 km), and peak displacement of 30 ft (9.2 m)
- Tsunami Parameters: Maximum tsunami amplitude of about 3.1 ft (0.9 m) at the Chesapeake Bay entrance with a period of 5,200 seconds obtained from the simulated tsunami hydrograph near Newport News VA as presented in Figure B-13 of NUREG/CR-1106 (NRC, 1979). The wave period was estimated as the period of the first wave cycle (peak to peak). NUREG/CR-1106 NRC (1979) used a linear shallow water wave model for the simulation of this tsunami.

2.4.6.4 Tsunami Analysis

Tsunami simulations were performed within the Chesapeake Bay using a two-dimensional, depth-averaged numerical model, TSU_NLSWE, Version 1.0. Because the water depth in the Chesapeake Bay is relatively shallow compared to the wavelength and amplitude of incident tsunamis, nonlinearity of waves and bottom friction effects are considered in the model formulation.The model is capable of simulating wave propagation in shallow waters using the nonlinear shallow water wave equations with bottom friction (NLSWE model), where the bottom friction term is taken as a function of the fluxes in the two horizontal directions and Manning's roughness coefficient. The model can also simulate wave propagation using the linear shallow water wave equations without bottom friction (TSU model).The model uses a leap-frog finite-difference scheme to numerically solve the governing partial differential equations. Tsunami simulations were conducted using both linear and nonlinear simulation models for both local and distant tsunami generators. Results were then compared to obtain the bounding tsunami amplitude at the CCNPP Unit 3 site.

2.4.6.4.1 Governing Equations

The governing equations used in the TSU_NLSWE model are shown below (Imamura, 2006) (IOC, 1997):

$$\frac{\partial \eta}{\partial t}+\frac{\partial P}{\partial x}+\frac{\partial Q}{\partial y}=0 \qquad \text{Eq. 2.4.6-1}$$

$$\frac{\partial P}{\partial t}+\frac{\partial}{\partial x}\left(\frac{P^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{PQ}{h}\right)+gh\frac{\partial \eta}{\partial x}+\frac{gn^2}{h^{7/3}}P\sqrt{P^2+Q^2}=0 \qquad \text{Eq. 2.4.6-2}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial y}\left(\frac{Q^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{PQ}{h}\right)+gh\frac{\partial \eta}{\partial y}+\frac{gn^2}{h^{7/3}}Q\sqrt{P^2+Q^2}=0 \qquad \text{Eq. 2.4.6-3}$$

Where:

- η represents the free surface displacement from still-water level;
- P and Q are the depth-averaged volume fluxes in the x and y directions, respectively;

- t is time;
- g is the acceleration of gravity;
- h is the water depth below the still-water level; and
- n is Manning's roughness coefficient.

Linearization of the governing equations in the TSU model option neglects the effect of convective terms in the equations of motion (second and third terms in Eq. 2.4.6-2 and Eq. 2.4.6-3). Additionally, bottom friction effects (the last term in Eq. 2.4.6-2 and Eq. 2.4.6-3) are neglected in the TSU model option. As a result, simulation results using the TSU model option provide a conservative upper bound solution for tsunami propagation in a shallow water environment such as the Chesapeake Bay.

A leap-frog, finite-difference scheme is employed to solve both the nonlinear and linear shallow water equations on a staggered grid in time and space, as shown in Figure 2.4-29. The equation of the continuity is approximated with an explicit, central-difference scheme. Approximation of the linear terms in the equations of motion also uses a central-difference scheme. An upwind scheme is applied to approximate the convection terms in the equations of motion. An implicit scheme is utilized for the bottom friction terms, as the friction term becomes a source of instability if it is represented using explicit scheme (Imamura, 2006; IOC, 1997).

Discretization of linear governing equations in finite-difference form generates numerical dispersion, which is a form of numerical error (Yoon, 2002). This numerical dispersion can be used as a surrogate for the physical dispersion neglected in the linear form of the shallow water equation by appropriately selecting the computational time step and grid spacing. For a fixed grid model with varying water depth, the accuracy of the linear model, therefore, is limited because of inherent model requirements of different grid sizes for different water depths. Yoon overcomes this limitation by separately calculating the computational grid spacing (termed as "the hidden grid spacing") at each time step, based on the dispersion criterion provided as input to the model. The computations are then performed on the hidden grids. At the end of each time step, the results are interpolated back at user-specified grid locations from the hidden grids. This technique has shown a considerable improvement in the accuracy of the solution of linear shallow water equations. This hidden grid approach was employed in developing the TSU_NLSWE model. The finite-difference schemes used in the models are represented in Figure 2.4-30 and Figure 2.4-31.

2.4.6.4.2 Model Simulations

Prior to using the TSU_NLSWE code for simulating tsunami propagation in Chesapeake Bay, it was necessary to verify the code. Verification was performed by comparing model simulation results against an analytical solution of Gaussian hump propagation developed by Carrier (2003). Comparison of the both the linear and nonlinear numerical solutions against the analytical solution resulted in good agreement for deep water. The model was also tested for a constant water depth of 10 m (32.8 ft) and the grid size of 360 m by 360 m (1181 ft by 1181 ft), which represents the relatively shallow depths of the Chesapeake Bay. The shallow water results for the linear simulation showed good agreement with the analytical solution. For the nonlinear simulation, a qualitative comparison showed that the numerical results appropriately predicted the nonlinear wave deformation and dissipation by bottom friction. A quantitative comparison for the nonlinear option was not possible as no analytical solution is available for the general nonlinear case. Yoon (2002) applied the linear model to simulate the propagation of the 1983 Nihonkai-Chubu tsunami. This earthquake-generated tsunami originated near the east rim of the Sea of Japan and impacted the Japanese coast. A comparison of model results with measured data along the Japan Sea coast showed that satisfactory agreement was obtained using the linear model (Yoon, 2002).

In addition, the TSU_NLSWE model was applied to simulate the tsunami event in San Francisco Bay generated by the 1964 Alaskan earthquake. The tsunami was triggered by the 9.2 magnitude (moment magnitude) Great Alaska Earthquake of 1964 that occurred on March 28, 1964 (National Research Council, 1972). At the time of occurrence, the earthquake was the most powerful in North America and the second most powerful in the recorded history of the world. Although the epicenter of the earthquake was on land, the shock waves were felt at the sea floor, causing a large submarine land displacement resulting in a large tsunami. According to NOAA records, the tsunami was generated at 3:36 a.m. Greenwich Mean Time (GMT) with an estimated maximum tsunami water height near the source of about 67 m (220 ft) above mean sea level (MSL), as obtained from eyewitness accounts. The tsunami wave swept through Prince William Sound, the Kodiak Islands and propagated south to the coasts of British Columbia, Washington, Oregon and California (National Research Council, 1972).

Both linear and non-linear models were applied to simulate tsunami propagation in San Francisco Bay. The simulated maximum tsunami amplitudes were compared with tsunami water heights recorded at five locations in San Francisco Bay. The recorded maximum water heights were estimated as one-half of the difference between the maximum tsunami crest and trough after tidal variations were removed from the data. The stations where tsunami water heights are available include the NOAA tide gages at San Francisco, Sea Cliff, Oakland and Alameda, and an eyewitness account at Sausalito. A comparison of model simulated water levels in the bay with observed data generally shows good agreement.

Based on these results, the TSU_NLSWE program code is considered verified.

The Chesapeake Bay Model Extent and Boundary Conditions

The TSU_NLSWE model code was used to provide estimates of maximum and minimum (low water) tsunami wave heights at the CCNPP Unit 3 site from both distant and local generators. Simulations were performed within the Chesapeake Bay for three potential tsunami sources generating the Probable Maximum Tsunami (PMT). The potential tsunamigenic sources are discussed in Section 2.4.6.1, and the source characteristics are described in Section 2.4.6.3. The characteristics of the incident tsunami waves at the entrance of the Chesapeake Bay and the computational cases for linear and nonlinear model simulation options are summarized in Table 2.4-28. Simulations were performed to obtain tsunami amplitude and drawdown for an initial water level condition corresponding to mean sea level (MSL) at the Chesapeake Bay Bridge Tunnel tide gauge. The PMT was then determined considering the simulated maximum tsunami amplitude at the CCNPP Unit 3 site, an antecedent water level condition based on the 10% exceedance high spring tide, sea level anomaly, and long-term sea level rise, as adopted in Section 2.4.5.

The Chesapeake Bay model domain extends approximately 180 mi (290 km) from near Plume Tree Point, Virginia to near the mouth of the Susquehanna River, including portions of the major river channels. Stream flow in the rivers and tidal variations were ignored in the tsunami simulations. A zero-flux condition was applied across fixed land boundaries. Flooding and drying of grid cells was not considered in the model.

Incoming tsunami amplitudes and periods for different cases, as presented in Table 2.4-28, were applied as regular sinusoidal waves along an internal boundary between Plume Tree Point, Virginia and Cape Charles, Virginia, as shown in Figure 2.4-32. The internal boundary was based on implementing a radiation boundary (Larsen, 1983). Implementation of the internal boundary, where the incoming tsunami is applied as a perturbation, requires that all outgoing waves are absorbed at the external boundaries of the model without reflection. This requirement was enforced by implementing non-reflective, absorbing layers (defined as "sponge" layers) for 10 grid lines along the boundaries. The procedure for defining a sponge layer is described by Larsen (1983). All outgoing waves, in terms of surface displacement and volume fluxes, are absorbed over the thickness of the sponge layers. Sponge layers were also implemented for the Patuxent, Potomac, Rappahannock and York Rivers along the west and Pocomoke Sound along the east boundary of the domain. Locations of the sponge layers are also shown in Figure 2.4-32. Boundaries for the other rivers, including the northern end of the Chesapeake Bay, were considered closed (no-flux) and fully reflective.

The Chesapeake Bay Bathymetry and Model Grid

Bathymetric data for the Chesapeake Bay were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Ocean Services program (NOAA, 2006b). The digital elevation model (DEM) data have a spatial resolution of 98.4 ft by 98.4 ft (30 m by 30 m) with coverage in 7.5-minute by 7.5-minute blocks (NOAA, 2006b). The depth soundings used to generate the bathymetry were surveyed over a period from 1859 to 1993. Thirty-six surveys were conducted in the 1859-1918 period, 37 in the 1930s, 91 in the 1940s, 66 in the 1950s, 25 in the 1960s, 24 in the 1970s, 14 in the 1980s, and 4 in the 1990s (NOAA, 2006b). The total range of sounding data is from 12.1 to -165.4 ft (3.7 to -50.4 m) at mean low water (MLW) with depths below MLW represented as negative values. The DEM data use the Universal Transverse Mercator (UTM) Zone 18N projected coordinate system with the North American Datum of 1927 (NAD27) for the horizontal coordinate system. The vertical datum is relative to MLW, where MLW is the average of all low water tides at a location over a 1983-2001 19-year period (or tidal epoch). The NOAA bathymetric data for the Chesapeake Bay are shown in Figure 2.4-123.

Bathymetric data were converted from local MLW datums to a global datum applicable for the entire model domain. MSL at Chesapeake Bay Bridge Tunnel (CBBT), which corresponds to the 1983-2001 tidal epoch, was adopted as the reference datum for the model and also assumed to be MSL for the CCNPP Unit 3 site. This assumption is conservative as the difference between the MSL and MLW at the CBBT station is the maximum inside the Chesapeake Bay. The MLW-MSL relationship at CBBT is given on the NOAA website (NOAA, 2007). Note that model results were converted to National Geodetic Vertical Datum of 1929 (NGVD 29) elevations for comparison with elevations of safety-related systems, structures, and components. The datum conversion relationship at the NOAA Cove Point, Maryland tide station (station 8577188) was used for this purpose. At the Cove Point station, MSL is 0.64 ft (0.195 m) higher than the NGVD 29 datum.

A square grid spacing of 360 m by 360 m (1181 ft by 1181 ft) was used to analyze tsunami wave propagation in the Chesapeake Bay. Typically, 10 to 20 grid points per wave length are recommended to accurately represent wave propagation in models based on the shallow water equations. Given a tsunami wave length of 33,260 m (109,093 ft), estimated based on the amplitude and period of the tsunami wave incident to the bay, the tsunami wave internal to the bay would be represented by about 92 grid points using the 360 m by 360 m grid and therefore adequately resolved. The effect of grid size on simulated tsunami water level at the CCNPP Unit 3 site was evaluated by comparing simulated results for grid sizes of 240 m by 240 m (787 ft by 787 ft) and 300 m by 300 m (984 ft by 984 ft). Figure 2.4-124 shows the variation of simulated water level at the CCNPP Unit 3 site for the three different grid sizes using the nonlinear model. These results show that the maximum water level at the CCNPP Unit 3 site are essentially the same for the 300 m by 300 m and 360 m by 360 m grids, while the maximum water level for the 240 m by 240 m was slightly lower. Based on this sensitivity analysis and a computational time requirement to satisfy dispersion criteria, a grid size of 360 m by 360 m was adopted for the computational domain. The numbers of grids in the two horizontal directions are 223 (east-west direction) and 790 (north-south direction). The bathymetric data used in the model, based on the 360 m by 360 m grid, are shown in Figure 2.4-32.

Numerical Simulation Cases

Numerical simulations were performed for three cases corresponding to the three tsunami generator sources identified in Section 2.4.6.1 and Table 2.4-26. For each case, simulations were performed with both linear (TSU) and nonlinear (NLSWE) models. The nonlinear NLSWE model includes the effects of wave dissipation due to bottom friction. To represent bottom friction, a constant Manning's roughness coefficient of 0.025 was used for the entire model domain for all three cases. The selected value represents natural channels in a good condition, as reported by Imamura (2006). Table 2.4-27 summarizes the model simulation conditions.

Model simulations were performed for a period of about 10 hours, which was selected by considering the tsunami travel time from the entrance of the Chesapeake Bay to the CCNPP Unit 3 site and the incoming tsunami period. A simulation time step of 5 seconds was selected based on a numerical stability criterion.

Wave characteristics generated along the internal boundary are shown in Figure 2.4-33, Figure 2.4-125, Figure 2.4-34, Figure 2.4-126, Figure 2.4-35, and Figure 2.4-36. These figures show that the water levels at three locations along the boundary agree reasonably well with the assumed incoming sinusoidal tsunami waves from the three potential tsunami sources. The three locations on the boundary are shown in Figure 2.4-32.

2.4.6.5 Tsunami Water Levels

The numerical simulation results of tsunami propagation in the Chesapeake Bay for different cases are summarized in Table 2.4-28. Contour maps of maximum computed water levels in the Chesapeake Bay for Case 1 for the nonlinear and linear simulations are shown in Figure 2.4-127 and Figure 2.4-128, respectively. These results show that the incoming tsunami waves dissipate quickly as they propagate up the Chesapeake Bay. The amounts of dissipation are similar in both the non-linear and linear simulations. The effects of wave non-linearity and bottom friction, accounted for in the nonlinear (NLSWE) model, result in additional dissipation of wave heights within the Chesapeake Bay. Therefore, simulation results from the liner (TSU) model are more conservative, providing greater amplitude and drawdown at the CCNPP Unit 3 site.

Variations in simulated water levels with time at the CCNPP Unit 3 site for the selected tsunami scenarios are shown in Figure 2.4-37 and Figure 2.4-38. These results show that the maximum tsunami amplitude at the CCNPP Unit 3 site is associated with Case 1, the Norfolk Canyon submarine landslide scenario, while the maximum tsunami drawdown that would occur is associated with Case 3, the Haitian earthquake scenario. Both maximum tsunami amplitude and drawdown were obtained with the linear (TSU) model. As shown in Table 2.4-28, the maximum tsunami amplitude and drawdown elevations at the CCNPP Unit 3 site are 1.07 ft (0.326 m) and 0.78 ft (0.237 m), respectively, as referenced to MSL. The results indicate that the linear solution of the shallow water equations provides bounding estimates of tsunami amplitude and drawdown at the CCNPP Unit 3 site.

An assessment of the sensitivity of model results and the PMT estimate to model inputs and assumptions indicated that there is uncertainty associated with simulating wave propagation in very shallow water depths near land boundaries. In particular, Synolakis (1987) indicates that run-up estimates from linear models are accurate provided that the ratio of tsunami amplitude to water depth is small. Ward (2001a) recommends that tsunami computations using linear models be confined to grid points where the water depth is greater than the amplitude of incoming tsunamis. At shallower water depths, Ward (2001a) argues that waves no longer amplify because of increasing bottom friction, and that the limiting amplitude approximates the tsunami run-up height. Because the Chesapeake Bay model includes water depths less than the amplitude of incoming tsunamis, the simulated maximum amplitude and drawdown, taken from the linear model, were increased to provide assurance that these values are not underestimated. The basis for the factor used to increase the maximum amplitude and drawdown is described below.

To quantitatively assess the effects of confining the tsunami computations to grid points where the ratio of tsunami amplitude to water depth is relatively large, a series of model sensitivity simulations were performed wherein the minimum allowable water depth (cutoff depth) was varied in the model. Three simulations with cutoff depths of 1.64 ft (0.5 m), 3.28 ft (1.0 m), and 6.56 ft (2.0 m) for both linear and nonlinear models were conducted using the Case 1 tsunami generator. In each simulation, portions of the domain having water depths less than the cutoff depth were eliminated from the model domain. The shallow water areas of the Chesapeake Bay affected by imposing cutoff depths include the western shoreline near the Potomac River mouth and upstream of the CCNPP Unit 3 site. The simulated water levels at the CCNPP Unit 3 site are shown on Figure 2.4-129 and Figure 2.4-130. The relative increases in maximum amplitude at the CCNPP Unit 3 site as a function of cutoff depth are summarized in Table 2.4-50.

The results from these simulations show that the amplitudes of the tsunami wave peaks and troughs at the CCNPP Unit 3 site generally increase with increasing cutoff depth for both linear and nonlinear models. Note that the maximum relative increase in amplitude (77 percent) occurred in the linear simulation with a 1.0 m cutoff depth; however, the maximum water level for this simulation appeared during the third wave peak, unlike the other cases wherein the relative increase was greatest for the first peak. Excluding this apparently anomalous case, the 2.0 m cutoff depth resulted in the maximum water level. Consequently, the selected maximum water level from the Case 1 linear simulation was increased by 60 percent to obtain the PMT water level at the CCNPP Unit 3 site. The same factor was also adopted for the PMT drawdown level. Therefore, the maximum tsunami amplitude and drawdown at the CCNPP Unit 3 site were determined to be 1.71 ft (0.522 m) and 1.24 ft (0.379 m), respectively.

The PMT water level at the CCNPP Unit 3 site was determined by adding an appropriate antecedent water level and a tsunami run-up height to the computed tsunami amplitude. The antecedent water level was established as 4.34 ft NGVD 29, which accounts for the 10% exceedance high spring tide (2.17 ft or 0.66 m NGVD 29), a sea level anomaly (1.1 ft or 0.34 m NGVD 29), and long-term sea level rise (1.07 ft or 0.33 m NGVD 29) as described in Section 2.4.5. The PMT water level is therefore (1.71 ft + 4.34 ft =) 6.05 ft (1.84 m) NGVD 29.

Mader (2001b) indicates that tsunami run-up is about 2 to 3 times the deep-water tsunami amplitude. Madsen and Fuhrman (2007) describe a methodology to estimate tsunami run-up on plane beaches employing the surf similarity parameter. Because the Chesapeake Bay bathymetry varies considerably from natural beaches, Madsen and Fuhrman's method may underestimate tsunami run-up at the CCNPP Unit 3 site. Therefore, a tsunami run-up of 3 times the maximum tsunami amplitude in the Chesapeake Bay near the site, as recommended by Mader (2001b), was used to provide a conservative estimate of run-up. The run-up height therefore was estimated as (3 x 1.71 ft =) 5.13 ft (1.563 m).

The PMT high-water level, considering the maximum tsunami amplitude, antecedent conditions and run-up, was therefore estimated as (6.05 ft + 5.13 ft =) 11.18 ft (3.408 m) NGVD 29 or rounded up to 11.5 ft (3.5 m) NGVD 29.

The PMT low-water level was estimated by combining the adjusted drawdown with mean lower-low water (MLLW) datum at the NOAA Cove Point, MD station. Because incoming tsunamis were assumed to have a sinusoidal wave shape that likely estimates the tsunami trough, use of MLLW as the antecedent water level for the low-water PMT estimate was considered adequate. The MLLW level at the CCNPP Unit 3 site is 0.01 ft (0.003 m) NGVD 29 as given in Section 2.4.11. Consequently, the PMT low-water level at the CCNPP Unit 3 site was estimated as (0.01 ft - 1.24 ft =) -1.23 ft (-0.375 m) NGVD 29 or rounded down to -1.5 ft (-0.46 m) NGVD 29.

The numerical simulation indicates that the tsunami waves would experience significant dissipation when propagating up the Chesapeake Bay. Incoming tsunami waves with an amplitude of 13 ft (4 m) at the internal boundary dissipated over a distance of about 90 mi (144 km) to an adjusted wave amplitude of 1.71 ft (0.522 m) at the CCNPP Unit 3 site when propagating over relatively shallow water depths.

The simulated travel time for the tsunami to arrive at the CCNPP Unit 3 site from the model boundary near the Chesapeake Bay entrance was found to be about 3.5 hours. Note that the periods of the incoming tsunami wave were selected to be 1 hour (3,600 seconds) for Cases 1 and 2, and 1.44 hours (5,200 seconds) for Case 3.

Because the PMT maximum water level of 11.5 ft NGVD 29 is much less than the probable maximum storm surge still-water level of 21.7 ft NGVD at the CCNPP Unit 3 site, as established in Section 2.4.5, the PMT maximum water level would not constitute the design basis flood elevation at the CCNPP Unit 3 site. As described in Section 2.4.11.2.3, the design basis low-water level in the Chesapeake Bay near the site is the result of a Probable Maximum Hurricane along the eastern shore.

2.4.6.6 Hydrography and Harbor or Breakwater Influences on Tsunami

The Dominion Cove Point Liquefied Natural Gas (LNG) facility near Cove Point has a platform that is approximately 1,500 ft (457 m) long. The platform is located approximately 4 mi (6.4 km) southeast of the CCNPP Unit 3 site. The platform is aligned with the main flow direction in the Chesapeake Bay and, therefore, will not cause any obstruction to tsunami propagation. The effect of the platform was not considered in tsunami model simulations. The bathymetric influence on tsunami propagation was included in the model simulation by the water depth.

2.4.6.7 Effects on Safety-Related Facilities

Because the CCNPP Unit 3 project area elevation is set at approximately 85.0 ft (25.9 m) NGVD 29, the safety-related facilities on the power block will not be affected by the PMT.

By comparing the probable maximum storm surge (as discussed in Section 2.4.5) and the PMT at the CCNPP Unit 3 site, it is evident that the maximum water level at the safety-related UHS makeup water intake structure would be governed by the probable maximum storm surge height. The minimum water level at this location also is governed by storm surge events as shown in Section 2.4.11. Therefore, probable maximum tsunami events will not constitute the governing design basis for the safety-related UHS makeup intake system and associated shore protection structures.

2.4.6.8 Hydrostatic and Hydrodynamic Forces

The hydrostatic forces are proportional to the water depth below the still-water level. Comparing still-water levels due to the PMT and probable maximum storm surge (PMSS) at 10% exceedance high tide antecedent condition at the CCNPP Unit 3 site, the PMSS water level (21.7 ft or 6.6 m NGVD 29) is about 10.2 ft or 3.1 m higher than the PMT water level (11.5 ft or 3.5 m NGVD 29).

The PMT maximum water level including run-up will be at the deck elevation of the safety-related UHS makeup water intake structure at 11.5 ft (3.5 m) NGVD 29 as described in Section 2.4.1.1. Coincident wind-wave runup is unlikely to reach the UHS makeup water intake structure as the intake structure is offset from the shoreline. Consequently, there would be insignificant dynamic wave forces on the UHS intake structure from the PMT wave. The hydrodynamic wave force on the UHS makeup water intake structure is controlled by the PMSS event, as described in Section 3.8.4.

2.4.6.9 Debris and Water-Borne Projectiles

The tsunami water level including tsunami amplitude, antecedent water level and run-up is estimated to be 11.5 ft (3.5 m) NGVD 29. The elevation of the UHS intake operating deck and pump room floor providing foundation for safety-related equipment including pumps are 11.5 ft (3.51 m) NGVD 29. The PMT at the CCNPP Unit 3 site will not affect the operation of the UHS makeup water intake structure because the tsunami water level is at the deck and pump floor elevation. Therefore, debris and water-borne projectiles are not expected to affect the UHS intake structure. The CCNPP Units 1 and 2 forebay baffle wall, CCNPP Unit 3 intake sheet pipe wall and inlet protection screen, protect the inlets of intake pipes that convey water to the UHS intake structure from debris and water-borne projectiles.

2.4.6.10 Effects of Sediment Erosion and Deposition

Because the PMT amplitude is 1.71 ft (0.522 m), the UHS makeup water intake structure is not affected by PMT. Because the Units 1 and 2 baffle wall and Unit 3 sheet pile wall protect the CCNPP Unit 3 intake pipe inlet area, erosion effects near the intake pipe inlet would be negligible.

The estimated PMT amplitude is small compared to the water depth in the CCNPP Units 1and 2 intake forebay and is not expected to produce high sediment transport capacity. Suspended sediments flowing towards the CCNPP Unit 3 intakes would travel through the opening underneath the Units 1 and 2 forebay baffle wall and would likely deposit in the CCNPP Unit 3 inlet area sheltered by the baffle wall and the sheet pile wall. Because the inlets of the intake pipes are located at about 10 ft (3.05 m) above the bed elevation, blockage of intake pipes due to sediment deposition is unlikely as a result of the PMT.

2.4.6.11 Consideration of Other Site-Related Evaluation Criteria

Three tsunami sources are selected to analyze the PMT at the CCNPP site. Two tsunami sources (Norfolk Canyon and Canary Islands) are assumed to generate the tsunami due to submarine landslide. The Norfolk Canyon landslide is assumed to be triggered by gas hydrate decomposition. The Canary Islands flank landslide is assumed to be generated by volcanism. These two tsunami-sources are not associated with the design basis earthquake.

A potential tsunami near Haiti will be generated by the fault displacement due to an earthquake. Since this earthquake will be a long-distance earthquake from the CCNPP site, the earthquake magnitude will be significantly attenuated during the propagation toward the CCNPP site. The magnitude of this earthquake at the CCNPP site will be less than the design basis earthquake.

The design basis earthquake of the CCNPP site is still limiting even when tsunami-generating earthquakes are taken into consideration.

Therefore, the tsunami event will not be combined with seismic events in the design of systems, structures, and components.

2.4.6.12 References

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2.4.7 Ice Effects

The U.S. EPR FSAR includes the following COL Items for Section 2.4.7:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information regarding ice effects and design criteria for protecting safety-related facilities from ice-produced effects and forces with respect to adjacent water bodies.
>
> A COL applicant that references the U.S. EPR design certification will evaluate the potential for freezing temperatures that may affect the performance of the

ultimate heat sink makeup, including the potential for frazil and anchor ice, maximum ice thickness, and maximum cumulative degree-days below freezing.

These COL Items are addressed as follows:

{As discussed in Section 2.4.1, the Calvert Cliffs Nuclear Power Plant (CCNPP) site is located on the western shore of the Chesapeake Bay, approximately 10.5 mi (16.9 km) southeast of Prince Frederick in Calvert County, Maryland. Figure 2.4-1 indicates the location of the site.

Reference to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD), unless otherwise stated.

Sections 2.4.7.1 through 2.4.7.10 are added as a supplement to the U.S. EPR FSAR.

2.4.7.1 Ice Conditions

Ice at a nuclear power plant site could occur in any one of the following forms:

- Surface ice and its associated forces
- Anchor ice formation on components
- Frazil ice that could clog intake flow passages
- Ice jams that could affect flow path to the water supply intake
- Breach of ice jams causing flooding at site
- Ice accumulation on roofs of safety-related structures and components
- Ice blockage of the drainage system causing flooding
- Ice accumulation causing reduction in water storage volume

Historical data characterizing ice conditions at the CCNPP site have been collected and the effects evaluated for CCNPP Unit 3. These data include ice cover and thickness observations in the Chesapeake Bay and its tributaries, ice jam records, and long term air temperature measurements from the nearby Patuxent River Naval Air Station meteorological tower (WBANID 13721). Patuxent River Naval Air Station is approximately 10 mi (16 km) south of the CCNPP site on the same (western) shore of the Chesapeake Bay. It also maintains a data record from 1945 to present. Figure 2.4-39 shows the location of the Patuxent River Naval Air Station relative to the site.

2.4.7.2 Description of the Cooling Water Systems

CCNPP Units 1 and 2

The existing CCNPP Units 1 and 2 use an open cycle once-through cooling system for their normal heat sink. The once-through Circulating Water System withdraws cooling water from Chesapeake Bay via the CCNPP Units 1 and 2 shoreline intake structure, circulates it through the main condensers, and returns the heated water to the Chesapeake Bay via the existing submerged outfall about 850 ft (259 m) offshore. Also relying on the Chesapeake Bay for its cooling water supply is the Salt Water System. The Salt Water System is a safety-related system that provides cooling water for the Service Water System, Component Cooling Water System, and Emergency Core Cooling System pump room coolers. Seal water for the circulating water pumps, which supply water to the main condensers, is also supplied by the Salt Water System. Each unit has three Salt Water System pumps that provide the driving head to move saltwater from the CCNPP Units 1 and 2 shoreline intake structure through the system and back to the existing circulating water discharge conduits.

CCNPP Unit 3

The CCNPP Unit 3 Circulating Water System (CWS) uses a closed-cycle wet cooling tower system as its normal heat sink. Makeup water to the CWS is supplied from the new nonsafety-related CWS makeup water intake structure which withdraws water from the Chesapeake Bay. Blowdown flow from the cooling tower is sent to a common retention basin for water quality treatment prior to discharging to an offshore outfall in the Chesapeake Bay. The CWS is a non-safety-related system.

CCNPP Unit 3 also has a safety-related Essential Service Water System (ESWS) to provide cooling water to the Component Cooling Water System heat exchangers and to the emergency diesel generator cooling jackets to dissipate heat. The ESWS is a closed-cycle system that uses mechanical draft cooling towers for heat removal. These cooling towers provide the Ultimate Heat Sink (UHS) function. Makeup water to the ESWS cooling towers is normally obtained from the desalinization plant that receives water from the CWS. No separate shoreline intake at the Chesapeake Bay is required for the desalinization system.

The basins of the ESWS cooling towers are sized to provide sufficient water to permit the ESWS to perform its safety-related heat removal function for up to 3 days (72 hours) post-accident under the worst anticipated environmental conditions without replenishment. Beyond the 72-hour post-accident period, makeup water is supplied from the new UHS makeup water intake structure, a safety-related structure situated on a common forebay with the CCNPP Unit 3 CWS makeup intake structure. Blowdown from the ESWS cooling towers discharges to the common retention basin and eventually to the new offshore outfall.

2.4.7.3 Intake and Discharge Structures

CCNPP Units 1 and 2 use water from the Chesapeake Bay for cooling purposes. Water is drawn to the CCNPP Units 1 and 2 intake structure on the shoreline east of the main plant through a 40 ft (12 m) to 51 ft (15.5 m) deep dredged channel that extends approximately 4,500 ft (1372 m) offshore. A baffle wall that extends to a depth of -28 ft (-8.5 m) over the intake channel, limits the intake to mostly bottom water. Water is discharged to the north of the plant through the existing outfall, which is approximately 850 ft (259 m) offshore. The outfall is located in a dredged discharge channel with a bottom elevation of about -19.5 ft (-5.9 m).

The Unit 3 UHS and CWS makeup water intakes are located about 500 ft (152 m) southeast of the Units 1 and 2 intake structure, and at approximately 60 ft (18 m) offset from the shoreline. They supply makeup water to the nonsafety-related CWS and to the safety-related ESWS cooling towers of Unit 3. Water will be withdrawn from the Chesapeake Bay and conveyed to a common forebay via two new 60-inch (152.4 cm) diameter safety-related intake pipes. The inlet of the two intake pipes is located adjacent to the Units 1 and 2 intake structure. The inlet area is sheltered from the current and wind-wave actions of the Chesapeake Bay by the existing baffle wall and a new sheet pile wall that extends from the shore to the southern corner (relative to Plant North) of the baffle wall. The safety-related UHS intake and nonsafety-related CWS intake structures are situated on opposite ends of the forebay. The CCNPP Unit 3 CWS makeup water intake structure houses a total of three CWS makeup pumps. The Unit 3 UHS makeup water intake structure houses a total of four UHS makeup pumps. All UHS makeup pumps are installed in individual pump bays, each with a set of dedicated bar screens (trash racks) and traveling water screens to filter out debris. The design minimum operating water levels at the Chesapeake Bay are -4 ft (-1.2 m) and -6 ft (-1.8 m) for the CWS and UHS makeup intakes, respectively.

Plant effluent going back to the Chesapeake Bay from CCNPP Unit 3 consists of cooling tower blowdown from the CWS cooling tower and the ESWS cooling towers, desalinization plant reject stream, and non-radioactive wastewater streams from the domestic water treatment and circulating water treatment systems. A 30 in (76.2 cm) diameter outfall pipe is used to discharge the plant effluent to a submerged 3-port diffuser located about 550 ft (168 m) offshore and approximately 1151 ft (351 m) south and 650 ft (198 m) east of the intake piping for Unit 3 (relative to Plant North).

Figure 2.4-49 shows the location of the CWS and UHS makeup water intake structures for CCNPP Unit 3. The layout of the CWS intake and outfall structures is shown in Section 10.4.5. The general arrangement of the safety-related UHS makeup intake is described in Section 9.2.5.

2.4.7.4 Historical Ice Formation

The climate at the CCNPP site is part of the Chesapeake Bay climate system. Based on air temperature data summaries collected at Patuxent River Naval Air Station from 1971 through 2000, the monthly average air temperature normal in the region ranges from about 36.1°F (2.3°C) in January to 78.1°F (25.6°C) in July, while the monthly minimum air temperature normal for January is 28.3°F (-2.1°C) and for February is 29.9°F (-1.17°C) (NOAA, 2002).

Daily air temperatures measured at the Patuxent River Naval Air Station meteorological station indicates that below freezing temperatures occur typically between the months of November and March. However, maximum accumulated freezing degree-days, as defined in Section 2.4.7.6, occur mostly in January and February.

Observations of ice cover conditions in the Chesapeake Bay indicate that the winters of 1977 through 1981 were unusually cold and icing conditions were more severe than normal. The winter of 1977 was the coldest and iciest winter on record in the region. The ice and snow coverage of the Chesapeake Bay was about 85%, compared to normal conditions of about 10% (NWS, 1982).

The National Ice Center (NIC) conducted ice surveys and produced ice charts showing spatial distribution of ice cover conditions in the Chesapeake Bay for the winters of 2000 through 2003 (NOAA, 2007a). The ice charts of January 28, 2000, February 1, 2004, January 24, 2005, and January 26, 2005, shown in Figures 2.4-40 to 2.4-43, indicate ice formation at and near the project site (NOAA, 2007a). The ice charts also include a description of ice conditions based on the Egg Code ice classification system and detailed in Figure 2.4-44 through Figure 2.4-46 (NOAA, 2007a).

The NIC ice charts indicate that new ice, which includes frazil, grease, slush, and shuga types of ice, and gray ice, with thickness 2 to 3 in (5.1 to 7.6 cm) are common in the southern part of the Chesapeake Bay. In particular, new ice seems to be more common near the CCNPP site.

According to NIC, the southern part of the Chesapeake Bay (south of 38°32′ latitude, about 8.5 mi (13.7 km) north of the CCNPP site), where the CCNPP site is located, is less prone to ice formation than the northern part and the tributaries. Nevertheless, the southern part of the

Chesapeake Bay does experience ice conditions when the winter temperatures are below normal.

Ice accumulation on the transmission towers and switchyard of existing CCNPP Units 1 and 2 has occurred during freezing rainfall. To date, events such as these have not affected the operation of CCNPP Units 1 and 2.

2.4.7.5 Frazil Ice

Research on the properties of frazil ice indicates that the nature and quantities of ice produced depends on the rate of cooling within a critical temperature range. Frazil ice forms when the water temperature is below 32°F (0°C), the rate of super cooling is greater than 0.018°F (0.01°C) per hour in turbulent flows, and there is no surface ice sheet to prevent the cooling (USACE, 1991) (Griffen, 1973). This type of ice, which is in the shape of discoids and spicules (Griffen, 1973) typically forms in shallow flowing water, such as in rivers and lakes, when the flow velocity is approximately 2 ft/s (0.61 m/s) or higher (IAHR, 1970).

If a submerged intake is located in shallow water where frazil ice is forming, ice may grow directly on metal surfaces such as the trash rack and/or water screens. This type of ice is called anchor ice (Griffen, 1973).

Neither frazil ice nor anchor ice have been observed in the intake structure of the existing CCNPP Units 1 and 2 since the start of operation. There is no public record of frazil or anchor ice obstructing other water intakes in the Chesapeake Bay. Formation of frazil ice at the existing intake could be precluded because of the potential recirculation of the heated cooling water discharge from CCNPP Units 1 and 2 back to the intake structure forebay. Based on the historical climate records, frazil ice or anchor ice is unlikely to occur to an extent that will affect the function of the makeup water intakes. Nevertheless, provisions to mitigate the formation of frazil and anchor ice at the intake structures are discussed in Section 2.4.7.7.

2.4.7.6 Surface Ice Sheet

The intake structures for CCNPP Unit 3 could be impacted by surface ice formation in multiple ways. For instance, the formation of a surface ice sheet could exert forces on the contact structures due to ice expansion. Unrestrained ice sheets drifting with currents could also exert force on the structures by direct impact. Finally, shallow water or shoreline intakes designed with approach channels can become obstructed by ice jams. Because the inlets of the Unit 3 intake pipes are submerged under the design minimum water level at the bay of -6 ft (1.8 m) for the safety-related UHS makeup water intake, there is no possibility that the inlet and the intake structures of Unit 3 would be impacted by drifting ice or unrestrained ice sheets.

Ice sheets formed outside of the existing baffle wall in the intake channel and the new sheet pile wall would not exert force within the new inlet area where the new intake pipes are located. This is because the existing baffle wall, extending to -28 ft (-8.5 m) , would restrict any drift ice from entering the intake forebay even at the minimum design operating water level in the bay of -6 ft (-1.8 m) for the UHS makeup water intake pipes. Drifting ice sheets coming over the top (5 ft (1.5 m)) of the baffle wall and sheet pile wall is also unlikely to occur. Drifting ice sheets formed between the baffle wall and sheet pile wall within the new intake area would be restricted by security barriers/bars at the entrance of each of the intake pipes.

Ice sheets formed within the common forebay for the CWS and UHS makeup intakes would be restricted by the skimmer walls at the entrance of the intake structures. The skimmer walls of the UHS makeup water intake would extend to a minimum of 2 ft (0.6 m) below its minimum design water level of -8 ft (-2.4 m) at the common forebay based on a design low water level of -6 ft (1.8 m) at the Chesapeake Bay. Bar screens would also prevent large pieces of ice from broken ice sheets from entering the traveling water screens and pump bays (NRC, 1979).

Even though surface ice has been observed in the southern part of Chesapeake Bay, ice jams causing interruption of the cooling water supply for CCNPP Units 1 and 2 have not been reported. It should be noted that the existing CWS system is equipped with a de-icing line that was designed to return a portion of the heated cooling water discharge downstream of the main steam condensers to the intake forebay during cold weather. Potential recirculation of the warm cooling water plume from the CCNPP Units 1 and 2 outfall back to the intake channel may also have been a mitigating factor in eliminating the formation of ice jams in the intake area. However, in the event that both CCNPP Units 1 and 2 are not operating during severe winter conditions, there would be no warm water recirculation back to the intake or to the intake channel to reduce ice formation. To assure the CCNPP Unit 3 safety-related makeup water supply would not be affected by surface ice, the possibility of ice jam formation and the potential for flow passage blockage are examined by estimating the maximum surface ice thickness that could form during the worst icing condition expected at the site.

The maximum ice thickness that could form at the CCNPP site was estimated using historical air temperature data from the nearby Patuxent River Naval Air Station meteorological tower for the period of 1945 through 2006. Surface ice thickness can be estimated as a function of accumulated freezing degree-days (AFDD) using the modified Stefan equation (USACE, 2004). AFFD is obtained by summing the freezing degree-days for each day, which is the difference between the freezing point (32°F (0°C)) and the average daily air temperature. Table 2.4-29 summarizes the estimated maximum accumulated freezing degree-days and the corresponding ice thickness estimate. As indicated in Table 2.4-29, for the water years 1946 through 2006, the maximum AFDD is 265.3 occurring on February 9, 1977 with the corresponding ice thickness estimated to be approximately 13 in (33 cm). This estimate is conservative in regards to seawater ice thickness because it assumes a freshwater freezing point of 32°F (0°C). Because the Chesapeake Bay is brackish, the freezing point will be depressed, which will mitigate the formation of surface ice. The conservatism is apparent when the 13 in (33 cm) estimate is compared to the 2 to 8 in (5.1 to 20.3 cm) ice thicknesses observed south of the Chesapeake Bay Bridge in early February of 1977, the iciest winter on record for the region (NWS, 1982). With the depth of the existing intake channel at 34 ft (10.4 m) to 45 ft (13.7 m) below the minimum operating water level of -6 ft (-1.8 m) at the Chesapeake Bay for the UHS makeup water intake, any ice jam formation at the site will not cause a complete blockage of the flow passage to the new intake pipes.

The surface ice layer, when present, insulates and provides protection against the formation of frazil ice. It is noted, however, that the formation of surface ice can exert a high load on the portions of the intake structure in contact with the ice. Ice-induced forces are accounted for in the design of the intake structure as discussed in Appendix 3E.4 of Section 3.8.4.

2.4.7.7 Ice Accumulation at the Site and Preventive Measures

The surface current induced by the water flowing into the CCNPP Unit 3 intake structures could cause ice floes around the intake structure to be withdrawn or moved by the water. The intake structure design incorporates deep skimmer walls and bar screens in order to prevent ice from reaching the pump bays. Additionally, continuous raking of the bar screens, frequent rotation of the traveling water screens and heat tracing of the equipment can be used to mitigate ice buildup at the intake.

For the ESWS cooling tower basins, measures will be taken to ensure that the basins underneath the cooling tower cells have a minimum of 72 hours water supply without the need for any makeup water during a design basis accident. As indicated in Section 2.4.7.2, any makeup water to the basins needed beyond the 72 hours post-accident period will be supplied from the new CCNPP Unit 3 UHS makeup water intake structure. In order to assure the availability of a minimum of 72 hours water supply in the ESWS cooling tower basins, the minimum volume in each basin will be established considering: (a) losses due to evaporation and drift under design basis accident conditions and design environmental conditions; (b) minimum submergence to avoid formation of harmful vortices at the pump suction; and (c) the operating range for basin water level control. During extreme cold weather conditions, operational controls will be implemented, as required, to assure the availability of the required volume. Tower operations during cold weather will mitigate ice buildup consistent with vendor recommendations (e.g., periodic fan operation in the reverse direction). Therefore, operational controls, together with system design features, will prevent ice formation in the ESWS cooling tower basins, as discussed in Section 9.2.5.

2.4.7.8 Effect of Ice on High and Low Water Levels and Potential for Ice Jam

Because the baffle wall and the sheet pile wall shelter the Unit 3 inlet area and the Units 1 and 2 intake forebay from the Chesapeake Bay, there is no potential for ice-induced low and high water levels that would affect the operation of the intakes. In addition, there is no reliance on open reservoirs such as ponds or basins for safety-related water supply, with the exception of the ESWS cooling tower basins as discussed in Section 2.4.7.7. Therefore, reduction of the reservoir water volume due to surface ice sheet formation would not be of concern. The potential for ice-induced low and high water levels are more likely to occur with river intakes in cold regions.

The baffle wall and the new sheet pile wall (with their top elevation at 5 ft (1.5 m) separate the Unit 3 intakes from the Chesapeake Bay. However, during severe winter storms, the baffle wall and the sheet pile wall could be overtopped by the high water level caused by a storm surge. According to the NOAA (NOAA, 2004), the highest water level at Sewells Point, Virginia generated by a winter storm between the years 1927 to 2003 was 5.05 ft (1.54 m) above mean higher high water (MHHW) occurring in March 1962. This rise in water level includes a correction for sea level rise to 2003.

Assuming conservatively that the same water level rise was experienced inside the Chesapeake Bay during the 1962 winter storm, the corresponding still-water level at the CCNPP site would be about 6.5 ft (2.0 m), using the tidal datum conversion scale at Cove Point, Maryland where the MHHW is 1.39 ft (0.42 m) above NGVD (NOAA, 2007b). It can, therefore, be postulated that the baffle wall and sheet pile wall could be overtopped by storm surges during extreme winter storm events. However, because the intake pipes are submerged and located below the lowest minimum operating water level of -6 ft (-1.8 m), inundation of the new inlet area during severe winter would not affect the functioning of the new intake pipes. The deck level of the UHS makeup water intake is at 11.5 ft (3.5 m) as shown in Figure 9.2-5. Therefore, no inundation at the UHS intake deck level is expected. As a result, there will be no impact to the UHS intake and winter storm surge will not affect the supply of emergency makeup water.

The probable maximum storm surge defined in Section 2.4.5 is higher than the expected winter storm surge, but it is postulated to be a hurricane event that occurs outside the winter seasons.

Although the tributaries to the Chesapeake Bay are prone to ice formation, there has been no major ice jam formation or flooding recorded due to breaching of ice jams on the Patuxent River in recent history. Two ice jam incidents are recorded to have occurred on one of the river's tributaries, the Little Patuxent River, at Savage, Maryland (USACE, 2007). One of the incidents occurred in January of 1944 and the other in February of 1948. However, Savage, Maryland, is about 62 river miles (100 river kilometers) from the mouth of Patuxent River; and therefore, the impact of any ice jam formation or breaching could not have had any effect on the CCNPP site. In addition, the streams close to the site have small drainage areas and would not pose the potential of ice flooding at the site. Section 2.4.1 discusses the streams and rivers in the vicinity of the site.

2.4.7.9 Effect of Ice and Snow Accumulation on Site Drainage

Air temperature measurements at the Patuxent River Naval Air Station meteorological station indicate that mean daily temperatures at the site have periodically fallen below freezing for multiple consecutive days in winter. This introduces the possibility of ice blockage of small catch basins; storm drains; culverts and roof drains. The flood protection design of the CCNPP Unit 3 safety-related facilities assumed that all catch basins, storm drains, and culverts are blocked by ice, snow or other obstructions, rendering them inoperative during a local probable maximum precipitation (PMP) event. Details of the local PMP analyses and flood protection requirements for the site are discussed in Section 2.4.2 and Section 2.4.10. Therefore, temporary blockage of site drainage areas will not affect the operation of safety-related facilities. According to the operating records of existing CCNPP Units 1 and 2, there have been no flooding incidents caused by ice blockage of storm drains on the site.

2.4.7.10 References

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USACE, 2004. Method to Estimate River Ice Thickness Based on Meteorological Data, ERDC/CRREL Technical Note 04-3, U.S. Army Corps of Engineers, June 2004.

USACE, 2007. Ice Jam Information Clearinghouse, U.S. Army Corps of Engineers, Website: http://www.crrel.usace.army.mil/icejams/index.htm, Date accessed: January 19, 2007.}

2.4.8 Cooling Water Canals and Reservoirs

The U.S. EPR FSAR includes the following COL Item for Section 2.4.8:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information and describe the design basis for cooling water canals and reservoirs used for makeup to the UHS cooling tower basins.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless otherwise stated.

Sections 2.4.8.1 through 2.4.8.2 are added as a supplement to the U.S. EPR FSAR.

2.4.8.1 Cooling Water Design

Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 does not include any canals or reservoirs used to transport or impound plant safety-related cooling water or for heat dissipation. As discussed in Section 2.4.1.1, both the nonsafety-related circulating water system (CWS) makeup water intake structure and safety-related Ultimate Heat Sink (UHS) makeup water intake structure for CCNPP Unit 3 will be located approximately 500 ft (152.4 m) southeast of the existing CCNPP Units 1 and 2 intake forebay. The new intakes, sharing a new forebay, are offset from the Chesapeake Bay by a distance of approximately 60 ft (18.3 m) and at an existing grade elevation of approximately 10 ft (3.05 m). Makeup water to the common forebay for the new intakes is conveyed via two buried pipes, from an area adjacent to the existing intake forebay, formed between the existing baffle wall (a skimmer wall), and a new sheet pile wall extending from the shore to the existing baffle wall. Figure 2.4-2 shows the locations of the new forebay and intake structures.

The common forebay has dimensions of approximately 100 ft (30.5 m) long and 80 ft (24.4 m) wide with a bottom elevation of approximately -22.5 ft (-6.9 m). The safety-related UHS and nonsafety-related CWS makeup water intake structures are situated on opposite ends of the common forebay. The details of the structure are described in Section 9.2.5 and Section 10.4.5. The common forebay has a minimum operating water level of -6.0 ft (-1.8 m) for the CWS makeup water intake and -8.0 ft (-2.4 m) for the UHS makeup water intake. The bases for the maximum UHS and CWS makeup water flow rates are discussed in Section 9.2.5 and Section 10.4.5, respectively. Section 2.4.11 provides the basis for the minimum operating levels.

Protection of the common forebay and the intake structures against wind waves, storm surge, erosion, and bay current actions is discussed in Section 2.4.10. As discussed in Section 2.4.7, potential ice effects cannot block the inlet area or interrupt the water supply to the UHS intake. The design of the safety-related SSCs will comply with the requirements of Regulatory Guide 1.27 (NRC, 1976).

2.4.8.2 References

NRC, 1976. Ultimate Heat Sink for Nuclear Power Plants, Regulatory Guide 1.27, Revision 2, U.S. Nuclear Regulatory Commission, January 1976.}

2.4.9 Channel Diversions

The U.S. EPR FSAR includes the following COL Item for Section 2.4.9:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information and demonstrate that in the event of diversion or rerouting of the source of cooling water, alternate water supplies will be available to safety-related equipment.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

The Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 site area is located in Calvert County within the Western Shore Uplands of the Atlantic Coastal Plain physiographic province and is bordered by the Chesapeake Bay to the east. The surrounding topography consists of gently rolling hills with surface topography ranging from sea level to nearly 130 ft (40 m) with an average relief of about 100 ft (31 m). The CCNPP site is well drained by short, ephemeral streams that form a principally dendritic drainage pattern. The nearest stream of significance to the site is Johns Creek. This stream drains to St. Leonard Creek and has a reach length of about 3.5 mi (5.6 km). The remaining streams draining the CCNPP site are either tributaries to Johns Creek or drain directly to the Chesapeake Bay. The Chesapeake Bay shoreline east of the CCNPP site consists mostly of steep cliffs with narrow beach areas. The CCNPP site and surrounding areas are shown in Figure 2.4-1.

Sections 2.4.9.1 through 2.4.9.8 are added as a supplement to the U.S. EPR FSAR.

2.4.9.1 Historical Channel Diversions

The Chesapeake Bay will be used to supply makeup water to the safety-related Ultimate Heat Sink (UHS) and non-safety-related Circulating Water Supply System (CWS) as described in Section 2.4.1.1. The Chesapeake Bay was formed toward the end of the last ice age, which marked the end of the Pleistocene epoch. As the glaciers retreated, large volumes of melting ice resulted in the ancestral Susquehanna River eroding older coastal plain deposits and forming a broad river valley. Subsequently, rising sea levels inundated the continental shelf and reached the mouth of the Chesapeake Bay about 10,000 years ago. Continued sea level rise eventually submerged the ancestral Susquehanna River Valley, creating the Chesapeake Bay. The Chesapeake Bay assumed its present dimensions about 3,000 years ago (CBP, 2004). Section 2.5.1 provides further description and discussion of the geologic processes that led to the formation of the Chesapeake Bay.

Given the seismic, topographical, geologic, and thermal evidence in the region, there is very limited potential for upstream diversion or rerouting of the Chesapeake Bay (due to channel migration, river cutoffs, ice jams, or subsidence) and adversely impacting safety-related facilities or water supplies.

2.4.9.2 Regional Topographic Evidence

The safety-related UHS makeup water intake and the non-safety-related CWS makeup water intake for CCNPP Unit 3 will be located approximately 500 ft (152.4 m) southeast of the existing CCNPP Units 1 and 2 intake structure. The Unit 3 intakes will be located onshore at approximately 60 ft (18.3 m) offset from the Chesapeake Bay shoreline (as shown on Figure 2.4-2) and at a grade elevation of approximately 10 ft (3.05 m). Makeup water is conveyed from the Chesapeake Bay via two buried intake pipes, with inlets located adjacent to the Units 1 and 2 intake forebay, to a common forebay of the Unit 3 UHS and CWS makeup water intake structures. High cliffs reaching elevations greater than 100 ft (30.5 m) exist upstream and downstream of the existing intake structure along the shoreline of the Chesapeake Bay. Approximately 2,500 ft (762 km) of the shoreline, including the CCNPP Units 1 and 2 intake embayment and the shoreline southeast of the intake structure to the existing barge jetty, are stabilized against shoreline erosion. The CCNPP Unit 3 plant will be located at an elevation of about 85 ft (26 m) and set back approximately 1,000 ft (305 m) from the Chesapeake Bay shoreline.

Both long-term and short-term sediment processes are responsible for shoreline erosion of the Chesapeake Bay. The slow rise in sea level, approximately 1.3 ft (0.4 m) over the last century (CBP, 2005), is the primary long-term process causing the shoreline to recede. Waves and surges due to occasional hurricanes may considerably change coastal morphology. These short-term erosive waves often reach the high, upland banks out of the range of normal tides and waves.

Shoreline locations near the CCNPP site in 1848, 1942 and 1993 are shown in Figure 2.4-47 (MGS, 2007). The local rate of shoreline change in the vicinity of the CCNPP site, as estimated by the Maryland Department of Natural Resource (MDNR), is shown in Figure 2.4-48 (MDNR, 2007). The rate of shoreline erosion south of the existing barge jetty and near the CCNPP Unit 3 site has been estimated by MDNR to be between 2 ft and 4 ft per year. North of the existing CCNPP Units 1 and 2 intake structure, MDNR has estimated the shoreline change to be between 2 ft (0.6 m) per year accretion and 4 ft (1.2 m) per year erosion. The stabilized shoreline near the intake structures prevents any shoreline retreat.

Observations of the shoreline near the site indicate that the steep slopes fail along irregular, near-vertical surfaces. These slope failures appear to be caused by shoreline erosion along the base of the cliffs, which results in undercutting a portion of the cliff. When the overlying weight of unconsolidated coastal plain deposits exceeds the shear strength of the soils, a portion breaks away from the cliff and drops to the beach level along a near-vertical failure surface. Shoreline processes, such as waves or tidal currents, erode the deposits that have fallen to the beach and transport the sand, silt and clay materials comprising these deposits along the beach.

The hill slope, adjacent to of the proposed CCNPP Unit 3 intake structures, is recessed from the beach and the shoreline is protected against erosion by an existing shoreline protection structure as shown in Figure 2.4-2 and Figure 2.4-48. It is therefore unlikely that the shoreline at this location will retreat due to the shoreline erosion processes described above.

Furthermore, any potential adverse impacts on safety-related facilities or water supplies should come from extremely slow changes, which can be remedied as they occur.

The occurrence of shoreline erosion immediately southeast of the barge jetty indicates that the net sediment transport in this area is likely directed towards the southeast with the jetty acting as a sediment barrier. Because makeup water supply to the CCNPP Unit 3 intake will be withdrawn from the bay at the inlet area adjacent to the Units 1 and 2 forebay, which is located approximately 2,000 ft (610 m) northwest of the barge jetty, any failures of steep slopes south of the jetty, as detailed in Figure 2.4-2, are not likely to result in sufficient transport of material north of the jetty. As such, these types of failures are not likely to impact the water supply to the CCNPP Unit 3 intake. Northwest of the existing CCNPP Units 1 and 2 intakes, Figure 2.4-48 indicates a low shoreline erosion potential (between 2 ft (0.6 m) per year erosion and 2 ft (0.6 m) per year accretion) for a distance of approximately 2,000 ft (610 m). Slope failures in this area may drop cliff materials on the beach, which will be gradually eroded and transported by waves and tidal currents. Any failures of this slope are not likely to result in blockage of the water supply to UHS and CWS makeup water intakes for CCNPP Unit 3, because the sediment transport rates associated with wave action and tidal currents are limiting. Additionally, because the CCNPP Unit 3 power block area is set back approximately 1,000 ft (305 m) from the shoreline, it is unlikely that shoreline erosion south of the barge jetty will impact CCNPP Unit 3.

2.4.9.3 Ice Causes

Although surface ice has been observed in the southern part of the Chesapeake Bay, ice jams causing channel diversions and interruption of the cooling water supply for CCNPP Units 1 and 2 have not been reported. The Unit 3 inlet area will be sheltered from the Chesapeake Bay by the existing Units 1 and 2 forebay baffle wall and the sheet pile wall. Due to the submerged entrance of water under the existing baffle wall, surface ice in the Chesapeake Bay has no effect on the cooling water supply at the Unit 3 intake pipe inlets. A further discussion on the formation of surface ice and the potential for an ice jam is provided in Section 2.4.7.

2.4.9.4 Site Flooding Due to Channel Diversion

The CCNPP site has streams and proposed drainage ditches near the site that could overflow and cause local flooding. Flood water from Johns Creek flows into the Maryland Western Shore watershed and poses a risk to CCNPP Unit 3 structures, systems, or components should the water level exceed the low point of the drainage divide boundary at Elevation 98.0 ft (29.9 m), which passes through the CCNPP Unit 3 switchyard. As discussed in Section 2.4.3, the maximum surface water elevation of Johns Creek is 65 ft (19.8 m) at the CCNPP site due to probable maximum precipitation. The drainage divide boundary is approximately 33.0 ft (10.1 m) above this level. Assuming the creek is partially blocked due to ice formation or fallen trees, the blockage is not assumed to cause the water to rise 33.0 ft (10.1 m). Water will flow around the partial blockage as the creek rises. Section 2.4.1 discusses the streams and rivers in the vicinity.

As indicated on Figure 2.4-7, the containment, fuel and safeguards buildings are located in the center and along the high point of the power block area. From the high point, site grading falls at a 1% slope to bio-retention drainage ditches located along the northern and southern edges of the CCNPP Unit 3 site area. There are four bio-retention ditches which drain the power block and the turbine building areas. Three of them run in the east-west direction; one north of CCNPP Unit 3, (North Ditch), one south of CCNPP Unit 3 and between CCNPP Unit 3 and the area reserved for equipment laydown (Center Ditch) and one south of the equipment laydown area (South Ditch). The fourth ditch (East Ditch) is located along the eastern edge of

CCNPP Unit 3 and the equipment laydown area. It collects flows from the other three ditches. The East Ditch is divided in two, to allow passage of the CCNPP Unit 3 security fence. Flows in the South Ditch and the southern half of the East Ditch do not have an impact on the PMP flood levels in CCNPP Unit 3 and are not discussed in this section.

The bio-retention ditches are constructed with base materials that promote infiltration of runoff from low intensity rainfall events. However, for large storms, the infiltration capacity of the base materials would be exceeded and overflow pipes are provided to direct the runoff to the stormwater basin located to the east of the power block. For the assessment of the local PMF levels, the overflow pipes and culverts in the drainage system are assumed to be clogged as a result of ice or debris blockage. In that case, PMP storm runoff from the area collected in the North and East Ditches would overflow along the northern and eastern edges (top of berm at Elevation 79 ft (24.1 m)), spilling out to the areas north and east of the power block down the bluff to Chesapeake Bay. Channels and diversion walls will be provided on the north side of the site to direct North Ditch overflows to the east and eventually to the Chesapeake Bay. Flows from the Center Ditch will discharge into the East Ditch before overflowing the eastern edge of the East Ditch.

Grading in the vicinity of the safety-related structures slopes away from the individual structures such that PMP ground and roof runoff will sheet flow away from each of these structures towards the collection ditches. Thus, sheet flows are prevented from entering the structures.

The maximum computed PMP water level in the power block area is Elevation 81.5 ft (24.8 m). However, the maximum PMP water level associated with a safety-related structure is Elevation 81.4 ft (24.8 m) which is 3.2 ft (1.0 m) below the reactor complex grade slab at Elevation 84.6 ft (25.8 m).

Based on the power block grading, entrance locations, and peak PMP water levels in the site ditches, all safety-related facility entrances are located above peak PMP ditch water levels and PMP sheet flows are prevented from reaching safety-related entrances.

2.4.9.5 Human-Induced Channel Flooding

Human-induced channel flooding of the Chesapeake Bay is not assumed because the Bay is a major drainage path for the Susquehanna River. There are no known Federal projects to channel or dam any portion of the Chesapeake Bay. The channel and diversion walls and site grading discussed above will be maintained to direct stormwater and ditch overflows away from the site and towards the Chesapeake Bay.

2.4.9.6 Alternate Water Sources

An alternate water source is not required for the CCNPP Unit 3 design. The emergency safety-related water supply to the Essential Service Water System cooling tower basins is brackish water from the Chesapeake Bay. In the event normal water supply is lost, there is a 72-hour volume of water available at each tower basin to deal with system losses before the emergency UHS makeup water supply is required to be initiated. In the event of a probable maximum hurricane where extreme weather conditions can persist for at most one day as discussed in Section 2.4.11, there is no need to switch to alternate UHS makeup sources. At the end of 72 hours, at least two out of four safety-related trains of makeup water will be put in operation to feed the corresponding basins with water drawn from the Chesapeake Bay.

2.4.9.7 Other Site-Related Evaluation Criteria

The potential for channel diversion from seismic or severe weather events is not considered to result in a loss of cooling water supply. The new common forebay of Unit 3 intakes is a seismic Category I structure, as described in Section 2.4.1 and no additional measures are necessary to protect against a potential channel diversion due to seismic events. Makeup water withdrawn from the Chesapeake Bay adjacent to the Units 1 and 2 intake forebay will be conveyed to the common forebay by pipes that will meet seismic Category I requirements. A postulated collapse of the shoreline cliffs to the north or south of the CCNPP site during a seismic or severe weather event not expected to result in silt depositing in the Units 1 and 2 forebay to such an extent that it would cause a loss of cooling water supply to the Unit 3 intakes.

2.4.9.8 References

CBP, 2004. Chesapeake Bay – Introduction to an Ecosystem, Chesapeake Bay Program, EPA 903-R-04-003, CBP/TRS 230/00, 2004.

CBP, 2005. Sediment in the Chesapeake Bay and Management Issues: Tidal Erosion Processes, Tidal Sediment Task Force of the Sediment Workgroup under the Chesapeake Bay Program, Nutrient Subcommittee, CBP-TRS276-05, 2005.

MDNR, 2007. Maryland Department of Natural Resources, Maryland Shorelines Online, Website: http://shorelines.dnr.state.md.us/shoreMapper/standard/, Date accessed: February 7, 2007.

MGS, 2007. Coastal and Estuarine Geology Program, Shoreline Change Maps, Maryland Geological Survey, Website: http://www.mgs.md.gov/coastal/maps/schangepdf.html, Date accessed: January 4, 2007 (Shoreline Changes, Cove Point Quadrangle, MD, Maryland, 7.5 Minute Series (Orthophotoquad), Maryland Department of Natural Resources, Maryland, 2001).}

2.4.10 Flooding Protection Requirements

The U.S. EPR FSAR includes the following COL Item in Section 2.4.10:

> A COL applicant that references the U.S. EPR design certification will use site-specific information to compare the location and elevations of safety-related facilities, and of structures and components required for protection of safety-related facilities, with the estimated static and dynamic effects of the design basis flood conditions.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

This section discusses the locations and elevations of safety-related facilities to identify the structures and components exposed to flooding. The safety-related facilities are compared to design basis flood conditions to determine if flood effects need to be considered in plant design or in emergency procedures.

All safety-related facilities are located in the power block area with the exception of the Ultimate Heat Sink (UHS) makeup water intake structure. The CCNPP Unit 3 UHS makeup water intake structure and the makeup water intake for the Circulating Water System (CWS) are located on the Chesapeake Bay shore southeast of the CCNPP Units 1 and 2 intake structure as shown in Figure 2.4-49. As discussed in Section 2.4.2, the maximum water level in the power block area due to a local PMP is Elevation 81.5 ft (24.8 m). All safety-related structures in the power block area have a minimum grade slab or entrance at Elevation 84.6 ft (25.8 m) or higher. Grading in the power block area around the safety-related facilities is such that all grades slope away from the structures at a minimum of 1% towards runoff collection ditches.

Additionally, the maximum estimated water surface elevations resulting from all design basis flood considerations discussed in Section 2.4.2 through Section 2.4.7 are below the entrance and grade slab elevations for the power block safety-related facilities. Therefore, flood protection measures are not required in the CCNPP Unit 3 power block area.

Flood protection measures are required for the CCNPP Unit 3 UHS makeup water intake structure. The nominal grade at the UHS makeup water intake structure is approximately at Elevation 10.0 ft (3.0 m). The maximum flood level at the UHS makeup water intake structure location is Elevation 33.2 ft (10.11 m) as a result of the surge and wave run-up associated with the probable maximum hurricane (PMH) as discussed in Section 2.4.5. Thus, the UHS makeup water intake structure would experience flooding during a PMH and flood protection measures are required.

The general arrangement of the CCNPP Unit 3 UHS makeup water intake structure is described in Section 9.2.5. Flood protection for the UHS makeup water intake structure consists of structural measures to withstand the static and dynamic flooding forces. Flood protection measures also include water proofing to prevent the flooding of the interior of the structures where pump motors and electrical equipment associated with the operation of the intake are located.

The static and dynamic flood forces that the CCNPP Unit 3 UHS makeup water intake structure will encounter during a PMH event include: the static water pressure from the maximum flood elevation, uplift pressures on the pump deck as well as uplift pressures on the entire intake structure, and dynamic wave forces on the structure walls and roof. A detailed description of these forces and other design basis loadings including seismic loadings, and the structural measures incorporated to withstand them, is found in Section 3.8.

The CCNPP Unit 3 UHS makeup water intake structure is offset from the Chesapeake Bay shoreline as shown on Figure 2.4-49. Makeup water to the CCNPP Unit 3 common forebay is conveyed from the Chesapeake Bay via two safety-related buried intake pipes. The intake pipes withdraw water from Chesapeake Bay in an inlet area protected by the existing Units 1 and 2 intake baffle wall and a sheet pile wall, as shown on Figure 2.4-49. The bottom elevation within the inlet area is maintained at an elevation of approximately -26 ft (6.1 m). The inlets of the intake pipes are protected by a security barrier and bars that will be designed to withstand PMH conditions. The security barrier and bars includes raking mechanism and extends from the deck elevation of approximately 11.5 ft (3.5 m) to an elevation of approximately -20 ft (6.1 m) near the intake pipe inlet. The shoreline near the UHS makeup water intake structure is protected against the PMH and coincident wind-wave conditions.

In addition to protection of structures against static, dynamic, and erosive forces, the pump house area of the CCNPP Unit 3 UHS makeup water intake structure must remain protected from flooding and the intrusion of water. Thus, these structures including any access are designed to be water tight. Structural walls and roofs will be designed with water stops at all construction joints to prevent leakage.

Any pipe, pump shaft, or other conduit penetrations through walls, floors and roofs will be sealed with water tight fittings. All access to these spaces will be provided with water tight doors or water tight hatches. The water tight measures will also be designed for the static and dynamic flood forces resulting from the PMH water levels and wave forces. Locations of the doors and hatches are provided on figures in Section 9.2.5. Doors and hatches will open outward and will be closed during normal plant operation.

Since all water-tight doors and hatches for the CCNPP Unit 3 UHS makeup water intake structure will be closed during normal operations, no special operating procedures or shutdown technical specifications will be necessary to ensure that flood protection measures are in place when Chesapeake Bay flood water levels associated with the PMH occur.}

2.4.11 Low Water Considerations

The U.S. EPR FSAR includes the following COL Item in Section 2.4.11:

> A COL applicant that references the U.S. EPR design certification will identify natural events that may reduce or limit the available cooling water supply, and will verify that an adequate water supply exists for operation or shutdown of the plant in normal operation, anticipated operational occurrences, and in low water conditions.

This COL Item is addressed as follows:

{This section investigates natural events that may reduce or limit the available cooling water supply to ensure that an adequate water supply exists to shut down the plant under conditions requiring safety-related cooling. Specifically, any issues due to a low water level in the Chesapeake Bay are investigated in this section.

The proposed site for Calvert Cliff Nuclear Power Plant (CCNPP) Unit 3 is located on the western shore of the Chesapeake Bay, in Calvert County, MD, approximately 10.5 mi (16.9 km) southeast of Prince Frederick, MD.

References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.11.1 through 2.4.11.7 are added as a supplement to the U.S. EPR FSAR.

2.4.11.1 Low Flow in Rivers and Streams

CCNPP Unit 3 relies on the Chesapeake Bay to supply water for safety-related and non-safety-related purposes. CCNPP Unit 3 does not draw water from any streams or rivers; thus, low water conditions resulting from the low flow in rivers and streams does not apply. The Chesapeake Bay is a drainage basin for many rivers and streams in the watershed area. The largest river flowing into the Chesapeake Bay is the Susquehanna River. Moreover, there are no dams downstream of the site for consideration and no dam will be constructed in the future as the Chesapeake Bay connects to the Atlantic Ocean. A description of the site and facilities is provided in Section 2.4.1.1.

Drought conditions in the area will affect the amount of water flowing into the Chesapeake Bay from area rivers and streams. As discussed in Section 2.4.11.3, historical low water levels in the Chesapeake Bay are due to tides, storm surges and tsunami events and not drought conditions because the Chesapeake Bay is connected to the Atlantic Ocean. The discharge pipe extends approximately 550 ft (168 m) into the Bay along the floor where the depth is greater than 10 ft (3 m). Therefore, extreme low water level conditions at -3.9 ft (-1.2 m) will not uncover the discharge pipe or affect the non-safety-related or safety-related makeup water supplies.

2.4.11.2 Low Water Resulting from Surges, Seiches, Tsunamis, or Ice Effects

The CCNPP Unit 3 site is located at the Chesapeake Bay area and the water level is controlled by the tide, storm surge and tsunami events. As a consequence, the drawdown effects from storm surge and tsunami are described in the following two sections. The effect from seiches on the site is negligible, as described in Section 2.4.5.4, and will have no impact on the plant with respect to low water considerations. Section 2.4.7 provides a detailed description of the CCNPP Unit 3 makeup water intakes and includes a description of conditions of ice formation or ice-jams that may result in low water level. However, as concluded in Section 2.4.7, the existing baffle wall and the sheet pile wall that separate the Chesapeake Bay from the inlet of the intake pipes allow cooling water to be drawn from the Chesapeake Bay without the potential of ice-induced low levels. In addition, Section 2.4.7 concluded that impact of any ice jam formation or breaching of the existing baffle wall could not have any detrimental effect on the proposed CCNPP Unit 3 site and the new makeup water intake structures.

2.4.11.2.1 Storm Surge Effect

Empirical Analysis

Surge studies for the Chesapeake Bay reveal that the negative storm surge could be obtained based on the historical hurricane studies (Pore, 1960) (USWB, 1963). The extreme negative surges would occur at the Chesapeake Bay when hurricanes travel close and parallel to the coastline as shown in Figure 2.4-50 (MDGIS, 2007). This is the most critical path because if a hurricane travels over land its strength is reduced. The historical negative surge data for several hurricanes near the site are summarized in Table 2.4-30 (Pore, 1960) (USWB, 1963). Two additional hurricanes with similar tracks have occurred since 1960, Hurricane Gloria (September of 1985) and Hurricane Emily (August of 1993). The annual minimum water levels recorded at Annapolis and Solomons Island Stations, shown in Table 2.4-32 (NOAA, 2006b) and Table 2.4-33 (NOAA, 2006c), are not associated with these two hurricanes. Therefore, Hurricane Donna has been selected as a typical hurricane to estimate the negative surge in the Chesapeake Bay area considering the data availability, because the wind data near the site area (at Cove Point and Lookout Point) during Hurricane Donna is available. Moreover, Hurricane Donna is one of the all-time great hurricanes and its path was such that it created a negative surge in the Chesapeake Bay (NOAA, 2006a).

Based on the available data, the maximum sustained wind speed at the Cove Point and Lookout Point was observed as 57 mph (50 knots) (88.5 km/hr) during Hurricane Donna (USWB, 1960). The Cove Point and Lookout Point are located about 6 miles (9.7 km) and 27 miles (43.5 km) south of the site, respectively, as shown in Figure 2.4-51 (MDGIS, 2007). Because the wind moves in a counter-clockwise direction, the wind direction changes from NE to N as the hurricane travels past the Chesapeake Bay. It can be inferred that the northerly wind would drive the water towards the south in the Chesapeake Bay and, therefore, the water level at Baltimore is lowest in the Chesapeake Bay area due to the wind setdown.

The lowest water level due to wind effects will take place during the passage of the Probable Maximum Hurricane (PMH) because the wind field due to the PMH is the strongest. The track of the PMH causing the lowest water level at the site location is indicated in Figure 2.4-50. The characteristics of the PMH for calculating the negative surge as detailed in EM

1110-2-1412, "Storm Surge Analysis and Design Water Level Determinations (USACE, 1986) are as follows:

From Figure C-10 (USACE, 1986), the K factor for the PMH, Latitude N37° (location of site) and for units of mph is K = 78.7. The Coriolis parameter is estimated to be f = 0.315/hr.

From Figure C-4 (USACE, 1986), the upper and lower limits of radius to the maximum winds for the PMH are:

Rlower = 10 nautical miles or Rlower = 11.51 mi (18.53 km)

Rupper = 26.2 nautical miles or Rupper = 30.15 mi (48.52 km)

The lowest sea-level pressure po (in inches Hg) at the hurricane center is determined from Figure C-2 (USACE, 1986) for the PMH at Chesapeake Bay:

po = 26.56 in Hg (67.46 cm Hg)

Finally, the peripheral pressure pn, the sea level pressure at the outskirts of the PMH hurricane is taken as

pn = 30.12 in Hg (76.50 cm Hg)

Using the PMH characteristics at the site and following the procedure described in EM 1110-2-1412 (USACE, 1986), the maximum sustained wind speed at the site area is estimated as 102.9 mph (165.6 kmph) when the eye of the PMH passes along the coastline as indicated in Figure 2.4-50.

The negative surge at the site due to Hurricane Donna is estimated to be -1.2 ft (-0.37 m) based on the data of Table 2.4-30 and by interpolating between the Annapolis and Solomons Island Stations. The storm surge is generally proportional to the square of the wind speed (USACE, 1959). Therefore the negative surge due to the PMH can be calculated on the basis of the law of proportionality as follows:

$$\frac{(\text{wind speed due to Hurricane Donna})^2}{(\text{negative surge at site})} = \frac{(\text{wind speed due to PMH})^2}{(\text{negative surge at site})} \Rightarrow \frac{57^2}{-1.2} = \frac{102.9^2}{\text{surge at site}} \qquad \text{Eq. 2.4.11-1}$$

Therefore, the negative surge due to the PMH is estimated as -3.9 ft (-1.2 m). Moreover, considering the westerly cross wind effects, the additional water level drop has to be added to the negative surge due to the PMH. Assuming that the additional setdown is equal to the setup due to the PMH given in Section 2.4.5 for an easterly wind, the additional setdown is 1.13 ft (0.34 m). Therefore, the total setdown, computed empirically, due to the PMH is -5.03 ft (-1.53 m).

SLOSH Analysis

To be consistent with methodology presented in FSAR Section 2.4.5 and as a conservative approach, the estimation of low water conditions is also determined using a SLOSH model.

Several model runs with a conservative combination of PMH parameters and storm tracks were performed. Utilizing SLOSH, the magnitude of the low water levels at the CCNPP Unit 3 site is estimated based on the PMH track causing the lowest water level at the site location as indicated in Figure 2.4-50 and PMH characteristics reported in the empirical analysis.

The initial Still Water Level (SWL) is incorporated directly in the SLOSH simulations and defined as the 10% Exceedance Low Tide. The 10-percent low tide probability of non-exceedance is computed statistically based on NOAA's 21-year synthetic tidal signal developed at the Solomons Island tide station. Log Pearson Type III provides the best representative distribution resulting in a 10-percent low tide probability of non-exceedance of -2.56 ft (-0.79 m) NGVD29.

Using SLOSH, the maximum negative surge (including the low water antecedent conditions) at the CCNPP Unit 3 site is -6.5 ft (-1.98 m) NGVD29, compared to -5.03 ft (-1 .53 m) computed empirically. The difference is attributed to the use of MLLW instead of the 10% exceedance low tide probability and that SLOSH provides a more conservative approach. This surge height was then adjusted to take into account the 20% margin (SLOSH model uncertainties) suggested in Technical Report NWS 48 (Jelesnianski, 1992). The final elevation thus obtained is -7.2 ft (-2.22 m) NGVD29.

Similar to the empirical analysis, consideration is given to wind wave effects from the westerly cross wind. The potential of wind wave induced run-down in the Intake Forebay, based on the Probable Maximum Hurricane (PMH) critical track, is analyzed using empirical equations from the Coastal Engineering Manual (USACE, 2008).

When the additional set-down is added to the maximum negative surge, the total negative surge is -7.7 ft (-2.34 m) in the Intake Forebay.

2.4.11.2.2 Tsunami Effect

Tsunami sources in the Atlantic Ocean were investigated in Section 2.4.6 to determine the probable maximum tsunami height. Any tsunami propagating from the Atlantic Ocean will be highly dispersed once it reaches the Chesapeake Bay area. Therefore, the tsunami effects will be minor compared to the storm surge.

The following three tsunami sources were considered: the Canary Islands tsunami, the Continental Shelf landslide tsunami and the Haiti tsunami. The minimum drawdown at the site among the above three sources is due to the hypothetical Haiti tsunami. The drawdown level due to the hypothetical Haiti tsunami which has the longest wave period has been predicted as -1.64 ft (-0.50 m). Details of the tsunami effects are given in Section 2.4.6.

2.4.11.2.3 Low Water Level Due to Surge and Tsunami

The combined low water levels for the cases of the negative storm surge and the tsunami are assumed to occur coincident with the occurrence of Mean Lower Low Water (MLLW) at the site. The MLLW, at the site is estimated by using the tide datum relationship at the Cove Point station. At Cove Point Station the MSL and MLLW are 3.13 ft (0.95 m) and 2.50 ft (0.76 m) above station datum, respectively. The datum at Cove Point is -0.01 ft (-0.003 m) MLLW. This value is adopted for the site and the respective low water levels at the site for the empirically calculated negative surge and tsunami are:

- MLLW + Negative Surge: 0.01 ft (0.003 m) - 5.03 ft (-1.53 m) = -5.02 ft (-1.53 m)

Eq. 2.4.11-2

- MLLW + Negative Tsunami: 0.01 ft (0.003 m) -1.64 ft (-0.50 m) = -1.63 ft (-0.50 m)

Eq. 2.4.11-3

Therefore, the lowest water level in the Forebay is due to negative storm surge predicted using SLOSH and is estimated as -7.7 ft (-2.34 m). The minimum water level for the safety-related Ultimate Heat Sink (UHS) makeup intake is discussed in Section 2.4.11.5.

2.4.11.3 Historical Low Water

The low water level based on the historical tide data is determined using the statistical method. Regulatory Guide 1.206 (NRC, 2007) does not mention the specific return period for the extreme low water level, but mentions the use of the 100-year drought as a design basis. The 100-year low water level is the appropriate design level for the non-safety-related makeup water intake for the Circulating Water System (CWS), while the probable minimum water level (due to negative storm surge from the PMH and MLLW) is the appropriate design level for the safety-related UHS makeup intake pumps.

Because there is no tide data for the site, the data at the two nearby stations was used for the statistical analysis in determining the low water level. These stations are: NOAA Station ID 8575512 at Annapolis, Maryland, and NOAA Station ID 8577330 at Solomons Island, Maryland (Figure 2.4-51). Other stations nearby have recorded the water levels for periods less than six months and, therefore, were not considered. The details of the two stations are provided in Table 2.4-31. Annapolis station is located about 37 miles (59.5 km) north of the CCNPP site and Solomons Island is located about 8 miles (12.9 km) south of the site.

The historical tide data at Annapolis station and Solomons Island station were used to analyze the 100-year low water level for the site. The data were obtained from NOAA (NOAA, 2006b and NOAA, 2006c) and all tide levels with no specific reference water level are based on the station datum (NOAA, 2006b) (NOAA, 2006c). For Annapolis, the data cover a period from 1929 to 2006, while for Solomons Island, the data cover a period from 1971 to 2006. The raw data are presented in Table 2.4-32 and Table 2.4-33.

The raw data mentioned above were analyzed using eight different probability density functions: normal, log-normal, exponential, generalized extreme value - Type 1 (Gumbel), Pearson - Type 3 (P3), log-Pearson - Type 3 (LP3), generalized extreme value - Type 3 and Weibull distributions. These eight probability distributions were considered before selecting the probability distribution that best fits the data. The equations for each probably density distribution can be found in (Rao, 2000). Goodness-of-fit of the distributions was evaluated using standard X^2 and Kolmogorov-Smirnov (K-S) tests. A distribution is considered acceptable when the test value is lower than a standard test value for a certain confidence interval (Rao, 2000) and for this case a 95% confidence interval was specified. From the analysis, none of the distributions fit the data very accurately for return periods higher than 10-years, even though they pass the X^2 and K-S tests. Therefore, the 100-year low water level was conservatively determined by visual inspection of the plotted data and is found to be 0.54 ft (0.16 m) above station datum for Annapolis (Figure 2.4-52) and 0.35 ft (0.11 m) above station datum for Solomons Island.

As a conservative approach, the 100-year low water level at the CCNPP Unit 3 site is selected based on the Annapolis station, which is lower than Solomons Island. Therefore, the 100-year low water is -3.90 ft (-1.19 m) and the minimum operating water level of the non-safety-related CWS makeup water intake is set at -4.0 ft (-1.22 m) at the inlet of the intake pipes.

According to a report from the U.S. Environmental Protection Agency (EPA, 1995), the historic rate of sea level rise at Annapolis and Solomons Island is 0.14 and 0.13 in/yr (3.6 and 3.3 mm/yr), respectively. Assuming the same rate of sea level rise, the water level in the Chesapeake Bay will rise by 3 to 3.3 in (7.6 to 8.3 cm) by 2030 (CBP, 2003). This estimation does not include the increase in global temperature. According to (CBP, 2003), the oceans would expand their volume, resulting in an 3 to 5 in (8 to 12 cm) rise in sea level. This rise, coupled with the regional rate of land subsidence around the Chesapeake Bay area, will result in a relative rise in the mean Chesapeake Bay water levels of 5 to 7 in (13 to 17 cm) by 2030 (CBP, 2003). Therefore, the MSL is expected to rise in the future, making the current estimates conservative. Although the second source (CBP, 2003) is less conservative but more realistic, because it includes global warming, the first source (EPA, 1995) was used because it estimates a smaller sea rise and thus is more conservative.

2.4.11.4 Future Controls

There are no future controls for the Chesapeake Bay that could affect the availability of water and the water level in the Chesapeake Bay.

2.4.11.5 Plant Requirements

In terms of plant requirements, the Essential Service Water System (ESWS) provides flow for normal operating conditions, for shutdown/cooldown and for Design Basis Accident (DBA) conditions. The ESWS pump in each train obtains water from the ESWS cooling tower basin of that train and circulates the water through the ESWS. Heated cooling water returns to the ESWS cooling tower to dissipate its heat load to the environment. Makeup water is required to compensate for ESWS cooling tower water inventory losses due to evaporation, drift, and blowdown associated with cooling tower operation. Makeup water to the ESWS cooling tower basins under normal operating and shutdown/cooldown conditions is provided by the plant Raw Water Supply System. Water is stored in the ESWS cooling tower basin, which provides at least 72 hours of makeup water for the ESWS cooling tower following a DBA. After 72 hours have elapsed under DBA conditions, emergency makeup water to the tower basins is provided by the safety-related UHS emergency makeup water pumps housed in the UHS makeup intake structure.

Under normal plant operating conditions, the makeup water for the CWS will be taken from the Chesapeake Bay by pumps at a maximum rate of approximately 44,320 gpm (167,769 lpm) for the unit. Under normal plant operating conditions, UHS gets its makeup from fresh water (desalination plant output).

Under DBA conditions, the CWS is lost, since it is non-safety-related. The ESWS makeup water under DBA conditions will be provided at a maximum flow rate of approximately 942 gpm (3,566 lpm) to accommodate the maximum evaporation rate (approximately 61 gpm (231 lpm)) and drift loss and seepage (approximately 19.5 gpm (74 lpm) for the unit) for two UHS cooling towers. Maximum ESWS blowdown and makeup rates are based on maintaining ten cycles of concentration and evaporation at 82°F (27.8°C) wet-bulb temperature and 20% relative humidity.

As discussed in Section 2.4.7.3, both the nonsafety-related circulating water system (CWS) makeup water intake structure and safety-related UHS makeup water intake structure for CCNPP Unit 3 are located approximately 500 ft (152.4 m) southeast of the CCNPP Units 1 and 2 intake structure. Makeup water to the common forebay for the Unit 3 intakes is conveyed via two buried pipes from an area adjacent to the Units 1 and 2 intake forebay formed between the existing baffle wall (acting as a skimmer wall) and a sheet pile wall extending from shore to the baffle wall. The two 60 in (1.5 m) diameter intake pipes are buried with a centerline depth at approximately -17 ft (-5.2 m). These buried pipes are safety-related structures. Four 100% capacity, vertical turbine, wet-pit UHS emergency makeup water pumps are provided to supply makeup water to the four-independent UHS cooling tower basins, one per train, with a capacity per pump of approximately 750 gpm (2835 lpm). The Forebay invert elevation is approximately at -22.5 ft (-6.9 m). The minimum design water level in the common Forebay and for the UHS makeup water pumps is set at -8 ft (-2.4 m). The available water depth of 14.5 ft (4.42 m) under the minimum design water level is sufficient to satisfy the pump submergence and Net Positive Suction Head (NPSH) requirements taking into account the pump intake head loss through screens even when the four UHS emergency makeup pumps are operating concurrently at 750 gpm (2,835 lpm).

Since the minimum design water level in the Forebay is set at -8 ft (-2.4 m) for the safety-related UHS makeup intake, the UHS makeup pumps supply sufficient water during the lowest water level due to negative surge from the PMH or tsunami (estimated at -7.7 ft (-2.34 m)). With a centerline elevation of the intake pipes at -17 ft (-5.2 m), there is no risk of vortices and air entrainment in the intake pipe.

Also, since the minimum design operating level in the bay for the nonsafety-related CWS makeup intake is set at -4.0 ft (-1.22 m), the CWS makeup pumps also supply sufficient water during the 100-year low water level (estimated at -3.9 ft (-1.19 m) in the bay. The amount of water withdrawn from the Chesapeake Bay will be subject to the state water withdrawal permit limits.

The Chesapeake Bay withdrawal permit for the cooling water of the CCNPP Unit 3 will be subject to the provisions of Title 5 of the Environment Article, Annotated Code of Maryland (MD, 2007). The EPA declared the Chesapeake Bay as an impaired water body in 1998 based on the Federal Water Pollution Control Act (USC, 2007) because of excess nutrients and sediments (CBP, 2003). Both the safety-related and non-safety-related makeup intakes comply with the Section 316(b) requirements for existing power plants of the Federal Water Pollution Control Act (USC, 2007).

The discharge flow from CCNPP Unit 3 is from a retention basin, which collects site nonradioactive wastewater and cooling tower blowdown to the Chesapeake Bay. Details of the outfall structure are provided in Section 10.4.5.

2.4.11.6 Heat Sink Dependability Requirements

The normal non-safety-related water supply to the UHS cooling tower basins is fresh water from a desalination plant (approximately 627 gpm (2,373 lpm)). The emergency safety-related water supply to the ESWS cooling tower basins is brackish water from the Chesapeake Bay from the emergency makeup water system (approximately 228 gpm (862 lpm) maximum anticipated per train). In the event normal water supply is lost, there is a 72 hour volume of water available at the tower basin to deal with system losses before the emergency UHS makeup water supply is required to be initiated.

The ESWS cooling tower basin design considers that the basin is operating just above the low operating water level at the start of an accident and that the normal non-safety-related makeup water supply is lost. At the end of 72 hours following the initiation of a DBA, enough water will remain in the basin to provide minimum submergence depth for vortex suppression and to maintain sufficient NPSH for the pumps, plus some margin. After 72 hours, the safety-related UHS makeup water system would begin supplying makeup water to the basins of the operating ESWS cooling towers (See Section 9.2.5). Details of the ESWS design bases for operation and normal or accidental shutdown and cooldown, as well as the water sources and the related retaining and conveyance systems, are provided in Section 9.2.5.

The UHS makeup water intake structure is designed to withstand the extreme meteorological and geo-seismic events, such as the probable maximum storm surge, probable maximum tsunami and tornadoes. Specifically, the invert elevation of the UHS makeup pump sump is set at a level to provide sufficient submergence depth to suppress harmful vortex formation and to maintain sufficient NPSH for the pump, under the design water level conditions.

In the event of a PMH, the resulting extreme low water level can persist at most for one day since the forward speed of the PMH around the site is estimated to be 20.3 mph (32.7 kmph). With this speed, the PMH would have traveled around 500 miles (805 km) in 24 hours and its effect on the site will diminish. Therefore, the site area can be out of the severe-influence area of the PMH after 24 hours. Nevertheless, the minimum design level is set at -6.0 ft (-1.83 m) at the existing intake channel based on the PMH. There is no need for alternate emergency UHS makeup sources in the event of a hurricane.

Design basis heat loads for various plant modes are provided in Section 9.2.5. Normal makeup water flow rate requirements for the UHS trains are based not only on providing sufficient inventory in the cooling tower basins for safe operation of the ESWS pumps but also on maintaining basin water chemistry, and takes into consideration maximum ESWS cooling tower evaporation, drift, and seepage losses. The Regulatory Guide 1.27 (NRC, 1976) criteria to provide water inventory for UHS operation during the 30 day post accident period have been incorporated into the CCNPP Unit 3 UHS design: Each ESWS cooling tower basins will have sufficient inventory to permit operation of the associated ESWS train for 72 hours following an accident without the need for additional makeup water. At the end of 72 hours, the safety-related UHS makeup water system will be put into operation to feed the ESWS cooling tower basins for the remaining 27 day period following an accident (See Section 9.2.5).

There are no other uses of water drawn from the UHS, such as fire water or system charging requirements. There are no other interdependent safety-related water supply systems to the UHS, like reservoirs or cooling lakes. There is no potential of blockage of the safety-related UHS makeup water intake due to ice or channel diversions as discussed in Sections 2.4.7 and 2.4.8.

2.4.11.7 References

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2.4.12 GroundWater

The U.S. EPR FSAR includes the following COL Item in Section 2.4.12:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information to identify local and regional groundwater reservoirs, subsurface pathways, onsite use, monitoring or safeguard measures, and to establish the effects of groundwater on plant structures.

This COL Item is addressed as follows:

{This section provides a description of the hydrogeologic conditions present at, and in the vicinity of the CCNPP site. This section describes the regional and local ground water resources that could be affected by the construction and operation of CCNPP Unit 3. The regional and site-specific data on the physical and hydrologic characteristics of these ground water resources are summarized to provide the basic data for an evaluation of potential impacts on the aquifers of the area.

Sections 2.4.12.1 through 2.4.12.6 are added as a supplement to the U. S. EPR FSAR.

2.4.12.1 Description and Use

2.4.12.1.1 Hydrogeologic Setting

Except where otherwise noted, the information presented in this section is summarized from the USGS Ground Water Atlas of the United States, Segment 11 (USGS, 1997a). The location of the CCNPP site in reference to the Mid-Atlantic States is shown in Figure 2.4-53. The site is located in Calvert County, MD and lies within the Coastal Plain Physiographic Province, at a distance of about 50 mi (80 km) east of the Fall Line. The Coastal Plain Physiographic Province is a lowland that is bordered by the Atlantic Ocean to the east and Fall Line to the west. The Fall Line is a demarcation, separating the eastern, unconsolidated coastal plain sediments from the consolidated rocks of the western physiographic provinces associated with the Appalachian Mountains. Although the Coastal Plain is generally a flat, seaward-sloping lowland, this province has areas of moderately steep local relief that reach elevations of several hundred feet.

The CCNPP site is underlain by approximately 2500 ft (762 m) of southeasterly dipping, Coastal Plain sedimentary strata of Cretaceous and Tertiary age. Underlying these sediments are crystalline and metamorphic rocks of Precambrian and Early Paleozoic age. The Cretaceous and Tertiary strata are comprised primarily of sedimentary deposits of silt, clay, sand, and gravel, which exhibit considerable lateral and vertical variations in lithology and texture. The strata form a wedge-shaped mass, which thickens and deepens to the southeast from the Fall Line towards the Atlantic Ocean (see Section 2.5.1 for additional geologic detail). Water-bearing units within the Coastal Plain sediments consist of unconsolidated to semi-consolidated sand aquifers separated by clay confining units. The sediments that compose the aquifer systems were deposited in non-marine, marginal marine, and marine environments during a series of marine transgressions and regressions during Cretaceous and Tertiary times (USGS, 1997a).

Parts of five physiographic provinces are present in the State of Maryland (Figure 2.4-54 and Figure 2.4-55). These include (from west to east) the:

- Appalachian Plateau Physiographic Province
- Valley and Ridge Physiographic Province
- Blue Ridge Physiographic Province
- Piedmont Physiographic Province
- Coastal Plain Physiographic Province

The provinces are illustrated in Figure 2.4-54, which also illustrates the aquifer systems associated with these provinces. Figure 2.4-55 depicts a cross-sectional schematic view of these provinces. Ground water occurrence is of significance to the site only within the Coastal Plain Physiographic province, specifically, the regional area of southern Maryland east of the Fall Line. The Fall Line identifies a contrast in topography and surficial geology between the western physiographic provinces and that of the eastern Coastal Plain Physiographic Province. However, a brief discussion of ground water within the other provinces is included below to provide a more complete picture of Maryland's hydrogeologic regimes.

2.4.12.1.1.1 Appalachian Plateau Physiographic Province

The Appalachian Plateau Province extends over most of West Virginia, more than one-half of Pennsylvania, and small parts of westernmost Virginia and Maryland. The province lies approximately 150 mi (241 km) west of the CCNPP site. It is bounded on the east and southeast by the Valley and Ridge Province. The Appalachian Plateau Province is underlain by rocks that are continuous with those of the bordering Valley and Ridge Province, but in the Appalachian Plateau Province the sedimentary rocks are nearly flat-lying, rather than being intensively folded and faulted (USGS, 1997a).

The Appalachian Plateau Province aquifers are contained in Paleozoic sedimentary rocks consisting mostly of shale, sandstone, conglomerate, and limestone. Coal beds are found in rocks of Pennsylvanian age. The water-yielding characteristics of these aquifers vary significantly due to local variations in lithology and thickness of the geologic units. Most of the productive aquifers lie within sandstones or conglomerates, but limestone formations locally yield significant volumes of water (USGS, 1997a).

2.4.12.1.1.2 Valley and Ridge Physiographic Province

The northeast-southwest trending Valley and Ridge Physiographic Province lies southeast of the Appalachian Plateau Physiographic Province and lies approximately 100 mi (161 km) west of the CCNPP site. This province is characterized by layered Paleozoic sedimentary rocks that have been complexly faulted and folded. These rocks range in age from Cambrian to Pennsylvanian. Well-cemented sandstones and conglomerates resistant to weathering form elongated mountain ridges. The less resistant limestone, dolomite, and shale are more easily eroded and form the intervening valleys between the ridges (USGS, 1997a), further described in Section 2.5.1.

The principal aquifers in the Valley and Ridge Province are carbonate rocks (limestone and dolomite) and sandstones that range in age from early to late Paleozoic. Most of the more productive aquifers are in carbonate rocks, primarily limestone, and most are in the valleys. However, the water-yielding character of the carbonate rocks depends on the degree of fracturing and development of solution cavities in the rock. Sandstone formations can also yield large volumes of water where these rocks are well fractured. Generally, the carbonate aquifers predominate in early Paleozoic rocks, whereas the sandstone aquifers are more often found in late Paleozoic rocks (USGS, 1997a).

2.4.12.1.1.3 Blue Ridge Physiographic Province

The Blue Ridge Physiographic Province lies east of the Valley and Ridge Province. It forms a thin (generally 5 to 20 mi (8 to 32 km) in width) and continuous band of mountains trending northeast to southwest from Pennsylvania to Georgia. The province boundary lies approximately 90 mi (145 km) northwest of the CCNPP site. The rocks comprising the Blue Ridge Province are geologically similar to those of the bordering Piedmont Province. Therefore, from a ground water perspective, the two provinces are often described together. The principal differences between the two provinces are relief, altitude, and geographical position. The Blue Ridge mountain belt contains primarily crystalline, igneous and high-grade metamorphic rocks consisting of coarse-grained gneisses and schists. Minor amounts of low-grade metamorphic rocks (phyllites and slates) and Early Cambrian sedimentary rocks occur along its western margin (USGS, 1997a).

The primary features for the storage and transmission of ground water in the Blue Ridge Province occur in surficial regolith and bedrock fractures. Although the porosity of the regolith varies, it is one to three orders of magnitude greater than the crystalline bedrock. Accordingly, the regolith has the capacity to store a much larger volume of water than the bedrock, which only contains water in fractures. Because the size, number, and interconnection of bedrock fractures decreases with depth, most of the ground water is stored in the regolith. Therefore, well yields are greatest in areas of greatest regolith thickness (USGS, 1997a).

2.4.12.1.1.4 Piedmont Physiographic Province

The Piedmont Physiographic Province lies east of the Blue Ridge Physiographic Province, and its eastern boundary lies approximately 50 mi (80 km) northwest of the CCNPP site. The Piedmont Province is bounded on the east by the Fall Line. The Fall Line is a zone of stream rapids that marks the position where streams flow from Piedmont Province's consolidated rocks to the Coastal Plain's unconsolidated sediments (Figure 2.4-54 and Figure 2.4-55). The Piedmont Province is an area of varied topography ranging from lowlands to peaks and ridges of moderate relief and elevation. The metamorphic and igneous rock types seen in the Blue Ridge Province are also present in the Piedmont Province. Sedimentary basins that formed within early Mesozoic crustal rift zones are also included in this province. These basins contain shale, sandstone, and conglomerate interbedded locally with basalt lava flows and minor coal beds. In places, these rocks are intruded by diabase dikes and sills (USGS, 1997a).

Aquifers in the Piedmont Province lie predominantly in the shallow, more fractured igneous and metamorphic rocks that underlie both the Blue Ridge and Piedmont Provinces. In some topographically low areas of the Piedmont Province, aquifers exist within the carbonate rocks and sandstones associated with the Mesozoic rift basins (USGS, 1997a).

2.4.12.1.1.5 Coastal Plain Physiographic Province

The Coastal Plain Physiographic Province is located east of the Piedmont Province and extends to the Atlantic coastline. The CCNPP site lies within this province on the western shore of Chesapeake Bay in Maryland. Semi-consolidated to unconsolidated sediments of Cretaceous and younger ages form a northeast trending band that narrows to the northeast and parallels the coast (Figure 2.4-54). These sediments overlie igneous and metamorphic basement rocks equivalent to those exposed in the Piedmont. The Coastal Plain Province sediments form a southeasterly thickening wedge-shaped mass ranging in thickness from 0 ft (0 m) at the Fall Line to as much as 8000 ft (2438 m) along the Atlantic coastline of Maryland (USGS, 1997a).

The sediments in this province consist of layers of sand, silt, and clay with minor amounts of gravel and calcareous sediments. Aquifers are found primarily in the sand, gravel, and calcareous sediments. They can be traced over long distances, although some occur in lenses and are localized. The aquifers are separated vertically by confining units consisting primarily of clay with lesser amounts of silt and sand. Depending on the thickness and sand content of the confining units, they can act locally as either aquitards or aquicludes by retarding vertical ground water flow to varying degrees (USGS, 1997a).

In the Mid-Atlantic States, the aquifers within the Coastal Plain Physiographic Province are referred to as the Northern Atlantic Coastal Plain aquifer system (Figure 2.4-54). This aquifer system extends from New Jersey to the Carolinas. Water-bearing units within the Coastal Plain Province sediments consist of unconsolidated to semi-consolidated sand aquifers separated by clay confining units. Although water moves more readily through the aquifers than the intervening confining units, water can leak through the confining units. Therefore, the aquifer systems are considered hydraulically interconnected to some degree (USGS, 1997a).

The principal aquifers within the system, from shallow to deep are as follows (USGS, 1997a):

- Surficial aquifer
- Chesapeake aquifer
- Castle Hayne-Aquia aquifer
- Severn-Magothy aquifer
- Potomac aquifer

The aquifer units dip east to southeast from the Fall Line towards the Atlantic Ocean. Outcrop areas are identified as areas where the up-dip terminus of the aquifer unit is exposed to the ground surface. The deeper the aquifer, the more western the outcrop area is towards the Fall Line. While the shallower the aquifer unit, the more easterly the outcrop area. The Fall Line is considered to be the western-most boundary of the outcrop areas for the Coastal Plain aquifer system. In southern Maryland, recharge areas to the shallow aquifer systems (Surficial and Chesapeake aquifers) are localized while the recharge areas for the deeper aquifer systems (Castle Hayne – Aquia, Severn – Magothy, and Potomac aquifers) are the outcrop areas to the west and northwest in Charles, Prince George's, and Anne Arundel counties (Figure 2.4-54).

2.4.12.1.2 Regional Hydrogeologic Description

The CCNPP site is located in southern Maryland. It is underlain by approximately 2500 ft (762 m) of southeasterly dipping sedimentary strata of Cretaceous and Tertiary age. The Cretaceous and Tertiary strata are comprised primarily of sedimentary deposits of silt, clay, sand, and gravel, which exhibit considerable lateral and vertical variations in lithology and texture. The stratum forms a wedge-shaped mass, which thickens to the southeast from the Fall Line towards the Atlantic Ocean.

For southern Maryland, investigators have refined the aquifer nomenclature system described in Section 2.4.12.1.1.5 based on local hydrostratigraphic conditions. From shallow to deep, the local aquifer systems are as follows: Surficial aquifer, Piney Point - Nanjemoy aquifer, Aquia aquifer, Magothy aquifer, and the Potomac Group of aquifers (MGS, 1996 and MGS, 1997). The major difference between the nomenclatures is that the Chesapeake aquifer is treated as a confining unit and that the Castle Hayne - Aquia aquifer system has been subdivided into the Piney Point - Nanjemoy and Aquia aquifers.

The refined nomenclature will be used to describe the regional hydrogeologic conditions in the vicinity of CCNPP Unit 3 site. The hydrostratigraphic column for the CCNPP site and surrounding area, identifying geologic units, confining units, and aquifers is illustrated in Figure 2.4-56 (MGS, 1997). A schematic cross-section of the Southern Maryland hydrostratigraphic units is presented in Figure 2.4-57. Geologic and stratigraphic unit descriptions are discussed further in Section 2.5.1.

2.4.12.1.2.1 Surficial Aquifer

In Calvert County, the unconfined Surficial aquifer consists of two informal stratigraphic units, the Lowland Deposits and the Upland Deposits. The units comprising the Lowland Deposits are Holocene to Pleistocene in age. They consist of sands and clays deposited in fluvial and estuarine environments. The Upland Deposits are Pliocene in age and consist primarily of sands and gravels deposited in fluvial environments. In Calvert and St. Mary's counties, the Lowland Deposits outcrop along the Patuxent and Potomac Rivers and the Chesapeake Bay; however, these deposits appear to be absent in the immediate vicinity of the CCNPP site. The Upland Deposits are geographically more extensive in St. Mary's County than in Calvert County, but they are present at the CCNPP site and form the entirety of the Surficial aquifer at the site (MGS, 1996).

Recharge to the Surficial Aquifer is almost exclusively by direct infiltration of precipitation. Flow within the aquifer is localized with water moving from recharge areas (local land surface) along short flow paths to discharge areas (nearby streams or springs). Some of the water may percolate downwards to recharge underlying aquifers. Based on information provided in USGS Ground Water Atlas of the United States, Segment 11 (USGS, 1997a), the average annual precipitation between 1951 and 1980 in the region was estimated at 44 in (112 cm) with an average annual runoff estimated as 15 in (38 cm) (34 percent). The remaining 29 in (74 cm) of precipitation is available as recharge to the aquifer system, with the exception of that removed from the hydrologic cycle by direct evaporation and plant evapotranspiration.

Within the southern Maryland region, the Surficial aquifer is not a reliable source of ground water. This is due to its relative thinness, limited saturated thickness (particularly during prolonged drought), and topographic dissections, which causes local ground water to discharge as small springs (USGS, 1997a). The Surficial aquifer is tapped by irrigation wells and some older farm and domestic wells, but it is not widely used as a potable water supply because of its vulnerability to contamination and reduced dependability during droughts (MGS, 2005). Wells completed in this aquifer generally yield less than 50 gpm (189 lpm). The ground water table is usually encountered within a depth of 50 ft (15 m) below ground surface (bgs) (USGS, 1997a).

2.4.12.1.2.2 Chesapeake Confining Unit

From youngest to oldest, the Miocene Chesapeake Group consists of the Saint Mary's, Choptank, and Calvert Formations. The Chesapeake Group is a significant aquifer east of the CCNPP site in the Delmarva Peninsula. However, beneath the western shore of Maryland, in the vicinity of the CCNPP site, the Chesapeake Group is described as a confining unit. With the exception of a relatively thin sandy unit at its base (lower Calvert Formation), the silts and clays of the Chesapeake Group are hydrostratigraphically undifferentiated, and they define the Chesapeake Confining Unit, which separates the overlying Surficial aquifer from the underlying Piney Point - Nanjemoy aquifer (MGS, 1996), although thin and discontinuous sand units capable of producing small quantities of ground water are present locally. These saturated materials beneath the western shore of Maryland may yield water, but not of quantities sufficient for most uses. Within the region, localized sand units are recharged by precipitation and percolation through the overlying Surficial aquifer, moving a few miles or less downgradient along the flow path, and discharging to the Chesapeake Bay, streams, or localized areas of pumping. The potentiometric surface of the localized sand aquifers in the Chesapeake Group is generally above mean sea level (USGS, 1997a).

In general, the Chesapeake Confining Unit thickens from northwest to southeast in Calvert County and ranges in thickness from approximately 115 to 300 ft (35 to 91.4 m). A boring log from a production well at the CCNPP site indicate that the base of the Chesapeake Confining Unit is at an elevation of approximately –205 ft (-62.5 m) msl and its total thickness is approximately 250 ft (76 m) (MGS, 1996).

2.4.12.1.2.3 Piney Point – Nanjemoy Aquifer

The Piney Point - Nanjemoy aquifer is stratigraphically complex, consisting of several geologic units. From youngest to oldest, the aquifer includes the following: the basal sandy strata of the lower to middle Miocene Chesapeake Group (lower Calvert Formation); unnamed upper Oligocene beds; the middle Eocene Piney Point Formation; and the sandy, upper part of the lower Eocene Nanjemoy Formation. Recharge to this aquifer is interpreted to be from direct infiltration of precipitation in northern Calvert County (lower Calvert Formation) and Anne Arundel County (Nanjemoy Formation) where these units are exposed at the surface. Recharge also presumably occurs from leakage from overlying aquifers. Discharge of the Piney Point - Nanjemoy aquifer is primarily from subaqueous exposures of the aquifer that are presumed to occur along the Continental Shelf. However, the northern portion of the Chesapeake Bay is a discharge area where the aquifer system is eroded by ancestral Susquehanna River paleochannels. Additional discharge occurs at local pumping locations (MGS, 1996).

The basal beds of the Calvert Formation are hydraulically connected to the underlying Piney Point - Nanjemoy aquifer. This unit is generally 10 to 20 ft (3 to 6 m) thick and consists of green to gray, glauconitic, fine to medium grained quartz sand. In places, this unit contains coarse shell fragments, phosphate nodules, and gravel (MGS, 1996). The underlying unnamed upper Oligocene beds are thin (less than 5 ft (1.5m)) to locally absent and very difficult to map in the subsurface. Consequently, the basal Calvert Formation sands and the unnamed upper Oligocene beds are treated as a single subsurface mapping unit (MGS, 1997).

The middle Eocene Piney Point Formation underlies the unnamed upper Oligocene beds and consists of shelly, glauconitic, quartzose sands and carbonate cemented interbeds of sands up to 5 ft (1.5 m) in thickness. The Piney Point Formation thickens to the southeast and ranges from 0 ft (0 m) in central Calvert County to approximately 45 ft (14 m) thick in southern Calvert County at Solomons. A boring log from a production well at the CCNPP site indicates that the base of the Piney Point Formation is at an approximate elevation of –225 ft (-68.6 m) msl and its total thickness is approximately 10 ft (3 m) (MGS, 1996).

The Piney Point Formation overlies lower Eocene beds of the Nanjemoy Formation. The Nanjemoy Formation coarsens upward overall from predominantly sandy silts and clays to dominantly clayey sands. This allows it to be subdivided into two hydrostratigraphic units. The sandy upper Nanjemoy Formation is hydraulically connected to the overlying Piney Point Formation and is assigned to the Piney Point - Nanjemoy aquifer. The more clayey sediments of the lower Nanjemoy Formation are placed in the Nanjemoy Confining Unit (MGS, 1996 and MGS, 1983). A boring log from a production well at the CCNPP site indicates that the base of the coarser grained upper Nanjemoy Formation (bottom of the Piney Point - Nanjemoy aquifer is at an approximate elevation of –315 ft (-96 m) msl and the total thickness of the Piney Point - Nanjemoy aquifer is approximately 115 ft (35 m) MGS, 1996).

Results from six pumping tests conducted in the Piney Point - Nanjemoy aquifer in the late 1970s indicate transmissivity values ranging from 275 ft^2/day to 690 ft^2/day (25.5 to 64.1 m^2/day). Similar transmissivity values ranging from 125 ft^2/day to 740 ft^2/day (11.6 to 68.7 m^2/day) were estimated from 90 well specific capacities derived from well completion reports (MGS, 1997). A storage coefficient of 0.0003 was applied to this aquifer as part of a ground water modeling effort by the State of Maryland (MGS, 1997).

Although a few major users in southern Calvert and St. Mary's counties pump from the Piney Point - Nanjemoy aquifer, it is primarily used for domestic water supply. Domestic well yields are generally less than 20 gpm (75.7 lpm) with maximum reported well yields of up to 200 gpm (757 lpm) in the Piney Point Formation and up to 60 gpm (227 lpm) in the Nanjemoy formation.

2.4.12.1.2.4 Nanjemoy Confining Unit

The Nanjemoy Confining Unit underlies the Piney Point - Nanjemoy aquifer and consists of the lower part of the early Eocene Nanjemoy Formation and the underlying late Paleocene Marlboro Clay. The lower Nanjemoy Formation consists of greenish-gray, glauconitic sandy clay. The underlying Marlboro Clay occurs at the base of the Nanjemoy Confining Unit and consists of a gray to pale-red plastic clay interbedded with reddish silt. A boring log from a production well at the CCNPP site indicates that the base of the lower Nanjemoy is at an approximate elevation of -415 ft (-126.5 m) msl and the Unit attains a thickness of approximately 90 ft (27.4 m). The boring log indicates that the base of the Marlboro Clay is at an approximate elevation of -440 ft (-134 m) msl and the Unit is approximately 25 ft (7.6 m) thick in the vicinity of the site (MGS, 1997).

The Marlboro Clay is described as much "tighter" than the muddy sands of the Nanjemoy Formation. Vertical hydraulic conductivities from laboratory tests performed on Nanjemoy samples in Queen Anne's county range from 6.6 x 10^{-3} ft/day to 6.8 x10^{-2} ft/day (2 x 10^{-3} to 2.1x 10^{-2}). Similar tests on Marlboro Clay samples generated lower results ranging from 9.5 x 10^{-5} ft/day to 4.5 x 10^{-4} ft/day (2.9 x 10^{-5} to 1.4 x 10^{-4}). Specific storage values assigned to the Nanjemoy Confining Unit in several ground water models range from 7.6 x 10^{-5} ft^{-1} to 1 x 10^{-5} ft^{-1} (24.9 x 10^{-5} m^{-1} to 3.28 x 10^{-5} m^{-1}). Laboratory results of specific storage tests on the Marlboro Clay range from 1.0 x 10^{-5} ft^{-1} to 1.1 x 10^{-4} ft^{-1} (3.28 x 10^{-5} m^{-1} to 3.6 x 10^{-4} m^{-1} (MGS, 1997).

2.4.12.1.2.5 Aquia Aquifer

In southern Maryland, the Aquia aquifer correlates with the late Paleocene Aquia Formation. The Aquia Formation is poorly to well sorted, shelly, and contains glauconitic quartz sand with carbonate cemented sandstones and shell beds. The Aquia Formation (aquifer) dips to the southeast with its upper surface ranging in elevation from approximately -100 ft (-30.5) msl in northern Calvert County to -500 ft (-152.4) msl just off Solomons in southern Calvert County. The aquifer's thickness varies considerably in Calvert County. It reaches a maximum thickness of approximately 200 ft (61 m) in east-central and northeastern Calvert County and thins to the northwest and southeast where it reaches a thickness of approximately 145 ft (44.2 m) at Solomons and 160 ft (48.8 m) at the boundary between Anne Arundel and Calvert counties. The Aquia aquifer thins progressively to the southeast where it grades into predominantly fine-grained sediments and hydraulically becomes a confining unit in southernmost St. Mary's County where it is no longer used for water supply. A boring log from a production well at the CCNPP site indicates that the base of the Aquia aquifer is at an approximate elevation of –560 ft msl and its total thickness is approximately 145 ft (44.2 m) (MGS, 1996).

Aquia aquifer transmissivity maps derived from pumping tests display a general correlation to Aquia aquifer thickness maps with highest transmissivity values in areas of greatest aquifer thickness. Reported transmissivities in northern Calvert County at Randle Cliff Beach are 1330 ft^2/day (123.6 m^2/day) where the Aquia reaches its maximum thickness of approximately 200 ft. Farther south, at Solomons, reported transmissivities are 755 ft^2/day (70.2 m^2/day) where the aquifer thins to approximately 145 ft (44.2 m). A transmissivity of 935 ft^2/day (86.9 m^2/day) is reported at the CCNPP site (MGS, 1997). Storage coefficient values of the Aquia aquifer determined from pumping tests in southern Maryland range from 4 x 10^{-4} to 1 x 10^{-4} (MGS, 1997).

The Aquia formation is one of the most productive aquifers on the Northern Atlantic Coastal Plain aquifer system in southern Maryland. Recharge to the Aquia aquifer is from direct infiltration of precipitation in central Anne Arundel and Prince George's counties where these units are exposed at the surface. Natural discharge of the Aquia aquifer is to the southeast, primarily from subaqueous exposures of the aquifer that are presumed to occur along the Continental Shelf. Other discharge occurs at local pumping locations.

The Aquia aquifer is used extensively for domestic and major-user water supplies in southern Maryland. By the 1980s, a deep cone of depression (up to 100 ft (30.5 m)) had developed in the Solomons area of Calvert and St. Mary's county area where it is heavily pumped for public, commercial, and military supplies (USGS, 2005a). This has diverted the ground water flow direction in Calvert County to the south and southeast toward these pumping centers. This is depicted in Figure 2.4-58. A 2003 potentiometric surface map of the Aquia aquifer that indicates the elevation and horizontal direction of ground water flow (USGS, 2005a). Because of these considerations, water supply managers in these counties are seeking to shift some ground water usage from the Aquia aquifer to deeper aquifers (MGS, 2005).

2.4.12.1.2.6 Brightseat Confining Unit

The confining unit underlying the Aquia aquifer is composed of several geologic units. These include the lower Paleocene Brightseat Formation and several upper Cretaceous units, including the Monmouth, Matawan, and Magothy Formations. The fine-grained sediments of these formations combine to form the hydraulically indistinguishable Brightseat Confining Unit. The Brightseat Confining Unit has a composite thickness ranging from approximately 20 to 105 ft (6.1 to 32 m). A boring log from a production well at the CCNPP site indicates that the base of the Brightseat Confining Unit is at an elevation of approximately -590 ft (-180 m) msl and the Unit attains a thickness of approximately 30 ft (9.1 m) (MGS, 1996).

Most researchers model the Brightseat Confining Unit as a no flow boundary; however, a few vertical hydraulic conductivity and specific storage values have been reported. Samples from Prince George's County yielded vertical hydraulic conductivity and specific storage values of 9.5×10^{-4} ft/day (2.9×10^{-4} m/day) and 7.4×10^{-5} ft^{-1} (24.3×10^{-5} m^{-1}), respectively. Vertical hydraulic conductivities for the Matawan Formation in the Annapolis area range from 5.7×10^{-5} ft/day to 3.1×10^{-4} ft/day (1.7×10^{-5} m/day to 9.4×10^{-5} m/day) (MGS, 1997).

2.4.12.1.2.7 Magothy Aquifer

In central Calvert County, the Magothy aquifer is contained in the Upper Cretaceous Magothy Formation. This unit consists of interbedded red, brown, and gray sands and clays. The Magothy aquifer is present in the northern and central portions of Calvert County where it is used extensively for public and domestic supplies. It thins to the south and pinches out in southern Calvert County where it is not a significant aquifer. The southern extent of the aquifer is estimated to lie somewhere between the CCNPP site and Solomons. A boring log from a production well at the CCNPP site indicates that the base of the Magothy aquifer is at an elevation of approximately -610 ft (-186 m) msl and the aquifer appears to attain a thickness of less than 25 ft (7.6 m) (MGS, 1996).

Transmissivities of 450 ft^2/day to 4570 ft^2/day (41.8 m^2/day to 424.6 m^2/day) have been reported for the Magothy aquifer in southern Anne Arundel County (MGS, 2002). Reported transmissivity values for southern Maryland counties range from 1000 ft^2/day to 12,000 ft^2/day (92.9 m^2/day to 1114.8 m^2/day. The primary use of this aquifer occurs in Anne Arundel, Prince George's, and Charles counties (Wolman, 2004).

Recharge to the Magothy aquifer is from direct infiltration of precipitation in northern Anne Arundel County where the Magothy Formation is exposed at the surface. In central Calvert County, flow is east-southeast, towards the Atlantic Coast. Other discharge occurs at local pumping locations (MGS, 1997 and USGS, 2005b).

A 2003 potentiometric surface map of the Magothy aquifer is presented in Figure 2.4-59 (USGS, 2005b) to establish the elevation and horizontal direction of ground water flow.

2.4.12.1.2.8 Potomac Group

The lower Cretaceous Potomac Group consists of the following (in descending order): the Patapsco, Arundel, and Patuxent Formations. These units form a thick (greater than 1500 ft (457 m)) series of unconsolidated sediments, which locally contain three confining units and three aquifers. Because of the significant depth of these formations, and the abundance of exploitable supplies of ground water in shallower aquifers, these units are not currently used as a significant source of ground water in the vicinity of the CCNPP site. Consequently, available hydrogeologic information for the Potomac Group of aquifers and confining units is limited.

The Upper Patapsco aquifer underlies the Magothy aquifer and is separated from it by clayey units in the top of the Patapsco Formation and bottom of the Magothy Formation. These clayey units are collectively referred to as the Upper Patapsco confining unit. The Upper Patapsco aquifer includes sand units in the upper part of the Patapsco Formation. This aquifer is not continuous and comprises complexly stratified sandy units separated locally by silts and clays. Individual sand units in the Upper Patapsco aquifer are difficult to correlate laterally, but they appear to be sufficiently interconnected at the regional scale to form a single aquifer (MGS, 2005). The aquifer extends to the northeast through Prince George's and Anne Arundel counties, and beneath Chesapeake Bay to the eastern shore of Maryland. The aquifer is recharged by precipitation at outcrops in western and northern Charles, Prince George's and Anne Arundel counties. It subcrops beneath the tidal part of the Potomac River, where river water intrusion has been documented in the Indian Head area (USGS, 1997b).

The Upper Patapsco aquifer is extensively used for public supply in central Charles County, where a cone of depression has formed as deep as elevation -136 ft (-41.5 m) msl. It is also pumped heavily by major users in Prince George's and Anne Arundel counties (Wolman, 2004). A few major users pump the Upper Patapsco aquifer in northern St. Mary's and Calvert counties (MGS, 2005). Pump tests performed in the Upper Patapsco aquifer in east-central Charles County yielded a transmissivity of 1110 ft^2/day (103 m^2/day) (MGS, 2007a). Upper Patapsco transmissivities reported for Charles and Anne Arundel counties range from 1000 ft^2/day to 10,000 ft^2/day (92.9 to 929 m^2/day) (Wolman, 2004).

The Lower Patapsco aquifer underlies the Upper Patapsco aquifer. The two aquifers are separated by clayey units forming the Middle Patapsco confining unit in the middle part of the Patapsco Formation. The Lower Patapsco aquifer comprises sandy units in the lower part of the Patapsco Formation. The aquifer extends northeast to northern Anne Arundel County, but its correlation to the west and southwest is uncertain. It extends across the Chesapeake Bay to the eastern shore of Maryland. The Lower Patapsco aquifer is pumped heavily by users in central and northwestern Charles County, but it is not currently used in St. Mary's or Calvert counties (MGS, 2005). Pumping tests performed in the Lower Patapsco aquifer in western Charles County yielded a transmissivity of 1130 ft^2/day (105 m^2/day). Specific capacity for wells used in these pump tests ranged from 1.8 gpm/ft to 7.1 gpm/ft (22.4 to 88.2 lpm/m) (Wolman, 2004 and MGS, 2004). Lower Patapsco aquifer transmissivities reported for Charles and Anne

Arundel counties range from 1000 ft^2/day to 5000 ft^2/day (92.9 to 464.5 m^2/day) (Wolman, 2004).

Potentiometric surface maps of the Upper and Lower Patapsco aquifers in 2003 are presented in Figure 2.4-60 and Figure 2.4-61 to establish the elevation and horizontal direction of ground water flow (USGS, 2005c and USGS, 2005d).

The Patuxent aquifer lies below the Lower Patapsco aquifer, and it is separated from it by the Arundel confining unit. The Arundel Formation consists of a thick series of dense clays and silts and probably does not allow much leakage. However, the Arundel Formation is not uniformly recognized in southern Maryland (see Section 2.5.1).

The Patuxent Aquifer is the deepest Coastal Plain aquifer in Maryland, and rests on the Piedmont bedrock surface. Patuxent aquifer transmissivities reported for Charles and Anne Arundel counties range from 200 ft^2/day to 8000 ft^2/day (18.6 to 743.2 m^2/day) (Wolman, 2004). Pumping tests performed in the Patuxent aquifer in western Charles County yielded a transmissivity of 937 ft^2/day (87 m^2/day). The specific capacity for the single Patuxent aquifer well used in this pumping test was 2.6 gpm/ft (32.3 lpm/m) (MGS, 2004). Pump tests performed on Patuxent aquifer municipal wells in Bowie, Maryland (northern Prince George's County) yielded an average transmissivity of 1468 ft^2/day (136.4 m^2/day) (Bowie, 2007). Because of its great depth and the known presence of brackish water in coastal areas, its potential for development is thought to be limited (Wolman, 2004).

2.4.12.1.3 Local and Site-Specific Hydrogeology and Sources

The topography at the site (Figure 2.4-62) is gently rolling with steeper slopes along stream courses. Local relief ranges from sea level up to an elevation of approximately 130 ft (39.6 m) msl with an average elevation of approximately 100 ft (30.5 m). The Chesapeake Bay shoreline consists mostly of steep cliffs with narrow beach areas. The site is well drained by short, intermittent streams. A drainage divide, which is generally parallel to the coastline, extends across the site. The area to the east of the divide drains into the Chesapeake Bay. The western area is drained by tributaries of Johns Creek and Goldstein Branch, which flow into St. Leonard Creek, located west of Maryland Highway MD 2/4 and subsequently into the Patuxent River. The Patuxent River empties into the Chesapeake Bay approximately 10 mi (16 km) southeast from the mouth of St. Leonard Creek. The Chesapeake Bay and Patuxent River define the eastern, southern, and western boundaries of Calvert County. The creeks and streams within the area influence the shallow aquifer systems beneath the site. Deeper aquifers are less influenced by incised streams and rivers.

Geotechnical and hydrogeological investigations provided information on the CCNPP Unit 3 site to depths of 400 ft (122 m) below ground surface. Subsurface information was collected from over 228 borings and cone penetrometer tests (CPTs). A detailed description of the geotechnical subsurface investigation, including the locations of these borings and CPTs is provided in Section 2.5. The location of the soil borings is provided on Figure 2.4-63.

Forty-seven (47) ground water observation wells were installed across the site. They were completed in the Surficial aquifer and water-bearing materials in the Chesapeake Group. The wells were located in order to provide adequate distribution with which to determine site ground water levels, subsurface flow directions, and hydraulic gradients beneath the site. Well pairs were installed at selected locations to determine vertical gradients. Field hydraulic conductivity tests (slug tests) were conducted in each observation well. Groundwater levels in the wells installed in 2006 were monitored monthly from July 2006 through June 2007 and have been monitored quarterly thereafter. Groundwater levels in the wells installed in 2008 were monitored monthly from September 2008 through October 2009, and will be monitored on a quarterly basis henceforth. Figure 2.4-64 and Figure 2.4-65 contain hydrogeologic cross sections for the strata penetrated by the soil borings at the CCNPP Unit 3 site. These cross sections cover the area in the vicinity of the CCNPP Unit 3 power block area.

2.4.12.1.3.1 Geohydrology

The elevations, thicknesses, and geologic descriptions of the sediments comprising the shallow hydrogeologic units (depths to 400 ft (122 m)) below ground surface) were determined from CCNPP Unit 3 geotechnical and hydrogeological borings. Geotechnical and geological descriptions of the material encountered are described in Section 2.5.

The unit thicknesses are interpreted from logs of soil borings drilled in the vicinity of the CCNPP Unit 3 site. The logs describe soil samples collected from the soil borings. The soil samples were generally 18 inches long and were not collected continuously, but approximately at 5-foot intervals. Interpolation between samples varies between different investigators and accounts for minor differences in the interpretation of layer thicknesses between Subsection 2.4.12 and Subsection 2.5.4.

Surficial Aquifer

The elevations, thicknesses, and geologic sediments comprising the Surficial aquifer, as determined from the CCNPP Unit 3 geotechnical and hydrogeological borings, are summarized as follows.

- The unconsolidated sediments comprising the Surficial aquifer consist primarily of fine to medium grained sands and silty or clayey sands. At relatively few locations and intervals, coarse grained sands were observed to comprise the bulk of the interval sampled.

- The Surficial aquifer is present above an elevation of approximately 65 (19.8 m) msl at the CCNPP site (Figure 2.4-64 and Figure 2.4-65). The thickness of the Surficial aquifer ranges from 0 ft (0 m), where local drainages have dissected the unit, to approximately 55 ft (16.8 m) at the site's higher elevations.

Chesapeake Confining Unit

The Chesapeake Confining Unit thickens from northwest to southeast in Calvert County and ranges in thickness from approximately 115 to 300 ft (35 to 91.4 m). A boring log from a production well at the CCNPP site indicates that the base of the Chesapeake Confining Unit is at an elevation of approximately –205 ft (-62.5 m) msl and its total thickness is approximately 250 ft (76.2 m) (MGS, 1996). The CCNPP Unit 3 soil borings advanced to this depth confirm this observation.

The elevations, thicknesses, and geologic descriptions of the sediments comprising the Chesapeake Confining Unit, as determined from the CCNPP Unit 3 geotechnical and hydrogeological borings, are summarized as follows.

- The unconsolidated sediments comprising the Chesapeake Confining Unit consist primarily of silty clays, silt, and silty fine-grained sands. Thin, interbedded fine- to medium-grained fossiliferous sands are common. Some of these sands are cemented with calcite.

- The base of the Chesapeake Confining Unit is observed at an elevation of approximately –205 ft (-62.5 m) msl in Boring B-401 and -215 ft (-65.5 m) msl in Boring B-301.
- The top of the Chesapeake Confining Unit ranges from an elevation of approximately 8 ft (2.4 m) msl in Boring B-701 at the Chesapeake Bay shore to approximately 65 ft (19.8 m) msl in borings where the overlying Upland Deposits comprising the Surficial aquifer were encountered.
- The thickness of the Chesapeake Confining Unit, as observed in Borings B-301 and B-401, is approximately 278 ft (84.8 m).
- Two thin, semi-continuous, water-bearing sand units were encountered in the upper portion of the Chesapeake Confining Unit. These units are informally referred to as the Upper Chesapeake Unit and the Lower Chesapeake Unit.
- The base of the Upper Chesapeake Unit ranges from approximately 16 ft (4.9 m) msl to -17 ft (-5.2 m) msl in elevation, has a mean thickness of approximately 46 ft (14.9 m), and reaches a maximum thickness of approximately 63 ft (19.2 m) at boring B-331. The minimum, observed thickness of the Upper Chesapeake Unit is 17 ft (5.2 m) at borings B-701 and B-702. The elevation of the top of the Upper Chesapeake Unit averages approximately elevation 41 ft (12.5 m) msl.
- The Lower Chesapeake Unit contains a higher silt and clay content than the Upper Chesapeake Unit. The base of the Lower Chesapeake Unit ranges in elevation from approximately -38 ft (-11.6 m) msl to -92 ft (-28.0 m) msl, has a mean thickness of approximately 36 ft (11 m), and reaches a maximum thickness of approximately 62 ft (18.9 m) at boring B-313. The minimum observed thickness of the Lower Chesapeake Unit was 19 ft (5.8 m) at boring B-327.
- The Upper Chesapeake Unit is separated from the overlying Surficial aquifer by the informally named relatively thin Upper Chesapeake aquitard. The thickness of the Upper Chesapeake aquitard ranges from approximately 4 to 36 ft (1.2 to 11 m) and averages approximately 20 ft (6.1 m). The Upper and Lower Chesapeake Units are separated by the informally named Middle Chesapeake aquitard. The thickness of the Middle Chesapeake aquitard ranges from approximately 4 to 22 ft (1.2 to 67 m). The Lower Chesapeake Unit is separated from the underlying Piney Point - Nanjemoy aquifer by the informally named and relatively thick Lower Chesapeake aquitard. Two CCNPP Unit 3 soil borings penetrated the Lower Chesapeake aquitard, which is approximately 170 ft (51.8 m) thick.

Piney Point – Nanjemoy Aquifer

The basal beds of the Calvert Formation are readily identified in the two CCNPP borings (B-301 and B-401) that penetrate this unit. The top of the basal Calvert Formation sands was observed at an elevation of approximately –205 ft (-62.5 m) msl in Boring B-301 and -215 ft (-65.5 m) msl in Boring B-401. The base of the Piney Point Formation was encountered at approximately -230 ft (-70.1 m) msl and -234 ft (-71.3 m) msl respectively. Borings B-301 and B-401 extended into the Nanjemoy Formation but did not penetrate through the Nanjemoy Confining Unit.

2.4.12.1.4 CCNPP Unit 3 Ground Water Use Projections

The sole source of fresh water for the operation of CCNPP Unit 3 will be a desalinization plant drawing raw water from the Chesapeake Bay. Other sources of fresh water will be required to support construction of CCNPP Unit 3 before the desalinization plant is operational. Construction activities requiring fresh water include concrete mixing and curing, dust suppression, sanitary and potable use by the construction workforce, hydrostatic testing of pipes and tanks, and wash water. The water needed during the projected 21 months of pre-construction and 68 months (approximately 6 years) of construction of CCNPP Unit 3 will be supplied by new production wells drilled into the Aquia Aquifer, the Upper Patapsco aquifer, or the Lower Patapsco aquifer. Other sources of fresh water that may be used to support construction are the groundwater pumped for construction dewatering and water trucked or barged from off site.

The Maryland Public Service Commission has issued a proposed Certificate of Public Convenience and Necessity (CPCN) to UniStar (MPSC, 2009). Condition 17 of the proposed CPCN authorizes UniStar to appropriate and use groundwater from up to two production wells in the Aquia aquifer to support the construction of CCNPP Unit 3. The groundwater allocation granted by this appropriation is limited to a daily average of 100,000 gallons on a yearly basis and a daily average of 180,000 gallons for the month of maximum use (MPSC, 2009).

Condition 28 of the proposed CPCN limits construction dewatering withdrawals from the Surficial aquifer to a daily average of 75,000 gallons on an average annual basis and a daily average not to exceed 100,000 gallons during the highest withdrawal month.

Based on water use estimates for normal conditions during construction, the maximum monthly water use total is calculated to be a daily average of 287,333 gallons. This value exceeds the groundwater allocation allowed by the CPCN. Therefore, other sources of water will be needed during this period, or the CPCN will need to be revised. Utilizing the dewatering effluent as a supplement for construction water use is the most attractive option; but it will require a revision to the dewatering limit in the CPCN.

After Unit 3 construction is complete, the desalination plant may be out of service occasionally for a period estimated to be no more than ten weeks, to permit maintenance and repair. During this period, continued operation of Unit 3 will require a back-up source of approximately 900 gpm of fresh water. The Aquia, Upper Patapsco, and Lower Patapsco aquifers are each capable of producing the fresh water supply required. However, three wells would be needed in the Aquia aquifer (one more than the maximum of two allowed by the CPCN) to reach the required 900 gpm flow, while only two wells would be necessary in either the Upper Patapsco or Lower Patapsco aquifers. In addition, the required 900 gpm of fresh water is substantially more than the 180,000 gpd for the month of maximum use allowed by the CPCN.

If properly managed, construction activities at CCNPP and any additional ground water withdrawals for construction of CCNPP Unit 3 should not adversely affect the local or regional ground water systems. There are currently no known or projected site discharges that do or could affect the local ground water system. Construction activities will affect the shallower, non-utilized water-bearing units beneath the site including the Surficial aquifer and upper water bearing units within the Chesapeake Group. However, these shallow units are not used locally for water supply and their relatively thin, discontinuous layers limit the extent to which construction impacts propagate off site.

2.4.12.2 Sources

2.4.12.2.1 Regional Ground Water Use

Ground water is extensively used as a source of water within the Coastal Plain and is the primary source of water supply in southern Maryland. The area is dependent on ground water for potable supplies because the major surface-water bodies are brackish and the small freshwater streams originating within the area lack adequate dam sites for reservoirs (MGS, 1997). Therefore, an objective of this section is to discuss the U.S. Environmental Protection Agency (U.S. EPA) sole source aquifers within the region, to identify and determine impacts to these aquifers due to the construction and operation of CCNPP Unit 3, and to describe the following: ground water use in southern Maryland, current users in Calvert County, current CCNNP ground water use, expected future ground water demand for southern Maryland and Calvert County.

2.4.12.2.2 Sole Source Aquifers

The Sole Source Aquifer (SSA) Program, which is authorized by the Safe Drinking Water Act, allows for protection when a community is dependent on a single source of drinking water and there is no possibility of a replacement water supply to be found. The U.S. EPA defines a sole or principal source aquifer as one which supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer (USEPA, 2007a).

The CCNPP site is located in EPA Region 3 (the District of Columbia, Delaware, Maryland, Pennsylvania, Virginia, and West Virginia). Six sole-source aquifers are identified in U.S. EPA Region 3 (as shown in Figure 2.4-82). None of the sole-source aquifers in U.S. EPA Region 3 are located in southern Maryland. Based on the evaluation of both the regional and local hydrogeologic systems presented in Sections 2.4.12.1.1 through 2.4.12.3, the construction and operation of CCNPP Unit 3 will not adversely impact the sole-source aquifers identified in EPA Region 3. The identified sole-source aquifers are beyond the boundaries of the local and regional hydrogeologic systems in southern Maryland.

2.4.12.2.3 Southern Maryland Ground Water Use

The Piney Point - Nanjemoy aquifer and underlying Aquia aquifer are the chief sources of ground water to Calvert and St. Mary's counties. The Piney Point - Nanjemoy aquifer is primarily used for domestic water supply. The Aquia aquifer is the primary source of ground water for major ground water appropriation in southern Maryland.

Early in the 20th century, few Aquia aquifer wells had been drilled in Calvert and St. Mary's counties. By mid-century, ground water demands were increasing in the region due to growth in population and industry and military use. Ground water usage was reported to have increased by 75 percent between 1940 (1.6 million gallons per day [mgpd] (6.1 mlpd)) and 1980 (2.8 mgpd (10.6 mlpd)). By the end of the 1980s, ground water pumpage had increased to about 4.8 mgpd (18.2 mlpd). Domestic pumpage accounted for about 60.1 percent of usage in 1991 and was about 3.4 mgpd (12.9 mlpd) in 1994. Ground water use was approximately evenly distributed between the Point Piney - Nanjemoy and the Aquia aquifers (MGS, 1997).

The underlying Magothy aquifer is present in the northern and central portions of Calvert County and farther north where it is now used extensively for public and domestic supplies in northern Calvert and Anne Arundel counties. It thins to the south and pinches out in southern Calvert County where it is not a significant aquifer. The underlying Upper Patapsco aquifer is used extensively for public supply in central Charles County, where multiple cones of depression have formed. It is also pumped heavily by major users in Prince George's and Anne

Arundel counties. A few users pump the Upper Patapsco aquifer in St. Mary's and northern Calvert counties. The Lower Patapsco aquifer is pumped heavily by users in central and northwestern Charles County, but it is not currently used as a major source of water in St. Mary's or Calvert counties (MGS, 1997).

2.4.12.2.4 Calvert County Ground Water Use

The Aquia aquifer is currently the primary source of ground water for the major appropriators in the county as the overlying Piney Point - Nanjemoy aquifer is increasingly being reserved for domestic users. The county Sanitary District operates major water-distribution systems as do numerous municipal and private water companies. In 1985, it was reported that major users withdrew approximately 73.4 percent from the Aquia aquifer, 19.4 percent from the Piney Point - Nanjemoy aquifer, and 7.2 percent from the deeper Magothy and Patapsco aquifers (MGS, 1997). By 1994, Calvert County withdrawals from the Piney Point - Nanjemoy and the Aquia aquifers totaled about 1.9 mgpd (7.2 mlpd) and 3.6 mgpd (14 mlpd), respectively.

A database obtained from the Water Supply Program, Maryland Department of Environment (MDE) in December 2006 for Calvert County lists the active Water Appropriations Permits for the county, including surface water permits, and ground water permits. The appropriated amount of ground water that was permitted in Calvert County in 2006 was approximately 5.3 mgpd (20 mlpd) for the daily average withdrawal rates (gallons withdrawn per year/ 365 days). The permitted average use during the month of maximum use was tabulated as approximately 9.3 mgpd (35 mlpd) (gallons withdrawn during the month of maximum use/ number of days in that month). Permitted users, aquifer or stream withdrawal rates, and other pertinent information are provided in Table 2.4-38.

The locations of the ground water users listed in Table 2.4-38 have a nominal mapping accuracy to the nearest 10,000 ft (3048 m). Due to this limited available accuracy, a figure depicting the locations of the ground water permits within the county was not developed. Because the location of these wells can not be accurately plotted, the nearest permitted MDE ground water well (beyond the boundary of the CCNPP site property boundary), downgradient from the site, is conservatively presumed to lie adjacent to the southeastern boundary of the site. At this location, the distance between the boundary and the center of the CCNPP Unit 3 power block area is approximately 1.1 mi (1.8 km) (Figure 2.4-83). The flow direction was based on the regional direction of flow within the Aquia aquifer (Figure 2.4-58).

The Safe Drinking Water Information System (SDWIS) (USEPA, 2007b) maintained by the U.S. EPA lists community, non-transient non-community, and transient non-community water systems that serve the public. Community water systems are defined as those that serve the same people year-round (e.g., in homes or businesses). Non-transient non-community water systems are those that serve the same people, but not year-round (e.g., schools that have their own water system). Transient non-community water systems are those that do not consistently serve the same people (e.g., rest stops, campground, and gas stations). Table 2.4-39 lists the community, non-transient non-community, and transient non-community water systems using ground water as their primary water source in Calvert County (USEPA, 2007b). Many of these listings correlate to those provided by the MDE. Coordinates for the locations of the water systems listed in the SDWIS database for Calvert County are not publicly released. In addition, many of the addresses provided are mail drop locations for the owners of water systems and, for some, addresses are not provided. Therefore, a figure depicting the locations of these systems was not developed. Because the location of these water systems can not be accurately plotted, the nearest downgradient water system (beyond the boundary of the CCNPP site property boundary), is assumed to be near the community of Lusby, approximately 2.7 mi (4.3 km) to the south (Figure 2.4-83).

2.4.12.2.5 CCNPP Units 1 and 2 Ground Water Use

Table 2.4-40 lists the MDE water appropriation permits and the ground water production wells currently residing at the CCNPP site. There are a total of 13 wells at the site. Five (5) Maryland Water Appropriations Permits have been issued to the CCNPP site for the operation of 12 ground water withdrawal wells. Seven (7) of the wells were completed in the Piney Point aquifer and the other five (5) wells were completed in the Aquia aquifer. The table also lists a historical Aquia well referred to as the Old Bay Farm location. At the CCNPP site, the Aquia aquifer ranges in elevation from approximately -560 ft (-170.7 m) msl to -415 ft (-126.5 m) msl. The Piney Point – Nanjemoy aquifer ranges in elevation from approximately -315 ft (-96 m) msl to -200 ft (-61 m) msl.

CCNPP Units 1 and 2 use ground water for potable supply, sanitary facilities, fire protection, and make-up water. CCNPP Units 1 and 2 obtains ground water from five Aquia aquifer wells (listed as CCNPP well Number 1 through well Number 5 on Figure 2.4-84). First appropriated in July 1969, these wells are listed under permit number CA69G010 (05). The water appropriation permit issued for these wells requires semi-annual reports of monthly ground water withdrawls to be provided to the State of Maryland. Table 2.4-41 summarizes the water withdrawal rates for a five year period (July 2001 through June 2006). Plant withdrawals from the Aquia aquifer average about 70.6 million gallons (267.4 million liters) every six months or approximately 141 million gallons a year (533.8 million liters a year).

Additional CCNPP ground water appropriation permits have relatively low use limits compared to those for permit number CA69G010 (05). These permits are summarized as follows:

MDE water appropriation permit CA63G003 (07), first issued in May 1963, authorized ground water use for potable supply, sanitary facilities, and filling a swimming pool at Camp Conoy (including the Eagle Den and Conference Center). Ground water can be obtained from four wells (Camp Conoy wells) from the Piney Point aquifer. Currently, three of the four wells are active. One well has been taken out of service.

- MDE water appropriation permit CA83G008 (03), first issued in August 1983, authorized ground water use for potable supply and sanitary facilities at the Visitor Center. Ground water can be obtained from one well in the Piney Point aquifer.
- MDE water appropriation permit CA89G007 (02), first issued in April 1989, authorized ground water use for potable supply, sanitary facilities, and lawn irrigation at the Rifle Range. Ground water can be obtained from one well from the Piney Point aquifer.
- MDE water appropriation permit CA89G107 (01), first issued in July 1995, authorized ground water use for non-potable supply at the Procedure Upgrade Project Trailers. Ground water can be obtained from one well in the Piney Point aquifer, northeast of the rifle range.

Ground water withdrawal rates by use category are not available; however, permitted withdrawal rates for CCNPP's five ground water appropriation permits are provided in Table 2.4-40.

As shown on Figure 2.4-89, the only existing CCNPP ground water production wells within the proposed CCNPP Unit 3 site are the three Camp Conoy wells in the Piney Point – Nanjemoy aquifer located east of the proposed Unit 3 power block. During construction of the CCNPP Unit 3 facility, the two active Camp Conoy wells immediately adjacent to CCNPP Unit 3 may need to be taken out of service. The other active Camp Conoy well (at the Eagle's Den) is approximately 1,400 ft (427 m) northeast of the center of the CCNPP Unit 3 area on the Calvert Cliffs bluff. The nearest CCNPP Units 1 and 2 Aquia production well (CCNPP Well #5) is approximately 900 ft (274 m) north of the center of the proposed CCNPP Unit 3 power block area.

2.4.12.2.6 Southern Maryland Ground Water Demands

Withdrawals from Maryland Coastal Plain aquifers have caused ground water levels in confined aquifers to decline by tens to hundreds of feet from their original levels (USGS, 2006). Beginning in the 1940s, with the development of the Patuxent Naval Air Station, water levels within the Aquia aquifer began to decline significantly. Between 1960 and 1985, ground water levels within the Aquia aquifer in southern Maryland declined at a relatively constant rate as ground water use increased over time. Since 1985, the decline in ground water levels has sharply increased as the demand for water from the Aquia aquifer and, to a lesser extent, deeper aquifers (Magothy and Patapsco) has increased substantially. The current rate of decline in many of the confined aquifers has been estimated at about 2 ft (61 cm) per year. Declines have been especially large in southern Maryland and parts of the eastern shore where ground water pumpage is projected to increase by more than 20 percent between 2000 and 2030 as population within the region is expected to grow by 37 percent (USGS, 2006).

Potentiometric surface maps developed on a regional scale by the U.S. Geological Survey (USGS) were used to evaluate the areal extent of ground water elevation decreases through time (Section 2.4.12.1.2). The USGS potentiometric surface maps for the Aquia, Magothy, Upper Patapsco, and Lower Patapsco aquifers in Southern Maryland for 2003 were presented as Figure 2.4-58 through Figure 2.4-61. Two areas in Calvert County show cones of depression in the Aquia aquifer. A small depression north of the site is present in the North Beach and Chesapeake Beach area and a large depression south of the site in the Solomons area appears to be having a significant regional effect on the Aquia aquifer. This larger cone of depression is influencing regional ground water flow out to a radius of at least 15 mi (24.1 km) from the pumping centers in the Solomons area (Figure 2.4-58). This area of influence includes the CCNPP site. Similar cones of depression are present in the lower aquifers, although they are not as pronounced in Calvert County (Figure 2.4-59 through Figure 2.4-61).

The USGS has also compiled historical water elevations for the Aquia, Magothy, Upper Patapsco, and Lower Patapsco aquifers in Southern Maryland to determine the magnitude of potentiometric surface declines through time. Potentiometric surface difference maps of these four southern Maryland aquifers are presented in Figure 2.4-85 through Figure 2.4-88, for various periods between 13 years and 28 years (USGS, 2005e, 2005f, 2005g, 2005h). As expected, the areas showing the largest cones of depression correlate with the largest historical declines in potentiometric surface elevations. From 1982 to 2003, the Aquia aquifer potentiometric surface has decreased over 100 ft (30.5 m) in elevation inside the center of the cone of depression at Solomons in southern Calvert County (Figure 2.4-85). Decreases of over 70 ft (21.3 m) were observed in the Magothy aquifer in northeastern Charles County (Figure 2.4-86), and smaller decreases were observed in the Upper and Lower Patapsco aquifers (Figure 2.4-88 and Figure 2.4-88). Figure 2.4-58 and Figure 2.4-87 suggest that local Aquia aquifer flow directions have been slightly deflected in the vicinity of the CCNPP site, possibly from CCNPP ground water use. This information demonstrates that local and regional ground water flow directions can be deflected or even reversed by ground water withdrawal from localized pumping centers.

In 1943, the USGS and the Maryland Geological Survey (MGS) began a statewide cooperative ground water monitoring network. Several private wells in the Solomons area of Calvert County were among the first to be monitored by what now is referred to as the Calvert County Ground-Water-Level Monitoring Network, which is a cooperative program between the Calvert County Department of Public Works, Bureau of Utilities, the MGS, and the USGS (USGS, 2007). This network of approximately 42 wells is mainly focused on monitoring the deeper, confined aquifers that are affected by local and regional ground water withdrawal. The major aquifers of interest are the Piney Point - Nanjemoy, Aquia, and Magothy aquifers. Recently, wells have been added to the system in order to study the availability of water in the deeper Upper and Lower Patapsco aquifers. Water-table monitoring wells have also been added, which are used as climate response wells for indicating local ground water recharge and drought conditions. The USGS provides water level trends for selected wells in the network (USGS, 2007). These wells are shown on Figure 2.4-89 and presented in Table 2.4-42.

Select well hydrographs from the Calvert County Ground-Water-Level Monitoring Network were reviewed to evaluate the temporal trends of the potentiometric surfaces of the aquifers underlying southern Calvert County. For each aquifer, the Calvert County Ground-Water-Level Monitoring Network well closest to the CCNPP site is evaluated as follows:

- Well CA Fd 51 is screened in the Piney Point-Nanjemoy aquifer and is located approximately 2.5 mi (4 km) southeast of the CCNPP site at Calvert Cliffs State Park. Ground water levels have been monitored since 1977 and show a nearly steady decrease in elevation from approximately 15.0 ft (4.6 m) to -3.0 ft (-0.9 m) msl. This rate of decline is approximately 0.6 ft/yr (18.3 cm/yr). The rate of decline appears to have decreased slightly since 2000 (Figure 2.4-90).

- Well CA Ed 42 is screened in the Aquia aquifer and is one of the production wells at the CCNPP site. Ground water levels have been monitored since 1978. It shows a much higher rate of ground water elevation decrease from approximately -19.0 ft (-5.8 m) msl to -92 (-28 m) ft msl. This corresponds to an overall rate of decline of approximately 2.6 ft/yr (79.3 cm/yr), although relatively stable elevations have been observed since 2003 (Figure 2.4-91).

- Well CA Dc 35 monitors the Magothy aquifer and is located approximately 6 mi northwest of the CCNPP site at Scientists Cliffs. Ground water levels have been monitored since 1975 and the data exhibit a very steady rate of ground water elevation decrease from approximately 8 ft (2.4 m) msl to -37 ft (-11.3 m) msl. This rate of decline of approximately 1.6 ft/yr (48.8 cm/yr) is less than that observed in the overlying Aquia aquifer (Figure 2.4-92).

- Ground water elevations in the Upper Patapsco aquifer were evaluated at well CA Db 96, located approximately 10 mi (16 km) northwest of the CCNPP site in Prince Frederick. Ground water levels in this well have only been monitored since 2003, but ground water level decreases in this aquifer are also observed. Ground water elevation decreased at a rate of approximately 1.4 ft/yr (42.7 cm/yr) from approximately -35.5 ft (-10.8 m) to -40.0 (-12.2 m) ft msl (Figure 2.4-93).

Ground water elevations in the Lower Patapsco aquifer were evaluated at well CA Fd 85, located approximately 3.5 mi southeast of the CCNPP site at Chesapeake Ranch Estates.

Ground water levels in this well have only been monitored since 2001, but ground water level decreases in this aquifer are observed. Ground water elevation decreased steadily from approximately -14.5 ft (-4.4 m) to -20.0 ft (-6.1 m) msl (Figure 2.4-96), a rate of approximately 1.1 ft/yr (33.5 cm/yr).

Calvert and St. Mary's counties are rapidly growing areas. Between 1980 and 1990 the combined population of the two-county area increased 34.7% (MGS. 1997). The population of these counties will continue to increase, putting additional demand on the area's ground water resources.

A 2004 report by an advisory committee on the management and protection of the State's Water Resources identified the need for a comprehensive assessment of ground water resources of the Maryland Coastal Plain (Wolman, 2004) (USGS, 2006). The assessment will be conducted by the MGS and the USGS in three phases between 2006 and 2013. The goal of the assessment is to develop tools to facilitate scientifically sound management of the ground water resources in the region.

MDE regulates major ground water users (those users pumping an average of 10,000 gallons or more) by requiring them to obtain Ground water Appropriation Permits to prevent the regional potentiometric surface from declining below the 80-percent management level (80% of the aquifer's available drawdown). Because substantial population growth is anticipated in both Calvert and St. Mary's counties, the MGS developed a numerical model to simulate water-level trends through 2020 (MGS, 1997) and subsequently updated through 2025 (MGS, 2001) using several future alternative pumping scenarios for the Piney Point - Nanjemoy and the Aquia aquifers. The model was calibrated by matching simulated water levels against 1952, 1980, and 1982 data and verified by matching simulated data against 1991 through 1994 water levels in 198 observations wells. Future domestic pumpage for 1995 to 2025 simulations were based on estimated population increases and evaluated by comparing simulated drawdowns with the permitted 80-percent management levels. Major appropriated pumpage and domestic pumpage for the Piney Point - Nanjemoy and Aquia aquifers were simulated in the calibration and predictive scenarios for Anne Arundel, Charles, and Prince George's counties. Major appropriated pumpage was also taken into account for the Maryland Eastern Shore counties. The Piney Point - Nanjemoy aquifer water levels remained substantially above the Aquia aquifer water levels, but it was suggested that in the future, large appropriators should be restricted from using this aquifer, leaving it to accommodate self-supplied domestic usage. In areas where Aquia domestic wells predominate, water levels could be stabilized by allocating major withdrawals to deeper, more productive aquifers such as the Magothy and Upper Patapsco.

The MGS recently developed a model to simulate and evaluate the potential for increasing ground water withdrawals from the deeper Upper Patapsco and Lower Patapsco aquifers in Southern Maryland (Calvert, Charles, and St. Mary's counties) (MGS, 2005). The results of this study projected that water demands within Calvert and St. Mary's counties through 2030 could be met by increasing pumpage in the Aquia aquifer without reducing water levels below the 80% management level. Shifting a portion of the public-supply withdrawals from the Aquia to the Upper Patapsco aquifer would result in an increase in available drawdown in the Aquia aquifer in many areas, with minimal effects on drawdowns near the aquifers outcrop areas in Charles County.

The MGS continues to conduct studies, including modeling efforts to understand and predict the effects of increasing ground water demands of the Coastal Plain aquifers within the state.

New users (or existing user applying to increase its withdrawal) would not be granted a permit if the proposed withdrawal rate is predicted to cause the regional head to fall below the management level.

2.4.12.3 Subsurface Pathways

2.4.12.3.1 Observation Well Data

Data collected from ground water observation wells installed for the CCNPP Unit 3 site subsurface investigation were used to develop ground water elevation contour maps and present ground water elevation trends. A total of 40 new observation wells with depths extending to 122 ft (37.2 m) bgs were installed from May to July 2006. Observation wells were installed in three distinct ground water bearing intervals: the Surficial aquifer (17 wells), a deeper sand unit at the top of the Chesapeake Formation, informally referred as the Upper Chesapeake unit (20 wells), and an even deeper sand unit in the Chesapeake, informally called the Lower Chesapeake unit (3 wells). No wells were installed in the deeper Piney Point - Nanjemoy aquifer.

Seven additional observation wells were installed in 2008 as part of the Supplemental COL Investigation. Five of these wells were installed to provide additional geotechnical information regarding slope stability and soil stresses near the new intake structure. Of these five wells, two were installed in the Surficial aquifer, one was installed in the Upper Chesapeake unit, and two were installed in the Lower Chesapeake unit. In addition, two wells were installed in the Power Block 3 area to provide additional water level information in the Upper Chesapeake Unit. All well screens are 10 feet in length.

The base of the well screens in the Surficial aquifer wells were placed at elevations ranging from approximately 81.6 ft (24.9 m) msl to 53.7 ft (16.4 m) msl. Elevations for the base of well screens in the Upper Chesapeake unit range from approximately 27.1 ft (8.3 m) msl to -10.3 ft (-3.1 m) msl, while the corresponding elevations for the Lower Chesapeake unit wells range from approximately -32.4 ft (-9.9 m) msl to -54.3 ft (-16.6 m) msl (Table 2.4-34).

Three well series designations are assigned to the CCNPP Unit 3 observation wells.

- OW-300 Series wells are located in the proposed CCNPP Unit 3 power block area.
- OW-400 series wells are located adjacent to the CCNPP Unit 3 power block area, generally to the southeast.
- The OW-700 series wells include all of the wells located outside of the power block areas. The OW-700 Series wells are located in the proposed cooling tower, switchyard, and support facility areas.

Four wells screened in the Surficial aquifer (OW-413A, OW-729, OW-770, and OW-778) are consistently dry, i.e. the depth to water is at or below the bottom of the well screens and exhibit minimal water level fluctuation and, therefore, are not included in the analysis. Observation well OW-779 appears to have been screened in the Chesapeake Confining unit between the Surficial aquifer and the Upper Chesapeake unit. This well is consistently dry and is also not included in the analysis. Additionally, observation well OW-744 appears to have been screened in a discontinuous sand unit between the water bearing sand units of the Surficial aquifer and the Upper Chesapeake unit and could not be grouped into one of the water-bearing units described above. Accordingly, the ground water elevation trends, flow directions, and rates presented below do not consider data from this well. Observation Well Locations are shown in Figure 2.4-66.

To evaluate vertical hydraulic gradients, several observation wells were installed as well clusters. Well clusters are a series of wells placed at the same location, with each well monitoring a distinct water bearing interval. Four well clusters were installed to evaluate the hydraulic gradient between the Surficial aquifer and the Upper Chesapeake unit, and four well clusters were installed to evaluate the gradient between the Upper Chesapeake and Lower Chesapeake units. Table 2.4-34 provides construction details for all observation wells installed onsite. Table 2.4-35 provides the ground water elevation data from these wells over time, listed in numerical order, whereas Table 2.4-36 presents a summary of the observation wells used in the following evaluations, segregated by aquifer.

Monthly water levels in the observation wells were measured to characterize seasonal trends in ground water levels and flow directions for the CCNPP Unit 3 site. Upon completion of well installation and development activities, monthly monitoring of the 2006 COL observation wells began in July 2006 and continued through June 2007. Quarterly monitoring of this well series was then initiated, commencing in September 2007 and continuing to the present with the last set of measurements performed in October 2009.

Installation and development activities for the 2008 Supplemental COL Investigation observation well series were completed in September 2008, at which time a monthly water level monitoring program was initiated for these wells. Monthly water level measurements for the 2008 Supplemental COL Investigation observation well series were taken from September 2008 through October 2009. Henceforth, ground water levels in this series will be monitored on a quarterly basis.

The following ground water potentiometric surface trend discussion is based the observation well data described above.

2.4.12.3.1.1 Surficial Aquifer

Ground water data for the Surficial aquifer are shown in Figure 2.4-67. These data exhibit seasonal variability in ground water elevations during the observation period (July 2006 to October 2009). A seasonal influence during this monitoring period was indicated by ground water elevation lows in the late fall through mid-winter, and ground water elevation highs in the spring and summer. For 12 of the 13 wells, maximum observed water levels for the observation period occurred in late spring to early summer of 2007. Generally, minimum observed water levels for the observation period occurred in the fall to winter of either 2007-2008 or 2008-2009. Ground water elevation fluctuations averaged approximately 4.7 ft (1.4 m), and the maximum observed fluctuation of 9.8 ft (3.0 m) was observed in OW-759A.

For the first year of monitoring, the ground water elevation data (summarized in Table 2.4-36) were used to develop ground water surface elevation contour maps for the Surficial aquifer on a quarterly basis. These maps are presented in Figure 2.4-68 through Figure 2.4-71 for July, September, December 2006, and March 2007, and Figure 2.4-97 for June 2007. After the first year of monitoring, groundwater surface elevation contour maps were developed semiannually to roughly coincide with observed maximum and minimum groundwater elevations in the Surficial aquifer. These contour maps are presented in Figures 2.4-109 through 2.4-112 for December 2007, July 2008, January 2009, and July 2009. For each mapping period, the spatial trend of the water table surface and horizontal gradients are similar.

Ground water elevations range from a high of approximately 85.7 ft (26.1 m) msl at well OW-423 to a low of approximately 65.9 ft (20.1 m) msl at well OW-743.

The ground water surface contour maps indicate that horizontal ground water flow in the Surficial aquifer is generally bi-modal. A northwest trending ground water divide roughly following a line extending through the southwestern boundary of the proposed power block area is present at the CCNPP site. Northeast of this divide, horizontal ground water flow is northeast toward Chesapeake Bay. Because the Surficial aquifer is not present below an elevation of approximately 65 ft (19.8 m) msl, ground water flowing in the northeastern direction likely discharges to small seeps and springs before reaching the Chesapeake Bay or CCNPP site streams. Ground water southwest of this divide flows to the southwest. Ground water flowing from the divide toward the hydraulic boundary created by John's Creek and Branch 3 presumably discharges from seeps and springs above the 65 ft (19.8 m) msl elevation level along these stream valleys.

In general, the horizontal hydraulic gradient for the Surficial aquifer decreases from north to south across the CCNPP site. In the northern portion of the CCNPP site, the hydraulic gradients associated with the southwesterly and northeasterly flow components are similar with values ranging from 0.0110 ft/ft and 0.0124 ft/ft, respectively. In the southern portion of the CCNPP site, the hydraulic gradient is lower (approximately 0.0086 ft/ft). In the northwest portion of the CCNPP site where a small portion of the site's ground water flow emanating from the ground water divide is to the north and west, the hydraulic gradient is approximately 0.0150 ft/ft.

Ground water elevations measured in the four well clusters that monitor head differences between the Surficial aquifer and the Upper Chesapeake unit indicated a downward vertical gradient between the Surficial aquifer and the Upper Chesapeake unit. Water table elevations in the Surficial aquifer range from approximately 32.8 to 43.0 ft (10.0 to 13.1 m) higher than the potentiometric surface of the Upper Chesapeake unit (Table 2.4-36) indicative of less-permeable material separating the two water-bearing units.

2.4.12.3.1.2 Upper Chesapeake Unit

Ground water elevation data for the Upper Chesapeake unit are shown in Figure 2.4-72. These data exhibit slightly more variability in ground water elevations during the observation period (July 2006 to October 2009) than those for the Surficial aquifer. Seasonal trends for the Upper Chesapeake are very similar to those in the Surficial aquifer; they are slightly more pronounced. A seasonal influence during the monitoring period was indicated by ground water elevation highs in spring and summer, with ground water elevation lows in fall and early winter. Maximum observed water levels for the observation period were recorded in spring to early summer 2007 for the 2006 COL observation wells. Water levels for the 2008 Supplemental COL Investigation wells recorded maximum values in May or June 2009. Minimum observed water levels in 19 of the 23 wells installed in the Upper Chesapeake unit occurred in October 2008. Although they exhibit the same general water level trends during the observation period, two wells (OW-708A and OW-769) exhibit noticeably higher ranges (amplitude) of elevation changes. On average, ground water elevations fluctuated approximately 5.4 ft (1.7 m), and the maximum observed fluctuation of 12.8 ft (3.9 m) was observed in OW-769.

For the first year of monitoring, the ground water potentiometric data summarized in Table 2.4-36 were used to develop ground water surface elevation contour maps for the Upper Chesapeake unit on a quarterly basis. These maps are presented in Figure 2.4-73 through Figure 2.4-76 for July 2006, September 2006, December 2006, and March 2007, and Figure 2.4-98 for June 2007. After the first year of monitoring, groundwater surface elevation contour maps were developed semiannually to roughly coincide with observed maximum and minimum groundwater elevations in the Upper Chesapeake unit. These contour maps are presented in Figures 2.4-113, 2.4-114, 2.4-115 and 2.4-117 for December 2007, July 2008, October 2008, April 2009, and October 2009. For each mapping period, the spatial trends of the potentiometric surface and the horizontal hydraulic gradients are similar, with elevations ranging from a high of approximately 42.1 ft (12.8 m) msl at observation well OW-401 to a low of approximately 1.8 ft (0.5 m) msl at well OW-774A.

The ground water surface contour maps indicate that horizontal ground water flow in the Upper Chesapeake unit ranges from north to east across most of the site. Ground water flowing in this direction likely discharges to the lower reaches of Branch 1 and Branch 2 and to seeps and springs in topographically low areas where the Upper Chesapeake unit is presumably exposed at the surface , including at the face of the Calvert Cliffs. It is also possible that a component of the Upper Chesapeake unit flow discharges directly to the Chesapeake Bay. The south central portion of the site exhibits a very flat horizontal hydraulic gradient over a large area centered over an area just southeast of the CCNPP Unit 3 power block area. It is possible that a ground water hydraulic divide exists along the southwestern boundary of the power block area, resulting in a flow direction beneath the western switchyard area towards St. John's Creek and Branch 3. A potential exists for localized Upper Chesapeake unit recharge associated with seepage from the small pond southeast of the CCNPP Unit 3 power block area at Camp Canoy (Figure 2.4-73 to Figure 2.4-76 , Figure 2.4-98, and Figures 2.4-113 through 2.4-117). In this area, the base of the pond is close to the top of the water bearing sands of the Upper Chesapeake unit.

In general, three different horizontal hydraulic gradients can be observed from the potentiometric surface data. The highest gradients, at approximately 0.0170 ft/ft are observed to the north and east of the CCNPP Unit 3 power block area. The horizontal hydraulic gradient southeast of the CCNPP Unit 3 power block area is slightly lower at approximately 0.0091 ft/ft. The lowest horizontal hydraulic gradient observed at the CCNPP site was in the southwestern corner of the site where the gradient approaches zero.

2.4.12.3.1.3 Lower Chesapeake Unit

Ground water data for the Lower Chesapeake unit are shown in Figure 2.4-77. The data exhibit similar ground water elevation trends to those observed in the Surficial aquifer and exhibit little variability in ground water elevations during the observation period (July 2006 to October 2009). A slight seasonal influence during the monitoring period was indicated by ground water elevation lows in the fall and winter, and ground water elevation highs in the spring and summer. This seasonal variation is not very pronounced in the two wells located near the Chesapeake Bay shoreline (OW-774B and OW-781). Maximum observed water levels were recorded in April 2007 for the 2006 COL observation wells. Maximum observed water levels for the 2008 Supplemental COL Investigation wells were recorded in June 2009. Minimum observed water levels occurred in fall 2008 and winter 2009. In general, ground water elevation fluctuations averaged approximately 3.6 ft (1.1 m), and the maximum observed fluctuation of 7.0 ft (2.1 m) was observed in OW-703B.

For the first year of monitoring, the ground water elevation data summarized in Table 2.4-36 were used to develop ground water surface elevation contour maps for the Lower Chesapeake unit on a quarterly basis. These maps are presented in Figure 2.4-78 through Figure 2.4-81 for July 2006, September 2006, December 2006, and March 2007, and Figure 2.4-99 for June 2007.

After the first year of monitoring, groundwater surface elevation contour maps were developed semiannually to roughly coincide with observed maximum and minimum groundwater elevations in the Lower Chesapeake unit. These contour maps are presented in Figures 2.4-118 through 2.4-122 for December 2007, April 2008, October 2008, April 2009, and October 2009. It should be noted that only five observation wells penetrate the Lower Chesapeake unit, and the monitoring area is limited to the area within and immediately north of the CCNPP Unit 3 power block area and near the UHS makeup water intake structure. For each mapping period, the spatial trend in the potentiometric surface shows very little change, with elevations ranging from a high of approximately 35.4 ft (10.8 m) msl in the vicinity of well OW-418B to a low of approximately 1.9 ft (0.6 m) msl at well OW-781.

The potentiometric surface contour maps suggest that horizontal ground water flow in the Lower Chesapeake aquifer is to the north-northeast across the coverage area. Ground water flowing in this direction likely discharges directly to the Chesapeake Bay because the silty sand unit containing the Lower Chesapeake unit is below sea level. Very little change in horizontal hydraulic gradient was observed during the monitoring period with values averaging approximately 0.0140 ft/ft.

Ground water elevations measured in the four well clusters that monitored head differences between the Upper Chesapeake unit and the Lower Chesapeake unit indicated a slight downward vertical gradient. Potentiometric surface elevations in the Upper Chesapeake unit range approximately 0.6 to 5.4 ft (0.2 to 1.7 m) higher than the ranges in the Lower Chesapeake unit. Potentiometric surface elevations in the two units are basically identical at the well clusters closest to the Chesapeake Bay, locations OW-703 and and OW-774.

2.4.12.3.2 Hydrogeologic Properties

The 40 ground water observation wells installed in connection with the CCNPP Unit 3 site subsurface evaluation were slug tested to determine in situ hydraulic conductivity values for the Surficial aquifer and Upper and Lower Chesapeake units. Table 2.4-37 summarizes the test results.

Ten of the 17 Surficial aquifer wells tested were used to calculate hydraulic conductivity values. Three wells screened in the Surficial aquifer had measurable water but at or below the bottom of the well screen (OW-413A, OW-729, and OW-770); therefore, the slug test results from these wells are not included in this analysis. The slug test data from three additional Surficial aquifer wells (OW-714, OW-718, and OW-766) were not used in this evaluation because the static water levels were below the top of the solid slugs inserted into the well to displace the water level. Additionally, observation well OW-744 appears to have been screened in a discontinuous sand unit between the water bearing sand units of the Surficial aquifer and the Upper Chesapeake unit. Because the following slug test analyses are categorized by the three distinct water bearing units encountered onsite, the hydraulic conductivity evaluations presented below do not consider slug test data from this well. Slug test data from all the Upper and Lower Chesapeake unit wells were used in the hydraulic conductivity evaluations.

Soil samples collected from the Surficial aquifer, Upper Chesapeake, and Lower Chesapeake units during the geotechnical investigation were submitted for laboratory testing to determine median grain size, moist unit weight, moisture content, and specific gravity. The results of these laboratory analyses were used to calculate bulk density and porosity values for the three water bearing units cited above. The following discussions on hydrogeological properties are derived from the CCNPP Unit 3 data evaluations for the Surficial aquifer, Upper

Chesapeake unit, and Lower Chesapeake unit. Hydrogeological property discussions for the Chesapeake Group aquitards comprising the Chesapeake Confining Unit and all deeper units described in Section 2.4.12.1.2 were summarized from the literature, where available. A detailed description of the geotechnical subsurface site investigation, including the hydrogeologic field program is described in Section 2.5.

2.4.12.3.2.1 Surficial Aquifer

Hydraulic conductivity values were determined from slug test results for the Surficial aquifer range from 0.040 ft/day to 17.4 ft/day (0.01 to 5.3 m/day), with a geometric mean of 0.910 ft/day (0.28 m/day) as detailed in Table 2.4-37. The range in values is considered to be indicative of the variability of the subsurface material composition (see Section 2.5). A transmissivity of 10.9 ft^2/day (1.01 m^2/day) for the Surficial aquifer was calculated using the mean hydraulic conductivity value cited above and an average saturated thickness of 12 ft (3.7 m).

An estimate of the effective porosity of the Surficial aquifer was developed based on the grain size distribution of soil samples collected during the geotechnical investigation. Using median grain size and Figure 2.17 in de Marsily (1986), an effective porosity value of 25.2% was estimated for the Surficial aquifer. However, Stephens et al. (1998) indicate that, based on the results of a field tracer test, effective porosities that are estimated from grain size data can over-estimate the actual effective porosities by approximately 45%. Therefore, the estimated effective porosity of the Surficial aquifer was reduced to 13.9% for transport calculations. Bulk density was estimated using moist unit weight and moisture content values from laboratory test results of the geotechnical samples. Bulk density in the Surficial aquifer was estimated to be 100.0 lb/ft^3 (1.60 g/cm^3).

Information on the vadose zone above the Surficial aquifer is limited. From the geotechnical data listed in Section 2.5.4, measured moisture contents by weight range from approximately 2.5% to 19.1%. The majority of the values ranged between 5% and 15%. Hydraulic conductivity for the Upland Deposits was estimated from grain size analyses as part of the CCNPP Units 1 and 2 FSAR investigation. A maximum hydraulic conductivity of 400 gpd/ft^2 (16,299 lpd/m) (53.6 ft/day (16.3 m/day)) was reported.

2.4.12.3.2.2 Chesapeake Group

The following discussion presents the evaluations of the hydrogeologic properties of the two water bearing units in the upper Chesapeake Group informally named the Upper Chesapeake and Lower Chesapeake units. This is followed by a description of the intervening and underlying Chesapeake Clay and Silt units comprising the remainder of the Chesapeake Group.

Upper Chesapeake Unit

The top of the silty sand unit comprising the informally named Upper Chesapeake unit lies approximately 50 ft (15 m) below the base of the Surficial aquifer. Hydraulic conductivities determined from the slug test results for the Upper Chesapeake unit range from 0.12 to 13.7 ft/day (0.04 m/day to 4.2 m/day), with a geometric mean of 0.740 ft/day (0.23 m/day) as detailed in Table 2.4-37. The range in values is indicative of the variability of the grain size and clay content of the material. A transmissivity of 31.8 ft^2/day (3.0 m^2/day) for the Upper Chesapeake unit is calculated using the mean hydraulic conductivity value cited above and an average saturated thickness of 43.0 ft (13.1 m/day).

An estimate of the effective porosity of the Upper Chesapeake unit was developed based on the grain size distribution of soil samples collected during the geotechnical investigation.

Using median grain size and Figure 2.17 in de Marsily (1986), an effective porosity value of 26.4% was estimated for the Upper Chesapeake unit. However, Stephens et al. (1998) indicate that, based on the results of a field tracer test, effective porosities that are estimated from grain size data can over-estimate the actual effective porosities by approximately 45%. Therefore, the estimated effective porosity of the Upper Chesapeake unit was reduced to 14.5% for transport calculations. Bulk density was estimated using moist unit weight and moisture content values from laboratory test results of the geotechnical samples. Bulk density in the Upper Chesapeake unit was estimated to be 95.6 lb/ft^3 (1.53 g/cm^3).

Lower Chesapeake Unit

The top of the informally named Lower Chesapeake unit generally lies approximately 15 ft (4.6 m) below the base of the Upper Chesapeake unit. Hydraulic conductivities determined from the slug test results for the three wells screened in the Lower Chesapeake unit range from 0.019 to 0.093 ft/day (0.006 to 0.028 m/day), with an arithmetic mean of 0.045 ft/day (1.37 cm/day) (Table 2.4-37). The arithmetic mean for the hydraulic conductivity was used instead of the geometric mean due to the very small sample size. These values are lower than those observed in the Surficial aquifer and the Upper Chesapeake unit by more than one order of magnitude. A transmissivity of 1.6 ft^2/day (0.15 m^2/day) for the Lower Chesapeake unit is calculated using the mean hydraulic conductivity value cited above and an average saturated thickness of 36.1 ft (11 m).

An estimate of the effective porosity of the Lower Chesapeake unit was developed based on the grain size distribution of soil samples collected during the geotechnical investigation. Using median grain size and Figure 2.17 in de Marsily (1986), an effective porosity value of 28.4% was estimated for the Lower Chesapeake unit. However, Stephens et al. (1998) indicate that, based on the results of a field tracer test, effective porosities that are estimated from grain size data can over-estimate the actual effective porosities by approximately 45%. Therefore, the estimated effective porosity of the Lower Chesapeake unit was reduced to 15.6% for transport calculations. Bulk density was estimated using moist unit weight and moisture content values from laboratory test results of the geotechnical samples. Bulk density in the Lower Chesapeake unit was estimated to be 83.6 lb/ft^3 (1.34 g/cm^3).

Chesapeake Clay and Silts

Clay and silt comprising the Upper Chesapeakeaquitard separates the Surficial aquifer from the underlying Upper Chesapeake unit. The aquitard immediately underlies the Surficial aquifer below an elevation of approximately 65 ft (19.8 m) msl. Laboratory tests performed on core samples in support of southern Maryland hydrogeologic studies reported vertical hydraulic conductivities ranging between 5.9×10^{-5} ft/day to 2.5×10^{-2} ft/day (1.8×10^{-5} m/day to 7.6×10^{-3} m/day (MGS, 1997). Vertical hydraulic conductivities established for ground water model calibrations associated with these studies, range from 8.6×10^{-6} ft/day to 8.6×10^{-5} ft/day (2.6×10^{-6} m/day to 2.6×10^{-5} ft/day), except for channeled areas where higher values were assigned to accommodate infilled deposits of sand and gravel (MGS, 1997). These sand units presumably correlate to the Upper and Lower Chesapeake units described herein. Assigned specific storage values ranged between 6.0×10^{-6} ft^{-1} and 1×10^{-5} ft^{-1} (2.0×10^{-5} m^{-1} and 3.3×10^{-5} m^{-1} for the Chesapeake Group aquitards in the Chesapeake Confining Unit (MGS, 1996).

2.4.12.3.3 Ground Water Flow and Transport

The following sections present the most probable ground water flow direction and travel time from the CCNPP Unit 3 power block area to nearby surface water features. Based on the evaluation summarized in the above sections, only the shallow water bearing units (Surficial aquifer and the Upper Chesapeake and Lower Chesapeake water-bearing units) would be affected by construction and operation of the CCNPP Unit 3. Ground water use associated with CCNPP Unit 3 operations is discussed in Section 2.4.12.1.4. Accidental release parameters and pathways for liquid effluents in ground water and surface water are presented in Section 2.4.13.

The ground water seepage velocity is defined as distance over time and is calculated as follows:

Velocity = [(hydraulic gradient) x (hydraulic conductivity)] / (effective porosity)

Effective porosity estimates for the water-bearing units were developed based on the grain size distribution of samples taken from the CCNPP site. Median grain size (d_{50}) values for samples collected in 2006 (Schnabel, 2007) and 2008 (MACTEC, 2009a) were sorted by stratigraphic unit. For each d_{50} value, an effective porosity value was estimated using Figure 2.17 in de Marsily (1986). The average value of effective porosity for each stratigraphic unit was calculated. However, Stephens et al. (1998) indicates that, based on the results of a field tracer test, effective porosities that are estimated from grain size data can over-estimate the actual effective porosity. The effective porosity estimated from the results of the field test was approximately 45% lower than that estimated based on the measured particle size. Therefore, in order to develop a more conservative estimate of the effective porosity, the estimates from the grain size data were reduced by 45%. The reduced effective porosities used for travel time calculations are: 0.139 for the Surficial aquifer, 0.145 for the Upper Chesapeake unit, and 0.156 for the Lower Chesapeake Unit. Since data was not available for the Upper Chesapeake aquitard and the Lower Chesapeake aquitard, effective porosity was estimated to be 0.06 for these layers based on a mean value for clays (ANL, 1993). The effective porosity of the fill material was estimated using the same method as for the water-bearing units. The materials tested for use as structural fill are expected to have a maximum d_{50} of 8 mm (MACTEC, 2009b). The maximum value is used as it gives the smallest effective porosity, and is thus more conservative. Using Figure 2.17 in de Marsily (1986), a d_{50} of 8 mm corresponds to an effective porosity of 0.150; which when reduced by 45% gives an effective porosity of 0.082.

The travel time is defined as rate of ground water movement for a set distance and is calculated as follows:

Travel Time = (distance) / (velocity)

2.4.12.3.3.1 Surficial Aquifer

In the vicinity of the CCNPP site, the Surficial aquifer is capable of transmitting ground water but is of limited areal and vertical extent. The Surficial aquifer (Upland Deposits) is not a reliable source of ground water because of its relative thinness, limited saturated thickness, and dissected topography that causes local ground water to discharge as small seeps and springs.

The ground water travel time in the Surficial aquifer was calculated from the center of the ground water divide in the CCNPP Unit 3 power block area to the projected discharge point in the headwater area of Branch 3. An average horizontal ground water velocity of 0.072 ft/day (0.022 m/day) was calculated using a mean horizontal hydraulic gradient of 0.0110 ft/ft between the ground water divide and Branch 3 (Figure 2.4-68 through Figure 2.4-71 , Figure 2.4-97, and Figure 2.4-109 through Figure 2.4-112), a hydraulic conductivity of 0.910 ft/day (0.28 m/day), and an effective porosity of 13.9% (Section 2.4.12.3.2.1) . Using a mean travel distance of approximately 1315 ft (400.8 m) from the ground water divide in the CCNPP Unit 3 power block to the closest downgradient point above 65 ft (19.8 m) msl in Branch 3, the ground water travel time from the power block area to Branch 3 was estimated to be about 50 years. East of the CCNPP Unit 3 reactor building, the flow paths to adjacent springs and seeps are presumed to be shorter, with shorter corresponding travel times for spring/seep discharge.

2.4.12.3.3.2 Upper Chesapeake Unit

Direct ground water discharge to surface water from the Upper Chesapeake unit likely occurs along the lower reaches of Branch 1 and Branch 2 at elevations below approximately 45 ft (13.7 m) msl where the Upper Chesapeake unit presumably outcrops. The ground water travel time in the Upper Chesapeake unit was calculated from the center of the CCNPP Unit 3 power block area northward to the projected discharge point at an elevation of 45 ft (13.7 m) msl in Branch 2. An average horizontal ground water velocity of 0.087 ft/day (0.026 m/day) was calculated using a mean horizontal hydraulic gradient of 0.017 ft/ft (Section 2.4.12.3.1.2) along the projected flowpaths between the center of the CCNPP Unit 3 power block and the discharge point in Branch 2 (Figure 2.4-73 through Figure 2.4-76 , Figure 2.4-98), and Figure 2.4-113 through Figure 2.4-117), a hydraulic conductivity of 0.740 ft/day (0.226 m/day), and an effective porosity of 14.5% (Section 2.4.12.3.2.2). Using a mean travel distance of approximately 470 ft (143.3 m) from the center of the CCNPP Unit 3 power block to the projected downgradient discharge point at 45 ft (13.7 m) msl in Branch 2, the ground water travel time from the power block area to Branch 2 was estimated to be about 15 years. Similarly, the ground water travel times in the Upper Chesapeake unit were calculated from a point south of the CCNPP Unit 3 power block area northeastward to the projected discharge point at an elevation of 45 ft (13.7 m) msl in Branch 1 and farther downgradient to Chesapeake Bay. Using the same average horizontal ground water velocity of 0.087 ft/day (0.026 m/day) and mean path distances of 1110 ft (338.3 m) and 1685 ft (513.6 m) to Branch 1 and the Chesapeake Bay, respectively, travel times of approximately 35 years and 53 years were calculated. It is possible that a ground water hydraulic divide exists along the southwestern boundary of the CCNPP Unit 3 power block area, resulting in a flow direction beneath the western switchyard area towards St. John's Creek and Branch 3.

2.4.12.3.3.3 Lower Chesapeake Unit

The ground water in the Lower Chesapeake unit likely discharges to the Chesapeake Bay, because this unit is entirely below sea level. The ground water travel time in the Lower Chesapeake unit was calculated from the center of the CCNPP Unit 3 power block area northeastward to the downgradient location of the Chesapeake Bay shoreline. An average horizontal ground water velocity of 0.0040 ft/day (0.0012 m/day) was calculated using a mean horizontal hydraulic gradient of 0.014 ft/ft (Section 2.4.12.3.1.3) along the projected flowpaths between the center of the CCNPP Unit 3 power block area and the shoreline (Figure 2.4-78 through Figure 2.4-81, Figure 2.4-118), andFigure 2.4-122 through Figure 2.4-123), a hydraulic conductivity of 0.045 ft/day (0.014 m/day), and an effective porosity of 15.6% (Section 2.4.12.3.2.2.2). The arithmetic mean for the hydraulic conductivity was used instead of the geometric mean due to the very small sample size. Using a distance of approximately 1540 ft (469 m) from the center of the CCNPP Unit 3 power block area to a downgradient point on the shoreline of Chesapeake Bay, the ground water travel time from the CCNPP Unit 3 power block area to the bay is estimated to be about 1054 years.

2.4.12.4 Monitoring or Safeguard Requirements

The observation well network in the vicinity of CCNPP Unit 3 currently consists of 40 wells constructed in the summer of 2006 and seven supplemental wells constructed in 2008.

Groundwater levels in the 40 wells installed in 2006 were monitored monthly from July 2006 through June 2007 and have been monitored quarterly thereafter. Groundwater levels in the seven wells installed in 2008 were monitored monthly from September 2008 through October 2009 and have been monitored quarterly thereafter. Quarterly groundwater level monitoring will continue until the onset of CCNPP Unit 3 construction, at which time most of the existing observation wells will be properly sealed and abandoned in accordance with MDE Regulation 26.04.04.11. Most of the wells are within the CCNPP Unit 3 power block area and adjacent areas that will be re-graded during construction. For this reason, all but nine of the existing wells will be properly abandoned to allow for construction and to eliminate the potential for the wells to become damaged during construction and potentially provide a pathway for contaminants to enter the local groundwater system.

Groundwater levels will continue to be monitored quarterly during the construction of CCNPP Unit 3 in the nine observation wells outside of the construction footprint. The following wells will remain: OW-768A, -769, -703A, 703B, -718, -725, -743, -759A and -759B. The objective of continued monitoring of water levels is to determine the long-term range of seasonal water-level fluctuation. The range of fluctuation during the construction period will be compared to that identified during monitoring before construction, to determine if groundwater gradients, flow directions and flow velocities are significantly affected by construction activities.

As soon as practical after construction is complete, and before CCNPP Unit 3 begins operation, approximately 29 new observation wells will be installed in the vicinity of CCNPP Unit 3. The locations of the proposed observation wells are shown on FSAR Figure 2.4-106. These 29 wells, together with the 9 existing wells, are comparable to the number of wells in the original observation network and provide sufficient coverage to monitor groundwater levels in the three aquifers of primary interest beneath the site of CCNPP Unit 3. These are (in increasing depth) the Surficial aquifer, the Upper Chesapeake unit and the Lower Chesapeake unit. Other deeper regional aquifers exist beneath the CCNPP Unit 3 site, but the shallowest of these (the Piney Point-Nanjemoy aquifer) is separated from the overlying Lower Chesapeake unit by an aquitard approximately 170 ft thick and it is unlikely that there is a significant flow path from the Lower Chesapeake unit to the deeper aquifers.

The proposed new wells are arrayed in 13 pairs and one well triplet. Eleven of these new well pairs, plus one well pair from the original nine wells, will monitor the vertical hydraulic gradient between the Surficial aquifer and the underlying Upper Chesapeake unit. Two of the new well pairs, plus one well pair from the original nine wells, will monitor the vertical gradient between the Upper Chesapeake unit and the underlying Lower Chesapeake unit. The well triplet will monitor the vertical hydraulic gradient between all three aquifers. Two of the original nine wells are single wells monitoring the Surficial aquifer and three of the original nine wells are single wells monitoring the Upper Chesapeake unit.

Groundwater levels in each of the 38 observation wells (9 existing and 29 new) in the post-construction network will be measured quarterly. The data will be used to construct water table contour maps for the Surficial aquifer and potentiometric surface contour maps for both the Upper and Lower Chesapeake units. These maps will allow determination of groundwater flow gradients, flow directions and flow velocities after operation of CCNPP Unit 3 begins. In addition, some of these wells may be used during plant operation to monitor groundwater quality, including identifying the presence of plant-related radionuclides in the vicinity of CCNPP Unit 3.

Safeguards will be used to minimize the potential of adverse impacts to the ground water by construction and operation of CCNPP Unit 3. These safeguards would include the use of lined containment structures around storage tanks (where appropriate), hazardous materials storage areas, emergency cleanup procedures to capture and remove surface contaminants, and other measures deemed necessary to prevent or minimize adverse impacts to the ground water beneath the CCNPP Unit 3 site. No ground water wells are planned for safety-related purposes.

2.4.12.5 Site Characteristics for Subsurface Hydrostatic Loading and Dewatering

Ground water conditions relative to the foundation stability of safety-related facilities and plans for the analysis of seepage and piping conditions during construction are discussed in Section 2.5.4.6. The completed surface grade for CCNPP Unit 3 is expected to range between elevations of 72 to 85 ft (21.9 to 25.9 m) msl, requiring cut and fill across the site area. The proposed maximum grade elevation of the nuclear island is approximately 83 ft (25.3 m) msl. The design depth for foundations of structures within the nuclear island is estimated to be at an approximate elevation of 40 ft (12.2 m) msl for the reactor containment structure.

Ground water elevations within the Surficial aquifer range from approximately elevation 65.9 to 85.7 ft (20.1 to 26.1 m) msl with the highest observed elevations occurring in the CCNPP Unit 3 power block area. Since the current maximum observed Surficial aquifer ground water elevation is 85.7 ft (26.1 m) msl in the nuclear island area, the water table currently lies approximately 45.7 ft (13.9 m) above the lowest subsurface portion of safety-related structures.

The U.S. EPR FSAR requires that the maximum ground water elevation be at least 3.3 ft (1.0 m) below grade for safety-related structures. As indicated above, existing data indicates that the maximum pre-construction ground water level is currently at or slightly above the proposed grade level in the nuclear island area, potentially outside of the U.S. EPR FSAR design envelope. Because the CCNPP Unit 3 cut and fill operations, site grading, and construction activities will alter the existing ground water system, ground water modeling using a three-dimensional, five layer numerical model was employed to evaluate these effects. The model was developed using Visual MODFLOW (Schlumberger, 2008). The groundwater model includes five layers, each of which describes one of the hydrostratigraphic units of the shallow groundwater system. Specifically, most of the top layer of the model (layer 1) represents the Surficial aquifer; most of the next lower layer (layer 2) represents the Upper Chesapeake aquitard; layer 3 represents the Upper Chesapeake unit, layer 4 the Middle Chesapeake aquitard, and layer 5, the lowermost layer of the model, describes the Lower Chesapeake unit. The two uppermost hydrostratigraphic units, the Surficial aquifer and the Upper Chesapeake aquitard, do not extend over the entire model domain. Because Visual Modflow requires that all layers extend over the entire model domain, cells within a particular layer where the hydrostratigraphic unit generally corresponding to that layer is absent were assigned the hydraulic properties of the unit that is present at that location. The Lower Chesapeake aquitard, which separates the Lower Chesapeake unit from the Piney Point/Nanjemoy aquifer, was not included explicitly in the three-dimensional model. The Lower Chesapeake aquitard is below the bottom of the model, which was treated as a no-flow boundary. A sensitivity analysis was conducted to assess the effect of this assumption. The sensitivity analysis indicated that the leakance to the Piney Point Aquifer, which can be estimated by the flux through a general head boundary at the bottom of layer 5, is relatively negligible compared with the horizontal flux towards Chesapeake Bay.

The thickness of each of the five units included in the model was defined from borehole data collected as part of the geotechnical investigation at the site. The model grid was rotated 90 degrees from the plant design grid so that the model north is equivalent to the plant east. All references to the signs of the compass are with respect with the model north, which is at 45-degree angle with the true north, pointing to the true northeast. The total areal extent of the model is about one and a quarter square mile [3.24 km^2], covering an area of 5180 ft [1579 m] by 6790 ft [2070 m]. The model domain extends southward approximately 0.25 mi [0.40 km] beyond the southern side of the Unit 3 switchyard into the Johns Creek watershed. To the model north, the domain extends into Chesapeake Bay about 50 ft [15 m] beyond the tip of the barge dock. In the model east-west direction, the domain extends about 0.35 mi [0.56 km] to the east of the eastern side of the Unit 3 power block and about 0.45 mi [0.72 km] to the west of the western side of the Unit 3 cooling tower.

Because the exact location of groundwater discharge from the Surficial aquifer and the Upper Chesapeake unit into nearby streams and other low-lying areas is not known, a drain condition was applied over the entire top layer of the model, except over the part of the model that is in Chesapeake Bay. The elevation of each drain was set at 0.1 ft [0.03 m] below the ground surface. A high value for the conductance of these drains was used to allow the discharge of groundwater out of the aquifer system when the water table reaches the ground surface.

In the top layer of the model, a constant head boundary condition was used to represent the Chesapeake Bay, and no flow conditions were used along the other three sides of the model. In the layers of the model representing the Upper and the Lower Chesapeake units, a general boundary condition was used on their southern and northern boundaries and a no-flow condition on the eastern and western sides. Layer 2 and layer 4 in the model represent the two aquitards, with the exception of the north side of layer 2 where the Upper Chesapeake unit is present. The northern boundary of layer 2 used a general head boundary while all other boundaries in layers 2 and 4 were treated as no-flow boundaries.

Different zones of groundwater recharge were used in the model simulations. These zones include forested areas, open undeveloped areas (i.e., areas covered with grasses and low shrubs), and paved areas. Also, different recharge zones were defined for forested areas over the Surficial aquifer, over the outcrop of the Upper Chesapeake aquitard and over the outcrop of the Upper Chesapeake unit.

In most simulations, each of the five hydrostratigraphic units was represented with a single value of horizontal hydraulic conductivity and a single value of vertical hydraulic conductivity. One alternative, conceptual geologic scenario and corresponding model employed two zones of horizontal hydraulic conductivity for the Upper Chesapeake unit. The second value represented a zone of low horizontal hydraulic conductivity relative the major portion of the unit. The horizontal to vertical anisotropy of hydraulic conductivity for all aquifer units was assumed to be 10:1.

Calibration parameters included hydraulic conductivity values in all units and the rate of groundwater recharge at the top layer of the model. Piezometric level data from monitoring wells discussed in Section 2.4.12.3.1 were used as calibration targets. The model was calibrated for steady-state conditions. For this purpose, the average value of the monthly or quarterly observations at each well in 2007 was used as a calibration target representing long-term average conditions. The calibrated hydraulic conductivity values were within the range of measured values in the hydraulic tests conducted in each aquifer unit. The calibrated hydraulic conductivity values for the aquitards were within the range of values for the confining layers used by the Maryland Geological Survey in their regional model (MGS, 2007b).

The simulated ground water levels were found to agree well with the observed values and reproduce the salient features of the flow patterns shown in Figure 2.4-68 through Figure 2.4-71, Figure 2.4-97, and Figure 2.4-109 though Figure 2.4-112 for the Surficial aquifer, in Figure 2.4-73 through Figure 2.4-76, Figure 2.4-98, and Figure 2.4-113 though Figure 2.4-117 for the Upper Chesapeake unit, and in Figure 2.4-78 through Figure 2.4-81, Figure 2.4-99, and Figure 2.4-118 through Figure 2.4-122 for the Lower Chesapeake unit based on the interpretation of the measured water levels. Because of inherent spatial variability in aquifer hydraulic conductivity, and potential spatial variability in actual infiltration versus runoff, an exact match between observed and calibrated ground water elevations is not expected.

The model was used to predict groundwater levels and flow direction at the site under post-construction conditions. For this purpose, the model was modified by replacing the current topography with the post-construction topography as shown in Figure 2.4-105. The post-construction model accounted for hydraulic properties of backfill and other fill material used to achieve the final grade plan and treated buildings with foundations that extend below elevation 80 ft [24 m] (NGVD 29) as barriers to shallow groundwater flow, incorporated stormwater treatment measures including surface sand filters, and considered changes in groundwater recharge resulting from the construction of Unit 3 and supporting facilities and structures.

Model cells in areas where building foundations extend to or near the bottom of the Surficial aquifer were designated as inactive and excluded from the model to indicate that the foundations are barriers to groundwater flow. Recharge rates over the area of the proposed buildings in the Unit 3 power block area were reduced to zero. The rate of recharge from the surface sand filters surrounding the power block area was estimated based on the amount of flow directed to the surface sand filters and the ability of the subsurface materials in these areas to accommodate these rates.

The post-construction model was used to estimate piezometric levels in the power block area. Modeled post-construction depth to the water table in the power block area is shown on Figure 2.4-95. The elevation of the water table across the power block area is shown on Figure 2.4-96. The model post-construction topography is shown on Figure 2.4-105.

In addition, the post-construction model was used to identify likely and other plausible pathways of postulated accidental effluent releases in the Nuclear Auxiliary Building (NAB), see Section 2.4.13.

The post-construction model was also used to quantify the impact of the construction of Unit 3 on groundwater discharge in Johns Creek. A sensitivity analysis was conducted to assess the impact of different assumptions and input parameter values on the model predictions. The sensitivity analysis included simulations for different values of hydraulic conductivity of the fill material, different assumptions for the performance of the surface sand filters designed to enhance groundwater recharge, an alternative hydraulic conductivity distribution in the Upper Chesapeake unit assumptions, and an assumption of leakage through the bottom of the Lower Chesapeake unit.

The major conclusions from the post construction simulations are:

a. The water table in the power block area will be well below the site grade level. In all simulations, the water table in the power block area was more than 25 ft [7.6 m] below the site grade level of 85 ft [26 m] (NGVD 29).

b. The groundwater pathway for liquid effluent releases from the NAB depends on the hydraulic conductivity of the fill material.

   Data from laboratory constant head permeability tests (ASTM Test Method D 2434-68(2006)) were used as a starting point to develop estimates of hydraulic conductivity for the structural fill material. These tests yielded hydraulic conductivities of $2.7\text{x}10^{-2}$ cm/s (77 ft/day) and $2.9\text{x}10^{-2}$ cm/s (82 ft/day) for structural fill materials compacted to about 95% of the maximum dry density using modified Proctor (ASTM D1557-07).

   However, it is noted that this type of laboratory test does not produce hydraulic conductivity values representative of those under field conditions. For each sample, the constant head permeability tests were performed under very high hydraulic gradients (0.3, 0.4 and 0.5) for which Darcy's Law does not typically apply. This is evidenced by the fact the three tests produced different values of permeability as the hydraulic gradient was varied. For example, the sample yielding an average hydraulic conductivity of $2.7\ \text{x}10^{-2}$ cm/s, yielded individual test results of $9.40\ \text{x}10^{-3}$ cm/s , $3.30\ \text{x}10^{-2}$ cm/s and $3.80\ \text{x}10^{-2}$ cm/s.

   The estimated horizontal hydraulic gradient in the fill material based on model runs for post-construction conditions is of the order of 0.02 (Bechtel, 2010). When hydraulic conductivity is plotted against the hydraulic gradient for the laboratory results, and the resulting curve is extrapolated to a hydraulic gradient of 0.02, the resulting hydraulic conductivity is of the order of $1\text{x}10^{-3}$ cm/s.

   Therefore, the lowest of the three measured values ($9.4\ \text{x}10^{-3}$, rounded to $1\ \text{x}10^{-2}$ cm/s) was conservatively selected as the upper bound for the hydraulic conductivity of the fill, and the extrapolated value of $1\ \text{x}10^{-3}$ cm/s representing hydraulic conductivity under predicted field flow conditions was selected as the lower bound for the hydraulic conductivity of the fill.

   - If the hydraulic conductivity of the fill is equal to the lower end of the range of expected values ($1\text{x}10^{-3}$cm/s [2.8 ft/day]), then releases from the bottom of the NAB will move first downwards to the Upper Chesapeake unit and then horizontally through this unit towards Chesapeake Bay where they will eventually discharge. Even with a conservative assumption of 0.145 for the effective porosity for the Upper Chesapeake unit, the estimated travel time from the release point to Chesapeake Bay is over 22 years.

   - If the hydraulic conductivity of the fill is equal to the upper end of the range of expected values ($1\text{x}10^{-2}$ cm/s [28 ft/day]), then releases from the bottom of the NAB will move horizontally through the fill material and discharge into Branch 2. The estimated travel time from the release point to discharge point is less than a year.

c. The impact of the construction of Unit 3 on the volume of groundwater discharge in Johns Creek will be negligible.

Details on the development of the groundwater model, the assumptions and input parameter values used as well as simulation results are presented in the Groundwater Model Report (Bechtel 2010).

The effect on local users of ground water from cutting, filling and grading the Unit 3 site will be negligible. The upland deposits of southern Calvert County are deeply incised by stream erosion, such that they are laterally discontinuous. This condition causes dissection of the Surficial aquifer into relatively small areas that are effectively isolated and have limited hydraulic connection. Furthermore, because of its thin and variable saturated thickness (typically less than 20 feet at CCNPP) and vulnerability to low yield during droughts, few water wells are completed in the Surficial aquifer in southern Calvert County. Deeper aquifers beneath the Surficial aquifer are effectively segregated from flow in the shallow aquifer. For these reasons, users of ground water near CCNPP are expected to experience no significant impacts to their water supplies due to construction or operation of Unit 3.

Construction of Unit 3 includes excavations for the power block and for the Ultimate Heat Sink (UHS) makeup water intake structure. Water within these excavations is typically derived from three sources: surface water from precipitation falling in the excavation, water stored within the materials being excavated, and ground water inflow to the excavation. Ground water inflow in the excavations is analyzed for a Representative case (most likely conditions) and an Upper Bound case (using maximum values). Precipitation into the excavations is estimated using the rational method (a mass balance method which relates discharge to inflow). The volume of water stored within the material to be excavated is estimated by multiplying the area of the excavation by the saturated thickness and the effective porosity of the materials. Ground water flow into the excavation is estimated by treating the excavation as a large diameter well. Variables used for the precipitation Representative case include a 2-year - 1-hour rainfall intensity of 1.75 inches, and a coefficient of runoff of 0.8. For the ground water inflow Representative case, the geometric mean hydraulic conductivity from slug tests of 0.91 ft/day for the Surficial aquifer and 0.74 ft/day for the Upper Chesapeake unit is used for calculations. For the precipitation Upper Bound case, variables used include a 2- year - 1-hour rainfall intensity of 2.5 inches, and a coefficient of runoff of 1.0. The maximum hydraulic conductivity from slug tests is used for the ground water inflow Upper Bound case, corresponding to 17.4 ft/day for the Surficial aquifer and 13.7 ft/day for the Upper Chesapeake unit.

The Power Block excavation is approximately 1,080 ft wide by 1,080 ft long. The bottom of the excavation is at elevation 32 ft msl, with the reactor tendon galleries extending to 30 ft msl. Plant grade is 85 ft msl. For the Surficial aquifer, the saturated thickness is estimated to be 20 ft, with an effective porosity of 25.2%. For the Upper Chesapeake unit, the saturated thickness is estimated to be 13.1 ft, with an effective porosity of 26.4%. The amount of water entering the excavation from precipitation is estimated to be 16,826 gpm for the Representative case, and 30,046 gpm for the Upper Bound case. The ground water stored in the excavation is estimated to be 74,147,852 gallons (43,972,347 gallons in the Surficial aquifer and 30,175,505 gallons in the Upper Chesapeake unit). Assuming a three month period for pumping, the equivalent pumping rate to remove the stored water would be 572 gpm. Ground water flow into the excavation is calculated to be 35 gpm (20 gpm from the Surficial aquifer and 15 gpm from the Upper Chesapeake unit) for the Representative case. The Upper Bound ground water flow into the excavation is calculated to be 250 gpm (140 gpm from the Surficial aquifer and 110 gpm from the Upper Chesapeake unit).

The UHS Makeup Water Intake Structure/Forebay/CWS Intake Structure excavation is approximately 100 ft wide by 300 ft long by 37 ft deep. The grade in the area is approximately 10 ft msl. In this location, the Surficial aquifer is absent, and the Upper Chesapeake unit is estimated to have a saturated thickness of 30 ft and an effective porosity of 26.4%. Precipitation into the excavation is estimated to be 433 gpm for the Representative case and 773 gpm for the Upper Bound case. Ground water stored in the excavation is estimated to be 1,777,372 gallons. Assuming a three month period for pumping, the equivalent pumping rate to remove the stored water would be 14 gpm. The ground water flow into the excavation is calculated to be 20 gpm for the Representative case and 110 gpm for the Upper Bound case.

Based on current ground water conditions and the anticipated facility surface grade between elevations of 72 to 85 ft (21.9 to 25.9 m), ground water is expected to be encountered at pre-construction depths from grade level to 16 ft (4.9 m) below grade. Surface water controls to minimize precipitation infiltration and the redirection of surface runoff away from the excavation and temporary construction dewatering areas are expected. A permanent ground water dewatering system is not anticipated to be a design feature for the CCNPP Unit 3 facility.

Electrical manholes within the facility area are expected to be at depths of 10 to 15 ft (3 to 4.6 m) below grade and, therefore, have the potential for encountering ground water that may eventually leak into these structures. Manhole sump pumps may be required to remove the water seeping into these features.

Groundwater sampling and testing at the CCNPP Unit 3 site has been performed in eight separate sampling events. Samples were field tested for pH, and laboratory samples were tested for sulfate and chloride concentrations. Data from these sampling events were analyzed to determine the expected water quality of the groundwater in the excavations. For samples obtained from the Surficial aquifer, the mean pH was found to be 5.2, with a seasonal low mean of 4.9. Test results from the Surficial aquifer gave a pH range of 4.5 to 6.9. Mean sulfate and chloride concentrations in the Surficial aquifer were 14.9 and 13.2 mg/l, respectively. Seasonal high Surficial aquifer mean sulfate and chloride concentrations were 21.8 and 18.9 mg/l, respectively. In the Upper Chesapeake unit, the mean pH was found to be 7.4, with a seasonal low mean of 7.1. Test results from the Upper Chesapeake unit gave a pH range of 6.4 to 8.0. Mean sulfate and chloride concentrations in the Upper Chesapeake were 51.4 and 45.0 mg/l, respectively. In the Upper Chesapeake unit, seasonal high mean sulfate and chloride concentrations were 65.1 and 50.7 mg/l, respectively.

Below grade concrete that will be located beneath the groundwater table in the backfilled power block area may be exposed to the aggressive low pH groundwater of the Surficial aquifer unless alternative design provisions are incorporated. Therefore, the facility design for such structures will include a waterproofing geomembrane envelope as described in Section 3.8.4.6.1.

Since it is possible for leakage to occur, a monitoring system (consisting of risers and drain sumps) will be installed inside the waterproofing geomembrane. The monitoring risers and drain sumps will be structure-specific and will be designed in parallel with the building foundations. Details regarding the groundwater monitoring systems are presented in Section 3.8.4.7 and 3.8.5.7.

2.4.12.6 References

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2.4.13 Pathways of Liquid Effluents in Ground and Surface Waters

The U.S. EPR FSAR includes the following COL Item in Section 2.4.13:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information on the ability of the groundwater and surface water environment to delay, disperse, dilute or concentrate accidental radioactive liquid effluent releases, regarding the effects that such releases might have on existing and known future uses of groundwater and surface water resources.

This COL Item is addressed as follows:

{Sections 2.4.13.1 through 2.4.13.3 are added as a supplement to the U.S. EPR FSAR.

2.4.13.1 Groundwater

This subsection provides a conservative analysis of a postulated, accidental liquid release of effluents to the ground water at the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 site. The accident scenario is described, and the conceptual model used to evaluate radionuclide transport is presented, along with potential pathways of contamination to water users. The radionuclide concentrations that a water user might be exposed to are compared against the regulatory limits.

2.4.13.1.1 Source Term

This subsection describes the ability of groundwater and surface water systems to delay, disperse, or dilute a liquid effluent if accidentally released from the site. The US EPR Design Certification Project General Arrangement Drawings were reviewed to determine which component in each of the main areas of the Nuclear Island outside containment could contain the maximum radionuclide concentration/volume. This review also indicated that the proposed design includes no buildings, facilities, or tanks containing radionuclides outside of the Nuclear Island. Components were evaluated based on their respective volumes and whether they could contain reactor coolant activity. Except for the Reactor Building, there is no secondary containment in the Nuclear Island compartments/buildings. The tanks and components that are designed to contain or process radioactive liquids are within the Nuclear Island. These components include (AREVA, 2007 and AREVA, 2008):

- Reactor Coolant Storage Tanks (RCSTs) (total of six, each with a gross volume of 4414 ft^3 [125 m^3]) in the Nuclear Auxiliary Building
- Liquid Waste Storage Tanks (total of five, 2473 ft^3 [70.0 m^3]net) in the Waste Building
- Volume Control Tank (350 ft^3 [9.9 m^3]) in the Fuel Building
- LHSI Heat Exchanger (total of four, 33 ft^3 [0.93 m^3] each) in the Safeguards Building

The RCST located in the Nuclear Auxiliary Building is the largest tank outside containment with radioactive contents. The liquid source terms considered included waste system Group I liquid waste hold-up tanks. The highest liquid source term is in the RCSTs with the assumptions of 0.25 percent failed fuel, unpurified, undiluted, and un-decayed reactor coolant. As a result, the total activity released from one RCST with the assumptions made bounds all the other radioactive liquid sources (AREVA, 2007).

The inventory of radionuclides in reactor coolant water, and its radionuclide activities are shown in Table 2.4-43. The reactor coolant activity levels represent the maximum activity levels without radioactive decay based on a 0.25 percent defective fuel rate (AREVA, 2007). The 0.25 percent defective fuel rate was selected to be consistent with the fuel failure rate prescribed by the U.S. EPR FSAR. This fuel failure rate is two times the 0.12 percent failure rate prescribed by Branch Technical Position (BTP) 11-6 (NRC, 2007) and provides a conservative bounding estimate of the radionuclide inventory and associated activity levels in the postulated release.

2.4.13.1.2 Groundwater Pathway

This subsection provides a conservative analysis of a postulated accidental liquid release of effluents to the groundwater at the CCNPP Unit 3 site. The accident scenario is described in this subsection along with the conceptual model used to evaluate the radionuclide transport with potential pathways of contamination to water users. The radionuclide concentrations to which a water user might be exposed are compared against the regulatory limits.

The analysis as outlined in NUREG 0800 Standard Review Plan (SRP) 2.4.13 and BTP 11-6 (NRC, 2007) considers the impact of a release on the nearest potable water supply and the use of water for direct human consumption or indirectly through animals (livestock watering), crops (agricultural irrigation), and food processing (water as an ingredient). For direct consumption, results are considered acceptable if an accidental release will not result in radionuclide concentrations in excess of the effluent concentration limits (*ECLs*) included in Appendix B (Table 2, Column 2, under the unity rule) to 10 CFR Part 20 (NRC, 2009) in the nearest source of potable water, located in an unrestricted area. For indirect exposure, bioaccumulation in the consumed animal or plant organisms is the pathway for exposure. For the CCNPP Unit 3 site, the potential for biological uptake, concentration, and human consumption of fish, crustaceans, and mollusks was considered for the groundwater pathway. For indirect exposure, results are considered acceptable if the dose associated with an accidental release does not exceed the annual dose limit given in 10 CFR 20.1301.

The groundwater pathway evaluation includes the components of advection, decay, retardation, and hydrodynamic dispersion. Where applicable, dilution of the postulated groundwater contaminant plume by the receiving surface water bodies is also considered.

A radionuclide assumed to be undergoing purely advective transport travels at the same velocity as groundwater. This approach is conservative because advective flow does not account for hydrodynamic dispersion, which would normally dilute radionuclide concentrations in groundwater through the processes of molecular diffusion and mechanical dispersion. However, this assumption is evaluated as the effects of hydrodynamic dispersion are also considered. Radionuclides in groundwater flow systems are subject to radioactive decay, the rate of which depends on the half-life of the radionuclide. Table 2.4-43 includes the half-lives of the radionuclides of concern. Retardation considers chemical interactions between dissolved groundwater constituents and the aquifer matrix. Contaminants that react with the aquifer matrix are retarded relative to the groundwater velocity. Reactions with the aquifer matrix include cation/anion exchange, complexation, oxidation-reduction reactions, and surface sorption. Site-specific partitioning coefficients (K_d) are presented in Table 2.4-44.

2.4.13.1.3 Conceptual Model

Figure 2.4-100 illustrates the conceptual model used to evaluate an accidental release of liquid effluent to groundwater, or to surface water via the groundwater pathway through the Upper Chesapeake unit. The most plausible groundwater pathways are north-northeast from CCNPP Unit 3 to a discharge location in Branch 2, and northeast along the shortest line to Chesapeake Bay (Figure 2.4-101). Besides these pathways, several other less likely alternative groundwater pathways were analyzed in order to conservatively bound the evaluation. The alternative pathways considered are the following (Figure 2.4-101):

- A pathway to the east-southeast discharging in Branch 1
- A pathway to the south-southwest discharging in Branch 3
- A pathway to the southwest discharging in Johns Creek
- A north-northeast pathway leading through the Engineered fill material to Branch 2. The possibility of this pathway is indicated by a groundwater model simulation in which the hydraulic conductivity of the fill is assigned the high end (28.34 ft/day) [0.01 cm/s] of its potential range (Section 2.4.12)

The first three of the four alternative pathways (to Branch 1, Branch 3 and Johns Creek) are not supported by the results of the post-construction groundwater flow model (Section 2.4.12). The key elements and assumptions embodied in the conceptual model of the most plausible pathways to Branch 2 and Chesapeake Bay, as well as in the alternative plausible conceptual models, are described and discussed below. The conceptual model of the site groundwater system is based on information presented in Section 2.4.12.

As previously indicated, a Reactor Coolant Storage Tank with a capacity of 4414 ft^3 (125 m^3) is assumed to be the source of the release. The tank is located within the Nuclear Auxiliary

Building, which will have a building slab top depth of approximately 41 ft below grade (12.5 m), at an elevation of approximately 45 ft MSL (13.7 m MSL). The Reactor Coolant Storage Tank is postulated to rupture, and 80 percent of its liquid volume (3531.2 ft^3 [100 m^3]) is assumed to be released in accordance with BTP 11-6 (NRC, 2007). Flow from the tank rupture is postulated to flood the building and migrate past the building containment structure and sump collection system and enter the subsurface at the top of the building slab at an elevation of approximately 45 ft (13.7 m) MSL. The groundwater model of post-construction conditions at the site suggests that the maximum potentiometric surface elevation at the Nuclear Auxiliary Building is approximately 55 ft (16.8 m) MSL (Section 2.4.12) (Figure 2.4-103). The effluent will flow vertically down through the saturated portion of the foundation fill material into the Upper Chesapeake unit.

For the pathways through the Upper Chesapeake unit, any travel time through the engineered fill between the Nuclear Auxiliary Building and the aquifer is conservatively neglected. Figure 2.4-104 depicts a cross-section from the post-construction groundwater model along this pathway. For the pathway through the engineered fill, the entire quantity of the accidental liquid effluent release remains in the fill material during subsurface transport and discharges to Branch 2, i.e. there is no downward vertical migration of the accidental liquid effluent release from the fill material to the Upper Chesapeake unit. Figure 2.4-107 depicts a cross-section from the post-construction groundwater model along this pathway. This assumption is consistent with results from the groundwater model used in sensitivity analysis of fill properties. Figure 2.4-107 displays results from this model which show horizontal flow through the fill material. The assumption that the entire pathway is through fill material is conservative relative to Figure 2.4-104 because the fill material has a higher hydraulic conductivity and lower effective porosity relative to the Upper Chesapeake unit. A higher hydraulic conductivity value and a lower effective porosity result in higher groundwater velocities, shorter travel times, and consequently greater radionuclide concentrations in the fill.

The entire 3531.2 ft^3 (100 m^3) volume of effluent is assumed to be instantaneously released into the groundwater system beneath the Nuclear Auxiliary Building. The effluent will continue flowing through the Upper Chesapeake unit (or engineered fill) with groundwater to the point of aquifer discharge.

The pre-construction site groundwater system consists of two water bearing units beneath the site; the Surficial aquifer and the Upper Chesapeake unit. The unconsolidated sediments comprising the Surficial aquifer consist primarily of fine- to medium-grained sands and silty or clayey sands. The Surficial aquifer extends above an elevation of approximately 65 ft MSL (19.8 m MSL). It is absent in some areas of the site where the elevation of the existing ground surface is below the base of the Surficial aquifer. Because the Surficial aquifer lies at an elevation well above the elevation of the postulated release point, it is not impacted by the postulated release from the Nuclear Auxiliary Building. Additionally, the water table elevation in the Surficial aquifer (approximately 81 ft (24.7 m) MSL) is approximately 46 ft (14.0 m) higher than the pieziometric elevation of the Upper Chesapeake unit (approximately 35 ft (10.7 m) MSL) as observed in observation well cluster 319 (Section 2.4.12). The post-construction groundwater model suggests that the potentiometric surface beneath the Nuclear Auxiliary Building in the Upper Chesapeake unit will be somewhat higher (approximately 55 ft (16.8 m) MSL) after construction (Figure 2.4-103). The elevation of the water table in the remaining portions of the Surficial aquifer will be similar to pre-construction levels. Consequently, the difference in elevation between the water table in the Surficial aquifer and the potentiometric surface in the Upper Chesapeake unit will still exceed 15 ft (4.6 m). Therefore, upward vertical transport from the Upper Chesapeake unit to the Surficial aquifer cannot occur, and the Surficial aquifer is not retained in the conceptual model.

The Surficial aquifer and a portion of the Upper Chesapeake aquitard in the power block area at the Unit 3 site will be removed as part of foundation excavation. Engineered fill and building foundations will replace the removed material. The proposed engineered fill will have a high hydraulic conductivity relative to the Surficial aquifer and the Upper Chesapeake aquitard. Groundwater models of post-construction conditions show a drop in water table to about 15 ft (4.6 m) above the elevation of the existing potentiometric surface in the Upper Chesapeake unit due to the relatively high conductivity of the fill material and removal of the aquitard material. Although the water table elevation will be lower, the piezometric levels in the Upper Chesapeake unit will be higher due to the removal of portions of the Upper Chesapeake aquitard and replacement with fill material. Consequently, the hydraulic gradient in the Upper Chesapeake unit is expected to increase for post-construction conditions.

For the first primary pathway, the effluent release immediately enters the Upper Chesapeake unit and remains within this unit as it flows to the projected discharge point in Branch 2 approximately 580 ft (177 m) down-gradient. Groundwater seepage would enter Branch 2 and eventually discharge with Branch 2 surface water into the Chesapeake Bay. For conservatism, it is assumed that the entire mass of nuclides from the postulated accidental effluent release will be discharged into Branch 2 (Figure 2.4-100).

Based on the results of the post-construction groundwater model, only a small fraction of groundwater flow in the Upper Chesapeake unit discharges into Branch 2. The majority of this flow passes under Branch 2 and discharges to Chesapeake Bay. This is the second primary pathway option (Figure 2.4-100, Figure 2.4-104, and Figure 2.4-107). Site specific subsurface investigation data indicates the basal portion of the Upper Chesapeake unit extends eastward beneath Chesapeake Bay (Schnabel, 2007). Therefore, a portion of the contaminated groundwater may discharge directly to the Bay rather than to the surface water in Branch 2. Because of this, the second primary pathway extending approximately 1315 ft (401 m) down-gradient from the Nuclear Auxiliary Building northeast along the shortest line to Chesapeake Bay is considered (Figure 2.4-101). For conservatism, this second plausible pathway assumes that none of the contaminant slug is intercepted by site streams and the entirety of the slug discharges to Chesapeake Bay.

Although the post-construction groundwater modeling analysis indicates a flowpath from the Nuclear Auxiliary Building north-northeast toward Branch 2 or northeast directly to Chesapeake Bay, it is conceivable that the groundwater elevation contours could change in such a way that the groundwater pathway could lead east toward Branch 1, could lead south-southwest towards Branch 3, or southwest towards Johns Creek. The pathways toward the south-southwest and southwest are considered very unlikely, as their occurrence would necessitate a more substantial change in the piezometric elevations beneath the site. Nonetheless, to demonstrate the conservatism of the analysis, this evaluation also considers the alternative potential groundwater pathways.

The presence of perennial flow in site streams indicates that the groundwater system is discharging steadily to surface water, and thus the water table must intersect the ground surface along these valleys. The piezometric level at Branch 2 to the north-northeast of Unit 3 (Figure 2.4-100) is assumed to be equal to the surface water elevation in the creek, which is approximately at elevation 22 ft (6.7 m) MSL at the predicted accidental release discharge point in Branch 2. The piezometric level at the bay, for the pathway to Chesapeake Bay, is assumed to be 0 ft MSL. For the alternative groundwater pathways to Branch 1, Johns Creek, and Branch 3, the downstream piezometric levels at the points of discharge to surface water are assumed to be equal to the ground surface elevations at the streams.

There are no existing water-supply wells between the postulated release points and the area where groundwater discharges.

2.4.13.1.4 Radionuclide Transport Analysis

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might impact existing and future water users in the vicinity of CCNPP Unit 3 based on an instantaneous release of the radioactive material contents of a RCST. A sequential screening analysis is employed to analyze contamination as described in Section 2.4.13.1.4.2. Radionuclide concentrations resulting from the analysis in each step are compared against the *ECLs* identified in 10 CFR Part 20, Appendix B, Table 2, Column 2 (NRC, 2009) to determine compliance. If the results for a step in the process exceed 1% of the *ECL*, that radionuclide is further analyzed in the following step. Results for each pathway evaluated are presented in Table 2.4-57 through Table 2.4-62.

This analysis accounts for the parent radionuclides expected to be present in the RCST plus progeny radionuclides that would be generated subsequently during transport; source radionuclide concentrations are listed in Table 2.4-43. The analysis considered progeny in the decay chain sequences that are important for dosimetric purposes. International Commission on Radiological Protection (ICRP) Publication 38 (ICRP, 1983) was used to identify the member for which the decay chain sequence can be truncated. For some of the radionuclides expected to be present in RCST, consideration of up to three members of the decay chain sequence was required. The derivation of the equations governing the transport of the parent and progeny radionuclides is presented in the following section.

2.4.13.1.4.1 Transport Equations for Parent and Progeny Radionuclides Accounting for Advection, Radioactive Decay, and Adsorption

The following equations are presented in terms of radionuclide activity concentrations, C. Activity concentration is the mean number of decays or disintegrations per unit time within a unit volume, measured in units of Curies (Ci), where 1 Ci = 3.70×10^{10} disintegrations per second. It is proportional to N, the number of radionuclide atoms present within the unit volume at that time, according to the relation $C=\lambda N$ in which λ is the radioactive decay constant.

Two-dimensional radionuclide transport along a groundwater flowline is governed by the advection-dispersion-reaction equation (Javandel, 1984), which can be stated for the parent radionuclide as:

$$R_1 \frac{\partial N_1}{\partial t} = D_x \frac{\partial^2 N_1}{\partial x^2} + D_y \frac{\partial^2 N_1}{\partial y^2} - v \frac{\partial N_1}{\partial x} - \lambda_1 R_1 N_1 \qquad \text{(Equation 2.4.13-1)}$$

where:

N = radionuclide concentration in terms of the number of atoms per unit volume;

R = retardation factor;

D_x = coefficient of longitudinal hydrodynamic dispersion;

D_y = coefficient of lateral (transverse) hydrodynamic dispersion;
v = average linear groundwater velocity;
λ = radioactive decay constant;
t = groundwater travel time from source to receptor or point of discharge to surface water;
x = distance along the groundwater flowline; and
y = distance normal to the groundwater flowline.

Subscripts on N, R and λ indicate the order in the decay chain, if daughter nuclides are produced.

The retardation factor is provided by Equation (6) in Javandel, 1984:

$$R = 1 + \frac{\rho_b K_d}{n_e} \qquad \text{(Equation 2.4.13-2)}$$

where:

ρ_b = bulk density (g/cm^3);
K_d = distribution coefficient (cm^3/g); and
n_e = effective porosity (dimensionless).

The average linear groundwater velocity (v) is determined using Darcy's law:

$$v = \frac{q}{n_e} = -\frac{K}{n_e}\frac{dh}{dx} \qquad \text{(Equation 2.4.13-3)}$$

where:

q = average linear Darcy velocity;
K = hydraulic conductivity; and
dh/dx = hydraulic gradient (h representing the hydraulic head and x the distance along the direction of ground water flow).

The radioactive decay constant (λ) can be written as:

$$\lambda = \frac{\ln(2)}{t_{1/2}} \qquad \text{(Equation 2.4.13-4)}$$

where:

$t_{1/2}$ = radionuclide half-life.

The dispersion coefficients, neglecting molecular diffusion, are estimated by:

$$D_x = \alpha_x v \ ; \ D_y = \alpha_y v \qquad \text{(Equation 2.4.13-5)}$$

where α_x and α_y are the longitudinal and lateral dispersivity, respectively. Based on the estimated dispersivities for the pathway to Branch 2, the products α_x v and α_y v are at least three to four orders of magnitude larger than the molecular diffusion coefficient. Therefore, the contribution of molecular diffusion to the dispersion coefficient is negligible.

As described in Konikow, 1978, the method of characteristics (MOC) approach can be used on Equation (2.4.13-1) to determine the material derivative of concentration:

$$\frac{dN}{dt} = \frac{\partial N}{\partial t} + \frac{dx}{dt}\frac{\partial N}{\partial x} \qquad \text{(Equation 2.4.13-6)}$$

The MOC approach provides the solution for a single particle of fluid moving along a pathline dictated by the groundwater velocity field. As C is constant across the particle, a spatial C gradient does not exist for the particle and hydrodynamic dispersion is dropped from the analysis. The characteristic equations for Equation (2.4.13-1) can then be expressed as follows:

$$\frac{dN}{dt} = -\lambda N \qquad \text{(Equation 2.4.13-7)}$$

$$\frac{dx}{dt} = \frac{v}{R} \qquad \text{(Equation 2.4.13-8)}$$

Equation (2.4.13-7) is the radioactive decay reaction for the radionuclide of interest and Equation (2.4.13-8) describes the particle pathline. The solutions of the system of equations comprising Equations (2.4.13-7) and (2.4.13-8) can be obtained by integration to yield the characteristic curves of Equation (2.4.13-1). For transport of a parent radionuclide, expressed in terms of activity, the equations representing the characteristic curves are:

$$C_1(t) = C_1^0 \exp\left(-\lambda_1 t\right) \qquad \text{(Equation 2.4.13-9)}$$

$$t = R_1 \frac{x}{v} \qquad \text{(Equation 2.4.13-10)}$$

where:

$C_1(t)$ = parent radionuclide activity concentration at time t;
$C_1{}^0$ = initial bounding parent activity concentration (Table 2.4-43);
λ_1 = radioactive decay constant for parent from Equation (2.4.13-4);
R_1 retardation factor for the parent radionuclide from Equation (2.4.13-2);

Similar relationships exist for progeny radionuclides. For the first progeny in the decay chain, the advection-dispersion-reaction equation is:

$$R_2 \frac{\partial N_2}{\partial t} = D_x \frac{\partial^2 N_2}{\partial x^2} + D_y \frac{\partial^2 N_2}{\partial y^2} - v\frac{\partial N_2}{\partial x} + d_{12}\lambda_1 R_1 N_1 - \lambda_2 R_2 N_2 \qquad \text{(Equation 2.4.13-11)}$$

where:

subscript 2 denotes properties/concentration of the first progeny; and

d_{12} = fraction of parent radionuclide transitions that result in production of progeny (also called the branching coefficient).

The characteristic equations for Equation (2.4.13-11), assuming R1 ≈ R2 can be derived as:

$$\frac{dN_2}{dt} = d_{12}\lambda_1 N_1 - \lambda_2 N_2$$ (Equation 2.4.13-12)

$$\frac{dx}{dt} = \frac{v}{R_2}$$ (Equation 2.4.13-13)

Recognizing that Equation (2.4.13-12) is formally similar to Equation B.43 in Kennedy and Strenge (1992), these equations can be integrated to yield an expression for the activity concentration of the first progeny radionuclide:

$$C_2 = K_1 \exp(-\lambda_1 t) + K_2 \exp(-\lambda_2 t)$$ (Equation 2.4.13-14)

$$t = R_2 \frac{L}{v}$$ (Equation 2.4.13-15)

for which:

$$K_1 = \frac{d_{12}\lambda_2 C_1^0}{\lambda_2 - \lambda_1}$$ (Equation 2.4.13-16)

$$K_2 = C_2^0 - \frac{d_{12}\lambda_2 C_1^0}{\lambda_2 - \lambda_1}$$ (Equation 2.4.13-17)

The advection-dispersion-reaction equation for the second progeny in the decay chain is:

$$R_3 \frac{\partial N_3}{\partial t} = Dx \frac{\partial^2 N_3}{\partial x^2} + Dy \frac{\partial^2 N_3}{\partial y^2} - v \frac{\partial N_3}{\partial x} + d_{13}\lambda_1 R_1 N_1 + d_{23}\lambda_2 R_2 N_2 - \lambda_3 R_3 N_3$$ (Equation 2.4.13-18)

where:

subscript 3 denotes properties/concentration of the second progeny radionuclide;

d_{13} = fraction of parent radionuclide transitions resulting in production of the second progeny (also called the branching coefficient);

d_{23} = fraction of first progeny transitions that result in production of the second progeny (also called the branching coefficient).

The characteristic equations for Equation (2.4.13-18), assuming R1 ≈ R2 ≈ R3 can be derived as:

$$\frac{dN_3}{dt} = d_{13}\lambda_1 N_1 + d_{23}\lambda_2 N_2 - \lambda_3 N_3$$ (Equation 2.4.13-19)

$$\frac{dx}{dt} = \frac{v}{R_3}$$ (Equation 2.4.13-20)

Considering the formal similarity of Equation (2.4.13-19) to Equation B.54 in Kennedy and Strenge (1992), Equations (2.4.13-19) and (2.4.13-20) can be integrated to yield:

$$C_3 = K_1\exp(-\lambda_1 t) + K_2\exp(-\lambda_2 t) + K_3\exp(-\lambda_3 t)$$ (Equation 2.4.13-21)

$$t = R_3\frac{L}{V}$$ (Equation 2.4.13-22)

for which:

$$K_1 = \frac{d_{13}\lambda_3 C_1^0}{\lambda_3 - \lambda_1} + \frac{d_{23}\lambda_2 d_{12}\lambda_3 C_1^0}{(\lambda_3 - \lambda_1)(\lambda_2 - \lambda_1)}$$ (Equation 2.4.13-23)

$$K_2 = \frac{d_{23}\lambda_3 C_2^0}{\lambda_3 - \lambda_2} - \frac{d_{23}\lambda_2 d_{12}\lambda_3 C_1^0}{(\lambda_3 - \lambda_2)(\lambda_2 - \lambda_1)}$$ (Equation 2.4.13-24)

$$K_3 = C_3^0 - \frac{d_{13}\lambda_3 C_1^0}{\lambda_3 - \lambda_1} - \frac{d_{23}\lambda_3 C_2^0}{\lambda_3 - \lambda_2} + \frac{d_{23}\lambda_2 d_{12}\lambda_3 C_1^0}{(\lambda_3 - \lambda_1)(\lambda_3 - \lambda_2)}$$ (Equation 2.4.13-25)

2.4.13.1.4.2 Sequential Screening Analysis Steps

To estimate radionuclide concentrations at groundwater discharge points, Equations (2.4.13-9), (2.4.13-14), and (2.4.13-21) were applied as appropriate along the groundwater pathway that would originate at the liquid effluent release point beneath the Nuclear Auxiliary Building at Unit 3 and terminate at the point of groundwater discharge, e.g., in Branch 2, or Branch 1, etc. The analysis was performed sequentially as described below.

1. First a screening analysis was completed considering advection and radioactive decay only.

2. Those radionuclides that exceeded one percent of their *ECL* in step 1 were then analyzed in step 2. The step 2 analysis accounts for advection and radioactive decay as well as retardation due to linear adsorption. One percent was chosen because, based on the number of radionuclides analyzed, if each exceeded one percent of its *ECL*, then the total dose could exceed the unity rule requirements established in 10 CFR Part 20, Appendix B (NRC, 2009). This was based on engineering judgment.

3. Those radionuclides that still exceeded one percent of their *ECL* after step 2 were analyzed further by accounting for advection, radioactive decay, adsorption, and dilution in the receiving surface water stream where applicable. For primary pathway 2, which goes from the Nuclear Auxiliary Building directly to Chesapeake Bay, dilution was not included in the analysis because the discharge point represents the boundary of the Upper Chesapeake unit and the bay.

4. Those radionuclides that still exceeded one percent of their *ECL* were analyzed further by accounting for advection, radioactive decay, adsorption, hydrodynamic dispersion, and dilution in surface water. Dilution was not employed in the analysis of the pathway directly to Chesapeake Bay as mentioned above.

In calculating the sum of the concentration to *ECL* ratios, all nuclides are included. For those nuclides whose analysis is not carried through a particular step, the contribution to the sum is taken from the last calculated activity concentration. For steps 1 to 3, if the activity concentration of any member of a radioactive decay chain exceeded one percent of its *ECL*, the entire decay chain was carried to the next step.

Implicit in this sequential screening approach is an assumption that it is conservative to eliminate radionuclides having concentrations smaller than one percent of their *ECLs* from further steps in the analysis. This is because the concentrations of individual radionuclides not exceeding one percent of their *ECLs* are used in the sum of ratios (unity rule) evaluation specified in 10 CFR Part 20, Appendix B. In other words, it is assumed that the concentration from step one will always exceed the concentration in step two, and so on (i.e., step 1 C > step 2 C > step 3 C > step 4 C), which results in conservative (high) concentration estimates for those radionuclides that are dropped in the earlier steps of the screening analysis.

The predicted radionuclide concentrations for the pathway directly to Chesapeake Bay and for the pathways through the Upper Chesapeake unit and through structural fill material to Branch 2 were also evaluated for the potential of biological uptake of radiological contamination and the human consumption of fish, crustaceans and mollusks harvested in the immediate vicinity of discharge in Chesapeake Bay.

2.4.13.1.4.3 Advection and Radioactive Decay

The initial screening analysis was performed considering advection and radioactive decay only. This analysis assumed that radionuclides migrate at the same rate as the groundwater and considered neither adsorption nor retardation, which would otherwise have resulted in a longer travel time and more radioactive decay. The concentrations of the radionuclides appearing in Table 2.4-43 were decayed for a period equal to the groundwater travel time from their point of release to their point of discharge. Retardation was not considered in this analysis so the analysis is equivalent to using Equations (2.4.13-9), (2.4.13-14), and (2.4.13-21) with a retardation factor of R=1. The resulting estimated activity concentrations are presented in Section 2.4.13.1.4.8.

2.4.13.1.4.4 Advection, Radioactive Decay, Retardation and Adsorption

The radionuclides retained from the initial screening analysis for the pathways are further evaluated considering adsorption and retardation in addition to advection and radioactive decay. The distribution coefficients used for these radionuclides were obtained from laboratory testing of samples from the site to determine site-specific K_d values for Mn, Co, Zn, Sr, Cs, Ce, Fe, and Ru (SRNL, 2007). The site-specific distribution coefficients (K_d) were obtained from analysis of 20 soil samples obtained from the CCNPP Unit 3 site – 11 samples from the Upper Chesapeake unit material, and 9 from the Surficial aquifer material (SRNL, 2007). The results of the laboratory K_d analysis are summarized in Table 2.4-44. For this analysis, the lowest K_d values measured for each radionuclide within the Upper Chesapeake unit or Surficial aquifer (for the engineered fill) were used. K_d values of zero were assigned to radionuclides for which site-specific tests were not available. Retardation factors were then calculated using Equation (2.4.13-2). Concentrations were determined at the points of groundwater discharge using Equation (2.4.13-9), (2.4.13-14), or (2.4.13-21) with the appropriate retardation factors, the results are presented in Section 2.4.13.1.4.9.

2.4.13.1.4.5 Advection, Radioactive Decay, Retardation, Adsorption, and Dilution in Surface Water

The radionuclides with concentrations greater than one percent of their respective *ECLs* after a screening analysis that accounted for advection, radioactive decay, and adsorption were further analyzed to additionally account for dilution in the receiving surface water streams. As the direct pathway to Chesapeake Bay assumes the entirety of the contaminant slug discharges directly to Chesapeake Bay, surface water dilution was not evaluated for this pathway.

Surface water concentration after dilution was estimated from the equation:

$$C_{sw} = C_{gw} d_f \qquad \text{(Equation 2.4.13-26)}$$

where:

C_{sw} = radionuclide concentration in surface water downstream;

C_{gw} = radionuclide concentration in the groudwater; and

d_f = dilution factor

The dilution factor is defined as:

$$d_f = \frac{Q_{gw}}{Q_{gw}+Q_{gw}} \qquad \text{(Equation 2.4.13-27)}$$

where:

Q_{gw} = flow rate of the liquid effluent released from the groudwater and discharging into the surface water;

Q_{sw} = surface water flow available for dilution; and

d_f = dilution factor

The flow rate of the liquid effluent in the groundwater is defined as:

$$Q_{gw} = A \cdot q \qquad \text{(Equation 2.4.13-28)}$$

where:

A = cross sectional area of the contaminant slug ; and

q = Darcy velocity, which may be obtained from Equation (2.4.13-3)

2.4.13.1.4.6 Advection, Radioactive Decay, Retardation, Adsorption, and Hydrodynamic Dispersion

The radionuclides with concentrations greater than one percent of their respective *ECLs* after the screening analysis that accounted for advection, radioactive decay, adsorption, and dilution were further analyzed to also account for hydrodynamic dispersion in groundwater. Advection, decay, retardation, and hydrodynamic dispersion were accounted for in the transport of the radionuclide to the discharge point. Surface water dilution, where applicable, was then calculated as dilution of the groundwater concentration by assuming complete mixing at the discharge point to the surface water body.

For parent radionuclides, the effects of dispersion were analyzed using the analytic solution of the two-dimensional advection-dispersion equation presented by Codell and Duguid (Equation 4.33 in AREVA, 2007) for transport in a vertically averaged layer of thickness b, and an instantaneous release of activity M uniformly distributed over width w. Using this method, the activity concentration, C, at the point of groundwater discharge (i.e., at horizontal position (x, y) relative to the source, where the groundwater pathline flows in the x direction) at time t is calculated as a function of the total initial radionuclide activity concentration, M as:

$$C(x,y,t)=\frac{M}{n_e R} X_1 Y_2 Z_2 \qquad \text{(Equation 2.4.13-29)}$$

where X_1, Y_2 and Z_2 are given by the expressions:

$$X_1=\frac{1}{\sqrt{4\pi D_x t/R}}\exp\left[-\frac{(x\text{-}vt/R)^2}{4D_x t/R}\text{-}\lambda t\right] \qquad \text{(Equation 2.4.13-30)}$$

$$Y_2=\frac{1}{2w}\left\{\text{erf}\left[\frac{(w/2+y)}{\sqrt{4D_y t/R}}\right]+\text{erf}\left[\frac{(w/2\text{-}y)}{\sqrt{4D_y t/R}}\right]\right\} \qquad \text{(Equation 2.4.13-31)}$$

$$Z_2=\frac{1}{b} \qquad \text{(Equation 2.4.13-32)}$$

where w is the conceptualized width of the contaminant slug in the aquifer, y is the lateral position with respect to the center of the pathline (i.e., distance to the left or right), b is the saturated thickness of the aquifer, and M is the released activity, which is equal to the activity concentration of each nuclide in the effluent times the postulated volume of the effluent release 3531.2 ft^3 (100 m^3).

The longitudinal dispersivity is estimated using the following two methods from the literature. An estimate of the longitudinal dispersivity, a_x, was obtained using Equation (32) in Neuman, 1990:

$$\alpha_x = 0.32x^{0.83} \qquad \text{(Equation 2.4.13-33)}$$

An alternative estimate of the dispersivity was computed using Equation (14b) from Xu, 1995:

$$\alpha_x = 0.83\text{Log}10(x)^{2.414} \qquad \text{(Equation 2.4.13-34)}$$

In Equations (2.4.13-33) and (2.4.13-34), x and a_x are in units of meters. In both cases, the lateral dispersivity was estimated to be one tenth of the longitudinal dispersivity, i.e., $a_y = 0.1\times a_x$, based on Bear, 1979.

The resulting radionuclide concentrations in groundwater predicted by Equations (2.4.13-29) and (2.4.13-35) were reduced to account for surface water dilution in the receiving streams using Equation (2.4.13-26).

Equation (2.4.13-29) is only applicable to parent radionuclides. In this calculation, seven progeny nuclides were found to have a concentration greater than one percent of their ECLs after accounting for advection, decay, adsorption, and dilution. These seven progeny nuclides and their parent nuclides are listed in Table 2.4-45, along with their half-lives. For decay chains containing three members, the parent that produces the larger fraction of the daughter nuclide is listed, as determined by the branching coefficients, which are included in Table 2.4-45.

It may be seen from Table 2.4-45 that the half-lives of Y-90 (Yttrium), Te-127 (Tellurium), and Te-129 are much shorter than the half-lives of their parent nuclides. Consequently, these progeny nuclides would decay very quickly relative to their parents, and for groundwater pathways having long travel times (e.g., months and years, rather than hours), the concentration of these progeny nuclides at down-gradient locations would be governed by the concentration of their parents. Therefore, in this analysis, the concentrations of Y-90, Te-127, and Te-129 at groundwater discharge points were calculated directly from the predicted concentrations of Sr-90, Te-127m, and Te-129m, respectively, using the appropriate branching coefficients:

$$C_2(x,t) = d_{12}C_1(x,t) \qquad \text{(Equation 2.4.13-35)}$$

where:

$C_1(x,t)$ = concentration of parent nuclide at distance x and time t from Equation (2.4.13-29)

$C_2(x,t)$ = concentration of progency nuclide at distance x and time t

The relationship of the parent - daughter half-lives for Np-239 - Pu-239 decay chain is the reverse of the relationship of the three decay chains mentioned above. The half life of Np-239 (2.355 days) is very short relative to Pu-239 (8.79E+06 days). Therefore, the concentration of Pu-239 was estimated by assuming that all Np-239 instantly decays to Pu-239 at t=0 and then applying Equation (2.4.13-29) to the Pu-239. Using the relationship A=λN, the initial activity concentration, $C_2^{\,0}$, of Pu-239 was estimated from the initial Np-239 concentration, $C_1^{\,0}$, as:

$$C_2^0 = \lambda_2 \frac{C_1^0}{\lambda_1} \qquad \text{(Equation 2.4.13-36)}$$

The simplifying approximations used above do not hold true for the decay chains that generate Nb-95 (Niobium), I-131 (Iodine), and La-140 (Lanthanum), due to the relatively smaller differences in their parent-progeny half-lives. Therefore, neither Equation (2.4.13-29) nor (2.4.13-35) could be reasonably applied to predict the effect of dispersion for these progeny nuclides. Accounting for dispersion in the transport of radioactive decay chains requires the simultaneous solution of the transport equations for the parent and the progeny (e.g., Equations 2.4.13-1 and 2.4.13-11). Instead of developing this solution, a simpler approach is applied in which dispersion is neglected, i.e., using Equations 2.4.13-9, 2.4.13-14, 2.4.13-21, and 2.4.13-26 as appropriate. Because of this, only advection, decay, retardation, and dilution (when applicable) have been applied for the Nb-95, I-131, and La-140 screening evaluations. The effect of dispersion is not accounted for, leading to conservative, i.e., higher, estimates of concentration.

2.4.13.1.4.7 Advection, Radioactive Decay, Retardation, Adsorption, Hydrodynamic Dispersion, and Biological Uptake and Potential Consumption of Fish, Crustaceans, and Mollusks

From the boundaries of the CCNPP Unit 3 site, all discharge, both surface water and groundwater, eventually reaches the Chesapeake Bay. Neither surface water nor groundwater discharge from the CCNPP Unit 3 site is used as a drinking water source. In the case that compliance with the *ECLs* is not demonstrated at the boundary of the restricted area, biological uptake and the corresponding potential for human exposure by ingestion is examined to ensure that *ECL* exceedance at the boundary will not lead to adverse human exposure. In this case, radionuclide concentrations predicted to be discharging into Chesapeake Bay were also evaluated for biological uptake and human ingestion of fish, crustaceans, and mollusks harvested from this area. The concentrations predicted to be discharging in surface streams, or discharging from groundwater for the Chesapeake Bay pathway, were considered as the exposure concentration for Chesapeake Bay biota, without accounting for any additional dilution in the Bay. These undiluted concentrations were used to estimate the biological uptake using the fish-water and mollusk-crustacean uptake ratios given in Tables D.11, D.12, and D.13 of PNNL, 2004.

The dose via each consumption pathway (mollusk/crustacean and fish) was determined using assumptions for fraction of food contaminated for mollusks/crustaceans (50 percent) and fish (25 percent), and standard default assumptions for annual consumption (6.9 kg/year fish and 1.0 kg/year seafood from NRC Regulatory Guide 1.109, taken as 50% mollusks and 50% crustaceans) and converted to a dose in millirem based on dose conversion factors from Eckerman, 1988. The rationale for using non-default values for the percent of contaminated fish, crustaceans, and mollusks is based on the likelihood that fishermen would fish outside of the area of contamination for at least 25% of the time and that fish, themselves are wide-ranging and would spend time both in and outside of the area of potential discharge, while for crustaceans and mollusks the assumption is that harvesting would be 50% outside the contaminated area due to the narrow width of the contamination plume entering the Bay (Section 2.4.13.1.4.10). The resultant dose for each compound by each intake exposure pathway was summed and a total exposure was determined. The total annual activity uptake from marine biota ingestion is:

$$A_i = CB_wIF_c \qquad \text{(Equation 2.4.13-36)}$$

where:

C = radionuclide groundwater concentration (pCi/L)

B_w = biota/water ration (L/Kg)

I = biota intake (Kg/yr); and

F_c = fraction of biota that is contaminated (unitless)

The annual dose from ingestion of contaminated biota is:

$$D_a = A_iDcf \qquad \text{Equation 2.4.13-37}$$

where:

Dcf = dose conversion factor (mrem/pCi)

2.4.13.1.4.8 Screening Analysis: Transport Considering Only Advection and Radioactive Decay

An initial screening analysis was performed considering only advection and radioactive decay. This analysis assumed that radionuclides migrate at the same rate as groundwater and considered no adsorption / retardation, which would otherwise result in a longer travel time and more radioactive decay. The concentrations of the radionuclides assumed to be released from the Reactor Coolant Storage Tank were decayed for a period equal to the groundwater travel time from the point of release to the point of discharge (e.g., Branch 2, Chesapeake Bay, etc.), using Equations (2.4.13-9), (2.4.13-14), or (2.4.13-21) as appropriate with $R_1=R_2=R_3=1$. Radionuclides having concentrations less than 1 percent of their respective *ECLs* were eliminated from consideration because their concentrations would be well below their regulatory limits. Any radionuclides having a concentration greater than or equal to 1 percent of their *ECL* were retained for further evaluation.

The travel times along the groundwater pathways were conservatively determined based on site-specific data and the post-construction groundwater model described in Section 2.4.12. A hydraulic conductivity of K = 13.7 ft/day (4.2 m/day) and an effective porosity of $n_e = 0.145$ were applied to all pathways through the Upper Chesapeake unit. For the alternative pathway through the fill material to Branch 2, a hydraulic conductivity of K = 28.3 ft/day (8.64 m/day or 0.01 cm/s) and an effective porosity of $n_e = 0.082$ were applied.

The average horizontal hydraulic gradient, dh/dx, was calculated for each groundwater pathway from its length, x, and from the hydraulic head at the point of release (the Nuclear Auxiliary Building at Unit 3), h_0, and the head at the point of discharge, h_1, as predicted by the post-construction groundwater model using the expression:

$$\frac{dh}{dx} = \frac{h_1 - h_0}{x}$$

The hydraulic head at the point of release was based on the maximum potentiometric surface level at the proposed Nuclear Auxiliary building location estimated to be 55 ft (16.8 m) MSL. The hydraulic gradient calculations for the pathways considered in this calculation are shown below. For the alternative pathway through the fill material to Branch 2, h_0, h_1, and dh/dx are not used. Rather, the groundwater travel time for this pathway is obtained from particle tracking in the groundwater model (Section 2.4.12). Its velocity was calculated from its length and travel time. The length of this pathway was shortened from 580 (176.8 m) to 540 (164.6 m) ft to account for the higher elevation of the fill material, which would discharge on a seepage face above Branch 2.

Use of the maximum groundwater level observed at the point of release is conservative because it results in the steepest gradients, the largest groundwater velocities, and shortest travel times. This assumption is very conservative because the surface water dilution is calculated using the 100-year low annual mean flow (Section 2.4.13.1.4.1.7), the occurrence of which would not likely coincide with a period of maximum hydraulic gradients.

The hydraulic gradients were entered into Equation (2.4.13-3) to determine the average linear groundwater velocity for each pathway. Straight-line distances were used in these calculations in order to obtain conservative estimates of the hydraulic gradients and groundwater velocities. Initial groundwater travel times were calculated from these lengths and velocities using Equation (2.4.13-10) with $R_1 = 1$. The resulting hydraulic gradients, groundwater velocities, and travel times are shown in Table 2.4-46.

It may be seen that the pathway to Branch 2 has the steepest hydraulic gradients and the shortest travel time.

Using Equations (2.4.13-9), (2.4.13-14), or (2.4.13-21) as appropriate with R = 1, the initial concentrations were decayed for a period equal to the travel time along each groundwater pathway. Radioactive decay data and decay chain specifications were taken from ICRP Publication 38 (ICRP, 1983) and Kennedy and Strenge, 1992. Tables 2.4-57 through 2.4-62 summarize the results and identify those radionuclides that would exceed their *ECLs* by more than 1 percent for each pathway evaluated. These radionuclides are listed for each groundwater pathway considered.

It may be seen that, when only advection and radioactive decay are considered, the pathways with the shortest travel times have the greatest number of radionuclide concentrations in excess of their effluent concentration limits. The nuclides listed in Table 2.4-47 are retained for step 2 in the transport analysis in which adsorption is also considered.

2.4.13.1.4.9 Transport Considering Advection, Radioactive Decay, and Adsorption

The radionuclides retained from the radioactive decay screening analysis were further evaluated considering retardation in addition to advection and radioactive decay.

Site-specific distribution coefficients were used for Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce. These values were based on the laboratory K_d analysis of eleven soil samples obtained from the Upper Chesapeake unit at the CCNPP Unit 3 site (SRNL, 2007) [Table 2.4-44]. For each of these radionuclides, the lowest K_d value measured in the Upper Chesapeake unit was used in the transport analysis to ensure conservatism. Distribution coefficients for tritium and iodine were taken to be zero because these elements are not expected to interact with the aquifer matrix based on their chemical characteristics. Distribution coefficients for other elements were also set equal to zero.

For the alternative pathway through the fill material to Branch 2, the minimum site-specific distribution coefficients for Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce that were measured in the Surficial aquifer material were adopted (based on nine soil samples, SRNL, 2007). Distribution coefficients for all other elements were set equal to zero for this pathway.

Retardation factors, R, were calculated using Equation (2.4.13-2) with the site specific distribution coefficients and with the effective porosity of n_e=0.145 and the bulk density of ρ_b =1.53 g/cm^3 for pathways through the Upper Chesapeake unit; n_e=0.082 and ρ_b =2.24 g/cm^3 were used for the alternative pathway through the fill material. Retardation factors for radionuclides with site-specific measurements (Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce) are shown in Table 2.4-48. Retardation factors for all other radionuclides were set to one (i.e. $K_d = 0$). Nuclides exceeding one percent of their *ECLs* are listed in Table 2.4-45. The nuclides are retained for step 3 of the transport analysis in which surface water dilution is also considered.

2.4.13.1.4.10 Transport Considering Advection, Radioactive Decay, Adsorption, and Dilution

For the purpose of evaluating the effects of the spill material on the surface water systems downstream of the discharge point, the average concentration and discharge of the highly diluted liquid effluent discharged from the aquifer were determined. The analysis presented below is based on the conservative assumption that there is no longitudinal or transverse dispersion of the liquid effluent in the groundwater.

Dimensions of the Contaminant Slug

The volume of the liquid release has been assumed to be 3,531.2 ft^3 (100 m^3), which represents 80 percent of the 4,414 ft^3 (125 m^3) capacity of one Reactor Coolant Storage Tank [NUREG-0800, BTP 11-6 (NRC, 2007) recommends that 80 percent of the liquid volume be considered in this analysis]. The volume of the Upper Chesapeake unit that would be occupied by the release is estimated by dividing the release volume (3,531.2 ft^3 [100 m^3]) by the effective porosity of 0.145. This results in an estimated volume of 24,353 ft^3 (689.6 m^3). For the alternative pathway through the fill material, the contaminant slug would occupy a volume of 43,063 ft^3 (1219.4 m^3) due to the lower effective porosity of 0.082.

For the purpose of this evaluation, it is assumed that the entire content of the tank leaks into the subsurface displacing all of the groundwater. This would result in a contaminant slug that is in the shape of a rectangular box. This is a simplifying assumption made for the purpose of this calculation. This slug then moves at the same rate as the surrounding groundwater and exhibits no dilution or dispersion, until it is discharged into the creek. This assumption results in a conservative estimate of the discharge concentration.

The shape of the resulting contaminant slug is assumed to be square in plan view and to extend vertically throughout the entire saturated thickness, b, of the Upper Chesapeake unit (the thickness of which varies along each flowpath). For the flowpath leading to Branch 2, the average thickness is estimated to be b = 33.7 (10.3 m) ft based on a cross-section taken from the groundwater model and shown in Figure 2.4-104 and Figure 2.4-107. The area of the contaminant slug in plan view is then estimated by dividing the volume by the saturated thickness, b. Consistent with the assumption that the contaminant slug is square in plan view, cross-sectional width, w, is equal to the square root of the planar area. The cross-sectional area of the contaminant slug normal to the groundwater flow direction would therefore be equal to the product of the saturated thickness, b, and the width, w.

The computation of the contaminant slug dimensions is shown in Table 2.4-51 for each of the groundwater pathways considered in this calculation. The aquifer thickness along each flow path was estimated from the Upper Chesapeake unit layers as defined in the groundwater model of post-construction conditions as discussed in Section 2.4.12.

The cross-sectional areas, A, shown in Table 2.4-52 are used in the calculation of the rates of discharge from the Upper Chesapeake unit for the various groundwater pathways.

Computation of Effluent Discharge Rates and Dilution Factors

The radionuclides discharging with the groundwater into the surface waters of Branches 1, 2, 3, or Johns Creek would mix with surface flows and with uncontaminated groundwater discharging in these streams, leading to the reduction of concentrations through dilution. No surface water dilution is assumed for the pathway discharging directly to Chesapeake Bay. The list of isotopes evaluated for dilution, provided in Table 2.4-49, includes those retained after the advection, radioactive decay, and adsorption screening evaluations described above and summarized in Table 2.4-57 to Table 2.4-62.

In order to estimate the dilution factors for each pathway, the rates of groundwater discharge passing underneath the Nuclear Auxiliary Building of Unit 3 to the discharge points must be estimated. It is assumed that in the event of an accidental release of the contents of a Reactor Coolant Storage Tank, the release will move directly into the Upper Chesapeake unit, neglecting any travel time through the unsaturated zone and/or through the fill material. The rate at which a release from a Reactor Coolant Storage Tank discharges to surface water is determined by the hydraulic properties of the Upper Chesapeake unit. A release would undergo saturated flow through the Upper Chesapeake unit to the aquifer discharge point (e.g., Branch 2).

The discharge rate itself is a function of the Darcy velocity (q), and of the assumed volume and dimensions of the resulting contaminant slug. The Darcy velocity for each groundwater pathway is calculated from the hydraulic conductivity and the horizontal hydraulic gradient using Equation (2.4.13-3). The discharge rate, Q_{gw}, from each groundwater pathway is determined using Equation (2.4.13-28). This is the rate at which groundwater contaminated with radionuclides would flow to the point of discharge from each pathway.

Compliance with 10 CFR Part 20 is assessed for the nearest potable water supply in an unrestricted area (BTP 11-6). The area between the site and the mouths of Branches 1 and 2 at Chesapeake Bay, and the location where the Chesapeake Bay pathway reaches Chesapeake Bay are considered restricted areas, because they are within land owned by CCNPP Unit 3 site. Therefore, for the pathways discharging to Branches 1 and 2, and Chesapeake Bay, compliance with *ECLs* is evaluated at the shoreline. Branch 3 flows into Johns Creek within CCNPP Unit 3 site property; Johns Creek flows west-southwest, exiting the CCNPP Unit 3 site property a short distance upstream of crossing Solomons Island Road. Therefore, for the pathways discharging to Branch 3 and Johns Creek, compliance is evaluated at the point where Johns Creek crosses the CCNPP Unit 3 site property line.

The 100-year low annual mean flows for these locations are used to derive surface water dilution factors. The 100-year low annual mean flow is defined as the average discharge over the course of one year having a non-exceedance return period of 100 years. It is anticipated that during the year in which the 100-year low annual mean flow occurs, surface flows in the watersheds may be intermittent or ephemeral, rather than perennial. However, over the course of the year, they would still yield some runoff in response to precipitation events. Base flows may occur during the cooler and relatively less dry parts of the year. It is assumed that 100-year low annual mean flows in small watersheds in the southern region of the Coastal Plain physiographic province of Maryland may be estimated based on the observed flows in other watersheds in this region using an inverse-distance relationship (Carpenter, 1996). It is assumed that this relationship, which was derived for use in predicting the 7-day, 14-day, and 30-day low-flows for return periods of 2, 10, and 20 years, may be used to estimate annual (365-day) low-flows with 100-year return periods.

The dilution factors are calculated using Equation (2.4.13-27) with the assumption that the accidental liquid effluent release occurs during the 100-year low annual mean flow in the receiving stream. Calculation of the dilution factors is presented in Table 2.4-52.

The dilution factors shown in Table 2.4-52 are applied to the radionuclides whose concentrations exceed one percent of their *ECLs* after screening step 2, to account for dilution in addition to advection, radioactive decay, and adsorption. The predicted activities of the radionuclides considering the combined effects of advection, radioactive decay, retardation, and dilution in surface water are summarized in Table 2.4-57 through Table 2.4-62. Nuclides exceeding one percent of their *ECLs* are listed in Table 2.4-49. These nuclides are further analyzed in step 4.

2.4.13.1.4.11 Transport Considering Advection, Radioactive Decay, Adsorption, Dispersion, and Dilution

This section presents the transport analysis considering the effects of advection, radioactive decay, adsorption, and hydrodynamic dispersion in groundwater. Surface water dilution is also accounted for as presented in Section 2.4.13.1.4.5.

Results presented in the preceding section, and summarized in Table 2.4-57 through Table 2.4-62, show that ratios of concentrations to *ECLs* would exceed one percent for fifteen radionuclides for the pathway to Branch 2 if the effect of dispersion in groundwater is not considered (Table 2.4-49). Similarly, concentrations exceed one percent of the *ECL* ratios for twelve radionuclides for the Chesapeake Bay pathway. Therefore, transport for the nuclides and groundwater pathways listed above was analyzed using a method that includes the effects of hydrodynamic dispersion.

An analytical solution (Codell and Duguid, 1983) was used to model transport of the radionuclides listed above through the Upper Chesapeake unit from underneath the Nuclear Auxiliary Building to the points of discharge to surface water. The two-dimensional mass transport equation given by Equation (2.4.13-29) was selected. Equation (2.4.13-29) accounts for advection, radioactive decay, adsorption, and longitudinal and lateral dispersion in groundwater. This modeling approach is still conservative, because it neglects the effect of dispersion in the vertical direction, which would further reduce the radionuclide concentrations.

The longitudinal dispersion coefficient was estimated as the product of the dispersivity and the transport velocity. The dispersivity is a property of the porous media and is a function of the scale of transport (Neuman, 1990). The longitudinal dispersivity, a_x, was estimated for each pathway using the following two methods from the literature:

- Equation (32) in Neuman, 1990, provided as Equation (2.4.13-33) above.
- Equation (14b) in Xu, 1995, provided as Equation (2.4.13-34) above.

These two methods provided a range of dispersivity estimates to consider in the calculation. It was decided to consider the range of estimated dispersivities given by these equations to identify conditions leading to the most adverse contamination. The resulting longitudinal dispersivity range for each pathway is shown in Table 2.4-54.

For two-dimensional solute transport, the transverse dispersivity must also be estimated. Bear (1979) indicates that the ratio of longitudinal to transverse dispersivity ranges from 5 to 24. In the lateral direction, the dispersivity was therefore reduced by a factor of 10.

With the exceptions of Ba-140 discharging to Branch 2 and of Co-60 and Te-129 discharging to the Chesapeake Bay pathway, the calculated peak concentrations of nuclides for these pathways result from the smaller of the dispersivity values. It is noted that using a higher dispersivity value (approximately 77 ft (23.5 m) and 152 ft (46.3 m) for discharge to Branch 2 and Chesapeake Bay respectively) typically produces earlier, but lower, peak concentrations than the dispersivity of 19 ft (5.8 m) because the higher longitudinal dispersivity causes greater spreading of the contaminant plume in the direction parallel to the average pore velocity. Except for Co-60 discharging to Chesapeake Bay, this trend is observed for all radionuclides evaluated for the effects of dispersion. This trend does not hold for the three noted exceptions due to a relatively high K_d value, in the case of Co-60, and to relatively short half-lives. Nuclides exceeding their *ECLs* after applying the dispersivity screening step are listed in Table 2.4-55.

The timing of the peak radionuclide concentrations varies due to differences in the retardation factors. Yttrium (Y-90) and Tellurium (Te-127 and Te-129) are exceptions to this finding. The timing of the Y-90, Te-127, and Te-129 peaks match the timing of the Sr-90, Te-127m, and Te129m peaks because the daughters are predicted directly from the parents.

As seen in Table 2.4-55, tritium (H-3) exceeds its *ECL* for the Chesapeake Bay pathway and the pathways through the Upper Chesapeake unit and the fill to Branch 2. In addition, Iodine (I-131) exceeds its *ECL* for the two pathways to Branch 2.

2.4.13.1.4.12 Transport Considering Advection, Radioactive Decay, Adsorption, Dispersion, and Biological Uptake and Potential Consumption of Fish, Crustaceans, and Mollusks

The activity concentrations resulting from the transport analysis were used to evaluate potential biological uptake and human ingestion of fish, crustaceans, and mollusks harvested in the immediate vicinity of groundwater discharge in Chesapeake Bay or in the vicinity of the point where Branch 2 flows into Chesapeake Bay using the method discussed in Section 2.4.13.1.4.7. The concentrations predicted to be discharging in surface streams, or discharging from groundwater for the Chesapeake Bay pathway, were considered as the exposure concentration for Chesapeake Bay biota, without accounting for any additional dilution in the Bay. This analysis was performed for the pathways having tritium (H-3) and Iodine (I-131) concentrations in excess of their *ECLs* at the points of discharge into Chesapeake Bay: the pathways to Branch 2 and the direct pathway through the Upper Chesapeake unit to the Bay. The predicted radionuclide concentrations (Tables 2.4-57, 2.4-58 and 2.4-62) were considered directly available for biological uptake, and a fish-water and mollusk-crustacean uptake ratio was applied from PNNL (2004). The results of these calculations and the evaluations are presented in Tables 2.4-57, 2.4-58 and 2.4-62. The total ingestion exposure for the direct Chesapeake Bay pathway is 12.42 millirem per year. For the pathways to Branch 2, the total ingestion exposure is 32.58 millirem per year for transport through the Upper Chesapeake unit and is 73.98 millirem per year for transport through the fill material.

These exposures are below the allowable exposure level to individual members of the public of 100 millirem per year required in 10 CFR 20.1301. In addition, these estimates are very conservative because they do not account for dilution due to the mixing of ground or surface water discharges into Chesapeake Bay, which may be expected to reduce the total ingestion exposure levels by at least one to two orders of magnitude.

2.4.13.1.5 Compliance with 10 CFR Part 20

As previously stated, the Upper Chesapeake unit is considered the most likely groundwater pathway to be impacted by an accidental release (tank rupture). Branch 2 and direct discharge to Chesapeake Bay are the most likely projected surface water discharge points of the hypothetically contaminated Upper Chesapeake unit groundwater. The radionuclide transport analysis presented above indicates that, with few exceptions, radionuclides accidentally released to the groundwater are individually below their *ECLs* prior to discharge offsite. The exceptions are tritium (H-3) concentrations for the pathways through the Upper Chesapeake unit and the fill to Branch 2 and in groundwater discharging directly to Chesapeake Bay. In addition, Iodine (I-131) exceeds its *ECL* for the two pathways to Branch 2. These exceptions result from very conservatively estimated hydraulic conductivities (i.e., 28.3 ft/day (8.6 m/day) for the fill, and 13.7 ft/day (4.2 m/day) for the Upper Chesapeake unit, the maximum observed value for this material) and effective porosities (0.145 for the Upper Chesapeake unit and 0.082 for the fill material).

10 CFR Part 20, Appendix B imposes additional requirements when the identity and activities of each radionuclide in a mixture are known. In this case, the ratio (groundwater activity concentration/*ECL*) present in the mixture and the concentration otherwise established in 10 CFR Part 20, Appendix B for the specific radionuclide not in a mixture must be determined. The sum of such ratios for all of the radionuclides in the mixture may not exceed "1" (i.e., "unity"). This sum of fractions approach has been applied to the radionuclide concentrations conservatively estimated above for each of the groundwater pathways considered. Results are summarized in Table 2.4-56.

An accidental liquid release of effluents to groundwater would not exceed 10 CFR Part 20 limits at the boundary for the pathways to Branch 1, John Creek, and Branch 3. The radionuclide mixture ratio used in this analysis represents the minimum calculated value observed for each radionuclide as it is carried through the advection / decay retardation / dispersion / dilution screening process. Individual radionuclides are carried through subsequent screening steps if their calculated values exceed one percent of the *ECL*. If individual radionuclide concentrations do not exceed one percent of their respective *ECLs*, the screening process stops and that calculated value is used in the sum of the fractions evaluation. This approach adds an additional level of conservatism since most radionuclides are not carried through the entire screening process.

For the pathways to Branch 2 and to Chesapeake Bay, the tritium (H-3) concentrations exceed the *ECL* when the most conservative hydraulic conductivity estimates are applied, as discussed above. Similarly, the iodine (I-131) concentration exceeds its *ECL* for the pathways to Branch 2, which discharges into Chesapeake Bay at the boundary of the restricted area. Although the water from Chesapeake Bay is not potable, indirect human exposure could theoretically result from the consumption of Chesapeake Bay fish and shellfish that have bioaccumulated radionuclides from the postulated accidental release. However, radionuclide concentrations would be greatly diluted by surface water in the Chesapeake Bay. Additionally, H-3, the only nuclide exceeding its *ECL* for the direct pathway to Chesapeake Bay, does not bioaccumulate in the environment. I-131 bioaccumulates at a moderate rate relative to the other nuclides in the source term.

Nonetheless, an evaluation of the annual human radiological dose received from the ingestion of Chesapeake Bay biota potentially contaminated from direct discharge to the Bay was performed for the pathway through the Upper Chesapeake unit to Chesapeake Bay and for the pathways to Branch 2. The results of this evaluation indicate the total ingestion exposure is 32.58 millirem per year for the pathway through the Upper Chesapeake unit to Branch 2, is 12.42 millirem per year for transport through the Upper Chesapeake unit to Chesapeake Bay, and is 73.98 millirem per year for alternative transport through the fill material to Branch 2. In all cases, the exposure is below the allowable total exposure level to individual members of the public of 100 millirem per year required in 10 CFR 20.1301. As discussed above, the estimated exposures are conservative because they do not account for dilution due to the mixing of ground or surface water discharges into Chesapeake Bay.

NUREG-0800 Section 15.7.3 requires NRC staff to assess if an evaluation considers the impacts of the postulated tank failure on the nearest potable water supply in an unrestricted area. "Supply" is defined as a well or surface water intake that is used as a water source for direct human consumption or indirectly through animals, crops, or food processing. Branch 2 is located in a restricted area and is not used for potable water supply, and the Chesapeake Bay is not used as a potable water supply. The alternative pathways to Branch 1, Johns Creek, and Branch 3 show compliance at the property boundary.

2.4.13.2 Surface Water Pathway

Calvert Cliffs Nuclear Power Plant Unit 3 facilities containing radionuclide inventories are located in the Nuclear Island (AREVA, 2007). For the Nuclear Auxiliary and Waste Buildings, the depth of the top of the basemat is approximately 41 ft (12.2 m) below grade (i.e., 86 ft - 45 ft). Assuming liquid releases from postulated Reactor Coolant Storage Tank and/or Liquid Waste Storage Tank ruptures would flood the lowest levels of the Nuclear Auxiliary and Waste Buildings, respectively, it is unlikely that a release could reach the ground surface and be capable of impacting surface water.

The concrete floor supporting the Volume Control Tank in the Fuel Building is at grade level. However, the room containing this tank is centrally located in the interior of the Fuel Building, and the tank is entirely surrounded by concrete walls. There are no doors providing entry to this room and access is only possible via a ladder through the top of the room. Therefore, a postulated release from the Volume Control Tank will not leave the Fuel Building, reach the ground surface, and impact surface water.

Two heat exchangers in each of the three Safeguards Buildings are located at grade level. One Safeguards Building (Building 2/3) houses its grade level heat exchangers within double wall concrete containment, and has no exterior doors leading into the building at grade level. The remaining Safeguard Buildings (Buildings 1 and 4) do not have double wall containment, and grade level exterior entry doors are present. However, these doorways are designed with six inch concrete thresholds, and the doors are watertight to a flood depth of one meter. Therefore, it is unlikely that a release from the grade level heat exchangers in the Safeguard Buildings will reach the ground surface and impact surface water.

Because there are no outdoor tanks that could release radioactive effluent, no accident scenario could result in the release of effluent directly to the surface water from outdoor tanks.

2.4.13.3 References

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2.4.14 Technical Specification and Emergency Operation Requirements

The U.S. EPR FSAR includes the following COL Item in Section 2.4.14:

> A COL applicant that references the U.S. EPR design certification will describe any emergency measures required to implement flood protection in safety-related facilities and to verify that there is an adequate water supply for shutdown purposes.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.Sections 2.4.14.1 and 2.4.14.2 are added as a supplement to the U.S. EPR FSAR.

2.4.14.1 Need for Technical Specifications and Emergency Operations Requirements

The preceding subsections of Section 2.4 provide an in-depth evaluation of the site's hydrologic acceptability for locating CCNPP Unit 3. The information provided below concludes that there is no need for emergency protective measures designed to minimize the impact of hydrology-related events on safety-related facilities. Therefore, the requirements of 10 CFR 50.36 (CFR, 2007a), 10 CFR Part 50, Appendix A, General Design Criteria 2 (CFR, 2007b), and 10 CFR Part 100 (CFR, 2007c) are met with respect to determining the acceptability of the site.

Sections 2.4.1 through 2.4.11 present a comprehensive discussion of the potential for flooding and low water at the site, including details of each potential cause and the resulting effects. These evaluations conclude that the probable maximum storm surge (PMSS) plus wave action during the probable maximum hurricane (PMH), the limiting case for flooding of safety related structures, systems, and components (SSCs) in the safety related Ultimate Heat Sink (UHS) Makeup Intake Structure on the Chesapeake Bay, results in a maximum bay water level of elevation 33.2 ft (10.11 m). They also conclude that flooding at the power block location, on the cliff above the Chesapeake Bay at elevation 84.6 ft (26.03 m), is not a credible threat from local watercourses due to intervening topography between those sources and the CCNPP site. These evaluations further conclude that flooding in the power block area of safety related SSCs due to local intense precipitation, or local probable maximum precipitation (PMP), will be prevented by the site drainage features engineered and constructed for that purpose. Still further, the evaluations conclude that the worst case low water event causes a drawdown of the Chesapeake Bay water level, at low tide, to elevation -6 ft (-1.85 m), which establishes the design low water level for adequate pump operation.

CCNPP Unit 3 is designed such that no actions need be captured in Technical Specifications or Emergency Operating Procedures to protect the facility from flooding or interruption of water supply for shutdown and cooldown purposes.

With respect to the limiting high water level at the UHS Makeup Intake Structure on the shore of Chesapeake Bay, the grade level for that structure is Elevation 10 ft (3.08 m) and the roof levels of the pump house and electrical enclosure are at elevation 26.5 ft (8.15 m). This structure, including the pump house and electrical enclosure, would thus be entirely submerged in the limiting case. However, the construction and normal operating configuration of the pump house and electrical enclosure is watertight, as described in Section 2.4.10. Thus, complete submergence of the UHS makeup intake structure will not adversely impact the functionality of the safety related equipment located within it.

Additionally, as described in U.S. EPR FSAR Section 9.2.5, the Essential Service Water System (ESWS) is designed for operation without makeup for 3 days following a design basis accident (DBA), and the UHS Makeup Water System makeup pumps are only required for ESWS makeup following those 72 hours post-DBA. Three days of cooling water inventory in the ESWS cooling tower basin is sufficient for shutdown and cooldown, should a potential flooding event require plant shutdown. Operation of the UHS Makeup Water System pumps is therefore not required for achieving cold shutdown. The minimum 3 day water inventory in the ESWS cooling tower basin, along with additional details of UHS/ESWS operation, are discussed in U.S. EPR FSAR Section 9.2.5 and Section 9.2.5.

The worst case low water event does not pose a potential of interrupting the supply of cooling water, as discussed in Section 2.4.11. The UHS Makeup Intake Structure includes a curtain wall and screens in the forebay that are designed to prevent ice blockages from stopping water flow to the ESWS makeup pump suction. Other potential low water conditions are also evaluated and accounted for in the establishment of the design low water level, as discussed Section 2.4.11.

Accordingly, no emergency protective measures are required to minimize the effect of hydrology-related events on safety-related facilities. Although the GHS makeup water system makeup pumps are not required for shutdown and cooldown, confirmation of watertight conditions will be accomplished through routine operator rounds and surveillance of the components comprising the watertight compartments.

2.4.14.3 References

CFR, 2007a. Technical Specifications, Title 10, Code of Federal Regulations, Part 50.36, 2007.

CFR, 2007b. General Design Criteria for Nuclear Power Plants, Criteria 2, Design Bases for Protection Against Natural Phenomena, Title 10, Code of Federal Regulations, Part 50, Appendix A, 2007.

CFR, 2007c. Reactor Site Criteria, Title 10, Code of Federal Regulations, Part 100, 2007.}

Table 2.4-1— {Monthly Streamflow for the Patuxent River at Bowie, MD, USGS Station No. 01594440, Patuxent River near Bowie, MD (1977 through 2005)}

	Discharge, cubic feet per second											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1977							131.1	126.5	77.8	220.7	314.3	748.2
1978	1,316	358.6	854.2	372.7	884.0	233.8	298.5	293.2	130.0	109.6	201.8	347.9
1979	1,290	1,232	817.5	523.8	460.8	611.6	220.0	531.9	1,358	1,093	458.8	384.5
1980	496.6	262.8	693.9	806.0	670.3	308.5	210.3	157.3	106.7	201.1	181.9	135.7
1981	119.2	319.5	173.2	188.1	236.6	209.7	145.6	90.7	116.9	117.4	107.6	158.3
1982	211.9	507.8	328.0	344.8	206.2	439.0	124.5	111.8	147.2	130.5	177.5	204.8
1983	173.2	317.8	683.0	1,247	719.9	766.9	176.6	137.5	110.4	285.8	424.2	1,030
1984	407.0	658.3	843.1	843.2	657.5	262.1	371.6	343.3	182.8	155.7	225.5	306.1
1985	173.7	536.1	203.9	167.4	238.4	193.6	134.5	104.5	211.4	163.0	276.1	214.9
1986	218.4	379.5	294.3	328.9	153.8	116.4	102.3	121.5	65.2	80.4	251.6	489.1
1987	428.3	286.2	365.1	459.8	291.2	192.4	176.1	86.1	379.0	160.0	316.4	368.6
1988	453.2	566.2	364.2	351.9	730.1	190.7	189.8	130. 4	119.0	114.1	278.6	180.0
1989	287.1	326.9	532.1	453.0	1,291	845.6	491.8	304.5	243.4	391.4	348.5	182.0
1990	462.1	424.5	374.8	581.8	578.4	324.7	209.9	306.3	125.6	332.6	305.6	459.4
1991	720.5	266.4	650.5	376.8	194.7	114.9	103.0	111.4	133.5	145.8	148.1	295.3
1992	217.8	251.6	399.5	260.9	221.2	234.6	248.4	153.7	188.0	167.7	350.5	537.5
1993	473.3	335.2	1,358	1,021	429.5	268.6	126.1	132.9	138.2	141.9	392.8	539.2
1994	657.6	930.1	1,318	648.5	347.4	182.9	239.7	319.0	202.3	153.4	193.9	237.6
1995	389.5	228.1	397.6	198.6	308.2	178.8	156.9	168.3	127.6	381.3	491.0	332.1
1996	1,035	549.5	566.6	598.3	575.9	654.4	579.2	474.8	701.6	614.1	747.2	1,357
1997	652.3	683.3	870.9	531.6	391.7	319.0	136.1	177.3	136.1	180.1	448.5	231.0
1998	605.6	890.7	1,124	648.5	669.1	361.7	163.3	124.8	111.2	114.6	123.4	128.1
1999	377.6	237.5	392.0	258.6	169.6	126.5	97.3	200.1	722.9	263.2	229.1	341.0
2000	269.0	420.7	511.9	581.3	271.0	318.9	293.9	225.3	362.9	166.1	171.1	312.5
2001	324.8	390.8	506.4	404.5	350.5	595.5	268.5	186.2	169.2	122.2	151.3	166.8
2002	177.4	141.6	244.2	291.5	269.9	135.1	116.5	98.6	124.4	239.7	371.2	477.7
2003	431.2	786.1	1,014	548.4	715.9	1,320	509.9	328.2	1,066	652.9	937.3	1,256
2004	449.5	919.2	507.0	697.3	437.5	347.3	364.4	336.8	254.7	178.3	343.5	372.1
2005	510.8	383.1	700.6	746.2	414.4	321.9	500.0	219.0	107.8			
Mean	476	485	610	517	460	363	237	210	273	253	320	421

Table 2.4-2— {Mean Daily Streamflow for the Patuxent River at Bowie, MD, USGS Station No. 01594440, Patuxent River near Bowie, MD (1977 through 2005)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	341	378	482	686	394	388	247	245	190	195	227	351
2	439	385	510	640	424	387	294	223	159	286	215	374
3	503	418	546	716	426	352	250	209	149	261	236	366
4	440	488	629	626	395	424	281	211	177	245	256	397
5	421	507	655	625	423	446	294	228	194	257	273	404
6	351	441	594	544	542	420	249	250	429	287	289	531
7	336	461	587	473	685	488	229	255	466	192	278	382
8	382	387	535	502	494	578	241	198	284	186	340	306
9	437	359	687	513	432	402	296	188	257	220	400	302
10	374	353	667	627	406	344	204	224	222	243	334	365
11	346	342	547	614	417	272	196	195	209	289	338	458
12	404	415	467	485	392	272	171	305	199	202	342	675
13	435	505	428	490	403	301	256	323	195	174	366	485
14	422	398	468	472	366	363	316	279	213	171	306	673
15	484	460	504	461	361	337	288	215	155	255	334	593
16	401	441	447	614	508	293	202	187	261	213	268	492
17	351	420	440	608	664	313	225	176	482	230	325	441
18	364	453	548	554	562	347	196	175	355	246	296	461
19	487	477	570	542	478	375	194	161	382	294	236	527
20	726	474	569	479	443	444	206	183	287	310	308	432
21	668	453	666	403	419	636	233	221	201	274	312	356
22	521	485	884	418	398	569	199	194	276	289	293	388
23	452	665	646	381	468	373	218	169	386	211	338	371
24	494	825	789	377	524	357	209	160	339	275	298	399
25	646	679	631	406	505	324	209	158	257	239	252	513
26	705	694	521	391	565	270	254	188	353	284	305	469
27	795	686	714	432	547	216	248	191	361	310	350	308
28	616	556	848	525	408	196	299	245	308	391	384	282
29	590	461	872	491	384	193	258	192	249	282	635	327
30	433		768	417	434	206	194	184	196	279	476	308
31	394		703		395		203	191		245		321

Table 2.4-3— {Maximum Daily Streamflow for the Patuxent River at Bowie, MD, USGS Station No. 01594440, Patuxent River near Bowie, MD (1977 through 2005)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	1,140	1,040	2,210	2,040	1,130	1,000	991	1,060	615	940	1,280	1,250
2	2,460	1,100	2,270	1,680	1,320	1,570	1,680	986	575	2,960	837	2,730
3	3,160	959	3,090	4,510	1,400	1,220	1,250	744	557	2,170	778	2,290
4	1,360	2,790	3,330	2,780	1,190	2,940	1,810	917	785	2,480	936	2,000
5	995	3,320	4,480	1,850	1,260	2,930	1,450	1,070	900	2,370	997	1,930
6	1,170	2,550	2,290	1,520	2,350	1,120	1,020	646	7,350	2,470	1,430	4,430
7	932	4,390	2,120	1,000	8,400	1,790	1,050	1,520	7,500	1,430	1,480	1,850
8	1,400	2,700	1,660	1,220	4,020	3,950	896	642	2,780	1,430	2,650	1,820
9	1,920	1,400	3,170	1,160	1,620	2,520	2,750	499	1,800	1,690	4,190	1,660
10	1,650	1,260	3,780	2,320	1,040	1,650	660	1,240	1,460	1,740	3,360	1,310
11	777	1,400	2,490	3,430	1,460	1,160	899	817	1,180	3,350	1,730	2,240
12	2,180	1,310	1,330	1,600	1,240	1,110	599	1,880	1,490	1,220	1,200	5,240
13	2,310	3,750	1,270	1,700	2,010	1,270	1,210	1,360	938	815	1,590	2,670
14	1,560	1,440	1,640	1,500	1,250	2,070	3,800	1,940	1,520	632	934	5,220
15	3,960	2,140	1,490	1,220	1,580	1,610	1,230	722	602	1,560	2,470	2,800
16	1,270	2,270	1,130	3,730	3,630	1,220	631	638	2,740	881	1,360	1,900
17	1,080	1,300	1,030	3,180	4,560	1,280	1,460	654	7,110	1,140	1,700	1,680
18	1,500	1,620	3,350	1,890	2,940	1,480	741	495	1,840	1,190	1,630	2,360
19	1,910	1,370	1,870	1,660	1,550	2,210	534	334	4,940	2,030	593	5,700
20	6,350	1,600	1,750	1,220	1,010	3,000	901	568	3,240	2,860	3,010	3,470
21	4,170	1,600	3,190	1,310	1,640	4,280	1,510	1,300	1,040	1,840	2,180	1,410
22	3,920	1,300	3,440	1,450	1,200	3,630	742	932	1,870	2,300	1,330	1,380
23	2,850	5,600	2,140	1,220	3,000	1,480	975	572	3,450	575	1,200	1,780
24	2,610	4,540	3,770	964	2,170	2,110	768	526	4,890	1,410	1,630	1,460
25	4,650	4,500	2,450	1,880	1,830	1,370	1,350	488	1,900	900	845	2,500
26	4,430	8,000	1,350	974	2,690	826	1,560	1,030	2,110	980	1,390	2,600
27	8,860	8,470	3,720	931	2,580	614	1,260	1,560	1,400	1,220	1,290	830
28	4,430	4,430	3,420	1,830	1,310	432	1,940	1,830	2,330	3,020	1,720	768
29	4,110	918	3,440	1,980	893	396	1,850	1,000	1,520	2,000	5,190	1,380
30	1,340		3,620	1,390	2,530	479	718	833	664	2,600	2,720	964
31	1,080		2,010		1,500		638	800		1,490		1,550

Table 2.4-4— {Minimum Daily Streamflow for the Patuxent River at Bowie, MD, USGS Station No. 01594440, Patuxent River near Bowie, MD (1977 through 2005)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	113	105	132	183	122	121	79	69	67	59	82	98
2	115	158	136	182	122	118	88	68	71	64	107	119
3	123	151	169	171	176	115	85	66	71	66	107	118
4	114	148	165	159	173	112	82	66	70	63	105	117
5	121	140	180	152	157	109	79	65	74	63	106	115
6	118	136	175	155	150	110	77	73	75	60	107	110
7	118	128	166	153	143	111	76	70	72	57	106	105
8	119	145	161	140	135	111	76	70	72	57	107	105
9	117	145	157	147	126	108	78	70	69	58	108	107
10	115	136	169	158	120	105	81	73	66	57	105	103
11	107	133	160	157	128	105	81	73	65	57	104	98
12	104	134	150	158	128	105	79	73	64	58	102	99
13	105	141	161	156	115	108	79	74	62	63	98	101
14	104	133	156	154	110	102	85	73	61	76	99	103
15	106	132	147	153	106	99	81	73	59	76	99	124
16	111	134	151	153	102	99	80	71	58	77	101	126
17	112	136	151	149	100	98	78	75	56	77	100	123
18	112	134	149	143	98	94	79	74	56	73	99	120
19	111	132	143	143	105	92	74	70	56	71	97	118
20	112	130	143	140	149	94	73	70	57	71	97	120
21	122	135	139	136	144	105	79	69	60	70	98	106
22	130	135	142	134	139	96	80	66	59	70	95	109
23	130	133	138	131	135	86	79	67	59	71	117	116
24	130	133	137	130	132	87	76	67	57	71	102	115
25	120	134	134	138	120	87	81	66	59	70	96	115
26	120	132	130	127	114	86	78	65	60	84	96	114
27	110	139	131	124	108	81	77	65	60	105	96	114
28	110	132	131	127	119	80	75	64	59	108	94	120
29	100	222	129	127	133	90	73	62	59	106	95	124
30	100		159	123	127	88	77	68	58	96	94	118
31	100		164		123		72	70		86		111

Table 2.4-5— {Monthly Streamflow for St. Leonard Creek at St. Leonard, MD, USGS Station No. 01594800, St. Leonard Creek near St. Leonard, MD (1956 through 2003)}

Discharge, cubic feet per second												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1956												6.74
1957	6.02	8.99	12.5	7.7	4.11	2.46	1.57	4.7	7.04	4.15	4.96	11.9
1958	13.3	15.2	22.9	26.1	26.1	13.9	10.8	14.9	9.1	9.65	8.46	8.78
1959	9.2	7.59	8.63	10.1	5.93	4.26	7.81	4.73	2.44	4.18	8.12	7.61
1960	7.98	9.68	8.89	11.8	13.5	9.57	10.5	8.23	13.1	10.4	11	10.9
1961	12.9	24.8	22	20.3	16.5	9.88	6.53	4.63	2.84	3.76	4.37	6.79
1962	7.69	7.51	12.1	14	7.45	6.39	3.85	2.78	3.03	3.79	10.1	6.49
1963	7.16	6.31	12.3	7.46	5.67	8.91	2.3	1.14	2.64	2.31	7.65	5.58
1964	9.67	10.5	9.49	10.8	6.16	3.93	3.45	1.37	1.71	4.06	5.12	5.88
1965	6.58	7.33	9.26	8.59	4.49	4.88	3.56	3.12	2.44	2.69	3.06	3.23
1966	4.33	9.53	5.55	5.49	5.32	1.72	0.8	0.326	4.59	4.42	3.08	4.99
1967	5.19	5.91	6.43	4.29	5.82	2.5	2.14	3.45	1.31	1.73	2.41	7. 23
1968	8.75	3.69	9.09	5.43	4.94	5.16	1.17	2.59	1.94	-	-	-
2000	-	-	-	-	-	-	-	-	-	3.35	4.34	6.2
2001	8.94	11.2	11.4	8.65	9.58	9.82	6.91	5.43	2.44	1.91	2.92	3.11
2002	4.25	3.45	4.73	4.32	3.76	1.14	0.074	0.415	1.63	1.93	5.7	6.26
2003	4.89	8.14	11.3	8.21	9.35	9.92	5.49	4.8	8.73			
Mean	7.8	9.3	11	10	8.6	6.3	4.5	4.2	4.3	4.2	5.8	6.8

Table 2.4-6— {Mean Daily Streamflow for St. Leonard Creek at St. Leonard, MD, USGS Station No. 01594800, St. Leonard Creek near St. Leonard, MD (1956 through 2003)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	10	8	13	12	9	7	3.5	4.1	3.8	5.3	5.1	4.8
2	8.3	7.1	9.8	11	9.1	9.6	3.6	3.1	3.5	4.1	5.7	4.5
3	7.1	6.4	9.7	10	8.4	14	4.3	3.4	3.6	3.6	6.3	5.9
4	6.7	8.5	8.9	9.8	8	7.9	3.9	3.9	3.4	3.6	4.9	6.6
5	5.9	9.3	11	10	9.6	7.2	3.7	4.8	2.9	3.5	4.6	5.5
6	8.1	8.9	12	9.9	8.5	6.2	4.2	4.5	2.6	4.6	6.7	6.2
7	9.6	9	10	11	11	7.4	3.4	3.3	6.7	4.4	11	5.6
8	7.1	10	11	12	9.9	7.7	4.3	5	2.9	3.6	5.2	5.5
9	7.6	9.6	11	11	9.1	5.8	4.3	2.9	2.7	3.9	4.7	7
10	7.6	8	8.6	9.8	7.5	6.5	4.3	3.1	3.9	3.2	8	6
11	6.6	8.2	8.4	13	9.3	5.2	4.9	3.8	6.2	2.9	4.9	6.7
12	6.4	8.7	13	11	8.5	5.3	5.4	3.8	10	2.8	4.9	9.5
13	6.6	9.9	10	13	7.5	5.8	5	4.8	4.6	2.8	5	7
14	15	8.7	10	11	7.3	7.6	5.8	3.9	4.4	3.7	4.6	7.6
15	10	8.2	8.9	9.3	7	5.5	7.4	2.9	3	3.7	4.7	6.3
16	7.7	9.9	9	9.4	7.4	5.4	5.6	3	3.6	3.4	4.5	8.2
17	6.5	9.3	11	9.2	6.5	5.6	3.4	3.5	4.4	4.4	5.3	8.5
18	6.1	8.8	12	9	7.3	5.2	3.3	2.5	4.1	3.7	5.4	7.8
19	6.5	14	12	9.1	7.8	5.7	3.2	3	5.5	6.1	5.6	5.7
20	9.7	9	17	9.8	8.1	6.3	3	4.8	4.9	5.5	5.2	5.9
21	8.9	8.6	16	9	6.9	6.8	3.4	3	8.4	4	4.7	7
22	8.4	9.3	15	9.4	8.2	5.4	3.1	3.5	3.9	6.1	5.9	5.2
23	8.3	11	13	12	8.5	5.2	3.6	3.2	4.1	4.1	5.2	6.3
24	7.8	9.1	11	9	6.7	6	4.5	4.8	3	4.3	7.2	6.6
25	8.9	10	10	9.1	7.3	6.2	3.5	17	3.1	3.5	7. 3	6.7
26	6.7	11	11	8.4	11	5.1	3.9	6.5	2.9	4.1	8.3	7.4
27	6.7	12	11	8.8	9.1	5.5	5.4	4.6	4.8	3.6	5.3	6.8
28	7	11	9.5	11	11	4.1	3.4	3.3	3.4	5.6	5	7.6
29	6.6	8.4	9.1	9.3	13	4.1	4.5	3.4	4.6	6.2	6.5	9.9
30	6.6		11	10	7.8	3.6	12	2.8	4.6	4.5	6.2	9.9
31	6.3		11		8.9		4.1	3.3		4.1		6

Table 2.4-7— {Maximum Daily Streamflow for St. Leonard Creek at St. Leonard, MD, USGS Station No. 01594800, St. Leonard Creek near St. Leonard, MD (1956 through 2003)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	54	28	43	39	22	16	8.7	14	11	29	21	9.4
2	24	18	20	31	27	33	8.7	9.4	13	10	22	8.7
3	18	13	18	25	22	71	15	9.1	10	8.7	22	23
4	12	40	18	23	25	23	11	13	13	9.1	18	19
5	11	30	29	41	54	14	9.8	16	9.4	7.9	15	16
6	27	22	22	30	38	13	16	21	9.1	24	19	19
7	41	25	25	24	51	28	10	11	60	19	60	13
8	11	30	28	43	32	27	13	38	11	9.6	14	17
9	19	50	32	21	28	16	12	9.4	9.1	13	10	32
10	17	29	18	23	25	30	13	7.9	23	7.9	49	24
11	11	22	17	63	46	15	14	8.7	27	6.9	13	16
12	13	22	57	28	32	16	25	15	115	6.6	11	26
13	11	49	21	50	21	24	16	23	18	6.9	15	15
14	90	26	28	35	20	46	19	18	17	14	10	15
15	33	20	18	24	20	12	53	9.1	7.9	7.5	9.8	11
16	16	35	20	23	19	11	34	8.7	14	6.9	9.8	42
17	13	30	30	21	19	18	9.4	15	16	15	17	35
18	12	28	40	19	18	11	8.3	7.5	16	8.5	14	21
19	13	57	29	19	30	17	7.9	9.8	27	41	10	12
20	35	24	95	20	35	15	7.5	28	30	23	9.4	12
21	23	24	48	22	21	22	9.1	11	69	9.8	9.4	25
22	21	26	34	21	24	17	9.1	13	11	40	25	9.5
23	15	47	47	73	31	14	19	13	24	19	11	15
24	21	27	31	30	17	24	22	23	11	16	22	12
25	40	26	27	24	30	16	12	140	8.8	8.3	26	16
26	20	22	29	22	45	18	9.8	32	7.2	8.3	36	26
27	13	46	33	24	35	28	20	18	23	7.9	11	16
28	12	41	26	40	44	11	11	16	11	39	9.8	28
29	13	11	22	26	53	10	18	14	17	47	15	33
30	14		27	27	21	9.1	124	12	19	14	20	36
31	14		33		37		16	12		13		12

Table 2.4-8— {Minimum Daily Streamflow for St. Leonard Creek at St. Leonard, MD, USGS Station No. 01594800, St. Leonard Creek Near St. Leonard, MD (1956 through 2003)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	1.1	3.5	2.1	4.4	3.5	1.4	0.18	0	0	0.2	1.1	2.4
2	1	3.7	2.8	3.9	3.3	1.1	0.13	0	0	0.15	1.2	2.4
3	1.4	3.4	3.7	3.7	3.5	0.64	0.13	0	0	0.1	1.2	2.6
4	2.1	3.4	4.4	3.7	3.5	0.64	0.13	0	0	0	1.3	2.7
5	2.5	2.8	4	3.7	3.3	0.76	0.1	0	0	0	2	2.8
6	4.2	3.2	3.9	3.5	3.3	1.4	0.08	0.06	0	0	2.1	2.8
7	3.8	3	3.9	3.5	3.1	1.6	0	0	0	0	2.1	2.8
8	3.6	3.5	3.9	3.3	2.9	1.8	0	0	0	0	2.1	2.9
9	3.4	3.6	3.8	3.3	2.9	1	0	0	0	0	2.1	2.9
10	3.7	3.4	4.1	3.3	2.9	1	0	0	0	0.1	2.1	2.8
11	3.3	3.2	4	3.3	2.7	0.64	0	0	0.01	0.2	2.1	2.9
12	3	3	3.9	3.6	3.1	0.64	0	0	0	1	2.1	2.9
13	3.3	2.8	4.4	3.6	3.1	0.9	0	0	0	1.1	2.1	2.6
14	3.3	2.8	4.2	3.4	2.7	1	0.13	0	0	0.5	2.1	3
15	3.2	3	4.1	3.4	2.7	1.1	0.13	0	0.13	0.39	2.3	2.6
16	3	3.2	3.9	2.6	2.9	1	0.06	0	0.4	1.5	2	2.1
17	2.9	3.8	4	2.3	2.6	0.9	0.06	0	0.2	1.5	2.1	2.3
18	2.6	3.6	4.1	1.9	2.3	0.76	0.01	0	0.2	1.5	2.1	3.1
19	2.8	3.5	4.1	2.4	2.6	0.52	0	0	0.23	1.5	2.3	2.7
20	3.1	2.9	3.9	3.4	3.1	0.64	0	0	0.13	0.62	2	2.6
21	3	2.9	3.9	2.9	2.7	0.77	0	0	0.13	0.48	2	2.1
22	3.5	2.8	3.9	4.1	2.7	0.65	0	0.01	0.06	0.35	2	1.9
23	3.5	2.3	3.9	3.7	2.4	0.46	0	0.06	0.06	0.35	2.4	2.1
24	3.1	2.2	4.1	3.7	3.2	0.46	0.13	0	0.01	0.35	2.4	3.3
25	3.4	2.3	3.9	3.3	2.8	0. 2	0.01	0	0	0.62	2.6	3.5
26	3.7	2.5	4	3.9	2.7	0.2	0.1	0	0.34	1.8	2.6	2.9
27	3.8	2.9	4.4	4.4	2.5	0.23	0.2	0	0.4	1.7	2.4	2.3
28	3.6	1.8	3.9	4.6	2.1	0.2	0.3	0	0.4	1.6	2.3	1.9
29	3.5	5	3.9	3.9	2.1	0.67	0.23	0	0.52	1.3	2.3	2.1
30	3		3.9	3.7	1.8	0.47	0.01	0	0.32	1.2	1.7	1.5
31	2.5		4.5		1.7		0	0		1.2		1.2

Table 2.4-9— {Estimated Monthly Mean Inflow to the Chesapeake Bay Based on Three Reference Stations (1951 through 2000)}

(Page 1 of 2)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1951	119,400	175,400	148,100	179,100	66,000	87,900	42,100	22,700	16,300	13,600	41,600	82,200	82,100
1952	173,500	123,300	182,100	180,100	142,100	47,000	33,500	30,400	38,800	16,800	68,300	97,100	94,400*
1953	136,000	111,100	170,700	129,000	123,600	74,400	23,700	17,000	12,700	10,800	17,900	48,000	72,800
1954	39,700	71,800	135,100	95,200	99,900	45,400	19,100	14,000	13,600	41,600	51,100	78,300	58,700
1955	83,300	79,400	208,800	90,300	46,300	44,900	19,100	93,400	26,800	79,700	74,000	33,300	73,400
1956	27,400	107,900	161,400	161,500	82,800	45,000	49,900	39,500	30,700	36,400	69,400	101,900	76,000
1957	76,400	109,900	114,800	183,800	62,700	37,500	19,500	11,900	17,900	19,700	30,600	93,000	64,400
1958	89,100	72,900	160,900	238,900	154,400	51,500	43,000	40,400	24,900	25,400	37,400	37,500	81,400*
1959	72,800	71,900	96,700	138,200	69,800	46,100	20,600	18,900	19,100	55,400	70,500	117,700	66,400
1960	95,500	118,100	84,000	230,700	145,700	92,900	32,100	26,100	42,600	22,100	24,300	20,100	77,400*
1961	30,000	144,300	181,400	202,900	111,000	55,700	31,700	29,200	23,200	38,000	31,500	63,800	78,000
1962	78,500	71,800	207,200	195,300	61,000	38,800	21,900	16,800	13,700	31,500	60,500	41,700	69,800
1963	65,800	43,200	228,600	86,400	55,700	40,600	17,200	12,200	10,600	8,600	18,800	38,200	52,400
1964	103,400	80,600	222,700	127,300	88,700	23,600	16,300	11,400	7,800	13,000	14,000	33,200	61,900
1965	65,200	110,300	118,000	112,900	59,300	23,900	13,000	12,000	11,700	21,300	20,500	25,500	49,000
1966	29,600	110,200	130,100	66,500	105,800	30,700	10,500	9,300	23,600	35,000	30,500	61,400	53,300
1967	61,000	67,000	205,100	101,300	120,900	38,700	30,600	47,800	27,500	51,000	67,000	104,600	77,200
1968	62,800	86,600	129,100	64,800	81,200	86,000	31,500	16,900	23,700	19,700	67,900	52,600	60,100
1969	46,900	58,800	68,800	93,100	57,300	39,100	36,200	80,700	23,800	17,300	44,300	62,200	52,300
1970	66,200	132,000	95,800	218,500	73,500	38,200	39,100	24,400	17,300	29,000	111,800	80,200	76,500
1971	74,100	163,000	167,400	73,300	104,500	68,000	22,900	32,400	32,400	54,500	47,300	108,800	78,600
1972	82,300	107,700	183,500	159,600	145,300	324,600	117,100	42,400	19,900	58,600	131,800	209,000	131,700
1973	108,400	144,800	138,500	174,700	127,000	76,400	44,900	34,500	30,100	34,600	52,300	176,000	94,900
1974	153,900	88,600	109,000	156,000	81,000	56,500	40,100	27,400	46,800	25,200	38,500	99,400	76,800
1975	97,600	155,600	185,000	96,700	121,800	77,700	56,100	30,200	155,100	118,000	77,400	66,000	102,700
1976	118,200	155,400	104,400	85,900	59,400	74,400	41,900	33,600	22,900	173,900	73,400	68,300	84,100
1977	31,100	34,500	195,600	152,600	49,830	23,800	29,700	22,600	44,600	97,400	124,100	155,100	80,400

Table 2.4-9— {Estimated Monthly Mean Inflow to the Chesapeake Bay Based on Three Reference Stations (1951 through 2000)}

(Page 2 of 2)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1978	171,800	75,800	231,600	158,500	182,700	53,500	39,900	46,100	25,300	22,500	25,600	61,900	91,700
1979	188,700	131,200	253,400	122,200	94,600	81,500	32,600	34,300	98,800	132,600	107,800	87,200	113,700
1980	88,800	42,900	151,000	205,200	104,800	40,800	28,800	21,000	15,000	14,000	24,200	31,100	64,000
1981	17,800	151,900	58,600	69,600	78,900	68,900	36,100	20,600	23,200	31,100	50,000	44,200	53,500
1982	60,900	134,900	169,900	123,000	54,100	147,200	42,400	25,900	15,700	17,300	25,700	58,500	72,400
1983	39,500	100,800	128,500	264,000	149,000	64,400	33,300	16,900	13,000	26,800	55,100	167,000	88,000
1984	56,000	216,300	151,000	251,000	134,000	76,000	62,700	73,600	27,900	22,800	33,200	92,300	99,100
1985	62,100	97,000	95,100	86,000	58,800	40,800	25,700	36,600	21,100	28,700	164,000	104,300	68,000
1986	53,700	125,000	169,000	95,800	52,400	45,900	29,700	31,900	17,400	25,900	72,400	114,200	69,100
1987	68,200	69,500	121,100	226,000	76,500	38,600	36,200	15,400	73,600	33,100	47,600	82,100	73,800
1988	66,500	93,200	78,300	70,300	139,000	36,400	21,000	17,600	25,200	16,900	47,200	31,200	53,400
1989	49,100	54,100	97,300	104,900	223,900	117,800	87,000	39,800	47,700	76,600	71,800	37,500	84,200
1990	94,100	153,600	78,600	104,300	113,500	67,200	50,500	38,100	30,300	135,400	80,400	134,800	89,800
1991	167,200	94,600	156,500	110,400	58,800	24,600	24,400	21,700	13,200	14,700	21,900	51,900	63,300
1992	58,000	54,600	124,800	134,600	77,600	68,400	43,300	37,900	38,200	35,700	92,600	103,600	72,400
1993	125,300	58,500	230,700	380,700	89,000	35,800	20,900	18,000	20,400	24,000	78,600	125,200	100,600
1994	69,500	152,400	298,000	230,500	87,500	45,300	43,800	83,900	37,400	28,500	41,300	83,300	99,800
1995	128,600	55,000	88,100	58,400	61,700	77,000	60,500	20,700	13,200	63,500	80,100	69,800	64,900
1996	244,600	142,200	152,200	139,000	155,900	86,300	54,100	57,600	142,000	97,900	130,000	219,900	135,200
1997	77,500	109,700	160,300	80,500	61,300	62,200	25,000	19,000	20,300	18,600	81,400	55,800	64,000
1998	199,700	235,900	223,100	178,700	152,900	57,300	41,600	20,900	14,100	17,500	14,400	16,400	97,700
1999	80,200	70,500	108,000	98,800	45,000	17,400	13,100	13,600	47,300	48,700	33,200	66,400	53,500
2000	44,500	85,200	141,500	149,000	83,300	70,000	34,000	34,200					

Table 2.4-10— {Details of Brighton and Rocky Gorge Dams}

Information	Brighton Dam	Rocky Gorge Dam
Record Number	26707	26722
Dam Name	Brighton Dam	Rocky Gorge Dam
Other Dam Name	Tridelphia Lake Dam	Duckett Dam
State ID	5	20
NID ID	MD00005	MD00020
Longitude (decimal degree)	-77.005	-76.8767
Latitude (decimal degree)	39.1933	39.1167
County	Montgomery	Prince Georges
River	Patuxent River	Patuxent River
Owner Name	Washington Suburban Sanitary Commission	Washington Suburban Sanitary Commission
Year Completed	1943	1953
Year Modified	1999	1986
Dam Length (ft, top of the dam)	995	840
Dam Height (to the nearest ft)	80	134
Maximum Discharge (cfs)	83,000	65,200
Maximum Storage (ac-ft)	27,000	22,000
Normal Storage (ac-ft)	19,000	17,000
Surface Area (acres)	800	773
Drainage Area (mi^2)	77.3	132.0
Down Stream Hazard Potential	High	High
State Regulated Agency	MD Water Management Administration	MD Water Management Administration
Spillway Type	Controlled	Controlled
Spillway Width (to the nearest ft)	260	190

Table 2.4-11— {Permitted Surface Water Withdrawals in Calvert County}

Owner	Permitted Withdrawal		Distance$^{(1)}$ (miles)	Intake Location$^{(2)}$		Water Source	Use Category	Remarks
	Max. Daily (gpd)	Yearly Average (gpd)		North × 10^3 ft	East × 10^3 ft			
Swann, J. Allen	183,000	31,000	22	310	890	Patuxent River	Irrigation	Farming
Morgan State University ERC	250,000	150,000	4	210	940	Patuxent River	Institutional	Environmental research facility
Beckman, Inc.	3,000	400	20	310	900	Chesapeake Bay	Irrigation	Hydroseeding
Dominion Cove Point LNG, LP	7,200,000	64,000	4	200	970	Chesapeake Bay	Hydrostatic testing and fire protection	Hydrostatic testing
Dominion Cove Point LNG, LP	15,000	3,500	4	200	970	Chesapeake Bay	Hydrostatic testing and fire protection	Horizontal drilling for pipeline
Dominion Cove Point LNG, LP	3,650,000	10,000	16	270	890	Patapsco River	Hydrostatic testing and fire protection	Hydrostatic testing
Calvert County Commissioners	5,000	150	8	180	950	Patuxent river	Institutional	Calvert Marine Museum
Cheseldine, Ronald W.	3,000	1,500	20	320	930	Chesapeake Bay	Aquaculture	Commercial crabbing operation
C&M Excavating Inc.	1,000	400	19	310	910	Chesapeake Bay	Irrigation	Hydroseeding
C&M Excavating Inc.	2,000	400	19	310	910	Chesapeake Bay	Irrigation	Hydroseeding
Chesapeake Biological Laboratory	864,000	864,000	10	170	950	Patuxent River	Institutional	Laboratory use
Calvert Cliffs Nuclear Power Plant, LLC.	3,600,000,000	3,500,000,000	-	220	960	Chesapeake Bay	Nuclear power generation	Cooling water

Notes:

(1)Distance from the CCNPP site.

(2)Maryland State Plane 1927 coordinate system. The accuracy of the location is ±10,000 ft. The Maryland State Plane 1927 coordinate system is based on North American Datum of 1927 (NAD27). NAD27 is a surface (or plane) to which horizontal positions in the U.S., Canada and Mexico are surveyed and referenced.

Table 2.4-12— {Sub-Basin Drainage Areas}

Sub-Basin	Drainage Area (Acres)	Drainage Area (sq mi)
North 1	10.45	0.0163
North 2	6.83	0.0107
Center 1	14.06	0.0220
Center 2	11.08	0.0173
East 1	6.95	0.0109
East 2	0.89	0.0014
Total	50.26	0.0785

Table 2.4-13— {HEC-HMS Sub-Basin Site PMP Peak Discharges}

Hydrologic Element	Drainage Area (mi^2)	Peak Discharge (cfs)	Runoff Volume (ac-ft)
Center Ditch	0.022	810.6	21.4
Center Junction	0.041	1,467.8	39.6
Center 1	0.022	810.6	21.4
Center 2	0.017	605.6	16.8
East Junction-1	0.052	1,869.4	50.2
East 1	0.011	401.6	10.6
East 2	0.001	51.6	1.4
North Ditch	0.016	600.6	15.9
North Junction	0.027	953.4	26.2
North 1	0.016	600.6	15.9
North 2	0.011	352.8	10.4
Center Ditch	0.022	810.6	21.4
Center Junction	0.041	1,467.8	39.6
Center 1	0.022	810.6	21.4
Center 2	0.017	605.6	16.8

Table 2.4-14— {HEC-RAS PMP Peak Discharges}

Ditch	Reach	Cross Section	Discharge (cfs)
Center Ditch	1	700	810.6
Center Ditch	1	600	911.5
Center Ditch	1	500	1,012.5
Center Ditch	1	400	1,113.4
Center Ditch	1	300	1,214.3
Center Ditch	1	200	1,315.3
Center Ditch	1	100	1,416.2
East Ditch	2	150	51.6
East Ditch	1	1,200	1,467.8
East Ditch	1	1,100	1,504.3
East Ditch	1	1,000	1,540.8
East Ditch	1	900	1,577.3
East Ditch	1	800	1,613.8
East Ditch	1	700	1,650.3
East Ditch	1	600	1,686.8
East Ditch	1	500	1,723.4
East Ditch	1	400	1,759.9
East Ditch	1	300	1,796.4
East Ditch	1	200	1,832.9
East Ditch	1	100	1,869.4
North Ditch	1	600	600.6
North Ditch	1	500	671.2
North Ditch	1	400	741.7
North Ditch	1	300	812.3
North Ditch	1	200	882.8
North Ditch	1	100	953.4

Table 2.4-15— {PMP Maximum Water Levels}

Ditch	Station	Discharge (cfs)	Minimum Channel Elevation (ft)	Maximum Water Level (ft)	Channel Velocity (ft/s)	Froude Number
North	600	600.6	76.0	79.8	3.1	0.3
	500	486.9	76.0	79.8	2.6	0.3
	400	388.7	76.0	79.7	2.1	0.2
	300	301.5	76.0	79.7	1.6	0.2
	200	219.9	76.0	79.7	1.2	0.1
	100	139.9	76.0	79.7	0.8	0.1
	0	0.9	76.0	79.7	0.0	0.0
East	1200	1,467.8	74.0	80.1	5.5	0.5
	1100	1,297.2	74.0	80.0	5.0	0.4
	1000	1,092.8	74.0	79.9	4.3	0.4
	900	921.5	74.0	79.8	3.7	0.3
	800	773.7	74.0	79.8	3.2	0.3
	700	641.7	74.0	79.7	2.7	0.2
	600	519.6	74.0	79.7	2.2	0.9
	500	404.8	74.0	79.7	1.7	0.1
	400	290.1	74.0	79.7	1.2	0.1
	300	176.4	74.0	79.7	0.7	0.1
	200	61.9	74.0	79.7	0.3	0.0
	100	1.9	74.0	79.7	0.0	0.0
	0	1.9	74.0	79.7	0.0	0.0
Center	700	810.6	76.0	81.6	1.9	0.2
	600	911.5	76.0	81.5	2.2	0.2
	500	1,012.5	76.0	81.5	2.5	0.2
	400	1,113.4	76.0	81.4	2.8	0.2
	300	1,214.3	76.0	81.3	3.2	0.3
	200	1,315.3	76.0	81.2	3.6	0.3
	100	1,416.2	76.0	81.0	4.2	0.4
	0	1,416.2	76.0	80.9	3.4	0.3

Table 2.4-16— {Safety-Related Facility Entrance Elevation Summary}

Safety-Related Facility	Entrance Elevation (ft)	Associated Cross Section	Ditch	PMP Peak Water Elevation (ft)	Freeboard (ft)
Northwestern UHSs	98.6 ft	600	North	79.8	18.8
Southeastern UHSs	98.6 ft	300	Center	81.3	17.3
North Diesel Generator	85.1 ft	500	North	79.8	5.3
South Diesel Generator	85.1 ft	500	Center	81.5	3.6
Reactor Complex*	84.6 ft	400	North	79.7	4.9
		400	Center	81.4	3.2

* Includes containment, fuel and safeguards buildings

Table 2.4-17— {Bio-Retention Ditch Dimensions}

Ditch	Invert Elevation (ft, NGVD 29)	Top of Ditch Elevation (ft, NGVD 29)			
		Left Bank	Right Bank	Side Slopes	Bottom Width (ft)
Center	76.0	79.0	80.4	3:1	47.0
North	76.0	79.0	79.0	3:1	37.0
East	74.0	79.0	79.0	3:1	25.0

Table 2.4-18— {Point (1 mi2) Probable Maximum Precipitation Depths}

Time (min)	PMP Depth in (cm)
60	18.48 (46.94)
30	13.86 (35.20)
15	9.70 (24.64)
5	6.15 (15.62)

Table 2.4-19— {PMP Peak Flow Rates}

Hydrologic Element	Drainage Area		Peak Discharge		Time of Peak (hr)
	mi^2	(km^2)	ft^3/sec	(m^3/sec)	
MD 2/4 Culvert	2.283	(5.912)	21,790	(617.02)	1:15
Sub-Basin 1	0.894	(2.315)	14,855	(420.64)	0:50
Sub-Basin 2	0.831	(2.152)	11,742	(332.49)	1:00
Junction 1	0.558	(1.445)	9,891	(280.1)	0:50
Sub-Basin 3	0.138	(0.357)	3,222	(91.24)	0:45
Sub-Basin 4	0.420	(1.087)	7,236	(204.9)	0:50

Table 2.4-20— {PMF Flow Rates}

Cross Section	River Station	Contributing Sub-Basins	PMP Discharges ft^3/sec (m^3/sec)					
			Profile 1 (0:50)	Profile 2 (0:55)	Profile 3 (1:00)	Profile 4 (1:05)	Profile 5 (1:10)	Profile 6 (1:15)
17	8552	1	7236.4 (204.91)	7111.0 (201.36)	6405.1 (181.37)	5320.2 (150.65)	4301.9 (121.82)	3358.5 (95.102)
11	5952	1 and 2	9891.4 (280.09)	9126.3 (258.43)	7995.8 (226.41)	6557.5 (185.68)	5182.1 (146.74)	3947.1 (111.77)
7	3922	1, 2, and 3	19969.3 (565.468)	20469.1 (579.620)	19737.8 (558.912)	17919.2 (507.415)	15582.9 (441.258)	12947.2 (366.624)
3	894	1, 2, 3, & 4 *	11121.9 (314.937)	14761.3 (417.993)	18043.7 (510.941)	20421.8 (578.281)	21650.2 (613.065)	21790.4 (617.035)

Note:

*Measured at culvert outlet. Includes storage effects.

Table 2.4-21— {Johns Creek PMF Water Surface Elevations}

Cross Section	River Station	Profile	Discharge ft^3/sec (m^3/sec)	Water Surface Elevation ft as msl (m as msl)
17	8552	1	7,236.4 (204.91)	**65.02 (19.81)**
		2	7,111.0 (201.36)	64.88 (19.77)
		3	6,405.1 (181.37)	64.15 (19.55)
		4	5,320.2 (150.65)	62.96 (19.19)
		5	4,301.9 (121.82)	61.72 (18.81)
		6	3,358.5 (95.102)	60.40 (18.41)
16	7702	1	7,236.4 (204.91)	**60.20 (18.35)**
		2	7,111.0 (201.36)	60.08 (18.31)
		3	6,405.1 (181.37)	59.34 (18.09)
		4	5,320.2 (150.65)	58.11 (17.71)
		5	4,301.9 (121.82)	56.85 (17.33)
		6	3,358.5 (95.102)	55.62 (16.95)
15	7112	1	7,236.4 (204.91)	56.10 (17.10)
		2	7,111.0 (201.36)	**56.15 (17.11)**
		3	6,405.1 (181.37)	55.78 (17.00)
		4	5,320.2 (150.65)	55.09 (16.79)
		5	4,301.9 (121.82)	54.37 (16.57)
		6	3,358.5 (95.102)	53.66 (16.35)
14	6902	1	7,236.4 (204.91)	55.97 (17.06)
		2	7,111.0 (201.36)	**56.03 (17.08)**
		3	6,405.1 (181.37)	55.66 (16.96)
		4	5,320.2 (150.65)	54.98 (16.76)
		5	4,301.9 (121.82)	54.28 (16.54)
		6	3,358.5 (95.102)	53.59 (16.33)
13	6402	1	7,236.4 (204.91)	54.04 (16.47)
		2	7,111.0 (201.36)	**54.24 (16.53)**
		3	6,405.1 (181.37)	54.18 (16.51)
		4	5,320.2 (150.65)	53.89 (16.42)
		5	4,301.9 (121.82)	53.49 (16.30)
		6	3,358.5 (95.102)	53.06 (16.17)
12	6177	1	7,236.4 (204.91)	53.83 (16.41)
		2	7,111.0 (201.36)	**54.05 (16.47)**
		3	6,405.1 (181.37)	54.03 (16.47)
		4	5,320.2 (150.65)	53.78 (16.39)
		5	4,301.9 (121.82)	53.42 (16.28)
		6	3,358.5 (95.102)	53.01 (16.16)

Note:

Bold indicates maximum water level at the cross section.

Table 2.4-22— {Five Highest Historical Water Levels at Baltimore and Annapolis}

Baltimore			Annapolis		
Hurricanes	**Date**	**Above MHHW ft (m)**	**Hurricanes**	**Date**	**Above MHHW ft (m)**
Unnamed	August 1933	6.75 (2.056)	Isabel	September 2003	5.76 (1.756)
Isabel	September 2003	6.48 (1.976)	Unnamed	August 1933	5.55 (1.691)
Connie	August 1955	5.22 (1.591)	Connie	August 1955	4.09 (1.248)
Unnamed	August 1915	4.53 (1.381)	Hazel	October 1954	3.90 (1.190)
Hazel	October 1954	4.33 (1.319)	Fran	September 1996	3.48 (1.060)

Table 2.4-23— PMH Parameters

Location		Time after landfall	Central Pressure	Peripheral Pressure	Radius
Lat	Long	(hours)	mbar	mbar	Miles
36.3784	75.805	0	897	1020	29.9
36.4800	76.108	1	906	1020	36.7
36.6309	76.344	2	914	1020	35.4
36.8372	76.501	3	921	1020	34.1
37.0903	76.589	4	928	1020	32.9
37.3777	76.624	5	935	1020	31.7
37.6869	76.624	6	941	1020	30.6
38.0057	76.603	7	946	1020	29.5
38.3215	76.579	8	951	1020	28.4
38.6246	76.563	9	956	1020	27.4
38.9156	76.557	10	961	1020	26.4
39.1978	76.558	11	965	1020	25.4
39.4743	76.564	12	969	1020	24.5
39.7484	76.572	13	972	1020	23.6
40.0233	76.579	14	976	1020	22.8
40.3016	76.583	15	979	1020	22.0
40.5831	76.585	16	982	1020	21.2

Table 2.4-24— {Comparison of Surge Results}

Method	Primary Surge	Cross Wind Setup	Initial Rise	High Tide (NGVD 29)	Long Term Sea level Rise	PMSS (NGVD 29)
Empirical	15.2 ft (4.63 m)	0.9 ft (0.27 m)	1.1 ft (0.34 m)	2.2 ft (0.67 m)	1.1 ft (0.33 m)	20.4 ft (6.22 m)
SLOSH	13.2 ft (4.02 m)		1.1 ft (0.34 m)	2.2 ft (0.67 m)	1.1 ft (0.33 m)	17.6 ft (5.35 m)

Table 2.4-25— {Historical Tsunamis Arriving at the Shores of the Eastern U.S. and Canada}

Date	Country	City	Latitude	Longitude	Earthquake(1) Magnitude	Tsunami Cause	Maximum Tsunami Water Height
11/01/1755	Portugal	Lisbon	36.000	-11.000	-	Earthquake	98.4 ft (30.00 m) (Lagos) (2) 9.8 ft (3 m) (East Coast) (4)
06/27/1864	Canada	Avalon Peninsula, Newfoundland	46.500	-53.700	-	Earthquake	-
09/01/1886	USA	Charleston, SC	32.900	-80.000	Mw 7.7	Earthquake	-
09/01/1895	USA	High Bridge, NJ	40.667	-74.883	Mfa 4.3	Earthquake	-
10/11/1918	USA	Mona Passage, Puerto Rico	18.500	-67.500	Mw 7.3	Earthquake	20 ft (6.10 m) (Punta Agujereada) (2) 0.2 ft (0.06 m) (Atlantic City) (3)
11/18/1929	Canada	Grand Banks, Newfoundland	44.690	-56.000	Mw 7.4	Earthquake and Submarine Landslide	23 ft (7.00 m) (Taylor's Bay) (2) 2.2 ft (0.68 m) (Atlantic City) (3)
08/04/1946	Dominican Republic	Northeastern Coast	18.920	-68.940	Unk 8.1	Earthquake	16.4 ft (5.00 m) (Rio Boba) (2) -
08/08/1946	Dominican Republic	Northeastern Coast	19.710	-69.510	Unk 7.9	Earthquake	2 ft (0.60 m) (San Juan) (3) -
05/19/1964	USA	Long Island, NY	-	-	-	Submarine Landslide	0.92 ft (0.28 m) (Plum Island) (3) -
12/26/2004	Indonesia	Off West Coast of Sumatra	3.295	95.982	Mw 9.0	Earthquake	167 ft (50.90 m) (Labuhan) (2) 0.75 ft (0.23 m) (Atlantic City) (3)

Notes:
1. Mw is moment magnitude scale, Mfa is logarithmic magnitude scale, and Unk is unknown scale.
2. Tide gauge record.
3. Deep ocean gauge record.
4. Estimate from numerical simulation.

The data presented on this table is not consistent with the NOAA website, 4 events related to the New Madrid earthquakes are reported on the NOAA website} - New Madrid is located near the Mississippi River in Missouri. According to the tsunami records, New Madrid earthquakes generated several waves in the rivers. As this tsunami source is not located along the East Coast of the U.S. or in the Atlantic Ocean, this kind of tsunami would not affect the water level at the site. Thus, tsunami sources in New Madrid, MO are excluded in Table 2.4-25 to be coherent with its title "Historical Tsunamis arriving at the Shores of the Eastern U.S. and Canada."

Table 2.4-26— {Tsunami Wave Characteristics at the Entrance of the Chesapeake Bay}

Case	Amplitude	Period (seconds)	Source Location
1	13 ft (4 m)	3,600	Norfolk Canyon submarine landslide
2	10 ft (3 m)	3,600	Canary Island submarine landslide
3	3.1 ft (0.9 m)	5,200	Haiti earthquake

Table 2.4-27— {Summary of Numerical Analysis for the Tsunami Propagation}

Parameter	Value
Governing equation	Nonlinear shallow water equation and linear shallow water equation
Computational domain	223 (east-west) by 790 (north-south)
Grid space	1,181 ft by 1,181 ft (360 m by 360 m) square
Time step	5 seconds
Bathymetry data	NOAA Chesapeake Bay Digital Elevation Model (resolution: 98.4 ft by 98.4 ft (30 m by 30 m))
Reference water level	Local mean sea level of Chesapeake Bay Bridge Tunnel
Manning’s roughness coefficient	0.025

Table 2.4-28— {Simulated Maximum and Minimum Tsunami Magnitude}

Case No.	Tsunami Magnitude		Remarks
	Maximum Amplitude	Minimum Drawdown	
1	0.51 ft (0.155 m) 1.07 ft (0.326 m)	0.17 ft (0.051 m) 0.61 ft (0.186 m)	Nonlinear and bottom friction Linear without bottom friction
2	0.43 ft (0.131 m) 0.80 ft (0.245 m)	0.16 ft (0.049 m) 0.46 ft (0.139 m)	Nonlinear and bottom friction Linear without bottom friction
3	0.42 ft (0.127 m) 0.86 ft (0.262 m)	0.34 ft (0.103 m) 0.78 ft (0.237 m)	Nonlinear and bottom friction Linear without bottom friction

Table 2.4-29— {Estimated Peak Freezing Degree-Days and Ice Thickness from 1946 to 2006}

Water Year	Peak AFDD		Ice Thickness (inches)	Water Year	Peak AFDD		Ice Thickness (inches)
	°F days	Date			°F days	Date	
1946	74.2	24-Dec	6.9	**1977**	265.3	9-Feb	13.0
1947	38.3	11-Feb	5.0	**1978**	207.5	9-Mar	11.5
1948	159.4	11-Feb	10.1	**1979**	188.0	20-Feb	11.0
1949	17.2	27-Dec	3.3	**1980**	57.1	13-Feb	6.0
1950	13.5	28-Feb	2.9	**1981**	160.2	18-Jan	10.1
1951	47.8	11-Feb	5.5	**1982**	171.6	28-Jan	10.5
1952	25.5	20-Dec	4.0	**1983**	22.5	21-Jan	3.8
1953	5.5	29-Dec	1.9	**1984**	110.8	23-Jan	8.4
1954	26.7	14-Jan	4.1	**1985**	118.5	11-Feb	8.7
1955	46.7	5-Feb	5.5	**1986**	36.3	31-Jan	4.8
1956	27.4	22-Dec	4.2	**1987**	67.0	29-Jan	6.5
1957	57.3	19-Jan	6.1	**1988**	123.4	16-Jan	8.9
1958	104.7	21-Feb	8.2	**1989**	33.0	18-Dec	4.6
1959	59.7	16-Dec	6.2	**1990**	157.6	29-Dec	10.0
1960	81.8	16-Mar	7.2	**1991**	9.4	23-Jan	2.5
1961	140.3	7-Feb	9.5	**1992**	11.8	20-Jan	2.7
1962	36.1	14-Jan	4.8	**1993**	11.2	20-Feb	2.7
1963	66.5	27-Feb	6.5	**1994**	121.8	22-Jan	8.8
1964	61.7	23-Dec	6.3	**1995**	30.0	9-Feb	4.4
1965	55.5	19-Jan	6.0	**1996**	70.8	7-Feb	6.7
1966	85.2	6-Feb	7.4	**1997**	41.5	20-Jan	5.2
1967	25.6	9-Feb	4.0	**1998**	5.2	1-Jan	1.8
1968	108.6	13-Jan	8.3	**1999**	27.7	11-Jan	4.2
1969	42.4	6-Jan	5.2	**2000**	113.4	3-Feb	8.5
1970	144.1	24-Jan	9.6	**2001**	71.7	5-Jan	6.8
1971	69.5	4-Feb	6.7	**2002**	21.7	4-Jan	2.3
1972	27.0	17-Jan	4.2	**2003**	107.3	28-Jan	5.2
1973	44.1	14-Jan	5.3	**2004**	129.9	2-Feb	9.1
1974	12.9	19-Dec	2.9	**2005**	82.4	3-Feb	7.3
1975	6.7	15-Jan	2.1	**2006**	10.3	21-Feb	2.6
1976	18.8	19-Jan	3.5				

Note:

Water year is the 12 month period from October through September. The water year is designated by the calendar year in which it ends.

Table 2.4-30— {Summary of Negative Surges of Major Hurricane Events}

Date		Hurricane Name	Negative Surge (ft) (m)		
			Baltimore	Annapolis	Solomons Island
1938	Sep-21	Not named	-3.2 (-0.98)	-2.2 (-0.67)	-1.4 (-0.43)
1944	Sep-14	Not named	-2.1 (-0.64)	-1.6 (-0.49)	-0.6 (-0.18)
1953	Aug-14	Barbara	-2.6 (-0.79)	-2.4 (-0.73)	-1.5 (0.46)
1954	Sep-11	Edna	-1.4 (-0.43)	-1.0 (-0.30)	-0.4 (-0.12)
1960	Sep-12	Donna	-2.6 (-0.79)	-1.5 (-0.46)	-1.0 (-0.30)

Table 2.4-31— {Summary of Information of the Stations and Range of Data Used}

Station Name	NOAA Station ID	Location		MSL above station datum	MLLW above station datum	MLLW in terms of MSL
		Latitude	Longitude	(ft) (m)	(ft) (m)	(ft) (m)
Annapolis	8575512	38° 59.0′ N	76° 28.8′ W	5.24 (1.60)	4.52 (1.38)	-0.72 (-0.22)
Solomons Island	8577330	38° 19.0′ N	76° 27.1′ W	4.48 (1.37)	3.72 (1.13)	-0.76 (-0.23)

Table 2.4-32— {Annual Minimum Water Levels at Annapolis Station}

Date	Annual Min. level (ft)		Date	Annual Min. level (ft)		Date	Annual Min. level (ft)	
	Station Datum	MSL		Station Datum	MSL		Station Datum	MSL
01/08/1929	1.00	-4.24	03/29/1955	1.90	-3.34	01/05/1981	2.13	-3.11
12/02/1930	1.70	-3.54	01/09/1956	1.80	-3.44	04/07/1982	1.49	-3.75
12/26/1931	1.50	-3.74	12/05/1957	1.70	-3.54	12/25/1983	2.31	-2.93
03/08/1932	1.50	-3.74	02/10/1958	2.21	-3.03	01/11/1984	2.89	-2.35
03/10/1933	1.40	-3.84	01/06/1959	1.38	-3.86	02/09/1985	1.43	-3.81
01/29/1934	1.80	-3.44	02/21/1960	1.90	-3.34	03/08/1986	2.01	-3.23
01/04/1935	1.60	-3.64	01/09/1961(2)	2.10	-3.14	02/09/1987	1.81	-3.43
09/18/1936	0.98	-4.26	12/31/1962	0.70	-4.54	01/14/1988	2.29	-2.95
02/17/1937	1.88	-3.36	01/01/1963	0.80	-4.44	11/21/1989	1.63	-3.61
02/28/1938	1.80	-3.44	02/12/1964	1.80	-3.44	02/26/1990	1.91	-3.33
01/26/1939	2.01	-3.23	12/26/1965	2.10	-3.14	12/19/1991	2.52	-2.72
02/15/1940	1.30	-3.94	12/27/1966	1.90	-3.34	12/06/1992	1.73	-3.51
03/19/1941	1.48	-3.76	02/26/1967	0.80	-4.44	03/18/1993	1.91	-3.33
02/03/1942	1.90	-3.34	01/08/1968	2.00	-3.24	11/24/1994	2.33	-2.91
02/15/1943	1.60	-3.64	02/10/1969	1.59	-3.65	02/06/1995	2.08	-3.16
12/02/1944	1.80	-3.44	02/26/1970	2.33	-2.91	11/27/1996	2.98	-2.26
01/25/1945	1.40	-3. 84	01/28/1971	1.99	-3.25	04/01/1997	1.73	-3.51
12/02/1946	1.20	-4.04	02/20/1972	1.79	-3.45	01/01/1998	2.40	-2.84
01/22/1947	1.90	-3.34	02/17/1973	2.07	-3.17	03/08/1999	2.71	-2.53
12/26/1948	1.60	-3.64	11/26/1974	2.56	-2.68	01/14/2000	1.74	-3.50
03/01/1949	2.10	-3.14	04/05/1975	0.66	-4.58	01/01/2001	2.83	-2.41
03/10/1950(1)	2.01	-3.23	01/09/1976(3)	2.80	-2.44	12/03/2002	2.29	-2.95
12/16/1951	1.80	-3.44	03/23/1977	2.22	-3.02	01/24/2003	1.77	-3.47
01/07/1952	1.90	-3.34	01/11/1978	1.88	-3.36	01/17/2004	2.28	-2.96
11/07/1953	1.70	-3.54	04/07/1979	2.45	-2.79	03/03/2005	2.40	-2.84
03/16/1954	1.90	-3.34	12/25/1980	1.24	-4.00	01/15/2006	1.70	-3.54

Notes:
(1) Same level observed on 02/27/1950
(2) Same level observed on 01/25/1961
(3) Same level observed on 01/23/1976

Table 2.4-33— {Annual Minimum Water Level at Solomons Island Station}

Date	Annual Min. level (ft)		Date	Annual Min. level (ft)	
	Station Datum	MSL		Station Datum	MSL
01/28/1971	0.97	-3.51	11/21/1989	1.80	-2.68
02/21/1972	1.32	-3.16	02/25/1990	1.41	-3.07
11/18/1973(1)	2.17	-2.31	12/16/1991	2.06	-2.42
03/06/1974	2.15	-2.33	12/06/1992	1.34	-3.14
04/05/1975	0.50	-3.98	03/15/1993	1.49	-2.99
12/22/1976	1.66	-2.82	11/24/1994	1.84	-2.64
01/02/1977	0.56	-3.92	02/06/1995	1.72	-2.76
01/11/1978	1.16	-3.32	04/24/1996	2.44	-2.04
04/07/1979	1.94	-2.54	04/01/1997	1.85	-2.63
12/25/1980	1.39	-3.09	01/01/1998	1.70	-2.78
01/05/1981	1.49	-2.99	03/08/1999	2.39	-2.09
04/07/1982	1.42	-3.06	01/28/2000	1.91	-2.57
12/25/1983	1.87	-2.61	01/01/2001	2.32	-2.16
02/08/1984(2)	2.37	-2.11	12/03/2002	2.14	-2.34
02/09/1985	1.16	-3.32	01/24/2003	1.60	-2.88
03/08/1986	1.53	-2.95	01/17/2004	2.06	-2.42
02/09/1987	1.86	-2.62	03/03/2005	2.15	-2.33
01/06/1988	2.00	-2.48	01/15/2006	2.05	-2.43

Notes:
(1) Based on 10 months data.
(2) Same level observed on 03/09/1984

Table 2.4-34— {CCNPP Unit 3 Observation Wells Construction Details}

(Page 1 of 3)

Well ID	Northing[1] (ft)	Easting[1] (ft)	Ground Surface Elevation (ft)	Well Pad Elevation (ft)	Top of Casing[2] Elevation (ft)	Boring Depth (ft)	Well Depth (ft)	Screen Diameter & Slot Size (in)	Screen Interval Depth		Screen Interval Elevation		Filterpack Interval Depth		CCNPP Hydrostratigraphic Unit
									Top (ft)	Bottom (ft)	Top (ft)	Botto m (ft)	Top (ft)	Bottom (ft)	
OW-301	217048.02	960814.47	94.51	94.78	96.27	80.0	77.0	2 / 0.010	65.0	75.0	29.5	19.5	61.0	80.0	Upper Chesapeake Unit
OW-304	217158.10	960920.80	68.78	69.28	71.01	72.8	72.0	2 / 0.010	60.0	70.0	8.78	-1.22	57.5	72.8	Upper Chesapeake Unit
OW-308	216928.00	960750.00	111.45	111.95	113.62	103.0	102.0	2 / 0.010	90.0	100.0	21.45	11.45	88.0	103.0	Upper Chesapeake Unit
OW-313A	217367.31	960705.30	51.03	51.31	53.20	57.5	52.5	2 / 0.010	40.0	50.0	11.0	1.0	35.0	57.5	Upper Chesapeake Unit
OW-313B	217372.35	960713.67	50.73	51.16	53.54	110.0	107.5	2 / 0.010	95.0	105.0	-44.3	-54.3	91.0	110.0	Lower Chesapeake Unit
OW-319A	216962.56	961116.12	103.13	103.31	104.91	35.0	32.0	2 / 0.010	20.0	30.0	83.1	73.1	15.0	35.0	Surficial Aquifer
OW-319B	216957.32	961125.02	103.53	103.85	105.35	85.0	82.0	2 / 0.010	70.0	80.0	33.5	23.5	65.0	85.0	Upper Chesapeake Unit
OW-323	217034.46	960057.07	106.96	107.55	109.69	43.5	42.0	2 / 0.010	30.0	40.0	77.0	67.0	26.0	43.5	Surficial Aquifer
OW-328	216828.86	960493.21	76.29	76.55	77.85	72.0	72.0	2 / 0.010	60.0	70.0	16.3	6.3	56.5	72.0	Upper Chesapeake Unit
OW-336	216643.18	960746.61	97.11	97.50	99.07	74.0	72.0	2 / 0.010	60.0	70.0	37.1	27.1	53.0	74.0	Upper Chesapeake Unit
OW-401	216348.86	961530.99	71.38	71.91	73.49	77.5	75.3	2 / 0.010	63.0	73.0	8.4	-1.6	57.0	77.5	Upper Chesapeake Unit
OW-413A	216703.14	961418.81	123.15	123.51	125.04	50.0	47.0	2 / 0.010	35.0	45.0	88.2	78.2	30.0	50.0	Surficial Aquifer
OW-413B	216694.88	961413.25	122.90	123.25	124.85	125.0	122.0	2 / 0.010	110.0	120.0	12.9	2.9	105.0	125.0	Upper Chesapeake Unit
OW-418A	216340.41	961966.46	43.66	44.31	45.83	40.0	37.0	2 / 0.010	25.0	35.0	18.7	8.7	21.0	40.0	Upper Chesapeake Unit
0W-418B	216340.25	961976.71	43.67	44.13	45.77	92.0	87.0	2 / 0.010	75.0	85.0	-31.3	-41.3	72.0	92.0	Lower Chesapeake Unit
OW-423	216339.99	960882.24	111.12	111.67	113.16	43.0	40.3	2 / 0.010	28.0	38.0	83.1	73.1	23.0	43.0	Surficial Aquifer
OW-428	216105.21	961212.38	113.92	114.32	115.92	50.0	47.0	2 / 0.010	35.0	45.0	78.9	68.9	30.0	50.0	Surficial Aquifer

Table 2.4-34— {CCNPP Unit 3 Observation Wells Construction Details}

(Page 2 of 3)

Well ID	Northing(1) (ft)	Easting(1) (ft)	Ground Surface Elevation (ft)	Well Pad Elevation (ft)	Top of Casing(2) Elevation (ft)	Boring Depth (ft)	Well Depth (ft)	Screen Diameter & Slot Size (in)	Screen Interval Depth		Screen Interval Elevation		Filterpack Interval Depth		CCNPP Hydrostratigraphic Unit
									Top (ft)	Bottom (ft)	Top (ft)	Botto m (ft)	Top (ft)	Bottom (ft)	
OW-436	215922.47	961446.87	108.13	108.53	110.39	50.0	41.0	2 / 0.010	29.0	39.0	79.1	69.1	24.0	50.0	Surficial Aquifer
OW-703A	218171.23	960967.72	44.02	44.44	45.65	49.0	47.0	2 / 0.010	35.0	45.0	9.0	-1.0	32.5	49.0	Upper Chesapeake Unit
OW-703B	218171.67	960958.91	45.57	45.97	47.53	80.0	80.0	2 / 0.010	68.0	78.0	-22.4	-32.4	65.0	80.0	Lower Chesapeake Unit
OW-705	217566.62	960917.18	47.71	47.77	50.22	52.0	52.0	2 / 0.010	40.0	50.0	7.7	-2.3	35.0	52.0	Upper Chesapeake Unit
OW-708A	217586.23	961803.52	37.44	37.82	39.61	34.0	34.0	2 / 0.010	22.0	32.0	15.4	5.4	19.0	34.0	Upper Chesapeake Unit
OW-711	216748.48	961741.61	52.92	53.26	55.31	50.0	47.0	2 / 0.010	35.0	45.0	17.9	7.9	30.0	50.0	Upper Chesapeake Unit
OW-714	215705.73	962034.37	116.02	116.32	117.98	50.0	50.0	2 / 0.010	38.0	48.0	78.0	68.0	36.0	50.0	Surficial Aquifer
OW-718	214133.58	961924.87	118.53	118.96	120.41	43.0	42.0	2 / 0.010	30.0	40.0	88.5	78.5	28.0	43.0	Surficial Aquifer
OW-725	214649.30	963212.73	58.04	58.38	59.94	60.0	60.0	2 / 0.010	48.0	58.0	10.0	0.0	46.0	60.0	Upper Chesapeake Unit
OW-729	214872.58	962445.93	118.88	119.44	121.11	42.0	42.0	2 / 0.010	30.0	40.0	88.9	78.9	28.0	42.0	Surficial Aquifer
OW-735	214805.48	961021.83	91.20	91.81	93.44	72.0	72.0	2 / 0.010	60.0	70.0	31.2	21.2	58.0	72.0	Upper Chesapeake Unit
OW-743	213320.62	961234.01	103.65	104.05	105.89	55.0	52.0	2 / 0.010	40.0	50.0	63.7	53.7	36.0	55.0	Surficial Aquifer
OW-744	216405.37	960089.41	97.50	97.96	99.81	50.0	50.0	2 / 0.010	38.0	48.0	59.5	49.5	36.0	50.0	Chesapeake Unit
OW-752A	215482.18	960250.12	95.30	95.73	97.00	37.0	37.0	2 / 0.010	25.0	35.0	70.3	60.3	19.0	37.0	Surficial Aquifer
OW-752B	215489.21	960257.57	95.79	96.09	97.41	97.0	97.0	2 / 0.010	85.0	95.0	10.8	0.8	83.0	97.0	Upper Chesapeake Unit
OW-754	217369.78	960290.37	67.00	67.21	68.85	44.0	44.0	2 / 0.010	32.0	42.0	35.0	25.0	30.0	44.0	Upper Chesapeake Unit
OW-756	215497.07	961212.39	106.56	107.07	108.77	42.0	42.0	2 / 0.010	30.0	40.0	76.6	66.6	28.0	42.0	Surficial Aquifer
OW-759A	214536.47	960055.02	97.78	98.05	99.69	35.0	32.0	2 / 0.010	20.0	30.0	77.8	67.8	17.0	35.0	Surficial Aquifer

Table 2.4-34— {CCNPP Unit 3 Observation Wells Construction Details}

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Well ID	Northing⁽¹⁾ (ft)	Easting⁽¹⁾ (ft)	Ground Surface Elevation (ft)	Well Pad Elevation (ft)	Top of Casing⁽²⁾ Elevation (ft)	Boring Depth (ft)	Well Depth (ft)	Screen Diameter & Slot Size (in)	Screen Interval Depth		Screen Interval Elevation		Filterpack Interval Depth		CCNPP Hydrostratigraphic Unit
									Top (ft)	Bottom (ft)	Top (ft)	Botto m (ft)	Top (ft)	Bottom (ft)	
OW-759B	214526.25	960056.32	98.35	98.72	100.14	90.0	87.0	2 / 0.010	75.0	85.0	23.4	13.4	70.0	90.0	Upper Chesapeake Unit
OW-765A	216424.51	959701.22	97.37	97.92	99.60	29.0	29.0	2 / 0.010	17.0	27.0	80.4	70.4	15.0	29.0	Surficial Aquifer
OW-765B	216420.42	959693.64	96.82	97.19	98.47	102.0	94.0	2 / 0.010	82.0	92.0	14.8	4.8	80.0	102.0	Upper Chesapeake Unit
OW-766	216932.89	959791.50	108.89	109.32	110.72	50.0	32.0	2 / 0.010	20.0	30.0	88.9	78.9	15.0	37.0	Surficial Aquifer
OW-768A	217106.06	962238.98	48.48	48.96	49.84	42.0	42.0	2 / 0.010	30.0	40.0	18.5	8.5	28.0	42.0	Upper Chesapeake Unit
OW-769	216589.75	962559.47	54.23	54.39	56.43	42.0	42.0	2 / 0.010	31.8	41.8	22.4	12.4	18.0	42.0	Upper Chesapeake Unit
OW-770	215466.60	962826.95	121.59	121.79	123.08	42.0	42.0	2 / 0.010	30.0	40.0	91.6	81.6	28.0	42.0	Surficial Aquifer
OW-774A	219187.30	961030.50	9.7	10.20	12.20	23.0	22.0	2 / 0.010	10.0	20.0	-0.3	-10.3	8.0	23.0	Upper Chesapeake Unit
OW-774B	219176.70	961020.20	10.1	10.50	12.55	52.8	52.0	2 / 0.010	40.0	50.0	-29.9	-39.9	37.5	52.8	Lower Chesapeake Unit
OW-778	219100.60	960728.60	113.3	113.70	115.45	52.0	52.0	2 / 0.010	40.0	50.0	73.3	63.3	38.0	52.0	Surficial Aquifer
OW-779	218958.70	960587.30	100.9	101.30	102.94	52.5	52.0	2 / 0.010	40.0	50.0	60.9	50.9	37.9	52.5	Chesapeake Unit
OW-781	219421.30	960764.40	10.3	10.80	12.87	53.0	52.0	2 / 0.010	40.0	50.0	-29.7	-39.7	37.0	53.0	Lower Chesapeake Unit

Notes:

1) Maryland State Plane (NAD 1927). The Maryland State Plane 1927 coordinate system is based on North American Datum of 1927 (NAD27). NAD27 is a surface (or plane) to which horizontal positions in the U.S., Canada and Mexico is surveyed and referenced.

2) Elevation is top of PVC Well Casing. Reference Point for Ground Water Level Monitoring

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

(Page 1 of 7)

Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007	July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
2006 COLA Observation Wells																						
OW-301	94.51	96.27	58.85	59.45	59.37	58.34	58.00	58.04	57.33	57.00	56.78	56.46	37.42	36.82	36.9	37.93	38.27	38.23	38.94	39.27	39.49	39.81
OW-313A	51.03	53.20	19.80	20.40	20.08	19.57	18.80	18.90	17.93	18.25	17.12	16.77	33.40	32.80	33.12	33.63	34.40	34.30	35.27	34.95	36.08	36.43
OW-313B	50.73	53.54	23.05	23.65	23.47	23.17	22.76	22.52	21.89	21.80	21.44	20.97	30.49	29.89	30.07	30.37	30.78	31.02	31.65	31.74	32.10	32.57
OW-319A	103.13	104.91	26.48	26.58	26.25	26.08	26.28	26.22	26.25	26.44	26.25	26.18	78.43	78.33	78.66	78.83	78.63	78.69	78.66	78.47	78.66	78.73
OW-319B	103.53	105.35	67.49	67.97	67.95	67.53	66.57	66.49	65.74	65.52	65.27	64.84	37.86	37.38	37.40	37.82	38.78	38.86	39.61	39.83	40.08	40.51
OW-323	106.96	109.69	27.8	28.22	28.37	28.13	27.96	27.26	26.88	26.45	26.52	25.88	81.89	81.47	81.32	81.56	81.73	82.43	82.81	83.24	83.17	83.81
OW-328	76.29	77.85	40.77	41.40	41.35	40.68	40.33	40.13	39.63	39.42	39.32	38.72	37.08	36.45	36.50	37.17	37.52	37.72	38.22	38.43	38.53	39.13
OW-336	97.11	99.07	60.99	61.36	61.52	60.45	60.42	60.19	59.65	59.20	59.25	58.76	38.08	37.71	37.55	38.62	38.65	38.88	39.42	39.87	39.82	40.31
OW-401	71.38	73.49	34.13	34.95	34.73	33.72	32.95	33.37	32.33	32.45	31.76	31.38	39.36	38.54	38.76	39.77	40.54	40.12	41.16	41.04	41.73	42.11
OW-413A(1)	123.15	125.04	45.87	45.85	45.87	45.87	45.87	45.86	45.83	45.77	45.76	45.75	79.17	79.19	79.17	79.17	79.17	79.18	79.21	79.27	79.28	79.29
OW-413B	122.90	124.85	86.60	87.30	87.13	86.46	85.14	85.56	84.40	84.75	83.57	83.25	38.25	37.55	37.72	38.39	39.71	39.29	40.45	40.10	41.28	41.60
OW-418A	43.66	45.83	8.22	9.44	8.60	7.97	6.45	7.60	6.40	6.91	5.68	5.57	37.61	36.39	37.23	37.86	39.38	38.23	39.43	38.92	40.15	40.26
OW-418B	43.67	45.77	12.52	13.36	12.90	12.47	11.67	12.85	11.03	11.27	10.74	10.42	33.25	32.41	32.87	33.30	34.10	32.92	34.74	34.5	35.03	35.35
OW-423	111.12	113.16	29.77	30.04	30.03	29.93	29.78	29.54	29.02	28.76	28.38	27.62	83.39	83.12	83.13	83.23	83.38	83.62	84.14	84.4	84.78	85.54
OW-428	113.92	115.92	37.82	37.92	37.98	38.07	38.01	37.89	37.69	37.25	37.17	36.47	78.10	78.00	77.94	77.85	77.91	78.03	78.23	78.67	78.75	79.45
OW-436	108.13	110.39	31.68	32.06	31.85	31.55	31.08	31.40	30.60	31.05	30.28	30.19	78.71	78.33	78.54	78.84	79.31	78.99	79.79	79.34	80.11	80.20
OW-703A	44.02	45.65	27.33	27.84	28.05	27.93	27.60	27.12	25.16	25.60	22.15	21.95	18.32	17.81	17.60	17.72	18.05	18.53	20.49	20.05	23.50	23.70
OW-703B	45.57	47.53	29.34	29.85	29.95	29.73	29.40	29.10	27.45	27.72	24.74	24.47	18.19	17.68	17.58	17.80	18.13	18.43	20.08	19.81	22.79	23.06
OW-705	47.71	50.22	20.28	21.10	20.67	20.10	19.02	19.40	17.82	18.60	16.57	16.35	29.94	29.12	29.55	30.12	31.20	30.82	32.40	31.62	33.65	33.87
OW-708A	37.44	39.61	13.39	15.01	13.85	12.78	10.46	12.58	8.96	12.20	6.71	6.77	26.22	24.60	25.76	26.83	29.15	27.03	30.65	27.41	32.90	32.84
OW-711	52.92	55.31	19.26	20.64	19.50	18.43	16.14	18.33	15.94	17.70	14.33	14.36	36.05	34.67	35.81	36.88	39.17	36.98	39.37	37.61	40.98	40.95
OW-714	116.02	117.98	45.93	46.28	46.33	46.36	46.19	45.87	45.60	45.42	45.21	44.78	72.05	71.70	71.65	71.62	71.79	72.11	72.38	72.56	72.77	73.20
OW-718	118.53	120.41	40.47	40.56	40.8	41.07	41.29	41.37	41.18	40.40	40.22	39.28	79.94	79.85	79.61	79.34	79.12	79.04	79.23	80.01	80.19	81.13
OW-725	58.04	59.94	32.8	33.87	33.92	33.56	32.54	32.30	30.77	30.77	29.77	28.95	27.14	26.07	26.02	26.38	27.40	27.64	29.17	29.17	30.17	30.99

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

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Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007	July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-729(1)	118.88	121.11	44.08	41.99	41.96	41.96	41.92	41.99	41.98	41.98	41.98	41.93	77.03	79.12	79.15	79.15	79.19	79.12	79.13	79.13	79.13	79.18
OW-735	91.20	93.44	54.18	55.17	55.14	54.57	53.31	53.24	52.36	52.13	52.16	51.40	39.26	38.27	38.30	38.87	40.13	40.20	41.08	41.31	41.28	42.04
OW-743	103.65	105.89	37.22	37.77	37.52	37.35	37.22	36.99	36.61	36.03	35.80	34.78	68.67	68.12	68.37	68.54	68.67	68.90	69.28	69.86	70.09	71.11
OW-744	97.50	99.81	32.97	33.52	33.15	32.96	32.47	32.52	32.06	31.97	31.73	31.33	66.84	66.29	66.66	66.85	67.34	67.29	67.75	67.84	68.08	68.48
OW-752A	95.30	97.00	24.76	25.18	25.35	25.36	25.23	24.08	23.34	22.77	22.68	21.57	72.24	71.82	71.65	71.64	71.77	72.92	73.66	74.23	74.32	75.43
OW-752B	95.79	97.41	59.55	60.25	60.05	59.75	59.38	59.16	58.77	58.60	58.58	58.01	37.86	37.16	37.36	37.66	38.03	38.25	38.64	38.81	38.83	39.40
OW-754	67.00	68.85	31.32	32.05	31.80	31.05	30.73	30.93	30.24	30.12	29.67	29.32	37.53	36.80	37.05	37.80	38.12	37.92	38.601	38.73	39.18	39.53
OW-756	106.56	108.77	29.98	30.17	30.42	30.55	30.59	30.46	30.04(3)	29.42	29.18	27.62	78.79	78.60	78.35	78.22	78.18	78.31	78.73	79.35	79.59	81.15
OW-759A	97.78	99.69	26.88	27.53	28.00	28.12	28.32	27.41	26.77	25.50	24.41	23.65	72.81	72.16	71.69	71.57	71.37	72.28	72.92	74.19	75.28	76.04
OW-759B	98.35	100.14	63.09	63.80	63.56	63.31	63.11	62.87	62.54	62.32	62.30	61.85	37.05	36.34	36.58	36.83	37.03	37.27	37.60	37.82	37.84	38.29
OW-765A	97.37	99.60	21.72	22.02	21.87	21.70	21.20	20.10	18.95	19.25	18.38	17.87	77.88	77.58	77.73	77.90	78.40	79.50	80.65	80.35	81.22	81.73
OW-765B	96.82	98.47	60.22	60.72	60.55	60.40	59.92	59.77	59.73	59.45	59.37	58.96	38.25	37.75	37.92	38.07	38.55	38.70	38.74	39.02	39.10	39.51
OW-766	108.89	110.72	28.88	29.36	29.42	29.20	29.20	28.76	28.11	27.60	27.30	26.77	81.84	81.36	81.30	81.52	81.52	81.96	82.61	83.12	83.42	83.95
OW-768A	48.48	49.84	24.05	24.88	24.04	23.67	23.12	23.65	23.10	23.26	22.53	22.62	25.79	24.96	25.80	26.17	26.72	26.19	26.74	26.58	27.31	27.22
OW-769	54.23	56.43	26.50	27.96	27.37	26.74	24.13	25.74	23.48	24.43	20.55	20.67	29.93	28.47	29.06	29.69	32.30	30.69	32.95	32.00	35.88	35.76
OW-770(1)	121.59	123.08	dry	42.10	42.09	42.08	42.09	42.11	42.10	42.10	42.10	42.10	dry	80.98	80.99	81.00	80.99	80.97	80.98	80.98	80.98	80.98
2008 COLA Supplemental Investigation Observation Wells																						
OW-304	68.78	71.01																				
OW-308	111.45	113.62																				
OW-774A	9.7	12.20																				
OW-774B	10.1	12.55																				
OW-778(1)	113.3	115.45																				
OW-779(1)	100.9	102.94																				
OW-781	10.3	12.87																				

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

(Page 3 of 7)

Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008	May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
2006 COLA Observation Wells																						
OW-301	94.51	96.27	57.32	58.67	59.92	60.75	59.62	59.58	60.57(2)	60.80			38.95	37.60	36.35	35.52	36.65	36.69	35.70	35.47		
OW-313A	51.03	53.20	18.23	19.56	21.05	21.52	20.32	23.80	21.51	21.71			34.97	33.64	32.15	31.68	32.88	29.40	31.69	31.49		
OW-313B	50.73	53.54	21.47	22.60	24.23	24.85	23.98	23.74	24.78	25.08			32.07	30.94	29.31	28.69	29.56	29.8	28.76	28.46		
OW-319A	103.13	104.91	26.26	26.57	26.95	27.25	26.2	26.28	26.68	26.08			78.65	78.34	77.96	77.66	78.71	78.63	78.23	78.83		
OW-319B	103.53	105.35	65.72	67.22	68.45	69.45	68.38	68.18	69.31	69.48			39.63	38.13	36.90	35.90	36.97	37.17	36.04	35.87		
OW-323	106.96	109.69	26.00	26.77	28.48	29.77	29.47	28.22	29.01	29.30			83.69	82.92	81.21	79.92	80.22	81.47	80.68	80.39		
OW-328	76.29	77.85	39.33	40.52	41.90	42.53	41.68	41.60	42.57	42.67			38.52	37.33	35.95	35.32	36.17	36.25	35.28	35.18		
OW-336	97.11	99.07	59.28	60.57	61.80	62.63	61.86	61.67	62.73	62.78			39.79	38.50	37.27	36.44	37.21	37.40	36.34	36.29		
OW-401	71.38	73.49	32.66	34.14	35.80	36.59	35.04	35.07	36.36	36.62			40.83	39.35	37.69	36.90	38.45	38.42	37.13	36.87		
OW-413A(1)	123.15	125.04	45.68	45.72	45.82	45.93	45.97	45.87	45.90	45.92			79.36	79.32	79.22	79.11	79.07	79.17	79.14	79.12		
OW-413B	122.90	124.85	84.84	86.42	88.05	89.02	87.37	87.36	88.65	88.87			40.01	38.43	36.80	35.83	37.48	37.49	36.20	35.98		
OW-418A	43.66	45.83	7.32	8.65	10.67	10.62	8.38	8.95	10.70	11.17			38.51	37.18	35.16	35.21	37.45	36.88	35.13	34.66		
OW-418B	43.67	45.77	11.33	12.55	14.50	14.96	13.02	13.13	14.67	15.16			34.44	33.22	31.27	30.81	32.75	32.64	31.10	30.61		
OW-423	111.12	113.16	27.42	27.87	29.53	31.70	32.02	31.01	31.56	31.87			85.74	85.29	83.63	81.46	81.14	82.15	81.60	81.29		
OW-428	113.92	115.92	36.20	36.63	37.56	38.47	38.82	38.40	38.46	38.57			79.72	79.29	78.36	77.45	77.10	77.52	77.46	77.35		
OW-436	108.13	110.39	30.72	31.22	32.32	33.26	33.12	32.10	32.82	33.06			79.67	79.17	78.07	77.13	77.27	78.29	77.57	77.33		
OW-703A	44.02	45.65	25.68	24.08	28.42	28.83	28.17	28.14	29.15	29.54			19.97	21.57	17.23	16.82	17.48	17.51	16.50	16.11		
OW-703B	45.57	47.53	27.68	26.47	30.38	30.72	30.02	30.80	31.02	31.42			19.85	21.06	17.15	16.81	17.51	16.73	16.51	16.11		
OW-705	47.71	50.22	18.72	20.22	21.80	22.18	20.75	20.90	22.21	22.50			31.50	30.00	28.42	28.04	29.47	29.32	28.01	27.72		
OW-708A	37.44	39.61	11.70	14.50	16.26	17.36	13.46	13.18	15.67	16.28			27.91	25.11	23.35	22.25	26.15	26.43	23.94	23.33		
OW-711	52.92	55.31	18.18	19.85	21.88	19.50	19.42	20.03	14.67	22.37			37.13	35.46	33.43	35.81	35.89	35.28	40.64	32.94		
OW-714	116.02	117.98	44.93	43.25	46.05	47.57	47.32	46.48	48.11	48.53			73.05	74.73	71.93	70.41	70.66	71.50	69.87	69.45		
OW-718	118.53	120.41	38.72	38.93	39.85	41.50	41.70	43.90(4)	41.78	41.82			81.69	81.48	80.56	78.91	78.71	76.51	78.63	78.59		
OW-725	58.04	59.94	30.47	34.14	34.82	35.72	33.83	34.32	35.87	36.27			29.47	25.80	25.12	24.22	26.11	25.62	24.07	23.67		

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

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Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008	May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-729(1)	118.88	121.11	42.00	42.00	42.00	41.96	41.98	41.98	42.00	42.00			79.11	79.11	79.11	79.15	79.13	79.13	79.11	79.11		
OW-735	91.20	93.44	52.37	53.74	55.98	56.72	55.09	55.32	56.80	57.01			41.07	39.70	37.46	36.72	38.35	38.12	36.64	36.43		
OW-743	103.65	105.89	34.57	34.14	37.17	38.35	38.26	38.65	39.82	39.97			71.32	71.75	68.72	67.54	67.63	67.24	66.07	65.92		
OW-744	97.50	99.81	31.73	32.47	33.70	33.83	33.34	33.47	34.07	34.22			68.08	67.34	66.11	65.98	66.47	66.34	65.74	65.59		
OW-752A	95.30	97.00	22.24	23.91	25.78	27.22	26.73	24.73	25.71	26.11			74.76	73.09	71.22	69.78	70.27	72.27	71.29	70.89		
OW-752B	95.79	97.41	58.50	59.32	60.68	61.05	60.43	60.47	61.46	61.57			38.91	38.09	36.73	36.36	36.98	36.94	35.95	35.84		
OW-754	67.00	68.85	30.33	31.33	32.50	32.98	31.86	32.00	32.87(2)	33.12			38.52	37.52	36.35	35.87	36.99	36.85	35.98	35.73		
OW-756	106.56	108.77	27.05	27.77	29.75	31.44	31.75	31.34	31.60	31.77			81.72	81.00	79.02	77.33	77.02	77.43	77.17	77.00		
OW-759A	97.78	99.69	23.73	21.08	28.27	30.58	29.86	30.92	29.52	29.84			75.96	78.61	71.42	69.11	69.83	68.77	70.17	69.85		
OW-759B	98.35	100.14	62.17	61.57	64.15	64.48	64.00	64.17	65.06	65.23			37.97	38.57	35.99	35.66	36.14	35.97	35.08	34.91		
OW-765A	97.37	99.60	18.28	20.12	22.12	22.57	21.73	21.55	22.25	22.42			81.32	79.48	77.48	77.03	77.87	78.05	77.35	77.18		
OW-765B	96.82	98.47	59.24	59.92	61.07	61.58	61.24	61.27	61.88	62.00			39.23	38.55	37.40	36.89	37.23	37.20	36.59	36.47		
OW-766	108.89	110.72	26.85	27.52	29.47	31.02	30.82	29.8	30.54	30.79			83.87	83.20	81.25	79.70	79.90	80.92	80.18	79.93		
OW-768A	48.48	49.84	23.55	24.15	26.17	26.75	23.84	24.42	26.34	26.81			26.29	25.69	23.67	23.09	26.00	25.42	23.50	23.03		
OW-769	54.23	56.43	24.68	26.40	26.37	30.27	27.70	28.07	29.88	33.33			31.75	30.03	30.06	26.16	28.73	28.36	26.55	23.10		
OW-770(1)	121.59	123.08	42.10	42.10	42.10	42.12	42.08	42.09	42.10	42.10			80.98	80.98	80.98	80.96	81.00	80.99	80.98	80.98		
2008 COLA Supplemental Investigation Observation Wells																						
OW-304	68.78	71.01							37.28	37.43	37.33	36.78							33.73	33.58	33.68	34.23
OW-308	111.45	113.62							78.33	78.41	78.29	78.00							35.29	35.21	35.33	35.62
OW-774A	9.70	12.20							10.13	10.21	10.15	9.98							2.07	1.99	2.05	2.22
OW-774B	10.10	12.55							10.15	10.00	10.15	10.04							2.40	2.55	2.40	2.51
OW-778(1)	113.3	115.45							dry	dry	dry	dry							dry	dry	dry	dry
OW-779(1)	100.9	102.94							dry	dry	dry	dry							dry	dry	dry	dry
OW-781	10.3	12.87							10.36	10.58	10.44	10.45							2.51	2.29	2.43	2.42

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

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Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009	January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
2006 COLA Observation Wells																						
OW-301	94.51	96.27	59.93			58.65			59.72			60.02	36.34			37.62			36.55			36.25
OW-313A	51.03	53.20	20.60			19.02			20.33			20.87	32.60			34.18			32.87			32.33
OW-313B	50.73	53.54	24.32			23.26			23.47			24.33	29.22			30.28			30.07			29.21
OW-319A	103.13	104.91	26.28			26.38			26.44			26.53	78.63			78.53			78.47			78.38
OW-319B	103.53	105.35	68.72			67.46			68.33			68.78	36.63			37.89			37.02			36.57
OW-323	106.96	109.69	29.57			29.08			27.55			28.72	80.12			80.61			82.14			80.97
OW-328	76.29	77.85	42.07			40.84			41.59			42.19	35.78			37.01			36.26			35.66
OW-336	97.11	99.07	62.24			60.97			61.80			62.28	36.83			38.10			37.27			36.79
OW-401	71.38	73.49	35.67			33.71			35.16			35.47	37.82			39.78			38.33			38.02
OW-413A(1)	123.15	125.04	45.98			45.97			45.77			45.88	79.06			79.07			79.27			79.16
OW-413B	122.9	124.85	87.80			86.07			87.51			87.72	37.05			38.78			37.34			37.13
OW-418A	43.66	45.83	9.00			6.74			9.46			8.66	36.83			39.09			36.37			37.17
OW-418B	43.67	45.77	13.47			12.09			13.28			13.62	32.30			33.68			32.49			32.15
OW-423	111.12	113.16	32.07			31.97			29.77			30.43	81.09			81.19			83.39			82.73
OW-428	113.92	115.92	38.85			38.86			37.68			38.13	77.07			77.06			78.24			77.79
OW-436	108.13	110.39	33.31			33.27			31.66			32.10	77.08			77.12			78.73			78.29
OW-703A	44.02	45.65	28.52			27.68			27.48			28.80	17.13			17.97			18.17			16.85
OW-703B	45.57	47.53	30.30			29.36			29.51			30.56	17.23			18.17			18.02			16.97
OW-705	47.71	50.22	21.02			18.95			20.81			21.42	29.20			31.27			29.41			28.80
OW-708A	37.44	39.61	12.81			9.28			13.64			12.57	26.80			30.33			25.97			27.04
OW-711	52.92	55.31	19.62			16.27			20.45			18.32	35.69			39.04			34.86			36.99
OW-714	116.02	117.98	48.19			47.73			46.04			47.17	69.79			70.25			71.94			70.81
OW-718	118.53	120.41	42.12			42.03			42.08			42.08	78.29			78.38			78.33			78.33
OW-725	58.04	59.94	34.80			32.66			33.97			35.23	25.14			27.28			25.97			24.71

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

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Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009	January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-729[1]	118.88	121.11	42.00			42.00			42.00			42.00	79.11			79.11			79.11			79.11
OW-735	91.20	93.44	55.77			53.88			55.25			55.8	37.67			39.56			38.19			37.64
OW-743	103.65	105.89	39.58			39.01			37.66			38.48	66.31			66.88			68.23			67.41
OW-744	97.50	99.81	33.47			32.98			33.16			33.37	66.34			66.83			66.65			66.44
OW-752A	95.30	97.00	26.43			26.04			23.72			25.66	70.57			70.96			73.28			71.34
OW-752B	95.79	97.41	60.78			59.89			60.39			60.75	36.63			37.52			37.02			36.66
OW-754	67.00	68.85	32.12			31.10			32.02			32.13	36.73			37.75			36.83			36.72
OW-756	106.56	108.77	31.99			32.04			30.13			30.77	76.78			76.73			78.64			78.00
OW-759A	97.78	99.69	30.23			30.18			27.28			28.76	69.46			69.51			72.41			70.93
OW-759B	98.35	100.14	64.45			63.61			63.95			64.14	35.69			36.53			36.19			36.00
OW-765A	97.37	99.60	22.27			21.05			20.97			22.17	77.33			78.55			78.63			77.43
OW-765B	96.82	98.47	61.50			60.94			60.91			61.33	36.97			37.53			37.56			37.14
OW-766	108.89	110.72	30.70			30.32			28.90			29.86	80.02			80.40			81.82			80.86
OW-768A	48.48	49.84	24.10			23.37			24.91			24.42	25.74			26.47			24.93			25.42
OW-769	54.23	56.43	28.57			24.74			28.03			28.66	27.86			31.69			28.40			27.77
OW-770[1]	121.59	123.08	42.10			42.10			42.11			42.11	80.98			80.98			80.97			80.97
2008 COLA Supplemental Investigation Observation Wells																						
OW-304	68.78	71.01	36.30	36.64	36.40	34.58	33.87	34.18	36.07	36.66	36.85	36.07	34.71	34.37	34.601	36.43	37.14	36.83	34.94	34.35	34.16	34.94
OW-308	111.45	113.62	77.62	77.77	77.71	76.41	75.57	75.43	77.18	77.64	77.73	77.18	36.00	35.85	35.91	37.21	38.05	38.19	36.44	35.98	35.89	36.44
OW-774A	9.70	12.20	10.34	10.45	10.01	9.37	9.53	9.14	9.70	9.82	10.001	9.70	1.86	1.75	2.19	2.83	2.67	3.06	2.50	2.38	2.19	2.50

Table 2.4-35— {CCNPP Unit 3 Observation Wells Water Level Elevations}

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Well ID	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
			January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009	January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-774B	10.10	12.55	10.52	10.48	10.17	9.78	9.76	9.48	9.92	9.91	10.06	9.92	2.03	2.07	2.38	2.77	2.79	3.07	2.63	2.64	2.49	2.63
OW-778(1)	113.3	115.45	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
OW-779(1)	100.9	102.94	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
OW-781	10.30	12.87	10.72	10.95	10.62	10.31	10.17	9.94	10.12	10.21	10.36	10.12	2.15	1.92	2.25	2.56	2.70	2.93	2.75	2.66	2.51	2.75

1. Questionable water level readings due to proximity of depth of water to bottom of well screen and/or minimal water level flucuation with time.
2. Reading from water level round was 41.90. Review suggested questionable reading. Retaken five days later and reading was 30.40
3. Readings from September 2008 water level for OW-301 (67.2 ft) and OW-754 (21.51 ft) questioned by reviewer. Originator provided corrected readings 10/8/08.
4. Reported as dry in remarks (water level measurement form).

Table 2.4-36— {CCNPP Unit 3 Observation Wells Used in Hydrologic Evaluation}

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Well ID	Aquifer Unit	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
				July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007	July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Surficial Aquifer																							
OW-319A	SA	103.13	104.91	26.48	26.58	26.25	26.08	26.28	26.22	26.25	26.44	26.25	26.18	78.43	78.33	78.66	78.83	78.63	78.69	78.66	78.47	78.66	78.73
OW-323	SA	106.96	109.69	27.80	28.22	28.37	28.13	27.96	27.26	26.88	26.45	26.52	25.88	81.89	81.47	81.32	81.56	81.73	82.43	82.81	83.24	83.17	83.81
OW-423	SA	111.12	113.16	29.77	30.04	30.03	29.93	29.78	29.54	29.02	28.76	28.38	27.62	83.39	83.12	83.13	83.23	83.38	83.62	84.14	84.40	84.78	85.54
OW-428	SA	113.92	115.92	37.82	37.92	37.98	38.07	38.01	37.89	37.69	37.25	37.17	36.47	78.10	78.00	77.94	77.85	77.91	78.03	78.23	78.67	78.75	79.45
OW-436	SA	108.13	110.39	31.68	32.06	31.85	31.55	31.08	31.40	30.60	31.05	30.28	30.19	78.71	78.33	78.54	78.84	79.31	78.99	79.79	79.34	80.11	80.20
OW-714	SA	116.02	117.98	45.93	46.28	46.33	46.36	46.19	45.87	45.60	45.42	45.21	44.78	72.05	71.70	71.65	71.62	71.79	72.11	72.38	72.56	72.77	73.20
OW-718	SA	118.53	120.41	40.47	40.56	40.80	41.07	41.29	41.37	41.18	40.40	40.22	39.28	79.94	79.85	79.61	79.34	79.12	79.04	79.23	80.01	80.19	81.13
OW-743	SA	103.65	105.89	37.22	37.77	37.52	37.35	37.22	36.99	36.61	36.03	35.80	34.78	68.67	68.12	68.37	68.54	68.67	68.90	69.28	69.86	70.09	71.11
OW-752A	SA	95.30	97.00	24.76	25.18	25.35	25.36	25.23	24.08	23.34	22.77	22.68	21.57	72.24	71.82	71.65	71.64	71.77	72.92	73.66	74.23	74.32	75.43
OW-756	SA	106.56	108.77	29.98	30.17	30.42	30.55	30.59	30.46	30.04	29.42	29.18	27.62	78.79	78.60	78.35	78.22	78.18	78.31	78.73	79.35	79.59	81.15
OW-759A	SA	97.78	99.69	26.88	27.53	28.00	28.12	28.32	27.41	26.77	25.50	24.41	23.65	72.81	72.16	71.69	71.57	71.37	72.28	72.92	74.19	75.28	76.04
OW-765A	SA	97.37	99.60	21.72	22.02	21.87	21.70	21.20	20.10	18.95	19.25	18.38	17.87	77.88	77.58	77.73	77.90	78.40	79.50	80.65	80.35	81.22	81.73
OW-766	SA	108.89	110.72	28.88	29.36	29.42	29.20	29.20	28.76	28.11	27.60	27.30	26.77	81.84	81.36	81.30	81.52	81.52	81.96	82.61	83.12	83.42	83.95
Upper Chesapeake Unit																							
OW-301	CU	94.51	96.27	58.85	59.45	59.37	58.34	58.00	58.04	57.33	57.00	56.78	56.46	37.42	36.82	36.90	37.93	38.27	38.23	38.94	39.27	39.49	39.81
OW-304	CU	68.78	71.01																				
OW-308	CU	111.45	113.62																				
OW-313A	CU	51.03	53.20	19.80	20.40	20.08	19.57	18.80	18.90	17.93	18.25	17.12	16.77	33.40	32.80	33.12	33.63	34.40	34.30	35.27	34.95	36.08	36.43
OW-319B	CU	103.53	105.35	67.49	67.97	67.95	67.53	66.57	66.49	65.74	65.52	65.27	64.84	37.86	37.38	37.40	37.82	38.78	38.86	39.61	39.83	40.08	40.51
OW-328	CU	76.29	77.85	40.77	41.40	41.35	40.68	40.33	40.13	39.63	39.42	39.32	38.72	37.08	36.45	36.50	37.17	37.52	37.72	38.22	38.43	38.53	39.13
OW-336	CU	97.11	99.07	60.99	61.36	61.52	60.45	60.42	60.19	59.65	59.20	59.25	58.76	38.08	37.71	37.55	38.62	38.65	38.88	39.42	39.87	39.82	40.31
OW-401	CU	71.38	73.49	34.13	34.95	34.73	33.72	32.95	33.37	32.33	32.45	31.76	31.38	39.36	38.54	38.76	39.77	40.54	40.12	41.16	41.04	41.73	42.11
OW-413B	CU	122.9	124.85	86.60	87.30	87.13	86.46	85.14	85.56	84.40	84.75	83.57	83.25	38.25	37.55	37.72	38.39	39.71	39.29	40.45	40.10	41.28	41.60
OW-418A	CU	43.66	45.83	8.22	9.44	8.60	7.97	6.45	7.60	6.40	6.91	5.68	5.57	37.61	36.39	37.23	37.86	39.38	38.23	39.43	38.92	40.15	40.26
OW-703A	CU	44.02	45.65	27.33	27.84	28.05	27.93	27.60	27.12	25.16	25.60	22.15	21.95	18.32	17.81	17.60	17.72	18.05	18.53	20.49	20.05	23.50	23.70
OW-705	CU	47.71	50.22	20.28	21.10	20.67	20.10	19.02	19.40	17.82	18.60	16.57	16.35	29.94	29.12	29.55	30.12	31.20	30.82	32.4	31.62	33.65	33.87

Table 2.4-36— {CCNPP Unit 3 Observation Wells Used in Hydrologic Evaluation}

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Well ID	Aquifer Unit	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
				July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007	July 2006	August 2006	September 2006	October 2006	November 2006	December 2006	January 2007	February 2007	March 2007	April 2007
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-708A	CU	37.44	39.61	13.39	15.01	13.85	12.78	10.46	12.58	8.96	12.20	6.71	6.77	26.22	24.60	25.76	26.83	29.15	27.03	30.65	27.41	32.90	32.84
OW-711	CU	52.92	55.31	19.26	20.64	19.50	18.43	16.14	18.33	15.94	17.70	14.33	14.36	36.05	34.67	35.81	36.88	39.17	36.98	39.37	37.61	40.98	40.95
OW-725	CU	58.04	59.94	32.80	33.87	33.92	33.56	32.54	32.30	30.77	30.77	29.77	28.95	27.14	26.07	26.02	26.38	27.40	27.64	29.17	29.17	30.17	30.99
OW-735	CU	91.20	93.44	54.18	55.17	55.14	54.57	53.31	53.24	52.36	52.13	52.16	51.40	39.26	38.27	38.30	38.87	40.13	40.20	41.08	41.31	41.28	42.04
OW-752B	CU	95.79	97.41	59.55	60.25	60.05	59.75	59.38	59.16	58.77	58.60	58.58	58.01	37.86	37.16	37.36	37.66	38.03	38.25	38.64	38.81	38.83	39.40
OW-754	CU	67.00	68.85	31.32	32.05	31.80	31.05	30.73	30.93	30.24	30.12	29.67	29.32	37.53	36.80	37.05	37.80	38.12	37.92	38.61	38.73	39.18	39.53
OW-759B	CU	98.35	100.14	63.09	63.80	63.56	63.31	63.11	62.87	62.54	62.32	62.30	61.85	37.05	36.34	36.58	36.83	37.03	37.27	37.60	37.82	37.84	38.29
OW-765B	CU	96.82	98.47	60.22	60.72	60.55	60.40	59.92	59.77	59.73	59.45	59.37	58.96	38.25	37.75	37.92	38.07	38.55	38.70	38.74	39.02	39.10	39.51
OW-768A	CU	48.48	49.84	24.05	24.88	24.04	23.67	23.12	23.65	23.10	23.26	22.53	22.62	25.79	24.96	25.80	26.17	26.72	26.19	26.74	26.58	27.31	27.22
OW-769	CU	54.23	56.43	26.50	27.96	27.37	26.74	24.13	25.74	23.48	24.43	20.55	20.67	29.93	28.47	29.06	29.69	32.30	30.69	32.95	32.00	35.88	35.76
OW-774A	CU	9.70	12.20																				
Lower Chesapeake Unit																							
OW-313B	CL	50.73	53.54	23.05	23.65	23.47	23.17	22.76	22.52	21.89	21.80	21.44	20.97	30.49	29.89	30.07	30.37	30.78	31.02	31.65	31.74	32.10	32.57
OW-418B	CL	43.67	45.77	12.52	13.36	12.90	12.47	11.67	12.85	11.03	11.27	10.74	10.42	33.25	32.41	32.87	33.30	34.10	32.92	34.74	34.50	35.03	35.35
OW-703B	CL	45.57	47.53	29.34	29.85	29.95	29.73	29.40	29.10	27.45	27.72	24.74	24.47	18.19	17.68	17.58	17.80	18.13	18.43	20.08	19.81	22.79	23.06
OW-774B	CL	10.10	12.55																				
OW-781	CL	10.30	12.87																				

Table 2.4-36— {CCNPP Unit 3 Observation Wells Used in Hydrologic Evaluation}

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Well ID	Aquifer Unit	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
				May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008	May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Surficial Aquifer																							
OW-319A	SA	103.13	104.91	26.26	26.57	26.95	27.25	26.2	26.28	26.68	26.08			78.65	78.34	77.96	77.66	78.701	78.63	78.23	78.83		
OW-323	SA	106.96	109.69	26.00	26.77	28.48	29.77	29.47	28.22	29.01	29.30			83.69	82.92	81.201	79.92	80.22	81.47	80.68	80.39		
OW-423	SA	111.12	113.16	27.42	27.87	29.53	31.70	32.02	31.01	31.56	31.87			85.74	85.29	83.63	81.46	81.14	82.15	81.60	81.29		
OW-428	SA	113.92	115.92	36.20	36.63	37.56	38.47	38.82	38.40	38.46	38.57			79.72	79.29	78.36	77.45	77.10	77.52	77.46	77.35		
OW-436	SA	108.13	110.39	30.72	31.22	32.32	33.26	33.12	32.10	32.82	33.06			79.67	79.17	78.07	77.13	77.27	78.29	77.57	77.33		
OW-714	SA	116.02	117.98	44.93	43.25	46.05	47.57	47.32	46.48	48.101	48.53			73.05	74.73	71.93	70.41	70.66	71.50	69.87	69.45		
OW-718	SA	118.53	120.41	38.72	38.93	39.85	41.50	41.70	43.90	41.78	41.82			81.69	81.48	80.56	78.91	78.701	76.51	78.63	78.59		
OW-743	SA	103.65	105.89	34.57	34.14	37.17	38.35	38.26	38.65	39.82	39.97			71.32	71.75	68.72	67.54	67.63	67.24	66.07	65.92		
OW-752A	SA	95.30	97.00	22.24	23.91	25.78	27.22	26.73	24.73	25.701	26.11			74.76	73.09	71.22	69.78	70.27	72.27	71.29	70.89		
OW-756	SA	106.56	108.77	27.05	27.77	29.75	31.44	31.75	31.34	31.60	31.77			81.72	81.00	79.02	77.33	77.02	77.43	77.17	77.00		
OW-759A	SA	97.78	99.69	23.73	21.08	28.27	30.58	29.86	30.92	29.52	29.84			75.96	78.61	71.42	69.11	69.83	68.77	70.17	69.85		
OW-765A	SA	97.37	99.60	18.28	20.12	22.12	22.57	21.73	21.55	22.25	22.42			81.32	79.48	77.48	77.03	77.87	78.05	77.35	77.18		
OW-766	SA	108.89	110.72	26.85	27.52	29.47	31.02	30.82	29.80	30.54	30.79			83.87	83.20	81.25	79.70	79.90	80.92	80.18	79.93		
Upper Chesapeake Unit																							
OW-301	CU	94.51	96.27	57.32	58.67	59.92	60.75	59.62	59.58	60.57	60.80			38.95	37.60	36.35	35.52	36.65	36.69	35.70	35.47		
OW-304	CU	68.78	71.01							37.28	37.43	37.33	36.78							33.73	33.58	33.68	34.23
OW-308	CU	111.45	113.62							78.33	78.41	78.29	78.00							35.29	35.21	35.33	35.62
OW-313A	CU	51.03	53.20	18.23	19.56	21.05	21.52	20.32	23.80	21.501	21.71			34.97	33.64	32.15	31.68	32.88	29.40	31.69	31.49		
OW-319B	CU	103.53	105.35	65.72	67.22	68.45	69.45	68.38	68.18	69.31	69.48			39.63	38.13	36.90	35.90	36.97	37.17	36.04	35.87		
OW-328	CU	76.29	77.85	39.33	40.52	41.90	42.53	41.68	41.60	42.57	42.67			38.52	37.33	35.95	35.32	36.17	36.25	35.28	35.18		
OW-336	CU	97.11	99.07	59.28	60.57	61.80	62.63	61.86	61.67	62.73	62.78			39.79	38.50	37.27	36.44	37.201	37.40	36.34	36.29		
OW-401	CU	71.38	73.49	32.66	34.14	35.80	36.59	35.04	35.07	36.36	36.62			40.83	39.35	37.69	36.90	38.45	38.42	37.13	36.87		
OW-413B	CU	122.9	124.85	84.84	86.42	88.05	89.02	87.37	87.36	88.65	88.87			40.001	38.43	36.8	35.83	37.48	37.49	36.20	35.98		
OW-418A	CU	43.66	45.83	7.32	8.65	10.67	10.62	8.38	8.95	10.70	11.17			38.501	37.18	35.16	35.21	37.45	36.88	35.13	34.66		
OW-703A	CU	44.02	45.65	25.68	24.08	28.42	28.83	28.17	28.14	29.15	29.54			19.97	21.57	17.23	16.82	17.48	17.51	16.50	16.11		
OW-705	CU	47.71	50.22	18.72	20.22	21.80	22.18	20.75	20.9	22.201	22.50			31.50	30.00	28.42	28.04	29.47	29.32	28.01	27.72		

Table 2.4-36— {CCNPP Unit 3 Observation Wells Used in Hydrologic Evaluation}

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Well ID	Aquifer Unit	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
				May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008	May 2007	June 2007	September 2007	December 2007	April 2008	July 2008	September 2008	October 2008	November 2008	December 2008
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-708A	CU	37.44	39.61	11.70	14.50	16.26	17.36	13.46	13.18	15.67	16.28			27.901	25.11	23.35	22.25	26.15	26.43	23.94	23.33		
OW-711	CU	52.92	55.31	18.18	19.85	21.88	19.50	19.42	20.03	14.67	22.37			37.13	35.46	33.43	35.81	35.89	35.28	40.64	32.94		
OW-725	CU	58.04	59.94	30.47	34.14	34.82	35.72	33.83	34.32	35.87	36.27			29.47	25.80	25.12	24.22	26.11	25.62	24.07	23.67		
OW-735	CU	91.20	93.44	52.37	53.74	55.98	56.72	55.09	55.32	56.80	57.01			41.07	39.70	37.46	36.72	38.35	38.12	36.64	36.43		
OW-752B	CU	95.79	97.41	58.50	59.32	60.68	61.05	60.43	60.47	61.46	61.57			38.901	38.09	36.73	36.36	36.98	36.94	35.95	35.84		
OW-754	CU	67.00	68.85	30.33	31.33	32.50	32.98	31.86	32.00	32.87	33.12			38.52	37.52	36.35	35.87	36.99	36.85	35.98	35.73		
OW-759B	CU	98.35	100.14	62.17	61.57	64.15	64.48	64.00	64.17	65.06	65.23			37.97	38.57	35.99	35.66	36.14	35.97	35.08	34.91		
OW-765B	CU	96.82	98.47	59.24	59.92	61.07	61.58	61.24	61.27	61.88	62.00			39.23	38.55	37.40	36.89	37.23	37.20	36.59	36.47		
OW-768A	CU	48.48	49.84	23.55	24.15	26.17	26.75	23.84	24.42	26.34	26.81			26.29	25.69	23.67	23.09	26.00	25.42	23.50	23.03		
OW-769	CU	54.23	56.43	24.68	26.40	26.37	30.27	27.70	28.07	29.88	33.33			31.75	30.03	30.06	26.16	28.73	28.36	26.55	23.10		
OW-774A	CU	9.70	12.20							10.13	10.21	10.15	9.98							2.07	1.99	2.05	2.22
Lower Chesapeake Unit																							
OW-313B	CL	50.73	53.54	21.47	22.60	24.23	24.85	23.98	23.74	24.78	25.08			32.07	30.94	29.301	28.69	29.56	29.80	28.76	28.46		
OW-418B	CL	43.67	45.77	11.33	12.55	14.50	14.96	13.02	13.13	14.67	15.16			34.44	33.22	31.27	30.81	32.75	32.64	31.10	30.61		
OW-703B	CL	45.57	47.53	27.68	26.47	30.38	30.72	30.02	30.80	31.02	31.42			19.85	21.06	17.15	16.81	17.501	16.73	16.51	16.11		
OW-774B	CL	10.10	12.55							10.15	10.00	10.15	10.04							2.40	2.55	2.40	2.51
OW-781	CL	10.30	12.87							10.36	10.58	10.44	10.45							2.51	2.29	2.43	2.42

Table 2.4-36— {CCNPP Unit 3 Observation Wells Used in Hydrologic Evaluation}

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Well ID	Aquifer Unit	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
				January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009	January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Surficial Aquifer																							
OW-319A	SA	103.13	104.91	26.28			26.38			26.44			26.53	78.63			78.53			78.47			78.38
OW-323	SA	106.96	109.69	29.57			29.08			27.55			28.72	80.12			80.61			82.14			80.97
OW-423	SA	111.12	113.16	32.07			31.97			29.77			30.43	81.09			81.19			83.39			82.73
OW-428	SA	113.92	115.92	38.85			38.86			37.68			38.13	77.07			77.06			78.24			77.79
OW-436	SA	108.13	110.39	33.31			33.27			31.66			32.10	77.08			77.12			78.73			78.29
OW-714	SA	116.02	117.98	48.19			47.73			46.04			47.17	69.79			70.25			71.94			70.81
OW-718	SA	118.53	120.41	42.12			42.03			42.08			42.08	78.29			78.38			78.33			78.33
OW-743	SA	103.65	105.89	39.58			39.001			37.66			38.48	66.31			66.88			68.23			67.41
OW-752A	SA	95.30	97.00	26.43			26.04			23.72			25.66	70.57			70.96			73.28			71.34
OW-756	SA	106.56	108.77	31.99			32.04			30.13			30.77	76.78			76.73			78.64			78.00
OW-759A	SA	97.78	99.69	30.23			30.18			27.28			28.76	69.46			69.51			72.41			70.93
OW-765A	SA	97.37	99.60	22.27			21.05			20.97			22.17	77.33			78.55			78.63			77.43
OW-766	SA	108.89	110.72	30.70			30.32			28.90			29.86	80.02			80.40			81.82			80.86
Upper Chesapeake Unit																							
OW-301	CU	94.51	96.27	59.93			58.65			59.72			60.02	36.34			37.62			36.55			36.25
OW-304	CU	68.78	71.01	36.30	36.64	36.40	34.58	33.87	34.18	36.07	36.66	36.85	36.07	34.701	34.37	34.601	36.43	37.14	36.83	34.94	34.35	34.16	34.94
OW-308	CU	111.45	113.62	77.62	77.77	77.71	76.401	75.57	75.43	77.18	77.64	77.73	77.18	36.00	35.85	35.901	37.21	38.05	38.19	36.44	35.98	35.89	36.44
OW-313A	CU	51.03	53.20	20.60			19.02			20.33			20.87	32.6			34.18			32.87			32.33
OW-319B	CU	103.53	105.35	68.72			67.46			68.33			68.78	36.63			37.89			37.02			36.57
OW-328	CU	76.29	77.85	42.07			40.84			41.59			42.19	35.78			37.01			36.26			35.66
OW-336	CU	97.11	99.07	62.24			60.97			61.80			62.28	36.83			38.10			37.27			36.79
OW-401	CU	71.38	73.49	35.67			33.701			35.16			35.47	37.82			39.78			38.33			38.02
OW-413B	CU	122.9	124.85	87.80			86.07			87.501			87.72	37.05			38.78			37.34			37.13
OW-418A	CU	43.66	45.83	9.00			6.74			9.46			8.66	36.83			39.09			36.37			37.17
OW-703A	CU	44.02	45.65	28.52			27.68			27.48			28.80	17.13			17.97			18.17			16.85
OW-705	CU	47.71	50.22	21.02			18.95			20.81			21.42	29.20			31.27			29.41			28.80

Table 2.4-36— {CCNPP Unit 3 Observation Wells Used in Hydrologic Evaluation}

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Well ID	Aquifer Unit	Ground Surface Elevation	Water Level Monitoring Reference Point Elevation	Depth to Water										Water Level Elevation									
				January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009	January 2009	February 2009	March 2009	April 2009	May 2009	June 2009	July 2009	August 2009	September 2009	October 2009
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
OW-708A	CU	37.44	39.61	12.81			9.28			13.64			12.57	26.80			30.33			25.97			27.04
OW-711	CU	52.92	55.31	19.62			16.27			20.45			18.32	35.69			39.04			34.86			36.99
OW-725	CU	58.04	59.94	34.80			32.66			33.97			35.23	25.14			27.28			25.97			24.71
OW-735	CU	91.20	93.44	55.77			53.88			55.25			55.80	37.67			39.56			38.19			37.64
OW-752B	CU	95.79	97.41	60.78			59.89			60.39			60.75	36.63			37.52			37.02			36.66
OW-754	CU	67.00	68.85	32.12			31.10			32.02			32.13	36.73			37.75			36.83			36.72
OW-759B	CU	98.35	100.14	64.45			63.601			63.95			64.14	35.69			36.53			36.19			36.00
OW-765B	CU	96.82	98.47	61.50			60.94			60.901			61.33	36.97			37.53			37.56			37.14
OW-768A	CU	48.48	49.84	24.10			23.37			24.901			24.42	25.74			26.47			24.93			25.42
OW-769	CU	54.23	56.43	28.57			24.74			28.03			28.66	27.86			31.69			28.40			27.77
OW-774A	CU	9.70	12.20	10.34	10.45	10.01	9.37	9.53	9.14	9.70	9.82	10.001	9.70	1.86	1.75	2.19	2.83	2.67	3.06	2.50	2.38	2.19	2.50
Lower Chesapeake Unit																							
OW-313B	CL	50.73	53.54	24.32			23.26			23.47			24.33	29.22			30.28			30.07			29.21
OW-418B	CL	43.67	45.77	13.47			12.09			13.28			13.62	32.30			33.68			32.49			32.15
OW-703B	CL	45.57	47.53	30.30			29.36			29.51			30.56	17.23			18.17			18.02			16.97
OW-774B	CL	10.10	12.55	10.52	10.48	10.17	9.78	9.76	9.48	9.92	9.91	10.06	9.92	2.03	2.07	2.38	2.77	2.79	3.07	2.63	2.64	2.49	2.63
OW-781	CL	10.30	12.87	10.72	10.95	10.62	10.31	10.17	9.94	10.12	10.21	10.36	10.12	2.15	1.92	2.25	2.56	2.70	2.93	2.75	2.66	2.51	2.75

Table 2.4-37— {CCNPP Unit 3 Observation Wells – Hydraulic Conductivities from Slug Tests}

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Well ID	Surficial Aquifer	Kh	Kh	Kh	Well ID	Upper Chesapeake Unit	Kh	Kh	Kh	Well ID	Lower Chesapeake Unit	Kh	Kh	Kh
		(ft/sec)	(cm/sec)	(ft/day)			(ft/sec)	(cm/sec)	(ft/day)			(ft/sec)	(cm/sec)	(ft/day)
OW-319A	SA	2.89E-06	8.81E-05	2.50E-01	OW-301	CU	1.58E-04	4.82E-03	1.37E+01	OW-313B	CL	2.74E-07	8.35E-06	2.37E-02
OW-323	SA	6.24E-05	1.90E-03	5.39E+00	OW-313A	CU	7.50E-06	2.29E-04	6.48E-01	0W-418B	CL	2.16E-07	6.58E-06	1.87E-02
OW-423	SA	6.86E-05	2.09E-03	5.93E+00	OW-319B	CU	3.42E-05	1.04E-03	2.95E+00	OW-703B	CL	1.08E-06	3.29E-05	9.33E-02
OW-428	SA	1.19E-05	3.63E-04	1.03E+00	OW-328	CU	3.79E-06	1.16E-04	3.27E-01		**max**	1.08E-06	3.29E-05	9.33E-02
OW-436	SA	2.80E-06	8.53E-05	2.42E-01	OW-336	CU	2.10E-05	6.40E-04	1.81E+00		**min**	2.16E-07	6.58E-06	1.87E-02
OW-743	SA	6.23E-07	1.90E-05	5.38E-02	OW-401	CU	6.77E-06	2.06E-04	5.85E-01		**mean**	5.23E-07	1.60E-05	4.52E-02
OW-752A	SA	7.03E-05	2.14E-03	6.07E+00	OW-413B	CU	2.78E-06	8.47E-05	2.40E-01		**geo mean**	4.00E-07	1.22E-05	3.45E-02
OW-756	SA	2.01E-04	6.13E-03	1.74E+01	OW-418A	CU	4.41E-06	1.34E-04	3.81E-01					
OW-759A	SA	4.64E-07	1.41E-05	4.01E-02	OW-703A	CU	1.34E-05	4.08E-04	1.16E+00					
OW-765A	SA	1.00E-05	3.05E-04	8.64E-01	OW-705	CU	4.99E-06	1.52E-04	4.31E-01					
	max	2.01E-04	6.13E-03	1.74E+01	OW-708A	CU	2.56E-05	7.80E-04	2.21E+00					
	min	4.64E-07	1.41E-05	4.01E-02	OW-711	CU	6.04E-06	1.84E-04	5.22E-01					
	mean	4.31E-05	1.31E-03	3.72E+00	OW-725	CU	7.54E-06	2.30E-04	6.51E-01					
	geo mean	1.05E-05	3.21E-04	9.10E-01	OW-735	CU	5.48E-05	1.67E-03	4.73E+00					
					OW-752B	CU	3.35E-06	1.02E-04	2.89E-01					
					OW-754	CU	5.29E-06	1.61E-04	4.57E-01					
					OW-759B	CU	1.77E-06	5.39E-05	1.53E-01					
					OW-765B	CU	1.36E-06	4.15E-05	1.18E-01					
					OW-768A	CU	5.29E-06	1.61E-04	4.57E-01					
					OW-769	CU	1.74E-05	5.30E-04	1.50E+00					
						max	1.58E-04	4.82E-03	1.37E+01					
						min	1.36E-06	4.15E-05	1.18E-01					
						mean	1.93E-05	5.87E-04	1.66E+00					
						geo mean	8.56E-06	2.61E-04	7.40E-01					

Table 2.4-37— {CCNPP Unit 3 Observation Wells – Hydraulic Conductivities from Slug Tests}

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Well ID	Surficial Aquifer	Kh	Kh	Kh		Well ID	Upper Chesapeake Unit	Kh	Kh	Kh		Well ID	Lower Chesapeake Unit	Kh	Kh	Kh
		(ft/sec)	(cm/sec)	(ft/day)				(ft/sec)	(cm/sec)	(ft/day)				(ft/sec)	(cm/sec)	(ft/day)

Note: Slug test results for 7 Surficial Aquifer wells (OW-413A, OW-714, OW-718, OW-729, OW-766, and OW-770) are not included because of invalid test conditions, questionable data, or the well was screened in a discontinuous sand unit.

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1962G001	(08)	BEACHES WATER COMPANY, INC.	08/1990	Y	68,800	114,900	230	950	124C	NANJEMOY FORMATION	02-13-11-05	LONG BEACH AND CALVERT BEACH COMMUNITY SUPPLY
CA	G	CA1962G006	(01)	ROGERS, WILLIAM C.	07/1962	N	3,000	3,500	320	930	125B	AQUIA FORMATION	02-13-10-05	NORTH BEACH LAUNDROMAT
CA	G	CA1962G007	(05)	TPI GROUP, LLC.	03/2005	N	4,500	7,500	250	900	124C	NANJEMOY FORMATION	02-13-11-01	CALVERT MOBILE HOME PARK - PDWIS# 004-0206
CA	G	CA1962G103	(02)	CHESAPEAKE BIOLOGICAL LABORATORY	11/1997	N	8,000	10,000	180	960	125B	AQUIA FORMATION	02-13-11-01	UM CHESAPEAKE BIOLOGICAL LABORATORY
CA	G	CA1962G201	(03)	BEACHES WATER COMPANY, INC.	08/1990	Y	49,200	82,200	230	950	125B	AQUIA FORMATION	02-13-11-05	LONG BEACH AND CALVERT BEACH COMMUNITY SUPPLY
CA	G	CA1963G001	(04)	SHIELDS, SR., ROY, J.	09/1996	N	500	800	340	900	125B	AQUIA FORMATION	02-13-11-01	COMMERCIAL RENTAL PROPERTY - LEASED BY BEAUTY SHOP
CA	G	CA1963G003	(07)	CALVERT CLIFFS NUCLEAR POWER PLANT, LLC.	07/2000	N	500	5000	220	960	124E	PINEY POINT FORMATION	02-13-10-05	CALVERT CLIFFS POWER PLANT - CAMP CANOY
CA	G	CA1963G005	(02)	SCOTT, JOHN, J.	05/1997	N	500	1,000	320	920	124C	NANJEMOY FORMATION	02-13-10-05	PREV.STRUCTURE BURNT APPROX.8 MOS. AGO - UNSURE WHEN REBUILDING
CA	G	CA1963G007	(05)	VERIZON MARYLAND INC.	03/2002	N	100	300	260	920	124C	NANJEMOY FORMATION	02-13-10-05	PRINCE FREDERICK FACILITY #34183
CA	G	CA1965G002	(04)	RAWLINGS, L. LOUISE	11/1997	N	6,300	10,000	250	920	124C	NANJEMOY FORMATION	02-13-11-01	PINE TRAILER PARK
CA	G	CA1965G003	(04)	BURKE, ALAN	03/2003	N	500	700	230	930	124C	NANJEMOY FORMATION	02-13-11-01	GATEWAY RESTAURANT
CA	G	CA1965G007	(05)	CALVERT COUNTY COMMISSIONERS	03/2005	N	100	1,000	260	920	124C	NANJEMOY FORMATION	02-13-10-05	PARKS & REC FACILITY (OLD FAIRGROUNDS SITE)
CA	G	CA1965G009	(04)	WATERS MEMORIAL UNITED METHODIST CHURCH	09/1997	N	300	800	230	930	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1966G001	(05)	CROOKS, EDWARD	08/2005	Y	25,000	40,000	240	940	124E	PINEY POINT FORMATION	02-13-10-05	WESTERN SHORES COMMUNITY SUPPLY - PDWIS# 004-0016
CA	G	CA1966G002	(01)	KNOTTY PINE BAR & GRILL	08/1965	N	500	1,000	220	950	122	MIOCENE	02-13-11-01	
CA	G	CA1966G005	(05)	CALVERT COUNTY COMMISSIONERS	04/2004	Y	16,000	25,000	330	900	125B	AQUIA FORMATION	02-13-11-01	LAKEWOOD SUBD COMMUNITY SUPPLY - PDWIS #0040008
CA	G	CA1966G006	(04)	MD STATE HIGHWAY ADMINISTRATION	03/1997	N	2,000	3,000	260	920	125B	AQUIA FORMATION	02-13-10-05	S.H.A. GARAGE
CA	G	CA1966G007	(02)	PATUXENT METHODIST CHURCH	08/1997	N	300	700	280	910	124C	NANJEMOY FORMATION	02-13-11-01	PATUXENT UNITED METHODIST CHURCH
CA	G	CA1966G008	(04)	WARD'S UNITED METHODIST CHURCH	07/1997	N	200	300	320	930	125B	AQUIA FORMATION	02-13-10-05	CHURCH
CA	G	CA1966G010	(05)	AMERICAN LEGION POST 206 INC.	05/1998	N	1,500	2,500	320	930	124C	NANJEMOY FORMATION	02-13-10-05	AMERICAN LEGION
CA	G	CA1966G011	(05)	CALVERT COUNTY COMMISSIONERS	09/2004	N	7,700	15,000	290	890	125B	AQUIA FORMATION	02-13-11-01	KING'S LANDING-POOL(1041140)/DIN HALL(1041053)/CHESPAX/ EQUES CTR
CA	G	CA1966G012	(04)	SPRING GROVE MARINA LTD.	07/1997	N	4,000	7,500	180	950	124E	PINEY POINT FORMATION	02-13-11-01	SPRING COVE MARINA
CA	G	CA1966G014	(04)	VICTOR STANLEY, INC.	03/1996	N	700	1,150	330	900	125B	AQUIA FORMATION	02-13-11-01	FURNITURE MANUFACTURER
CA	G	CA1967G003	(01)	SAINT ANTHONY'S CHURCH	11/1966	N	1,000	1,500	320	930	124C	NANJEMOY FORMATION	02-13-10-05	
CA	G	CA1967G005	(04)	AL BANNA, EDMAD	02/2002	N	300	500	250	910	125B	AQUIA FORMATION	02-13-11-01	CITGO GAS & GALLO'S DELI
CA	G	CA1967G006	(06)	CALVERT COUNTY DAY SCHOOL, INC.	08/2005	N	8,300	11,900	280	910	125B	AQUIA FORMATION	02-13-11-01	CALVERTON SCHOOL - PDWIS# 104-0022

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1968G001	(04)	PLUM POINT UNITED METHODIST CHURCH	08/2001	N	300	500	280	930	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH
CA	G	CA1968G003	(02)	AMERICAN LEGION GRAY-RAY POST #220	05/1997	N	300	500	240	920	124C	NANJEMOY FORMATION	02-13-11-01	AMERICAN LEGION
CA	G	CA1968G004	(05)	MIDDLEHAM & ST PETER'S PARISH	02/1999	N	300	600	210	960	124E	PINEY POINT FORMATION	02-13-10-05	CHURCH, PARISH HALL, DAY SCHOOL, PROJECT SMILE(THRIFT SHOP/OFFICE
CA	G	CA1968G005	(04)	KING'S APOSTLE CHURCH OF GOD INC.	01/1998	N	300	500	310	930	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH
CA	G	CA1968G008	(05)	PROUT, CLAIRE, EBY	07/2004	N	1,200	2,000	220	920	124C	NANJEMOY FORMATION	02-13-10-05	PATUXENT CAMPSITES
CA	G	CA1968G009	(05)	CALVERT COUNTY COMMISSIONERS	07/2000	Y	25,000	42,000	240	940	124E	PINEY POINT FORMATION	02-13-10-05	KENWOOD BEACH COMMUNITY SUPPLY
CA	G	CA1969G002	(04)	CALVARY BIBLE CHURCH	05/1996	N	300	500	220	950	124E	PINEY POINT FORMATION	02-13-11-01	SANITARY & POTABLE SUPPLY FOR CHURCH
CA	G	CA1969G003	(05)	BROOKS UNITED METHODIST CHURCH	03/2004	N	200	300	230	930	124E	PINEY POINT FORMATION	02-13-11-04	CHURCH - PDWIS #1041011
CA	G	CA1969G005	(05)	COX FAMILY LLLP	04/2006	N	500	900	260	920	125B	AQUIA FORMATION	02-13-11-01	WINEGARDNER PONTIAC-GMC
CA	G	CA1969G007	(04)	SMITH, SHERMAN & MABEL,	04/1998	N	300	500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	BARBER SHOP/CARRY OUT
CA	G	CA1969G008	(04)	ASSOCIATION OF SEVENTH-DAY ADVENTISTS, CHESAPEAKE CONFERENCE	07/2000	N	300	500	240	930	124E	PINEY POINT FORMATION	02-13-11-01	CHURCH
CA	G	CA1969G009	(05)	FULL GOSPEL ASSEMBLY OF GOD	04/2006	N	600	800	250	920	124E	PINEY POINT FORMATION	02-13-10-05	CHURCH
CA	G	CA1969G010	(05)	CALVERT CLIFFS NUCLEAR POWER PLANT, LLC.	07/2000	Y	450,000	865,000	220	960	125B	AQUIA FORMATION	02-13-10-05	CALVERT CLIFFS NUCLEAR POWER PLANT - FENCED AREA

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1969G013	(05)	BREEZY POINT MARINA, INC.	03/2004	N	2,400	5,000	290	940	124C	NANJEMOY FORMATION	02-13-10-05	MARINA - 230 SLIPS
CA	G	CA1969G014	(04)	PADILLA, JAIME, A.	11/1998	N	2,800	4,000	250	930	124C	NANJEMOY FORMATION	02-13-11-01	ADAM'S THE PLACE FOR RIBS RESTAURANT
CA	G	CA1969G015	(04)	R.S. LEITCH COMPANY	04/1994	N	100	200	190	960	124E	PINEY POINT FORMATION	02-13-11-01	SOUTHEND SEVICE CENTER, INC. - SERVICE STATION
CA	G	CA1970G002	(03)	DOWELL PLAZA, INC.	03/1986	N	300	500	190	960	124C	NANJEMOY FORMATION	02-13-11-01	TWO UNIT OFFICE BUILDING
CA	G	CA1970G003	(03)	KRICK PLUMBING & HEATING CO., INC.	04/1998	N	150	300	320	910	125B	AQUIA FORMATION	02-13-11-01	KRICK PLUMBING & HEATING SHOP
CA	G	CA1970G004	(07)	CALVERT COUNTY COMMISSIONERS	07/2004	Y	50,000	86,000	330	910	211D	MAGOTHY FORMATION	02-13-11-01	CAVALIER COUNTRY SUBD COMMUNITY SUPPLY - PDWIS# 0040002
CA	G	CA1970G005	(06)	CALVERT COUNTY PUBLIC SCHOOLS	01/2003	Y	27,000	45,000	260	920	125B	AQUIA FORMATION	02-13-11-01	CALVERT HIGH SCHOOL & CALVERT CAREER CENTER
CA	G	CA1970G007	(06)	CALVERT COUNTY COMMISSIONERS	02/2004	Y	60,000	100,000	250	900	125B	AQUIA FORMATION	02-13-11-01	CALVERT COUNTY INDUSTRIAL PARK
CA	G	CA1971G001	(04)	HARBOR ISLAND MARINA, INC.	07/2002	N	900	1,800	180	960	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1971G002	(02)	CALVERT COUNTY PUBLIC SCHOOLS	08/1996	N	2,000	3,300	290	910	125B	AQUIA FORMATION	02-13-11-01	HUNTINGTOWN ELEMENTARY SCHOOL
CA	G	CA1971G004	(04)	SOLOMONS BEACON INN LIMITED PARTNERSHIP	01/2004	N	3,000	6,000	180	950	124E	PINEY POINT FORMATION	02-13-11-01	SOLOMONS BEACON MARINA
CA	G	CA1972G001	(04)	CALVERT COUNTY PUBLIC SCHOOLS	09/2003	Y	18,000	23,000	310	900	211D	MAGOTHY FORMATION	02-13-11-01	NORTHERN HIGH SCHOOL & MIDDLE SCHOOL
CA	G	CA1972G002	(05)	CALVERT COUNTY COMMISSIONERS	12/2001	Y	35,000	60,000	330	890	211D	MAGOTHY FORMATION	02-13-11-01	SHORES OF CALVERT SUBDIVISION

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1972G003	(06)	TOWN OF CHESAPEAKE BEACH	12/2004	Y	630,000	1,100,000	310	930	125B	AQUIA FORMATION	02-13-10-05	CHESAPEAKE BEACH COMMUNITY SUPPLY - PDWIS# 004-0003
CA	G	CA1973G001	(03)	HOWLIN JR., EDWARD, B.	09/2000	N	5,500	8,000	320	900	124C	NANJEMOY FORMATION	02-13-11-01	DUNKIRK VILLAGE SHOP/BUS CENTER - COMBINE CA73G001 & CA85G004
CA	G	CA1973G002	(04)	CALVERT COUNTY COMMISSIONERS	07/2004	N	3,600	5,000	240	930	125B	AQUIA FORMATION	02-13-11-01	COLLEGE OF SOUTHERN MARYLAND CALVERT COUNTY - PDWIS# 1040049
CA	G	CA1973G003	(04)	CALVERT COUNTY PUBLIC SCHOOLS	06/2004	N	200	300	290	910	124C	NANJEMOY FORMATION	02-13-11-01	HUNTING CREEK ALTERNATIVE SCHOOL - PDWIS# 1040025
CA	G	CA1973G004	(04)	CALVERT COUNTY PUBLIC SCHOOLS	06/2004	N	2,000	3,000	260	920	125B	AQUIA FORMATION	02-13-10-05	BROOKS ADMINISTRATIVE CENTER - PDWIS# 1040006
CA	G	CA1973G005	(04)	CALVERT COUNTY PUBLIC SCHOOLS	06/2004	N	5,000	6,000	260	920	125B	AQUIA FORMATION	02-13-11-01	CALVERT COUNTRY & CALVERT ELEMENTARY SCHOOLS - PDWIS# 1040012
CA	G	CA1973G006	(04)	CALVERT COUNTY COMMISSIONERS	12/2001	N	500	800	310	900	125B	AQUIA FORMATION	02-13-11-01	CHANEYVILLE TOURIST CENTER & FAIRVIEW BRANCH LIBRARY
CA	G	CA1973G007	(02)	BD. OF CO. COMMISSIONERS OF CALVERT CO.	08/1996	N	800	1,300	310	920	125B	AQUIA FORMATION	02-13-10-05	MT. HOPE COMMUNITY CENTER
CA	G	CA1973G008	(04)	CALVERT COUNTY PUBLIC SCHOOLS	06/2004	N	5,000	10,000	260	920	125B	AQUIA FORMATION	02-13-11-01	CALVERT MIDDLE SCHOOL - PDWIS# 1040018
CA	G	CA1973G009	(04)	CALVERT COUNTY PUBLIC SCHOOLS	06/2004	N	5,000	7,000	320	910	125B	AQUIA FORMATION	02-13-11-01	MT. HARMONY ELEMENTARY SCHOOL - PDWIS# 1040030
CA	G	CA1973G010	(04)	CALVERT COUNTY PUBLIC SCHOOLS	07/1997	N	5,300	8,900	200	960	124E	PINEY POINT FORMATION	02-13-11-01	APPEAL ELEMENTARY - ONE WELL PRIMARY OTHER WELL FIRE SUPP/BACK-UP

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1973G011	(04)	CALVERT COUNTY COMMISSIONERS	06/1995	N	500	800	230	930	124C	NANJEMOY FORMATION	02-13-11-01	FAMILY RESOURCE CENTER/ HEAD START
CA	G	CA1973G012	(01)	GLASCOCK, BEDFORD C.	12/1972	N	2,600	3,500	180	950	124E	PINEY POINT FORMATION	02-13-11-01	
CA	G	CA1973G013	(05)	CALVERT COUNTY BOARD OF COMMISSIONERS	02/2002	Y	29,000	44,000	320	920	125B	AQUIA FORMATION	02-13-10-05	PARIS OAKS SUBDIVISION
CA	G	CA1973G014	(07)	DOMINION COVE POINT LNG, LP	03/2004	Y	32,000	50,000	200	970	125B	AQUIA FORMATION	02-13-10-05	LIQUEFIED NATURAL GAS TERMINAL
CA	G	CA1973G015	(04)	CALVERT COUNTY BOARD OF COMMISSIONERS	08/2003	N	700	1,000	260	920	124C	NANJEMOY FORMATION	02-13-10-05	PRINCE FREDERICK WASTEWATER TREATMENT PLANT
CA	G	CA1973G017	(04)	BRANDYWINE CORPOREX PLAZA II LP	02/2004	N	1,500	2,000	310	900	125B	AQUIA FORMATION	02-13-11-01	RETAIL CENTER
CA	G	CA1974G001	(03)	VAN DINE, PETER D.	10/1993	N	1,000	1,500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	MERGANSER AIRCRAFT CORP.
CA	G	CA1974G002	(05)	CALVERT COUNTY COMMISSIONERS	07/2000	Y	25,000	37,500	270	940	124C	NANJEMOY FORMATION	02-13-10-05	DARES BEACH - NANJEMOY
CA	G	CA1974G003	(02)	GIBBONS, RICHARD, M.	05/1997	N	400	600	180	950	124E	PINEY POINT FORMATION	02-13-11-01	WATER FOR OFFICE
CA	G	CA1974G004	(03)	JESCHKE, CRAIG, A.	10/1993	N	1,000	1,500	320	910	125B	AQUIA FORMATION	02-13-11-01	MEDICAL CENTER
CA	G	CA1974G005	(06)	CALVERT COUNTY BOARD OF COMMISSIONERS, ,	05/1994	Y	245,000	370,000	260	920	125B	AQUIA FORMATION	02-13-11-01	PRINCE FREDERICK COMMUNITY WATER SUPPLY
CA	G	CA1974G007	(03)	T H B MANAGEMENT SERVICES, LLC	02/2004	N	5,000	8,800	310	900	125B	AQUIA FORMATION	02-13-11-01	
CA	G	CA1974G008	(03)	HUNTINGTOWN VOLUNTEER FIRE DEPARTMENT	05/1994	N	1,200	2,000	290	910	125B	AQUIA FORMATION	02-13-11-01	FIRE DEPT. & RESCUE SQUAD

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1974G009	(03)	CALVERT COUNTY PUBLIC SCHOOLS	03/1997	N	3,000	4,000	230	930	125B	AQUIA FORMATION	02-13-11-01	MUTUAL ELEMENTARY SCHOOL
CA	G	CA1974G102	(02)	CALVERT COUNTY COMMISSIONERS	07/2000	Y	25,000	37,500	270	940	125B	AQUIA FORMATION	02-13-10-05	DARES BEACH - AQUIA
CA	G	CA1975G001	(04)	VERIZON MARYLAND INC.	03/2002	N	200	300	320	920	125B	AQUIA FORMATION	02-13-11-01	NORTH BEACH FACILITY #35078
CA	G	CA1975G002	(03)	CALVERT COUNTY BOARD OF COMMISSIONERS	04/1998	N	1,000	5,000	260	910	125B	AQUIA FORMATION	02-13-11-01	OLD LANDFILL OFFICE BLDG
CA	G	CA1975G004	(01)	UNIVERSITY OF MARYLAND	03/1976	N	1,000	1,500	250	900	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1975G005	(03)	COLLIER, CHARLES	04/1998	N	1,100	2,200	270	910	124C	NANJEMOY FORMATION	02-13-11-01	LORD CALVERT BOWLING ALLEY
CA	G	CA1976G005	(07)	CALVERT COUNTY COMMISSIONERS	07/2006	Y	6,300	23,800	250	910	125B	AQUIA FORMATION	02-13-11-01	HALLOWING POINT PARK - PDWIS# 1041185 (MAINT) & 1041015 (CONCESS)
CA	G	CA1976G006	(05)	HARVEST FELLOWSHIP PRESBYTERIAN CHURCH	04/2001	N	100	200	210	960	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1976G007	(02)	ALL SAINTS EPISCOPAL CHURCH	08/1996	N	200	300	300	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1976G010	(02)	HARBOUR COAST INC.	09/1997	N	1,500	2,000	180	960	124E	PINEY POINT FORMATION	02-13-11-01	RESTAURANT/LOUNGE
CA	G	CA1976G011	(03)	THE GOTT COMPANY	07/2000	N	200	300	200	960	124E	PINEY POINT FORMATION	02-13-11-01	NATIONS BANK - LUSBY BRANCH
CA	G	CA1977G001	(02)	MARYLAND TOBACCO GROWERS ASSOCIATION	07/1987	N	500	600	290	910	124C	NANJEMOY FORMATION	02-13-11-01	R.K. AGRI SERVICES, INC.
CA	G	CA1977G002	(03)	RAJA HAWIT, MD & RICHARD GHAFFAS, MD	02/1999	N	1,200	2,000	280	910	124C	NANJEMOY FORMATION	02-13-11-01	MEDICAL OFFICES

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1977G005	(03)	FERRENZ, BRIAN, F.	06/2000	N	300	500	310	910	125B	AQUIA FORMATION	02-13-11-01	MT. HARMONY AUTO SERVICE - AUTO REPAIR
CA	G	CA1977G006	(03)	DUNKIRK SUPPLY, INC.	06/1999	N	400	600	320	920	125B	AQUIA FORMATION	02-13-11-01	DUNKIRK SUPPLY - TRUSS PLANT
CA	G	CA1977G008	(03)	CALVERT COUNTY PUBLIC SCHOOLS	11/1999	N	7,500	10,000	210	960	125B	AQUIA FORMATION	02-13-11-01	SOUTHERN MIDDLE SCHOOL
CA	G	CA1977G009	(03)	GLASCOCK, BEDFORD, C.	09/1999	N	1,500	2,000	180	950	124E	PINEY POINT FORMATION	02-13-11-01	SHOPPING CENTER
CA	G	CA1977G011	(03)	MT. OLIVE UNITED METHODIST CHURCH	11/2004	N	200	300	260	920	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH - PDWIS# 104-1062
CA	G	CA1977G016	(04)	CALVERT COUNTY COMMISSIONERS	03/2003	Y	33,000	45,000	260	910	125B	AQUIA FORMATION	02-13-11-01	CALVERT COUNTY DETENTION CENTER
CA	G	CA1977G017	(03)	AMERICAN LEGION POST 274	06/2000	N	800	1,200	200	960	124E	PINEY POINT FORMATION	02-13-11-01	ARICK L. LORE POST 274, THE AMERICAN LEGION INC.
CA	G	CA1977G018	(03)	DORAN, JOHN, T.	06/2000	N	1,000	1,500	250	910	124C	NANJEMOY FORMATION	02-13-11-01	R.T&E LAND - TRADE CENTER - OFFICE/WAREHOUSE BUILDING
CA	G	CA1977G019	(03)	SOUTHERN MARYLAND ELECTRIC COOPERATIVE	12/1999	N	2,000	3,000	260	920	125B	AQUIA FORMATION	02-13-10-05	ELECTRIC UTILITY AT 901 DARES BEACH ROAD
CA	G	CA1978G001	(03)	ST. PAUL UNITED METHODIST CHURCH	03/2001	N	600	800	200	960	124E	PINEY POINT FORMATION	02-13-10-05	CHURCH, PARSONAGE, DAY SCHOOL
CA	G	CA1978G003	(03)	PARKERS CREEK WATER COMPANY	08/2000	N	2,700	4,600	250	930	124E	PINEY POINT FORMATION	02-13-10-05	PARKERS CREEK KNOLLS SUBD COMMUNITY SUPPLY
CA	G	CA1978G004	(09)	BOARD OF COMMISSIONERS OF CALVERT COUNTY	12/1996	Y	128,600	214,700	320	930	125B	AQUIA FORMATION	02-13-10-05	SUMMIT, HIGHLANDS & CHESAPEAKE LIGHTHOUSE SBDNS.
CA	G	CA1978G006	(02)	HILL, THOMAS	05/1997	N	1,000	1,500	310	910	125B	AQUIA FORMATION	02-13-11-01	OPTIMIST CLUB

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1978G008	(04)	CALVERT COUNTY COMMISSIONERS	06/2003	Y	6,500	9,000	250	920	125B	AQUIA FORMATION	02-13-11-01	MASON ROAD/WOODRIDGE COMM. SUPPLY
CA	G	CA1978G009	(03)	COOPERS UNITED METHODIST CHURCH	06/2000	N	200	300	320	900	125B	AQUIA FORMATION	02-13-11-01	CHURCH
CA	G	CA1978G010	(02)	MC ALLUM, T., J.	03/2000	N	500	800	300	910	125B	AQUIA FORMATION	02-13-10-05	B & M MOBILE TUNE-UP
CA	G	CA1978G011	(04)	CALVERT BEACH WATER COMPANY INC.	05/1998	Y	40,000	70,000	230	950	124E	PINEY POINT FORMATION	02-13-10-05	CALVERT BEACH PARK WEST SUBDIVISION
CA	G	CA1978G012	(03)	FOWLER, GENEVIEVE, M.	09/2000	N	300	500	260	920	124C	NANJEMOY FORMATION	02-13-10-05	SEARS APPLIANCE STORE (FORMERLY A GROCERY STORE)
CA	G	CA1978G013	(02)	OLIVET UNITED METHODIST CHURCH	05/1997	N	100	300	180	960	122	MIOCENE	02-13-11-01	
CA	G	CA1978G015	(03)	THE CHRIST CHILD SOCIETY	04/2000	N	1,000	4,000	220	920	124C	NANJEMOY FORMATION	02-13-11-01	CHRIST CHILD SUMMER CAMP
CA	G	CA1979G001	(04)	J.H. GRIBBLE & SONS, INC.	09/2002	N	9,600	9,800	250	920	125B	AQUIA FORMATION	02-13-10-05	CALVERT WELL DRILLING COMPANY
CA	G	CA1979G002	(02)	ADAMS, R. SCOTT	10/2005	N	1,200	2,000	210	960	124E	PINEY POINT FORMATION	02-13-11-01	FRYING PAN RESTAURANT - PDWIS# 104-1036
CA	G	CA1979G003	(03)	SOLID GROUND FARM, INC.	06/2001	N	6,900	41,000	220	920	125B	AQUIA FORMATION	02-13-11-01	HORSE & ALFALFA FARM
CA	G	CA1979G004	(05)	CALVERT COUNTY COMMISSIONERS	07/2006	Y	6,000	29,400	320	900	211D	MAGOTHY FORMATION	02-13-11-01	DUNKIRK DISTRICT PARK - PDWIS# 104-1013
CA	G	CA1979G005	(03)	FRANKEL DMD, BENNETT, F.	01/2006	N	2,000	3,400	260	910	124C	NANJEMOY FORMATION	02-13-11-01	PRINCE FREDERICK PROFESSIONAL BLDG - PDWIS# 104-1095
CA	G	CA1979G006	(02)	RIDGEWAY, JON R. AND PEGGY JO	09/1996	N	2,000	3,400	340	900	125B	AQUIA FORMATION	02-13-11-01	MULTI FAMILY APARTMENT UNIT

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1979G008	(03)	CALVERT COUNTY BOARD OF COMMISSIONERS	06/2001	N	600	2,000	240	920	124C	NANJEMOY FORMATION	02-13-11-01	BATTLE CREEK CYPRESS SWAMP NATURE CENTER
CA	G	CA1979G009	(03)	RANDLE CLIFF COMMUNITY CHURCH	06/2001	N	100	300	300	930	124C	NANJEMOY FORMATION	02-13-10-05	
CA	G	CA1979G010	(02)	TOWN OF CHESAPEAKE BEACH	09/1996	N	1,000	1,500	320	930	124C	NANJEMOY FORMATION	02-13-10-05	TOWN ROADS BUILDING
CA	G	CA1979G011	(02)	DODSON, JOSEPH, S.	08/1996	N	400	600	250	920	124C	NANJEMOY FORMATION	02-13-10-05	KEN MAR LIQUORS
CA	G	CA1979G013	(02)	BETHEL WAY OF THE CROSS CHURCH	09/1996	N	500	2,500	300	910	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH
CA	G	CA1980G001	(02)	HILL & JOHN PRINCIPE, ROBERT	07/1996	N	500	800	340	900	125B	AQUIA FORMATION	02-13-11-01	LIQUOR STORE & DELI
CA	G	CA1980G003	(03)	JOHNSON ACRES WATER COMPANY	05/2003	N	3,200	5,400	220	940	124C	NANJEMOY FORMATION	02-13-11-01	JOHNSON ACRES SUBD - COMMUNITY SUPPLY
CA	G	CA1980G004	(03)	CALVERT COUNTY SPORTSMEN'S CLUB, INC.	08/2002	N	300	500	250	920	124C	NANJEMOY FORMATION	02-13-11-01	CLUB
CA	G	CA1980G005	(03)	VERIZON MARYLAND INC.	03/2002	N	100	200	230	930	124E	PINEY POINT FORMATION	02-13-11-01	PORT REPUBLIC/MUTUAL FACILITY #34087
CA	G	CA1980G008	(02)	SHELDON, NANETTE	07/1990	N	1,200	2,000	300	930	124C	NANJEMOY FORMATION	02-13-10-05	RANDLE CLIFFS COMMUNITY SUPPLY
CA	G	CA1980G009	(01)	SKIP JACK, INC.	11/1980	N	500	800	180	960	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1980G010	(02)	DRUM POINT YACHT CLUB, INC.	11/1990	N	600	1,000	190	960	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1981G001	(06)	CALVERT COUNTY COMMISSIONERS	06/2006	Y	3,300	21,100	200	970	124E	PINEY POINT FORMATION	02-13-10-05	COVE POINT PARK-1041186(MAINT)/ 1041111(CONCESSION)/ 104-1255(POOL)

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1981G003	(03)	MT. HARMONY UNITED METHODIST CHURCH	12/2003	N	300	400	320	910	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1981G006	(02)	EMMANUEL SEVENTH-DAY ADVENTIST CHURCH	07/1991	N	100	300	260	920	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH
CA	G	CA1981G008	(01)	SOLID ROCK CHURCH OF OUR LORD JESUS CHRI	09/1981	N	400	600	250	930	124E	PINEY POINT FORMATION	02-13-10-05	
CA	G	CA1981G010	(02)	CHRISTIAN BIBLE CENTER, INCORPORATED	09/1991	N	300	500	280	920	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1981G011	(03)	MC CARTNEY, LABEN, J.	11/2005	N	300	500	260	920	124C	NANJEMOY FORMATION	02-13-11-01	PENN AUTO
CA	G	CA1981G012	(03)	MERILLAT, STEPHEN M.	01/2004	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	AQUA MAINTENANCE SERVICES
CA	G	CA1981G014	(02)	HARBOR HILLS CITIZENS ASSOCIATION, INC.	09/1991	N	300	1,000	230	920	124C	NANJEMOY FORMATION	02-13-11-01	MARINA
CA	G	CA1981G015	(03)	ERSOY, OSMAN Z.	10/2003	N	300	500	270	910	124C	NANJEMOY FORMATION	02-13-11-01	O'BRIEN REALTY
CA	G	CA1981G016	(02)	CALVERT BANK & TRUST COMPANY	09/1996	N	300	500	310	900	125B	AQUIA FORMATION	02-13-11-01	BANK BRANCH OFFICE - CHANEYVILLE
CA	G	CA1982G001	(03)	FLAG HARBOR PARTNERSHIP	10/2004	N	1,000	4,000	230	950	124E	PINEY POINT FORMATION	02-13-10-05	MARINA - 165 SLIPS/2 EMPLOYEES/POOL - PDWIS# 104-1099
CA	G	CA1982G002	(03)	PADGETT, BASCOMBE, G.	05/2004	N	6,800	10,200	270	900	125B	AQUIA FORMATION	02-13-11-01	RESIDENTIAL GWHP W/ RECHARGE WELL
CA	G	CA1982G003	(04)	THOMPSON, PAUL	07/2005	N	3,000	5,000	290	930	124C	NANJEMOY FORMATION	02-13-10-05	RESIDENTIAL GWHP W/ RECHARGE WELL
CA	G	CA1982G004	(03)	PRINCE FREDERICK MOTOR COMPANY, INC.	03/2004	N	900	1,500	260	920	124E	PINEY POINT FORMATION	02-13-10-05	AUTO SALES & SERVICE

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1982G006	(03)	FIRST LUTHERAN CHURCH	09/2001	N	300	500	300	910	125B	AQUIA FORMATION	02-13-11-01	CHURCH
CA	G	CA1982G007	(04)	M & D PARTNERS, LLC.	12/2004	N	7,500	12,500	250	900	125B	AQUIA FORMATION	02-13-11-01	HALLOWING POINT MOBILE HOME PARK - PDWIS# 004-0208
CA	G	CA1982G008	(03)	CALVERT SKATING ASSOCIATES, INC.	01/2006	N	1,000	1,500	310	900	125B	AQUIA FORMATION	02-13-11-01	CALVERT ROLLER SKATING CENTER - PDWIS# 104-1018
CA	G	CA1982G010	(03)	SOUTHERN MARYLAND OIL, INC.	10/2005	N	200	300	320	910	125B	AQUIA FORMATION	02-13-11-01	PETROLEUM PRODUCTS DISTRIBUTOR
CA	G	CA1983G002	(02)	THE FIRST NATIONAL BANK OF MARYLAND	09/1996	N	300	500	260	920	124C	NANJEMOY FORMATION	02-13-11-01	BANK
CA	G	CA1983G005	(03)	WEBER, KARL & DEBORAH	04/2005	N	300	500	270	920	124C	NANJEMOY FORMATION	02-13-11-01	CHARLES F. WEBER CO., INC
CA	G	CA1983G006	(03)	CHRIST EPISCOPAL CHURCH	07/2005	N	800	1,500	240	930	124E	PINEY POINT FORMATION	02-13-11-01	CHURCH/PARISH HOUSE/ RESIDENCE - PDWIS# 104-1115
CA	G	CA1983G007	(02)	CHURCH OF CHRIST AT PRINCE FREDERICK	12/2000	N	500	800	290	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1983G008	(03)	CALVERT CLIFFS NUCLEAR POWER PLANT, LLC.	07/2000	N	300	500	220	960	124E	PINEY POINT FORMATION	02-13-10-05	CALVERT CLIFFS POWER PLANT - VISTORS CENTER
CA	G	CA1983G009	(03)	DUNKIRK SUPPLY INC.	08/1997	N	1,400	2,300	310	910	125B	AQUIA FORMATION	02-13-11-01	RETAIL LUMBER YARD
CA	G	CA1983G011	(03)	RICKER, MICHAEL	01/2006	N	5,000	9,000	200	960	124E	PINEY POINT FORMATION	02-13-11-01	POTABLE/SANITARY & COMMERCIAL GWHP - PDWIS# 104-1023
CA	G	CA1983G013	(03)	CALVERT COUNTY PUBLIC SCHOOLS	11/1999	N	100	200	310	900	125B	AQUIA FORMATION	02-13-11-01	WELL-NORTHERN HS WWTP & WELL-CONCESSION STAND/ FIELD IRRIGATION

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CA	G	CA1983G014	(03)	MATTHEWS, GAYLE B. & STELLA J.	06/2001	N	3,000	6,000	220	950	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP - NO RETURN
CA	G	CA1984G001	(02)	BUCKINGHAM, MICHAEL, H.	02/1994	N	300	500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	BAY METAL WORKS
CA	G	CA1984G002	(02)	MCLELLAND, SLATEN, A.	08/1996	N	3,000	3,500	340	900	125B	AQUIA FORMATION	02-13-11-01	GROUNDWATER HEAT PUMP
CA	G	CA1984G003	(03)	BOARD OF COMMISSIONERS OF CALVERT CO.	03/2006	Y	550,000	825,000	190	960	125B	AQUIA FORMATION	02-13-11-01	SOLOMONS ISLAND/LUSBY COMMUNITY WATER SUPPLY
CA	G	CA1984G005	(01)	ASBURY COMMUNITY CHURCH, INC.	06/1984	N	100	300	250	910	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA1984G007	(02)	DASH IN FOOD STORES, INC.	05/1996	N	500	1,000	320	910	125B	AQUIA FORMATION	02-13-11-01	CONVENIENCE STORE
CA	G	CA1984G008	(02)	KING, ESTATE OF BOYD	08/1996	N	500	800	260	920	124C	NANJEMOY FORMATION	02-13-11-01	RADIO SHACK - CALVERT VILLAGE SHOPPING CENTER
CA	G	CA1984G010	(02)	EASTERN & ST. JOHN U.M.C.	07/1996	N	400	700	200	960	124E	PINEY POINT FORMATION	02-13-11-01	EAST JOHN YOUTH CENTER
CA	G	CA1984G012	(02)	FIRST BAPTIST CHURCH, ,	08/1996	N	300	1,000	250	920	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH
CA	G	CA1984G013	(02)	CHURCH OF JESUS CHRIST OF LDS, CALVERT BRANCH	08/1997	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH OF JESUS CHRIST OF LATTER-DAY SAINTS
CA	G	CA1984G015	(02)	MORRIS, MICHAEL F., AND SHARON	09/1999	N	4,000	7,000	320	900	125B	AQUIA FORMATION	02-13-11-01	GWHP - RECHARGE WELL
CA	G	CA1984G016	(04)	STROCON, INC.	07/2002	N	1,300	1,800	310	910	125B	AQUIA FORMATION		02-13-11-01
CA	G	CA1984G017	(02)	MULLER, KENNETH, M.	08/1996	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	MT. HARMONY PROFESSIONAL CENTER

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CA	G	CA1985G001	(03)	MARYLAND HISTORICAL TRUST	10/2004	N	5,700	7,300	210	940	124E	PINEY POINT FORMATION	02-13-11-01	JEFFERSON PATTERSON PARK & MUSEUM - PDWIS# 104-1131
CA	G	CA1985G002	(03)	TALPALAR ET AL, JAY, & BEVERLY	12/2005	N	800	1,200	290	910	125B	AQUIA FORMATION	02-13-11-01	7-11 & PIZZA SHOP/CARPET STORE/VIDEO RENTAL - NEW WELL AQUIA
CA	G	CA1985G003	(02)	SOUTHERN MARYLAND ISLAMIC CENTER	08/2000	N	300	500	270	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1985G005	(02)	DEPARTMENT OF NATURAL RESOURCES	01/1999	N	500	600	250	900	125B	AQUIA FORMATION	02-13-11-01	SOUTHERN SERVICE CENTER
CA	G	CA1985G006	(02)	HOWLIN, EDWARD, B.	08/1997	N	1,400	2,000	320	900	125B	AQUIA FORMATION	02-13-11-01	PROFESSIONAL BUILDING - PDWIS# 104-1201
CA	G	CA1985G008	(02)	THOMAS DEVENNEY	08/1997	N	700	1,200	320	900	125B	AQUIA FORMATION	02-13-11-01	PEACHTREE COURT CENTER
CA	G	CA1985G009	(02)	LAKE, WILLIAM, B.	11/2001	N	2,000	4,000	220	950	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP - OVERBOARD DISCHARGE
CA	G	CA1985G010	(02)	BOWLES, JOHN	06/1998	N	300	450	330	890	125B	AQUIA FORMATION	02-13-11-01	BUILDING CONTRACTOR
CA	G	CA1985G011	(02)	MILLER, JAMES, A.	11/2001	N	2,500	4,000	220	950	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP
CA	G	CA1985G012	(03)	EDWARD B. HOWLIN, INC.	03/2003	N	9,800	16,000	320	920	124C	NANJEMOY FORMATION	02-13-11-01	CONCRETE BATCH PLANT - PROCESS WATER AND POTABLE
CA	G	CA1985G014	(02)	CALVERT LIGHTHOUSE TABERNACLE	07/2002	N	300	500	260	930	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1985G015	(02)	CALVERT COUNTY PUBLIC SCHOOLS	11/1997	N	2,200	3,500	310	910	125B	AQUIA FORMATION	02-13-10-05	SUNDERLAND ELEMENTARY SCHOOL
CA	G	CA1985G016	(02)	ZION HILL CHURCH OF GOD IN CHRIST	07/2000	N	300	500	190	960	124E	PINEY POINT FORMATION	02-13-11-01	CHURCH

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1985G017	(02)	CONNOR, ROBERT & DARLENE	11/1998	N	300	500	240	910	124C	NANJEMOY FORMATION	02-13-11-01	RAY GROCERY STORE
CA	G	CA1985G018	(02)	GROVER, JUNE, L.	04/1998	N	300	500	240	940	124E	PINEY POINT FORMATION	02-13-10-05	PLUMBING SHOP
CA	G	CA1986G001	(02)	CLEARY & CARL G. BROWN, FRANK, J.	04/1998	N	1,100	1,900	310	910	124C	NANJEMOY FORMATION	02-13-11-01	BROWN-CLEARY OFFICE BLDG- CUSTOM HOME BUILDER & ANIMAL HOSPITAL
CA	G	CA1986G002	(02)	BESCHE OIL COMPANY, INC.	04/1998	N	300	500	200	960	124E	PINEY POINT FORMATION	02-13-11-01	LUSBY SUNOCO GAS STATION AND REPAIR GARAGE
CA	G	CA1986G005	(02)	CALVERT COUNTY BOARD OF COMMISSIONERS	05/1998	N	350	500	230	940	124E	PINEY POINT FORMATION	02-13-11-01	TRASH COMPACTOR
CA	G	CA1986G006	(02)	HUNTINGTOWN UNITED METHODIST CHURCH	06/2000	N	300	500	290	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1986G007	(04)	CALVERT COUNTY COMMISSIONERS	03/2006	Y	30,000	45,000	230	940	125B	AQUIA FORMATION	02-13-11-01	ST. LEONARD MUNICIPAL SUPPLY - PDWIS# 004-0013
CA	G	CA1986G008	(02)	ELLIS, JOHN	12/1998	N	2,500	4,000	330	900	125B	AQUIA FORMATION	02-13-11-01	GWHP
CA	G	CA1986G009	(02)	TAYLOR, WILLIAM, R.	11/1998	N	3,000	5,000	270	920	124C	NANJEMOY FORMATION	02-13-11-01	GWHP AND SOME LIVESTOCK WATERING (CHANGE IN TYPE)
CA	G	CA1986G010	(02)	PRINCE FREDERICK CONGREGATION OF JEHOVAH	08/2000	N	200	300	280	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1986G011	(02)	BENNETT, CHARLES & GAIL	03/1999	N	300	500	200	960	124E	PINEY POINT FORMATION	02-13-11-01	MEDICAL SERVICES
CA	G	CA1986G012	(02)	CALVERT COUNTY GOVERNMENT	03/2001	N	900	1,500	200	980	124E	PINEY POINT FORMATION	02-13-10-05	COVE POINT LIGHT RESIDENCES
CA	G	CA1986G013	(03)	SILPASUVAN, SUWAT	02/2006	N	500	800	270	910	124C	NANJEMOY FORMATION	02-13-11-01	CALVERT PROFESSIONAL PARK - DOCTORS OFFICES - PDWIS# 104-1204

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1986G014	(02)	SHERIDAN ET AL, DANIEL, P.	10/1998	N	1,000	1,500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	LAZY J'S TAVERN
CA	G	CA1986G015	(02)	BOARD OF COMMISSIONERS CALVERT COUNTY	06/2000	N	100	1,500	260	920	125B	AQUIA FORMATION	02-13-10-05	COURTHOUSE STANDBY WELL - PDWIS #104-0083
CA	G	CA1986G016	(02)	BURKE, ALAN,	10/1998	N	500	800	200	960	124E	PINEY POINT FORMATION	02-13-11-01	GUIDO'S RESTAURANT
CA	G	CA1986G017	(02)	WENTWORTH NURSERY, INC.	08/2004	N	1,500	4,500	250	920	124C	NANJEMOY FORMATION	02-13-10-05	POTABLE/SANITARY & NURSERY IRRIGATION - 1 AC
CA	G	CA1987G001	(01)	STOKES, PAUL	03/1987	N	300	500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	PAUL STOKES & SONS, INC. (PLUMBING)
CA	G	CA1987G004	(02)	FIRE DEPARTMENT & RESCUE SQUAD INC., HUNTINGTOWN VOLUNTEER	08/2000	N	100	150	290	910	124C	NANJEMOY FORMATION	02-13-11-01	HUNTINGTOWN POST OFFICE
CA	G	CA1987G005	(02)	DUNKIRK ASSOCIATES, LLC,	06/2002	N	3,000	4,500	320	900	125B	AQUIA FORMATION	02-13-11-01	DUNKIRK TOWN SQUARE SHOPPING CENTER
CA	G	CA1987G006	(02)	CALVERT COUNTY BOARD OF COMMISSIONERS	04/2000	N	500	1,000	230	950	124E	PINEY POINT FORMATION	02-13-99-98	FLAG PONDS PARK
CA	G	CA1987G007	(01)	MARYLAND TOBACCO GROWERS ASSOCIATION	07/1987	N	350	500	290	910	124C	NANJEMOY FORMATION	02-13-11-01	JOHN'S OPEN PIT BAR-B-QUE
CA	G	CA1987G008	(02)	EDSINGER, ROBERT	11/2004	N	2,000	4,000	230	920	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP W/ RECHARGE WELL
CA	G	CA1987G009	(01)	STEVENSON, DOUGLAS	08/1987	N	300	500	310	910	125B	AQUIA FORMATION	02-13-11-01	STEVENSON POOLS OFFICE
CA	G	CA1987G010	(02)	CALVERT COUNTY BOARD OF COMMISSIONERS	05/1998	N	1,000	5,000	290	930	124C	NANJEMOY FORMATION	02-13-10-05	PLUM POINT TRASH COMPACTOR SITE
CA	G	CA1987G011	(03)	SINGH, RAGHUVIR	11/2004	N	100	300	290	910	124C	NANJEMOY FORMATION	02-13-11-01	LIQUOR STORE

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1987G012	(02)	SUNTRUST BANK	11/2001	N	300	400	320	900	125B	AQUIA FORMATION	02-13-11-01	SUNTRUST BANK
CA	G	CA1987G014	(01)	MOORE, SEWELL	10/1987	N	7,000	14,500	220	940	124E	PINEY POINT FORMATION	02-13-11-01	GROUND WATER HEAT PUMP
CA	G	CA1987G015	(02)	WILLIS, MICHAEL & LORI	01/2000	N	3,000	5,000	260	940	124C	NANJEMOY FORMATION	02-13-10-05	GROUND WATER HEAT PUMP
CA	G	CA1987G016	(01)	BEVERLY, LINWOOD	01/1988	N	3,000	5,000	240	930	124E	PINEY POINT FORMATION	02-13-11-01	GROUND WATER HEAT PUMP
CA	G	CA1987G017	(02)	GOLLUB, MELVIN	11/1999	N	100	200	250	910	124C	NANJEMOY FORMATION	02-13-11-01	RADIO STATION - WMJS
CA	G	CA1987G018	(02)	MOORE, SEWELL, T.	01/2000	N	3,000	5,000	220	940	124E	PINEY POINT FORMATION	02-13-11-01	GWHP - RECHARGE WELL
CA	G	CA1987G019	(02)	BOWEN, EDWARD, L.	03/2000	N	500	800	250	930	124E	PINEY POINT FORMATION	02-13-10-05	JACK & JILL DAY CARE CENTER
CA	G	CA1987G020	(01)	ABNER, ROBERT	03/1988	N	100	200	310	930	125B	AQUIA FORMATION	02-13-10-05	MARINA
CA	G	CA1988G001	(02)	HEGARTY KOPICKI INCORPORATED	06/2000	N	300	500	290	910	124C	NANJEMOY FORMATION	02-13-11-01	OFFICE
CA	G	CA1988G002	(02)	GRIBBLE, JOSEPH, H.	06/2002	N	4,000	6,000	180	970	124E	PINEY POINT FORMATION	02-13-10-05	GROUND WATER HEAT PUMP
CA	G	CA1988G003	(02)	GRACE BRETHREN CHURCH	12/1996	N	600	1,000	320	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH & PARSONAGE
CA	G	CA1988G004	(02)	BAY STATE INSULATION INC.	06/2000	N	200	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	INSULATION CONTRACTOR
CA	G	CA1988G005	(01)	CARROLL WESTERN CHURCH	04/1988	N	300	500	240	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH
CA	G	CA1988G006	(02)	T. AND T. LUMBER COMPANY, INC.	03/2001	N	800	1,200	240	930	124E	PINEY POINT FORMATION	02-13-11-01	?

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1988G007	(01)	SPARROW, DOUG	10/1988	N	3,000	6,000	260	910	124C	NANJEMOY FORMATION	02-13-11-01	GROUND WATER HEAT PUMP
CA	G	CA1988G008	(03)	MYCHALUS, IHOR & ANNE	11/2001	N	3,000	5,000	180	960	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GROUND WATER HEAT PUMP SYSTEM
CA	G	CA1988G009	(03)	THE TOWN OF NORTH BEACH,	09/2006	Y	185,000	300,000	320	930	125B	AQUIA FORMATION	02-13-10-05	MUNICIPAL SUPPLY - PDWIS# 004-0030
CA	G	CA1988G010	(01)	PENN, JAMES & PATRICIA	12/1988	N	300	500	250	910	124C	NANJEMOY FORMATION	02-13-11-01	PATTI'S QUICK SHOP
CA	G	CA1989G002	(03)	KUNST, MARY ANN AND JAMES W.	11/2005	N	3,000	6,000	180	960	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP W/ RECHARGE WELL
CA	G	CA1989G003	(03)	SELECT PRODUCTS, INC.	07/2001	N	100	200	180	960	124E	PINEY POINT FORMATION	02-13-11-01	MARINA
CA	G	CA1989G004	(02)	SELECT PRODUCTS, INC.	07/2001	N	6,000	12,000	180	960	122H	MIOCENE SERIES	02-13-11-01	CATAMARANS RESTAURANT - GWHP
CA	G	CA1989G005	(01)	FLORIA, JOSEPH	04/1989	N	3,000	6,000	300	910	124C	NANJEMOY FORMATION	02-13-11-01	GROUND WATER HEAT PUMP
CA	G	CA1989G007	(02)	CALVERT CLIFFS NUCLEAR POWER PLANT, LLC.	07/2000	N	500	1,000	220	960	124E	PINEY POINT FORMATION	02-13-11-01	RIFLE RANGE -DRINKING FOUNTAIN, SINK, LAWN IRRIGATION
CA	G	CA1989G008	(03)	HOWLIN, JR., EDWARD, B.	01/2005	N	21,000	33,200	320	900	211D	MAGOTHY FORMATION	02-13-11-01	SHOPPES @ APPLE GREEN - PDWIS # 104-0076
CA	G	CA1989G009	(02)	HUDSON JR., JOHN, W.	06/2001	N	300	500	270	910	125B	AQUIA FORMATION	02-13-11-01	HUDSON'S SUNOCO & MINI MART INC.
CA	G	CA1989G010	(02)	COLUMBIA INVESTMENTS, LLC	10/2003	N	500	800	270	910	124C	NANJEMOY FORMATION	02-13-11-01	AUTO BODY REPAIR
CA	G	CA1989G011	(02)	CERRITO FAMILY PROPERTIES LLC	07/2001	N	1,000	1,500	340	900	125B	AQUIA FORMATION	02-13-11-01	RETAIL, OFFICE AND SERVICES

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1989G012	(02)	SNEADE, WILLIAM, D.	06/2001	N	500	700	320	920	125B	AQUIA FORMATION	02-13-10-05	HARDWARE STORE
CA	G	CA1989G013	(02)	WILLIAMS, JENNIFER	11/2005	N	1,000	1,600	270	910	124C	NANJEMOY FORMATION	02-13-11-01	FIRST IMPRESSIONS DAYCARE - PDWIS# 104-0054
CA	G	CA1989G015	(01)	RICHARD & PHYLLIS HORSMON	09/2001	N	3,000	12,000	220	940	112	PLEISTOCENE	02-13-11-01	NURSERY
CA	G	CA1989G016	(02)	CALVERT ELKS LODGE #2620	07/2001	N	500	800	260	920	124C	NANJEMOY FORMATION	02-13-10-05	MEETING HALL
CA	G	CA1989G017	(03)	CHESAPEAKE CHURCH	11/2005	N	1,100	2,200	300	910	124C	NANJEMOY FORMATION	02-13-11-01	CHURCH & SHILOH CHRISTIAN ACADEMY PDWIS# 104-1176
CA	G	CA1989G018	(02)	CALVERT COUNTY BOARD OF COMMISSIONERS	06/1998	N	1,000	5,000	200	960	124E	PINEY POINT FORMATION	02-13-11-01	APPEAL/LUSBY COMPACTOR SITE
CA	G	CA1989G019	(03)	JEFFERSON, AGNES	12/2004	N	100	300	210	960	124E	PINEY POINT FORMATION	02-13-11-01	D.J.'S MARKET-PDWIS# 104-1029 (INACTIVE) - PROP FOR SALE
CA	G	CA1989G020	(03)	CALVERT COUNTY PUBLIC SCHOOLS	12/2002	N	6,000	9,000	280	920	125B	AQUIA FORMATION	02-13-11-01	PLUM POINT ELEMENTARY SCHOOL
CA	G	CA1989G021	(02)	RAYMOND-WOOD FUNERAL HOME, P.A.	10/2005	N	500	700	320	900	125B	AQUIA FORMATION	02-13-11-01	FUNERAL HOME AND FLORIST SHOP - PDWIS# 104-1190
CA	G	CA1989G022	(02)	J & K INVESTMENT ASSOCIATES, L.L.C.	12/2001	N	900	1,500	320	900	125B	AQUIA FORMATION	02-13-11-01	OFFICE BLDG - 10020 SOUTHERN MARYLAND BLVD
CA	G	CA1989G023	(02)	WAYSON, MORGAN	09/2002	N	6,100	10,000	310	910	125B	AQUIA FORMATION	02-13-11-01	OFFICE/WAREHOUSE SPACE/ SAMES INDUSTRIAL CENTER
CA	G	CA1989G107	(01)	CALVERT CLIFFS NUCLEAR POWER PLANT, LLC.	07/2000	N	300	500	220	960	124E	PINEY POINT FORMATION	02-13-11-01	PUP TRAILERS - NON-POTABLE SUPPLY ONLY
CA	G	CA1990G001	(02)	QUALITY BUILT HOMES, INC.	10/2003	N	600	1,200	220	950	112	PLEISTOCENE	02-13-11-01	

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1990G004	(03)	GIGLIOTTI, FELIX	09/2003	N	2,500	5,000	180	960	124E	PINEY POINT FORMATION	02-13-11-01	GWHP
CA	G	CA1990G005	(02)	CALVERT COUNTY PUBLIC SCHOOLS	12/2002	N	5,000	7,000	280	920	125B	AQUIA FORMATION	02-13-11-01	PLUM POINT MIDDLE SCHOOL
CA	G	CA1990G006	(02)	GRAY, BRUCE	05/1997	N	1,000	2,800	280	930	124C	NANJEMOY FORMATION	02-13-10-05	GWHP - RETURN WELL
CA	G	CA1990G008	(04)	DUNKIRK MARKET PLACE LLC,	07/2004	Y	15,000	30,000	320	900	125B	AQUIA FORMATION	02-13-11-01	DUNKIRK MARKET PLACE - 1 WELL - PDWIS# 1040064
CA	G	CA1990G009	(02)	BOWEN, DOUGLAS R.	11/2002	N	200	300	270	910	124C	NANJEMOY FORMATION	02-13-11-01	WASHING FARM EQUIPMENT.
CA	G	CA1990G010	(02)	CALVERT COUNTY COMMISSIONERS	12/2002	N	300	500	250	910	124C	NANJEMOY FORMATION	02-13-11-01	WASTE WATER TREATMENT PLANT.
CA	G	CA1990G011	(02)	RIVERA III, MODESTO S.	12/2002	N	300	500	260	920	124C	NANJEMOY FORMATION	02-13-11-01	MEDICAL OFFICE BUILDING.
CA	G	CA1990G012	(02)	KATZENBERGER, FRANK & KATHI	01/2003	N	300	500	220	960	124E	PINEY POINT FORMATION	02-13-11-01	FRANK'S GARAGE INC.
CA	G	CA1990G013	(02)	CRANE JR., JOHN, T.	01/2003	N	300	500	210	960	124E	PINEY POINT FORMATION	02-13-11-01	GROCERY STORE
CA	G	CA1990G014	(04)	DONALDSON, STEVEN, E.	09/2005	N	3,000	6,000	180	160	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP W/ RETURN WELL
CA	G	CA1990G015	(03)	MURRAY, JR., RAYMOND, W.	09/2005	N	3,000	6,000	180	960	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP W/ RECHARGE WELL
CA	G	CA1990G016	(02)	RADEACKAR, RANDY,	10/1996	N	3,000	6,000	180	960	122	MIOCENE	02-13-11-01	GWHP.
CA	G	CA1990G017	(02)	EASTERN UNITED METHODIST CHURCH	11/2002	N	300	500	190	960	124E	PINEY POINT FORMATION	02-13-11-01	CHURCH
CA	G	CA1991G005	(02)	CROSSROAD CHRISTIAN CHURCH, INC.	07/2003	N	1,200	1,800	230	940	125B	AQUIA FORMATION	02-13-11-01	CHURCH & SCHOOL

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1991G006	(02)	MT. GETHSEMANE BAPTIST CHURCH	09/2006	N	100	200	290	920	124C	NANJEMOY FORMATION	02-13-10-05	CHURCH - PDWIS# 104-1129
CA	G	CA1991G008	(02)	MOUNT HOPE METHODIST CHURCH	07/2004	N	100	300	300	910	125B	AQUIA FORMATION	02-13-10-05	
CA	G	CA1991G023	(02)	AMERICAN LEGION POST #85	04/2004	N	100	300	290	910	125B	AQUIA FORMATION	02-13-11-01	AMERICAN LEGION
CA	G	CA1991G024	(02)	COLLINS CONTROLS, INC.	11/2003	N	500	1,000	210	960	124E	PINEY POINT FORMATION	02-13-11-01	WAREHOUSE-ELECTRICAL AND MASONRY CONTRACTORS
CA	G	CA1991G028	(02)	CALVERT COUNTY PUBLIC SCHOOLS	01/2004	N	4,400	6,600	200	960	124C	NANJEMOY FORMATION	02-13-11-01	PATUXENT ELEMENTARY SCHOOL
CA	G	CA1992G002	(02)	CHOICE HOME CENTER, INC.	01/2006	N	300	500	310	900	125B	AQUIA FORMATION	02-13-11-01	FLOORING CENTER
CA	G	CA1992G010	(02)	BECKER BROTHERS ENTERPRISES	07/1996	N	13,100	21,800	290	940	124C	NANJEMOY FORMATION	02-13-10-05	55-LOT BREEZY POINT ESTATES SUBDIVISION
CA	G	CA1992G024	(02)	SAFEWAY INC.	07/2004	N	8500	11,800	320	900	125B	AQUIA FORMATION	02-13-11-01	DUNKIRK MARKET PLACE SAFEWAY - PDWIS# 1040069
CA	G	CA1992G027	(02)	CALVERT COUNTY COMMISSIONERS	06/2004	N	400	700	200	970	124C	NANJEMOY FORMATION	02-13-11-01	FIRE SUBSTATION NO. 3A
CA	G	CA1992G029	(02)	ABDALLA, ET AL, NAJAH,	03/1996	N	10,700	17,800	230	930	124E	PINEY POINT FORMATION	02-13-11-01	MILLS POND SUBDIVISION
CA	G	CA1992G035	(03)	QUALITY BUILT HOMES, INC.	04/1997	N	14,700	24,600	280	930	124C	NANJEMOY FORMATION	02-13-10-05	WILBURN ESTATES SUBD - ADD 20 LOTS TO PLATTED 42
CA	G	CA1992G037	(02)	RAY ENTERPRISES, INC., ,	08/1995	N	7,200	12,100	220	920	124C	NANJEMOY FORMATION	02-13-11-01	WILLIAMS WHARF PLANTATION - 30 LOT SBDN
CA	G	CA1992G039	(02)	STONE, LOUIS, P.	01/2005	N	600	900	210	930	124E	PINEY POINT FORMATION	02-13-11-01	2 APARTMENTS

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CA	G	CA1993G007	(02)	SOUTHERN CALVERT BAPTIST CHURCH	07/2005	N	1,000	2,000	190	960	124E	PINEY POINT FORMATION	02-13-11-01	CHURCH - PDWIS# 1041161
CA	G	CA1993G008	(02)	MORGAN STATE UNIVERSITY	03/2005	N	2,000	3,000	210	940	124E	PINEY POINT FORMATION	02-13-11-01	ENVIRONMENTAL RESEARCH FACILITY
CA	G	CA1993G010	(02)	STALLINGS, LARRY R. & JUDY C.	12/2005	N	400	700	290	920	124C	NANJEMOY FORMATION	02-13-10-05	THE ANOINTED HANDS HAIR SALON/STALLING NAT'L ENTER/TRAILER
CA	G	CA1993G011	(03)	FDI POSTAL PROPERTIES II, INC.	03/2006	N	300	500	320	910	124C	NANJEMOY FORMATION	02-13-11-01	OWINGS POST OFFICE
CA	G	CA1993G020	(02)	TYRRELL, BRENDA	11/2005	N	1,800	3,000	320	920	125B	AQUIA FORMATION	02-13-11-01	PRIMETIME CHILDRENS CENTER
CA	G	CA1993G033	(02)	BOWEN, GORDON, F.	08/2005	N	300	400	290	910	124C	NANJEMOY FORMATION	02-13-11-01	BOWEN'S GROCERY - PDWIS# 104-1008
CA	G	CA1993G035	(01)	GRANADOS, MICHAEL & ROBERT	08/1993	N	8700	70,000	270	900	125B	AQUIA FORMATION	02-13-11-01	GRANADOS FARMS
CA	G	CA1993G038	(03)	BAYLINE BUILDERS & DEVELOPERS, INC.	03/2004	N	8,800	14,700	290	930	125B	AQUIA FORMATION	02-13-10-05	37-LOT HOLBROOK ESTATES SECT II SUBD
CA	G	CA1993G039	(04)	JLH GROUP, LLC	09/2004	N	1,000	1,900	260	910	124C	NANJEMOY FORMATION	02-13-11-01	DUPONT BLDG - PARK PLACE LOT 7RR - OFFICE & SUITES
CA	G	CA1993G040	(02)	BUCKLER, GORMAN, A.	08/2005	N	4,800	7,900	270	910	124C	NANJEMOY FORMATION	02-13-11-01	BUCKLER MOBILE HOME PARK - PDWIS# 004-0209
CA	G	CA1993G041	(01)	GRANADOS, MICHAEL & ROBERT	08/1993	N	8700	70,000	270	900	122	MIOCENE	02-13-11-01	GRANADOS FARMS
CA	G	CA1993G044	(02)	EVELYN NESTOR	05/1997	N	8,800	14,800	230	930	124E	PINEY POINT FORMATION	02-13-11-01	LOST MILL SBDN.
CA	G	CA1993G045	(02)	MATHEW, MD, SCARIA	10/2005	N	300	500	200	960	124E	PINEY POINT FORMATION	02-13-11-01	MEDICAL OFFICE

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1993G048	(04)	NAVAL AIR STATION	04/2006	Y	80,000	150,000	180	950	125B	AQUIA FORMATION	02-13-11-01	CENTRAL SUPPLY FOR PATUXENT NAVAL AIR STATION
CA	G	CA1994G004	(02)	NRL - CHESAPEAKE BAY DETACHMENT	02/2006	Y	25,000	51,000	300	930	125B	AQUIA FORMATION	02-13-10-05	CHESAPEAKE BY DETACHMENT - CHESAPEAKE BEACH - PDWIS# 004-0019
CA	G	CA1994G008	(02)	THE GOTT COMPANY	03/2006	N	500	700	200	960	124E	PINEY POINT FORMATION	02-13-11-01	"FASTOP" MINI-MART #54 - PDWIS# 104-1180
CA	G	CA1994G009	(02)	MARYLAND DEPARTMENT OF TRANSPORTATION	08/1994	N	300	500	260	910	124C	NANJEMOY FORMATION	02-13-11-01	PRINCE FREDERICK VEHICLE EMISSION TESTING FACILITY
CA	G	CA1994G011	(02)	CRAIG, JANET, L.	03/2006	N	1,500	3,000	290	910	125B	AQUIA FORMATION	02-13-11-01	DAYCARE FACILITY - PDWIS# 104-0084
CA	G	CA1994G023	(01)	MATHEWS, SCARIA	06/1994	N	300	500	200	960	122	MIOCENE	02-13-11-01	MEDICAL BUILDING
CA	G	CA1994G025	(02)	WLHSPE, LLC	11/2005	N	100	300	320	920	125B	AQUIA FORMATION	02-13-11-01	FRIENDLY SELF STORAGE
CA	G	CA1994G026	(03)	CALVERT COUNTY FAIR, INCORPORATED	05/2006	N	2,200	8,000	250	910	124C	NANJEMOY FORMATION	02-13-11-01	CALVERT COUNTY FAIR GROUNDS (104-1110)
CA	G	CA1994G028	(03)	CALVERT COUNTY COMMISSIONERS	03/2006	Y	6,000	9,500	290	910	125B	AQUIA FORMATION	02-13-11-01	COMMUNITY SUPPLY - TARA SUBD - 25 HOMES - PDWIS# 004-0034
CA	G	CA1994G033	(02)	HENNON, JR., JAMES, F.	07/1995	N	3,400	5,600	270	930	124C	NANJEMOY FORMATION	02-13-11-01	14L GARRETT ACRES SUBDIVISION
CA	G	CA1994G039	(01)	CEDAR BEACH HOMEOWNERS ASSOC., INC.	08/1994	N	100	300	250	900	124C	NANJEMOY FORMATION	02-13-11-01	CEDAR BEACH COMMUNITY PIER
CA	G	CA1994G044	(01)	CALVERT COUNTY COMMISSIONERS	10/1994	N	300	500	210	930	124C	NANJEMOY FORMATION	02-13-11-01	BROOMES ISLAND COMMUNITY CENTER
CA	G	CA1994G052	(02)	SCHMEISER, HAROLD R. & LAURIE T.	07/2006	N	600	1,000	230	900	125B	AQUIA FORMATION	02-13-11-01	DUNKIRK ANIMAL HOSPITAL - PDWIS# 104-1239

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1994G057	(01)	WILLOWS DEVELOPMENT COMPANY	12/1994	N	6,400	10,700	290	940	124C	NANJEMOY FORMATION	02-13-10-05	WILLOWS BEACH HOME SBDN
CA	G	CA1995G003	(01)	WALKER, DONALD, C.	02/1995	N	250	300	310	910	125B	AQUIA FORMATION	02-13-11-01	YESTERYEAR FURNISHINGS, INC.
CA	G	CA1995G004	(01)	PERRY, THOMAS, C.	02/1995	N	6,000	10,000	340	900	125B	AQUIA FORMATION	02-13-11-01	HARNISHAN SBDN
CA	G	CA1995G005	(02)	THE SHOPPES AT DUNKIRK, LLC	07/2005	N	5,600	8,100	320	900	125B	AQUIA FORMATION	02-13-11-01	COUNTRY PLAZA SHOPPING CENTER - PDWIS# 104-1152
CA	G	CA1995G006	(02)	GRACE, MARK & PEGGY	08/1998	N	2,500	10,000	300	890	125B	AQUIA FORMATION	02-13-11-01	PITCH & PUT GOLF COURSE T & GREENS ONLY 9 HOLES
CA	G	CA1995G010	(01)	PENWICK VILLAGE LIMITED PARTNERSHIP	03/1995	N	2,000	2,500	330	900	125B	AQUIA FORMATION	02-13-11-01	CALVERT GATEWAY CITGO
CA	G	CA1995G011	(01)	GREEN, SR., GEORGE	03/1995	N	2,900	4,900	290	930	124C	NANJEMOY FORMATION	02-13-10-05	THE ESTATE OF LEROY GREEN
CA	G	CA1995G019	(02)	BOARD OF COMMISSIONERS OF CALVERT COUNTY	07/2005	Y	10,000	15,000	200	960	125B	AQUIA FORMATION	02-13-11-01	SOUTHERN PINES SENIOR - TIED TO SOLOMONS/LUSBY PDWIS# 004-0002
CA	G	CA1995G026	(01)	PAINTER, WILLIE	01/1996	N	10,000	16,700	300	920	125B	AQUIA FORMATION	02-13-10-05	SUNDERLEIGH SBDN (42 LOTS)
CA	G	CA1995G030	(03)	CALVERT COUNTY COMMISSIONERS	11/2000	Y	14,700	24,600	290	910	125B	AQUIA FORMATION	02-13-11-01	WALNUT CREEK COMMUNITY SUPPLY (PHASE III)
CA	G	CA1995G031	(01)	SOUTHERN MARYLAND OIL, INCORPORATED	07/1995	N	300	500	200	960	124E	PINEY POINT FORMATION	02-13-11-01	LUSBY TEXACO
CA	G	CA1995G032	(01)	CHAFFEE, CHRIS	07/1995	N	3,400	5,600	260	910	124C	NANJEMOY FORMATION	02-13-11-01	14L CHAFFEE PROPERTY SBDN
CA	G	CA1995G035	(01)	DUNLAP, STEVEN, H.	07/1995	N	2,700	4,400	230	930	124E	PINEY POINT FORMATION	02-13-11-01	STRATHEMOOR 11L SBDN

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1995G040	(01)	DINARDO, BRIAN	07/1995	N	1,000	4,000	220	930	124E	PINEY POINT FORMATION	02-13-11-01	SOUTHERN MD GREENHOUSE - NURSERY (PLANTS)
CA	G	CA1995G047	(01)	PRALEY, EDWARD	09/1995	N	3,400	5,600	270	910	124C	NANJEMOY FORMATION	02-13-11-01	14 LOT HUNTINGTOWN SOUTH SBDN
CA	G	CA1995G048	(01)	LEE FUNERAL HOME, INC.	09/1995	N	500	800	310	900	125B	AQUIA FORMATION	02-13-11-01	LEE FUNERAL HOME
CA	G	CA1995G049	(02)	MURRAY, J., D.	11/1996	N	11,500	19,200	320	910	125B	AQUIA FORMATION	02-13-11-01	48-LOT CABIN BRANCH SBDN
CA	G	CA1995G051	(01)	CLEARY, SR., FRANK,	11/1995	N	2,700	4,400	310	900	125B	AQUIA FORMATION	02-13-11-01	11L WILLIAMS PROPERTY SUBDIVISION
CA	G	CA1995G055	(01)	GATES, JR., ANDREW G.,	10/1995	N	300	500	300	910	124C	NANJEMOY FORMATION	02-13-11-01	GATES GREENHOUSE
CA	G	CA1995G057	(03)	CASTLETON COMMUNITY ASSOCIATION INC.	10/2002	N	300	500	280	920	124C	NANJEMOY FORMATION	02-13-11-01	CASTLETON SBDN - LAWN IRRIGATION & MAKE-UP WATER FOR FOUNTAIN
CA	G	CA1995G059	(01)	COX, MAURICE,	12/1995	N	300	500	260	910	124C	NANJEMOY FORMATION	02-13-11-01	OFFICE
CA	G	CA1995G060	(01)	BROWN, THOMAS PARRAN III/MELVIN,	12/1995	N	5,000	8,000	240	940	124E	PINEY POINT FORMATION	02-13-11-01	20- LOT SUBDIVISION
CA	G	CA1995G062	(01)	WOOD, FRANK	12/1995	N	500	800	320	910	125B	AQUIA FORMATION	02-13-11-01	SISK AUTO BODY
CA	G	CA1996G005	(01)	VENTURE UPHOLSTERY, INC.	02/1996	N	400	700	310	910	124C	NANJEMOY FORMATION	02-13-11-01	COMMERCIAL TRUCK SEAT SALES/UPHOLSTERY
CA	G	CA1996G008	(01)	ALEXANDER, R. BROOKE KAINE AND RICHA	02/1997	N	27,500	45,800	270	930	124C	NANJEMOY FORMATION	02-13-11-01	RESUBDIVISION OF 71 PLATTED LOTS INTO 115 LOTS
CA	G	CA1996G009	(01)	MILL BRANCH LLC, C/O MORGAN RUSSELL	02/1996	N	6,200	10,300	300	900	124C	NANJEMOY FORMATION	02-13-11-01	26 LOT SUBDIVISION

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1996G015	(01)	HOMES AMERICA CORPORATION	03/1996	N	400	700	300	910	124C	NANJEMOY FORMATION	02-13-10-05	CHIPS TOWING SERVICE
CA	G	CA1996G016	(01)	DOUBLE D FITNESS CENTER	04/1996	N	800	1,300	260	910	124C	NANJEMOY FORMATION	02-13-11-01	HEALTH AND FITNESS CENTER
CA	G	CA1996G018	(02)	HOWLIN, EDWARD, B.	06/1996	N	8,800	14,700	310	920	124C	NANJEMOY FORMATION	02-13-10-05	37 LOT ASPEN WOODS SUBD
CA	G	CA1996G019	(01)	WATHEN, KENNETH, L.	04/1996	N	500	800	230	940	124E	PINEY POINT FORMATION	02-13-11-01	SELF-STORAGE FACILITY AND APARTMENT
CA	G	CA1996G020	(01)	CALVERT MEMORIAL HOSPITAL	04/1996	N	2,600	4,000	330	900	125B	AQUIA FORMATION	02-13-11-01	PHYSICIAN'S OFFICE BUILDING
CA	G	CA1996G021	(04)	WELLONS, III & DIANE L. WELLONS, L. THOMAS	07/2005	N	500	800	260	910	124C	NANJEMOY FORMATION	02-13-11-01	LOT #2 - FUTURE COMMERCIAL ESTABLISHMENT
CA	G	CA1996G022	(04)	WELLONS, III & DIANE WELLONS, L. THOMAS	07/2005	N	500	800	260	910	124C	NANJEMOY FORMATION	02-13-11-01	LOT #3 - FUTURE COMMERCIAL ESTABLISHMENT
CA	G	CA1996G023	(04)	WELLONS, III & DIANE L. WELLONS, L. THOMAS	07/2005	N	500	800	260	910	124C	NANJEMOY FORMATION	02-13-11-01	LOT #4 - FUTURE COMMERCIAL ESTABLISHMENT
CA	G	CA1996G025	(02)	TROTT, RAYMOND, G.	04/1998	N	2,600	4,300	280	900	124C	NANJEMOY FORMATION	02-13-11-01	11-LOT SUBD
CA	G	CA1996G026	(03)	CALVERT COUNTY BOARD OF COMMISSIONERS	03/2000	Y	37,000	61,000	320	910	125B	AQUIA FORMATION	02-13-11-01	CROSS POINT COMMUNITY SUPPLY - CHANGE OF OWNER
CA	G	CA1996G036	(02)	GODSGRACE 1652, LLC	12/2004	N	500	800	310	900	125B	AQUIA FORMATION	02-13-11-01	OFFICE BUILDING PDWIS# 104-1209
CA	G	CA1996G039	(01)	THE CARROLL INDEPENDENT FUEL COMPANY	07/1996	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	CITGO GAS/SERVICE STATION

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1996G044	(01)	GROVER, RUTH	09/1996	N	7100	11,900	320	910	124C	NANJEMOY FORMATION	02-13-11-01	30 LOT SUBD
CA	G	CA1996G045	(01)	MARQUESS, ELINOR, J.	09/1996	N	6,700	11,200	300	910	124C	NANJEMOY FORMATION	02-13-11-01	28 LOT SUBD
CA	G	CA1996G046	(01)	WARD, DOROTHY, T.	09/1996	N	3,300	5,500	280	920	124C	NANJEMOY FORMATION	02-13-11-01	14 LOT SUBD
CA	G	CA1996G049	(01)	APPLE CREEK DEVELOPMENT CORPORATION	09/1996	N	4,000	6,700	240	910	124E	PINEY POINT FORMATION	02-13-11-01	17L APPLE CREEK SUBD
CA	G	CA1996G050	(01)	BUTTON, LELIA, M.	09/1996	N	8,800	14,700	230	930	124E	PINEY POINT FORMATION	02-13-11-01	37 LOT AUGUST RUN SUBD
CA	G	CA1996G052	(02)	TYRRELL, BRENDA	11/2005	N	2,000	3,300	320	920	125B	AQUIA FORMATION	02-13-11-01	PRIMETIME YOUTH ACTIVITY CENTER
CA	G	CA1996G055	(02)	CALVERT ANIMAL WELFARE LEAGUE	05/2004	N	1,000	2,500	260	910	125B	AQUIA FORMATION	02-13-11-01	CALVERT ANIMAL WELFARE LEAGUE
CA	G	CA1996G058	(01)	IRN, INC.	11/1996	N	300	500	190	960	124E	PINEY POINT FORMATION	02-13-11-01	DOWELL STORAGE
CA	G	CA1996G241	(01)	TWIN SHIELDS GOLF CLUB, INC.	07/2005	N	300	600	340	900	125B	AQUIA FORMATION	02-13-11-01	CONCESSION(CLUB HOUSE) & BATHROOMS - PDWIS# 1041096
CA	G	CA1997G001	(01)	KING, EUNICE	09/1997	N	11,200	18,600	300	900	125B	AQUIA FORMATION	02-13-11-01	OAKMOUNT MANOR RES SUBD
CA	G	CA1997G002	(01)	MCINTYRE, DONALD	01/1997	N	1,000	1,600	270	910	124C	NANJEMOY FORMATION	02-13-11-01	NURSERY
CA	G	CA1997G010	(02)	GEORGE MATHEWS & ASSOCIATES	04/1998	N	2,100	3,500	200	960	124E	PINEY POINT FORMATION	02-13-11-01	3-LOT COMMERCIAL SUBD "LUSBY TOWN SQUARE"
CA	G	CA1997G014	(01)	LEWIS, DAVID, R	04/1997	N	2,900	4,800	320	890	125B	AQUIA FORMATION	02-13-11-01	12 LOT SUBD

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1997G017	(01)	HARDESTY, MAURICE	05/1997	N	2,800	4,700	300	910	125B	AQUIA FORMATION	02-13-11-01	13-LOT CHANCELLORS RUN SUBD
CA	G	CA1997G019	(01)	LEWIS, DAVID, R.	05/1997	N	2,900	4,700	320	890	125B	AQUIA FORMATION	02-13-11-01	12-LOT LOVING FARM SUBD
CA	G	CA1997G020	(01)	MELVIN BROWN - EUGENE SMITH	06/1997	N	5,200	8,800	200	950	124E	PINEY POINT FORMATION	02-13-11-01	SUBDIVISION
CA	G	CA1997G023	(01)	GLENN BOWEN, ROBERT FOWLER, &	08/1997	N	8,100	13,500	270	920	124C	NANJEMOY FORMATION	02-13-11-01	34 LOT SUBDIVISION - LOTTIES REST
CA	G	CA1997G026	(01)	TANAVAGE, LEE, C.	07/1997	N	8,400	12,000	200	960	124E	PINEY POINT FORMATION	02-13-11-01	GENERIC SHOPPING, TAVERN, OFFICE BUILDING, BANK
CA	G	CA1997G027	(01)	COLLINSON, RICHARD	08/1997	N	8,300	14,000	240	910	124E	PINEY POINT FORMATION	02-13-11-01	35-LOT FOX FIELD SUBDIVISION
CA	G	CA1997G028	(01)	APOSTOLIC FAITH CHURCH	08/1997	N	300	500	320	910	125B	AQUIA FORMATION	02-13-11-01	CHURCH
CA	G	CA1997G029	(01)	FAI-MAR CORPORATION	08/1997	N	1,200	1,600	270	910	124C	NANJEMOY FORMATION	02-13-11-01	FULL SERVICE CAR WASH
CA	G	CA1997G030	(01)	ISLAND BAY L.L.C.	09/1997	N	2,900	4,800	220	940	124E	PINEY POINT FORMATION	02-13-11-01	ISLAND CREEK SUBD
CA	G	CA1997G031	(01)	QUALITY BUILT HOMES, INC.	09/1997	N	1,200	2,000	230	930	124E	PINEY POINT FORMATION	02-13-11-01	ADDITION TO PREV. RECORDED 38-LOT SUBD THAT WAS NEVER PERMITTED
CA	G	CA1997G032	(01)	GOLDSTEIN, LOUIS, L.	09/1997	N	200	300	240	930	124C	NANJEMOY FORMATION	02-13-11-01	FLOWER STAND
CA	G	CA1997G034	(01)	MULFORD SR. & WILLIAM FOWLER, RICHAR	09/1997	N	300	500	250	910	124C	NANJEMOY FORMATION	02-13-11-01	BARSTOW POST OFFICE
CA	G	CA1997G035	(02)	KOPICKI & MICHAEL HEGARTY, CHESTER	02/2002	N	6,000	10,000	290	910	125B	AQUIA FORMATION	02-13-11-01	FARM VALLEY NURSERY -

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CA	G	CA1997G036	(01)	FOWBOWLSTONE L.L.P.	10/1997	N	8,100	13,500	270	930	124C	NANJEMOY FORMATION	02-13-11-01	35-LOT RES. SUBD
CA	G	CA1997G038	(01)	WARD, S., CHESTER	01/1998	N	4,600	7,700	320	920	124C	NANJEMOY FORMATION	02-13-10-05	20-LOT SUBD OF L.E. WARD PROPERTY
CA	G	CA1997G039	(01)	FINLEY, ELLIOTT, C.	01/1998	N	3,000	5,000	300	910	124C	NANJEMOY FORMATION	02-13-11-01	13-LOT SUBD
CA	G	CA1997G040	(01)	JOY, WAYNE, H.	01/1998	N	5,000	8,100	190	970	124E	PINEY POINT FORMATION	02-13-11-01	21-LOT SUBD
CA	G	CA1998G001	(01)	EASTERN PETROLEUM CORPORATION	02/1998	N	300	500	340	900	125B	AQUIA FORMATION	02-13-11-01	AMOCO GAS STATION (EP5)
CA	G	CA1998G002	(01)	MCKAY MANAGEMENT AND INVESTMENT COMPANY	02/1998	N	9,000	15,000	200	960	124E	PINEY POINT FORMATION	02-13-11-01	SOUTH CALVERT MARKETPLACE - GROCERY STORE AND RETAIL STORES
CA	G	CA1998G003	(01)	VAN HOY, DAVID	04/1998	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	CENTURY 21 REAL ESTATE OFFICE
CA	G	CA1998G004	(01)	SMITHVILLE UNITED METHODIST CHURCH	05/1998	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	REPLACEMENT WELL- NO PREVIOUS PERMIT LOCATED
CA	G	CA1998G006	(01)	CALVERT COUNTY BOARD OF COMMISSIONERS	05/1998	N	1,000	5,000	280	910	124C	NANJEMOY FORMATION	02-13-11-01	HUNTINGTOWN COMPACTOR SITE
CA	G	CA1998G009	(01)	PARRAN, JR., THOMAS	05/1998	N	9,500	15,800	230	950	124E	PINEY POINT FORMATION	02-13-11-01	PARRAN'S GRANT SECTION II - 41 LOT SUBD
CA	G	CA1998G010	(01)	EMMANUEL BAPTIST CHURCH	06/1998	N	300	500	280	910	125B	AQUIA FORMATION	02-13-11-01	CHURCH
CA	G	CA1998G011	(01)	JOHNSON, LANKFORD	06/1998	N	500	800	230	930	124E	PINEY POINT FORMATION	02-13-11-01	BROTHERS JOHNSON INC.
CA	G	CA1998G013	(01)	WAYSON JR., MORGAN	07/1998	N	500	800	310	910	125B	AQUIA FORMATION	02-13-11-01	SELF STORAGE RENTAL

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CA	G	CA1998G014	(01)	HENNIG FAMILY LIMITED PARTNERSHIP	09/1998	N	13,700	22,900	230	940	124E	PINEY POINT FORMATION	02-13-11-01	59-LOT ORIOLE LANDING SBDN
CA	G	CA1998G015	(02)	LOGAN, RICHARD, EDWARD	08/1998	N	2,600	4,300	230	930	124E	PINEY POINT FORMATION	02-13-11-01	11-LOT RES. SUBD. - CHANGE IN LAND OWNERSHIP
CA	G	CA1998G016	(01)	SUNDERLAND LTD PARTNERSHIP	08/1998	N	500	2,000	300	910	124C	NANJEMOY FORMATION	02-13-11-01	CONTRACTING OFFICE & WAREHOUSE
CA	G	CA1998G017	(01)	MARRICK PROPERTIES,INC.	02/2000	N	27,000	44,000	330	900	125B	AQUIA FORMATION	02-13-11-01	113-LOT SBDN
CA	G	CA1998G018	(01)	BLANCADO, RICHARD	08/1998	N	7,100	42,000	230	910	124C	NANJEMOY FORMATION	02-13-11-01	IRRIGATION AND POND FILLING
CA	G	CA1998G019	(01)	CARTER, SR., ROBERT	09/1998	N	2,300	3,900	300	900	124C	NANJEMOY FORMATION	02-13-11-01	PRESENTLY 10 LOT RES. SUBD., 6 FORMER LOTS ALREADY SOLD,MORE LAND
CA	G	CA1998G022	(01)	HORSMON, RICHARD, A.	09/1998	N	3,500	5,900	220	940	122	MIOCENE	02-13-11-01	HORSMON, R., BELLE GROVE SUBD LOTS 6 -20/ CA92G012 LOT1-5 INACT.
CA	G	CA1998G023	(01)	HOWSARE, WILLIAM	09/1998	N	300	500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	6 EMPLOYEES
CA	G	CA1998G025	(01)	GOTT COMPANY	09/1998	N	500	700	230	940	124E	PINEY POINT FORMATION	02-13-11-01	FAST STOP GAS AND CONVENIENCE STORE
CA	G	CA1998G026	(01)	PITCHER, CARL, L.	11/1998	N	4,000	20,000	230	930	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENCE/IRRIGATION
CA	G	CA1998G028	(02)	BUCKINGHAM, MICHAEL, H.	07/2001	N	300	500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	BAY METAL WORKS INC.
CA	G	CA1998G030	(01)	BEE'S AUTO SUPPLY INCORPORATED OF PRINCE	11/1998	N	300	500	250	920	124C	NANJEMOY FORMATION	02-13-10-05	BEE'S AUTO SUPPLY - NEW WELL - CANNOT LOCATE EXISTING PERMIT
CA	G	CA1998G031	(01)	DUNKIRK BAPTIST CHURCH	11/1998	N	300	500	330	900	125B	AQUIA FORMATION	02-13-11-01	DUNKIRK BAPTIST CHURCH

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1998G124	(01)	J. ALLEN SWANN	08/1999	Y	45,000	272,000	310	890	211D	MAGOTHY FORMATION	02-13-11-01	IRRIGATION MAGOTHY AQUIFER
CA	G	CA1999G002	(01)	WEEMS, CLAUDE, RONALD	02/1999	N	300	500	230	940	124E	PINEY POINT FORMATION	02-13-11-01	DICKSON'S EMPORIUM (FLOWER & GIFT SHOP)
CA	G	CA1999G004	(01)	TOCHTERMANN, WILLIAM	02/1999	N	500	800	210	930	124E	PINEY POINT FORMATION	02-13-11-01	BILL'S MARINA
CA	G	CA1999G005	(01)	RUSSELL, MORGAN	03/1999	N	1,500	2,500	300	910	124C	NANJEMOY FORMATION	02-13-10-05	EXCAVATING COMPANY
CA	G	CA1999G007	(01)	WOOD, GARY	03/1999	N	9,500	16,000	200	970	124E	PINEY POINT FORMATION	02-13-11-01	41-LOT FOXHOLE RESIDENTIAL SUBDIVISION
CA	G	CA1999G011	(01)	SWANN, HAZEL, M.	07/1999	N	4,200	7,000	310	890	124C	NANJEMOY FORMATION	02-13-11-01	PATUXENT SUNSET SUBDIVISION (18-LOT)
CA	G	CA1999G012	(01)	RAUSCH, MYRTLE, M.	07/1999	N	300	500	320	910	124C	NANJEMOY FORMATION	02-13-11-01	RAUSCH FUNERAL HOME
CA	G	CA1999G013	(01)	YANNONE, JOHN, J.	07/1999	N	1,000	1,500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	CAR WASH AND AUTOMOTIVE CENTER
CA	G	CA1999G014	(01)	OGLE, CLARISSA	07/1999	N	6,500	10,800	280	920	124C	NANJEMOY FORMATION	02-13-11-01	SINGLE FAMILY DWELLING
CA	G	CA1999G015	(01)	TEDDER, RICHARD, C.	07/1999	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	RICH'S QUICK LUBE LLC
CA	G	CA1999G016	(01)	GOLDSTEIN, PHILIP, T.	08/1999	N	9,300	15,500	230	940	124E	PINEY POINT FORMATION	02-13-11-01	OLD GLORY 40-L RES. SUBD
CA	G	CA1999G017	(02)	US POSTAL SERVICE	10/1999	N	200	300	240	940	124E	PINEY POINT FORMATION	02-13-10-05	US POST OFFICE, 4 EMPL, WELL REPLACE-NEW BLDG-PREV NOT PERMITTED
CA	G	CA1999G018	(02)	CALVERT COUNTY COMMISSIONERS	02/2002	Y	38,200	64,000	280	920	125B	AQUIA FORMATION	02-13-11-01	COMMUNITY SUPPLY - MARLEY RUN SUBD

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA1999G021	(01)	VAN HOY, DAVID	12/1999	N	5,800	9,700	280	900	124C	NANJEMOY FORMATION	02-13-11-01	OAKWOOD MANOR 25-L RESIDENTIAL SUBDIVISION
CA	G	CA1999G022	(01)	EL-DAMALOUJI, ISSAM, F.	12/1999	N	4,000	6,600	280	920	124C	NANJEMOY FORMATION	02-13-11-01	20-LOT BARAKAT RESIDENTIAL SUBD - 17 WELLS
CA	G	CA2000G001	(01)	GOTT JR, JOHN, M.	02/2000	N	4,600	7,700	230	920	124C	NANJEMOY FORMATION	02-13-11-01	20-L DEER RUN SUBD (RESIDENTIAL)
CA	G	CA2000G002	(01)	NORFOLK, DALE & ANN	02/2000	N	3,900	6,600	320	920	124C	NANJEMOY FORMATION	02-13-10-05	17-L NORFOLK PLACE SUBD (RESIDENTIAL)
CA	G	CA2000G004	(01)	KENT, SARAH	04/2000	N	4,400	7,400	280	910	124C	NANJEMOY FORMATION	02-13-11-01	CHANCE POINT RESIDENTIAL SUBD
CA	G	CA2000G005	(01)	THOMPSON, SHIRLEY, E.	04/2000	N	4,900	8,100	280	920	124C	NANJEMOY FORMATION	02-13-11-01	21-LOT HUNTING CREEEK HILLS RESIDENTIAL SUBD
CA	G	CA2000G006	(01)	MC CONKEY, KELLY, D.	05/2000	N	4,500	20,000	330	900	125B	AQUIA FORMATION	02-13-11-01	MC CONKEY - VOLUNTARY AGRICULTURE
CA	G	CA2000G007	(01)	KAINE, BROOKE	11/2000	N	11,000	18,500	320	910	125B	AQUIA FORMATION	02-13-11-01	47-LOT RESIDENTIAL COVENANT CREEK SUBD
CA	G	CA2000G008	(01)	SUSAN CHAN	06/2000	N	300	500	300	910	124C	NANJEMOY FORMATION	02-13-11-01	ROUTES 2 & 4 LIQUORS
CA	G	CA2000G009	(02)	MURPHY DEVELOPMENT LLC	07/2003	N	2,000	3,500	300	910	124C	NANJEMOY FORMATION	02-13-11-01	RETAIL CENTER FOR 5 BUSINESSES - ONE TO BE FLOOR SYSTEMS
CA	G	CA2000G010	(01)	JLH GROUP LLC	06/2000	N	900	1,500	260	910	124C	NANJEMOY FORMATION	02-13-11-01	RETAIL WAREHOUSES - TO BE LEASED
CA	G	CA2000G011	(02)	POUNSBERRY, RONALD & SHEREE	03/2004	N	1,500	2,500	290	910	125B	AQUIA FORMATION	02-13-11-01	SLEEPY HOLLOW DAYCARES AND RESIDENCE
CA	G	CA2000G014	(02)	DUNKIRK VOLUNTEER FIRE DEPARTMENT, INC.	09/2002	N	1,000	2,500	320	900	125B	AQUIA FORMATION	02-13-11-01	3170 WEST WARD RD - DUNKIRK VFD NEW SITE

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2000G015	(02)	OSBORNE PROPERTIES LLC	09/2002	N	1,500	3,000	320	900	125B	AQUIA FORMATION	02-13-11-01	10200 SOUTHERN MD BLVD - ARBYS
CA	G	CA2000G016	(01)	BECKMAN, INC.	07/2000	N	2,000	5,000	310	900	124C	NANJEMOY FORMATION	02-13-11-01	LANDSCAPING BUSINESS/ COMMERCIAL NURSERY/ HYDROSEEDING
CA	G	CA2000G018	(02)	CHIARAMONTE, FRANCIS, P.	09/2002	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	3180 WEST WARD RD - LOT 4 DUNKIRK COMMERCIAL PARK
CA	G	CA2000G019	(03)	HOPEWELL PROPERTIES, LLC.	11/2006	N	900	1,700	320	900	125B	AQUIA FORMATION	02-13-11-01	10000 FT*2 OFFICE BUILDING
CA	G	CA2000G020	(03)	CALVERT INVESTMENT PROPERTIES, L.L.C.	07/2005	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	3185 WEST WARD RD - LOT 2 DUNKIRK COMMERCIAL PARK
CA	G	CA2000G021	(02)	CHIARAMONTE, FRANCIS, P.	09/2002	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	3195 WEST WARD RD - LOT 1 DUNKIRK COMMERCIAL PARK
CA	G	CA2000G024	(01)	BRISCOE, CROFTON	10/2000	N	200	300	210	940	124C	NANJEMOY FORMATION	02-13-11-01	LIVESTOCK & POTABLE
CA	G	CA2000G027	(01)	JONES SR., PHILLIP	11/2000	N	200	300	280	910	124C	NANJEMOY FORMATION	02-13-11-01	LIVESTOCK WATERING
CA	G	CA2000G028	(01)	CALVERT COUNTY COMMISSIONERS	12/2000	N	100	200	280	920	124C	NANJEMOY FORMATION	02-13-11-01	MARLEY RUN REC. AREA-SNACK STAND
CA	G	CA2001G001	(01)	SNEADE, DAVE	01/2001	N	400	700	200	960	124E	PINEY POINT FORMATION	02-13-11-01	SNEADES ACE HARDWARE
CA	G	CA2001G002	(01)	KELLY, PATRICK	01/2001	N	100	200	280	930	124C	NANJEMOY FORMATION	02-13-10-05	LIVESTOCK WATERING
CA	G	CA2001G003	(01)	HUMM, ET.AL., JOSEPH	03/2001	N	9300	15,300	310	900	124C	NANJEMOY FORMATION	02-13-11-01	SINGLE FAMILY RESIDENTIAL SUBDIVISION
CA	G	CA2001G004	(01)	MORRIS, JR., JAMES, S.	03/2001	N	8,100	13,600	300	990	125B	AQUIA FORMATION	02-13-11-01	CLAIREMONT-SINGLE FAMILY RESIDENTIAL

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2001G005	(01)	MORGAN WAYSON, JR.	05/2001	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	MORGAN WAYSON, JR. DUNKIRK BUS.CENT LOT1
CA	G	CA2001G006	(01)	MORGAN WAYSON, JR.	05/2001	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	MORGAN WAYSON, JR. DUNKIRK BUS.CENT. LOT 2
CA	G	CA2001G007	(02)	NSM REALTY, LLC	12/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	DUNKIRK BUSINESS CENTER, LOT 3
CA	G	CA2001G008	(02)	J & J DEVELOPMENT CORPORATION	05/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE DEVELOPMENT
CA	G	CA2001G009	(02)	WAYSON,JR., MORGAN	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE - DUNKIRK BUS.CENT. LOT 5
CA	G	CA2001G010	(02)	QUALITY INVESTORS, LLC	06/2004	N	100	300	310	910				DUNKIRK BUSINESS CTR LOT 6
CA	G	CA2001G011	(02)	BCJJ, LLC	06/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	DUNKIRK BUS CTR - LOT #7 - 635 KEITH LANE
CA	G	CA2001G012	(02)	BCJJ, LLC	06/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	DUNKIRK BUSINESS CENTER - LOT #8 - 615 KEITH LANED
CA	G	CA2001G013	(02)	WAYSON,JR., MORGAN	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE - DUNKIRK BUS.CENT. LOT 9
CA	G	CA2001G014	(02)	WAYSON,JR., MORGAN	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE - DUNKIRK BUS.CENT. LOT 10
CA	G	CA2001G015	(02)	WAYSON,JR., MORGAN	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE - DUNKIRK BUS.CENT. LOT 11
CA	G	CA2001G016	(02)	WAYSON,JR., MORGAN	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE - DUNKIRK BUS.CENT. LOT 12
CA	G	CA2001G017	(02)	WAYSON,JR., MORGAN	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE - DUNKIRK BUS.CENT. LOT 13
CA	G	CA2001G018	(04)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	12/2005	N	1,400	2,500	310	910	125B	AQUIA FORMATION	02-13-11-01	LOT 14, DUNKIRK BUS. CTR - 7 UNITS - WELL DRILLED TO AQUIA

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2001G021	(01)	ARMIGER, MILTON, W.	07/2001	N	9,100	15,100	280	910	124C	NANJEMOY FORMATION	02-13-11-01	ARMIGER
CA	G	CA2001G022	(02)	TAYLOR BUSINESS CENTER, LLC	11/2004	N	300	500	310	910	124C	NANJEMOY FORMATION	02-13-11-01	7640 INVESTMENT CT, LOT #8
CA	G	CA2001G024	(01)	MORGAN WAYSON, JR.	09/2001	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	MORGAN WAYSON, JR. 7656 INVESTMENT CT, LOT #10
CA	G	CA2001G025	(02)	DRURY, ROBERT & MICHELLE	10/2002	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA2001G026	(03)	PHIPPS, W., SCOTT	05/2006	N	200	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	CHESAPEAKE INDUSTRIES - 7672 INVESTMENT CT LOT #12R
CA	G	CA2001G028	(03)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	09/2004	N	100	300	310	910	125B	AQUIA FORMATION	02-13-11-01	AUTO REPAIR BUSINESS/7665 INVESTMENT CT/N CAL IND PK LOT 15
CA	G	CA2001G029	(02)	TRUMPY PROPERTIES, LLC	12/2002	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	
CA	G	CA2001G031	(03)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	12/2005	N	3,000	4,500	310	910	125B	AQUIA FORMATION	02-13-11-01	7632 INVESTMENT CT, LOT 4RR - WELL DRILLED TO AQUIA
CA	G	CA2001G032	(02)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	09/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE BUSINESS, JR. 7673 INVESTMENT CT, LOT #14R
CA	G	CA2001G033	(02)	MICHAEL H. BUCKINGHAM	07/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	MICHAEL BUCKINGHAM 7600 INVESTMENT CT, LOT #1
CA	G	CA2001G034	(01)	MICHAEL H. BUCKINGHAM	07/2001	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	MICHAEL H. BUCKINGHAM INVESTMENT COURT, LOT #5
CA	G	CA2001G035	(01)	VAN WIE BUILDERS, INC.	10/2001	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	VAN WIE BULDERS, INC. 7601 INVESTMENT CT, LOT #22R
CA	G	CA2001G036	(01)	CONSTANTINE, CHRIS	07/2001	N	3,700	6,200	300	930	124C	NANJEMOY FORMATION	02-13-01-05	CONSTANTINE

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CA	G	CA2001G038	(01)	KEIR, KENNETH, G.	09/2001	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	KEN KEIR RACE CARS
CA	G	CA2001G039	(02)	KEIR, KENNETH, G.	10/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	AUTO REPAIR - N. CALVERT IND PARK LOT 2
CA	G	CA2001G040	(02)	SCHWENK, JOHN, P.	10/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE BUSINESS @ 7615 GINGER LANE
CA	G	CA2001G041	(02)	SCHWENK, JOHN, P.	10/2004	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	FUTURE BUSINESS @ 7625 GINGER LANE
CA	G	CA2001G042	(01)	COLLEGE OF SOUTHERN MARYLAND	09/2001	N	1300	3,000	260	910	124C	NANJEMOY FORMATION	02-13-11-01	PRINCE FREDERICK
CA	G	CA2001G043	(01)	CONSTANTINE, CHRIS, G.	09/2001	N	3,700	6,200	300	930	124C	NANJEMOY FORMATION	02-13-10-05	SINGLE FAMILY RESIDENCE SUBDIVISION
CA	G	CA2001G044	(01)	HANCE, TOM	10/2001	N	600	800	240	930	124E	PINEY POINT FORMATION	02-13-11-01	FARM AND GREENHOUSE
CA	G	CA2001G047	(01)	RAUSH FUNERAL HOME	11/2001	N	350	500	230	930	124E	PINEY POINT FORMATION	02-13-11-01	RAUSH FUNERAL HOME
CA	G	CA2001G048	(01)	SELLERS, PAUL	10/2001	N	600	900	240	940	124E	PINEY POINT FORMATION	02-13-11-01	LIVESTOCK WATERING
CA	G	CA2001G049	(01)	YANNONE, JOHN, J.	12/2001	N	1,000	1,500	200	960	124E	PINEY POINT FORMATION	02-13-11-01	AUTOMOTIVE SERVICE
CA	G	CA2002G001	(01)	CALVERT COUNTY PUBLIC SCHOOLS	10/2003	Y	15,500	38,000	290	910	125B	AQUIA FORMATION	02-13-11-01	HUNTINGTON HIGH SCHOOL
CA	G	CA2002G002	(02)	LITTEN, CURTIS & VIALONDA	08/2005	N	1,200	2,000	290	910	125B	AQUIA FORMATION	02-13-11-01	VET&ANIMAL HOSPITAL/ DANCE INSTRUCT/PAINT CONTR
CA	G	CA2002G003	(01)	RODBELL, LARRY	02/2002	N	400	500	260	930	125B	AQUIA FORMATION	02-13-11-01	DOG KENNEL

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CA	G	CA2002G006	(01)	GERTZ, RODNEY	04/2002	N	1,000	1,500	220	950	124E	PINEY POINT FORMATION	02-13-11-01	RODNEY GERTZ - SAW MILL DUST CONTROL
CA	G	CA2002G007	(01)	PETRALIAE, SALVATORE	04/2002	N	300	900	300	920	125B	AQUIA FORMATION	02-13-11-01	SALVATORE
CA	G	CA2002G009	(02)	BAYSIDE LAND DEVELOPMENT, LLC	05/2006	N	500	900	270	910	125B	AQUIA FORMATION	02-13-11-01	BAYSIDE TOYOTA-CHEVROLET - PDWIS #104-1230
CA	G	CA2002G010	(01)	PENWICK VILLAGE, L.L.C.	10/2003	Y	32,000	48,000	320	900	211D	MAGOTHY FORMATION	02-13-11-01	COMMERCIAL DEVELOPMENT - CALVERT GATEWAY
CA	G	CA2002G013	(02)	CALVERT COUNTY BOARD OF COMMISSIONERS	03/2004	N	500	600	290	940	125B	AQUIA FORMATION	02-13-10-05	BREEZY PT BEACH BATHHOUSE & SNACK BAR - PDWIS #1041154
CA	G	CA2002G016	(02)	WAWA, INC.	10/2005	N	800	1,700	320	900	125B	AQUIA FORMATION	02-13-11-01	WAWA CONVENIENCE STORE-PDWIS# 104-1248
CA	G	CA2002G017	(01)	CHIARAMONTE, FRANCIS, P.	09/2002	N	300	500	320	900	125B	AQUIA FORMATION	02-13-11-01	CHIARAMONTE - 3180 FERRY LANDING RD
CA	G	CA2002G018	(01)	7 ELEVEN, INC.	09/2002	N	500	800	300	910	124C	NANJEMOY FORMATION	02-13-10-05	7-ELEVEN STORE #2543-33340
CA	G	CA2002G020	(01)	WOOD, CHARLES	11/2002	N	2,600	4,300	300	910	124C	NANJEMOY FORMATION	02-13-11-01	COXCOMBE ESTATES SUBDIVISION
CA	G	CA2002G021	(01)	SAFEWAYM INC.	12/2002	N	200	300	320	900	125B	AQUIA FORMATION	02-13-11-01	GASOLINE SERVICE STATION
CA	G	CA2002G113	(01)	CALVERT COUNTY BOARD OF COMMISSIONERS	03/2004	N	1,000	2,000	290	940	124C	NANJEMOY FORMATION	02-13-10-05	BREEZY PT CAMPGROUND BATHHOUSE & LOWER CAMPGROUNDS PDWIS #1040072
CA	G	CA2003G001	(01)	MASK, CRAIG	02/2003	N	2,600	15,700	230	920	124E	PINEY POINT FORMATION	02-13-11-01	VEG IRRIGATION
CA	G	CA2003G004	(01)	CVS DUNKIRK MARKETPLACE, L.L.C.	03/2003	N	300	500	320	900	124C	NANJEMOY FORMATION	02-13-11-02	CVS STORE # 1881 - 10095 WARD ROAD

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2003G005	(01)	BRIGHT, WYLMA AND ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION
CA	G	CA2003G006	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION
CA	G	CA2003G007	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	LOT 3 - BRIGHT PROPERTY INDUSTRIAL SUBDIVISION
CA	G	CA2003G008	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION LOT 4
CA	G	CA2003G009	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION LOT 5
CA	G	CA2003G010	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION
CA	G	CA2003G011	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION LOT 7
CA	G	CA2003G012	(01)	BRIGHT, WYLMA & ELDON	03/2003	N	100	200	320	920	125B	AQUIA FORMATION	02-13-10-05	BRIGHT PROPERTY INDUSTRIAL SUBDIVISION LOT 8
CA	G	CA2003G014	(01)	CALVERT CO. BD OF COMMISSIONERS	04/2003	N	300	500	180	950	124E	PINEY POINT FORMATION	02-13-11-01	SOLOMONS WWTP - HEADWORKS SITE
CA	G	CA2003G015	(01)	CALVERT CO. BD OF COMMISSIONERS	04/2003	N	600	1,200	200	960	124C	NANJEMOY FORMATION	02-13-11-01	SOLOMONS WWTP-APPEAL SITE
CA	G	CA2003G016	(01)	EDWARD B. HOWLIN, INC.	06/2003	N	4,300	7,900	320	920	125B	AQUIA FORMATION	02-13-11-01	EDWARD B. HOWLIN INC. - OFFICES/WAREHOUSES
CA	G	CA2003G017	(01)	CHESAPEAKE HIGHLANDS MEMORIAL GARDENS	08/2003	N	8,000	16,000	240	930	125B	AQUIA FORMATION	02-13-11-01	CHESAPEAKE HIGHLANDS MEMORIAL GARDEN

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2003G018	(02)	WAYSON, MORGAN	04/2006	N	1,000	1,500	310	910	125B	AQUIA FORMATION	02-13-11-01	SOLID WASTE RECYCLING/ TRUCKING/MILLWRIGHT/ CONTRACTORS
CA	G	CA2003G019	(01)	WOOD, SR., CHARLES	11/2003	N	2,600	4,200	300	910	124C	NANJEMOY FORMATION	02-13-11-01	11 LOT SINGLE FAMILY RESIDENTIAL SUBDIV.
CA	G	CA2003G021	(02)	HAMPSHIRE, ANTHONY	03/2004	N	500	800	290	910	125B	AQUIA FORMATION	02-13-11-01	CHESAPEAKE MONTESSORI - HAMPSHIRE
CA	G	CA2004G005	(01)	CHARLOTTE RUSSELL & WINDMILL. L.L.C.	02/2004	N	800	1,600	300	910	125B	AQUIA FORMATION	02-13-10-05	RETAIL CENTER
CA	G	CA2004G006	(01)	TOWNE, KAREN	02/2004	N	100	300	320	920	125B	AQUIA FORMATION	02-13-11-01	KAREN TOWNE
CA	G	CA2004G007	(01)	CALVERT COUNTY BOARD OF COMMISSIONERS	03/2004	N	2,000	4,000	210	960	124E	PINEY POINT FORMATION	02-13-11-05	BGE FIELD FACILITY - PARKS & REC
CA	G	CA2004G008	(01)	MATTESON, JOHN	05/2004	N	300	500	250	920	124C	NANJEMOY FORMATION	02-13-10-05	MATTESON SUPPLY - GAS/ MOTOR REPAIR/SUPPLY
CA	G	CA2004G009	(01)	FISHER/TOM LANTZ, MARK	07/2004	N	3,100	12,200	320	910	125B	AQUIA FORMATION	02-13-11-01	GRAYS FIELD FOUNDATION - RECREATION FIELD IRRIGATION
CA	G	CA2004G010	(01)	CALVERT TRASH SERVICE, INCORPORATED	08/2004	N	200	400	310	910	124C	NANJEMOY FORMATION	02-13-11-01	CALVERT TRASH
CA	G	CA2004G012	(01)	LAVERENZ, TERRY	10/2004	N	200	2,500	240	920	124C	NANJEMOY FORMATION	02-13-11-01	LIVESTOCK WATERING - 17 HORSES
CA	G	CA2004G013	(01)	EWALT FAMILY, LLC	11/2004	N	100	200	230	920	124C	NANJEMOY FORMATION	02-13-11-01	EWALT FAMILY LLC PRIVATE PIER
CA	G	CA2004G014	(01)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	11/2004	N	300	500	290	910	124C	NANJEMOY FORMATION	02-13-11-01	BANK & VACANT RETAIL SLOT
CA	G	CA2004G015	(01)	CALVERT COUNTY COMMISSIONERS	02/2005	N	100	200	240	920	124E	PINEY POINT FORMATION	02-13-11-01	GRAYS ROAD RECREATION AREA - DOG EXERCISE AREA

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2005G001	(01)	LYSNE, MARK, A.	02/2005	N	100	200	240	920	124C	NANJEMOY FORMATION	02-13-11-01	RESIDENTIAL GREENHOUSE IRRIGATION
CA	G	CA2005G002	(01)	CHURCH BY THE CHESAPEAKE, INC.	02/2005	N	600	1,200	240	930	124E	PINEY POINT FORMATION	02-13-11-01	CHURCH
CA	G	CA2005G003	(01)	RUSSELL, MARY	03/2005	N	200	500	280	930	124C	NANJEMOY FORMATION	02-13-10-05	LUCKY CRICKET FARM - HORSES
CA	G	CA2005G004	(01)	WILLIAMS ROAD DEVELOPMENT, L.L.C.	10/2006	N	34,800	58,200	260	910	125B	AQUIA FORMATION	02-13-11-01	152-L COLLEGE STATION SUBD
CA	G	CA2005G005	(01)	HEALEY, PAT & TONI	04/2005	N	900	1,500	290	910	125B	AQUIA FORMATION	02-13-11-01	NOAH'S ARK LEARNING CENTER - PDWIS# 104-0080
CA	G	CA2005G006	(01)	THE TIDEWATER SCHOOL, INC.	04/2005	N	800	1,300	290	910	124C	NANJEMOY FORMATION	02-13-11-01	THE TIDEWATER SCHOOL - PDWIS# 104-0067
CA	G	CA2005G010	(01)	HARMS DEVELOPMENT, LLC	09/2006	N	8,900	14,900	270	930	124C	NANJEMOY FORMATION	02-13-11-01	39-L FARMS @ HUNTING CREEK SUBD (#LOTS REDUCED FROM 179 APF ORD)
CA	G	CA2005G011	(02)	SMTCCAC, INC.	11/2005	N	900	1,500	280	910	125B	AQUIA FORMATION	02-13-11-02	CARROLL VICTORIA LODGE (PDWIS #104-0071)
CA	G	CA2005G016	(01)	FAIRVIEW CENTRE, INC.	08/2005	N	3,400	5,000	310	900	125B	AQUIA FORMATION	02-13-11-01	FAIRVIEW SOUTH - 7 UNIT SHOPPING CENTER
CA	G	CA2005G017	(01)	CLEARY, FRANK	08/2005	N	300	6,000	310	890	125B	AQUIA FORMATION	02-13-11-01	FRIDAY'S CREEK VINEYARD/ WINERY - 400 VINES
CA	G	CA2005G018	(01)	MARKETPLACE PROFESSIONAL CENTER, L.L.C.	08/2005	N	2,500	3,700	320	900	125B	AQUIA FORMATION	02-13-11-01	OFFICES - PDWIS# 1041210
CA	G	CA2005G019	(01)	BRINSON, JENNIFER	10/2005	N	1,100	2,000	320	910	124C	NANJEMOY FORMATION	02-13-11-01	IMAGINE NATIONS EARLY LEARNING CENTER - PDWIS# 104-0081
CA	G	CA2005G020	(01)	MS. BEV'S PLACE LLC	10/2005	N	1,400	2,300	330	900	125B	AQUIA FORMATION	02-13-11-01	MS. BEVS PLACE DAYCARE - PDWIS# 104-0004

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2005G021	(01)	ALLEN, DOUG & SUSAN	11/2005	N	1,000	2,000	220	940	124E	PINEY POINT FORMATION	02-13-11-01	LIVESTOCK WATERING - VARIETY
CA	G	CA2005G022	(02)	JESUS THE GOOD SHEPHERD,	10/2006	N	2,000	3,000	320	900	125B	AQUIA FORMATION	02-13-11-01	CHURCH & SCHOOL - PDWIS# 104-1184 ADDING A 3RD WELL
CA	G	CA2005G023	(01)	BIGSBY, TINA	11/2005	N	700	1100	270	920	124C	NANJEMOY FORMATION	02-13-11-01	MISS TINA'S DAY CARE - PDWIS# 104-0052
CA	G	CA2005G024	(01)	WAYSON LAND HOLDINGS LTD. PARTNERSHIP	11/2005	N	100	300	310	910	124C	NANJEMOY FORMATION	02-13-11-01	COMMERCIAL FLEX SPACE
CA	G	CA2005G025	(01)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	04/2006	N	1,600	2,900	310	910	124C	NANJEMOY FORMATION	02-13-11-01	ANNAPOLIS SOUTH MARINE LOT 1
CA	G	CA2005G026	(01)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	11/2005	N	800	1,300	320	920	125B	AQUIA FORMATION	02-13-10-05	PARIS OAKS CENTER - PDWIS# 104-1070
CA	G	CA2005G028	(01)	BROTHERS' JOHNSON, INC.	12/2005	N	300	600	230	930	124E	PINEY POINT FORMATION	02-13-11-01	LIVESTOCK WATERING - CATTLE
CA	G	CA2005G029	(01)	WHITE SANDS CORPORATION	12/2005	N	1,500	2,500	210	950	124E	PINEY POINT FORMATION	02-13-11-01	WHITE SANDS RESTAURANT/ VERA FREEMAN - PDWIS# 1041150
CA	G	CA2005G030	(01)	WAYSON LAND HOLDINGS LIMITED PARTNERSHIP	04/2006	N	3,500	5,000	220	950	124E	PINEY POINT FORMATION	02-13-11-01	CALVERT CLIFFS BUSINESS CENTER-FLEX SPACE-PDWIS# 104-0089
CA	G	CA2006G001	(01)	WELLS, WALTER AND SUSAN HANCE-	03/2006	N	500	900	220	910	124C	NANJEMOY FORMATION	02-13-11-01	LIVESTOCK WATERING - 70 TOTAL CATTLE/HORSES
CA	G	CA2006G002	(01)	CALVERT LLC.	04/2006	N	5,300	8,800	310	920	124C	NANJEMOY FORMATION	02-13-10-05	23-L EAGLE'S TRACE SUBD
CA	G	CA2006G006	(01)	GREATER MOUNT ZION, INCORPORATED	05/2006	N	2,500	4,000	250	910	124C	NANJEMOY FORMATION	02-13-11-01	GREATER MT. ZION BAPTIST CHURCH - PDWIS# 104-0090

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks
CA	G	CA2006G007	(01)	LOWER MARLBORO UNITED METHODIST CHURCH	05/2006	N	100	300	300	890	125B	AQUIA FORMATION	02-13-11-04	CHURCH
CA	G	CA2006G012	(01)	BTIP, LLC	07/2006	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	BRIGHT PROPERTY INDUSTRIAL SUBD LOT 1
CA	G	CA2006G013	(01)	BTIP, LLC	07/2006	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	BRIGHT PROPERTY INDUSTRIAL SUBD LOT 2
CA	G	CA2006G014	(01)	BTIP, LLC	07/2006	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	BRIGHT PROPERTY INDUSTRIAL SUBD LOT 3
CA	G	CA2006G015	(01)	BTIP, LLC	07/2006	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	BRIGHT PROPERTY INDUSTRIAL SUBD LOT 4
CA	G	CA2006G016	(01)	BTIP, LLC	07/2006	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	BRIGHT PROPERTY INDUSTRIAL SUBD LOT 5
CA	G	CA2006G017	(01)	BTIP, LLC	07/2006	N	300	500	320	920	124C	NANJEMOY FORMATION	02-13-11-01	BRIGHT PROPERTY INDUSTRIAL SUBD LOT 6
CA	G	CA2006G018	(01)	RIDDLE, RITA	09/2006	N	100	300	210	940	124E	PINEY POINT FORMATION	02-13-11-01	HORSE FARM WATERING
CA	G	CA2006G019	(01)	ACCIPITER, COURTNEY	09/2006	N	200	400	290	910	124C	NANJEMOY FORMATION	02-13-11-01	OLD TOWN AUTOMOBILE - CAR SALES
CA	G	CA2006G021	(01)	GALLAHAN, WILLIAM, ALTON	09/2006	N	6,000	9900	250	920	125B	AQUIA FORMATION	02-13-10-05	26-LOT GALLAHAN'S CHOICE RES SUBDD
CA	G	CA2006G023	(01)	MILLER, LAWRENCE	11/2006	N	2,000	4,000	180	960	124E	PINEY POINT FORMATION	02-13-11-01	RESIDENTIAL GWHP W/ RECHARGE WELL

Table 2.4-38— {Listing of Maryland Department of the Environment (MDE) Water Appropriations Permits for Calvert County, Maryland}

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County	GorS	WAPID	Rev-t4	Owner	EffDate-t7	ReptCode	AGPD	MGPD	North-thouFt27	East-thouFt27	AquiCd	AquiNam	Basin	Remarks

Field Explanations
County: CA is Calvert County
GorS: Ground or Surface water appropriate
WAPID: Permit ID
rev-t4: Permit Revision
Owner: Owner or the property
EffDate-t7: Effective date of last revision of the permit
ReptCode: Does the permit have to report pumpage
AGPD: Permit quantity as gallons per day (gpd) - yearly average
MGPD:

- Ground water is a average use during the month of maximum use
- Surface water is average use during day of maximum use

North-thouFt27: Location information, thousands of feet north of the origin, Maryland State Plane 1927. Normal accuracy is to the nearest 10,000 ft.
East-thouFt27: Location information, thousands of feet east of the origin, Maryland State Plane 1927. Normal accuracy is to the nearest 10,000 ft.
AquiCd:

- Ground water is the aquifer identification code
- Surface water is the stream identification code.

AquiNam:

- Ground water is the aquifer name
- Surface water is the stream name

Basin: Eight digit basin code

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

(Page 1 of 11)

Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
BEACHES WATER COMPANY	CALVERT	1800	Ground water	Active		MD0040009
BUCKLER MOBILE HOME PARK	CALVERT	65	Ground water	Active		MD0040209
CALVERT BEACH - DECATUR STREET	CALVERT	350	Ground water	Active		MD0040024
CALVERT BEACH / FOREST TRAIL	CALVERT	100	Ground water	Active		MD0040020
CALVERT MOBILE HOME PARK	CALVERT	80	Ground water	Active		MD0040206
CAVALIER COUNTRY	CALVERT	400	Ground water	Active		MD0040002
CHESAPEAKE BEACH	CALVERT	3000	Ground water	Active		MD0040003
CHESAPEAKE HEIGHTS (BAYSIDE FOREST)	CALVERT	850	Ground water	Active		MD0040018
CHESAPEAKE RANCH ESTATES	CALVERT	9750	Ground water	Active		MD0040004
CROSS POINT SUBDIVISION	CALVERT	462	Ground water	Active		MD0040052
DARES BEACH	CALVERT	600	Ground water	Active		MD0040005
HALLOWING POINT TRAILER PARK	CALVERT	100	Ground water	Active		MD0040208
HUNTING HILLS	CALVERT	150	Ground water	Active		MD0040006
JOHNSON ACRES WATER CO	CALVERT	50	Ground water	Active		MD0040032
KENWOOD BEACH	CALVERT	350	Ground water	Active		MD0040007
LAKEWOOD	CALVERT	200	Ground water	Active		MD0040008
MARLEY RUN	CALVERT	171	Ground water	Active		MD0040053
NORTH BEACH	CALVERT	3000	Ground water	Active		MD0040030
PARIS OAKS / DAYS END	CALVERT	275	Ground water	Active		MD0040010
PARKERS CREEK KNOLLS	CALVERT	60	Ground water	Active		MD0040031
PINE TRAILER PARK	CALVERT	65	Ground water	Active		MD0040210
PRINCE FREDERICK	CALVERT	3150	Ground water	Active		MD0040011
REGENCY MANOR MOBILE HOME PARK	CALVERT	224	Ground water	Active		MD0040202
SCIENTISTS CLIFFS	CALVERT	425	Ground water	Active		MD0040014
SHORES OF CALVERT	CALVERT	400	Ground water	Active		MD0040015
SOLOMONS	CALVERT	2700	Ground water	Active		MD0040027
SOLOMONS RECREATION CENTER	CALVERT	1200	Ground water	Active		MD0040023
SOUTHERN PINES ELDERLY HOUSING	CALVERT	93	Ground water	Active		MD0040033
ST. LEONARD	CALVERT	200	Ground water	Active		MD0040013
SUMMIT/HIGHLANDS	CALVERT	800	Ground water	Active		MD0040026
TAPESTRY NORTH	CALVERT	60	Ground water	Active		MD0040205
TARA SUBDIVISION	CALVERT	75	Ground water	Active		MD0040034
WALNUT CREEK	CALVERT	168	Ground water	Active		MD0040035
WESTERN SHORES	CALVERT	155	Ground water	Active		MD0040016
WHITE SANDS	CALVERT	100	Ground water	Active		MD0040017
WOODBRIDGE - MASON ROAD	CALVERT	100	Ground water	Active		MD0040025
ACCENT MOBILE HOME PARK	CALVERT	25	Ground water	Closed	9/1/1981	MD0000069

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
ALL SAINTS DAY CARE CENTER	CALVERT	38	Ground water	Closed	9/1/1981	MD0000875
ANCHORAGE TRAILER PARK	CALVERT	32	Ground water	Closed	2/1/1988	MD0040203
ANCHORAGE TRAILER PARK	CALVERT	32	Ground water	Closed	9/1/1981	MD0002691
BAY VIEW MANOR TRAILER PARK	CALVERT	142	Ground water	Closed	9/1/1981	MD0002483
BAY VIEW MOBILE MANOR	CALVERT	100	Ground water	Closed	1/1/2006	MD0040204
BEACHES WATER CO	CALVERT	400	Ground water	Closed	10/1/1990	MD0040029
BROOKS DAY CARE CENTER	CALVERT	30	Ground water	Closed	9/1/1981	MD0000892
CALVERT CHRISTIAN SCHOOL AND	CALVERT	200	Ground water	Closed	9/1/1981	MD0000895
CALVERT CO NURSING CENTER	CALVERT	50	Ground water	Closed	9/1/1981	MD0002688
CALVERT COUNTY NURSING CENTER	CALVERT	100	Ground water	Closed	7/1/1993	MD0040201
CALVERT COUNTY NURSING CENTER	CALVERT	41	Ground water	Closed	9/1/1981	MD0000898
CALVERT MEMORIAL HOSPITAL	CALVERT	78	Ground water	Closed	9/1/1981	MD0000903
CALVERT MOBILE HOMES PARK	CALVERT	60	Ground water	Closed	9/1/1981	MD0002693
CAVALIER COUNTRY WATER ASSOC I	CALVERT	436	Ground water	Closed	9/1/1981	MD0002686
CHESAPEAKE BEACH	CALVERT	640	Ground water	Closed	9/1/1981	MD0002270
CHESAPEAKE RANCH WATER CO INC	CALVERT	1448	Ground water	Closed	9/1/1981	MD0002551
CIRCLE S TRAILER PARK	CALVERT	28	Ground water	Closed	6/1/1981	MD0002639
DARES BEACH WATER COMPANY	CALVERT	644	Ground water	Closed	9/1/1981	MD0002687
FRISCOE TRAILER PARK	CALVERT	84	Ground water	Closed	9/1/1981	MD0002692
GRAY-RAY CENTER	CALVERT	30	Ground water	Closed	9/1/1981	MD0000935
HUNTING HILLS ESTATES	CALVERT	124	Ground water	Closed	9/1/1981	MD0002325
KENWOOD BEACH WATER SYSTEM	CALVERT	320	Ground water	Closed	9/1/1981	MD0002719
LAKEWOOD	CALVERT	60	Ground water	Closed	9/1/1981	MD0002326
LONG BEACH WATER CO	CALVERT	1244	Ground water	Closed	9/1/1981	MD0002720
PINE TRAILER PARK	CALVERT	84	Ground water	Closed	9/1/1981	MD0002690
PRNC FRED-CALV CO SAN DIST INC	CALVERT	500	Ground water	Closed	9/1/1981	MD0002685
RANDLE CLIFF HEAD START CENTER	CALVERT	30	Ground water	Closed	9/1/1981	MD0000969
REGENCY MANOR MOBILE PARK	CALVERT	108	Ground water	Closed	2/1/1988	MD0002327
SAINT LEONARD DEV CORP INC	CALVERT	160	Ground water	Closed	9/1/1981	MD0002755
SCIENTISTS CLIFFS SERVICE CO I	CALVERT	651	Ground water	Closed	9/1/1981	MD0002677
SHORES OF CALVERT WAT ASSC INC	CALVERT	260	Ground water	Closed	9/1/1981	MD0002678
WESTERN SHORES	CALVERT	120	Ground water	Closed	9/1/1981	MD0002721
WHITE SANDS CORPORATION	CALVERT	56	Ground water	Closed	9/1/1981	MD0002552
APPEAL ELEMENTARY SCHOOL	CALVERT	569	Ground water	Active		MD1040001
BAYSIDE CHEVROLET BUICK INC.	CALVERT	34	Ground water	Active		MD1041230
BREEZY POINT SNACKBAR	CALVERT	25	Ground water	Active		MD1040092
BROOKS ADMINISTRATION BUILDING	CALVERT	106	Ground water	Active		MD1040006

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
CALVERT CAREER CENTER	CALVERT	800	Ground water	Active		MD1040011
CALVERT CLIFFS NUCLEAR - OFFICE BUILDING	CALVERT	362	Ground water	Active		MD1040055
CALVERT CLIFFS NUCLEAR - PROTECTED AREA	CALVERT	482	Ground water	Active		MD1040002
CALVERT CO. INDUSTRIAL PARK	CALVERT	100	Ground water	Active		MD1040051
CALVERT COUNTRY & CALVERT ELEMENTARY	CALVERT	900	Ground water	Active		MD1040012
CALVERT COUNTY EMERGENCY CENTER	CALVERT	30	Ground water	Active		
CALVERT COUNTY JAIL	CALVERT	150	Ground water	Active		
CALVERT GATEWAY + MCDONALD # 16243	CALVERT	25	Ground water	Active		
CALVERT HIGH SCHOOL	CALVERT	1450	Ground water	Active		
CALVERT MIDDLE SCHOOL	CALVERT	675	Ground water	Active		
CALVERTON SCHOOL	CALVERT	500	Ground water	Active		
CARDINAL HICKEY ACADEMY/JESUS THE GOOD	CALVERT	380	Ground water	Active		
CARROLL VICTORIA LODGE - HUNTINGTOWN	CALVERT	87	Ground water	Active		
CHESAPEAKE MONTESSORI LIMITED	CALVERT	77	Ground water	Active		
CROSSROAD CHRISTIAN CHURCH & DAYCARE	CALVERT	133	Ground water	Active		
DOMINION COVE POINT LNG, LP	CALVERT	55	Ground water	Active		
DUNKIRK BUSINESS CENTER I	CALVERT	250	Ground water	Active		
DUNKIRK MARKET PLACE	CALVERT	50	Ground water	Active		
DUNKIRK MEDICAL CENTER	CALVERT	200	Ground water	Active		
DUNKIRK SAFEWAY STORE #1129	CALVERT	25	Ground water	Active		
DUNKIRK TOWN SQUARE SHOPPING CENTER	CALVERT	40	Ground water	Active		
DUNKIRK VILLAGE SHOPPING CENTER	CALVERT	25	Ground water	Active		
FAIRVIEW CENTRE, INC.	CALVERT	30	Ground water	Active		
FIRST IMPRESSIONS DAYCARE CENTER	CALVERT	40	Ground water	Active		
HUNTING CREEK ALTERNATIVE SCHOOL	CALVERT	60	Ground water	Active		
HUNTINGTOWN ELEMENTARY SCHOOL	CALVERT	609	Ground water	Active		
HUNTINGTOWN HIGH SCHOOL	CALVERT	1540	Ground water	Active		
IMAGINE NATIONS EARLY LEARNING CENTER	CALVERT	60	Ground water	Active		
JEFFERSON PATTERSON PARK & MUSEUM	CALVERT	35	Ground water	Active		
KID'S FARM, INC.	CALVERT	105	Ground water	Active		
LAURIAN BUILDING	CALVERT	30	Ground water	Active		
LYONS CREEK SHOPPING CENTER	CALVERT	95	Ground water	Active		
MARKETPLACE PROFESSIONAL CENTER, LLC	CALVERT	110	Ground water	Active		
MISS TINA DAY CARE	CALVERT	40	Ground water	Active		
MS. BEV'S PLACE	CALVERT	75	Ground water	Active		
MT. HARMONY ELEMENTARY SCHOOL	CALVERT	706	Ground water	Active		
MUTUAL ELEMENTARY SCHOOL	CALVERT	894	Ground water	Active		

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
NAVAL RESEARCH LAB., CHESAPEAKE BAY DIV.	CALVERT	200	Ground water	Active		
NOAH'S ARK LEARNING CENTER	CALVERT	63	Ground water	Active		
NORTHERN MIDDLE & HIGH SCHOOLS	CALVERT	2470	Ground water	Active		
PATUXENT ELEMENTARY SCHOOL	CALVERT	637	Ground water	Active		
PLUM POINT ELEMENTARY SCHOOL	CALVERT	615	Ground water	Active		
PLUM POINT MIDDLE SCHOOL	CALVERT	881	Ground water	Active		
PRIME TIME YOUTH ACTIVITY CENTER	CALVERT	99	Ground water	Active		
SHILOH CHRISTIAN ACADEMY	CALVERT	74	Ground water	Active		
SLEEPY HOLLOW DAYCARE	CALVERT	65	Ground water	Active		
SNEADE'S ACE HARDWARE (LUSBY)-DAVLYN LLC	CALVERT	40	Ground water	Active		
SNEADES HARDWARE (OWINGS) - DAVLYN LLC	CALVERT	40	Ground water	Active		
SOLOMONS WASTEWATER TREATMENT PLANT	CALVERT	27	Ground water	Active		
SOUTHERN MIDDLE SCHOOL	CALVERT	745	Ground water	Active		
SUNDERLAND ELEMENTARY SCHOOL	CALVERT	481	Ground water	Active		
THE SHOPPES AT DUNKIRK LLC -COUNTRY PLZ	CALVERT	60	Ground water	Active		
THE TIDEWATER SCHOOL	CALVERT	61	Ground water	Active		
BEACH ELEMENTARY (0040003)	CALVERT	25	Ground water	Closed	7/1/1992	
BEAVERS NURSERY 2	CALVERT	22	Ground water	Closed	5/1/1994	
BROOKS CHILD DEVELOPMENT CT.	CALVERT	62	Ground water	Closed	7/1/1995	
BUSY BEE NURSERY INC.	CALVERT	45	Ground water	Closed	2/1/2003	
BUSY LITTLE BEAVERS	CALVERT	25	Ground water	Closed	12/1/1989	
CALVERT CO. BOE	CALVERT	25	Ground water	Closed	3/1/1991	
CALVERT ELEMENTARY (1040012)	CALVERT	25	Ground water	Closed	7/1/1992	
CALVERT MEMORIAL HOSPITAL	CALVERT	25	Ground water	Closed	7/1/1993	
CALVERT NURSING CENTER	CALVERT	130	Ground water	Closed	12/1/1989	
CALVERT SR. HIGH/VO TECH.	CALVERT	25	Ground water	Closed	3/1/1991	
COLLEGE OF SOUTHERN MD - CALVERT CAMPUS	CALVERT	501	Ground water	Closed	5/1/2005	
CROSS POINT	CALVERT	25	Ground water	Closed	8/1/1999	
GRACE BRETHERN SCHOOL	CALVERT	25	Ground water	Closed	9/1/1990	
ISLAND CREEK COMMUNITY CENTER	CALVERT	85	Ground water	Closed	1/1/2006	
KIDDIE CORRAL	CALVERT	22	Ground water	Closed	12/1/1994	
LITTLE FLOCK DAY CARE	CALVERT	25	Ground water	Closed	5/1/1994	
NORTHERN HIGH (1040034)	CALVERT	25	Ground water	Closed	6/1/1991	
RAGGEDY ANN & ANDYS	CALVERT	25	Ground water	Closed	3/1/1991	
RANDLE CLIFF HEAD START CENTER	CALVERT	25	Ground water	Closed	12/1/1989	
ST PAULS UM PRESCHOOL	CALVERT	25	Ground water	Closed	3/1/1991	
STATE HIGHWAY ADMINISTRATION	CALVERT	50	Ground water	Closed	12/1/1993	

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
TOPAZ MARINE CORP	CALVERT	25	Ground water	Closed	6/1/1991	
7-11 SUNDERLAND	CALVERT	25	Ground water	Active		
7TH DAY ADVENTIST CHURCH OF PR. FRED.	CALVERT	25	Ground water	Active		
ADAMS RIBS	CALVERT	195	Ground water	Active		
ALL SAINTS EPISCOPAL CHURCH	CALVERT	502	Ground water	Active		
AMERICAN LEGION POST 206	CALVERT	25	Ground water	Active		
AMERICAN LEGION POST 274	CALVERT	25	Ground water	Active		
APOSTOLIC FAITH CHURCH	CALVERT	25	Ground water	Active		
BAY BREEZE STATE PARK	CALVERT	25	Ground water	Active		
BENNETT & BATONG MEDICAL	CALVERT	25	Ground water	Active		
BETHEL WAY CHURCH	CALVERT	25	Ground water	Active		
BILL'S BOAT RENTAL	CALVERT	25	Ground water	Active		
BOWENS GROCERY	CALVERT	25	Ground water	Active		
BREEZY POINT BATHHOUSE	CALVERT	56	Ground water	Active		
BREEZY POINT BEACH/CAMP	CALVERT	25	Ground water	Active		
BREEZY POINT GRILL WINE & SPIRITS	CALVERT	0	Ground water	Active		
BREEZY PT BEACH CLUB MARINA	CALVERT	25	Ground water	Active		
BRIDGE DINER	CALVERT	25	Ground water	Active		
BRIGHT CENTER EAST	CALVERT	25	Ground water	Active		
BRIGHT CENTER WEST	CALVERT	250	Ground water	Active		
BROWN CLEARY BUILDING (CALVERT ANIMAL)	CALVERT	25	Ground water	Active		
BURNOUTS BAR & GRILL / STETSONS	CALVERT	0	Ground water	Active		
CALVARY BIBLE CHURCH	CALVERT	25	Ground water	Active		
CALVARY UNITED APOSTOLIC CHURCH	CALVERT	25	Ground water	Active		
CALVERT ARUNDEL MEDICAL	CALVERT	25	Ground water	Active		
CALVERT CLIFFS NUCLEAR - BALLFIELD	CALVERT	25	Ground water	Active		
CALVERT CLIFFS NUCLEAR - CAMP CONOY POOL	CALVERT	200	Ground water	Active		
CALVERT CLIFFS STATE PARK	CALVERT	25	Ground water	Active		
CALVERT DENTAL ASSOCIATES	CALVERT	25	Ground water	Active		
CALVERT ELKS LODGE	CALVERT	25	Ground water	Active		
CALVERT LIGHTHOUSE TABERNACLE	CALVERT	25	Ground water	Active		
CALVERT MEDICAL CENTER	CALVERT	25	Ground water	Active		
CALVERT PROFESSIONAL BUILDING	CALVERT	212	Ground water	Active		
CALVERT SKATING CENTER	CALVERT	25	Ground water	Active		
CAMP CONOY EAGLES DEN	CALVERT	25	Ground water	Active		
CHINA KING RESTAURANT	CALVERT	25	Ground water	Active		
CHRIST CHURCH PARISH HOUSE	CALVERT	25	Ground water	Active		

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
CHURCH OF CHRIST	CALVERT	25	Ground water	Active		
CHURCH OF LATTER DAY SAINTS	CALVERT	25	Ground water	Active		
CJ'S FOOD STORE	CALVERT	25	Ground water	Active		
COOPER UM CHURCH	CALVERT	25	Ground water	Active		
COVE POINT PARK MAINTENANCE BLDG	CALVERT	25	Ground water	Active		
COVE POINT PARK SNACK BAR	CALVERT	25	Ground water	Active		
CURTIS LITTEN - RIDGEWAY BUILDING	CALVERT	45	Ground water	Active		
CVS DUNKIRK	CALVERT	25	Ground water	Active		
CYPRESS SWAMP NATURE CENTER	CALVERT	25	Ground water	Active		
DASH IN OWINGS	CALVERT	25	Ground water	Active		
DOMINOS PIZZA-HUNTINGTOWN	CALVERT	25	Ground water	Active		
DON'S GENERAL STORE	CALVERT	25	Ground water	Active		
DOUBLE D'S SPORTS	CALVERT	42	Ground water	Active		
DUNKIRK ANIMAL HOSPITAL	CALVERT	25	Ground water	Active		
DUNKIRK BAPTIST CHURCH	CALVERT	303	Ground water	Active		
DUNKIRK CITGO	CALVERT	704	Ground water	Active		
DUNKIRK DISTRICT PARK	CALVERT	25	Ground water	Active		
DUNKIRK SUPPLY - LUSBY	CALVERT	25	Ground water	Active		
DUNKIRK SUPPLY - TRUSS PLANT	CALVERT	25	Ground water	Active		
DUNKIRK SUPPLY OWINGS	CALVERT	25	Ground water	Active		
DUNKIRK VOL FIRE DEPT	CALVERT	25	Ground water	Active		
EAST JOHN YOUTH CENTER	CALVERT	25	Ground water	Active		
EMMANUAL BAPTIST CHURCH	CALVERT	310	Ground water	Active		
EMMANUEL SEVENTH DAY ADVENTIST CHURCH	CALVERT	25	Ground water	Active		
EMMANUEL U M CHURCH	CALVERT	25	Ground water	Active		
ETERNAL BUZZ TATTOO PARLOR	CALVERT	25	Ground water	Active		
FAIRVIEW CENTER	CALVERT	25	Ground water	Active		
FASTOP #54	CALVERT	225	Ground water	Active		
FASTOP #56	CALVERT	1207	Ground water	Active		
FIRST BAPTIST CHURCH	CALVERT	25	Ground water	Active		
FIRST LUTHERAN CHURCH	CALVERT	25	Ground water	Active		
FLAG HARBOR POOL	CALVERT	167	Ground water	Active		
FLAVOR OF THE SOUTH CAFE	CALVERT	69	Ground water	Active		
FRYING PAN	CALVERT	25	Ground water	Active		
GATEWAY CENTER	CALVERT	25	Ground water	Active		
GATEWAY NORTH	CALVERT	25	Ground water	Active		
GENTLE FAMILY DENTISTRY	CALVERT	25	Ground water	Active		

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
GRACE BRETHREN CHURCH - EAST WING	CALVERT	608	Ground water	Active		
GRACE BRETHREN CHURCH - WEST WING	CALVERT	25	Ground water	Active		
GRAY-RAY AMER LEGION POST #220	CALVERT	25	Ground water	Active		
GREATER BIBLE WAY CHURCH	CALVERT	19	Ground water	Active		
GUIDOS RESTAURANT	CALVERT	25	Ground water	Active		
HALLOWING POINT PARK	CALVERT	25	Ground water	Active		
HALLOWING POINT PARK MAINTENANCE BLDG	CALVERT	25	Ground water	Active		
HARVEST FELLOWSHIP	CALVERT	25	Ground water	Active		
HEGARTY AND KOPICKI BUILDING	CALVERT	25	Ground water	Active		
HOPKINS & WAYSON / EXPRESSIONS CATERING	CALVERT	25	Ground water	Active		
HOWLIN BUILDING	CALVERT	25	Ground water	Active		
HUDSON'S SUNOCO	CALVERT	25	Ground water	Active		
HUNTINGTOWN MEDICAL BUILDING	CALVERT	90	Ground water	Active		
HUNTINGTOWN NORTH/FLOOR SYSTEMS	CALVERT	125	Ground water	Active		
HUNTINGTOWN PLAZA SHOPPING CENTER	CALVERT	25	Ground water	Active		
HUNTINGTOWN UM CHURCH	CALVERT	25	Ground water	Active		
HUNTINGTOWN VOL FIRE DEPT	CALVERT	25	Ground water	Active		
ISLAND CREEK PROPERTIES	CALVERT	25	Ground water	Active		
J & J PHYSICAL THERAPY	CALVERT	25	Ground water	Active		
JEHOVAHS WITNESS OF PRINCE FREDERICK	CALVERT	25	Ground water	Active		
JLH BUILDING	CALVERT	25	Ground water	Active		
KINGS LANDING CAMP	CALVERT	25	Ground water	Active		
KINGS LANDING POOL	CALVERT	25	Ground water	Active		
LEE FUNERAL HOME	CALVERT	303	Ground water	Active		
LEN'S MARKET/MARINA	CALVERT	25	Ground water	Active		
LORD CALVERT BOWL	CALVERT	25	Ground water	Active		
LUSBY SUNOCO	CALVERT	25	Ground water	Active		
MARLEY RUN RECREATION AREA	CALVERT	25	Ground water	Active		
MATTESON SUPPLY COMPANY	CALVERT	2	Ground water	Active		
MIDDLEHAM & ST PETERS PARISH	CALVERT	25	Ground water	Active		
MT GETHSEMANE BAPTIST CHURCH	CALVERT	25	Ground water	Active		
MT HARMONY UMC	CALVERT	54	Ground water	Active		
MT HOPE CENTER	CALVERT	25	Ground water	Active		
MT OLIVE UM CHURCH	CALVERT	25	Ground water	Active		
NEW CALVERT CO FAIRGROUND	CALVERT	25	Ground water	Active		
OPTIMISTS CLUB BINGO	CALVERT	25	Ground water	Active		
PARIS CENTER (FKA GRIFFITHS)	CALVERT	25	Ground water	Active		

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
PATUXENT CAMPSITES	CALVERT	37	Ground water	Active		
PETERS UM CHURCH	CALVERT	25	Ground water	Active		
PRINCE FREDERICK PROFESSIONAL BLDG	CALVERT	120	Ground water	Active		
RAUSCH FUNERAL HOME OWINGS	CALVERT	20	Ground water	Active		
RAUSCH FUNERAL HOME PORT REPUBLIC	CALVERT	55	Ground water	Active		
RAYMOND FUNERAL HOME	CALVERT	25	Ground water	Active		
REID BUILDING	CALVERT	25	Ground water	Active		
ROUTE 231 CITGO	CALVERT	25	Ground water	Active		
ROUTE 260 AMOCO	CALVERT	25	Ground water	Active		
SAFEWAY GAS STATION	CALVERT	25	Ground water	Active		
SCHEIBELS CONSTRUCTION	CALVERT	43	Ground water	Active		
SEWELL FUNERAL HOME	CALVERT	25	Ground water	Active		
SMECO BUILDING	CALVERT	193	Ground water	Active		
SMITHVILLE U M CHURCH	CALVERT	25	Ground water	Active		
SOLID ROCK CHURCH	CALVERT	25	Ground water	Active		
SOUTHERN CALVERT BAPTIST CHURCH	CALVERT	86	Ground water	Active		
ST EDMONDS UM CHURCH	CALVERT	25	Ground water	Active		
ST NICHOLAS LUTHERAN	CALVERT	25	Ground water	Active		
ST PAUL UM CHURCH	CALVERT	25	Ground water	Active		
STONEYS CRAB HOUSE	CALVERT	25	Ground water	Active		
TASTY KWIK	CALVERT	25	Ground water	Active		
THE PAVILLION AT GODSGRACE	CALVERT	25	Ground water	Active		
THE QUILTING ROOM (FRMLY ISLAMIC CENTER)	CALVERT	25	Ground water	Active		
TOWN & COUNTRY LIQUORS/BARBER SHOP	CALVERT	2	Ground water	Active		
TOWN CENTER AMOCO	CALVERT	25	Ground water	Active		
TWIN SHIELDS GOLF CLUB	CALVERT	25	Ground water	Active		
WATERS MEMORIAL UM CHURCH	CALVERT	25	Ground water	Active		
WAWA #573	CALVERT	10	Ground water	Active		
WHITE SANDS RESTAURANT	CALVERT	25	Ground water	Active		
WINDSORS EZ STOP	CALVERT	25	Ground water	Active		
WORLD GYM	CALVERT	10	Ground water	Active		
7-ELEVEN DUNKIRK	CALVERT	25	Ground water	Closed	8/1/1999	
AMER LEGION POST 206	CALVERT	25	Ground water	Closed	2/1/1999	
ANDREA'S CATERING	CALVERT	25	Ground water	Closed	3/1/1993	
B G & E (FIRING RANGE)	CALVERT	25	Ground water	Closed	8/1/1999	
BARSTOW PROFESSIONAL BUILDING	CALVERT	25	Ground water	Closed	1/1/2002	
BAYSIDE MARKET	CALVERT	25	Ground water	Closed	3/1/1993	

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
BETTY SUE'S CONFECTIONARY	CALVERT	25	Ground water	Closed	2/1/1999	
BG&E VISITOR CENTER	CALVERT	200	Ground water	Closed	5/1/2002	
BISHOPS STAND	CALVERT	25	Ground water	Closed	5/1/2005	
BJ'S BAKERY	CALVERT	25	Ground water	Closed	12/1/1996	
BROOKS UM CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
C & B TEXACO	CALVERT	25	Ground water	Closed	3/31/2006	
CALVARY BAPTIST CHURCH	CALVERT	25	Ground water	Closed	11/1/1999	
CALVERT CAFE	CALVERT	25	Ground water	Closed	2/1/1999	
CALVERT CLIFFS NUCLEAR CONFERENCE CENTER	CALVERT	100	Ground water	Closed	10/1/2004	
CALVERT COUNTY FAIRGROUND	CALVERT	25	Ground water	Closed	1/1/2002	
CALVERT MARINA	CALVERT	25	Ground water	Closed	2/1/1999	
CALVERT MEATS	CALVERT	25	Ground water	Closed	8/1/1999	
CARROLL WESTERN UM CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
CHESAPEAKE HILLS COUNTRY CLUB	CALVERT	25	Ground water	Closed	8/1/1999	
CHESSIES HUNTINGTOWN	CALVERT	25	Ground water	Closed	8/1/1999	
CHRIST CHILD CAMP	CALVERT	25	Ground water	Closed	5/1/2005	
CHRIST CHILD CAMP POOL	CALVERT	25	Ground water	Closed	5/1/2005	
CHRISTIAN BIBLE CENTER	CALVERT	25	Ground water	Closed	11/1/1999	
CHURCH OF GOD	CALVERT	25	Ground water	Closed	5/1/2005	
CORNER STONE BAPTIST CHURCH	CALVERT	25	Ground water	Closed	11/1/1999	
COUNTRY CUTS	CALVERT	25	Ground water	Closed	3/1/1993	
COUNTRY DOCKS	CALVERT	25	Ground water	Closed	5/1/2005	
DJ'S MINI MART	CALVERT	25	Ground water	Closed	1/1/2002	
DODSONS GROCERY	CALVERT	25	Ground water	Closed	8/1/2000	
DUNKIRK AMOCO	CALVERT	25	Ground water	Closed	8/1/2000	
DUNKIRK COMMUNITY CHAPEL	CALVERT	25	Ground water	Closed	11/1/1999	
DUNKIRK MARKET PLACE (SEE 104-0064)	CALVERT	25	Ground water	Closed	3/31/2006	
DUNKIRK SEAFOOD MARKET	CALVERT	25	Ground water	Closed	11/1/1999	
DUNKIRK URGENT CARE CENTER	CALVERT	25	Ground water	Closed	3/31/2006	
EASTERN U M CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
FAMILY MEDICINE	CALVERT	25	Ground water	Closed	12/1/2000	
FRANCHI'S RESTAURANT	CALVERT	25	Ground water	Closed	12/1/1996	
GASHOP 2	CALVERT	25	Ground water	Closed	5/1/2005	
GATSBY DOCKSIDE GALLERY	CALVERT	25	Ground water	Closed	9/1/1988	
HAWKINS GROCERY DUNKIRK	CALVERT	25	Ground water	Closed	12/1/1996	
HIGH'S-PARIS SHOPPING CENTER	CALVERT	25	Ground water	Closed	2/1/1999	
HULIO'S CHUCKWAGON	CALVERT	25	Ground water	Closed	2/1/1999	

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

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Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
IGA FOODLINER	CALVERT	25	Ground water	Closed	12/1/1996	
IGA NORTH BEACH	CALVERT	25	Ground water	Closed	12/1/1996	
ISLAND CREEK HEADSTART	CALVERT	25	Ground water	Closed	3/31/2006	
J & J FOODS	CALVERT	25	Ground water	Closed	6/1/2001	
J & J RESTAURANT	CALVERT	100	Ground water	Closed	3/1/1993	
JENEVAS CAKES	CALVERT	25	Ground water	Closed	2/1/2006	
JOE & THELMA CATERING	CALVERT	25	Ground water	Closed	5/1/2005	
KNOTTY PINE BAR & GRILL	CALVERT	25	Ground water	Closed	12/1/1996	
LAKE SNACK BAR	CALVERT	25	Ground water	Closed	2/1/1999	
LICKEDY SPLITS	CALVERT	25	Ground water	Closed	2/1/1999	
LILLIE'S CATERING SERVICE	CALVERT	25	Ground water	Closed	9/1/1988	
LITTLE PONDEROSA OWINGS	CALVERT	25	Ground water	Closed	9/1/1988	
MARKETPLACE PROFESSIONAL BUILDING	CALVERT	25	Ground water	Closed	3/1/2001	
MARYLAND TOBACCO GROWERS ASSOC	CALVERT	25	Ground water	Closed	9/1/1988	
MOTHER BROWN'S GROCERY	CALVERT	25	Ground water	Closed	12/1/1996	
MS. LIZZIES	CALVERT	25	Ground water	Closed	3/1/1993	
MT HOPE UM CHURCH	CALVERT	25	Ground water	Closed	2/1/2006	
N. BEACH STORE & OFFICES	CALVERT	25	Ground water	Closed	12/1/1996	
NEPTUNE'S	CALVERT	25	Ground water	Closed	12/1/1996	
NORTH BEACH POST OFFICE	CALVERT	25	Ground water	Closed	12/1/1996	
NORTH BEACH TOWN OFFICES	CALVERT	25	Ground water	Closed	12/1/1996	
OASIS SNACK BAR	CALVERT	25	Ground water	Closed	3/1/1993	
OHALLORANS BAR & GRILL	CALVERT	25	Ground water	Closed	8/1/1999	
OLIVET UNITED METHODIST CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
PATUXENT UM CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
PENWICK HOUSE	CALVERT	25	Ground water	Closed	1/1/2002	
PIZZA OVEN	CALVERT	25	Ground water	Closed	2/1/1999	
PLATER'S TAVERN	CALVERT	25	Ground water	Closed	1/1/1998	
PLUM POINT UM CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
R & J LIQUORS	CALVERT	25	Ground water	Closed	1/1/2002	
R & W MARKET	CALVERT	25	Ground water	Closed	3/1/1993	
R/K AGRICULTURAL CENTER	CALVERT	25	Ground water	Closed	11/1/1999	
RANDLE CLIFF MARKET	CALVERT	25	Ground water	Closed	8/1/2000	
S & S SEAFOOD	CALVERT	25	Ground water	Closed	11/1/2000	
SNELLS FEED STORE	CALVERT	25	Ground water	Closed	11/1/1999	
SOLOMONS CHARGE UNITED METHODIST	CALVERT	25	Ground water	Closed	11/1/1999	
SOUTHERN COMMUNITY CENTER	CALVERT	25	Ground water	Closed	3/31/2006	

Table 2.4-39— {Listing of U.S. Environmental Protection Agency (EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community |Water Systems in Calvert County, Maryland}

(Page 11 of 11)

Water System Name	County(s) Served	Population Served	Primary Water Source Type	System Status	Date Closed	Water System ID
ST ANTHONYS CHURCH	CALVERT	25	Ground water	Closed	8/1/1999	
ST JOHNS UM CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
SURREY INN	CALVERT	25	Ground water	Closed	9/1/2000	
TRUEMAN H.B. LUMBER CO.	CALVERT	25	Ground water	Closed	12/1/1996	
TWIN BEACH COMM. CENTER	CALVERT	25	Ground water	Closed	12/1/1996	
WARDS MEMORIAL METHODIST CHURCH	CALVERT	25	Ground water	Closed	5/1/2005	
WARREN DENTON SEAFOOD	CALVERT	25	Ground water	Closed	1/1/2002	
WEEMS BUILDING	CALVERT	25	Ground water	Closed	3/1/1993	
WEEMS TAVERN	CALVERT	25	Ground water	Closed	2/1/1999	
WHITE SANDS POOL	CALVERT	25	Ground water	Closed	3/31/2006	
ZION HILL CHURCH OF CHRIST	CALVERT	25	Ground water	Closed	5/1/2005	

Table 2.4-40— {Maryland Department of the Environment (MDE) Water Appropriation Permits for the Calvert Cliffs Nuclear Power Plant}

Permit Number	Location	Limit (gpd)	Expires	Report	Aquifer	Wells
CA69G010 (05)	CCNPP	450,000/865,000	7/1/2012	yes	Aquia	5
CA63G003 (07)	Camp Conoy	500/5,000	7/1/2012	no	Piney Point	4
CA83G008 (03)	Visitor's Center	300/500	7/1/2012	no	Piney Point	1
CA89G007 (02)	Rifle Range	500/1,000	7/1/2012	no	Piney Point	1
CA89G107(01)	PUP Trailers	300/500	7/1/2012	n/a	Piney Point	1
None	Old Bay Farm	None	n/a	n/a	Aquia	1

Field Explanations
Permit Number: MD Water Appropriation and Use Permit
Location: Area within CCNPP
Limit: Daily average of gallons on a yearly basis/daily average of gallons for the month of maximum use
Expires: Permit Expiration Date
Report: Requirements to report semi-annual ground water withdrawals
Aquifer: Aquifer source
Wells: Permitted site wells

Table 2.4-41— {Calvert Cliffs Nuclear Power Plant – Water Use Report (in gallons), Maryland Department of Environment (MDE) Water Appropriation Permit CA69G010 (05)}

	2001	2002	2003	2004	2005	2006
January		14495320	11392300	14992760	11148840	10041320
February		10342670	10857000	12414190	11607670	10346610
March		9481760	10165800	11692830	12870800	10012940
April		9742450	11195700	10572530	8977320	14271134
May		10653390	15828550	12288900	13827740	11781229
June		11305160	14877230	15858200	11987770	10936940
July	12106107	15271750	12902030	13892440	8336940	
August	13012084	13006370	12537070	13045600	8786380	
September	12573675	13707430	11507340	11817990	8343530	
October	11603068	11100240	10885500	13004910	9394250	
November	12220342	13171740	12553100	10932310	7566650	
December	11051880	10740610	14021400	11456340	9629400	
Annual Totals	**72567156**	**143018890**	**148723020**	**151969000**	**122477290**	**67390173**

Table 2.4-42— {Calvert County Ground-Water-Level Monitoring Network – Selected Water Level Monitoring Wells}

Well Number	Aquifer/Formation Screened	Location	Water Level Frequency Measurements
CA Bb 10	Magothy	Mt. Hope	Twice Yearly
CA Bb 23	Magothy	Cavalier Country	Twice Yearly
CA Bb 27	Aquia	Dunkirk	Real-Time
CA Bb 28	Nanjemoy	Dunkirk	Monthly
CA Cc 18	Aquia	Randle Cliff	Monthly
CA Cc 55	Upper Patapsco	Randle Cliff	Twice Yearly
CA Cc 56	Magothy	Randle Cliff	Twice Yearly
CA Cc 57	Aquia	Huntington	Monthly
CA Db 47	Aquia	Prince Frederick	Real-Time
CA Db 65	Brandywine	Prince Frederick	Monthly
CA Db 96	Upper Patapsco	Prince Frederick	Recorder
CA Dc 35	Magothy	Scientist Cliffs	Twice Yearly
CA Ed 32	Piney Point-Nanjemoy	White Sands	Twice Yearly
CA Ed 42	Aquia	Calvert Cliffs	Twice Yearly
CA Ed 49	Piney Point-Nanjemoy	Long Beach	Twice Yearly
CA Ed 52	Aquia	Calvert Cliffs Power Plant	Recorder
CA Fc 13	Choptank-St.Marys Und.	Jefferson-Patterson St. Pk	Monthly
CA Fd 51	Piney Point-Nanjemoy	Calvert Cliffs St. Pk	Twice Yearly
CA Fd 54	Aquia	Calvert Cliffs St. Pk	Real-Time
CA Fd 70	Aquia	Chesapeake Ranch Estates	Twice Yearly
CA Fd 85	Lower Patapsco	Chesapeake Ranch Estates	Recorder
CA Fe 22	Piney Point-Nanjemoy	Cove Point	Twice Yearly
CA Gd 6	Aquia	Solomons	Twice Yearly
CA Gd 61	Aquia	Solomons	Real-Time

Table 2.4-43— {Reactor Coolant Storage Tank Radionuclide Inventory}

(Page 1 of 2)

Radionuclide	Half-life[1] $t_{1/2}$(days)	Concentration[2] (µCi/g)	Radionuclide	Half-life[1] $t_{1/2}$(days)	Concentration[2] (µCi/g)
H-3	4.51E+03	1.00E+00	Te-127m	1.09E+02	4.40E-04
Na-24	6.25E-01	3.70E-02	Te-127*	3.90E-01	0.00E+00
Cr-51	2.77E+01	2.00E-03	I-129	5.73E+09	4.60E-08
Mn-54	3.13E+02	1.00E-03	I-130	5.15E-01	5.00E-02
Fe-55	9.86E+02	7.60E-04	Te-129m	3.36E+01	1.50E-03
Fe-59	4.45E+01	1.90E-04	Te-129*	4.83E-02	2.40E-03
Co-58	7.08E+01	2.90E-03	Te-131m	1.25E+00	3.70E-03
Co-60	1.93E+03	3.40E-04	Te-131*	1.74E-02	2.60E-03
Zn-65	2.44E+02	3.20E-04	I-131*	8.04E+00	7.40E-01
Br-83	9.96E-02	3.20E-02	Te-132	3.26E+00	4.10E-02
Kr-83m*	7.63E-02	0.00E+00	I-132*	9.58E-02	3.70E-01
Br-84	2.21E-02	1.70E-02	I-133	8.67E-01	1.30E+00
Br-85	2.01E-03	2.00E-03	Xe-133m*	2.19E+00	0.00E+00
Kr-85*	1.87E-01	0.00E+00	Xe-133*	5.25E+00	0.00E+00
Rb-88	1.24E-02	1.00E+00	Te-134	2.90E-02	6.70E-03
Rb-89	1.06E-02	4.70E-02	I-134*	3.65E-02	2.40E-01
Sr-89*	5.05E+01	6.30E-04	I-135	2.75E-01	7.90E-01
Sr-90	1.06E+04	3.30E-05	Xe-135m*	1.06E-02	0.00E+00
Y-90*	2.67E+00	7.70E-06	Xe-135*	3.79E-01	0.00E+00
Sr-91	3.96E-01	1.00E-03	Cs-134	7.53E+02	1.70E-01
Y-91m*	3.45E-02	5.20E-04	Cs-136	1.31E+01	5.30E-02
Y-91*	5.85E+01	8.10E-05	Cs-137	1.10E+04	1.10E-01
Sr-92	1.13E-01	1.70E-04	Ba-137m*	1.77E-03	1.00E-01
Y-92*	1.48E-01	1.40E-04	Cs-138	2.24E-02	2.20E-01
Y-93	4.21E-01	6.50E-05	Ba-140	1.27E+01	6.20E-04
Zr-95	6.40E+01	9.30E-05	La-140*	1.68E+00	1.60E-04
Nb-95m*	3.61E+00	0.00E+00	Ce-141	3.25E+01	8.90E-05
Nb-95*	3.52E+01	9.30E-05	Ce-143	1.38E+00	7.60E-05
Mo-99	2.75E+00	1.10E-01	Pr-143*	1.36E+01	8.80E-05
Tc-99m*	2.51E-01	4.60E-02	Ce-144	2.84E+02	6.90E-05
Ru-103	3.93E+01	7.70E-05	Pr-144m*	5.00E-03	0.00E+00

Table 2.4-43— {Reactor Coolant Storage Tank Radionuclide Inventory}

(Page 2 of 2)

Radionuclide	Half-life[1] $t_{1/2}$(days)	Concentration[2] (µCi/g)	Radionuclide	Half-life[1] $t_{1/2}$(days)	Concentration[2] (µCi/g)
Rh-103m	3.90E-02*	6.80E-05	Pr-144*	1.20E-02	6.90E-05
Ru-106	3.68E+02	2.70E-05	W-187	9.96E-01	1.80E-03
Rh-106*	3.43E-04	2.70E-05	Np-239	2.36E+00	8.70E-04
Ag-110m	2.50E+02	2.00E-07	Pu-239*	8.79E+06	0.00E+00
Ag-110*	2.85E-04	0.00E+00			

Notes:
Values from ICRP (1983) and Kennedy and Strenge (1992)
Values from Reference AREVA, 2007.
* Decay chain progeny.

Table 2.4-44— {Summary of the Radionuclide K_d Values for 20 Soils (mean of two replicates) and Averages (units: ml/g)}

(Page 1 of 2)

Soil	Ground-water[(a)]	pH[(b)]	Mn		Co		Zn		Sr		Cs		Ce		Fe		Ru[(c)]	
			Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev
C-1C	SA	6	5.6	0.6	6.9	1.2	11	1.6	6	2.5	>579.0	9.4	>121.3	19.8	338.4	264.2	3315	1321
C-2C	CU	7.6	586.3	2.5	>1104.9	0	>444.8	8.1	18.1	10.9	>895.5	8	>115.8	0.8	>2066.9	9.3	**1979**	368
C-3C	SA	2.6	6.2	0.5	7.1	0.6	8.5	2	11.8	5.2	>558.0	7.4	>111.6	29.8	**0**	0.1	**158**	20
C-4C	SA	5.9	**1.5**	0.5	**1.7**	0.9	**1.6**	1.3	**1.7**	2.5	>707.2	234.4	**35.1**	3.5	>1053.4	1458.9	>5694	5965
C-5C	CU	7	172	106.2	424.6	378.5	>373.1	1.9	35.3	37.1	>1169.5	369.8	>102.9	1.3	>2093.9	5.2	>8014	722
C-6C	CU	7.4	63.7	1.4	88.7	20.7	>504.2	238.9	17.6	15.8	>856.5	13.5	>94.7	1.4	>2079.0	26.9	3615	661
C-7C	SA	3	5.4	0.6	5.3	0.5	1069.4	1502	30.8	12	>588.6	2.8	51.9	1.3	0	0.1	388	5.01
C-8C	SA	4.9	8.8	5.4	9.3	4.2	9.8	3.6	>25.9	20.7	>693.9	153.2	>109.6	28.4	1319.1	205.1	>8051	5957
C-9C	SA	5.8	11.7	5.6	11.4	5.8	12.6	5.5	13.3	7.3	>727.9	157.2	>98.5	1.4	>2070.6	8.7	6029	870
C-10C	SA	7.8	10.4	2.3	8.9	1.3	10.3	2	12.6	1	>588.8	1.2	>87.0	0.7	1060.9	406.6	>7933	151
C-11C	SA	3.9	5	0.1	6.1	0.6	9	0.3	9.7	7.8	**>553.2**	12.1	75.3	18.7	0	0.6	615	158
C-12C	CU	7.3	614.6	26.4	>1046.5	33	>469.9	24.1	>58.3	1.4	>971.0	59.1	>122.7	2.7	>2092.0	3.7	>7134	820
C-13C	CU	7.4	24.5	11.8	46.8	20.7	>384.0	28.4	10	6.8	>1141.1	154.9	>104.0	0.8	>2089.9	11.5	>4719	4000
C-14C	CU	7.8	611.5	29.8	>1061.0	83.3	>469.3	1.7	44.4	14	>1401.1	655.9	>118.5	2.6	>2073.3	17.3	3522	224
C-15C	CU	7.8	262.9	38.1	>557.8	144.5	>185.4	14.2	>22.4	0.1	>454.9	70.9	>50.2	1.9	>2074.9	3.9	>4817	597
C-16C	CU	7.7	25.5	14.4	39.7	12.5	>163.3	27.5	**3.3**	3.1	**>325.9**	31.6	**>41.9**	0.8	>2079.6	4.1	>3959	1422
C-17C	CU	3.4	**4.9**	1	**5.9**	1.5	**6.6**	1.4	9.2	3.3	>421.7	218.9	>68.9	52.6	**203.3**	56.2	>10148	698
C-18C	SA	6.4	617.1	2.5	>1143.6	37.1	>462.1	18.7	>59.7	2.1	>884.9	50.9	>119.0	11	>2100.3	3	>5650	39.2
C-19C	CU	7.2	25.2	19.4	76	76.5	>332.3	125.5	10.8	4.1	>756.0	57.3	>87.9	25.8	>2080.7	6	>5812	62.8

Table 2.4-44— {Summary of the Radionuclide K_d Values for 20 Soils (mean of two replicates) and Averages (units: ml/g)}

(Page 2 of 2)

Soil	Ground-water[(a)]	pH[(b)]	Mn		Co		Zn		Sr		Cs		Ce		Fe		Ru[(c)]	
			Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev
C-20C	CU	4.9	584.5	20.9	>1121.0	36.3	>429.2	9.7	>93.4	46.8	>993.5	27	>76.6	2.4	>2161.8	131.4	>7122	2955
Average	All		182.4	257.3	>338.7	471.4	>267.8	277.1	>24.7	23.4	>763.4	275.8	>89.7	28	>1452	868	>4934	2775
Average	SA	only	74.6	203.5	>133.4	378.9	>177.1	366.6	>19.0	17.8	>653.5	109.9	>89.9	30.5	>883	850	>4204	3181
Average	CU	only	270.5	271.4	>506.6	488.2	>342.0	157.7	>29.3	27.1	>853.4	339.2	>89.5	27.3	>1918	569	>5531	238

Values in **bold** text represent the minimum observed (most conservative) K_d values used in the retardation analysis.

[a] CU = Upper Chesapeake; SA = Surficial Aquifer

[b] pH 1:1 soil: water (Reported in Schnabel, 2007)

[c] Ru K_d values are semi-quantitative due to large analytical uncertanties (Relative Standard Deviation (RSD) = 20%; typically RSD = 10%) associated with the Inductively Couple Plasma - Mass Spectrometry (ICP-MS) analyses.

Table 2.4-45— {Progeny Nuclides with Activity Concentrations > 1% of *ECL*s After Accounting for Advection, Decay, Adsorption, and Dilution}

Parent Nuclide	Progeny Nuclide	Parent Branching Coefficient	Parent Half-life (days)	Progeny Half-life (days)
Sr-90	Y-90	1.000	1.06E+04	2.67E+00
Zr-95	Nb-90	0.993	6.40E+01	3.52E+01
Te-127m	Te-127	0.976	1.09E+02	3.90E-01
Te-129m	Te-129	0.650	3.36E+01	4.83E-02
Te-131m	I-131	0.778	1.25E+00	8.04E+00
Ba-140	La-140	1.000	1.27E+01	1.68E+00
Np-239	Pu-239	1.000	2.36E+00	8.79E+06

Table 2.4-46— {Calculated Hydraulic Gradients, Groundwater Velocities, and Travel Times

Aquifer / flow medium	**Upper Chesapeake Unit**					**Fill**
Discharges to	**Branch 2**	**Chesapeake Bay**	**Branch 1**	**Johns Creek**	**Branch 3**	**Branch 2**
X (feet)	580	1,315	1,515	2,900	2,510	540
$\mathbf{H_0}$ (feet)	55	55	55	55	55	*
$\mathbf{H_1}$ (feet)	22	0	28	30	34	*
dh/dx	-0.0569	-0.0418	-0.0178	-0.00862	-0.00837	*
K (ft/day)	13.7	13.7	13.7	13.7	13.7	28.3
Darcy velocity, **q** (ft/day)	0.779	0.573	0.244	0.118	0.115	0.385
Effective porosity, $\mathbf{n_e}$	0.145	0.145	0.145	0.145	0.145	0.082
Velocity, **v** (ft/day)	5.38	3.95	1.68	0.815	0.790	4.70
Velocity, **v** (ft/year)	1963	1443	615	297	289	1715
Travel time, **t** (yrs)	0.295	0.911	2.46	9.75	8.69	0.315

* Gradient data are not used for the fill pathway because its travel time was extracted directly from the groundwater model. Its velocity was calculated from its length and travel time. The length of this pathway was shortened from 580 to 540 ft to account for the higher elevation of the fill material, which would discharge on a seepage face above Branch 2.

Table 2.4-47— {Summary of Results for the Transport Analysis Considering Only Advection and Radioactive Decay

Aquifer / Flow medium	**Discharges to**	**Radionuclides with Activity Concentration > 1% of *ECL***
Upper Chesapeake Unit	Branch 2	H-3, Cr-51, Mn-54, Fe-55, Fe-59 Co-58, Co-60, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Cs-134, Cs-136, Cs-137, Ba-140, La-140, Ce-141, Ce-144, Pr-144, and Pu-239
	Chesapeake Bay	H-3, Mn-54, Fe-55, Co-58, Co-60, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-106, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Cs-134, Cs-137, Ce-144, Pr-144, and Pu-239
	Branch 1	H-3, Mn-54, Fe-55, Co-58, Co-60, Zn-65, Sr-90, Y-90, Ru-106, Te-127m, Te-127, I-129, Cs-134, Cs-137, Ce-144, Pr-144 and Pu-239
	Johns Creek	H-3, Mn-54, Fe-55, Co-60, Sr-90, Y-90, Ru-106, I-129, Cs-134, Cs-137, and Pu-239,
	Branch 3	H-3, Mn-54, Fe-55, Co-60, Sr-90, Y-90, Ru-106, I-129, Cs-134, Cs-137, and Pu-239
Fill	Branch 2	H-3, Cr-51, Mn-54, Fe-55, Fe-59 Co-58, Co-60, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Cs-134, Cs-136, Cs-137, Ba-140, La-140, Ce-141, Pr-143, Ce-144, Pr-144, and Pu-239

Table 2.4-48— {Retardation Factors Calculated Using Site-Specific Distribution Coefficients}

Unit	Value	Mn	Co	Zn	Sr	Cs	Ce	Fe	Ru
Upper Chesapeake Unit	Kd	4.9	5.9	6.6	3.3	325.9	41.9	203.3	1979
	R	52.7	63.3	70.6	35.8	3440	443	2146	20883
Fill	Kd	1.5	1.7	1.6	1.7	553.2	35.1	0	158
	R	42	47.5	44.8	47.5	15130	961	1	4322

Table 2.4-49— {Summary of Results for the Transport Analysis Considering Advection, Radioactive Decay, and Adsorption}

Aquifer / Flow medium	**Discharges to**	**Radionuclides with Activity Concentration > 1% of *ECL***
Upper Chesapeake Unit	Branch 2	H-3, Cr-51, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Ba-140, La-140, and Pu-239
	Chesapeake Bay	H-3, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-129m, and Pu-239
	Branch 1	H-3, Sr-90, Y-90, Te-127m, Te-127, I-129, and Pu-239
	Johns Creek	H-3, Sr-90, I-129, and Pu-239
	Branch 3	H-3, Sr-90, I-129, and Pu-239
Fill	Branch 2	H-3, Cr-51, Fe-55, Fe-59, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Ba-140, La-140, and Pu-239

Table 2.4-50— {Simulated Maximum Tsunami Magnitude at Site for Various Cutoff Depths for Case 1}

Simulation Condition		Maximum Amplitude	% Amplitude Change
Cutoff Depth	**Model Option**		
0.0 m	Nonlinear	0.51 ft (0.155 m)	-
	Linear	1.07 ft (0.326 m)	-
0.5 m	Nonlinear	0.57 ft (0.175 m)	12.9
	Linear	1.39 ft (0.423 m)	29.8
1.0 m	Nonlinear	0.65 ft (0.198 m)	27.7
	Linear	1.89 ft (0.577 m)	77.0
2.0 m	Nonlinear	0.80 ft (0.244 m)	57.4
	Linear	1.72 ft (0.524 m)	60.7

Table 2.4-51— {Dimensions of the Contaminant Slug}

Aquifer / flow medium	**Upper Chesapeake Unit**					**Fill**
Discharges to	**Branch 2**	**Chesapeake Bay**	**Branch 1**	**Johns Creek**	**Branch 3**	**Branch 2**
Volume of release, ft^3	3,531.2	3,531.2	3,531.2	3,531.2	3,531.2	3,531.2
Effective porosity, $\mathbf{n}_e$	0.145	0.145	0.145	0.145	0.145	0.082
Volume in aquifer, **V**,ft^3	24353	24353	24353	24353	24353	43063
Vertical thickness: **b**,ft	33.7	30.8	38.5	43.8	44.1	10.0
Planar area: **V/b**, ft^2	722	792	633	556	552	4306
Cross-sectional width: $\mathbf{w} = (\mathbf{V/b})^{\mathbf{0.5}}$, ft	26.9	28.1	25.2	23.6	23.5	65.6
Cross-sectional area: **Axc** = **b**×**w**, ft	907	865	968	1033	1036	656

Table 2.4-52— {Calculation of Effluent Discharge Rates and Dilution Factors}

Aquifer / flow medium		**Upper Chesapeake Unit**					**Fill**
Discharges to		**Branch 2**	**Chesapeake Bay**	**Branch 1**	**Johns Creek**	**Branch 3**	**Branch 2**
Dh/dx	ft/ft	-0.0569	-0.0418	-0.0178	-0.00862	-0.00837	**
K	ft/day	13.7	13.7	13.7	13.7	13.7	28.3
Darcy velocity, **q**	ft/day	0.779	0.573	0.244	0.118	0.115	0.385
Cross-sectional area **Axc**	ft^2	907	865	968	1033	1036	656
Effluent discharge **Q_{gw}** *	ft^3/day	706.6	495.9	236.3	122.0	118.8	252.7
	ac-ft/yr	5.925	4.158	1.982	1.023	0.996	2.119
100-yr low annual mean flow, **Q_{sw}**	ac-ft/yr	57.5	N/A	19.8	288	288	57.5
Dilution factor, **d_f**		0.0934	1	0.0910	0.00354	0.00345	0.0355
Inverse: **1 / d_f**		10.7	1	11.0	282	290	28.1

* **Q_{gw}** is the flow rate of the liquid effluent released to the ground water and discharging into the surface water.

** Gradient data are not used for this flow path because its travel time was obtained directly from the groundwater model. The travel time was obtained from particle tracking in the model.

Table 2.4-53— {Summary of Results for the Transport Analysis Considering Advection, Radioactive Decay, Adsorption, and Dilution in Surface Water}

Aquifer / Flow medium	Discharges to	Radionuclides with Activity Concentration/*ECL* > 1%
Upper Chesapeake Unit	Branch 2	H-3, Cr-51, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Ba-140, and La-140
	Chesapeake Bay	H-3, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-127m and Pu-239
	Branch 1	H-3, Sr-90, Y-90, Te-127m, and I-129
	Johns Creek	H-3
	Branch 3	H-3
Fill	Branch 2	H-3, Fe-55, Fe-59, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Te-127m, Te-127, Te-129m, and I-131Â

Table 2.4-54— {Estimated Longitudinal Dispersivities}

Aquifer / flow medium		**Upper Chesapeake Unit**					**Fill**
Discharges to		**Branch 2**	**Chesapeake Bay**	**Branch 1**	**Johns Creek**	**Branch 3**	**Branch 2**
x (feet)		580	1,315	1,515	2,900	2,510	540
a_x (feet)	Neuman, 1990	77.0	152	171	293	260	72.6
	Xu, 1995	19.2	27.4	29.0	37.0	35.1	18.6

Table 2.4-55— {Summary of Results for the Transport Analysis Considering Advection, Radioactive Decay, Adsorption, and Dilution}

Aquifer / Flow medium	Discharges to	Radionuclides with Activity Concentration>*ECL*
Upper Chesapeake Unit	Branch 2	H-3, I-131
	Chesapeake Bay	H-3
	Branch 1	None
	Johns Creek	None
	Branch 3	None
Fill	Branch 2	H-3, I-131

Table 2.4-56— {Sum of Radionuclide Activity Concentration / *ECL* Ratios for each Pathway}

Aquifer / flow medium	**Upper Chesapeake Unit**					**Fill**
Discharges to	**Branch 2**	**Chesapeake Bay**	**Branch 1**	**Johns Creek**	**Branch 3**	**Branch 2**
Sum of Activity Concentration/*ECL* ratios	8.12	5.60	0.299	0.0102	0.0222	5.20

Table 2.4-57— {Transport Analysis for Pathway to Chesapeake Bay (1)}

(Page 1 of 3)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	**Progeny in Chain**	**ECLa ($\mu Ci/cm^3$)**	**Half-life[b] $t_{1/2}$ (years)**	**Reactor Coolant Activity[c] ($\mu Ci/cm^3$)**	**Ground Water Activity ($\mu Ci/cm^3$)**	**Ground Water Activity / ECL**	**Ground Water Activity ($\mu Ci/cm^3$)**	**Ground Water Activity / ECL**	**Surface Water Activity ($\mu Ci/cm^3$)**	**Surface Water Activity / ECL**	**Surface Water Activity ($\mu Ci/cm^3$)**	**Surface Water Activity / ECL**	**Final Activity ($\mu Ci/cm^3$)**	**Final Activity / ECL**	**Total Dose -- Aquatic *Ingestion (mrem/year)***
H-3		1.00E-03	12.348	1.0E+00	9.50E-01	9.50E+02	9.50E-01	9.50E+02	9.50E-01	9.50E+02	5.35E-03	5.35E+00	5.35E-03	5.35E+00	7.62E-01
Na-24		5.00E-05	0.002	3.7E-02	2.0E-162	3.93E-158							1.96E-162	3.93E-158	7.60E-159
Cr-51		5.00E-04	0.076	2.0E-03	4.8E-07	9.68E-04							4.84E-07	9.68E-04	1.02E-01
Mn-54		3.00E-05	0.857	1.0E-03	4.8E-04	1.60E+01	1.36E-20	4.53E-16					1.36E-20	4.53E-16	8.98E-14
Fe-55		1.00E-04	2.700	7.6E-04	6.0E-04	6.01E+00	6.96E-222	6.96E-218					6.96E-222	6.96E-218	5.88E-215
Fe-59		1.00E-05	0.122	1.9E-04	1.1E-06	1.07E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Co-58		2.00E-05	0.194	2.9E-03	1.1E-04	5.58E+00	9.23E-93	4.62E-88					9.23E-93	4.62E-88	4.70E-86
Co-60		3.00E-06	5.284	3.4E-04	3.0E-04	1.01E+02	1.77E-07	5.91E-02	1.77E-07	5.91E-02	9.41E-11	3.14E-05	9.41E-11	3.14E-05	3.61E-03
Zn-65		5.00E-06	0.668	3.2E-04	1.2E-04	2.49E+01	3.11E-33	6.21E-28					3.11E-33	6.21E-28	9.73E-25
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00		
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00		
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	6.6E-06	8.31E-01	5.65E-75	7.06E-70					5.65E-75	7.06E-70	8.96E-70
Sr-90		5.00E-07	29.120	3.3E-05	3.2E-05	6.46E+01	1.52E-05	3.04E+01	1.52E-05	3.04E+01	2.48E-09	4.97E-03	2.48E-09	4.97E-03	6.07E-03
	Y-90	7.00E-06	0.007	7.7E-06	3.2E-05	4.61E+00	1.52E-05	2.17E+00	1.52E-05	2.17E+00	2.48E-09	3.55E-04	2.48E-09	3.55E-04	1.43E-02
Sr-91		2.00E-05	0.001	1.0E-03	1.1E-256	5.49E-252	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	7.0E-257	3.48E-254	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	1.7E-06	2.14E-01	4.05E-66	5.07E-61					4.05E-66	5.07E-61	2.06E-59
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	7.5E-243	3.75E-238							7.50E-243	3.75E-238	1.82E-236

Table 2.4-57— {Transport Analysis for Pathway to Chesapeake Bay (1)}

(Page 2 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life^b $t_{1/2}$ (years)	Reactor Coolant Activity^c (µCi/cm^3)	Advection & Radioactive Decay^d		+ Retardation^e		+ Dilution^f		+ Dispersion^g		Final Activity (µCi/cm^3)	Final Activity / ECL	Bio-Accumulation
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL			Total Dose -- Aquatic *Ingestion (mrem/year)*
Zr-95		2.00E-05	0.175	9.3E-05	2.5E-06	1.26E-01	2.53E-06	1.26E-01	2.53E-06	1.26E-01	2.04E-08	1.02E-03	2.04E-08	1.02E-03	8.59E-03
	Nb-95m	3.00E-05	0.010	0.0E+00	1.9E-08	6.23E-04	1.87E-08	6.23E-04	1.87E-08	6.23E-04			1.87E-08	6.23E-04	8.50E-03
	Nb-95	3.00E-05	0.096	9.3E-05	5.5E-06	1.82E-01	5.45E-06	1.82E-01	5.45E-06	1.82E-01			5.45E-06	1.82E-01	2.77E+00
Mo-99		2.00E-05	0.008	1.1E-01	4.1E-38	2.06E-33							4.12E-38	2.06E-33	1.64E-32
	Tc-99m	1.00E-03	0.001	4.6E-02	4.0E-38	3.97E-35							3.97E-38	3.97E-35	1.46E-34
Ru-103		3.00E-05	0.108	7.7E-05	2.2E-07	7.23E-03							2.17E-07	7.23E-03	3.59E-01
	Rh-103m	6.00E-03	0.000	6.8E-05	2.2E-07	3.61E-05							2.16E-07	3.61E-05	1.69E-04
Ru-106		3.00E-06	1.008	2.7E-05	1.4E-05	4.81E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	1.4E-05		0.00E+00						0.00E+00		
Ag-110m		6.00E-06	0.684	2.0E-07	7.9E-08	1.32E-02	7.95E-08	1.32E-02	7.95E-08	1.32E-02	4.71E-10	7.85E-05	4.71E-10	7.85E-05	3.81E-03
	Ag-110	NaN	0.000	0.0E+00	1.1E-09		1.06E-09		1.06E-09				1.06E-09		
Te-127m		9.00E-06	0.298	4.4E-04	5.3E-05	5.89E+00	5.30E-05	5.89E+00	5.30E-05	5.89E+00	3.51E-07	3.90E-02	3.51E-07	3.90E-02	6.45E+00
	Te-127	1.00E-04	0.001	0.0E+00	5.2E-05	5.19E-01	5.19E-05	5.19E-01	5.19E-05	5.19E-01	3.43E-07	3.43E-03	3.43E-07	3.43E-03	5.28E-01
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	4.60E-08	2.30E-01	2.58E-10	1.29E-03	2.58E-10	1.29E-03	3.01E-03
I-130		2.00E-05	0.001	5.0E-02	1.6E-196	7.75E-192							1.55E-196	7.75E-192	3.10E-191
Te-129m		7.00E-06	0.092	1.5E-03	1.6E-06	2.24E-01	1.57E-06	2.24E-01	1.57E-06	2.24E-01	3.54E-08	5.06E-03	3.54E-08	5.06E-03	8.43E-01
	Te-129	4.00E-04	0.000	2.4E-03	1.0E-06	2.55E-03	1.02E-06	2.55E-03	1.02E-06	2.55E-03			1.02E-06	2.55E-03	4.57E-01
Te-131m		8.00E-06	0.003	3.7E-03	2.7E-83	3.37E-78							2.70E-83	3.37E-78	5.46E-76
	Te-131	8.00E-05	0.000	2.6E-03	6.1E-84	7.59E-80							6.07E-84	7.59E-80	1.22E-77
	I-131	1.00E-06	0.022	7.4E-01	2.6E-13	2.57E-07							2.57E-13	2.57E-07	5.79E-07
Te-132		9.00E-06	0.009	4.1E-02	7.4E-33	8.23E-28							7.40E-33	8.23E-28	1.55E-25
	I-132	1.00E-04	0.000	3.7E-01	7.6E-33	7.63E-29							7.63E-33	7.63E-29	2.17E-28
I-133		7.00E-06	0.002	1.3E+00	3.4E-116	4.85E-111							3.40E-116	4.85E-111	1.49E-110
	Xe-133m	NaN	0.006	0.0E+00	4.1E-48								4.08E-48		
	Xe-133	NaN	0.014	0.0E+00	2.1E-20								2.09E-20		

Table 2.4-57— {Transport Analysis for Pathway to Chesapeake Bay (1)}

(Page 3 of 3)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Final Activity (µCi/cm^3)	Final Activity / ECL	Total Dose -- Aquatic *Ingestion (mrem/year)*
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
	Xe-135	NaN	0.001	0.0E+00	7.0E-265								7.00E-265		
Cs-134		9.00E-07	2.062	1.7E-01	1.3E-01	1.39E+05	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	1.2E-09	1.99E-04							1.20E-09	1.99E-04	2.52E-03
Cs-137		1.00E-06	30	1.1E-01	1.1E-01	1.08E+05	3.94E-33	3.94E-27					3.94E-33	3.94E-27	3.69E-26
	Ba-137m	NaN	0.000	1.0E-01	1.0E-01		3.72E-33						3.72E-33		
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	8.5E-12	1.06E-06							8.50E-12	1.06E-06	1.81E-06
	La-140	9.00E-06	0.005	1.6E-04	9.8E-12	1.09E-06							9.79E-12	1.09E-06	8.41E-06
Ce-141		3.00E-05	0.089	8.9E-05	7.4E-08	2.46E-03							7.37E-08	2.46E-03	9.02E-02
Ce-143		2.00E-05	0.004	7.6E-05	1.1E-77	5.34E-73							1.07E-77	5.34E-73	2.05E-71
	Pr-143	2.00E-05	0.037	8.8E-05	4.0E-12	1.98E-07							3.96E-12	1.98E-07	1.25E-05
Ce-144		3.00E-06	0.778	6.9E-05	3.1E-05	1.02E+01	5.11E-161	1.70E-155					5.11E-161	1.70E-155	4.55E-154
	Pr-144m	NaN	0.000	0.0E+00	5.5E-07		9.09E-163						9.09E-163		
	Pr-144	6.00E-04	0.000	6.9E-05	3.1E-05	5.11E-02	5.11E-161	8.52E-158					5.11E-161	8.52E-158	
W-187		3.00E-05	0.003	1.8E-03	4.6E-104	1.54E-99							4.62E-104	1.54E-99	5.70E-99
Np-239		2.00E-05	0.006	8.7E-04	2.533E-46	1.27E-41	2.53E-46	1.27E-41	2.53E-46	1.27E-41			2.53E-46	1.27E-41	3.60E-39
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	2.33E-10	1.17E-02	1.31E-12	6.55E-05	1.31E-12	6.55E-05	1.18E-02
Highlighted values exceed one percent of the ECL													**Sum=**	**5.60**	**12.42**

(1): There is no dilution for this pathway because it discharges directly into Chesapeake Bay. Dilution in Chesapeake Bay is neglected.
Footnotes for Table 2.4-57 are shown after Table 2.4-62

Table 2.4-58— {Transport Analysis for Pathway to Branch 2}

(Page 1 of 3)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	Progeny in Chain	ECLa (μCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (μCi/cm^3)	Ground Water Activity (μCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (μCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (μCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (μCi/cm^3)	Surface Water Activity / ECL	Final Activity (μCi/cm^3)	Final Activity / ECL	Total Dose -- Aquatic *Ingestion (mrem/year)*
H-3		1.00E-03	12.348	1.0E+00	9.84E-01	9.84E+02	9.84E-01	9.84E+02	9.19E-02	9.19E+01	1.53E-03	1.53E+00	1.53E-03	1.53E+00	2.17E-01
Na-24		5.00E-05	0.002	3.7E-02	4.0E-54	8.00E-50							4.00E-54	8.00E-50	1.55E-50
Cr-51		5.00E-04	0.076	2.0E-03	1.3E-04	2.69E-01	1.34E-04	2.69E-01	1.26E-05	2.51E-02	2.96E-07	5.92E-04	2.96E-07	5.92E-04	6.26E-02
Mn-54		3.00E-05	0.857	1.0E-03	7.9E-04	2.62E+01	3.40E-09	1.13E-04					3.40E-09	1.13E-04	2.25E-02
Fe-55		1.00E-04	2.700	7.6E-04	7.0E-04	7.04E+00	1.54E-74	1.54E-70					1.54E-74	1.54E-70	1.30E-67
Fe-59		1.00E-05	0.122	1.9E-04	3.5E-05	3.54E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Co-58		2.00E-05	0.194	2.9E-03	1.0E-03	5.04E+01	2.78E-32	1.39E-27					2.78E-32	1.39E-27	1.42E-25
Co-60		3.00E-06	5.284	3.4E-04	3.3E-04	1.09E+02	2.93E-05	9.77E+00	2.74E-06	9.12E-01	9.76E-10	3.25E-04	9.76E-10	3.25E-04	3.74E-02
Zn-65		5.00E-06	0.668	3.2E-04	2.4E-04	4.71E+01	1.25E-13	2.51E-08					1.25E-13	2.51E-08	3.93E-05
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00		
	Kr-85	NaN	0.001	0.0E+00	4.5E-179								4.52E-179		
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	1.5E-04	1.82E+01	5.86E-27	7.33E-22					5.86E-27	7.33E-22	9.30E-22
Sr-90		5.00E-07	29.120	3.3E-05	3.3E-05	6.55E+01	2.57E-05	5.13E+01	2.40E-06	4.79E+00	1.13E-09	2.26E-03	1.13E-09	2.26E-03	2.76E-03
	Y-90	7.00E-06	0.007	7.7E-06	3.3E-05	4.68E+00	2.57E-05	3.67E+00	2.40E-06	3.42E-01	1.13E-09	1.61E-04	1.13E-09	1.61E-04	6.50E-03
Sr-91		2.00E-05	0.001	1.0E-03	9.6E-86	4.81E-81	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	6.1E-86	3.04E-83	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	2.5E-05	3.07E+00	1.14E-24	1.43E-19					1.14E-24	1.43E-19	5.81E-18
Sr-92		4.00E-05	0.000	1.7E-04	3.9E-292	9.86E-288							3.94E-292	9.86E-288	1.36E-287
	Y-92	4.00E-05	0.000	1.4E-04	2.4E-223	6.08E-219							2.43E-223	6.08E-219	2.48E-217
Y-93		2.00E-05	0.001	6.5E-05	4.6E-82	2.32E-77							4.64E-82	2.32E-77	1.13E-75

Table 2.4-58— {Transport Analysis for Pathway to Branch 2}

(Page 2 of 3)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Final Activity (µCi/cm³)	Final Activity / ECL	Total Dose -- Aquatic *Ingestion (mrem/year)*
Zr-95		2.00E-05	0.175	9.3E-05	2.9E-05	1.44E+00	2.89E-05	1.44E+00	2.70E-06	1.35E-01	5.00E-08	2.50E-03	5.00E-08	2.50E-03	2.10E-02
	Nb-95m	3.00E-05	0.010	0.0E+00	2.1E-07	7.13E-03	2.14E-07	7.13E-03	2.00E-08	6.65E-04			2.00E-08	6.65E-04	9.07E-03
	Nb-95	3.00E-05	0.096	9.3E-05	5.1E-05	1.69E+00	5.06E-05	1.69E+00	4.73E-06	1.58E-01			4.73E-06	1.58E-01	2.40E+00
Mo-99		2.00E-05	0.008	1.1E-01	1.7E-13	8.51E-09							1.70E-13	8.51E-09	6.77E-08
	Tc-99m	1.00E-03	0.001	4.6E-02	1.6E-13	1.64E-10							1.64E-13	1.64E-10	6.04E-10
Ru-103		3.00E-05	0.108	7.7E-05	1.1E-05	3.82E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-103m	6.00E-03	0.000	6.8E-05	1.1E-05	1.91E-03	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ru-106		3.00E-06	1.008	2.7E-05	2.2E-05	7.35E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	2.2E-05		0.00E+00						0.00E+00		
Ag-110m		6.00E-06	0.684	2.0E-07	1.5E-07	2.47E-02	1.48E-07	2.47E-02	1.38E-08	2.31E-03			1.38E-08	2.31E-03	1.12E-01
	Ag-110	NaN	0.000	0.0E+00	2.0E-09		1.97E-09		1.84E-10				1.84E-10		
Te-127m		9.00E-06	0.298	4.4E-04	2.2E-04	2.46E+01	2.22E-04	2.46E+01	2.07E-05	2.30E+00	3.63E-07	4.04E-02	3.63E-07	4.04E-02	6.67E+00
	Te-127	1.00E-04	0.001	0.0E+00	2.2E-04	2.17E+00	2.17E-04	2.17E+00	2.03E-05	2.03E-01	3.55E-07	3.55E-03	3.55E-07	3.55E-03	5.46E-01
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	4.30E-09	2.15E-02	7.13E-11	3.56E-04	7.13E-11	3.56E-04	8.31E-04
I-130		2.00E-05	0.001	5.0E-02	4.3E-65	2.15E-60							4.30E-65	2.15E-60	8.60E-60
Te-129m		7.00E-06	0.092	1.5E-03	1.6E-04	2.31E+01	1.62E-04	2.31E+01	1.51E-05	2.16E+00	3.28E-07	4.68E-02	3.28E-07	4.68E-02	7.80E+00
	Te-129	4.00E-04	0.000	2.4E-03	1.1E-04	2.64E-01	1.05E-04	2.64E-01	9.85E-06	2.46E-02	2.13E-07	5.33E-04	2.13E-07	5.33E-04	9.56E-02
Te-131m		8.00E-06	0.003	3.7E-03	3.8E-29	4.81E-24	3.85E-29	4.81E-24	3.59E-30	4.49E-25			3.59E-30	4.49E-25	7.28E-23
	Te-131	8.00E-05	0.000	2.6E-03	8.7E-30	1.08E-25	8.66E-30	1.08E-25	8.09E-31	1.01E-26			8.09E-31	1.01E-26	1.63E-24
	I-131	1.00E-06	0.022	7.4E-01	6.8E-05	6.76E+01	6.76E-05	6.76E+01	6.31E-06	6.31E+00			6.31E-06	6.31E+00	1.42E+01
Te-132		9.00E-06	0.009	4.1E-02	4.4E-12	4.91E-07							4.41E-12	4.91E-07	9.23E-05
	I-132	1.00E-04	0.000	3.7E-01	4.5E-12	4.55E-08							4.55E-12	4.55E-08	1.29E-07
I-133		7.00E-06	0.002	1.3E+00	4.3E-38	6.21E-33							4.35E-38	6.21E-33	1.90E-32
	Xe-133m	NaN	0.006	0.0E+00	3.5E-17								3.54E-17		
	Xe-133	NaN	0.014	0.0E+00	1.7E-07								1.69E-07		

Table 2.4-58— {Transport Analysis for Pathway to Branch 2}

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					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	Progeny in Chain	ECLa (μCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (μCi/cm^3)	Ground Water Activity (μCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (μCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (μCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (μCi/cm^3)	Surface Water Activity / ECL	Final Activity (μCi/cm^3)	Final Activity / ECL	Total Dose -- Aquatic *Ingestion (mrem/year)*
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	9.4E-119	3.12E-114							9.37E-119	3.12E-114	8.91E-114
	Xe-135m	NaN	0.000	0.0E+00	1.5E-119								1.50E-119		
	Xe-135	NaN	0.001	0.0E+00	3.7E-86								3.74E-86		
Cs-134		9.00E-07	2.062	1.7E-01	1.5E-01	1.71E+05	7.30E-150	8.11E-144					7.30E-150	8.11E-144	1.00E-142
Cs-136		6.00E-06	0.036	5.3E-02	1.8E-04	2.93E+01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-137		1.00E-06	30	1.1E-01	1.1E-01	1.09E+05	7.01E-12	7.01E-06					7.01E-12	7.01E-06	6.57E-05
	Ba-137m	NaN	0.000	1.0E-01	1.0E-01		6.63E-12						6.63E-12		
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	1.8E-06	2.19E-01	1.75E-06	2.19E-01	1.63E-07	2.04E-02	1.05E-08	1.31E-03	1.05E-08	1.31E-03	2.24E-03
	La-140	9.00E-06	0.005	1.6E-04	2.0E-06	2.24E-01	2.02E-06	2.24E-01	1.88E-07	2.09E-02			1.88E-07	2.09E-02	1.62E-01
Ce-141		3.00E-05	0.089	8.9E-05	8.9E-06	2.97E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-143		2.00E-05	0.004	7.6E-05	1.8E-28	9.10E-24	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	3.9E-07	1.94E-02	0.00E+00	0.00E+00					0. 00E+00	0.00E+00	0.00E+00
Ce-144		3.00E-06	0.778	6.9E-05	5.3E-05	1.77E+01	1.65E-55	5.49E-50					1.65E-55	5.49E-50	1.47E-48
	Pr-144m	NaN	0.000	0.0E+00	9.4E-07		2.93E-57						2.93E-57		
	Pr-144	6.00E-04	0.000	6.9E-05	5.3E-05	8.84E-02	1.65E-55	2.74E-52					1.65E-55	2.74E-52	
W-187		3.00E-05	0.003	1.8E-03	4.4E-36	1.46E-31							4.37E-36	1.46E-31	5.40E-31
Np-239		2.00E-05	0.006	8.7E-04	1.406E-17	7.03E-13	1.41E-17	7.03E-13	1.31E-18	6.57E-14			1.31E-18	6.57E-14	1.87E-11
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	2.18E-11	1.09E-03			2.18E-11	1.09E-03	1.96E-01
Highlighted values exceed one percent of the ECL													**Sum=**	**8.12**	**32.58**
Footnotes for Table 2.4-58 are shown after Table 2.4-62															

Table 2.4-59— {Transport Analysis for Pathway to Branch 1}

(Page 1 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (μCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (μCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (μCi/cm^3)	Final Activity / ECL
					Ground Water Activity (μCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (μCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (μCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (μCi/cm^3)	Surface Water Activity / ECL		
H-3		1.00E-03	12.348	1.0E+00	8.71E-01	8.71E+02	8.71E-01	8.71E+02	7.92E-02	7.92E+01	2.94E-04	2.94E-01	2.94E-04	2.94E-01
Na-24		5.00E-05	0.002	3.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Cr-51		5.00E-04	0.076	2.0E-03	3.3E-13	6.67E-10							3.34E-13	6.67E-10
Mn-54		3.00E-05	0.857	1.0E-03	1.4E-04	4.55E+00	2.48E-49	8.28E-45					2.48E-49	8.28E-45
Fe-55		1.00E-04	2.700	7.6E-04	4.0E-04	4.04E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Fe-59		1.00E-05	0.122	1.9E-04	1.6E-10	1.56E-05							1.56E-10	1.56E-05
Co-58		2.00E-05	0.194	2.9E-03	4.3E-07	2.17E-02	3.03E-245	1.51E-240					3.03E-245	1.51E-240
Co-60		3.00E-06	5.284	3.4E-04	2.5E-04	8.20E+01	4.52E-13	1.51E-07					4.52E-13	1.51E-07
Zn-65		5.00E-06	0.668	3.2E-04	2.5E-05	4.96E+00	1.15E-82	2.30E-77					1.15E-82	2.30E-77
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00	
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	2.8E-09	3.47E-04							2.77E-09	3.47E-04
Sr-90		5.00E-07	29.120	3.3E-05	3.1E-05	6.22E+01	4.04E-06	8.08E+00	3.68E-07	7.35E-01	4.40E-11	8.79E-05	4.40E-11	8.79E-05
	Y-90	7.00E-06	0.007	7.7E-06	3.1E-05	4.45E+00	4.04E-06	5.77E-01	3.68E-07	5.25E-02	4.40E-11	6.28E-06	4.40E-11	6.28E-06
Sr-91		2.00E-05	0.001	1.0E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	2.1E-09	2.58E-04							2.07E-09	2.58E-04
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Zr-95		2.00E-05	0.175	9.3E-05	5.4E-09	2.72E-04							5.44E-09	2.72E-04

Table 2.4-59— {Transport Analysis for Pathway to Branch 1}

(Page 2 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
	Nb-95m	3.00E-05	0.010	0.0E+00	4.0E-11	1.34E-06							4.02E-11	1.34E-06
	Nb-95	3.00E-05	0.096	9.3E-05	1.2E-08	4.02E-04							1.21E-08	4.02E-04
Mo-99		2.00E-05	0.008	1.1E-01	3.6E-100	1.79E-95							3.57E-100	1.79E-95
	Tc-99m	1.00E-03	0.001	4.6E-02	3.4E-100	3.44E-97							3.44E-100	3.44E-97
Ru-103		3.00E-05	0.108	7.7E-05	9.8E-12	3.27E-07							9.80E-12	3.27E-07
	Rh-103m	6.00E-03	0.000	6.8E-05	9.8E-12	1.63E-09							9.78E-12	1.63E-09
Ru-106		3.00E-06	1.008	2.7E-05	5.0E-06	1.65E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	5.0E-06		0.00E+00						0.00E+00	
Ag-110m		6.00E-06	0.684	2.0E-07	1.6E-08	2.75E-03							1.65E-08	2.75E-03
	Ag-110	NaN	0.000	0.0E+00	2.2E-10								2.19E-10	
Te-127m		9.00E-06	0.298	4.4E-04	1.4E-06	1.60E-01	1.44E-06	1.60E-01	1.31E-07	1.46E-02	9.69E-10	1.08E-04	9.69E-10	1.08E-04
	Te-127	1.00E-04	0.001	0.0E+00	1.4E-06	1.41E-02	1.41E-06	1.41E-02	1.28E-07	1.28E-03	9.23E-10	9.23E-06	9.23E-10	9.23E-06
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	4.19E-09	2.09E-02	1.19E-11	5.95E-05	1.19E-11	5.95E-05
I-130		2.00E-05	0.001	5.0E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Te-129m		7.00E-06	0.092	1.5E-03	1.3E-11	1.86E-06							1.30E-11	1.86E-06
	Te-129	4.00E-04	0.000	2.4E-03	8.5E-12	2.12E-08							8.49E-12	2.12E-08
Te-131m		8.00E-06	0.003	3.7E-03	7.8E-220	9.78E-215							7.82E-220	9.78E-215
	Te-131	8.00E-05	0.000	2.6E-03	1.8E-220	2.20E-216							1.76E-220	2.20E-216
	I-131	1.00E-06	0.022	7.4E-01	1.5E-34	1.52E-28							1.52E-34	1.52E-28
Te-132		9.00E-06	0.009	4.1E-02	3.1E-85	3.43E-80							3.09E-85	3.43E-80
	I-132	1.00E-04	0.000	3.7E-01	3.2E-85	3.18E-81							3.18E-85	3.18E-81
I-133		7.00E-06	0.002	1.3E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-133m	NaN	0.006	0.0E+00	4.0E-126								4.05E-126	
	Xe-133	NaN	0.014	0.0E+00	6.0E-53								6.04E-53	
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00

Table 2.4-59— {Transport Analysis for Pathway to Branch 1}

(Page 3 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
	Xe-135	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Cs-134		9.00E-07	2.062	1.7E-01	7.4E-02	8.25E+04	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	1.1E-22	1.87E-17							1.12E-22	1.87E-17
Cs-137		1.00E-06	30	1.1E-01	1.0E-01	1.04E+05	1.04E-86	1.04E-80					1.04E-86	1.04E-80
	Ba-137m	NaN	0.000	1.0E-01	9.8E-02		9.85E-87						9.85E-87	
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	3.4E-25	4.27E-20							3.41E-25	4.27E-20
	La-140	9.00E-06	0.005	1.6E-04	3.9E-25	4.37E-20							3.93E-25	4.37E-20
Ce-141		3.00E-05	0.089	8.9E-05	4.1E-13	1.38E-08							4.13E-13	1.38E-08
Ce-143		2.00E-05	0.004	7.6E-05	8.0E-202	4.00E-197							8.01E-202	4.00E-197
	Pr-143	2.00E-05	0.037	8.8E-05	1.0E-24	5.13E-20							1.03E-24	5.13E-20
Ce-144		3.00E-06	0.778	6.9E-05	7.7E-06	2.56E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Pr-144m	NaN	0.000	0.0E+00	1.4E-07		0.00E+00						0.00E+00	
	Pr-144	6.00E-04	0.000	6.9E-05	7.7E-06	1.28E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00
W-187		3.00E-05	0.003	1.8E-03	1.9E-275	6.33E-271							1.90E-275	6.33E-271
Np-239		2.00E-05	0.006	8.7E-04	8.543E-119	4.27E-114	8.54E-119	4.27E-114	7.77E-120	3.89E-115			7.77E-120	3.89E-115
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	2.12E-11	1.06E-03			2.12E-11	1.06E-03
Highlighted values exceed one percent of the ECL													**Sum=**	**0.299**
Footnotes for Table 2.4-59 are shown after Table 2.4-62														

Table 2.4-60— {Transport Analysis for Pathway to Branch 3}

(Page 1 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life^b $t_{1/2}$ (years)	Reactor Coolant Activity^c (µCi/cm^3)	Advection & Radioactive Decay^d		+ Retardation^e		+ Dilution^f		+ Dispersion^g		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
H-3		1.00E-03	12.348	1.0E+00	6.14E-01	6.14E+02	6.14E-01	6.14E+02	2.12E-03	2.12E+00	3.44E-06	3.44E-03	3.44E-06	3.44E-03
Na-24		5.00E-05	0.002	3.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Cr-51		5.00E-04	0.076	2.0E-03	6.2E-38	1.25E-34							6.23E-38	1.25E-34
Mn-54		3.00E-05	0.857	1.0E-03	8.8E-07	2.94E-02	1.13E-164	3.78E-160					1.13E-164	3.78E-160
Fe-55		1.00E-04	2.700	7.6E-04	8.2E-05	8.15E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Fe-59		1.00E-05	0.122	1.9E-04	6.3E-26	6.30E-21							6.30E-26	6.30E-21
Co-58		2.00E-05	0.194	2.9E-03	9.2E-17	4.58E-12							9.16E-17	4.58E-12
Co-60		3.00E-06	5.284	3.4E-04	1.1E-04	3.62E+01	1.60E-35	5.33E-30					1.60E-35	5.33E-30
Zn-65		5.00E-06	0.668	3.2E-04	3.9E-08	7.71E-03							3.86E-08	7.71E-03
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00	
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	7.6E-23	9.45E-18							7.56E-23	9.45E-18
Sr-90		5.00E-07	29.120	3.3E-05	2.7E-05	5.37E+01	1.99E-08	3.98E-02	6.87E-11	1.37E-04			6.87E-11	1.37E-04
	Y-90	7.00E-06	0.007	7.7E-06	2.7E-05	3.83E+00	1.99E-08	2.85E-03	6.88E-11	9.82E-06			6.88E-11	9.82E-06
Sr-91		2.00E-05	0.001	1.0E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	4.0E-21	5.04E-16							4.04E-21	5.04E-16
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Zr-95		2.00E-05	0.175	9.3E-05	1.1E-19	5.34E-15							1.07E-19	5.34E-15

Table 2.4-60— {Transport Analysis for Pathway to Branch 3}

(Page 2 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life^b $t_{1/2}$ (years)	Reactor Coolant Activity^c (µCi/cm^3)	Advection & Radioactive Decay^d		+ Retardation^e		+ Dilution^f		+ Dispersion^g		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
	Nb-95m	3.00E-05	0.010	0.0E+00	7.9E-22	2.63E-17							7.90E-22	2.63E-17
	Nb-95	3.00E-05	0.096	9.3E-05	2.4E-19	7.91E-15							2.37E-19	7.91E-15
Mo-99		2.00E-05	0.008	1.1E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Tc-99m	1.00E-03	0.001	4.6E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ru-103		3.00E-05	0.108	7.7E-05	3.6E-29	1.19E-24							3.57E-29	1.19E-24
	Rh-103m	6.00E-03	0.000	6.8E-05	3.6E-29	5.94E-27							3.56E-29	5.94E-27
Ru-106		3.00E-06	1.008	2.7E-05	6.8E-08	2.28E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	6.8E-08		0.00E+00						0.00E+00	
Ag-110m		6.00E-06	0.684	2.0E-07	3.0E-11	4.99E-06							2.99E-11	4.99E-06
	Ag-110	NaN	0.000	0.0E+00	4.0E-13								3.98E-13	
Te-127m		9.00E-06	0.298	4.4E-04	7.5E-13	8.32E-08							7.49E-13	8.32E-08
	Te-127	1.00E-04	0.001	0.0E+00	7.3E-13	7.33E-09							7.33E-13	7.33E-09
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	1.59E-10	7.93E-04			1.59E-10	7.93E-04
I-130		2.00E-05	0.001	5.0E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Te-129m		7.00E-06	0.092	1.5E-03	5.4E-32	7.64E-27							5.35E-32	7.64E-27
	Te-129	4.00E-04	0.000	2.4E-03	3.5E-32	8.71E-29							3.48E-32	8.71E-29
Te-131m		8.00E-06	0.003	3.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Te-131	8.00E-05	0.000	2.6E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-131	1.00E-06	0.022	7.4E-01	9.6E-120	9.64E-114							9.64E-120	9.64E-114
Te-132		9.00E-06	0.009	4.1E-02	1.8E-295	2.02E-290							1.82E-295	2.02E-290
	I-132	1.00E-04	0.000	3.7E-01	1.9E-295	1.88E-291							1.88E-295	1.88E-291
I-133		7.00E-06	0.002	1.3E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-133m	NaN	0.006	0.0E+00	0.0E+00								0.00E+00	
	Xe-133	NaN	0.014	0.0E+00	1.5E-183								1.52E-183	
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00

Table 2.4-60— {Transport Analysis for Pathway to Branch 3}

(Page 3 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
	Xe-135	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Cs-134		9.00E-07	2.062	1.7E-01	9.1E-03	1.02E+04	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	5.7E-75	9.58E-70							5.75E-75	9.58E-70
Cs-137		1.00E-06	30	1.1E-01	9.0E-02	9.00E+04	9.58E-302	9.58E-296					9.58E-302	9.58E-296
	Ba-137m	NaN	0.000	1.0E-01	8.5E-02		9.07E-302						9.07E-302	
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	5.8E-79	7.29E-74							5.83E-79	7.29E-74
	La-140	9.00E-06	0.005	1.6E-04	6.7E-79	7.46E-74							6.71E-79	7.46E-74
Ce-141		3.00E-05	0.089	8.9E-05	3.5E-34	1.15E-29							3.46E-34	1.15E-29
Ce-143		2.00E-05	0.004	7.6E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	3.1E-75	1.56E-70							3.13E-75	1.56E-70
Ce-144		3.00E-06	0.778	6.9E-05	3.0E-08	9.99E-03							3.00E-08	9.99E-03
	Pr-144m	NaN	0.000	0.0E+00	5.3E-10								5.34E-10	
	Pr-144	6.00E-04	0.000	6.9E-05	3.0E-08	5.00E-05							3.00E-08	5.00E-05
W-187		3.00E-05	0.003	1.8E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Np-239		2.00E-05	0.006	8.7E-04	0.000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00
	Pu-239	2.00E-08	24,065	0.0E+00	2.330E-10	1.17E-02	2.33E-10	1.17E-02	8.04E-13	4.02E-05			8.04E-13	4.02E-05
Highlighted values exceed one percent of the ECL													**Sum=**	**0.0222**
Footnotes for Table 2.4-60 are shown after Table 2.4-62														

Table 2.4-61— {Transport Analysis for Pathway to Johns Creek}

(Page 1 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
H-3		1.00E-03	12.348	1.0E+00	5.79E-01	5.79E+02	5.79E-01	5.79E+02	2.05E-03	2.05E+00	2.75E-06	2.75E-03	2.75E-06	2.75E-03
Na-24		5.00E-05	0.002	3.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Cr-51		5.00E-04	0.076	2.0E-03	4.1E-42	8.11E-39							4.05E-42	8.11E-39
Mn-54		3.00E-05	0.857	1.0E-03	3.8E-07	1.25E-02	3.38E-184	1.13E-179					3.38E-184	1.13E-179
Fe-55		1.00E-04	2.700	7.6E-04	6.2E-05	6.22E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Fe-59		1.00E-05	0.122	1.9E-04	1.6E-28	1.56E-23							1.56E-28	1.56E-23
Co-58		2.00E-05	0.194	2.9E-03	2.1E-18	1.05E-13							2.11E-18	1.05E-13
Co-60		3.00E-06	5.284	3.4E-04	9.5E-05	3.16E+01	2.53E-39	8.44E-34					2.53E-39	8.44E-34
Zn-65		5.00E-06	0.668	3.2E-04	1.3E-08	2.58E-03							1.29E-08	2.58E-03
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00	
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	3.8E-25	4.78E-20							3.82E-25	4.78E-20
Sr-90		5.00E-07	29.120	3.3E-05	2.6E-05	5.23E+01	8.11E-09	1.62E-02	2.87E-11	5.74E-05			2.87E-11	5.74E-05
	Y-90	7.00E-06	0.007	7.7E-06	2.6E-05	3.74E+00	8.11E-09	1.16E-03	2.87E-11	4.10E-06			2.87E-11	4.10E-06
Sr-91		2.00E-05	0.001	1.0E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	4.2E-23	5.26E-18							4.20E-23	5.26E-18
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Zr-95		2.00E-05	0.175	9.3E-05	1.6E-21	8.23E-17							1.65E-21	8.23E-17

Table 2.4-61— {Transport Analysis for Pathway to Johns Creek}

(Page 2 of 3)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
	Nb-95m	3.00E-05	0.010	0.0E+00	1.2E-23	4.06E-19							1.22E-23	4.06E-19
	Nb-95	3.00E-05	0.096	9.3E-05	3.7E-21	1.22E-16							3.65E-21	1.22E-16
Mo-99		2.00E-05	0.008	1.1E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Tc-99m	1.00E-03	0.001	4.6E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ru-103		3.00E-05	0.108	7.7E-05	4.0E-32	1.33E-27							3.98E-32	1.33E-27
	Rh-103m	6.00E-03	0.000	6.8E-05	4.0E-32	6.63E-30							3.98E-32	6.63E-30
Ru-106		3.00E-06	1.008	2.7E-05	3.3E-08	1.10E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	3.3E-08		0.00E+00						0.00E+00	
Ag-110m		6.00E-06	0.684	2.0E-07	1.0E-11	1.71E-06							1.03E-11	1.71E-06
	Ag-110	NaN	0.000	0.0E+00	1.4E-13								1.37E-13	
Te-127m		9.00E-06	0.298	4.4E-04	6.5E-14	7.18E-09							6.46E-14	7.18E-09
	Te-127	1.00E-04	0.001	0.0E+00	6.3E-14	6.33E-10							6.33E-14	6.33E-10
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	1.63E-10	8.14E-04			1.63E-10	8.14E-04
I-130		2.00E-05	0.001	5.0E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Te-129m		7.00E-06	0.092	1.5E-03	1.9E-35	2.71E-30							1.89E-35	2.71E-30
	Te-129	4.00E-04	0.000	2.4E-03	1.2E-35	3.08E-32							1.23E-35	3.08E-32
Te-131m		8.00E-06	0.003	3.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Te-131	8.00E-05	0.000	2.6E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-131	1.00E-06	0.022	7.4E-01	3.6E-134	3.64E-128							3.64E-134	3.64E-128
Te-132		9.00E-06	0.009	4.1E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-132	1.00E-04	0.000	3.7E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
I-133		7.00E-06	0.002	1.3E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-133m	NaN	0.006	0.0E+00	0.0E+00								0.00E+00	
	Xe-133	NaN	0.014	0.0E+00	1.2E-205								1.18E-205	
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00

Table 2.4-61— {Transport Analysis for Pathway to Johns Creek}

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Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm^3)	Final Activity / ECL
					Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL		
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
	Xe-135	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Cs-134		9.00E-07	2.062	1.7E-01	6.4E-03	7.13E+03	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	8.1E-84	1.35E-78							8.08E-84	1.35E-78
Cs-137		1.00E-06	30	1.1E-01	8.8E-02	8.78E+04	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Ba-137m	NaN	0.000	1.0E-01	8.3E-02		0.00E+00						0.00E+00	
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	4.6E-88	5.76E-83							4.61E-88	5.76E-83
	La-140	9.00E-06	0.005	1.6E-04	5.3E-88	5.90E-83							5.31E-88	5.90E-83
Ce-141		3.00E-05	0.089	8.9E-05	9.4E-38	3.12E-33							9.35E-38	3.12E-33
Ce-143		2.00E-05	0.004	7.6E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	8.8E-84	4.39E-79							8.78E-84	4.39E-79
Ce-144		3.00E-06	0.778	6.9E-05	1.2E-08	3.91E-03							1.17E-08	3.91E-03
	Pr-144m	NaN	0.000	0.0E+00	2.1E-10								2.09E-10	
	Pr-144	6.00E-04	0.000	6.9E-05	1.2E-08	1.95E-05							1.17E-08	1.95E-05
W-187		3.00E-05	0.003	1.8E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Np-239		2.00E-05	0.006	8.7E-04	0.000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00
	Pu-239	2.00E-08	24,065	0.0E+00	2.330E-10	1.17E-02	2.33E-10	1.17E-02	8.25E-13	4.12E-05			8.25E-13	4.12E-05
Highlighted values exceed one percent of the ECL													**Sum=**	**0.0102**
Footnotes for Table 2.4-61 are shown after Table 2.4-62														

Table 2.4-62— {Transport Analysis for Pathway to Branch 2 through Fill}

(Page 1 of 4)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	**Progeny in Chain**	**ECLa (µCi/cm^3)**	**Half-life[b] $t_{1/2}$ (years)**	**Reactor Coolant Activity[c] (µCi/cm^3)**	**Ground Water Activity (µCi/cm^3)**	**Ground Water Activity / ECL**	**Ground Water Activity (µCi/cm^3)**	**Ground Water Activity / ECL**	**Surface Water Activity (µCi/cm^3)**	**Surface Water Activity / ECL**	**Surface Water Activity (µCi/cm^3)**	**Surface Water Activity / ECL**	**Final Activity (µCi/cm^3)**	**Final Activity / ECL**	**Total Dose -- Aquatic *Ingestion (mrem/year)***
H-3		1.00E-03	12.348	1.0E+00	9.82E-01	9.82E+02	9.82E-01	9.82E+02	3.49E-02	3.49E+01	3.56E-03	3.56E+00	3.56E-03	3.56E+00	5.07E-01
Na-24		5.00E-05	0.002	3.7E-02	1.5E-57	3.02E-53							1.51E-57	3.02E-53	5.84E-54
Cr-51		5.00E-04	0.076	2.0E-03	1.1E-04	2.25E-01	1.13E-04	2.25E-01	3.99E-06	7.99E-03			3.99E-06	7.99E-03	8.44E-01
Mn-54		3.00E-05	0.857	1.0E-03	7.8E-04	2.58E+01	2.25E-08	7.50E-04					2.25E-08	7.50E-04	1.49E-01
Fe-55		1.00E-04	2.700	7.6E-04	7.0E-04	7.01E+00	7.01E-04	7.01E+00	2.49E-05	2.49E-01	2.55E-06	2.55E-02	2.55E-06	2.55E-02	2.15E+01
Fe-59		1.00E-05	0.122	1.9E-04	3.2E-05	3.17E+00	3.17E-05	3.17E+00	1.12E-06	1.12E-01	1.39E-07	1.39E-02	1.39E-07	1.39E-02	1.30E+01
Co-58		2.00E-05	0.194	2.9E-03	9.4E-04	4.70E+01	1.74E-26	8.70E-22					1.74E-26	8.70E-22	8.86E-20
Co-60		3.00E-06	5.284	3.4E-04	3.3E-04	1.09E+02	4.78E-05	1.59E+01	1.70E-06	5.66E-01	4.55E-09	1.52E-03	4.55E-09	1.52E-03	1.74E-01
Zn-65		5.00E-06	0.668	3.2E-04	2.3E-04	4.62E+01	1.42E-10	2.84E-05					1.42E-10	2.84E-05	4.45E-02
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00		
	Kr-85	NaN	0.001	0.0E+00	1.6E-190								1.63E-190		
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	1.3E-04	1.65E+01	1.78E-36	2.22E-31					1.78E-36	2.22E-31	2.82E-31
Sr-90		5.00E-07	29.120	3.3E-05	3.3E-05	6.55E+01	2.31E-05	4.62E+01	8.21E-07	1.64E+00	1.81E-09	3.61E-03	1.81E-09	3.61E-03	4.41E-03
	Y-90	7.00E-06	0.007	7.7E-06	3.3E-05	4.68E+00	2.31E-05	3.30E+00	8.21E-07	1.17E-01	1.81E-09	2.58E-04	1.81E-09	2.58E-04	1.04E-02
Sr-91		2.00E-05	0.001	1.0E-03	3.8E-91	1.90E-86	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	2.4E-91	1.20E-88	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	2.3E-05	2.82E+00	6.93E-33	8.66E-28					6.93E-33	8.66E-28	3.52E-26
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00

Table 2.4-62— {Transport Analysis for Pathway to Branch 2 through Fill}

(Page 2 of 4)

Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm³)	Half-life^b $t_{1/2}$ (years)	Reactor Coolant Activity^c (µCi/cm³)	Advection & Radioactive Decay^d Ground Water Activity (µCi/cm³)	Advection & Radioactive Decay^d Ground Water Activity / ECL	+ Retardation^e Ground Water Activity (µCi/cm³)	+ Retardation^e Ground Water Activity / ECL	+ Dilution^f Surface Water Activity (µCi/cm³)	+ Dilution^f Surface Water Activity / ECL	+ Dispersion^g Surface Water Activity (µCi/cm³)	+ Dispersion^g Surface Water Activity / ECL	Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation Total Dose -- Aquatic *Ingestion (mrem/year)*
	Y-92	4.00E-05	0.000	1.4E-04	8.5E-238	2.12E-233							8.48E-238	2.12E-233	8.64E-232
Y-93		2.00E-05	0.001	6.5E-05	3.8E-87	1.92E-82							3.84E-87	1.92E-82	9.33E-81
Zr-95		2.00E-05	0.175	9.3E-05	2.7E-05	1.34E+00	2.68E-05	1.34E+00	9.50E-07	4.75E-02	1.09E-07	5.45E-03	1.09E-07	5.45E-03	4.58E-02
	Nb-95m	3.00E-05	0.010	0.0E+00	2.0E-07	6.60E-03	1.98E-07	6.60E-03	7.03E-09	2.34E-04			7.03E-09	2.34E-04	3.19E-03
	Nb-95	3.00E-05	0.096	9.3E-05	4.8E-05	1.59E+00	4.76E-05	1.59E+00	1.69E-06	5.64E-02			1.69E-06	5.64E-02	8.59E-01
Mo-99		2.00E-05	0.008	1.1E-01	2.8E-14	1.42E-09							2.84E-14	1.42E-09	1.13E-08
	Tc-99m	1.00E-03	0.001	4.6E-02	2.7E-14	2.73E-11							2.73E-14	2.73E-11	1.01E-10
Ru-103		3.00E-05	0.108	7.7E-05	1.0E-05	3.37E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-103m	6.00E-03	0.000	6.8E-05	1.0E-05	1.68E-03	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ru-106		3.00E-06	1.008	2.7E-05	2.2E-05	7.25E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	2.2E-05		0.00E+00						0.00E+00		
Ag-110m		6.00E-06	0.684	2.0E-07	1.5E-07	2.42E-02	1.45E-07	2.42E-02	5.16E-09	8.60E-04			5.16E-09	8.60E-04	4.18E-02
	Ag-110	NaN	0.000	0.0E+00	1.9E-09		1.93E-09		6.86E-11				6.86E-11		
Te-127m		9.00E-06	0.298	4.4E-04	2.1E-04	2.35E+01	2.12E-04	2.35E+01	7.52E-06	8.35E-01	8.13E-07	9.03E-02	8.13E-07	9.03E-02	1.49E+01
	Te-127	1.00E-04	0.001	0.0E+00	2.1E-04	2.07E+00	2.07E-04	2.07E+00	7.36E-06	7.36E-02	7.93E-07	7.93E-03	7.93E-07	7.93E-03	1.22E+00
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	1.63E-09	8.16E-03			1.63E-09	8.16E-03	1.90E-02
I-130		2.00E-05	0.001	5.0E-02	3.0E-69	1.51E-64							3.01E-69	1.51E-64	6.02E-64
Te-129m		7.00E-06	0.092	1.5E-03	1.4E-04	2.00E+01	1.40E-04	2.00E+01	4.97E-06	7.09E-01	6.77E-07	9.67E-02	6.77E-07	9.67E-02	1.61E+01
	Te-129	4.00E-04	0.000	2.4E-03	9.1E-05	2.28E-01	9.11E-05	2.28E-01	3.23E-06	8.08E-03			3.23E-06	8.08E-03	1.45E+00
Te-131m		8.00E-06	0.003	3.7E-03	7.5E-31	9.34E-26	7.47E-31	9.34E-26	2.65E-32	3.32E-27			2.65E-32	3.32E-27	5.37E-25
	Te-131	8.00E-05	0.000	2.6E-03	1.7E-31	2.10E-27	1.68E-31	2.10E-27	5.97E-33	7.46E-29			5.97E-33	7.46E-29	1.20E-26
	I-131	1.00E-06	0.022	7.4E-01	3.7E-05	3.66E+01	3.66E-05	3.66E+01	1.30E-06	1.30E+00			1.30E-06	1.30E+00	2.93E+00
Te-132		9.00E-06	0.009	4.1E-02	9.7E-13	1.08E-07							9.73E-13	1.08E-07	2.03E-05

Table 2.4-62— {Transport Analysis for Pathway to Branch 2 through Fill}

(Page 3 of 4)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	Progeny in Chain	ECLa (µCi/cm^3)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm^3)	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm^3)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm^3)	Surface Water Activity / ECL	Final Activity (µCi/cm^3)	Final Activity / ECL	Total Dose -- Aquatic *Ingestion (mrem/year)*
	I-132	1.00E-04	0.000	3.7E-01	1.0E-12	1.00E-08							1.00E-12	1.00E-08	2.85E-08
I-133		7.00E-06	0.002	1.3E+00	1.5E-40	2.11E-35							1.48E-40	2.11E-35	6.47E-35
	Xe-133m	NaN	0.006	0.0E+00	3.7E-18								3.73E-18		
	Xe-133	NaN	0.014	0.0E+00	6.6E-08								6.59E-08		
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	1.6E-126	5.32E-122							1.60E-126	5.32E-122	1.52E-121
	Xe-135m	NaN	0.000	0.0E+00	2.6E-127								2.56E-127		
	Xe-135	NaN	0.001	0.0E+00	8.4E-92								8.38E-92		
Cs-134		9.00E-07	2.062	1.7E-01	1.5E-01	1.70E+05	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	1.2E-04	2.01E+01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-137		1.00E-06	30	1.1E-01	1.1E-01	1.09E+05	1.74E-49	1.74E-43					1.74E-49	1.74E-43	1.63E-42
	Ba-137m	NaN	0.000	1.0E-01	1.0E-01		1.64E-49						1.64E-49		
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	1.2E-06	1.49E-01	1.19E-06	1.49E-01	4.22E-08	5.28E-03			4.22E-08	5.28E-03	8.99E-03
	La-140	9.00E-06	0.005	1.6E-04	1.4E-06	1.52E-01	1.37E-06	1.52E-01	4.86E-08	5.40E-03			4.86E-08	5.40E-03	4.17E-02
Ce-141		3.00E-05	0.089	8.9E-05	7.7E-06	2.55E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-143		2.00E-05	0.004	7.6E-05	5.1E-30	2.53E-25	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	2.7E-07	1.35E-02	0. 00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-144		3.00E-06	0.778	6.9E-05	5.2E-05	1.74E+01	6.73E-122	2.24E-116					6.73E-122	2.24E-116	6.00E-115
	Pr-144m	NaN	0.000	0.0E+00	9.3E-07		1.20E-123						1.20E-123		

Table 2.4-62— {Transport Analysis for Pathway to Branch 2 through Fill}

(Page 4 of 4)

					Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]				Bio-Accumulation
Parent Radio-nuclide	**Progeny in Chain**	**ECLa ($\mu Ci/cm^3$)**	**Half-life[b] $t_{1/2}$ (years)**	**Reactor Coolant Activity[c] ($\mu Ci/cm^3$)**	**Ground Water Activity ($\mu Ci/cm^3$)**	**Ground Water Activity / ECL**	**Ground Water Activity ($\mu Ci/cm^3$)**	**Ground Water Activity / ECL**	**Surface Water Activity ($\mu Ci/cm^3$)**	**Surface Water Activity / ECL**	**Surface Water Activity ($\mu Ci/cm^3$)**	**Surface Water Activity / ECL**	**Final Activity ($\mu Ci/cm^3$)**	**Final Activity / ECL**	**Total Dose -- Aquatic** ***Ingestion (mrem/year)***
	Pr-144	6.00E-04	0.000	6.9E-05	5.2E-05	8.69E-02	6.73E-122	1.12E-118					6.73E-122	1.12E-118	
W-187		3.00E-05	0.003	1.8E-03	3.1E-38	1.03E-33							3.10E-38	1.03E-33	3.83E-33
Np-239		2.00E-05	0.006	8.7E-04	1.736E-18	8.68E-14	1.74E-18	8.68E-14	6.16E-20	3.08E-15			6.16E-20	3.08E-15	8.75E-13
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	8.27E-12	4.14E-04			8.27E-12	4.14E-04	7.46E-02
Highlighted values exceed one percent of the ECL													**Sum=**	**5.20**	**73.98**

Footnotes to Table 2.4-57 through Table 2.4-62

a. ECL values were derived from 10 CFR Part 20, Appendix B, Table 2, Column 2 (Title 10, Code of Federal Regulations, U.S. Nuclear Regulatory Commission). The term "NaN" represents "Not a Number" and indicates that a Maximum Effluent Concentration Limit (ECL) was not available.

b. Half-lives were obtained from ICRP (1983) and Kennedy and Strenge (1992), and converted from days to years.

c. Source term activity concentrations were obtained from Reference AREVA, 2007.

d. "Advection and Radioactive Decay" values were calculated from Eq. (2.4.13-9), (2.4.13-14), or (2.4.13-21) depending on the position in decay chain. These calculations assume that the retardation factor (Equation 2.4.13-2) is equal to 1 (R=1).

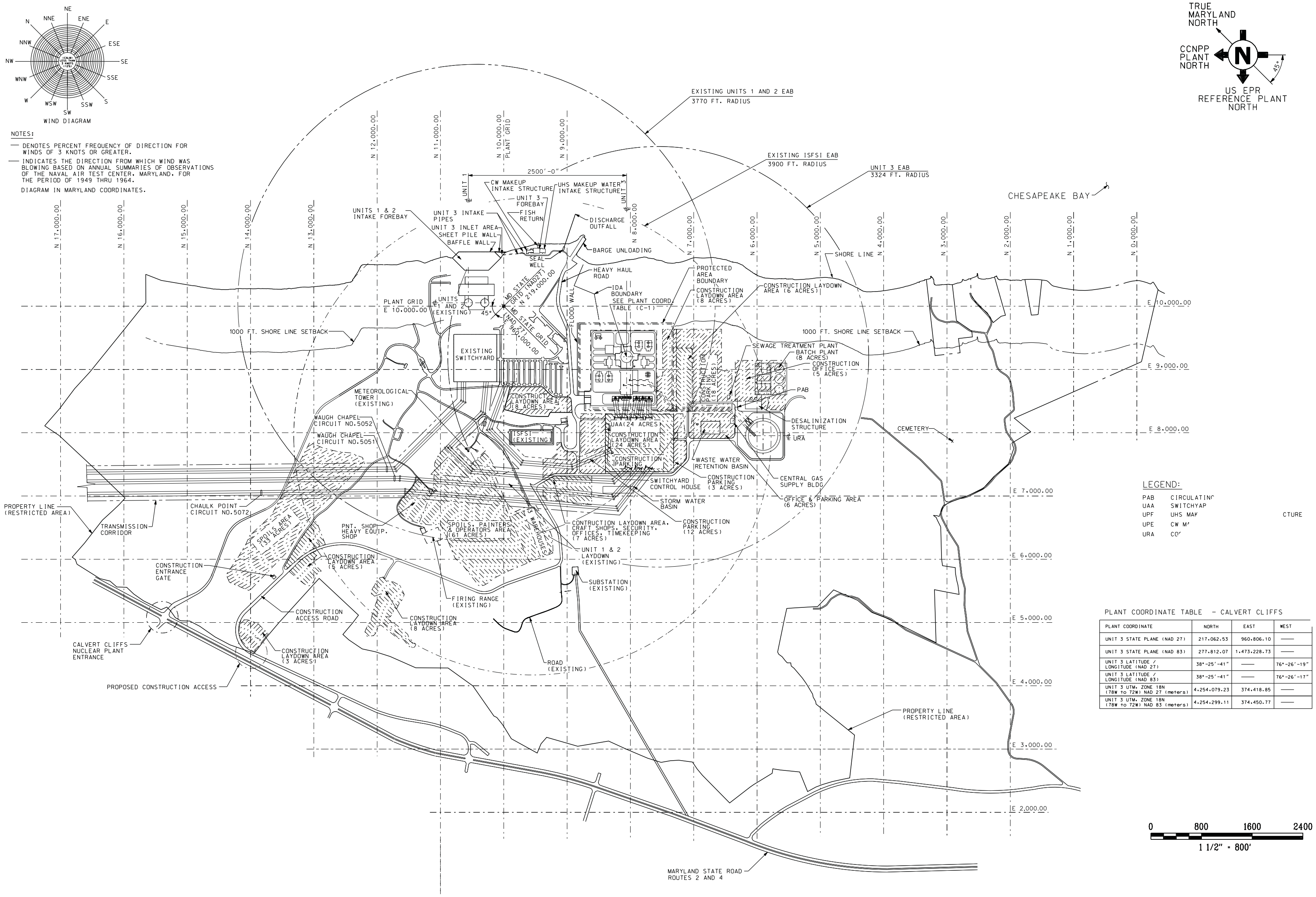
e. "Retardation" values were calculated from Eq. (2.4.13-9), (2.4.13-14), or (2.4.13-21) depending on their position in the decay chain using retardation factors derived from Equation 2.4.13-2. Retardation factors were calculated for elements for which site-specific distribution coefficients were available (Table 2.4-44). For elements which site-specific distribution coefficients are not available, the retardation factor was assumed to be equal to 1 (i.e., corresponding with K_d=0).

1. Dilution was accounted for using Eq. (26) and the dilution factors in Table 2.4-52. Dilution factors for contaminated groundwater discharges to surface water were calculated based on the 100-year low annual mean flow in the receiving stream.

2. Dispersion was accounted for using Codell and Duguid (1983). The dispersion values that are shown in the tables have been multiplied by the dilution factors.

Figure 2.4-1— {Site Area Topography and Drainage}

BASED ON USGS 7.5 MINUTE SERIES
TOPOGRAPHIC MAP, COVE POINT
QUADRANGLE, 1987



NOTES:

— DENOTES PERCENT FREQUENCY OF DIRECTION FOR WINDS OF 3 KNOTS OR GREATER.

— INDICATES THE DIRECTION FROM WHICH WIND WAS BLOWING BASED ON ANNUAL SUMMARIES OF OBSERVATIONS OF THE NAVAL AIR TEST CENTER, MARYLAND, FOR THE PERIOD OF 1949 THRU 1964.

DIAGRAM IN MARYLAND COORDINATES.

PLANT COORDINATE TABLE - CALVERT CLIFFS

PLANT COORDINATE	NORTH	EAST	WEST
UNIT 3 STATE PLANE (NAD 27)	217,062.53	960,806.10	——
UNIT 3 STATE PLANE (NAD 83)	277,812.07	1,473,228.73	——
UNIT 3 LATITUDE / LONGITUDE (NAD 27)	38°-25′-41″	——	76°-26′-19″
UNIT 3 LATITUDE / LONGITUDE (NAD 83)	38°-25′-41″	——	76°-26′-17″
UNIT 3 UTM, ZONE 18N (78W to 72W) NAD 27 (meters)	4,254,079.23	374,418.85	——
UNIT 3 UTM, ZONE 18N (78W to 72W) NAD 83 (meters)	4,254,299.11	374,450.77	——

Figure 2.4-2— {Site Utilization Plot Plan}

Figure 2.4-3— {Chesapeake Bay Sub-Watershed and CCNPP Unit 3 Site Locations}

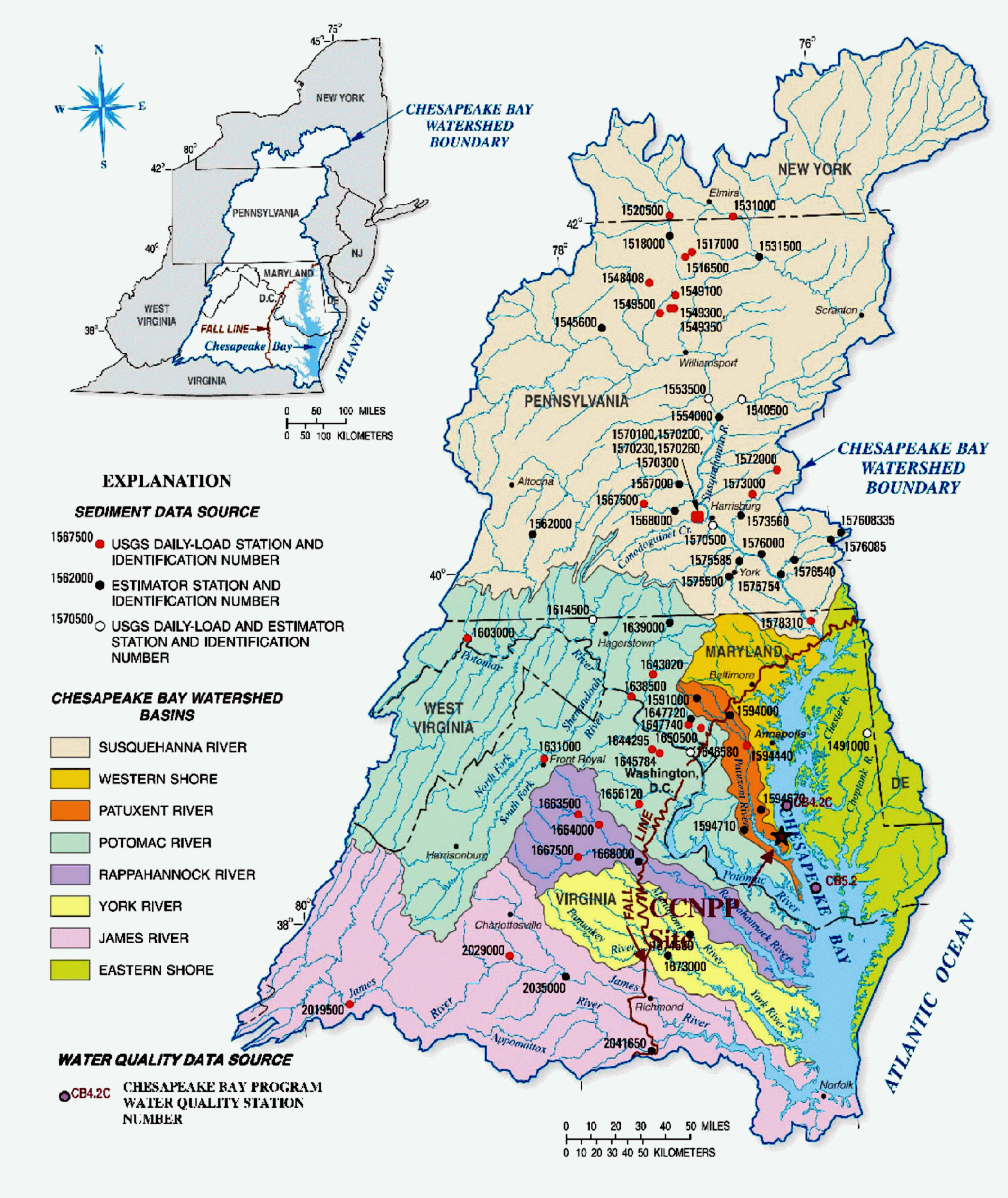


Figure 2.4-4— {Mean, Maximum and Minimum Monthly Streamflows for the Patuxent River at Bowie, MD, USGS Station No. 01594440, Patuxent River Near Bowie, MD (1977-06-01 Through 2005-09-30)}

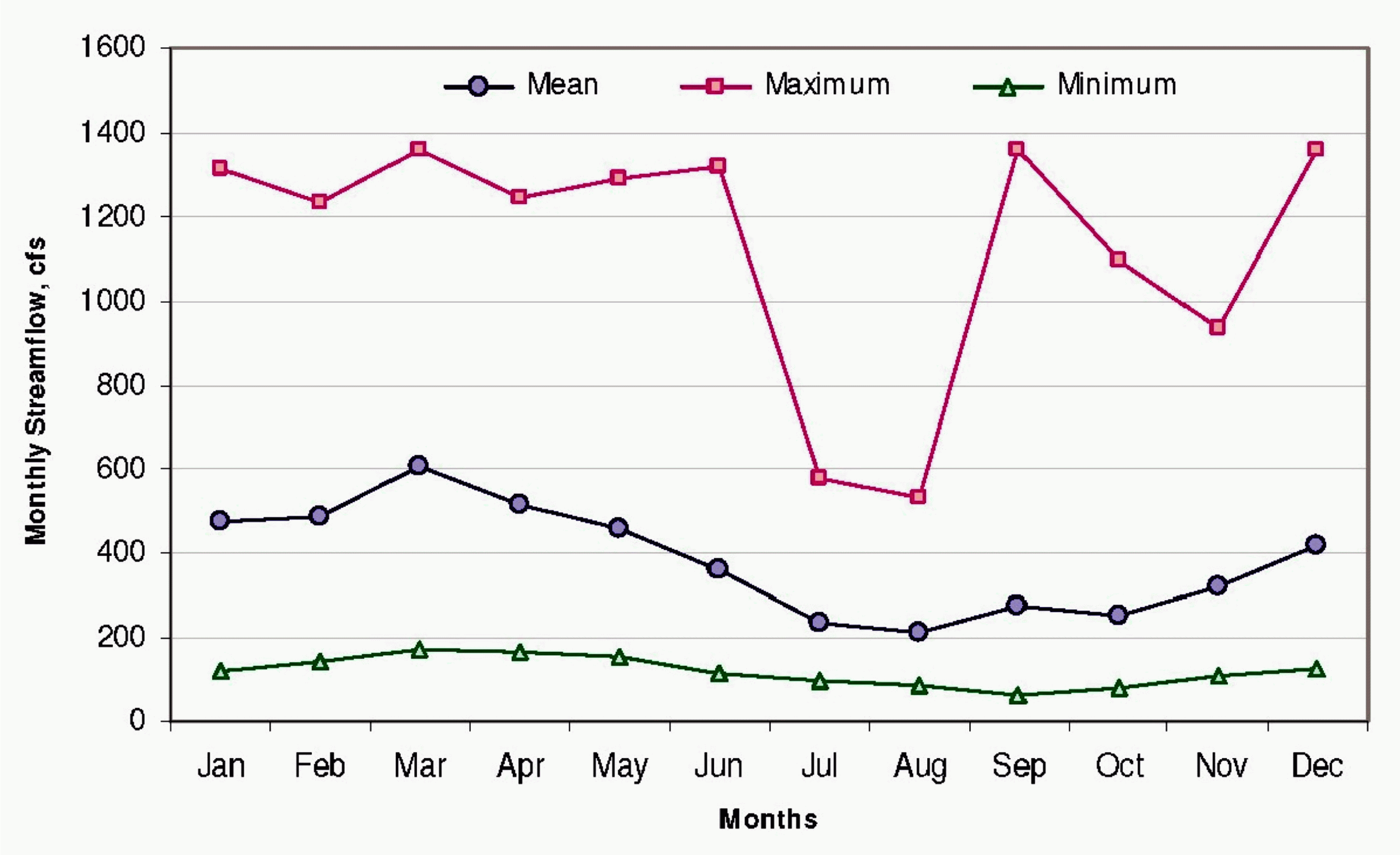


Figure 2.4-5— {Sub-Watershed Delineation of the Lower Patuxent River Watershed}

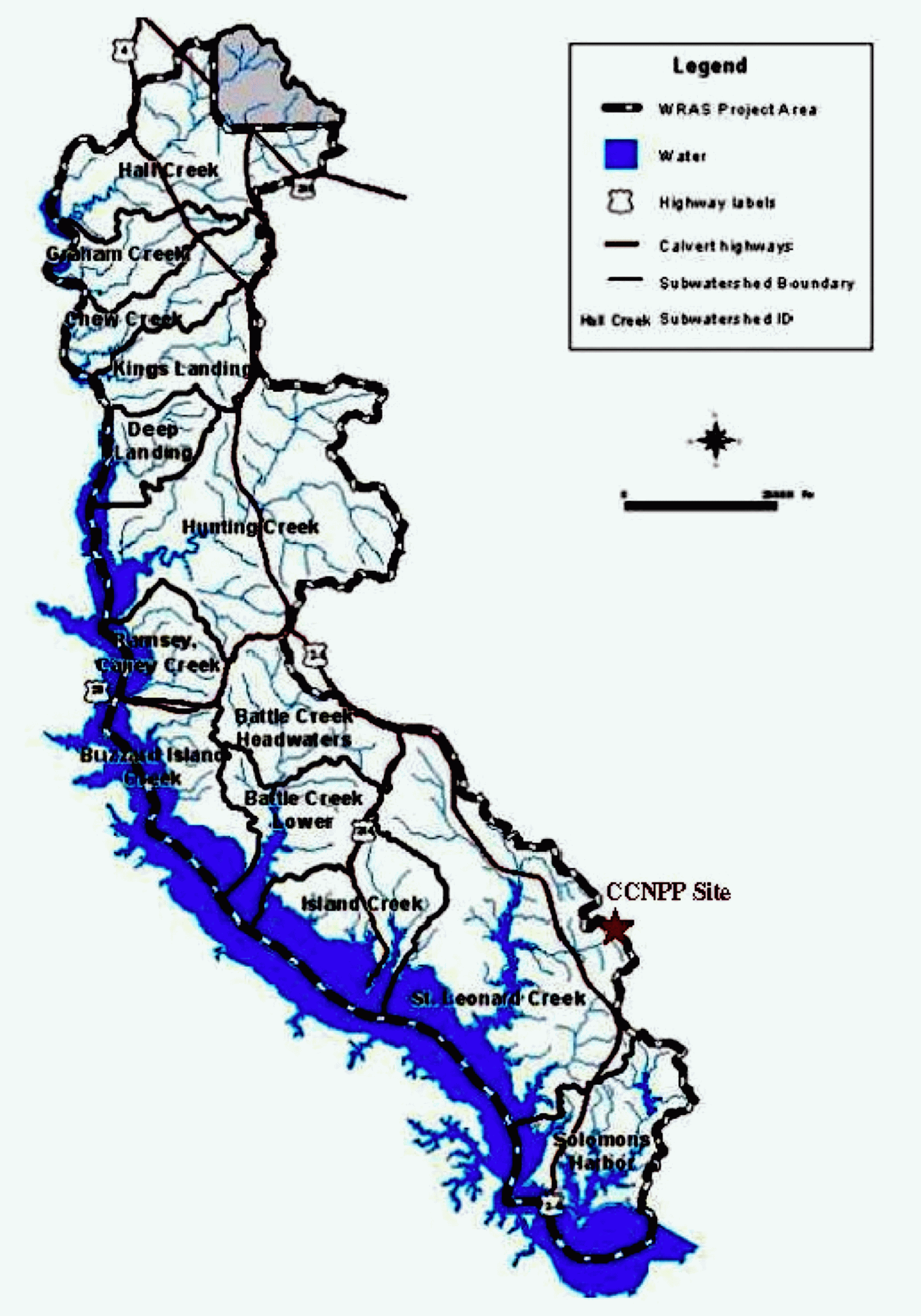


Figure 2.4-6— {Mean, Max and Min Monthly Streamflows for St. Leonard Creek at St. Leonard, MD, USGS Station No. 01594800, St. Leonard Creek Near St. Leonard, MD (1956-12-01 Through 2003-09-30)}

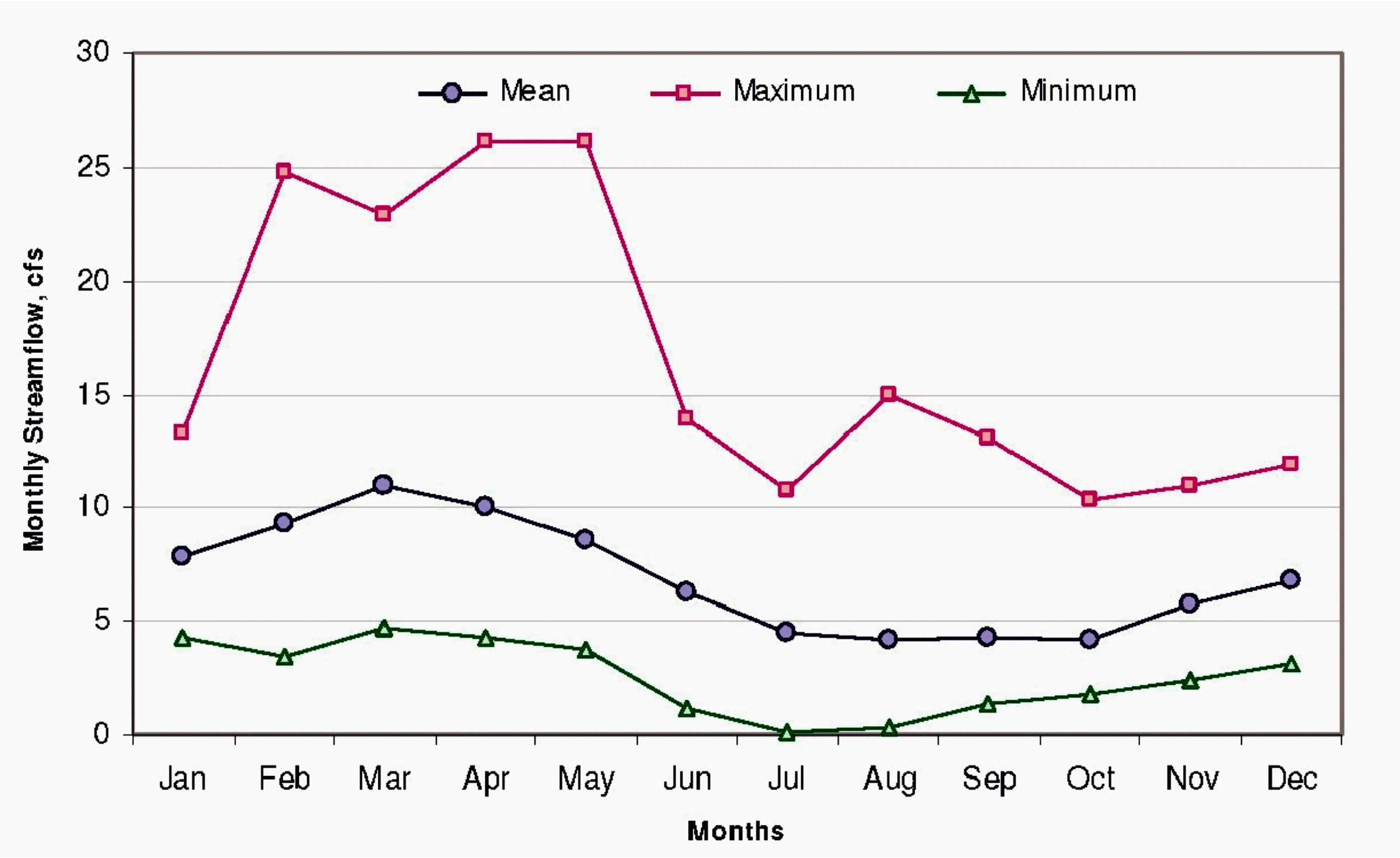
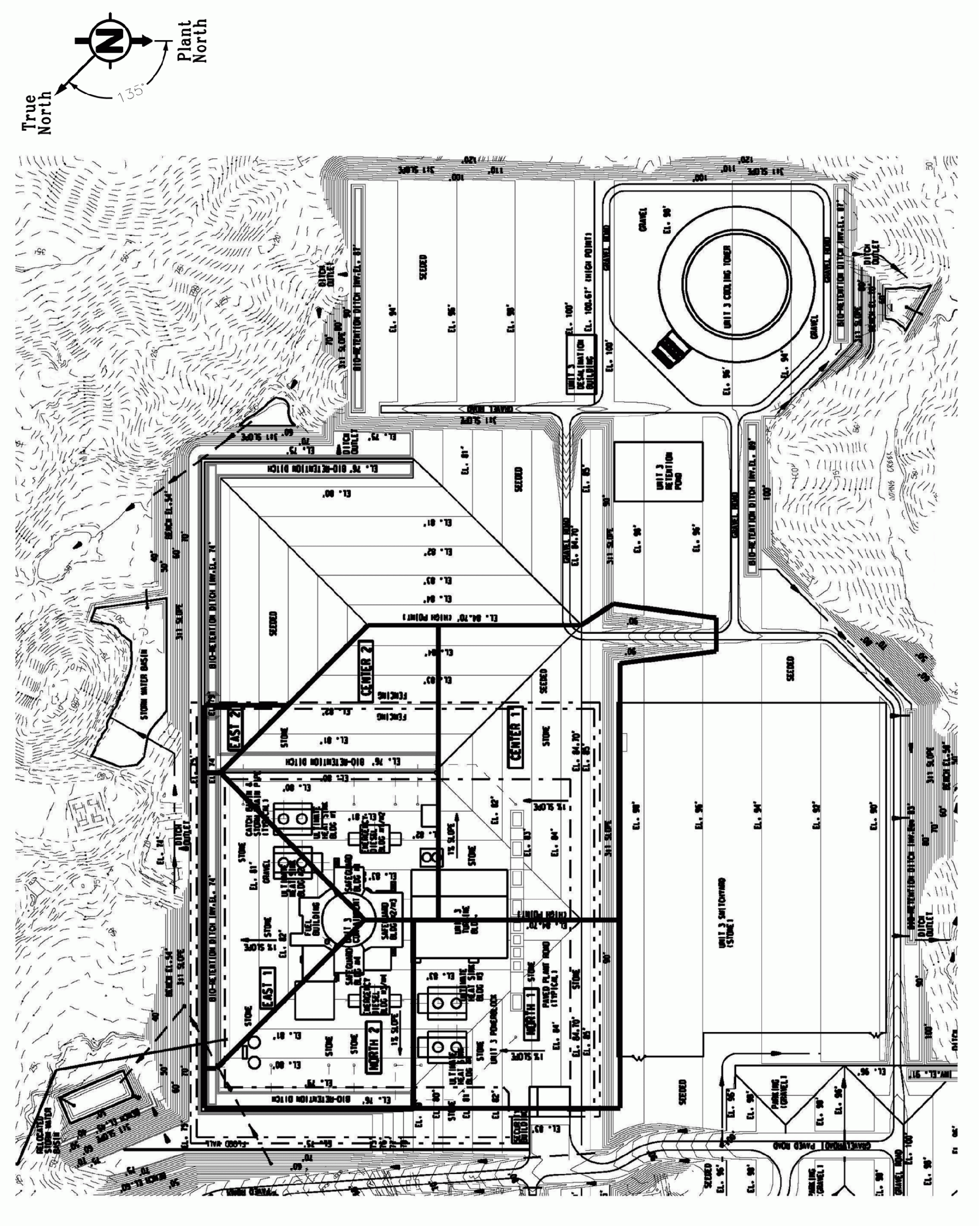


Figure 2.4-7— {CCNP UNIT 3 Sub-Basin Drainage Boundaries}



See Figure 1.2-1 for Powerblock layout

Figure 2.4-8— {HEC-HMS Hydrologic Diagram}

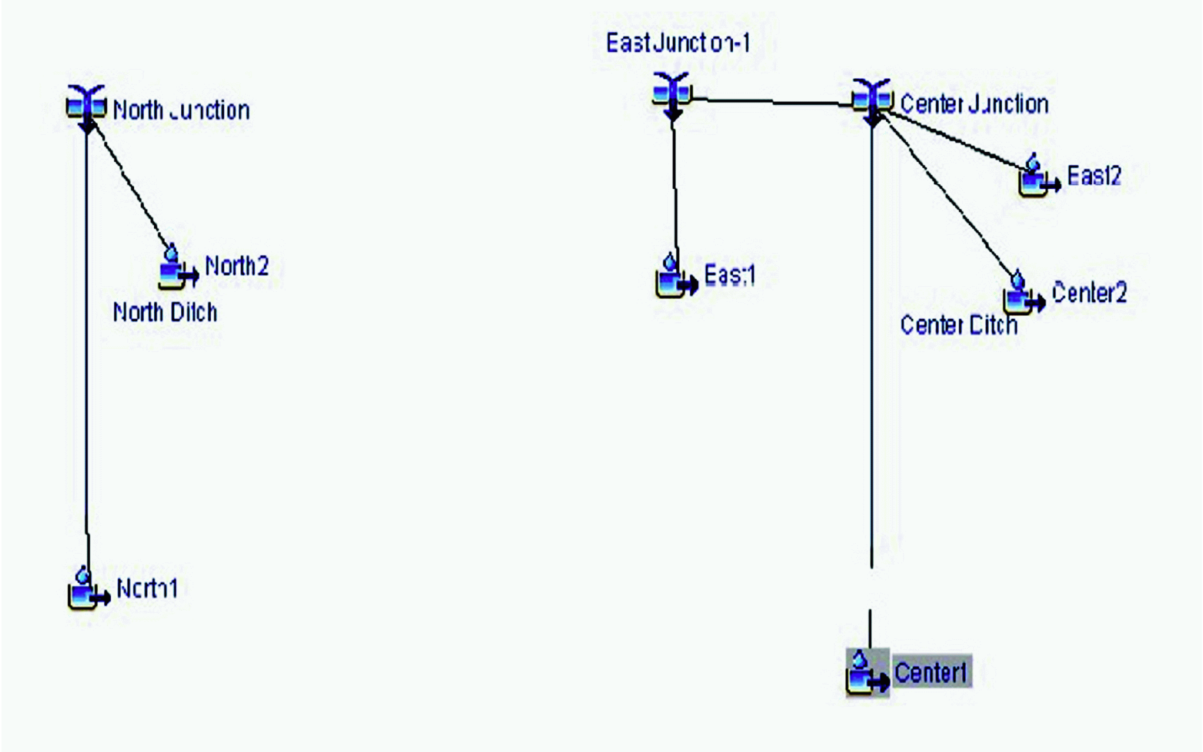
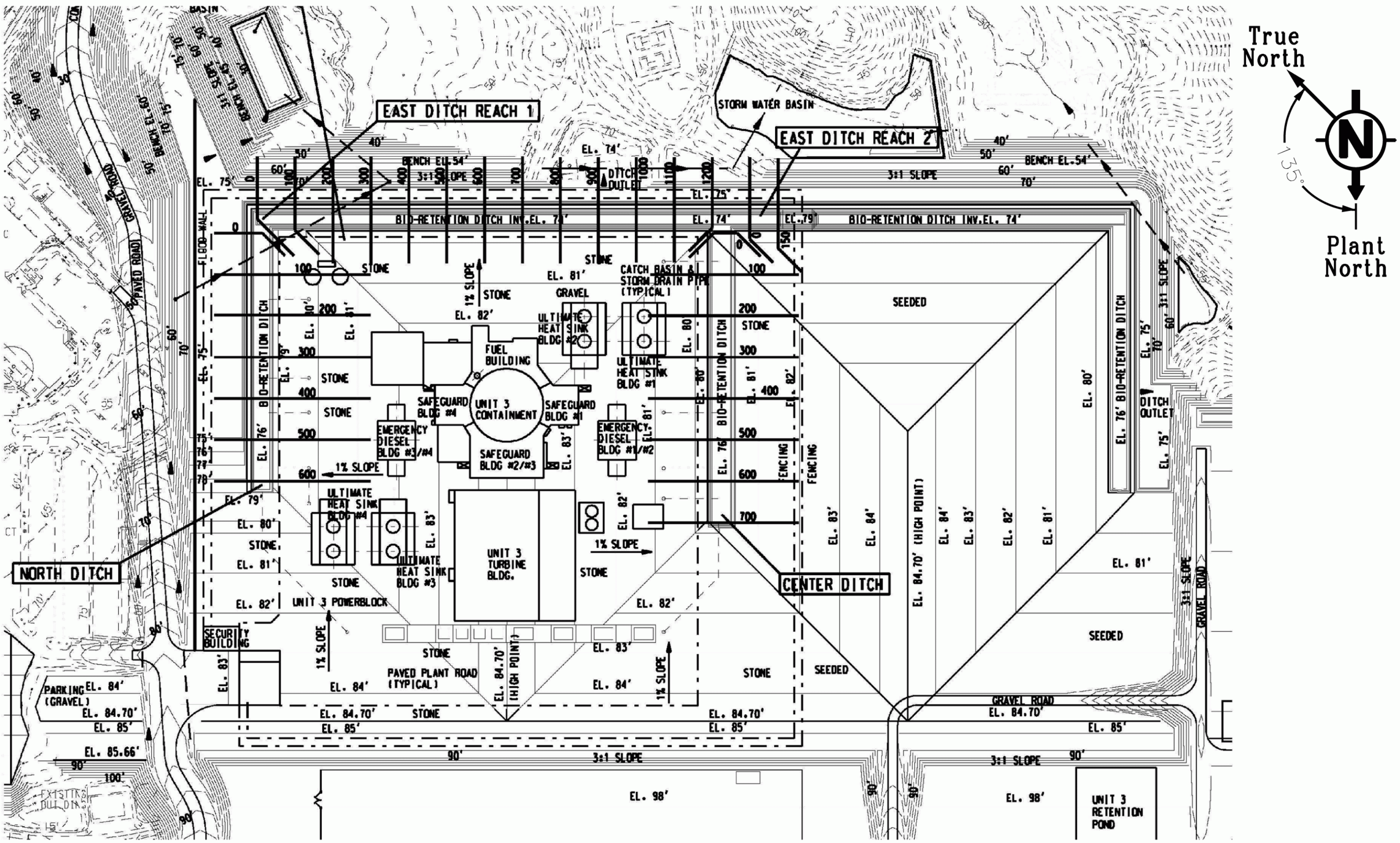


Figure 2.4-9— {CCNPP Unit 3 Drainage Ditch Cross Sections}



See Figure 1.2-1 for Powerblock layout

Figure 2.4-10— {Site Location}

Figure 2.4-11— {Johns Creek Watershed}

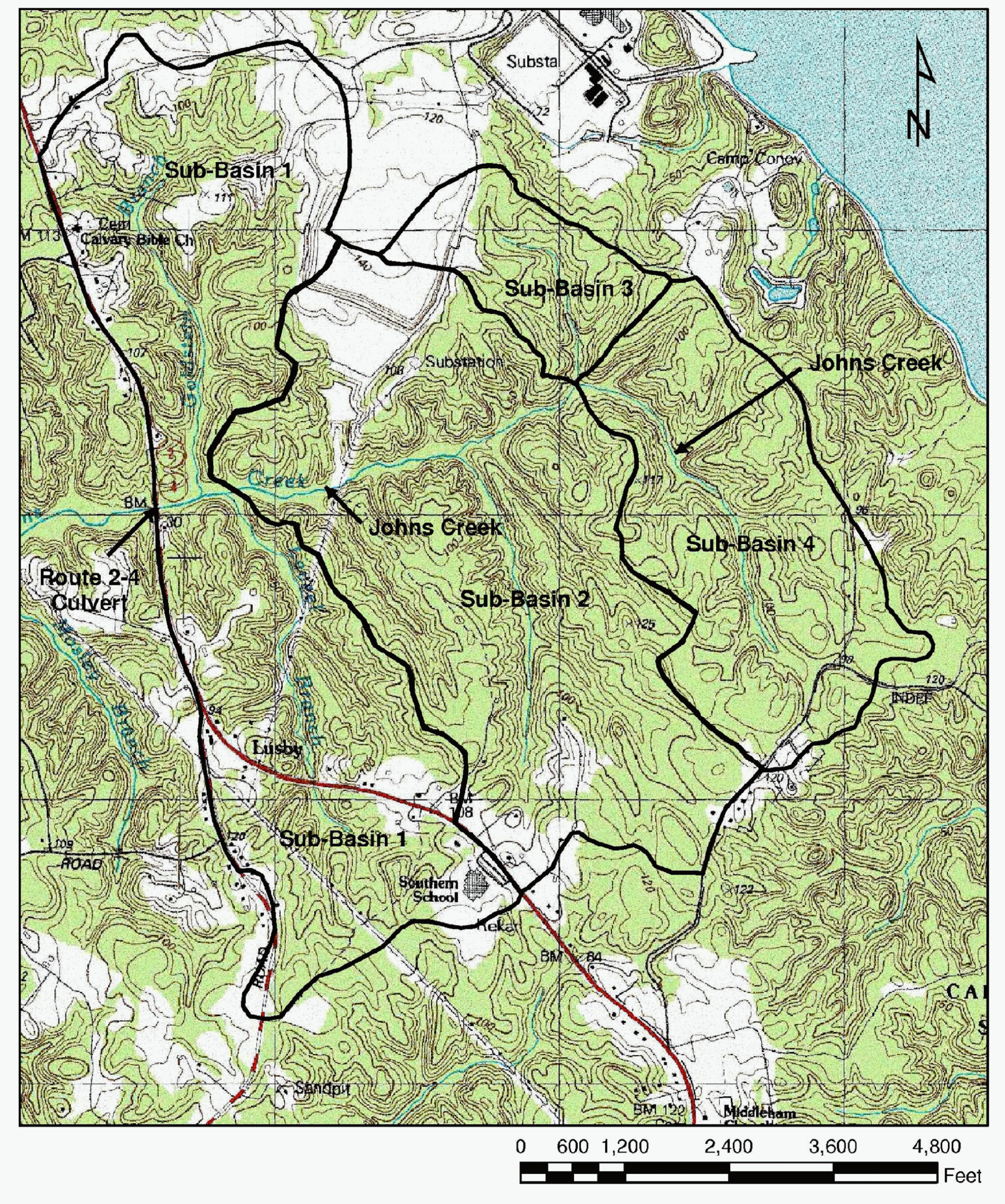


Figure 2.4-12— {HEC-HMS Watershed Schematic}

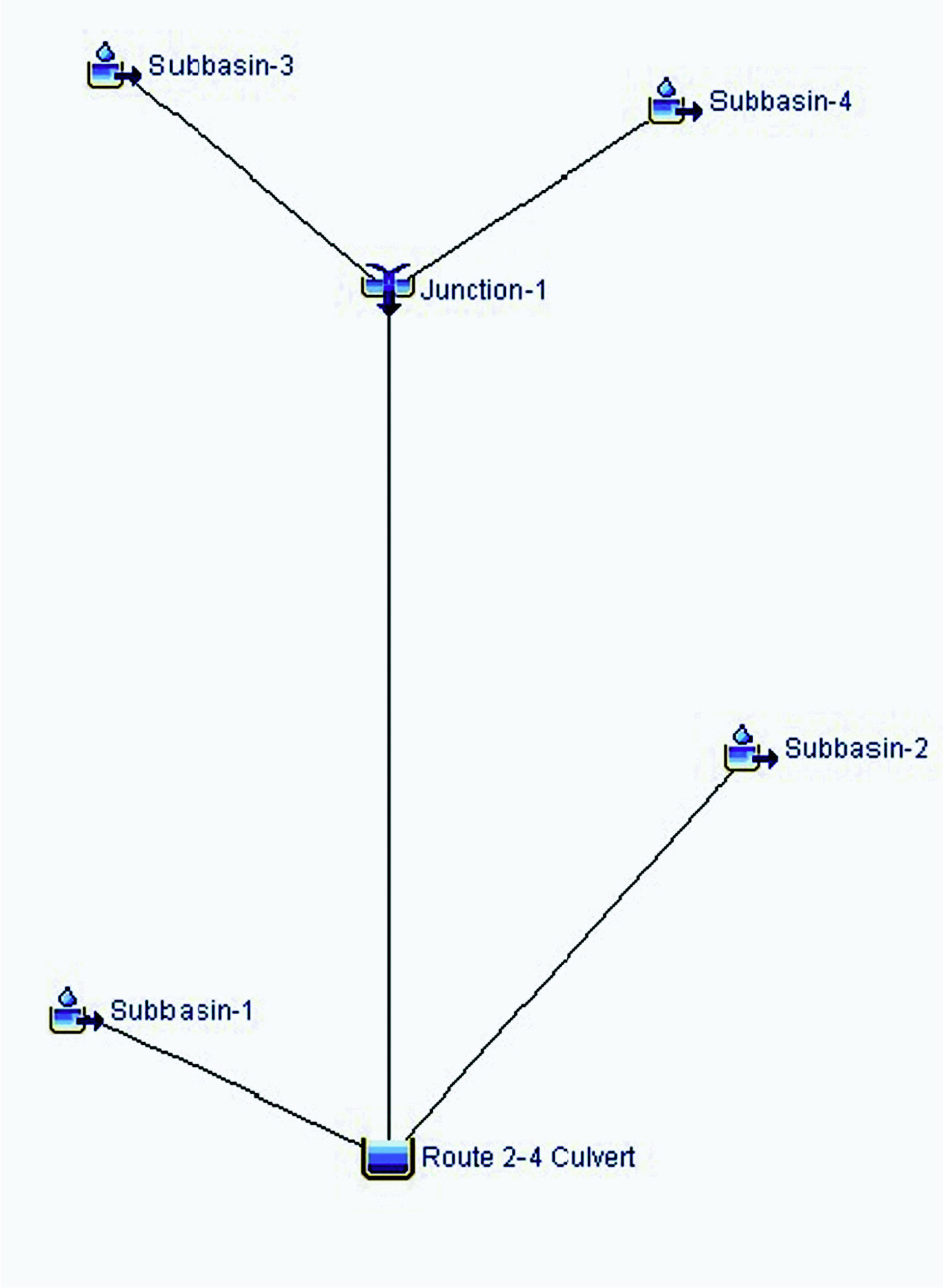


Figure 2.4-13— {Storage And Inflow & Outflow Hydrographs at Maryland Route 2-4 Culvert}

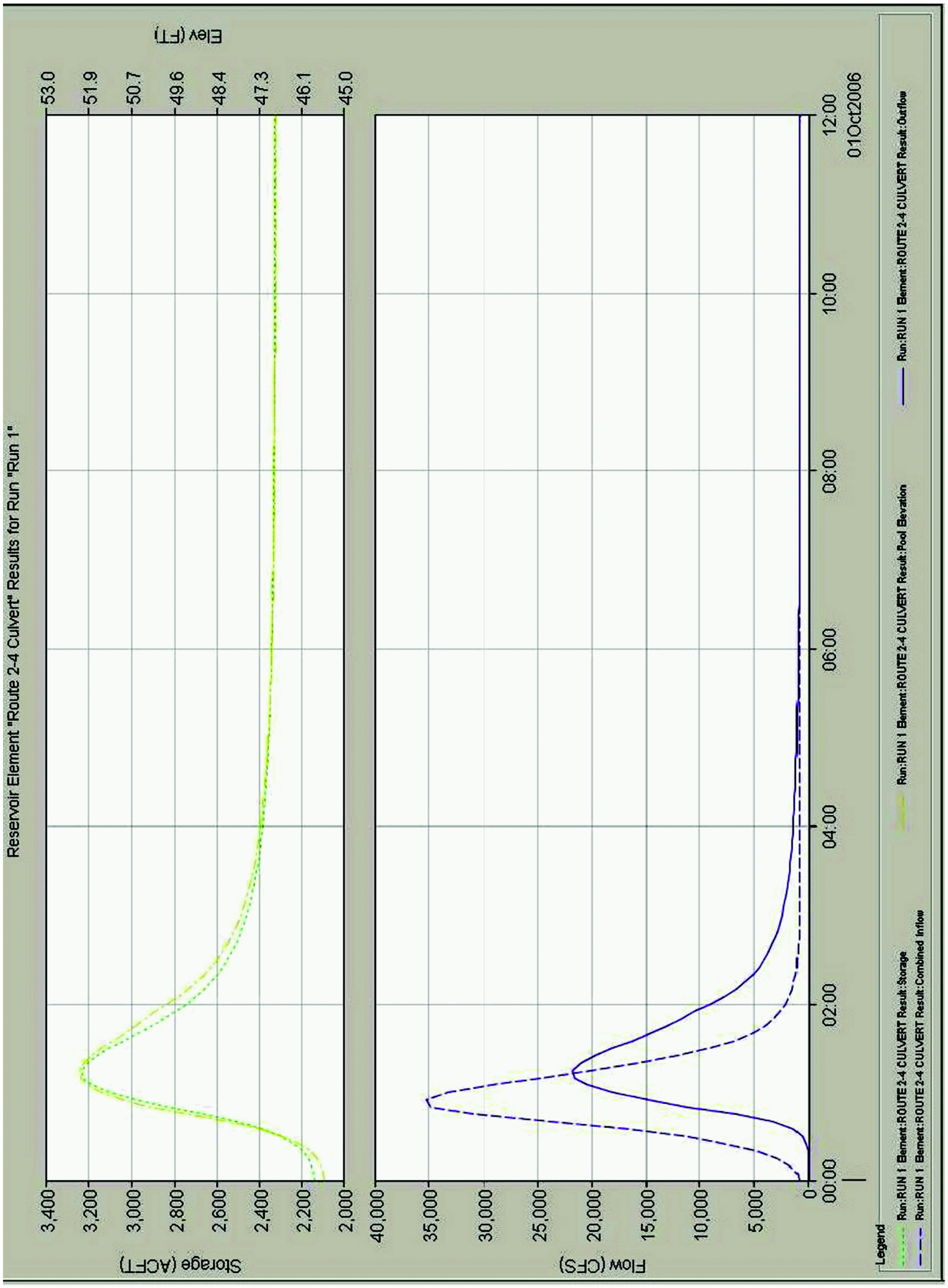


Figure 2.4-14— {Sub-Basin 1 Hydrograph}

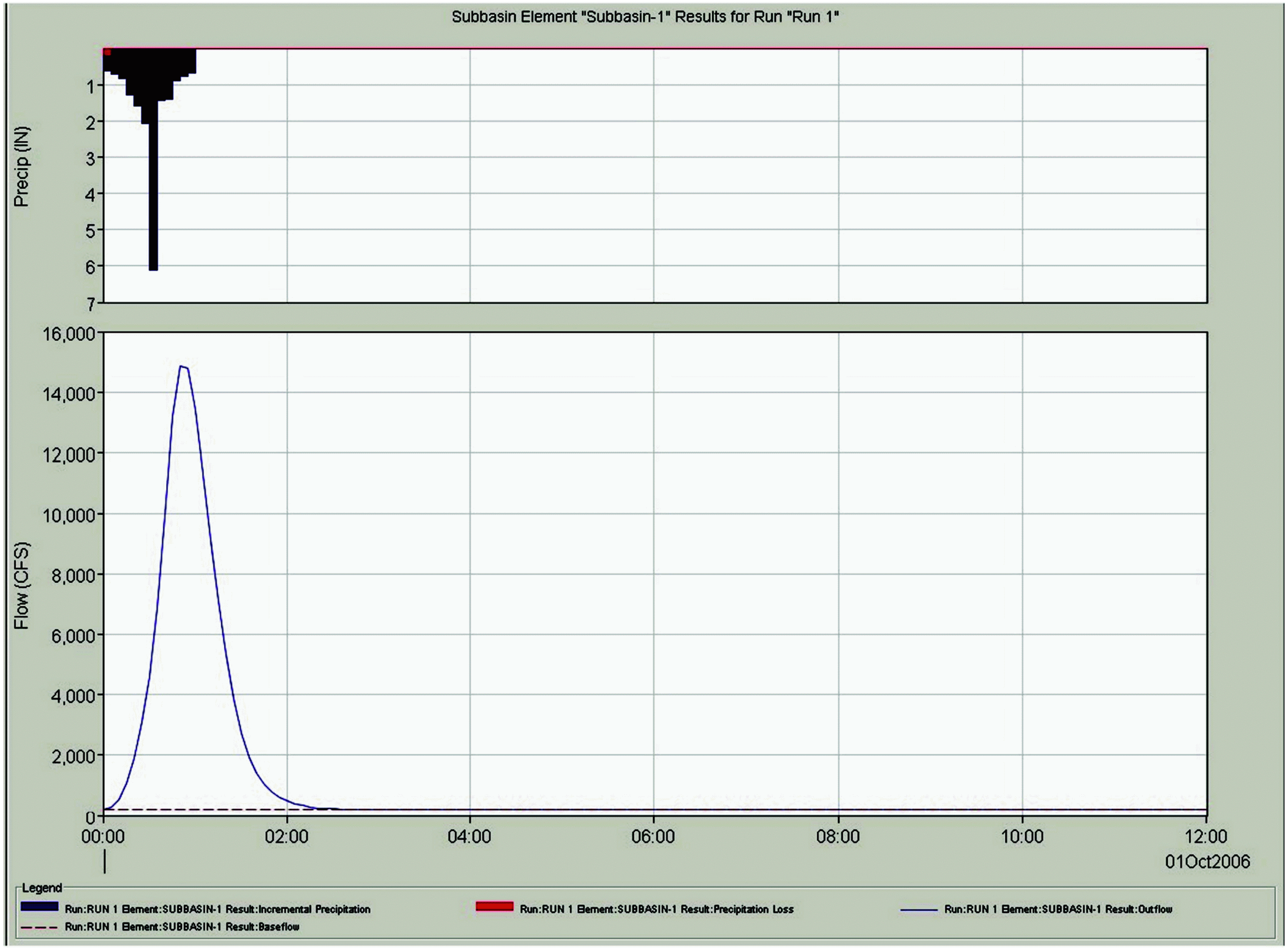


Figure 2.4-15— {Sub-Basin 2 Hydrograph}

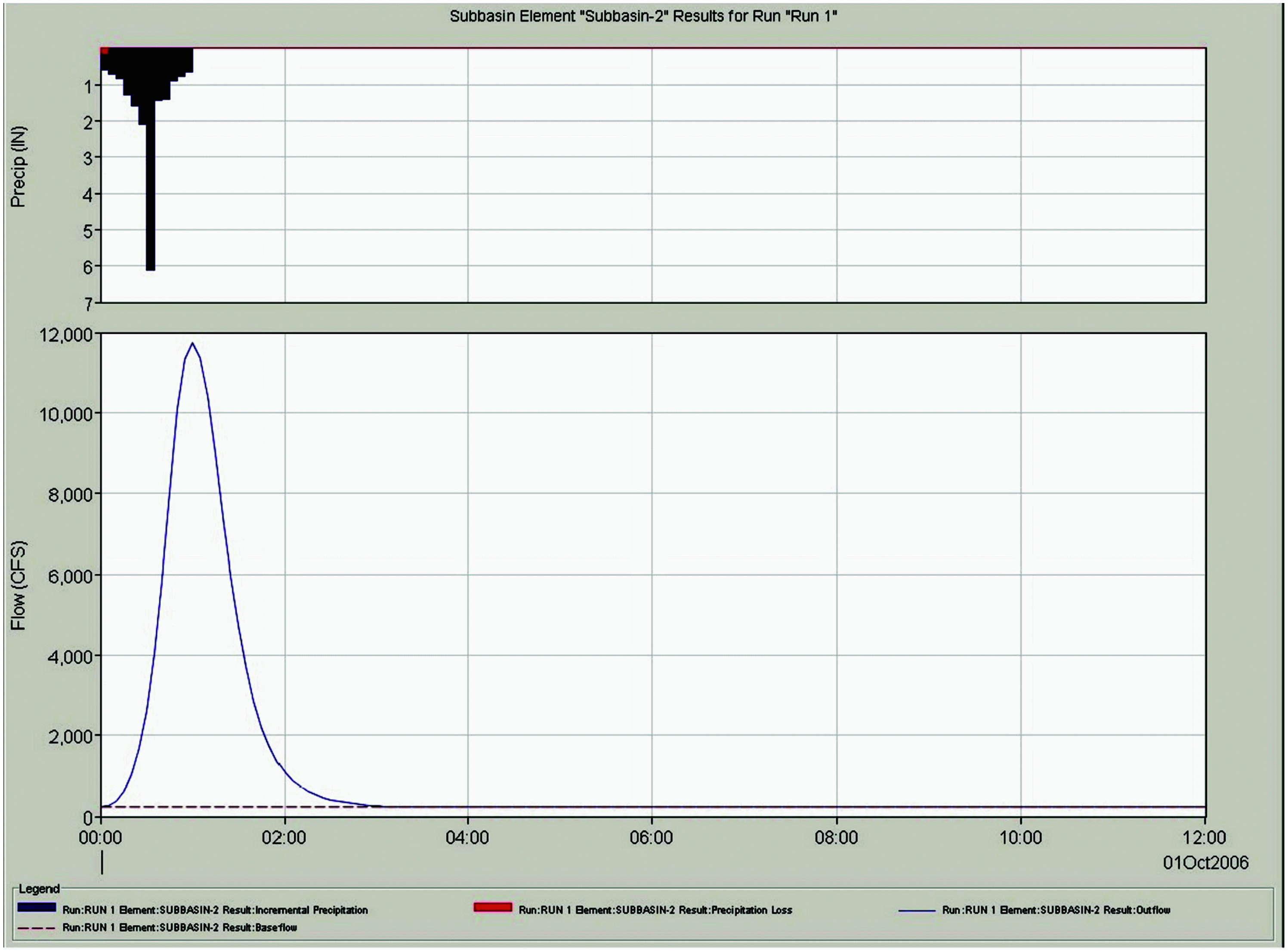


Figure 2.4-16— {Sub-Basin 3 Hydrograph}

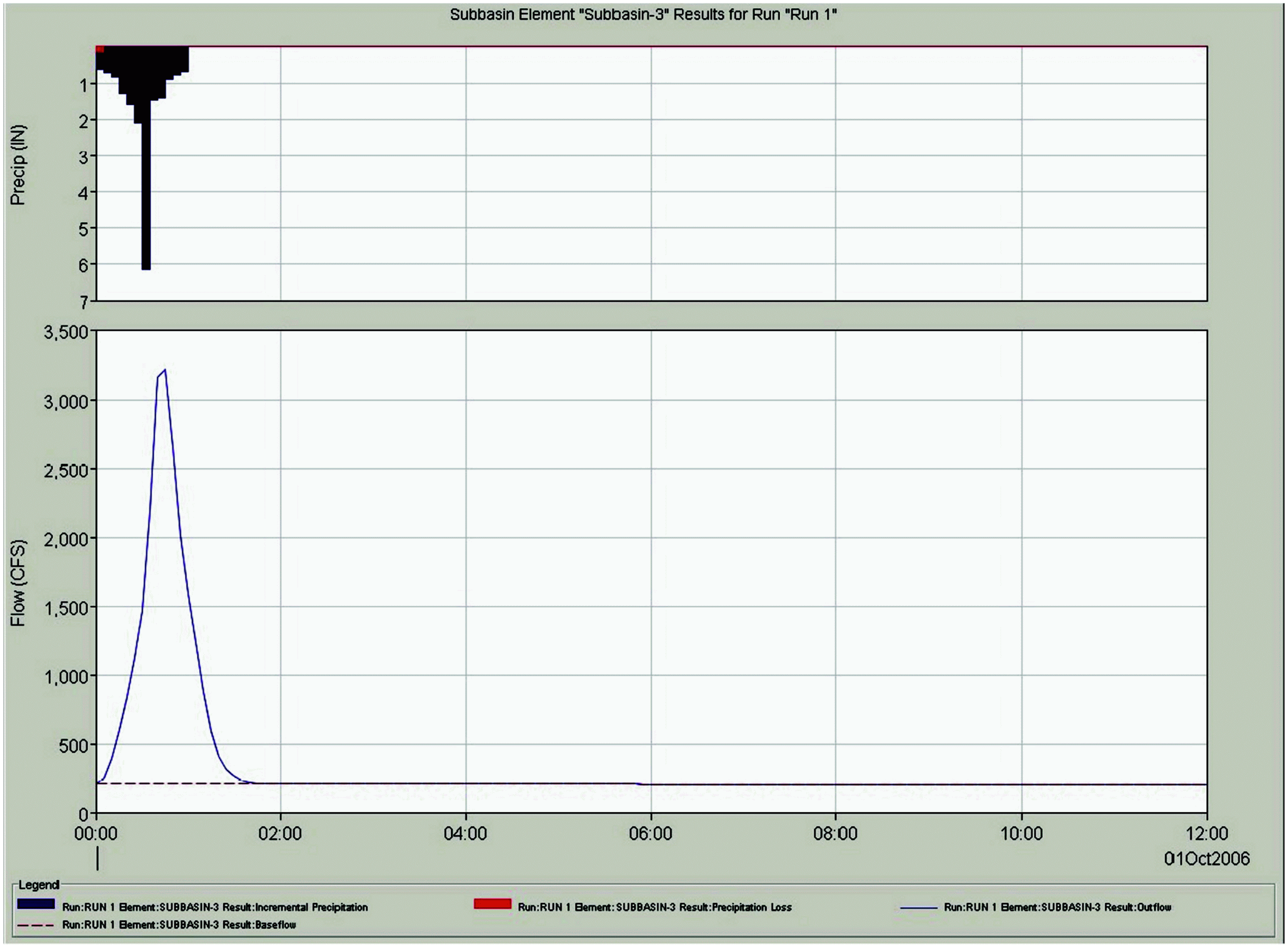


Figure 2.4-17— {Sub-Basin 4 Hydrograph}

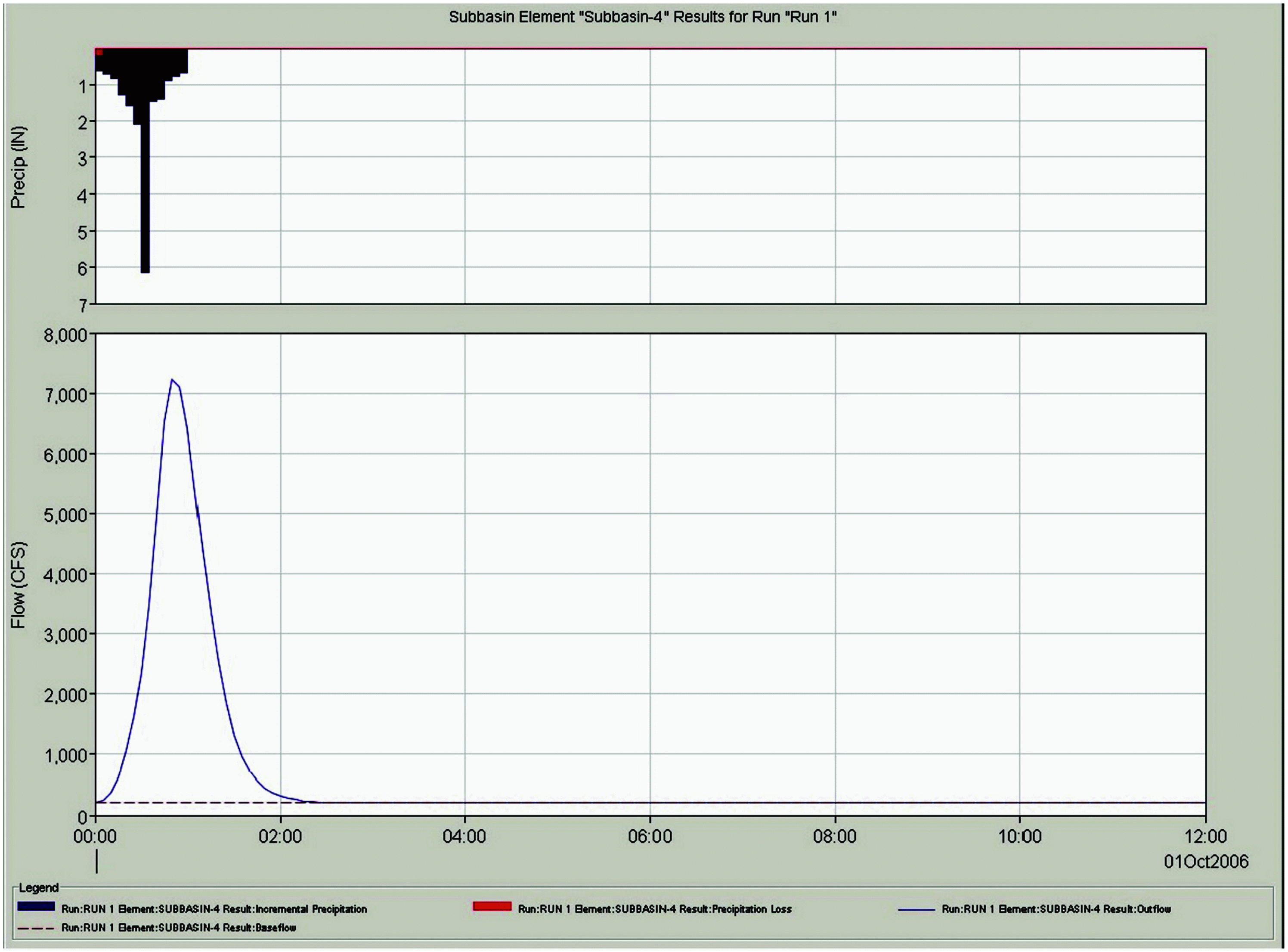


Figure 2.4-18— {HEC-RAS Cross Section Locations}

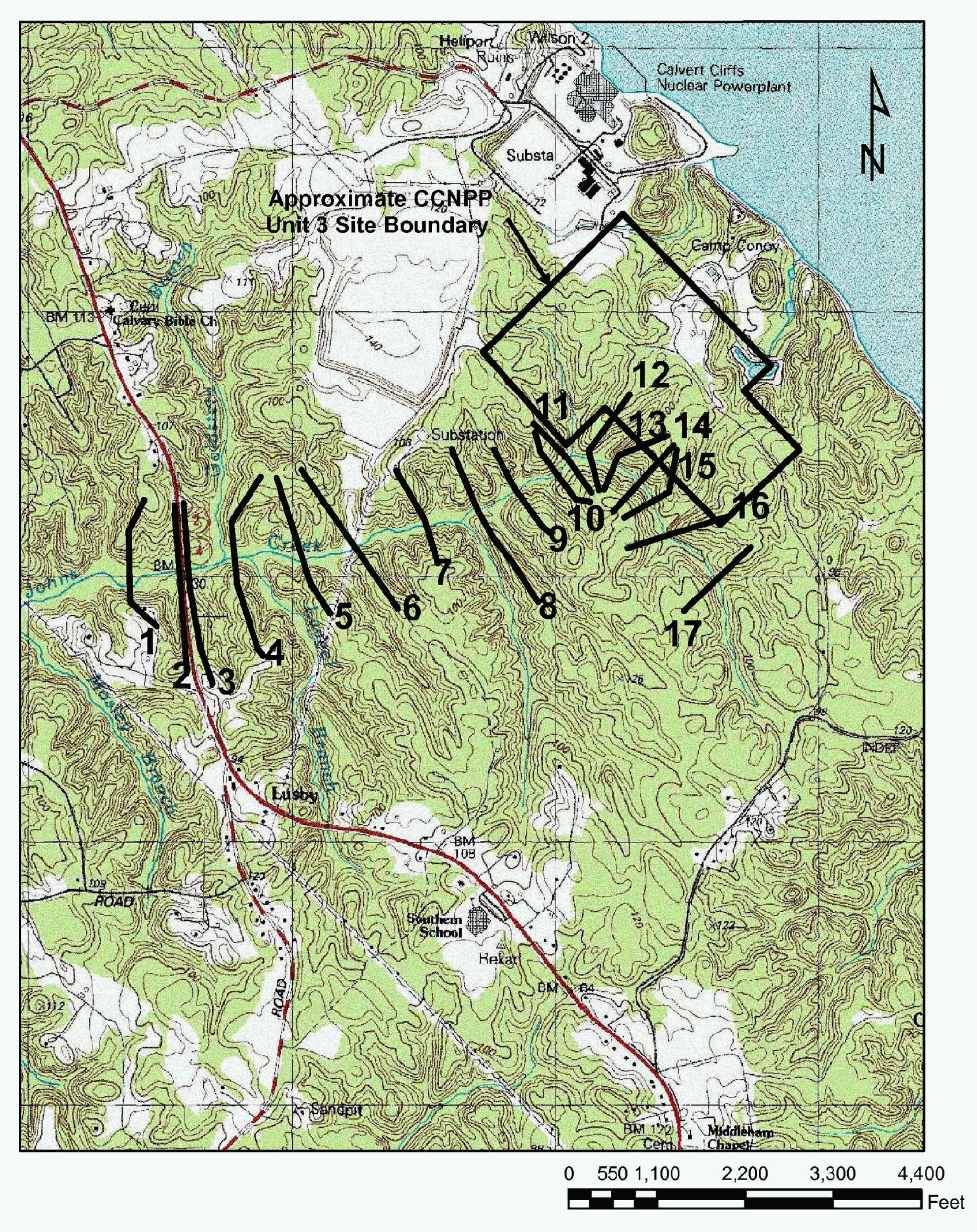


Figure 2.4-19— {Johns Creek PMF Water Surface Profiles}

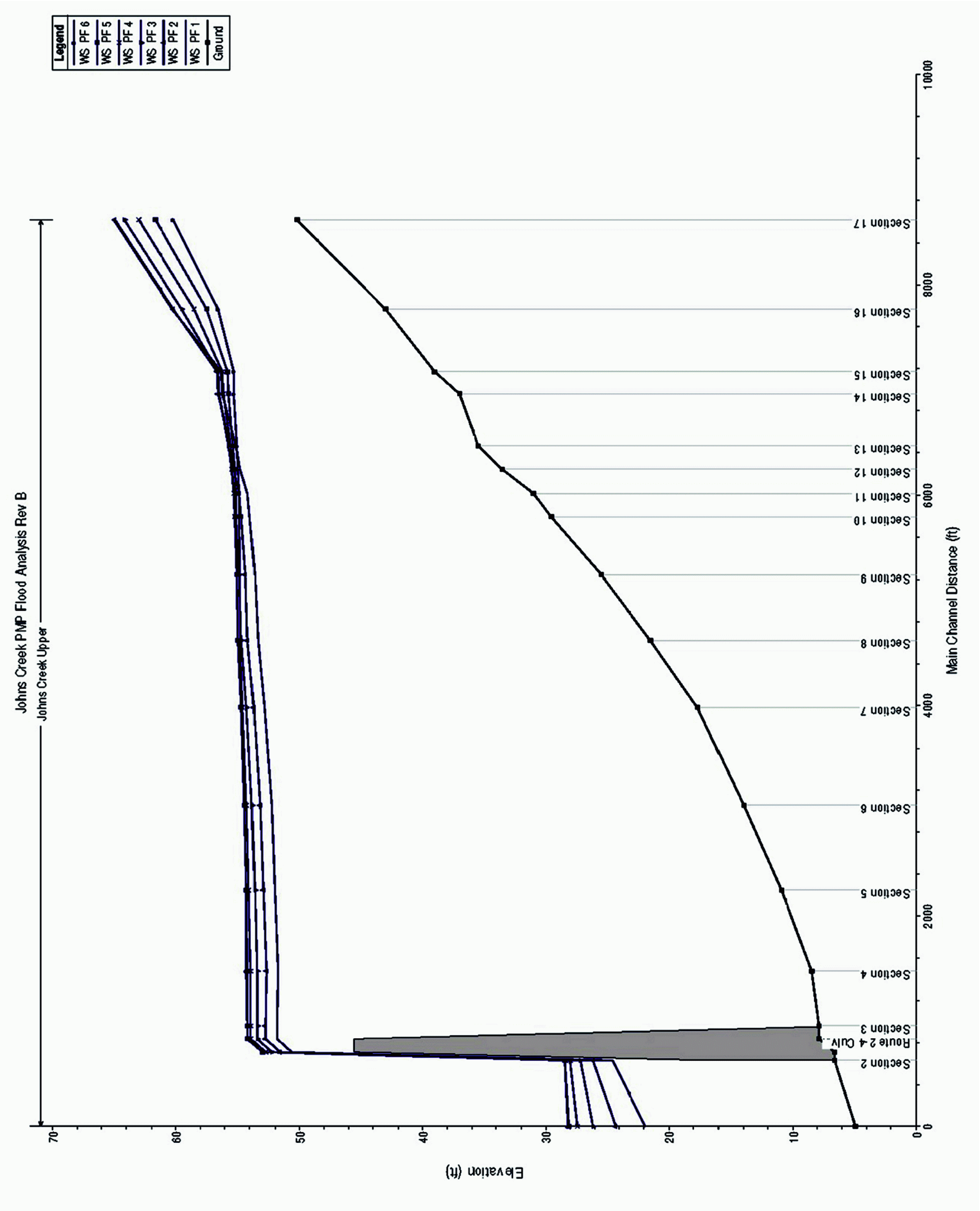


Figure 2.4-20— {Patuxent River Watershed And Dam Locations}

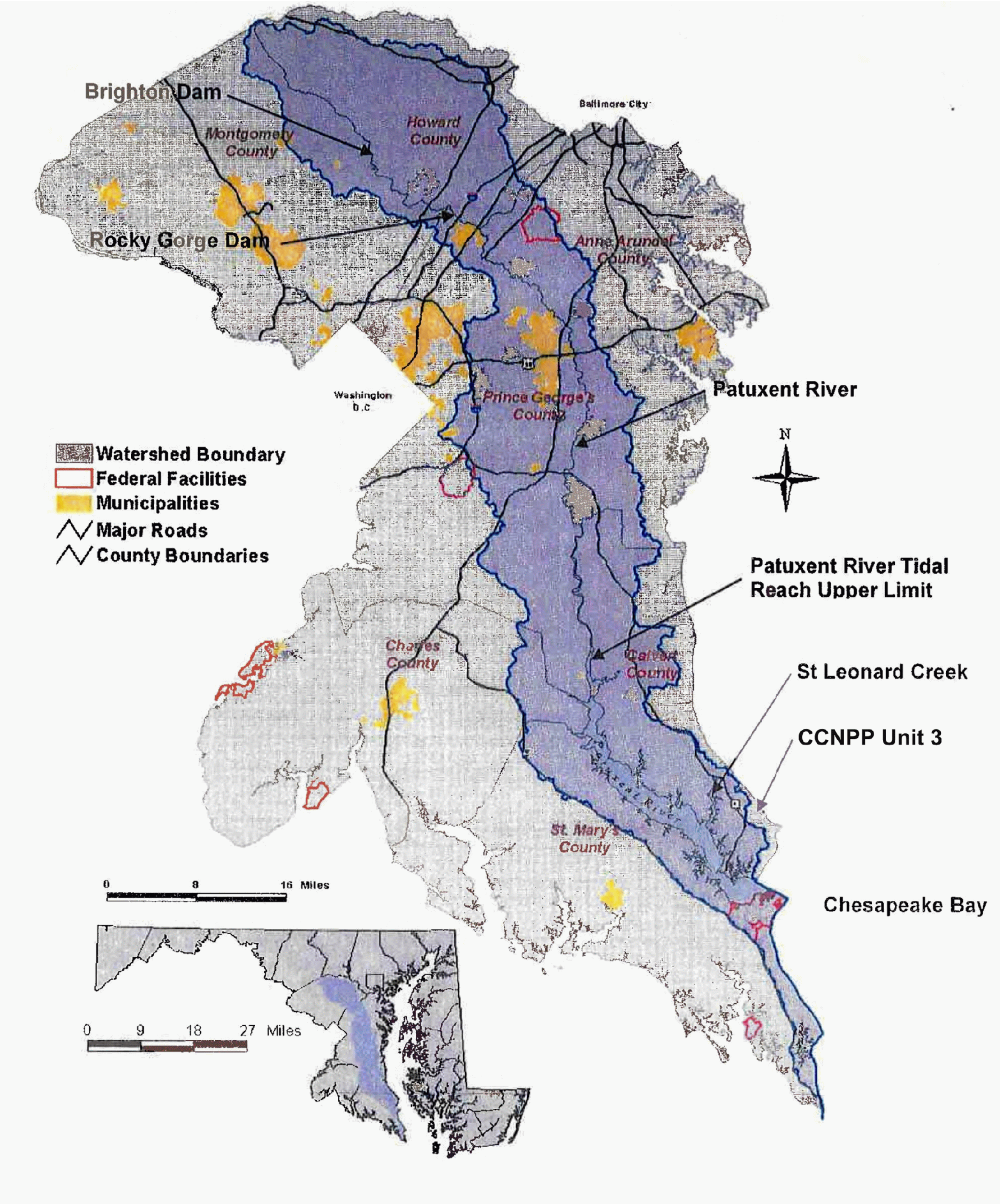


Figure 2.4-21— {SLOSH Chesapeake Bay Model Grid (SLOSH Basin cp2) and the Location of CCNPP Unit 3}

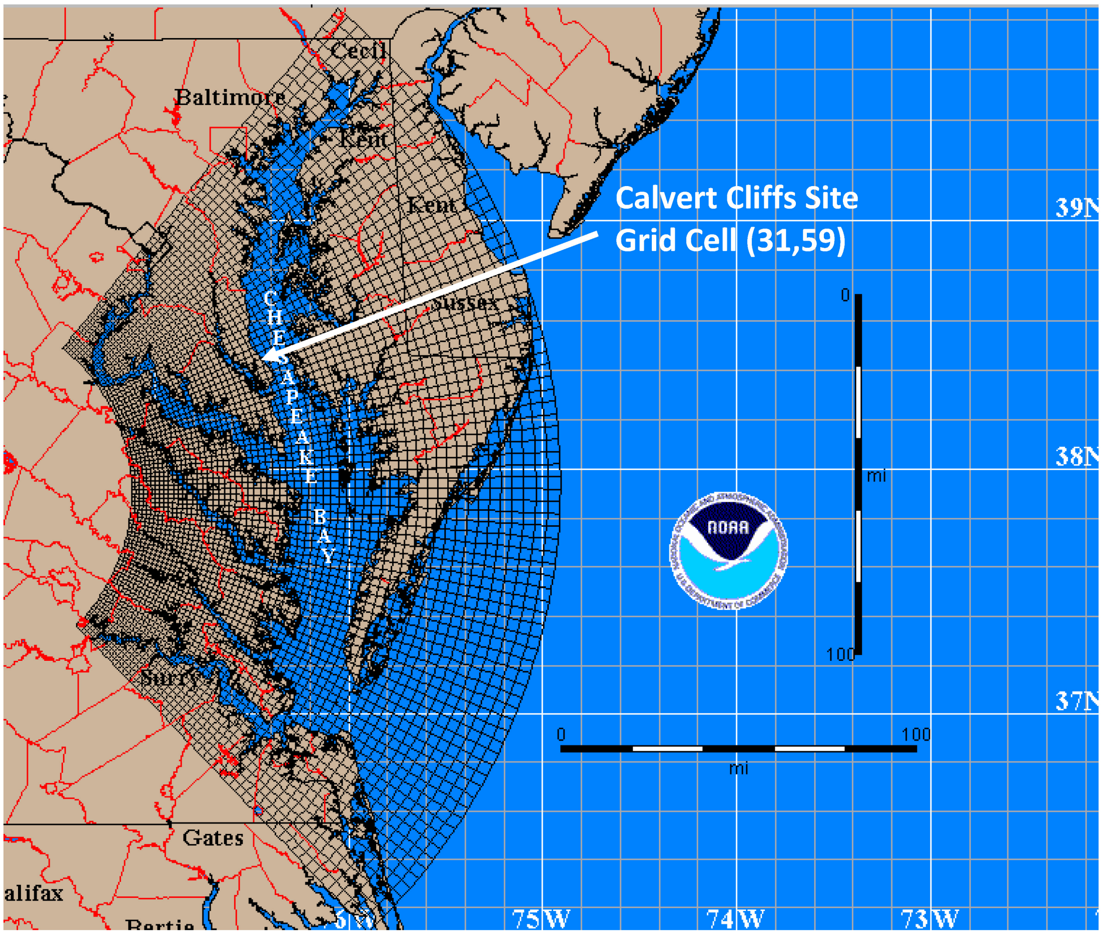
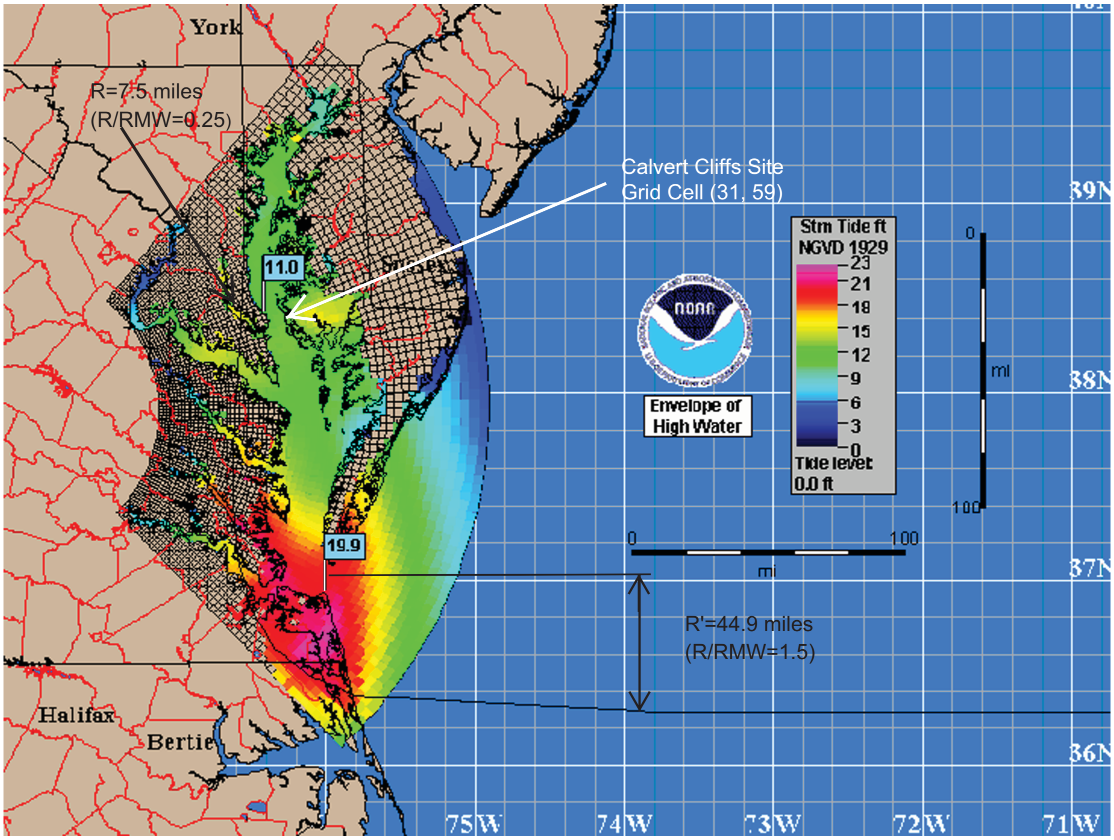


Figure 2.4-22— {Selected Storm Track and the Envelop of Resulting Surge Elevation in the SLOSH Chesapeake Bay Basin for the PMH}



Note: R is the distance from the Site; R' is the distance from the Chesapeake Bay entrance; RMW is the PMH upper bound radius of maximum wind.

Colors and the flags show the maximum surge elevations at the grid locations.

Figure 2.4-23— {SLOSH Model Simulated Time History of Surge Elevation at the Site (Grid Cell 31, 59) for the Selected PMH Conditions}

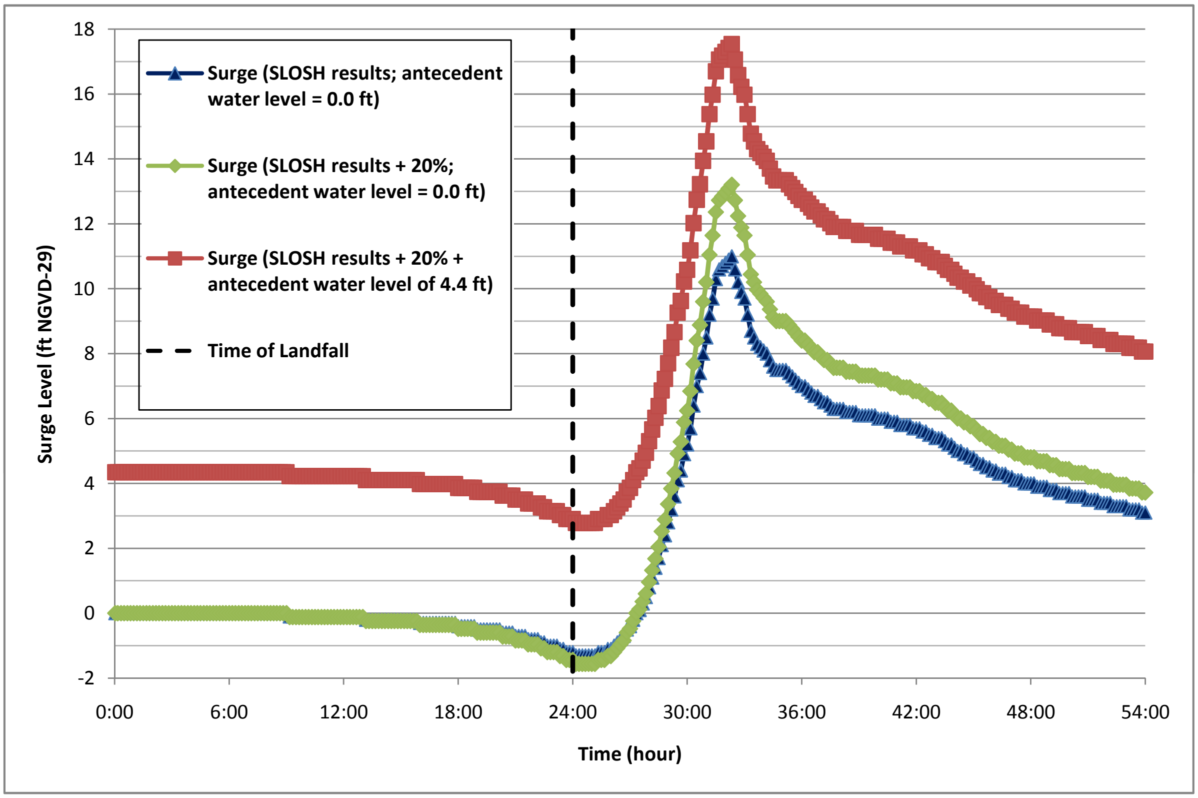


Figure 2.4-24— {SLOSH Model Simulated Time History of Wind Speed at the Site (grid cell 31, 59) for the Selected PMH Conditions}

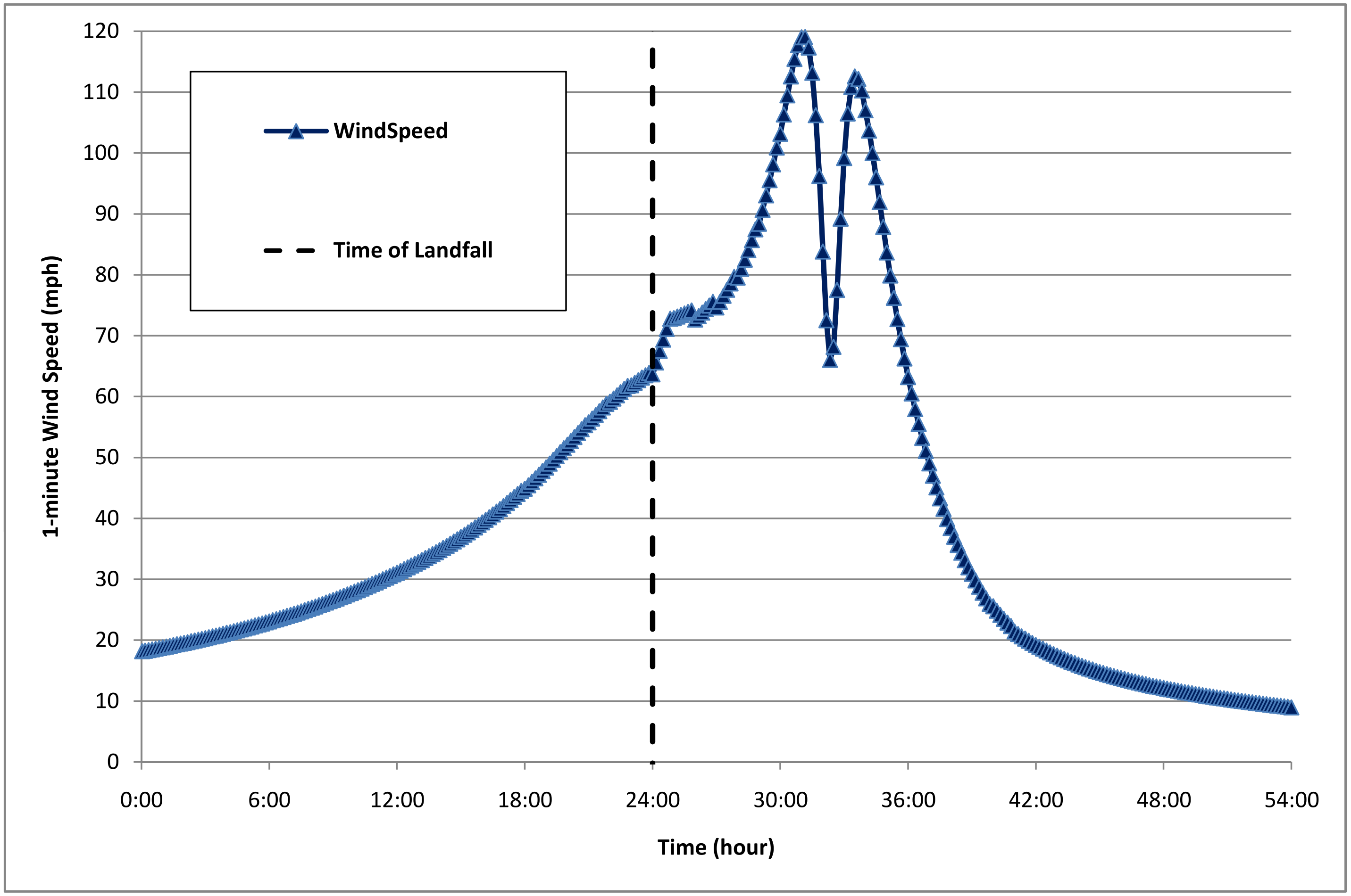


Figure 2.4-25— {Schematic Description of UHS Makeup Water Intake Location and Exposure for Wind Wave Estimation}

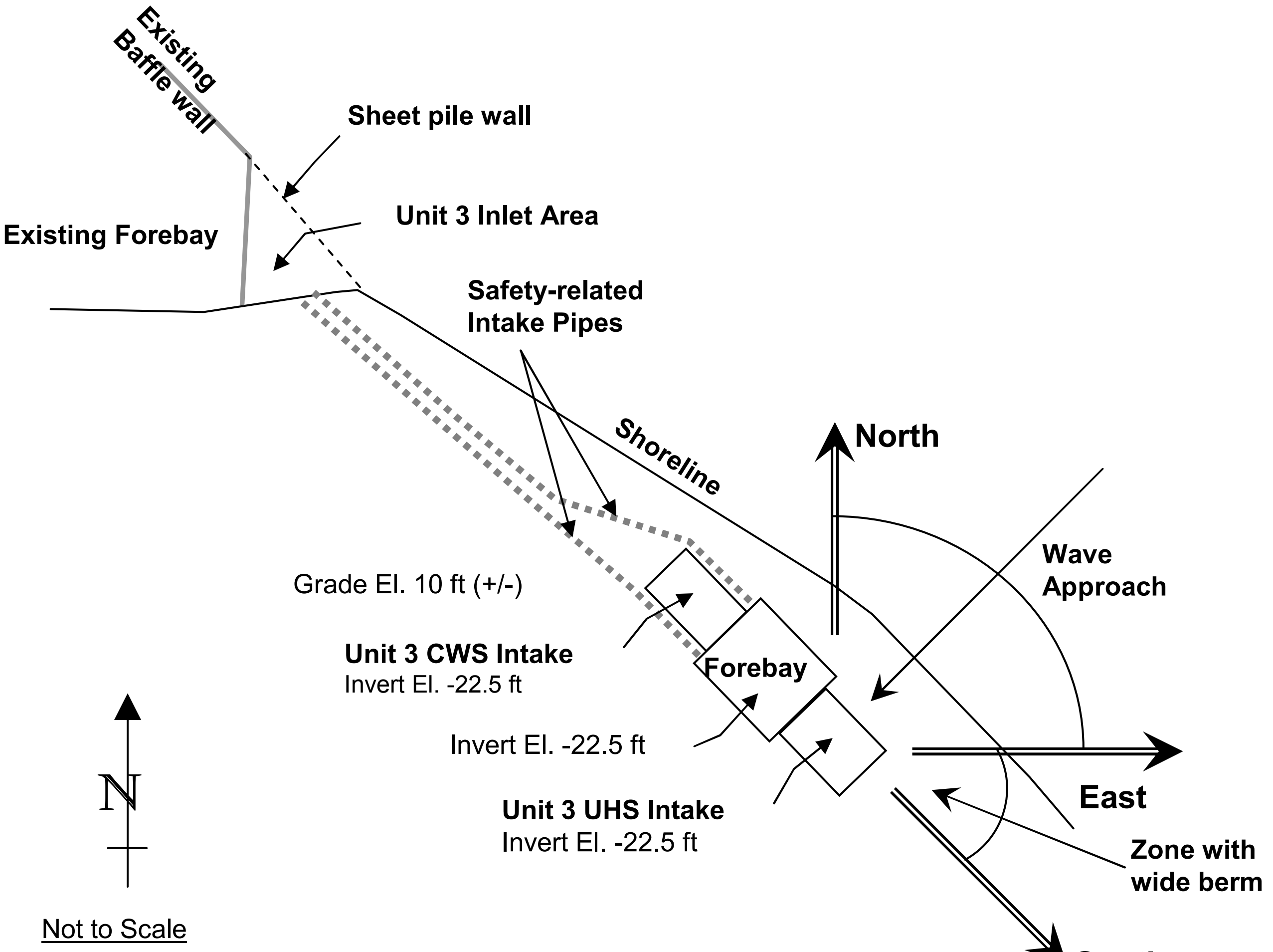
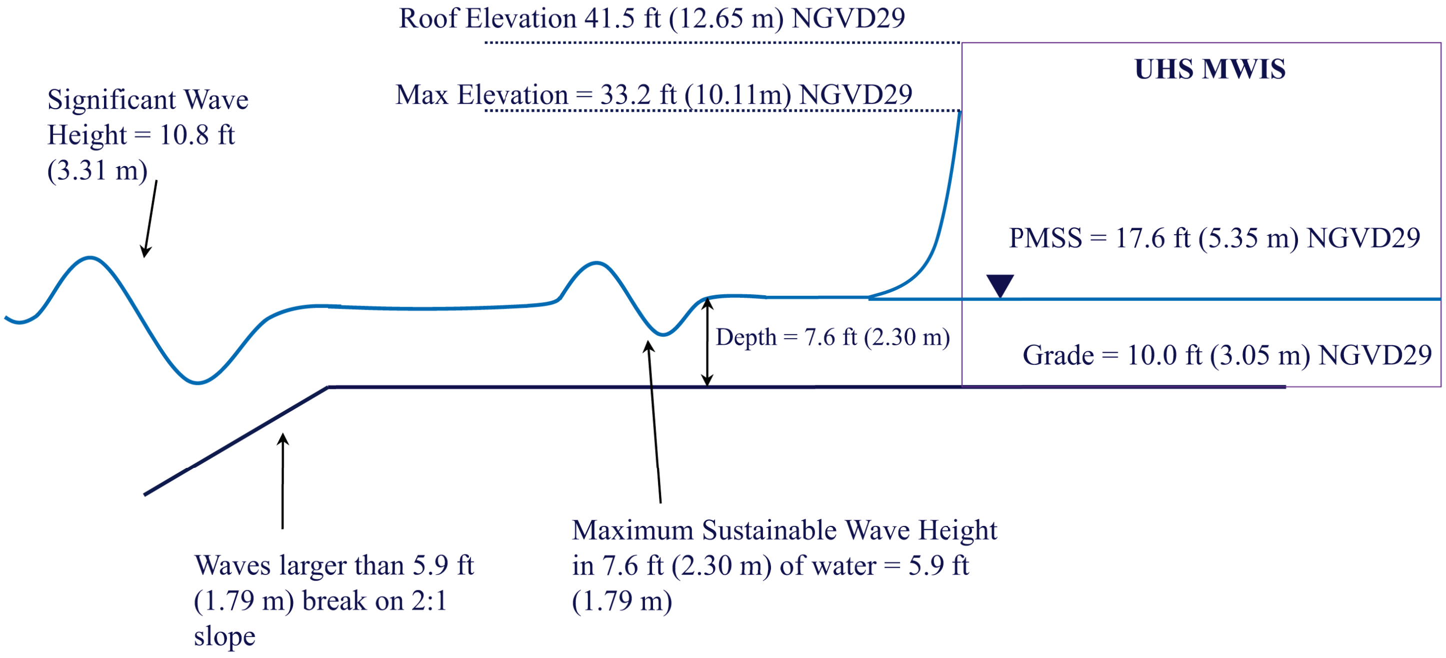
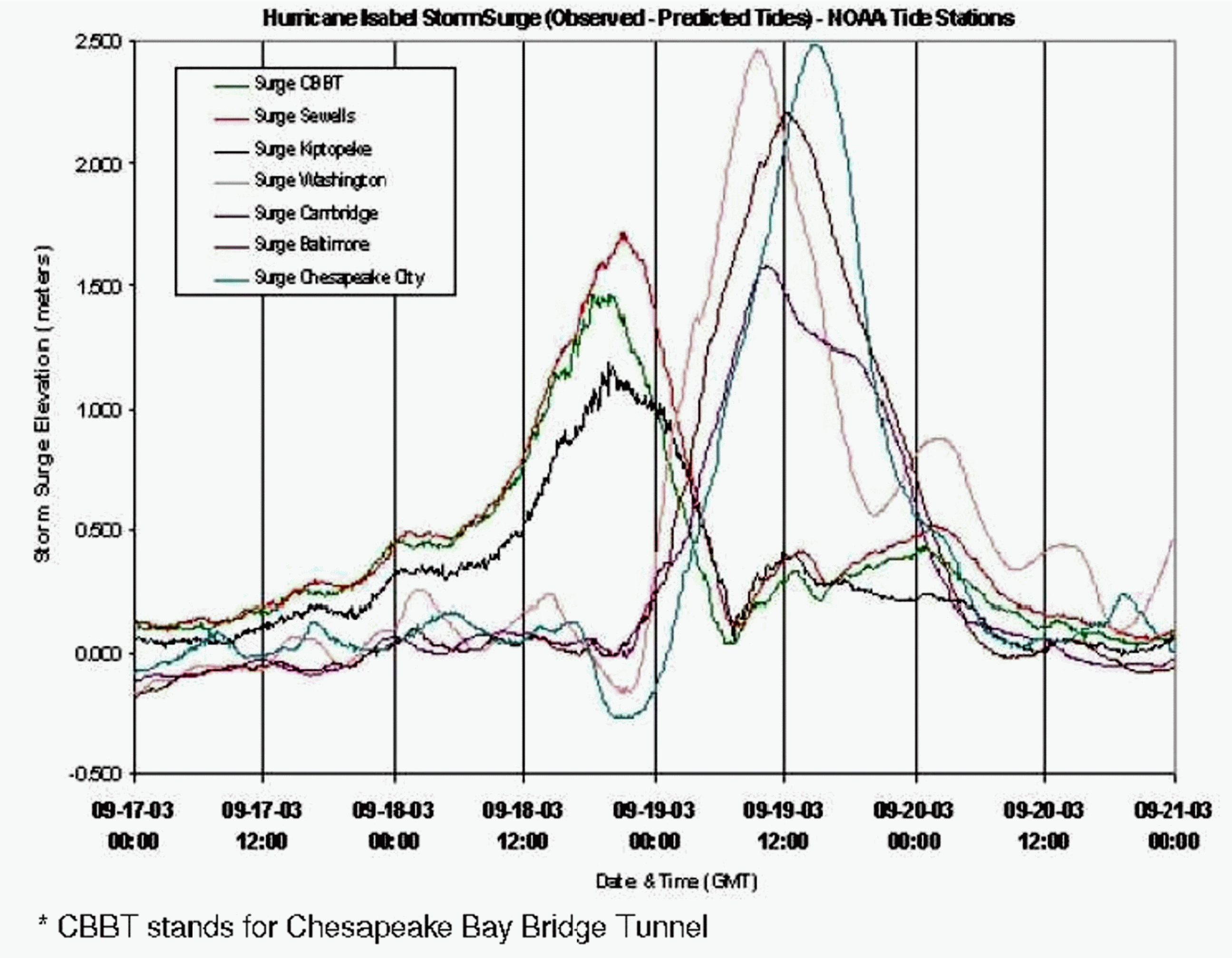


Figure 2.4-26— {Schematic Diagram Wave Runup on the UHS Makeup Water Intake Structure (MWIS)}



Drawing not to scale

Figure 2.4-27— {Storm Surge Heights at Different Locations in the Chesapeake Bay During Hurricane Isabel 2003}



* CBBT stands for Chesapeake Bay Bridge Tunnel

Figure 2.4-28— {Map Of Tsunami Source Generators}

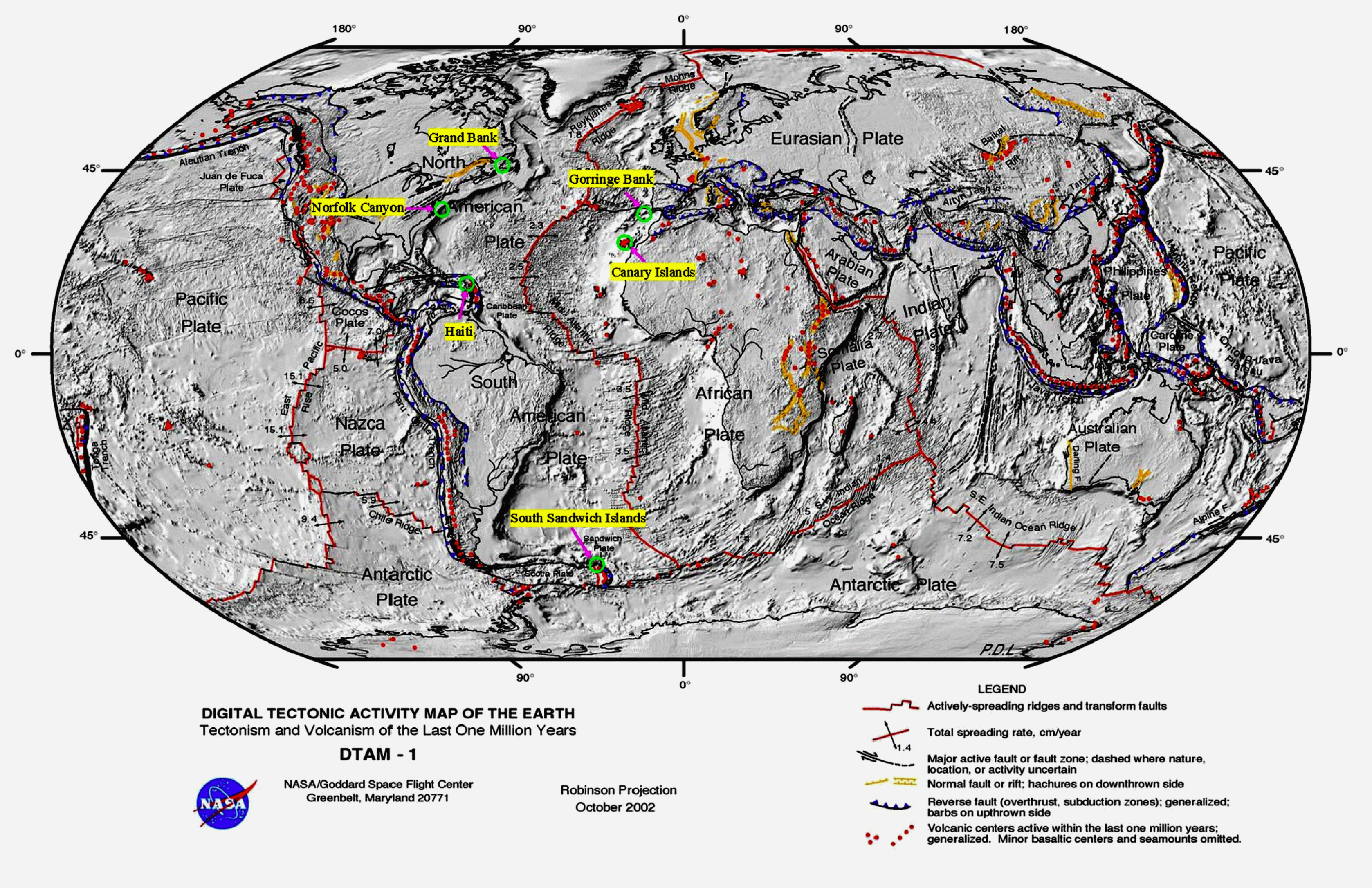
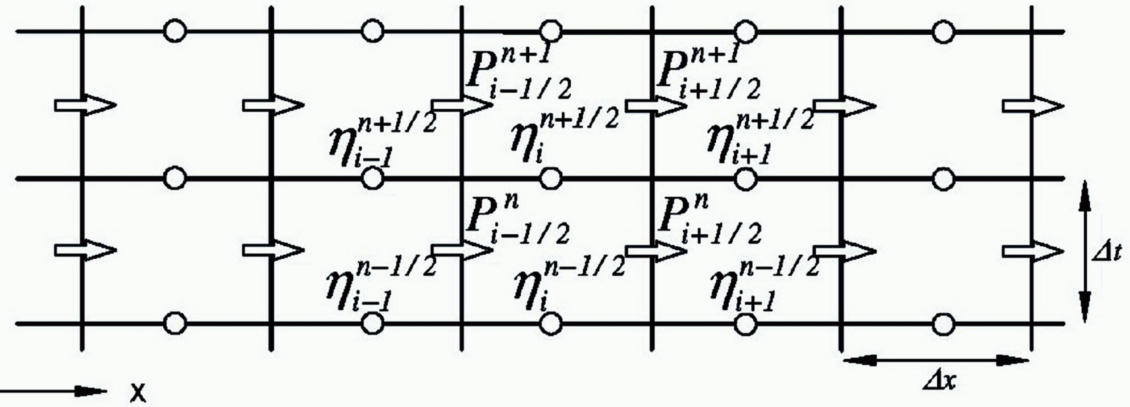
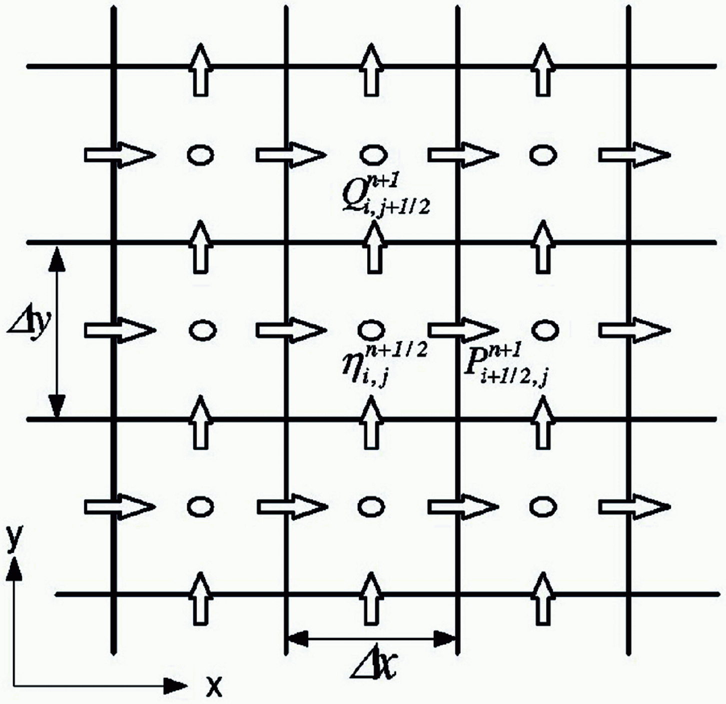


Figure 2.4-29— {Staggered Grid for Leap-Frog Scheme}



(a) Time Domain



(b) Space Domain

Figure 2.4-30— {Time Grid Scheme for Assignment of Variables}

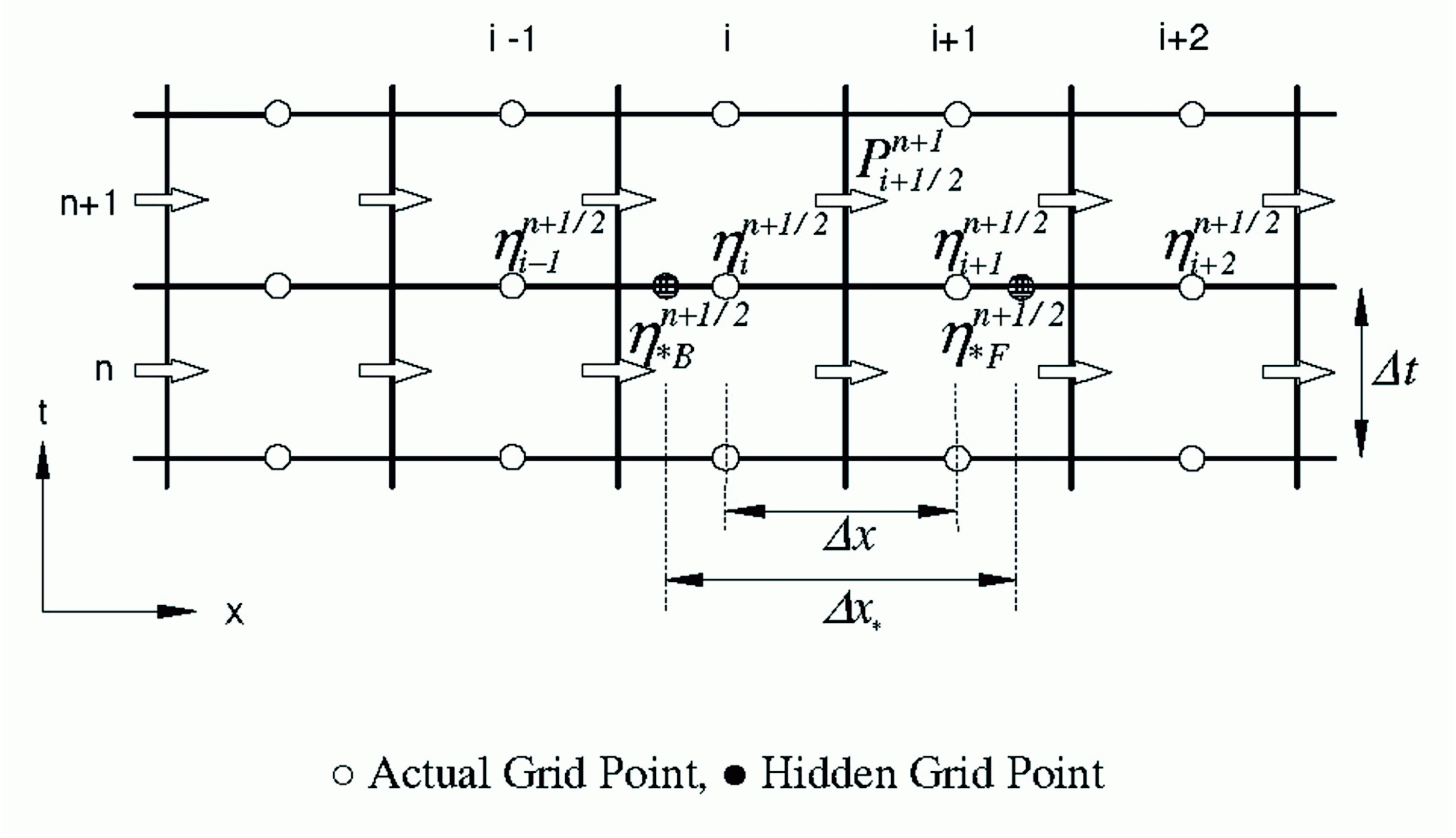


Figure 2.4-31— {Spatial Grid Scheme for Assignment of Variables}

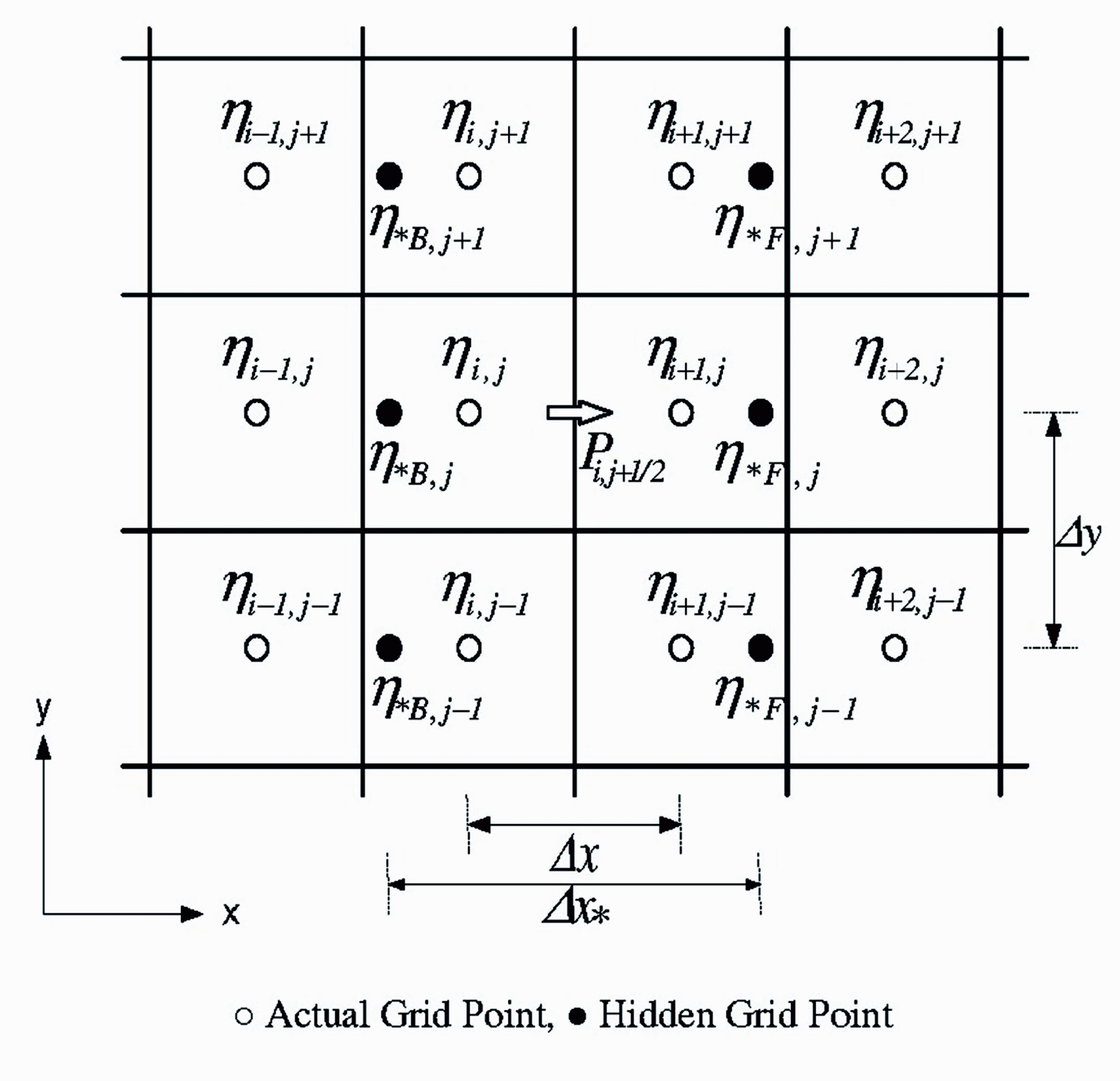


Figure 2.4-32— {Computational Domain and Model Bathymetry for Tsunami Simulation in Chesapeake Bay}

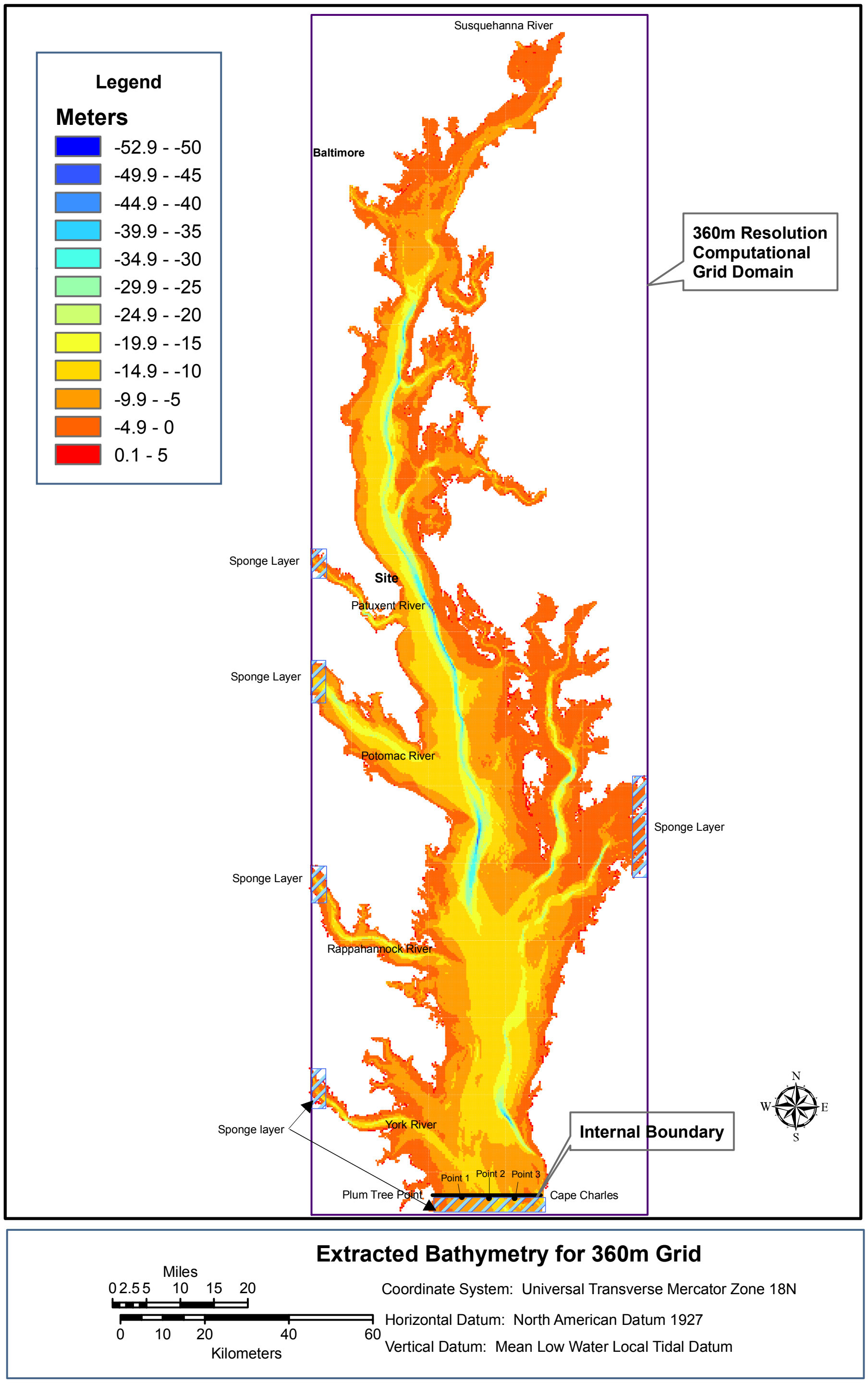


Figure 2.4-33— {Water Levels Along Internal Boundary for Case 1, Nonlinear Model}

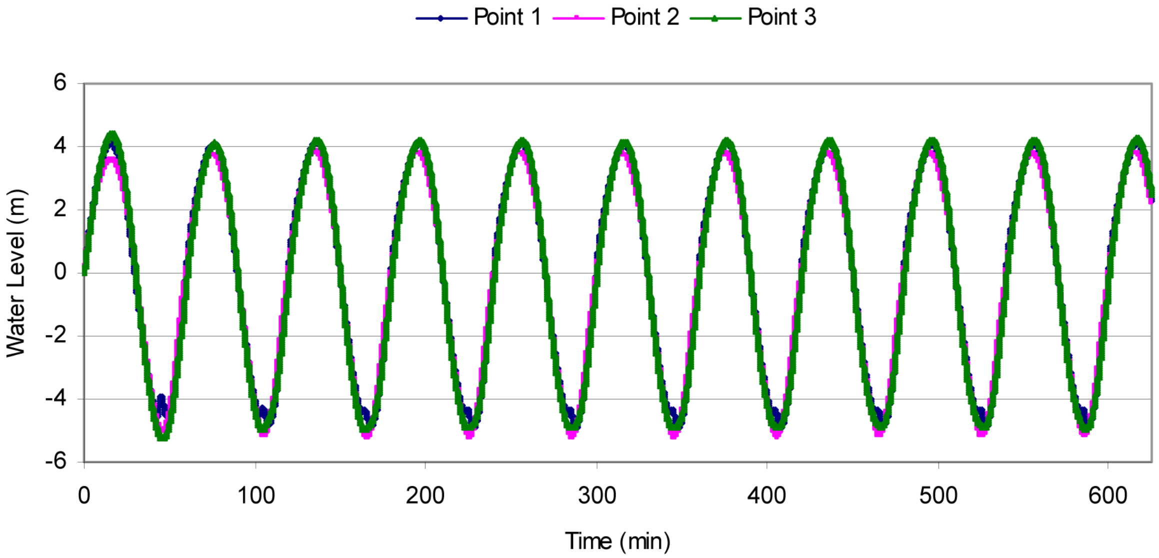


Figure 2.4-34— {Water Levels Along Internal Boundary Case 2, Nonlinear Model}

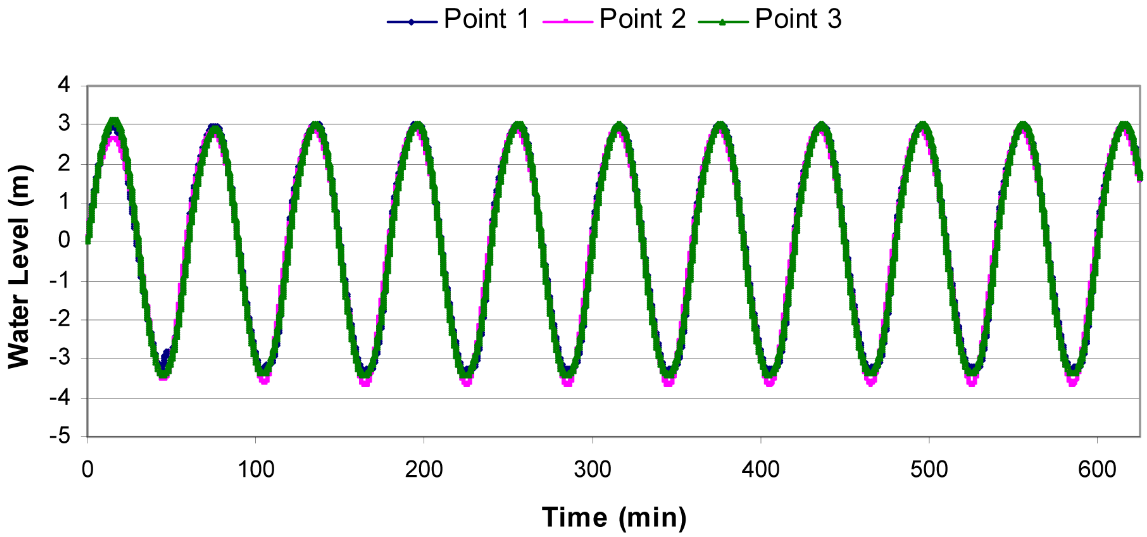


Figure 2.4-35— {Water Levels Along Internal Boundary for Case 3, Nonlinear Model}

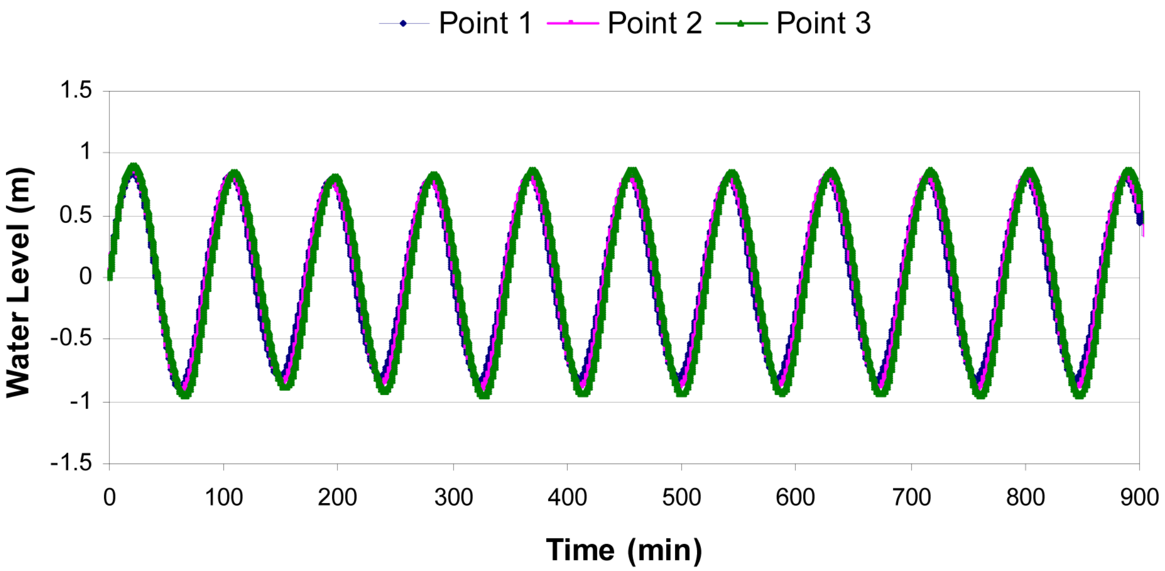


Figure 2.4-36— {Water Levels Along Internal Boundary for Case 3, Linear Model}

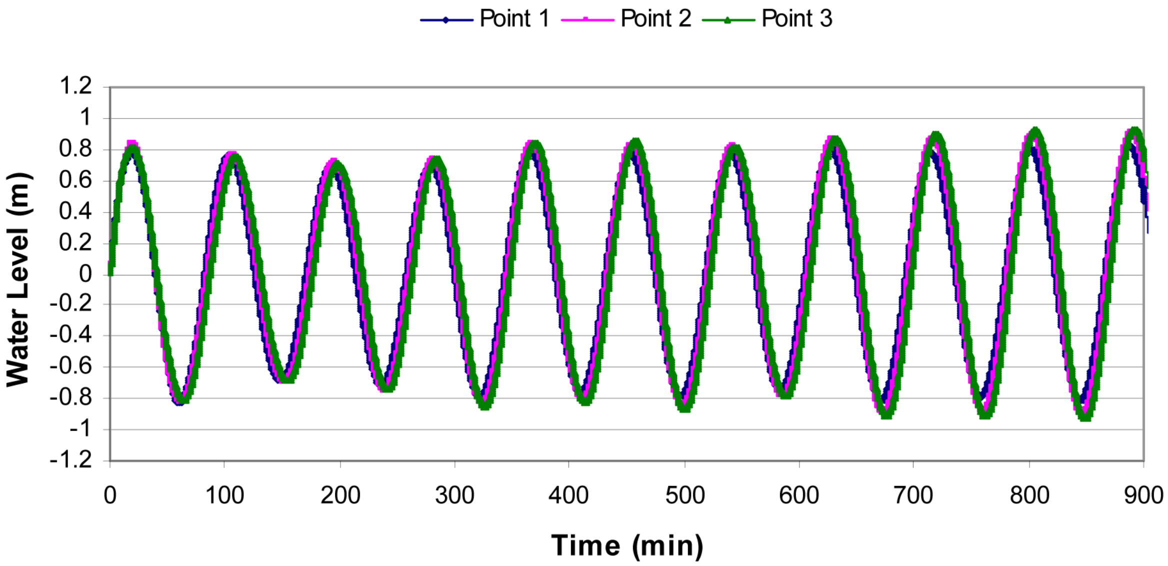


Figure 2.4-37— {Time History Of Tsunami Water Levels Case 1 through 3, Nonlinear Model}

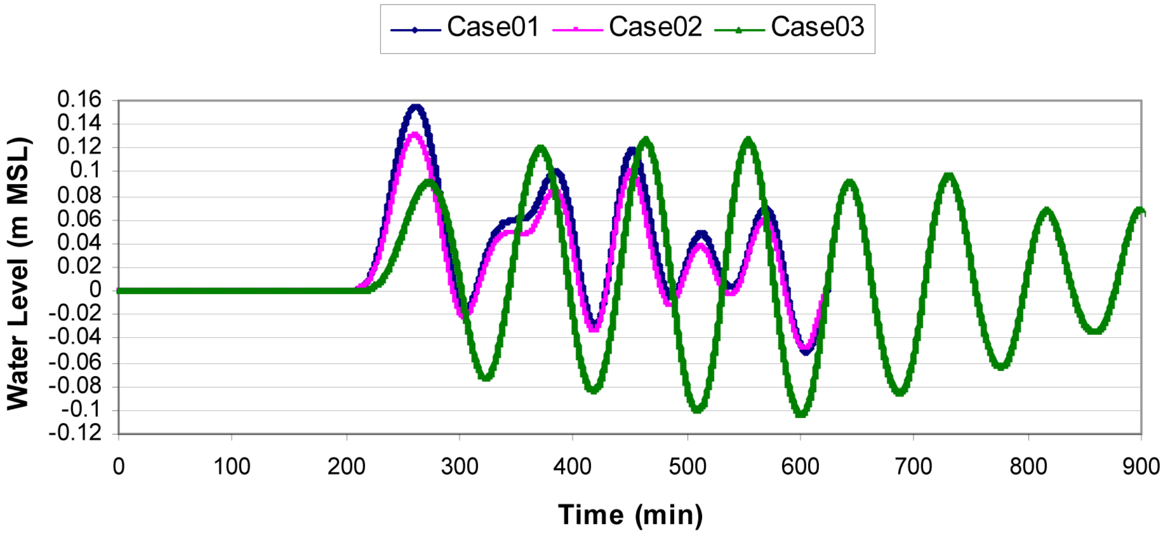


Figure 2.4-38— {Time History Of Tsunami Water Levels Case 1 through 3 Linear Model}

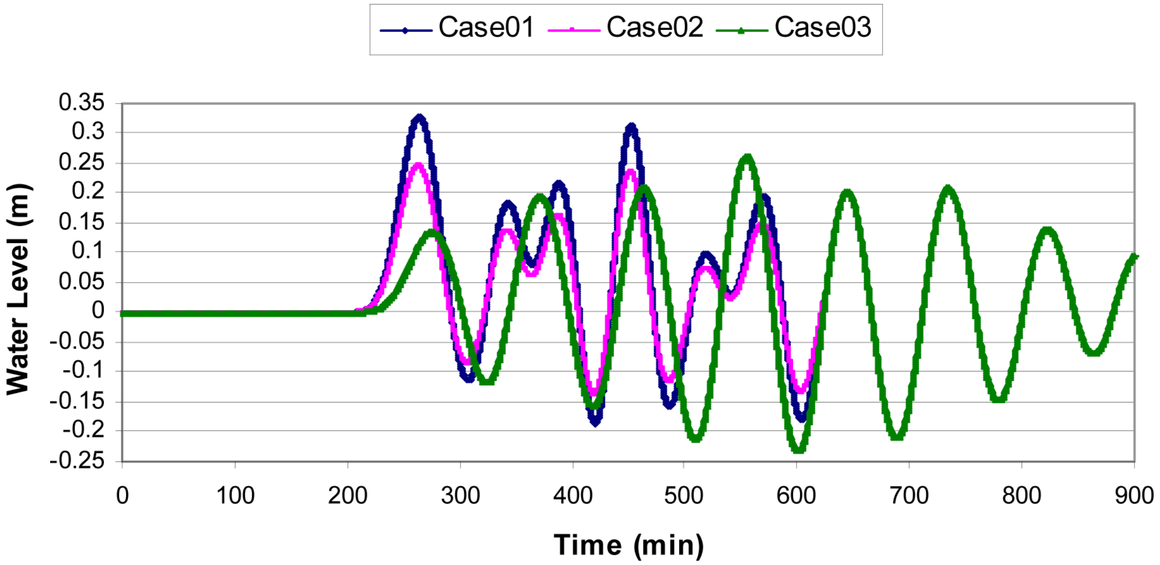


Figure 2.4-39— {General Site Region}

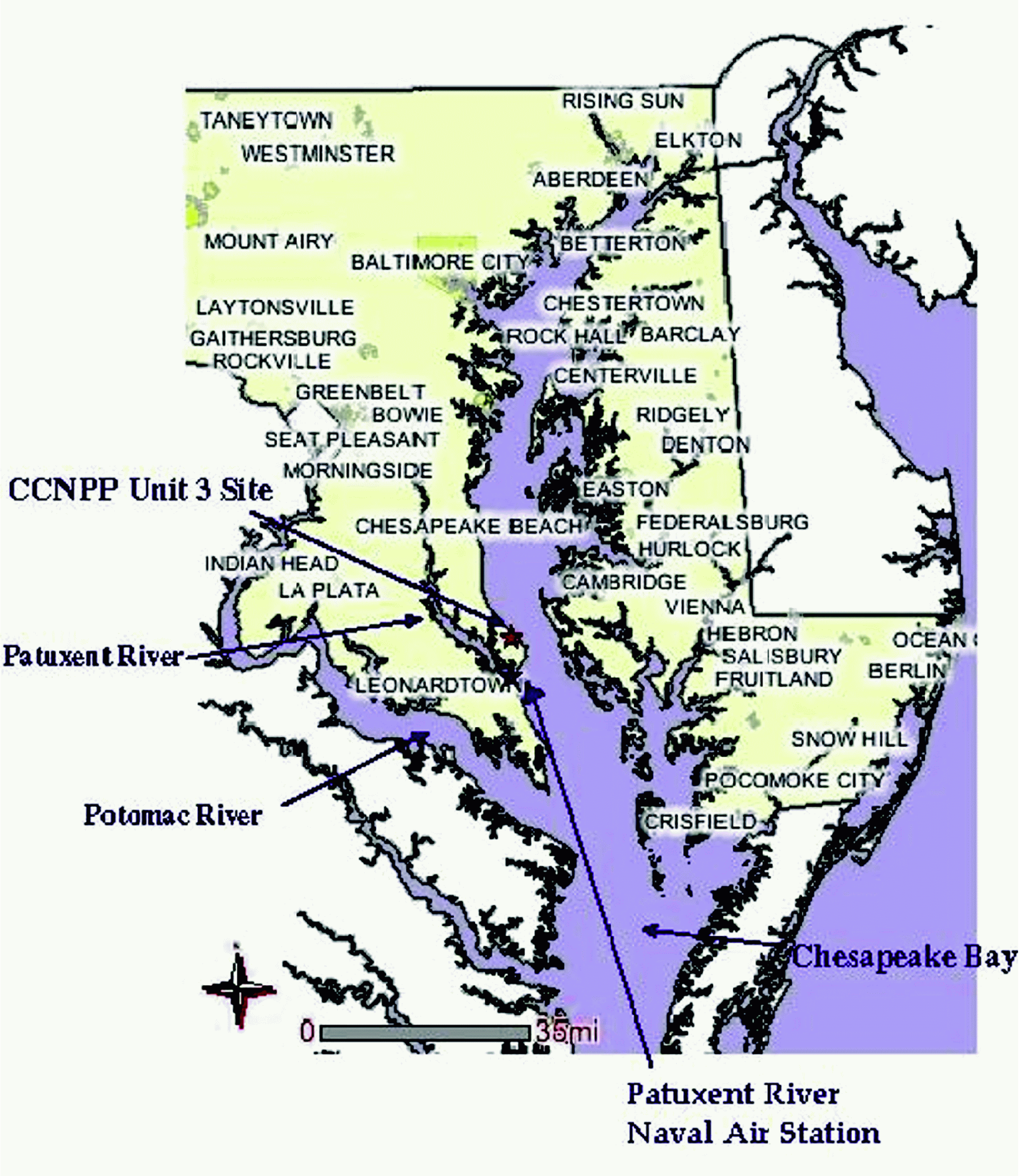
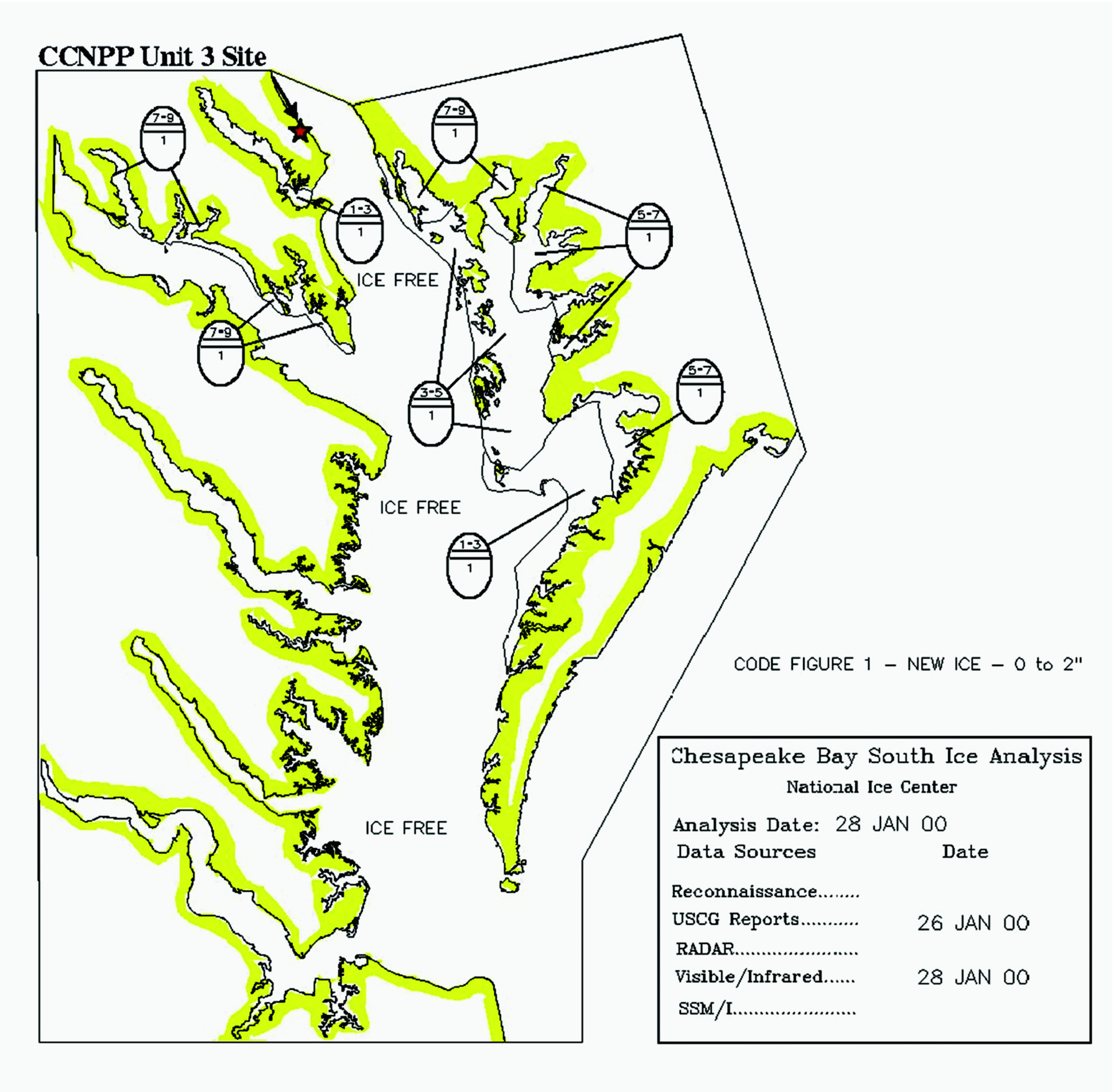


Figure 2.4-40— {South Chesapeake Bay Ice Analysis- January 28, 2000}



Chesapeake Bay South Ice Analysis
National Ice Center

Analysis Date: 28 JAN 00

Data Sources	Date
Reconnaissance........	
USCG Reports...........	26 JAN 00
RADAR.......................	
Visible/Infrared......	28 JAN 00
SSM/I.......................	

Figure 2.4-41— {South Chesapeake Bay Ice Analysis- February 01, 2004}

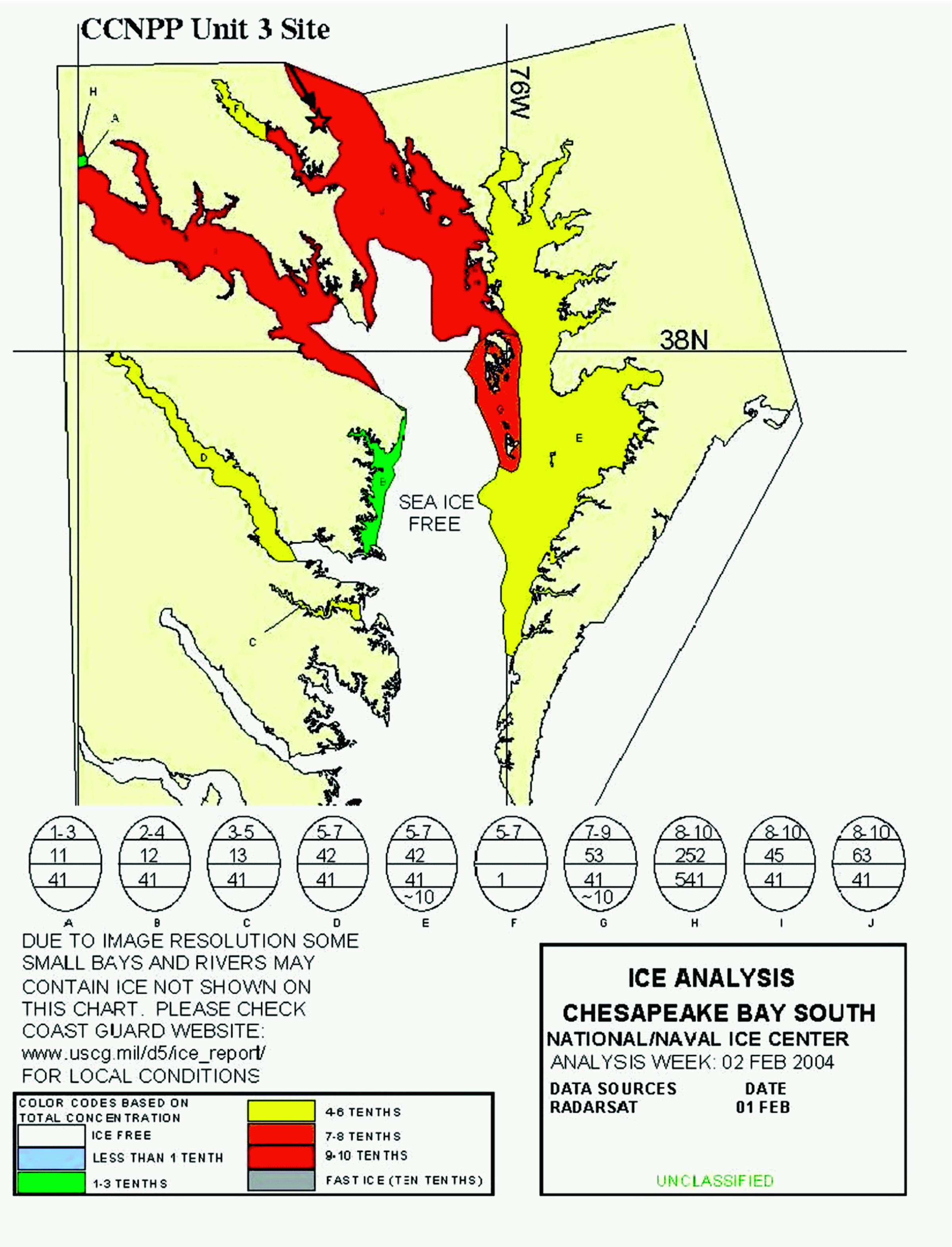


Figure 2.4-42— {South Chesapeake Bay Ice Analysis- January 24, 2005}

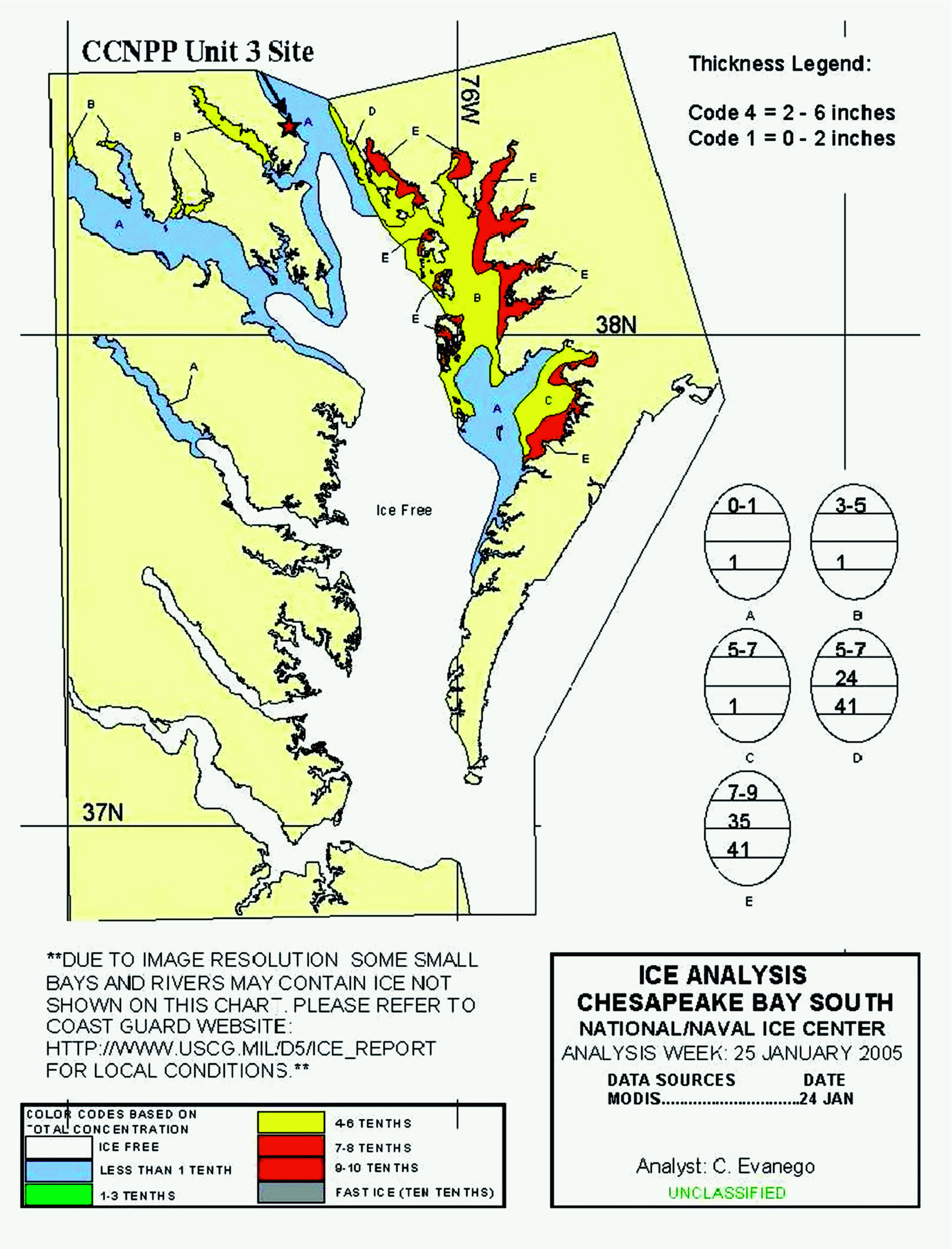


Figure 2.4-43— {South Chesapeake Bay Ice Analysis- January 26, 2005}

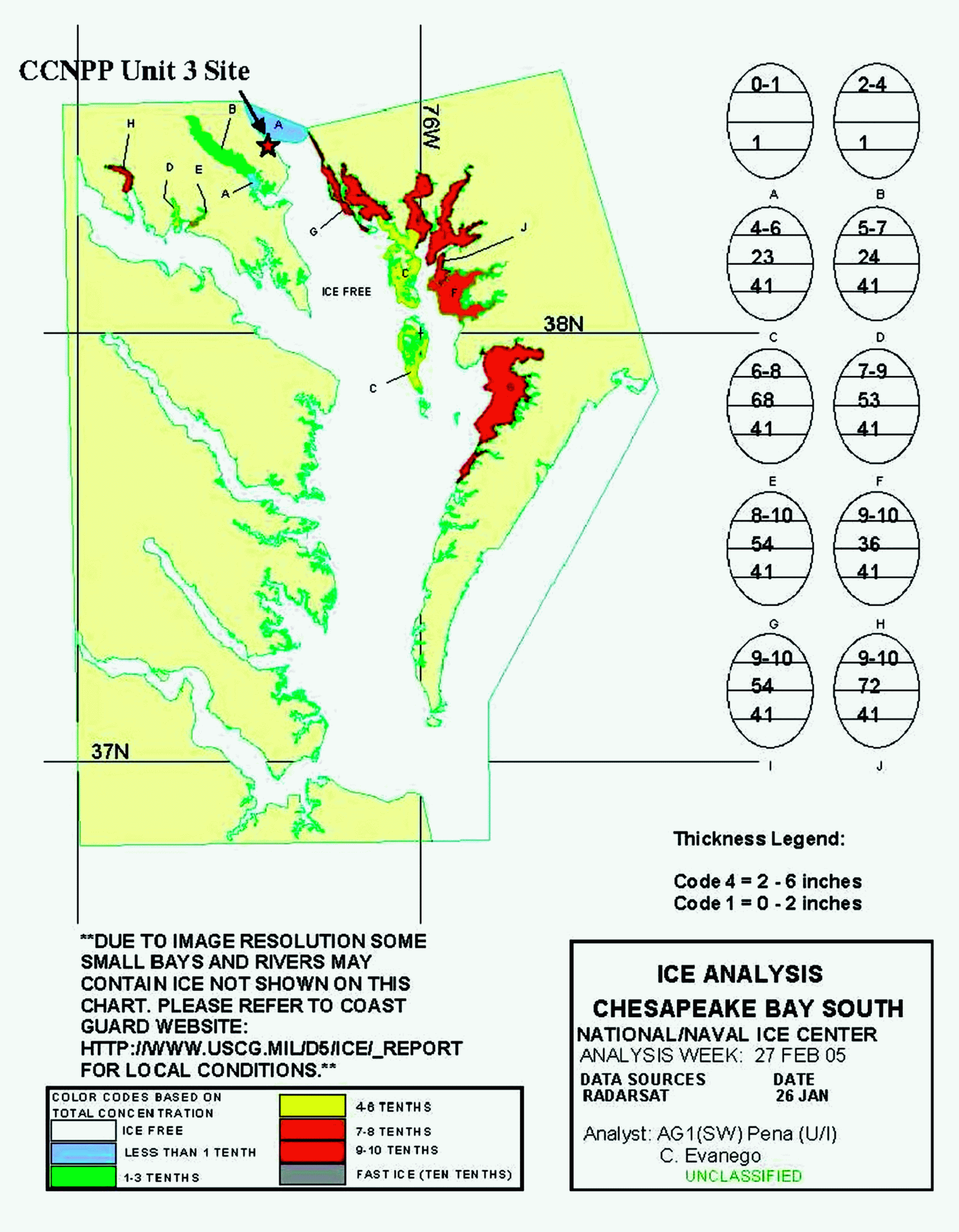
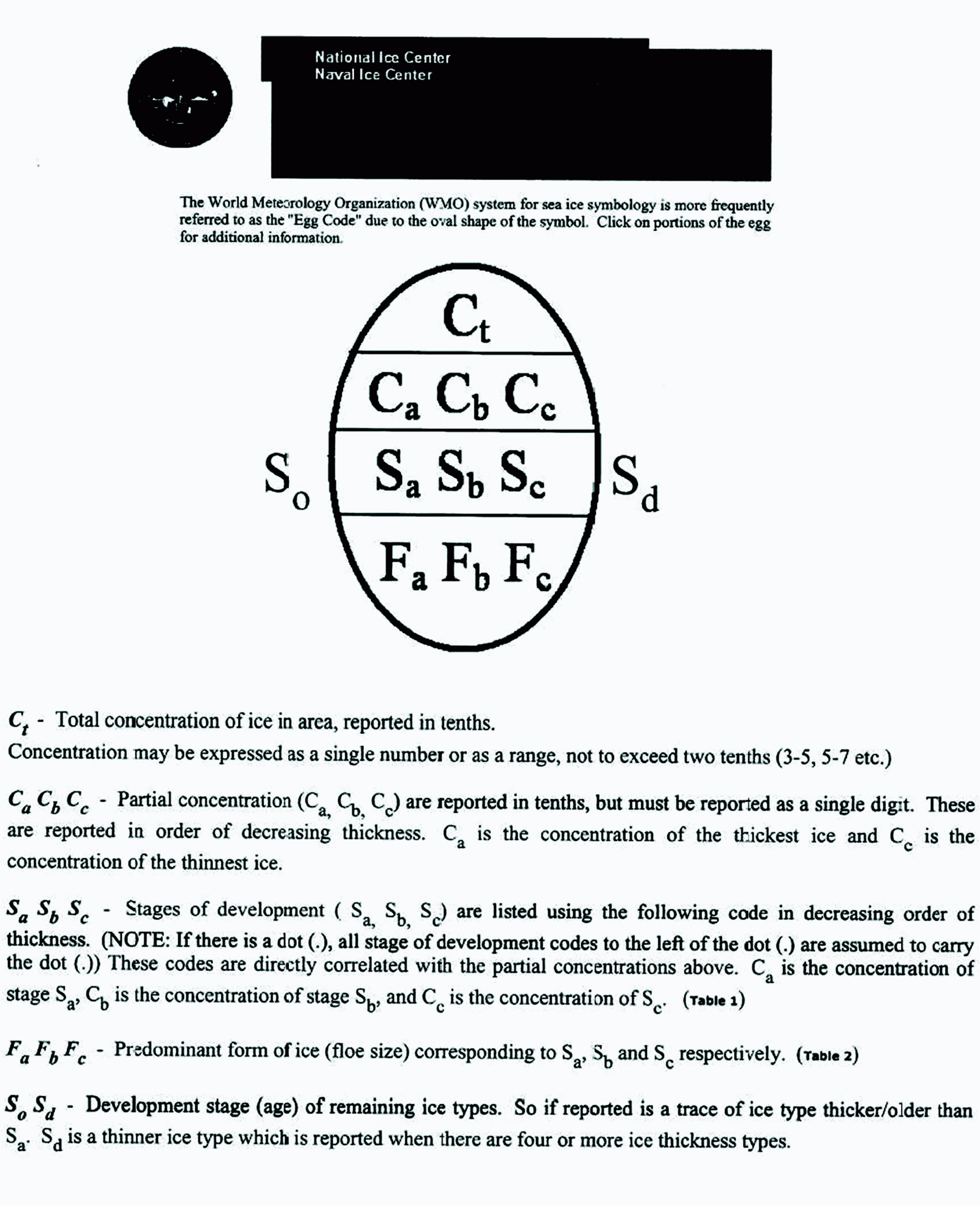


Figure 2.4-44— {EGG Code}



The World Meteorology Organization (WMO) system for sea ice symbology is more frequently referred to as the "Egg Code" due to the oval shape of the symbol. Click on portions of the egg for additional information.

C_t - Total concentration of ice in area, reported in tenths.
Concentration may be expressed as a single number or as a range, not to exceed two tenths (3-5, 5-7 etc.)

C_a C_b C_c - Partial concentration (C_a, C_b, C_c) are reported in tenths, but must be reported as a single digit. These are reported in order of decreasing thickness. C_a is the concentration of the thickest ice and C_c is the concentration of the thinnest ice.

S_a S_b S_c - Stages of development (S_a, S_b, S_c) are listed using the following code in decreasing order of thickness. (NOTE: If there is a dot (.), all stage of development codes to the left of the dot (.) are assumed to carry the dot (.)) These codes are directly correlated with the partial concentrations above. C_a is the concentration of stage S_a, C_b is the concentration of stage S_b, and C_c is the concentration of S_c. (**Table 1**)

F_a F_b F_c - Predominant form of ice (floe size) corresponding to S_a, S_b and S_c respectively. (**Table 2**)

S_o S_d - Development stage (age) of remaining ice types. So if reported is a trace of ice type thicker/older than S_a. S_d is a thinner ice type which is reported when there are four or more ice thickness types.