Chapter 3 Virginia's Environmental Resources

Virginia is a state defined by its natural resources. Unlike many western states that have boundaries based on latitude and longitude, most of the states founded initially by English colonists have boundaries defined by natural features. Most of Virginia's state and county boundaries are defined by a combination of natural features, especially rivers and divides, and straight survey lines. Even when straight survey lines were used to define Virginia's boundaries, natural features were used as a point of origin. Virginia's boundaries are marked by the Atlantic Ocean to the east; a non-natural, almost straight line based upon latitude to the south; the Potomac River (generally) to the north; and mountains that divide watersheds to the west.

This Chapter provides an overview of the Commonwealth's climatic characteristics and the relationship between climate and vital surface water and groundwater resources. Hydrology and water budgets are discussed along with a description of existing geologic conditions and their potential effects on the quality and quantity of groundwater.

Climate

Virginia's temperate climate is actually quite diverse. According to the Virginia State Climatology Office, the State has five different climate regions: Tidewater, Piedmont, Northern Virginia, Western Mountain, and Southwestern Mountain (see Table 3-1). Virginia's latitude, topography, prevailing westerly winds, and the influence of the Atlantic Ocean determine the climate. Average temperatures in the State generally decrease from southeast to northwest, with two particularly distinct areas. The Coastal Plain physiographic province, moderated by the Atlantic Ocean, has fewer hot and cold days, less snowfall, and a longer growing season than is typical for the rest of the Commonwealth. Because of its elevation, the Appalachian Plateau physiographic province has fewer hot days, more cold days, and more snowfall than the rest of the Commonwealth.

Most of Virginia is considered to have a "humid, sub-tropical" climate east of the Blue Ridge. West of the Blue Ridge in the southern part of the Shenandoah Valley and the Roanoke Valley, the climate is classified as "humid continental" and "maritime temperate" with lower humidity and cooler temperatures by an average of 5 to 10 degrees in all four seasons.

Climate Region	Average Temperature January (°F)	Average Temperature July (°F)
Tidewater (includes Tidewater & Hampton Roads, southern Chesapeake Bay and Eastern Shore)	35-48	71-85
Piedmont (includes Central Virginia)	27-47	68-88
Northern Virginia (includes Northern VA and northern Chesapeake Bay area)	19-42	61-86
Western Mountain (includes Shenandoah Valley)	27-45	65-87
Southwestern Mountain (includes southwest Blue Ridge Highlands and the Heart of Appalachia)	22-44	60-85

Table 3-1: Average Precipitation for the five climate regions within Virginia[52]

In addition to being temperate, Virginia is also a well-watered State, with frequent rainfall that is not normally severe enough to cause flooding. Between 1981 and 2010, the annual average for total precipitation in Richmond was 43.6 inches, and 46.5 inches in Virginia Beach[53]. Average annual precipitation varies across climate regions from approximately 38 inches in Northern Virginia to approximately 47 inches in the Southwestern Mountain region (see Figure 3-1). Despite typically generous rainfall, Virginia has experienced severe droughts in the past: significant multi-year drought events occurred in 1930-1932, 1962-1971, 1985-1988, and 1999-2002.

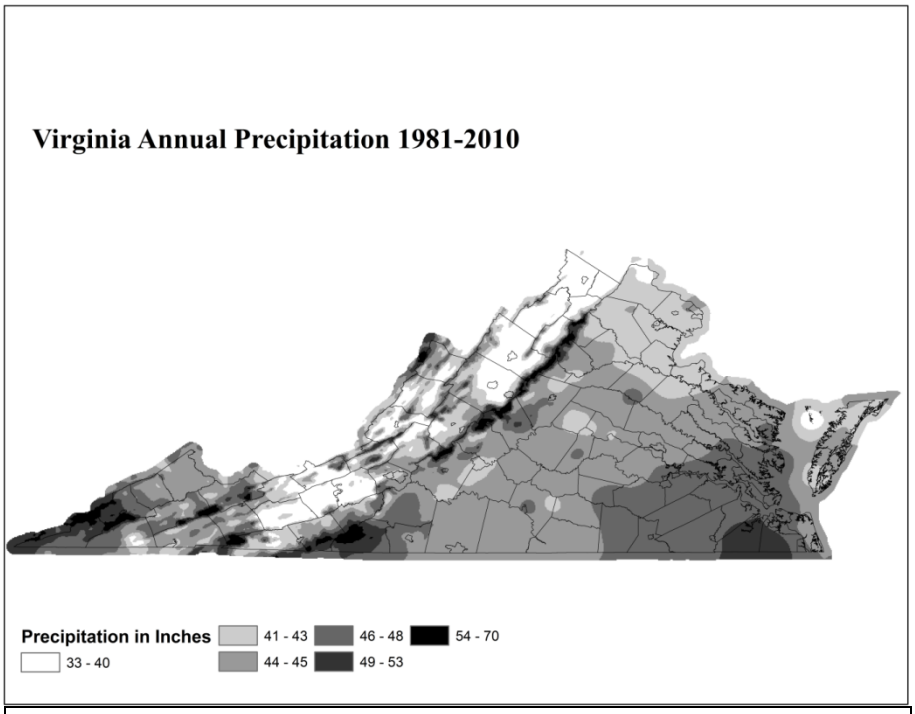

Figure 3-1 Average Annual Precipitation across Virginia

[52] Southeast Regional Climate Center: http://www.sercc.com/
[53] National Climatic Data Center, *NOAA's 1981-2010 Climate Normals*

Influences of Landscape, Rivers, and Streams on Climate

The landforms in these climate regions contribute to local climate in three ways. First is proximity to the coast and the warm waters of the Gulf Stream. As moisture-laden air crosses the coast of Virginia, storms grow in size and intensity, impacting the eastern slopes and foothills of the Blue Ridge Mountains. The great coastal storms of 1962, remembered primarily because of the high surf and storm surges along Virginia's coast, also produced record snowfalls along the northern section of the Blue Ridge Mountains.

The character of Virginia's streams is a direct reflection of the geologic and physiographic provinces over which they flow.

Secondly, the relatively high relief of the Appalachian and Blue Ridge mountain systems influence Virginia's climate by causing a rain shadow effect through which storms drop abundant precipitation on the windward side of the mountains and little precipitation on the leeward side. Along the southwest to northeast trending mountain chains of western Virginia, storm directions are sometimes from the west and sometimes from the east. When the flow is from the west, the New River and Shenandoah River Valleys are in the rain shadow of the Appalachian Mountains; when the airflow is from the east, they are in the shadow of the Blue Ridge Mountains. As a result, portions of the New River and Shenandoah River Valleys are among the driest portions of the Commonwealth.

Virginia's complex pattern of rivers and streams that drain precipitation and modify the pattern of moist airflow is the third important contribution to climate. Virginia's river systems drain the Commonwealth's terrain in all four geographical directions. In far southwestern Virginia, the Clinch and Holston Rivers drain south into North Carolina and Tennessee. The New River flows northwestward into the Ohio River, while the Shenandoah River drains northward into the Potomac River. Finally, the Chowan, James, Rappahannock, Roanoke, and York Rivers drain eastward through the Piedmont and into the Coastal Plain. The air moving across Virginia flows either up these river valleys or over the crests of the mountains and down into the valleys, and weather patterns change depending upon which way the river flows. As an example, a flow of moist air from the south would move up the Holston River Basin, increasing rainfall up river at higher elevations. However, this same southerly airflow would be downhill into the New River drainage, and on toward the Ohio River Basin, a phenomenon that is not conducive to rainfall.

Hydrology of Virginia

Hydrology is the study of the waters of the earth on and below the surface of the planet. Hydrology also involves the study of the various properties of water and its relationship with the living and nonliving environment. Over most of Virginia, abundant precipitation causes a significant amount of runoff to streams, lakes, and rivers. Consequently, the hydrologic system is dominated by surface water features.

Virginia has over 50,000 miles of streams and rivers which are part of nine major river basins: Albemarle-Chowan, Chesapeake Bay-Small Coastal, James, New, Potomac-Shenandoah, Rappahannock, Roanoke, Tennessee-Big Sandy, and York. A summary description of each of these major river basins is included in Appendix B, Major Basin Summaries.

The character of Virginia's streams is a direct reflection of the geologic and physiographic province over which they flow. Valley and Ridge streams flow briskly down linear valleys between parallel ridges. Northern Blue Ridge streams fall rapidly from ridge crests to the low country on either side of the range. Only the James, Potomac, and Roanoke Rivers breach the Blue Ridge. Streams meander across the Piedmont with low to moderate gradients, but drop swiftly to the Coastal Plain in the Fall Zone. Coastal Plain streams have low gradients and become wide estuaries as they approach the Chesapeake Bay.

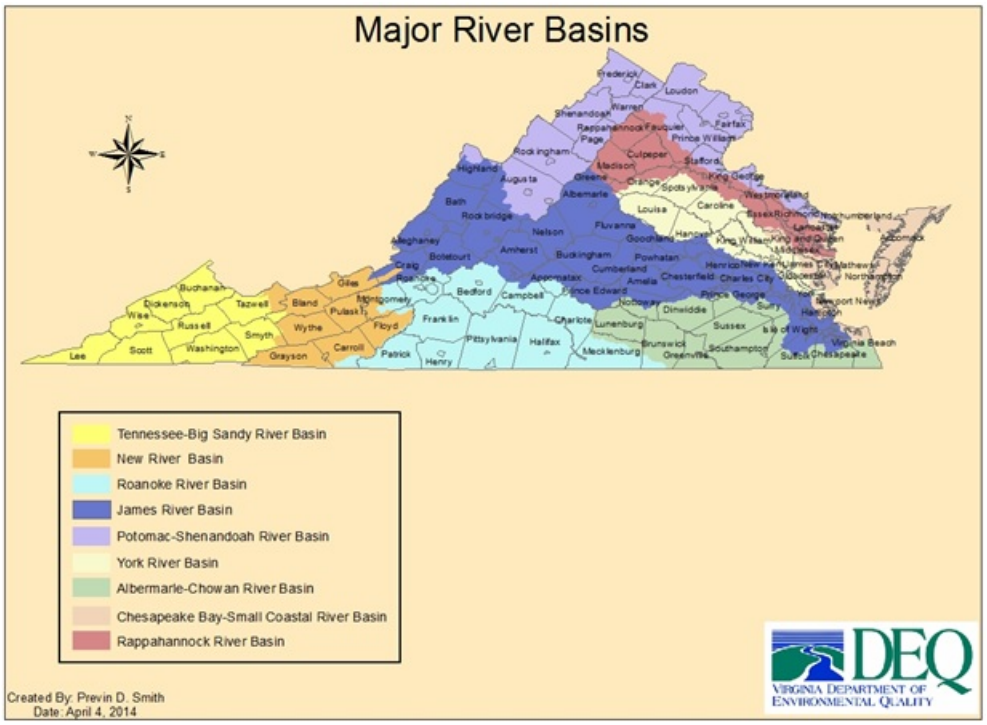

Figure 3-2: Virginia's Major River Basins

Virginia also contains a significant number of reservoirs formed by constructing dams across streams and rivers. The 248 publicly-owned lakes in the Commonwealth have a combined area of 130,344 acres. Three large impoundments (Lakes Gaston, Kerr, and Smith Mountain) account for two-thirds of this total. Many thousands of other smaller, publically and privately-held lakes, reservoirs, and ponds, some of significant size, dot the landscape. There are only two natural lakes in Virginia: Lake Drummond in Great Dismal Swamp and Mountain Lake in southwestern Virginia. Other significant water features of Virginia include approximately 236,900 acres of tidal and coastal wetlands, 808,000 acres of freshwater wetlands,

120 miles of Atlantic Ocean coastline, and over 2,300 square miles of estuaries. Virginia's highly indented shoreline, including the Chesapeake Bay and its sub-estuaries, is conservatively estimated to be 3,315 miles long. The total combined flow of all freshwater streams in the State is estimated at about 25 billion gallons per day. Maps of major rivers, streams, reservoirs, and lakes can be found in Appendix B, Major Basin Summaries.

Hydrologic Cycle and Virginia's Water Budget

The natural sequence through which water travels across or beneath the earth's surface and between the earth and the atmosphere is referred to as the hydrologic cycle. A water budget is an accounting of the input and output components of this cycle for a particular place and time. Ideally, input equals output minus any change in storage within surface water and groundwater reservoirs. With reasonable planning and informed decisions, a water budget can be a useful tool in water resource management.

For Virginia, a long-term water budget can be estimated by examining evaporation, precipitation, and streamflow data collected over several decades and assuming that 1) groundwater infiltration equals groundwater discharge to surface waters as baseflow, and 2) changes in storage over this period are negligible. Inputs include precipitation and surface water inflow. Evapo-transpiration, the combined release of water from the earth's surface via evaporation plus transpiration from plants, is the major output from the system. Surface water outflow from the major river basins, either westward to adjoining states or to the Chesapeake Bay, make up more than 25% of the total output. For comparison, statewide withdrawals of surface water and groundwater during 2012 (excluding those for power generation) totaled 1,221 million gallons per day, or approximately 1.4% of total outflow.

Virginia's Long-Term Water Budget:

Inflow:
Precipitation: 43 inches/year (87,172 mgd)
Surface water: 1 inch/year (2,974 mgd)
Inflow Total: 44 inches/year (90,146 mgd)

Outflow:
Evapotranspiration: 32 inches/year (65,146 mgd)
Surface water: 12 inches/year (25,000 mgd)
Outflow Total: 44 inches/year (90,146 mgd)

A statewide water budget based on long-term averages can be misleading. Although long-term average annual precipitation and evaporation do not vary by more than several inches across the State, the temporal variation at any particular location can vary tremendously month to month and year to year. Evapotranspiration has a significant seasonal variation, with the greatest amount occurring during the warm months of the growing season. Precipitation can range from well below normal over long periods during drought years to well above normal during wetter than average years. Figure 3-3 illustrates the variation in monthly precipitation at a station in central Virginia during the period from 1998 through 2004. During the drought years of 1999 through 2002, precipitation was below average during most months.

During the following wetter period of 2003 through 2004, monthly precipitation exceeded the long-term average during most months.

Because these largest input and output components of the water budget vary so much over short periods of time, the other components also change over relatively short periods. Over a time scale of a few years or less, groundwater and reservoir storage changes are significant and perhaps always in a state of flux, and there is a lag in time between groundwater recharge and the discharge of groundwater to streams as baseflow. During drought years when low precipitation results in low streamflow levels and decreased reservoir storage, the impact of water withdrawals becomes magnified, particularly during summer months when water withdrawal demands and evapotranspiration rates are at their maximum levels. During extended, multi-year droughts, low precipitation during winter months results in less recharge to the groundwater flow system. Consequently, the lower groundwater levels produce less baseflow to streams during the following summers, which further impacts streamflows and can also negatively affect the availability of water for off-stream beneficial uses.

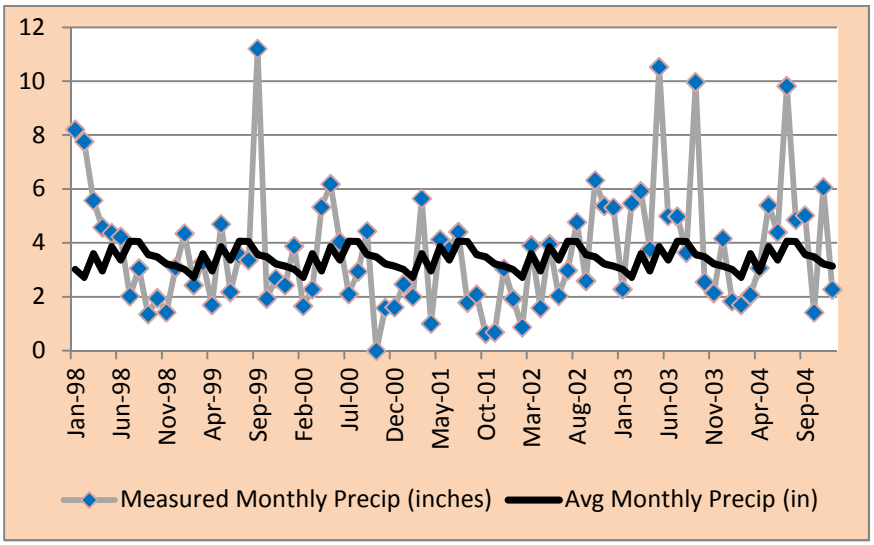

Figure 3-3: Measured monthly precipitation and long-term average precipitation at Bremo Bluff, Fluvanna County: 1998-2004

Geology and Groundwater

Virginia is over 400 miles wide along its southern boundary, reaching from the Atlantic Ocean in the east, crossing the eastern continental divide into the Mississippi Basin to the west. Much of the precipitation Virginia receives in any given period of time runs off into streams and rivers, while the rest returns to groundwater. Groundwater exists in underground pore spaces between rock particles and sediment grains, and in openings such as cracks, faults, fissures, and solution cavities within the rocks and unconsolidated sediments. The available quantity of groundwater depends on the number and size of the pore spaces and openings and the water permeability of the rocks.

Virginia crosses five physiographic provinces. The physiographic and geologic characteristics of each province are discussed in the following sections of this Chapter, as are the potential effects of those characteristics on the quality and quantity of groundwater.

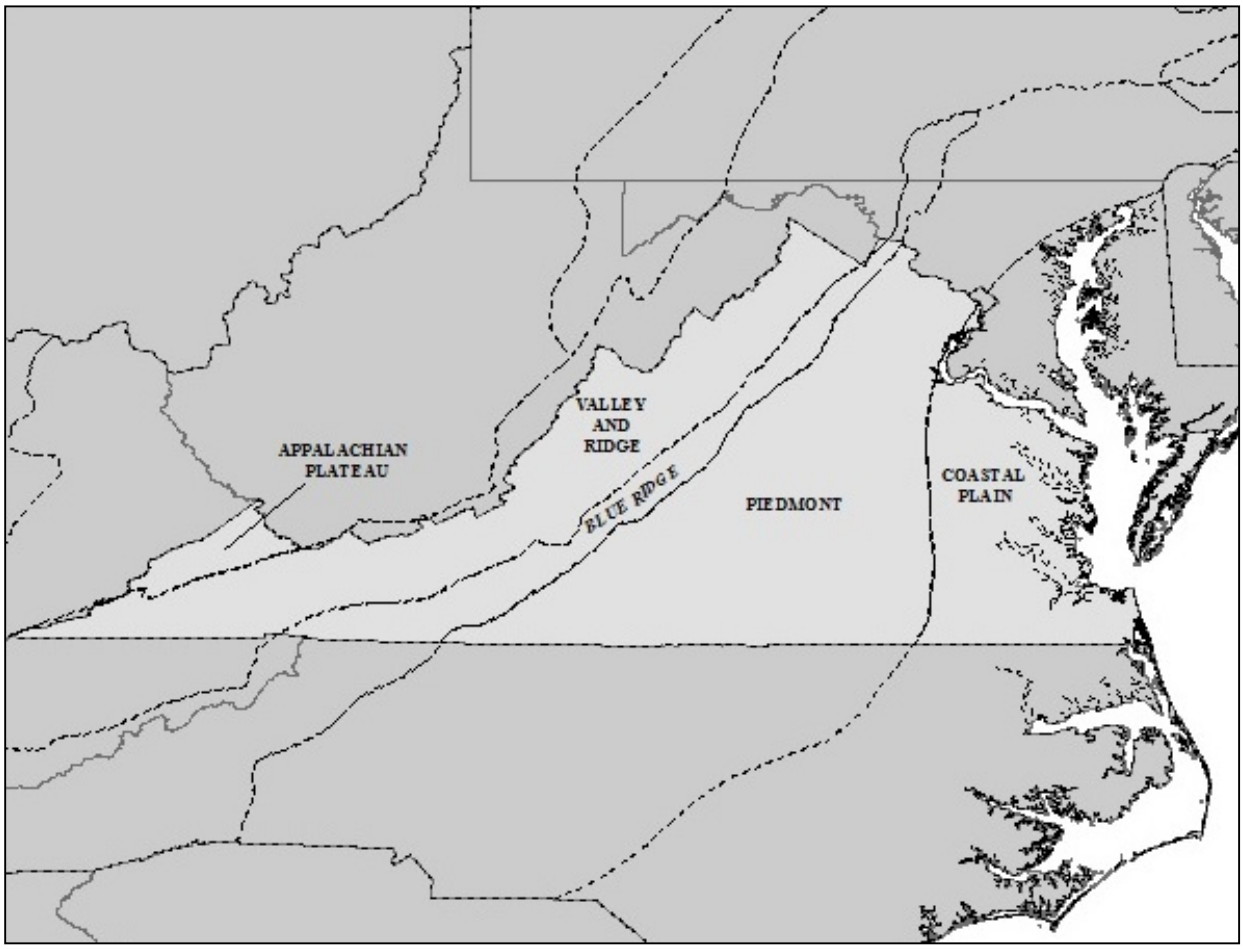

Figure 3-4: Physiographic Provinces of Virginia

Appalachian Plateau Physiographic Province

The Southwestern portion of Virginia lies in the Appalachian Plateau Physiographic Province, northwest of the Valley and Ridge Physiographic Province, characterized by rugged, well-dissected landscape with dendritic drainage patterns. Rocks in the Appalachian Plateau are sedimentary, horizontally lying or broadly and gently folded, with a dendritic drainage pattern (where stream valleys keep splitting in a random pattern). Older Cambrian rocks form basement layers, with younger Pennsylvanian rocks on top often exposed due to present day erosion. Commonly, the top-most Pennsylvanian rocks are composed of hard sandstone, forming mountain tops and containing coal. Rivers have eroded deep valleys into the sandstone to expose softer rocks below. Elevations in the Appalachian Plateau range from 1,000 feet to 3,000 feet above sea level, with High Knob near Norton, VA rising to over 4,000 feet. Average elevations range from 2,000 feet to 2,500 feet above sea level.

The Appalachian Plateau Province encompasses two sub-provinces, the Allegheny Plateau and the Cumberland Plateau. The boundary between the two sub-provinces is a feature known as the Allegheny Front, lying near the New River in West Virginia. The Allegheny Front is an area of transition between the upturned edges of the Appalachian Plateau, where the horizontal beds of the Plateau give way to the folded beds of the Valley and Ridge. The Appalachian Plateau is only structurally a plateau: some parts of the Plateau exhibit a low relief, plateau-like morphology; however, much of the Appalachian Plateau is strongly dissected by stream erosion. The resulting topography is rugged, with small, narrow valleys (or hollows) twisting through the resulting mountains. The older surface is evident in the pattern of hilltops, all tending to reach the same elevation.

Only a small portion of Virginia lies in the Appalachian Plateau Province and is located entirely in the Cumberland Plateau sub-province. The surface of the Cumberland Plateau is underlain by the same Paleozoic sedimentary rocks as the Valley and Ridge - principally sandstone, shale, and coal. While the sedimentary rocks are similar, in the Cumberland Plateau sub-province, these rocks have not been deformed and still occur in horizontal beds.

Groundwater quality in the Cumberland Plateau sub-province is generally poor due to high acidity and concentrations of iron, manganese, sulfates, and total dissolved solids. Quality varies with depth, with the first 100 feet of rock below stream level often being of poor quality, and naturally saline waters occurring at depths greater than 300 feet. Better quality water can be found at depths of 150 to 300 feet below stream level; however, in coalmining areas, some groundwater has become acidic due to mine drainage and is usually unsuitable for most uses. Because of these naturally occurring quality issues, establishing a well with dependable water quality and quantity can be an investment in time and money. Delineation of the source for implementation of protection practices is also a challenge.

Reported groundwater use is relatively low for this region. Groundwater extraction rates are likely higher due to the amount used for mining, which is generally exempt from annual withdrawal reporting (See Chapter 2 Virginia's Collaborative Water Management Framework). Well depths range from four to 1,738 feet, but median value is 150 feet below land surface.

Well-cemented sandstone is ubiquitous throughout plateau rock formation; therefore, secondary permeability features such as bedding-plane separations, open fractures, and cleats found in coal beds account for the majority of groundwater movement in the region. Downward groundwater gradients exploit stress-relief fractures along valley walls and result in localized, shallow flow systems that ultimately discharge near valley floors. Regional groundwater movement is likely dominated by enhanced secondary permeability along coal-bed cleats. Groundwater transmissivity along coal seams is of greater magnitude than all other rock types or lithologic contacts in the plateaus and, in general, transmissivity for all rock types decreased significantly at depths below 300 feet[54]. Harlow and Lecain also noted predominantly downward gradient flow within boreholes that intercepted multiple water bearing zones.

Valley and Ridge Physiographic Province

The geology of the Valley and Ridge Physiographic Province consists of Cambrian to Mississippian sedimentary rocks that were faulted, tilted, and folded during the Pennsylvanian and Permian periods. The rocks are found in thrust-fault bounded blocks that repeat the rock layers in parallel sandstone ridges and shale and carbonate valleys. This construction forms a trellis drainage pattern formed by rivers forced to run parallel to long ridges. Consolidated sedimentary rocks deposited beneath ancient seas underlie the Valley and Ridge Province and include limestone, sandstone, dolomite, and shale.

The western boundary of the Valley and Ridge Physiographic Province is the Alleghany Front, marking an abrupt change from the flat lying rocks of the Plateau to the folded/faulted rocks in the Valley and Ridge. In general, the more resistant sandstones and shale are the rock types often present in the ridges and upland areas, protecting the softer bedrock below from erosion, but yielding only enough water for rural and domestic supplies. In the lowlands, such as the Shenandoah Valley, limestone and dolomite occur beneath the surface forming the most productive aquifers in Virginia's consolidated rock formations. It is an area of well-developed karst topography created by the erosion of the limestone over thousands to millions of years, characterized by features such as sinkholes, caves, sinking streams, and large perennial springs. In many parts of the carbonate Valley and Ridge, springs remain extremely important water resources for individual, community, and industrial water supply. Spring discharges in this terrain commonly exceed several hundreds to thousands of gallons per minute (GPM) with a maximum recorded discharge of 16,646 GPM. Discrete spring discharges have been shown to account for between 65 and

[54] Harlow and Lecain, 1993

97% of surface streamflow in this terrain[55]. Sustained well yields of over 1,000 GPM have been demonstrated in portions of the carbonate valley and ridge, especially in areas overlain by unconsolidated siliciclastic overburden shed from the western slope of the Blue Ridge Mountains.

The connection between groundwater and surface water plays a major role in groundwater recharge in the Valley and Ridge Province, where streams often cross fault zones recharging aquifers. Wells in the fault zones have the greatest yields. Recharge also occurs through surface runoff into limestone sinkholes, bypassing filtration through the soil. This can cause serious water quality problems, because polluted surface water may be introduced directly into the groundwater system. Groundwater quality can also be adversely affected by private trash dumps located in sinkholes that receive surface run-off. In addition, carbonate formations contribute to the "hardness" of the groundwater. The karst limestone terrain in the valley poses difficult problems for wellhead protection area delineation, because underground conduits may act much like surface rivers. Some studies have suggested that surface water drainage patterns may be the best way to delineate wellhead protection areas in such circumstances.

Blue Ridge Physiographic Province

The Blue Ridge Physiographic Province is a relatively narrow zone, ranging from four to 25 miles wide, inclusive of both the Blue Ridge Mountains (the Shenandoah National Park and the Blue Ridge Parkway) and the strip of land to the east running through Galax, Charlottesville, Culpepper, and Warrenton. Located to the west of the Piedmont Province, the Blue Ridge Province contains mountains with some of the highest elevations in the State. Geologically, the Province is defined primarily by the rocks underlying it, course-grained igneous (granitic) and metamorphic Grenville basement rocks, with some late Proterozoic intrusive and sedimentary rocks present as well, rather than its topography. On the eastern flank of the Blue Ridge, the bedrock lies beneath a thin layer of soil and weathered rock. Largely impervious, these are the oldest rocks in the Commonwealth, ranging from approximately 1.1 billion to 1.9 billion years old, and resulting well yields are low. The bedrock contains water primarily in joints, fractures, and faults.

Although the occurrence of groundwater in the fractured rock of the Blue Ridge is ubiquitous, the ability of these groundwater systems to transmit and store groundwater is highly variable and dependent on the extent and orientation of the fractured network, as well as the source of groundwater recharge to the fractured-rock groundwater system.

There has been little residential or industrial development in the Blue Ridge Physiographic Province, with groundwater use developed mainly for private domestic needs rather than for public wells. Generally, the

[55] Harlow and other, 2005; Nelms and Moberg, 2010

Blue Ridge area provides a limited source of groundwater due to steep terrain, thin soil, and rapid run-off over impermeable rocks. This leads to low groundwater recharge and low well yields. The lower slopes of the mountains are the most favorable areas for groundwater accumulation. Springs are common and are often used for private water supplies. Because the rocks in the Blue Ridge are relatively insoluble, the groundwater is not severely mineralized, but iron content is high in some locations.

Obtaining good supplies of groundwater in the Blue Ridge for uses other than residential often entails site specific studies that incorporate surface geophysical and geological mapping methods to target and maximize well yields due to the localized nature of groundwater storage in fractured rock. More regional sources of groundwater in the Blue Ridge occur in a structurally complex zone in the Vinton/Roanoke area, where transverse faulting is suspected to play a role in the creation of high transmissivity groundwater systems. Higher well yields have been shown to occur along the western flank of the Blue Ridge Anticlinorium in the Buena Vista area. By contrast, the eastern flank of the Blue Ridge Anticlinorium is often a poor producer of water. This phenomenon is thought to be influenced by the topographic position and structural orientation of the quartzites in the Antietam Formation along Bull Run Mountain, and the presence of low transmissivity phyllites in the Candler Formation nearly along strike to the south. In the core of the Anticlinorium, well yields are highly variable, but site-specific targeting of groundwater in this area often proves to be fruitful.

Piedmont Physiographic Province

The largest of Virginia's physiographic provinces, the Piedmont Province extends from the Fall Zone or Fall Line in the east which separates the Piedmont Province from the Coastal Plain Province to the mountains of the Blue Ridge Province in the west. The province is characterized by gently rolling topography, deeply weathered bedrock, and a relative scarcity of solid outcrop. Hard, crystalline igneous and metamorphic formations dominate this region, with some areas of sedimentary rocks and saprolite (residual clay or silt) deposits overlying the bedrock. The size and number of fractures and faults in the bedrock which store and transmit groundwater decrease with depth, so most significant water supplies are found within a few hundred feet of the surface.

Fairly large yields of water can be obtained where fracture and fault systems are extensive such as the Western Piedmont along the base of the Blue Ridge Mountains. The diversity of subsurface geology of the Piedmont Province results in wide variations of groundwater quality and well yields, limiting the use of groundwater in many locations. For example, a few areas have problems with high iron concentrations and acidity. Dry holes are not uncommon in the Piedmont Province and groundwater is usually limited to fractures within 300 feet of the land surface. Because of the range in groundwater quality and quantity in this region, as well as the varying potential for contamination, well site evaluation and well monitoring is very important. From a wellhead protection standpoint, assumptions about the porosity and permeability

of the overlying saprolite may have to be made so that reasonable estimates of wellhead protection areas can be calculated.

Although the occurrence of groundwater in the Piedmont Province is ubiquitous, the ability of fractured rock aquifers in the Piedmont to supply groundwater varies locally. Well yields in the Piedmont vary greatly and have been documented to yield less than one GPM to over 1,000 GPM.

Obtaining good supplies of groundwater in the Piedmont Province for uses other than residential often entails site-specific studies that incorporate surface geophysical and geological mapping methods to target and maximize well yields due to the localized nature of groundwater storage in fractured rock.

Coastal Plain Physiographic Province

The Coastal Plain is Virginia's easternmost province and is composed of flat landscapes with wide rivers that are easy to navigate. The Coastal Plain is a broad, low relief surface that slopes gently toward the ocean and is comprised of three sub-provinces: upland, lowland, and Barrier Island and salt marshes. The Coastal Plain is the youngest of Virginia's physiographic provinces, with rocks that were deposited after the Atlantic Ocean began to form early in the Mesozoic Period. Several low, wave-cut terraces punctuate the landscape where the softer sedimentary rocks of the Coastal Plain abut the more resistant metamorphic rocks of the Piedmont, creating a low escarpment visible on the landscape, known as the Fall Line. The Fall Line passes roughly through Fairfax County, Fredericksburg, Richmond, Petersburg, and Emporia, and is so named because where rivers cross the Fall Line, there are rapids or falls. On the Potomac River, a fairly broad "fall zone" extends from Great Falls downstream nearly to Alexandria. The falls were barriers to ocean-going vessels even in the Colonial period and had a major influence on early European settlement patterns in Virginia.

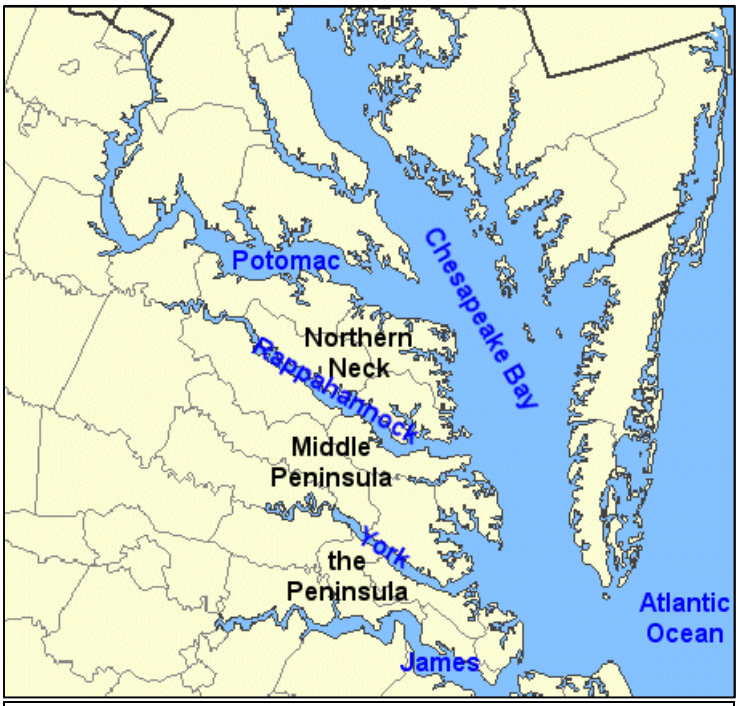

Figure 3-5 Three Peninsulas in the Coastal Plain

The topography of the Coastal Plain is that of a terraced landscape stepping down to the coast and to the major rivers: the Potomac, Rappahannock, York, and James - large, tidal rivers that flow southeastward across the Coastal Plain to the Chesapeake

Bay, which, in turn, empties into the Atlantic Ocean. The risers (scarps) are former shorelines and the treads are emergent bay and river bottoms. The higher, older plains in the western part of the Coastal Plain are more dissected by stream erosion than the lower, younger terrace treads. This landscape was formed over the last few million years as sea level rose and fell in response to the repeated melting and growth of large continental glaciers and as the Coastal Plain slowly uplifted. During the glacial maxima, much of the continental shelf was emergent and the Susquehanna flowed through the Chesapeake lowland and across the exposed shelf to the sea 80 kilometers or more to the east.

The stream-cutting of the Pleistocene Period also led to the dissection of the Coastal Plain into three peninsulas or “necks” known today by the names applied by Virginia's European settlers: Northern Neck, Middle Peninsula, and Virginia Peninsula, also known as “the Peninsula.”

The Northern Neck is the northern most of three peninsulas on the western shore of the Chesapeake Bay. Bounded by the Potomac River on the north and the Rappahannock River on the south, it encompasses Lancaster, Northumberland, Richmond, and Westmoreland Counties. The Middle Peninsula is the second of the three large peninsulas, lying between the Virginia Peninsula and the Northern Neck. The Middle Peninsula is bounded by the Rappahannock River on the north and the York River on the South, and encompasses Essex, Gloucester, King and Queen, King William, Mathews, and Middlesex Counties. Early settlement in Virginia focused on the Virginia Peninsula, bounded by the York River, James River, Hampton Roads, and the Chesapeake Bay. Today, the Virginia Peninsula encompasses the Counties of James City and York and the Cities of Williamsburg, Newport News, Hampton, and Poquoson.

The Coastal Plain region is the only one in Virginia that is composed mostly of unconsolidated deposits, primarily alternating layers of sand, gravel, shell rock, silt, and clay. More groundwater is stored in these very permeable materials than in any other province in the Commonwealth. Consequently, a large portion of Virginia’s groundwater use occurs in the Coastal Plan. In many cases, a shallow unconfined aquifer system lies above relatively impermeable clay beds and is the source of water for hundreds of domestic and other capacity wells. The pollution potential in the uppermost unconfined aquifer is high because of the permeability coupled with the high population density and agricultural activities in the area. Except for areas where saltwater, iron, and hydrogen sulfide occur, the natural water quality in the Coastal Plain aquifers is good. In aquifers near a saltwater interface, saltwater may migrate west as aquifers are pumped. As a result, water from the deep aquifers on much of the lower York-James Peninsula and the Norfolk-Virginia Beach area generally contains high chloride concentrations, rendering the water too salty for domestic use without treatment. However, the deeper system of confined aquifers is the principal source of major groundwater withdrawals in the region.

The Virginia Coastal Plain is part of an aquifer system reaching from New Jersey to Alabama. In Virginia, the multi-aquifer system is bounded on the west by the fall line and the east by a saline density boundary. The Coastal Plain aquifer system hydrogeologic framework is comprised of 19 units which include one unconfined aquifer, seven confined aquifers, and 11 confining units[56]. The Potomac, Virginia Beach, Pedee,and surficial aquiers are quartz/feldspathic sand and gravel; the Aquia, Piney Point, St. Marys, and Yorktown-Eastover aquifers are fossil shell material. Historically, the lower/middle/upper Potomac aquifer has the most withdrawal pressure. This aquifer is the most dominate hydrologic unit in the Coastal Plain and supplies the major industrial, commercial, agricultural, public water supply, and domestic residential users through the province. The Yorktown-Eastover aquifer and the Piney Point aquifer are the second and third most heavily used aquifers.

Confining layers that separate the aquifers restrict, but do not prevent, vertical flow between the aquifers. The recharge area to these aquifers occurs miles away from where the formations outcrop, but infiltration from the water table and shallower confined aquifer also recharge the deeper confined aquifers and could carry pollutants into these deeper reaches. The Coastal Plain presents a complex wellhead protection problem where the deep confined aquifers are concerned. The shallower aquifer, however, may have a more direct interaction with the surface and present a relatively straightforward challenge.

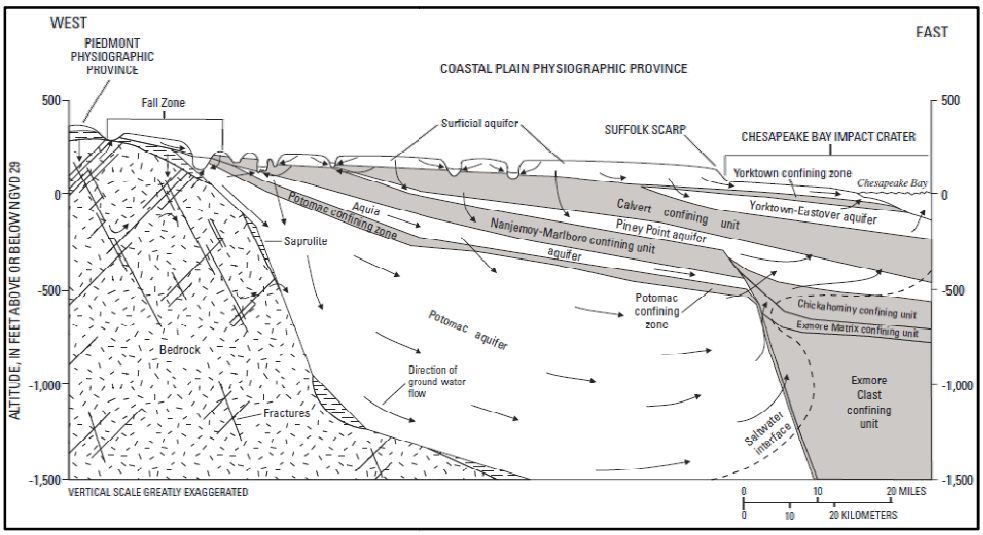

Figure 3-6: Vertical section through the Coastal Plain Physiographic Province

Chesapeake Bay Impact Crater

About 35 million years ago in the late Eocene Epoch, a bolide (comet or asteroid-like object from space) hit the earth, leaving behind a crater in the continental shelf near the Town of Cape Charles on Virginia's

[56] McFarland and Bruce USGS Professional Paper 1731-2006

Eastern Shore. The bolide created what geologists call the “Exmore Crater,” or the Chesapeake Bay Impact Crater (CBIC). Geologists believe the bolide was as large as Rhode Island and as deep as the Grand Canyon. Although the bolide did not create the Chesapeake Bay, it helped determine that a bay would eventually be located there. The inner rim of the CBIC is 23 miles in diameter and the outer rim is 56 miles in diameter. The outer disruption boundary is approximately 80 miles in diameter.

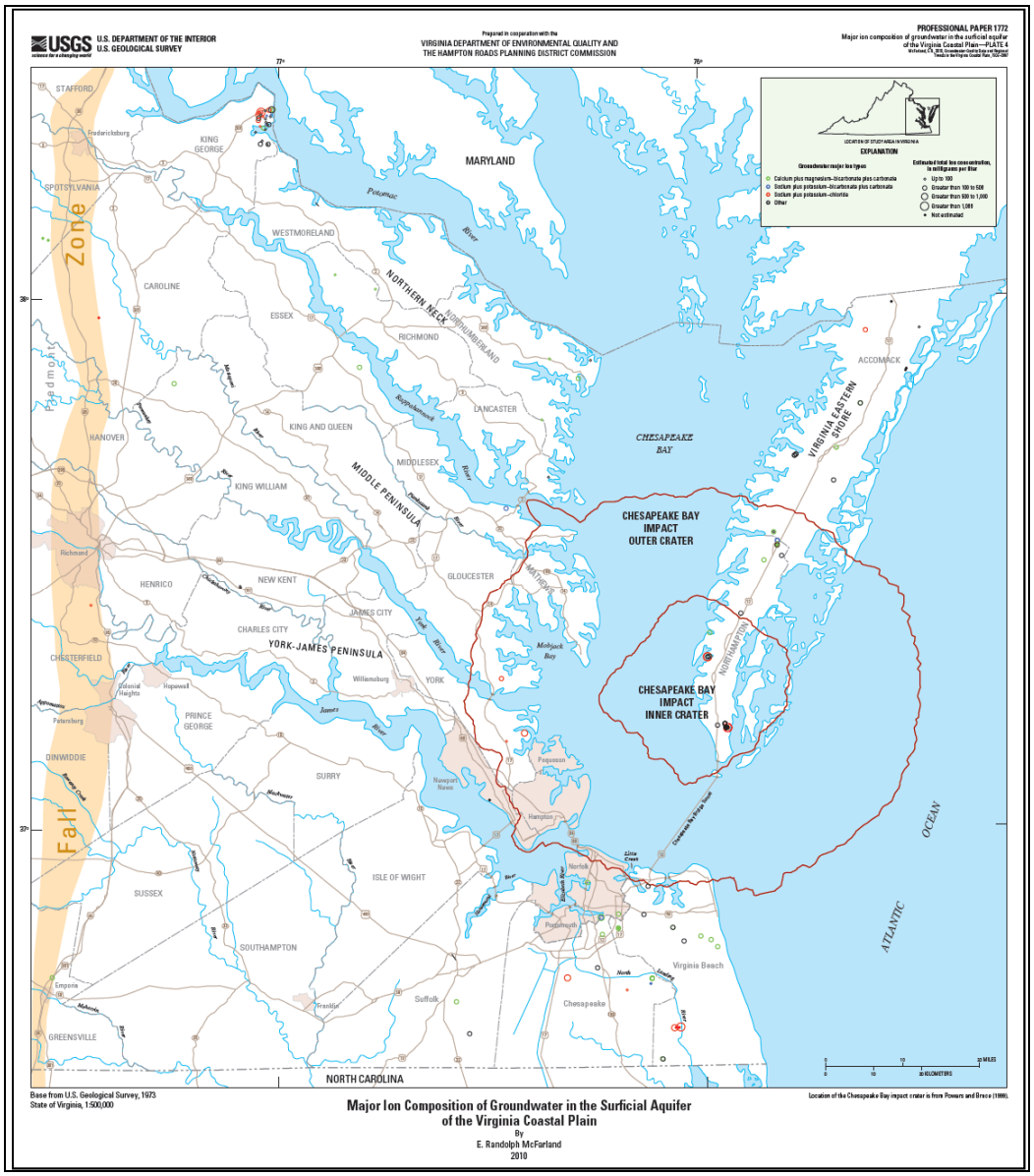

Figure 3-7: Chesapeake Bay Impact Crater

Since the CBIC discovery, studies have been done that have revised the understanding of Coastal Plain evolution. In particular, several consequences of the impact that still affect citizens around the Bay today have been revealed: land subsidence, river diversion, disruption of coastal aquifers, ground instability,

and the location of the Chesapeake Bay. The CBIC truncates the Potomac and Aquia aquifers in eastern Virginia. Differential flushing of salty groundwater over geologic time has resulted in the Virginia inland saltwater wedge. The inland saltwater wedge is characterized by elevated chloride and sodium concentrations in the Potomac aquifer as far west as Williamsburg.