2.4 GEOLOGY

2.4.1 INTRODUCTION AND SUMMARY

This section of the report presents the results of the geologic phase of the environmental study. This phase of the study included a geologic investigation of the site and surrounding area, a review of pertinent geologic literature (References 1 through 23), and interviews with personnel from government agencies and private organizations (References 24 through 33). Subsurface geologic conditions within the site were investigated in detail by exploratory borings.

The site is underlain by approximately 2,500' of southeasterly dipping sedimentary strata of Cretaceous and Tertiary age. Underlying these sediments are crystalline and metamorphic rocks of Precambrian and Early Paleozoic age.

Sediments of the Chesapeake Group of Miocene age underlie the proposed plant area to a depth of about 200'. The material in this group consists of essentially horizontally-stratified sandy and clayey silt with occasional interbeds of sand and shells. It is relatively impervious and dense and provides adequate foundation support for the nuclear power plant. The Miocene sediments are underlain by dense, relatively pervious glauconitic sand and silt of Eocene age.

No known or suspected faults are present in the sedimentary strata underlying the site. The closest known faults are located in the Piedmont Province in Western Maryland, approximately 50 miles from the site.

The site is considered satisfactory, from a geologic standpoint, for construction and operation of a nuclear power plant.

2.4.2 REGIONAL GEOLOGY

2.4.2.1 Physiography

The site lies within the Coastal Plain Physiographic Province about 50 miles east of the Fall Zone. The Fall Zone separates the low-lying gently rolling terrain of the Coastal Plain from the higher relief of the Piedmont Physiographic Province. The provinces are shown on Figure 2.4-1, Regional Physiographic Map.

The Coastal Plain in Maryland is a low plain rising from sea level to about Elevation +250' at the Fall Zone. Relief in the region ranges generally from about 20 to 100'. The regional slope of the Coastal Plain is to the east at approximately 1.5 ft/mile. The topography of the region is characterized by a series of broad, step-like terraces. The terraces are successively less dissected by stream erosion from west to east. The region is well drained by a large number of small streams.

2.4.2.2 Stratigraphy

The general geologic characteristics of the region are shown on Figure 2.4-2, Regional Geologic Map. The Piedmont Province consists of a complex of igneous and metamorphic rocks of Precambrian and Early Paleozoic age with areas of sedimentary and igneous rocks of Triassic age. Beneath the Coastal Plain Province these rocks are concealed by younger strata of Cretaceous and Tertiary age. The buried surface of the basement igneous and metamorphic rocks slopes to the southeast at about 50 ft/mile. In the vicinity of the site, the surface of the basement complex is located approximately 2,500' below sea level. The Cretaceous and Tertiary strata consist 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 to the southeast and pinches out to the northwest toward the Fall Zone.

A generalized geologic cross-section of the Coastal Plain is presented on Figure 2.4-3, Regional Geologic Section. A detailed description of the stratigraphy at the site is presented on Figure 2.4-4, Geologic Columnar Section - Site Area.

2.4.2.3 Structure

The thick sedimentary strata of the Coastal Plain in the vicinity of the site have remained essentially undeformed since they were deposited up to 135 million years ago. They are believed to have been affected only by slow regional crustal downwarping during their deposition. No known faults have been identified within the Cretaceous and Tertiary sedimentary deposits in the site area. Some local, very shallow folds have been recognized in the Coastal Plain sediments about 40 miles south of the site. These structures are possibly related to depositional conditions rather than to post-depositional tectonic activity. The strata exposed for many miles along the Chesapeake Bay shoreline show no visible signs of faulting or deformation.

There is no known fault or geologic evidence of faulting in the deep crystalline rocks in the area. The absence of deformation in the overlying sediments indicates that no major faults are present in the area. Significant tectonic features of the region are shown on Figure 2.4-5, Regional Tectonic Map.

The closest known faults to the site are more than 50 miles to the west in the Precambrian and Early Paleozoic rocks of the Piedmont Physiographic Province. The rocks in the Piedmont are highly folded, and many zones of major faulting have been identified. Most earthquake activity in the region can be related to them. Some of these faults, the closest of which are located about 60 miles southwest of the site, theoretically could be projected beneath the Coastal Plan strata toward the general location of the site. However, such faults are local rather than regionally continuous and appear to be associated with individual fault troughs containing Triassic sediments. Concealed local faults of this type in the basement rock may be responsible for part of the minor earthquake activity in the Coastal Plain of Maryland.

2.4.2.4 Geologic History

The recognizable geologic history of the region begins with the deposition of Paleozoic sediments on a Precambrian granitic and metamorphic basement complex. Thick sequences of sedimentary rocks, which accumulated during the Cambrian and Ordovician Periods of geosynclinal deposition were subsequently uplifted, folded, faulted, and metamorphosed during the late Paleozoic Period of mountain building. This activity was followed by another period of uplift along the axis of the Appalachian Mountain chain at the end of the Triassic Period.

Slow regional downwarping of the Coastal Plain started during Early Cretaceous time and continued intermittently through Tertiary time. South and east of the Fall Zone the Piedmont was depressed below sea level providing a base on which the sediments were deposited. Several periods of submergence and emergence resulted in alternate deposition and erosion of continental and marine deposits throughout Cretaceous and Tertiary times.

Near the end of the Tertiary Period (Pliocene time) the area is believed to have been above sea level. This resulted in erosion of the sediments deposited

previously during Early Pliocene and Late Miocene time, so that Miocene sediments are presently exposed in the site area.

During Early Pleistocene time, the ocean advanced westward to the Fall Zone, completely covering the Coastal Plain. Fluctuating sea levels, occurring during Pleistocene time, resulted in alternating periods of erosion and deposition along what are now the major terraces and scarps of the region. A veneer of Pleistocene soils covers most of Coastal Plain. At present, the land is again being submerged by a very slow rise of the sea level.

2.4.3 SITE GEOLOGY

2.4.3.1 General

The site is located on the west shore of the Chesapeake Bay in an area characterized by densely wooded, low, flat to gently rolling terrain of low to moderate relief. Ground surface elevations at the site range from sea level to about +130', with an average Elevation of approximately +100'. Nearly vertical cliffs, over 100' high in places, are located along the shore of the Chesapeake Bay. The plant is located in an area near the east edge of the site where the preexisting ground Elevation was about +65'. The final grade Elevation is about +45'.

2.4.3.2 Surficial Deposits

The upland areas of the site (areas above Elevation +70') are underlain by sediments of Pleistocene age. These sediments consist primarily of silt and sand, and as encountered at the boring locations, range up to about 50' in thickness. The portion of the site below Elevation +70', which includes the plant area, is underlain by relatively impervious sediments of the Chesapeake Group of Miocene age. The contact between the Pleistocene and Miocene sediments is relatively even and slopes very gently toward the southeast. The surficial geology of the site is shown on Figure 2.4-6, Site Geologic Map.

2.4.3.3 Subsurface Deposits

The details of the subsurface geology were investigated primarily by means of ten exploratory borings at the locations shown on Figure 2.4-7, Plot Plan.

The borings ranged in depth from 146' to 332' and were drilled with truck-mounted rotary drilling equipment. Data were obtained from the borings through continuous observation of drill cuttings and examination of undisturbed samples collected by Dames & Moore geologists and engineers.

The soil samples were obtained at intervals in each boring ranging between 3-1/2 and 15', utilizing the Dames & Moore soil sampler illustrated on Figure 2.4-8, Soil Sampler Type U. A few samples were obtained using a standard split-spoon sampler. The number of hammer blows required to drive the sampler a distance of 1' into undisturbed material is recorded in the column entitled "blow count" on the left side of each boring log. The energy used to advance the samplers was greater than that in a standard penetration test, resulting in generally lower blow counts.

All samples were examined and logged in the field and then shipped to Dames & Moore's New York office for further examination and appropriate laboratory testing. Detailed descriptions of the materials encountered in the borings are shown on Figures 2.4-9A through 2.4-9J, Logs of Borings. The type of sampler used and data relative to the energy used to advance the sampler are presented on the logs

of borings. The depth of ground water after completion of drilling operations and the date on which the borings were completed also are presented on the logs.

The site is underlain by a relatively simple sequence of strata, which is shown on Figures 2.4-10A, 2.4-10B, and 2.4-10C, Geologic Sections A-A, B-B, and C-C, respectively. Details of the strata exposed along the shore of the Chesapeake Bay are illustrated on Figure 2.4-11, Schematic Cliff Section, Plant Area.

The Chesapeake Group is approximately 270' in thickness and occurs between Elevation +70' and Elevation -200'. It is composed primarily of gray and green, fine sandy and clayey silt which is relatively impervious. Occasional interbeds of sand and small shells are present, particularly in the upper portion of the group. The upper 15 to 30' of the Chesapeake Group, where exposed in the plant area, have been highly oxidized by weathering.

The Chesapeake Group in the region has been divided from top to bottom into the St. Mary's formation, the Choptank formation, and the Calvert formation. For purposes of this study, these formations are essentially identical.

Eocene deposits consisting of about 350' of dense, relatively pervious, green, interbedded glauconitic sands and silts with some clays are present below Elevation -200'. The uppermost Eocene deposit, the Piney Point formation, is approximately 40' thick and is composed primarily of glauconitic sand. Because this formation is continuous and distinctive, it provided an excellent horizon for correlation stratigraphy at the site. The contact between the Chesapeake Group and the Piney Point formation occurs at about Elevation -200' and is essentially horizontal throughout the site.

The deeper sediments underlying the Piney Point formation (below an Elevation of about -240') were not investigated, but they have been identified in nearby water wells. The names and descriptions of these formations are shown on Figure 2.4-4.

No evidence of faulting was observed at the site in surface outcrops, in the borings, or in the results of the geophysical surveys. A good correlation of subsurface stratigraphy was obtained between the borings. The strata exposed along several miles of the western Chesapeake Bay shoreline in the vicinity of the site show no visible deformation. A view of the slightly dipping strata is shown on Figure 2.4-12, Cliff Face Photograph - Plant Site Vicinity.

A poorly developed crack pattern, believed to be related to desiccation, is exposed in outcrops of the Chesapeake Group strata. These cracks are noticeable in places along the cliffs facing the Chesapeake Bay in material where the effects of weathering are pronounced.

2.4.4 SHORE EROSION

The cliffs bordering the Chesapeake Bay along the east side of the site have receded due to shoreline erosion at a maximum rate of about 2' per year. This rate of erosion was calculated from records of measurements made along the shore from 1848 to 1945. The measurements were updated to 1967 by means of recent topographic maps and aerial photographs.

The data indicate that the shoreline at the site receded a maximum of 200' between 1848 and 1945. The average rate of recession along various sections of the eroded coast, including part of the site, has ranged up to 2.1' per year. Changes along the shoreline are shown on Figure 2.4-13, Shoreline Changes.

A field check on the rate of shore erosion was provided by an unidentified monument located near the southeast corner of the site. The inscription on this monument reads: "The bank was 55' from this line[1] in August 1936." On September 8, 1967, the bank was only 36' from the monument. Therefore, 19' of bank recession has occurred at this location since 1936, representing an average of 0.6' per year.

Shoreline recession along the site is due mainly to wave erosion, particularly storm waves, undercutting the cliff. This results in sloughing of the overlying material. Generally, only the surficial 1'-2' of the cliff face slough at any one time. In the proximity of localized jointing, up to 5' of the cliff face may slough at one time.

Records show that 645 acres of land along a 31.3 mile section of the shoreline in Calvert County were lost between 1848 and 1945 due to erosion. However, during the same interval of time, 115 acres were gained by redeposition.

Approximately 3700 lineal ft of shore protection has been placed in front of the plant area, as shown on Figure 1-3A. The shore protection consists of onsite material placed in front of the cliffs and faced with filter cloth and layered riprap.

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[1] Line refers to an engraved line on top of the monument.

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