GEORGE WASHINGTON BIRTHPLACE

NATIONAL MONUMENT

GEOLOGIC RESOURCE MANAGEMENT ISSUES

SCOPING SUMMARY

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Sand spit at the mouth of Popes Creek Estuary. Photograph by Melanie Ransmeier, Geologic Resources Division, National Park Service.

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Executive Summary

A Geologic Resources Evaluation scoping meeting and field trip for George Washington Birthplace National Monument took place at the monument near Colonial Beach, Virginia on July 25, 2005. Scoping meeting participants identified the following list of geologic resource management issues. These topics are discussed in detail on pages 18- 26.

1. Sediment budget for Popes Creek watershed including sediments contributed to the Chesapeake Bay, sediment transport with migrating knick points and sediment traps, and sediment storage behind the spit at the mouth of the estuary.

2. Erosion rates and processes affecting upland ravines and terraces, slope stability, lateral fluvial migration, swamp and spit erosion, and Potomac shoreline erosion of beaches and bluffs.

3. Connections between geology and other scientific disciplines at George Washington Birthplace including biology, archaeology, and paleontology.

4. Hydrogeologic system at Popes Creek including the development of a 3- D terrane model and the establishment of baseline conditions.

5. Recreational demands including visitor safety along scarps and at the base of bluffs, and fossil collecting.

6. Seismicity from the nearby Stratford fault system deep beneath the regolith and numerous other small- scale faults, as well as the continual downloading of the Chesapeake Bay impact structure.

7. Geologic outreach and cooperation.

8. Geochemical characteristics of the Popes Creek watershed including nutrients and pollutants trapped in sediments.

9. Surrounding development and landownership concerns including urban encroachment at park boundaries, potential pollution influx from neighboring areas, and conflicts regarding shoreline erosion of private lands.

10. Connections between geology and the Plantation’s history to appeal to visitors interested in a deeper connection to the landscape

Introduction

This report briefly describes the general geology of George Washington Birthplace National Monument (GEWA), including a geologic history of the monument, geologic resource management issues in the monument, and the status of the Geologic Resource Evaluation (GRE) digital geologic mapping projects related to the monument. The National Park Service held a Geologic Resource Evaluation scoping meeting for George Washington Birthplace National Monument in Colonial Beach, Virginia on Monday, July 25, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the park's geologic issues. Products derived from the scoping meeting will include: (1) digitized geologic maps covering the park; (2) updated and verified bibliography; (3) scoping summary (this report); and (4) Geologic Resource Evaluation report which brings together all of these products.

George Washington Birthplace National Monument was established during President Herbert Hoover's administration on January 23, 1930. The park commemorates the 1732 birthplace of the first president, preserving the heart of Augustine Washington's Popes Creek Plantation as well as the 17th century home site of John Washington and the Washington Family burial ground. The area is archaeologically rich with sites pre- dating European settlement. The monument covers 662 acres of Atlantic Coastal Plain on the Northern Neck of Virginia between the Rappahannock and Potomac Rivers. The park is 61 km (38 miles) east of Fredericksburg, VA. It protects one of the most pristine Potomac River tributary watersheds (Popes Creek) as well as a stretch of Potomac River shoreline.

Map Notes

The Inventory and Monitoring Program and George Washington Birthplace National Monument identified 3 quadrangles of interest (Figure 1). The park is also interested in the geology of the following 5 quadrangles: Dahlgren, Colonial Beach North, Loretto, Champlain, and Montross.

Rollins Fork Quadrangle is mapped as part of the 2000 Mixon et al. Fredericksburg 30' X 60' quadrangle that was incorporated in the digital Geologic map database of the Washington DC area (Figure 1):

Mixon,, R.B., Pavlides, Louis, Powars, D.S., Froelich, A.J., Weems, R.E., Schindler, J.S., Newell, W.L., Edwards, L.E., and Ward, L.W., 2000, Geologic map of the Fredericksburg 30' X 60' quadrangle, Virginia and Maryland (Sheet 1 of 2), U.S. Geological Survey, Geologic Investigations Series Map I- 2607, 1:100,000 scale (2540)

Davis, A.M., Southworth, C.S., Reddy, J.E., and Schindler, J.S., 2001, Geologic map database of the Washington DC area featuring data from three 30 X 60 minute quadrangles: Frederick, Washington West, Fredericksburg, U.S. Geological Survey, Open- File Report OF- 01- 227, 1:100,000 scale (3136)

A recently published U.S. Geological Survey Open File Report (OF- 2005- 1025) covers the Colonial Beach South Quadrangle at 1:24,000 scale. In addition, the Colonial Beach South and Stratford Hall Quadrangles are both mapped as part of the Lenoardtown 30x60 minute quadrangle:

McCartan, Lucy, Newell, W.L., Owens, J.P., and Bradford, G.M., 1995, Geologic map and cross sections of the Leonardtown 30 x 60- minute quadrangle, Maryland and Virginia, U.S. Geological Survey, Open- File Report OF- 95- 665, 1:100,000 scale (3457)

Additionally, Wayne Newell of the U.S. Geological Survey has 1:24,000 scale map coverage of 9 quadrangles in the GEWA area, including 6 of some interest to the park, as part of the *Geology of the Central Rappahannock River Area* mapping project. To date, this map has not been published.

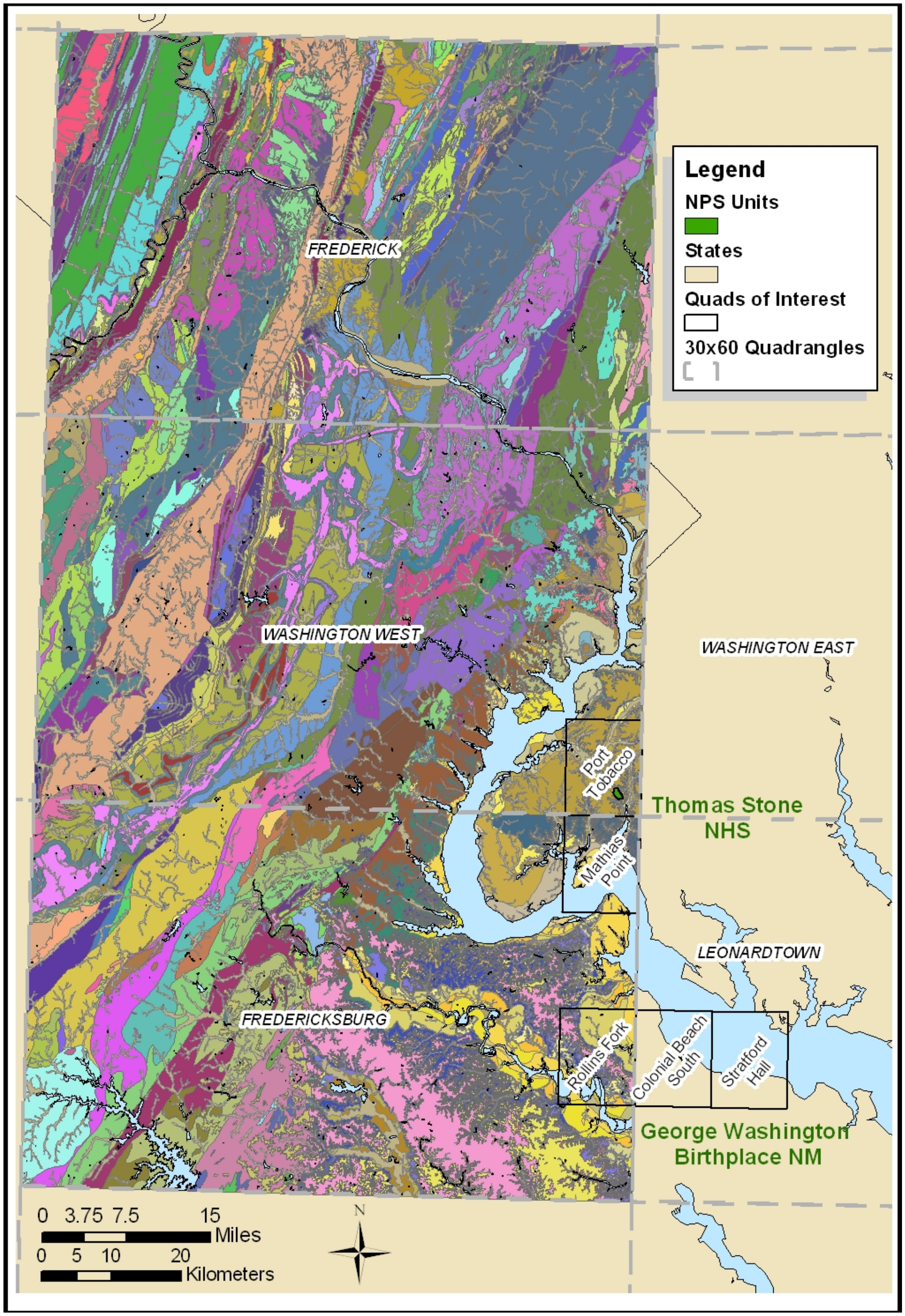

Figure 1: GEWA and THST Quadrangles of Interest and Proximity to USGS OF-01-227
Geologic map database of the Washington DC area

The Maryland Geological Survey produced the following geologic maps for Charles and St. Mary's Counties at 1:62,500 scale (Figure 2). However, none of these maps completely covers the GEWA quadrangles of interest.

Dryden, A.L., Jr., 1939, Map of Charles County showing the geological formations, Maryland Geological Survey, County Geologic Maps, 1:62,500 scale (GMAP_ID 3251)

Hack, J.T., 1977, Geologic map for land- use planning, Prince Georges County, Maryland, U.S. Geological Survey, I- 1004, 1:62,500 scale (GMAP_ID 1442)

McCarten, Lucy, 1989, Geologic map of Charles County, Maryland Geological Survey, County Geologic Maps, 1:62,500 scale (GMAP_ID 2943)

McCarten, Lucy, 1989, Geologic map of St. Mary's County, Maryland Geological Survey, County Geologic Maps, 1:62,500 scale (GMAP_ID 3353)

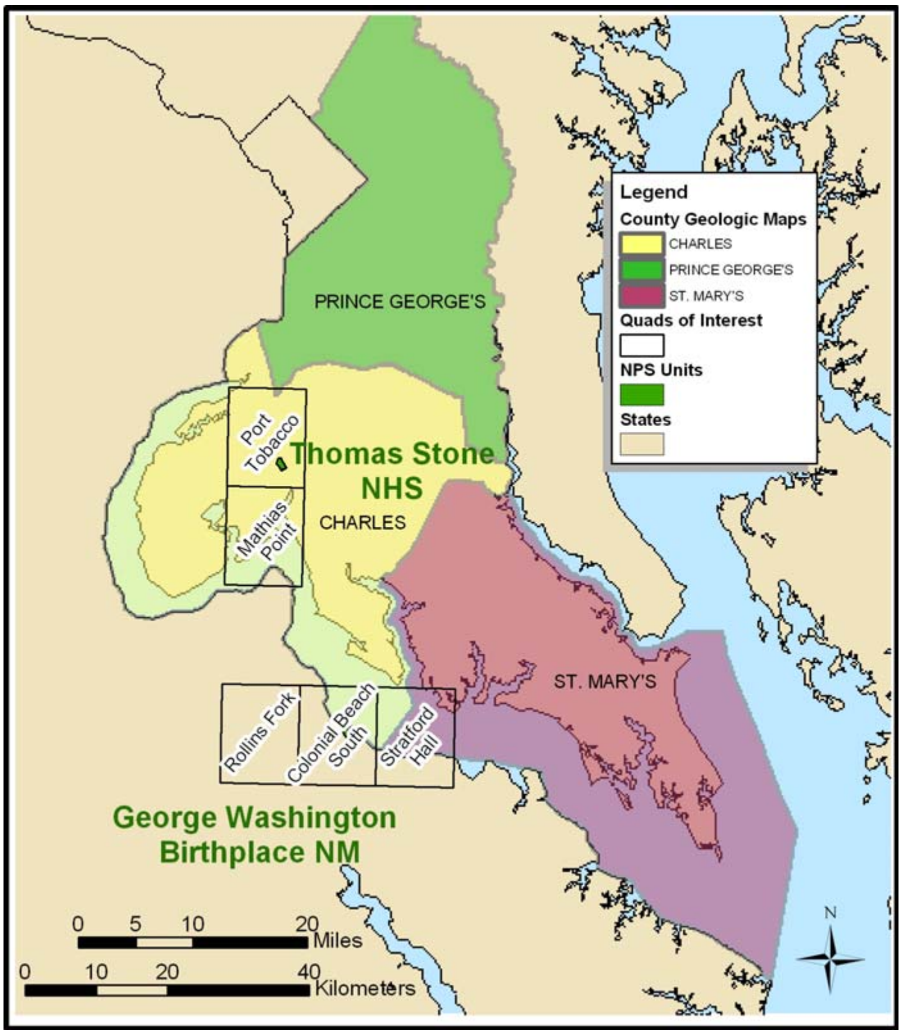

Figure 2: GEWA and THST Quadrangles of Interest and Proximity to Maryland Geological Survey County Geologic Maps

Many other maps exist for the region that include coverage of the geology, shoreline change, aeromagnetic- gravity, mineral and mineral potential, folio, geochemical and hydrogeology, and stratigraphy, etc. The maps are available from agencies such as the U.S. Geological Survey, the Maryland Geological Survey, and the Geological Society of America.

Lidar surveys provide vital information for mapping Quaternary age deposits, which is traditionally difficult given the level of vegetative cover of the coastal plain. Lidar surveys were completed for the monument area in 2001 and 2005. These surveys could be used for shoreline change comparisons. The use of aerial photographs, erosion rates, as well as seasonal GPS shoreline surveys would also help the monument monitor the changes in shoreline and better manage this resource. Additional mapping at a smaller scale within park boundaries would be helpful for park resource management and interpretation.

Mapping Deliverables

Each of the three quadrangles of interest for GEWA will be approached differently. The Rollins Fork quadrangle will be extracted from the digital Geologic map database of the Washington DC area (OF- 01- 227) and converted to the NPS GRE Geology – GIS Data Model. GRE staff will digitize the recently published Colonial Beach South quadrangle (OF- 2005- 1025) using the NPS GRE Geology – GIS Data Model. It is likely that the Stratford Hall quadrangle will be clipped from the USGS Leonardtown 30'x60' (OF- 95- 665) and digitized using the NPS GRE Geology – GIS Data Model. However, if it is possible to obtain the Stratford Hall portion of Wayne Newell's unpublished *Geology of the Central Rappahannock River Area* mapping project that information could be digitized instead. Bruce Heise will investigate this possibility and make a decision in collaboration with the GRE team during the early part of NPS fiscal year 2006. Once the three quadrangle maps have been digitized or converted according to the standards of the NPS GRE Geology – GIS Data Model they will then be compiled for delivery to the park.

Physiography

George Washington Birthplace National Monument lies on the Northern Neck of Virginia between the Rappahannock and Potomac Rivers within the Atlantic Coastal Plain physiographic province. The Popes Creek watershed and its interaction with the Potomac River dominate the landscape at the park. The watershed includes several wetland areas including Longwood and Digwood swamps, a large estuary sheltered by a sand spit along the Potomac shoreline, and upland terraces and ravines.

In the area of George Washington Birthplace, the eastern United States is divided into 5 physiographic provinces with associated local subprovinces. These are, from east to west, the Atlantic Coastal Plain, the Piedmont Plateau, the Blue Ridge, the Valley and Ridge, and the Appalachian Plateaus provinces (Figure 3).

The Atlantic Coastal Plain province is primarily flat terrain with elevations ranging from sea level to about 100 m (300 ft) in Maryland. Sediments eroding from the Appalachian Highland areas to the west formed the wedge- shaped sequence of soft sediments that were deposited intermittently on the Atlantic Coastal Plain during periods of higher sea level over the past 100 million years. These sediments are now more than 2,438 m (8,000 ft) thick at the Atlantic coast and are continually reworked by fluctuating sea levels and the erosive action of waves along the coastline. Large streams and rivers in the Coastal Plain province, including the James, York, Rappahannock, and Potomac continue transporting sediment and extending the coastal plain eastward. Beyond the province to the east the submerged Continental Shelf province extends for another 121 km (75 miles).

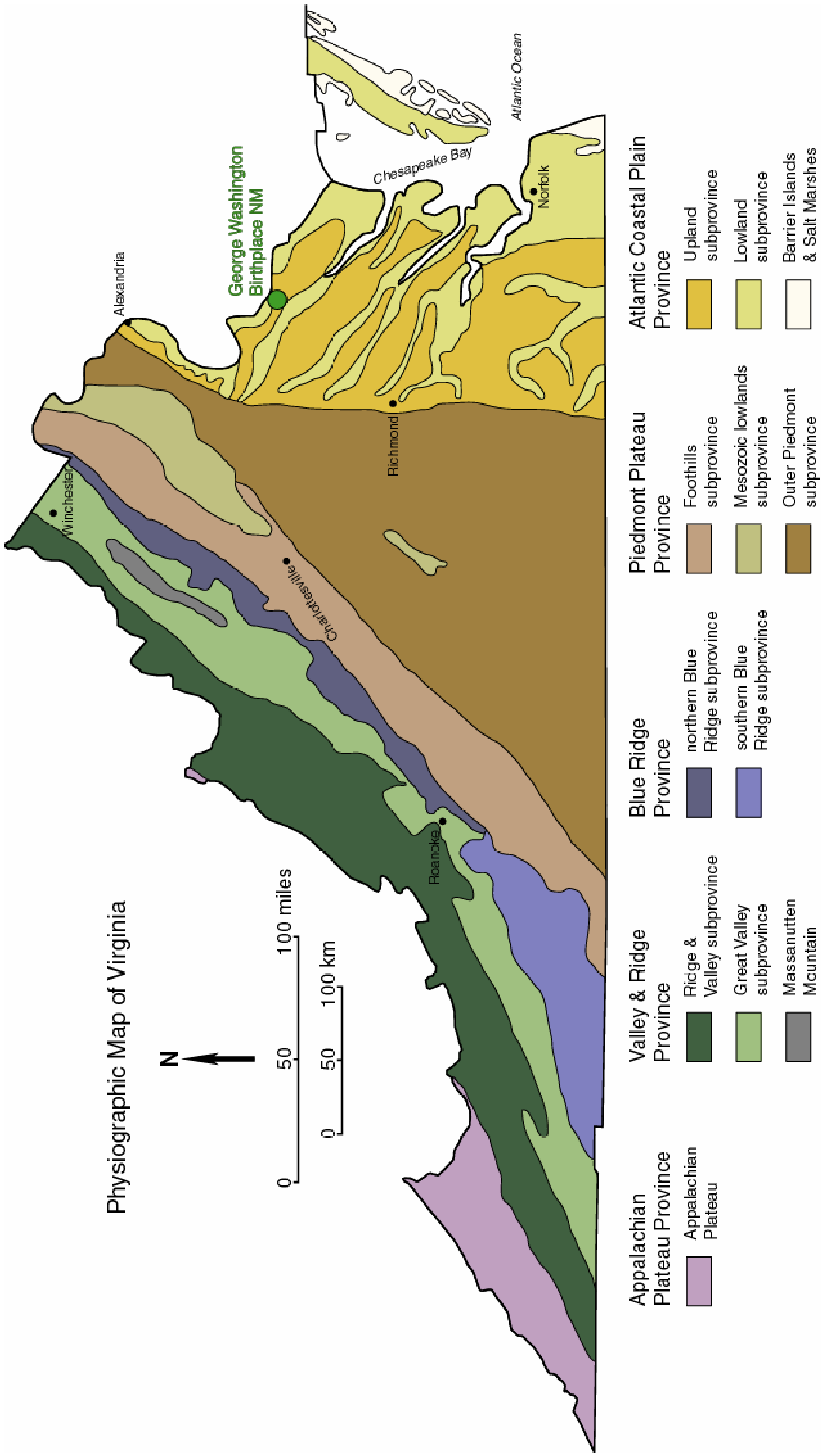

Figure 2: Location of Colonial National Historical Park relative to the physiographic provinces of Virginia. Graphic is adapted from Bailey (1999).

Geologic History of Central Virginia

Proterozoic Era – In the mid Proterozoic, during the Grenville orogeny, a supercontinent formed which included most of the continental crust in existence at that time. The sedimentation, deformation, plutonism (the intrusion of igneous rocks), and volcanism associated with this event are manifested in the metamorphic gneisses in the core of the modern Blue Ridge Mountains (Harris et al., 1997). These rocks were deposited over a period of 100 million years and are more than a billion years old, making them among the oldest rocks known from this region. They form a basement upon which all other rocks of the Appalachians were deposited (Southworth et al., 2001).

The late Proterozoic, roughly 600 million years ago, brought a tensional, rifting tectonic setting to the area. The supercontinent broke up and an oceanic basin formed that eventually became the Iapetus Ocean. In this tensional environment, flood basalts and other igneous rocks such as diabase and rhyolite added to the North American continent. These igneous rocks were intruded through cracks in the granitic gneisses of the Blue Ridge core and extruded onto the land surface during the break- up of the continental land mass (Southworth et al., 2001). The Iapetus basin collected many of the sediments that would eventually form the Appalachian Mountains and Piedmont Plateau.

Early Paleozoic Era – From Early Cambrian through Early Ordovician time there was another period of orogenic activity along the eastern margin of the continent. The Taconic orogeny (~440- 420 Ma in the central Appalachians) was a volcanic arc – continent convergence. Oceanic crust, basin sediments, and the volcanic arc from the Iapetus basin were thrust onto the eastern edge of the North American continent. The Taconic orogeny involved the closing of the ocean, subduction of oceanic crust, the creation of volcanic arcs and the uplift of continental crust (Means, 1995). In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards to the west creating a deep basin that filled with mud and sand eroded from the highlands to the east (Harris et al., 1997). This so- called Appalachian basin was centered on what is now West Virginia.

This shallow marine to fluvial sedimentation continued for a period of about 200 million years during the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods, resulting in thick piles of sediments derived from the eroding highlands that rose to the east during the Taconian orogeny (Ordovician), and the Acadian orogeny (Devonian). The Acadian orogeny (~360 Ma) continued the mountain building of the Taconic orogeny as the African continent approached North America (Harris et al., 1997). Similar to the preceding Taconic orogeny, the Acadian event involved land mass collision, mountain building, and regional metamorphism (Means 1995). This event was focused north of present day central Virginia.

Late Paleozoic Era – Following the Acadian orogenic event, the proto- Atlantic Iapetus Ocean was completely destroyed during the Late Paleozoic as the North American continent collided with the African continent. This formed the Appalachian mountain belt we see today and a supercontinent named Pangaea. This mountain building episode is called the Alleghanian orogeny (~325 – 265 Ma)and was the last major orogeny of the Appalachian evolution (Means, 1995). During this orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were transported as a massive block westward onto younger rocks of the Valley and Ridge. The amount of compression was extreme. Estimates are of 20- 50 percent shortening which translates into 125–350 km (75- 125 miles) of lateral translation (Harris et al., 1997).

Mesozoic Era – Following the Alleghenian orogeny, during the late Triassic, a period of rifting began as joined continents began to break apart from about 230-200 Ma. The supercontinent Pangaea was divided into roughly the continents that persist today. This episode of rifting or crustal fracturing initiated the formation of the current Atlantic Ocean and caused many block- fault basins to develop with accompanying volcanism (Harris et al., 1997; Southworth et al., 2001). Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroding mountains. These were deposited at the base of the mountains as alluvial fans and spread eastward to be part of the Atlantic Coastal Plain (Duffy and Whittecar 1991; Whittecar and Duffy, 2000; Southworth et al., 2001).

The amount of material that has been eroded from the Appalachian Mountains, as inferred from the now- exposed metamorphic rocks, is immense. Many of the rocks exposed at the surface must have been at least 20 km (~10 miles) below the surface prior to regional uplift and erosion. The erosion continues today with the Potomac, Rappahannock, Rapidan, James, and Shenandoah Rivers stripping the Coastal Plain sediments, lowering the mountains, and depositing alluvial terraces along the rivers, creating the present landscape.

Cenozoic Era – Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. The isostatic adjustments that uplifted the continent after the Alleghenian orogeny continued at a subdued rate throughout the Cenozoic Period (Harris et al., 1997). These adjustments may be responsible for occasional seismic events felt throughout the region.

The landscape at George Washington Birthplace is profoundly impacted by the deposition of Tertiary and younger sediments and the subsequent erosion of these units by evolving waterways. Popes Creek and its associated wetlands, estuaries, and tributaries are among the least engineered waterways in the Chesapeake Bay watershed. This natural riverine environment continues to cut terraces, entrench channels, shift bars and other sediments, and cut scarps and ravines as it responds to changes in climate, seasonal storms, and human influences.

Though glaciers from the Pleistocene Ice Ages never reached the central Virginia area (the southern terminus was in northeastern Pennsylvania), the intermittent colder climates of the ice ages played a role in the formation of the landscape at George Washington Birthplace National Monument. Freeze and thaw cycles within unconsolidated terrace units homogenized bedding features. Cold climate subaerial deposits contain fossils such as mastodon teeth. Sea level fluctuations during ice ages throughout the Pleistocene caused the baselevel of many of the area's rivers to change. During lowstands (sea level drops), the rivers eroded their channels exposing the deformed bedrock of the Piedmont Plateau to the west. During oceanic highstands, the river basins flooded and deposition resulted in deposits of beach sediments in the park area.

Stratigraphy

(from Geologic Map of the Fredericksburg 30'x60' Quadrangle, Virginia and Maryland, U.S. Geological Survey, Geologic Investigations Series Map I- 2607, 1:100,000 scale, 2000)

The rock units exposed within and surrounding the monument are relatively young deposits of the Atlantic Coastal Plain. At depth, the Lower Cretaceous Potomac Formation underlies most of the area. This formation is comprised of feldspathic quartz sand and sandstone, silty channel- bar deposits, and lignitic sandy silt and clay layers. Atop the Potomac Formation is the upper Paleocene Aquia Formation of glauconitic sands, silts, clays, and containing some scant fossil layers. Nanjemoy Formation deposits from the lower Eocene overlie the Aquia Formation and are exposed in ravines. These are glauconitic sands, clays, silts, and mixed layers. Miocene age deposits of the Chesapeake Group overlie the Aquia and Nanjemoy Formations in the park area. This includes the prominent Calvert Formation of marine sands, silts, and clays that contains abundant fossils such as shark teeth. An unconformity separates the Calvert Formation from the Eastover Formation (not exposed near the monument), which grades upwards into the younger marine, intertidal, and fluvial deposits of Pliocene age.

Younger deposits include the Yorktown Formation and Pliocene sands and gravels. The Yorktown Formation is a maximum of 25 m (82 ft) thick and contains quartz and feldspar sands mixed with lesser clays and silts. The upper Pliocene Bacons Castle Formation includes gravelly sand and sandy- silty- clayey upper layers. These are often found in high- level terrace areas. The more recent deposits at the park include various Quaternary age units. The fine to coarse sand, gravel, silt and clay of the Windsor Formation (Moorings Unit) is of lower Pleistocene to upper Pliocene age. The gravelly Charles City Formation, the sands and silts of the Chuckatuck Formation as well as the Shirley Formation of coarse sands, gravels, pebbles and occasional boulders are of the middle Pleistocene. The upper Pleistocene Tabb Formation contains sands, gravels, silts and clays and underlies low terraces in the area. The Tabb Formation has three members: the Poquoson, the Lynnhaven, and the Sedgefield Members.

The youngest units at George Washington Birthplace National Monument include thick sedimentary deposits of sand, gravel, silt and clays, which are often reworked from older units and redeposited on the landscape. Several sand and gravel bars, channel gravels, and paleoscarps are present across the mouth of Popes Creek. Associated with this watershed are marsh and swamp deposits, and shelly sands. Additionally, artificial fill from construction of roads, dams, bridges, landfills, and highways are present on the historical landscape at George

Washington Birthplace National Monument. Some of these anthropogenic deposits are recording the historic evolution of the landscape, others are from recent developments within and surrounding the monument area.

Structure

The Rappahannock anticlinorium dominates the structural features present to the west of George Washington Birthplace National Monument. The anticlinorium extends from the Stafford, Virginia area southwards beyond the James River. The anticlinorium trends roughly northeast and plunges to the northeast. The eastern portions of the anticlinorium are comprised of island- arc deposits and some felsic plutons. Associated with the anticlinorium is the parallel trending Quantico synclinorium within the Quantico Formation on the western side of the structure. The feature is bound on the east by the Spotsylvania thrust fault and on the west by the Long Branch fault. The northern end is truncated by the right- lateral Accockeek fault just northwest of Fredericksburg and contains the Salem Church allochthon (meaning its origin is elsewhere from its surrounding rocks), a relatively small fault- bounded area of granitic gneiss. (Mixon et al. 2000). Structures along the limbs of the anticlinorium suggest multiple phases of folding and at least two metamorphic events. (Onasch, 1986; Mixon et al., 2000).

Most of the regional structures are high- angle reverse faults present near the boundary between the western Atlantic Coastal Plain and the eastern side of the Piedmont. They are all part of the Stafford fault system within the inner Coastal Plain of Virginia. The Stafford Fault system extends along the Fall Line 68 km (42 miles) from Spotsylvania (west of the monument) northeastward to southern Fairfax County. These features are en echelon, or step- like in map trend and all strike northeast. Vertical displacement along these features is minor, only 10- 60 m (33- 197 ft), but this amount of offset significantly affects the thickness and distribution of Coastal Plain sediments (Mixon et al., 2000). Sediments present on the western, upthrown blocks are thinner than their counterparts on the eastern downthrown blocks across the high- angle reverse faults. Small- scale faults within the monument and adjacent areas have had a pronounced influence on landform development. Most of these are not well exposed.

Significant Geologic Resource Management Issues

1. Sediment budget for Popes Creek watershed

Enormous amounts of sediment are stored on the landscape at George Washington Birthplace. These sediments are recycled and weathered from unconsolidated upland units such as the Charles City Formation. Repeating sequences of sands, channel cross beds, silt, clay and humic floodplain deposits exposed in upland ravines record movement of the river system over the landscape.

Other sediments are entrained within the fluvial system of Popes Creek and form migrating bars, marshes, deltas, and channel deposits. Knick points develop in the upland areas, the river then passes in turn into a meandering breach, a gullied reach, and then passes into another knick point before unloading the sediment behind a sediment trap. This system of progressive knick points and sediment traps retains much of the reworked sediments that would otherwise be washed into the Potomac River.

Several bars and paleoscarps across the mouth of Popes Creek record some of the watershed's former reaches. A sandy spit protects the estuarine bay at the mouth of Popes Creek. Proto- Popes Creek channel deposits supply sediments to this system today. However, this dynamic environment changes rapidly and channels cutting into the bar are resulting in a net loss of sediment to the spit. A thin veneer of loose, wind blown sediments add fine- grained deposits locally.

Research and monitoring questions and suggestions include:

- How much sediment is contributed to the Chesapeake Bay from the Popes Creek watershed?
- Where is the fine- grained sediment deposited?
- Correlate hurricane and storm layers spatially.
- Research stream sediment loads to determine their effects on aquatic and riparian biota. Is sediment loading in the monument streams following a seasonal pattern?

2. Erosion rates and processes

One of the major goals of the monument is to present the historical context of the area; this includes preserving and restoring any old buildings and the landscape around them. Maintaining this colonial landscape often means working against natural geologic changes, which presents several management challenges. Geologic processes such as landsliding, slumping, chemical weathering, and slope creep are constantly changing the landscape at the park. Runoff erodes sediments from any open areas and carries them down streams and gullies. Erosion naturally diminishes higher areas such as ridges and hills, undermines foundations, degrades bridge foundations, erodes streams back into restoration areas, and fills in the lower areas such as trenches, ditches, and stream ravines distorting the historical context of the landscape.

Erosion processes at George Washington Birthplace range from rain and surface flow, freeze and thaw cycles to mass wasting. Cracks (vertical tectonic joints and horizontal sheet joints) within the Potomac shoreline bluffs focus water flow and consequently erode, widening until stability is lost and a large portion of the bluff spalls off. The stratigraphic relationship between the relatively impermeable Calvert Formation and the permeable, loose sediments (pebble- cobble beds and fluvial channels) above creates a ramp surface that facilitates large slumps and slides along the bluffs. Erosion within the estuary is also causing islands, including Grand Island, to disappear.

Storms such as Hurricane Isabel in 2003 cause significant changes to the landscape of the park. Coastal erosion rates for the slopes and bluffs of the middle Potomac River are 1.3 to 2.5 cm (0.5 – 1 inch) per year. However, during the Isabel storm event, between 8 and 9 m (25- 30 ft) of bluff and beach erosion occurred in places. One- third of an entire archaeological site was lost during the storm and the Harry Brooks site is now threatened. The park boundaries extend to the Potomac shoreline, thus shoreline erosion is causing loss of park land and additionally altering microenvironments.

Scientists at the Virginia Institute of Marine Science have modeled ways to attempt to protect the shoreline, beaches, points, and bluffs at George Washington Birthplace including breakwaters, pocket beach formation, chevron rock structures, etc. However, funding is not adequate at this time to take these measures.

Research and monitoring questions and suggestions include:

- Perform several shoreline surveys per year to detect seasonal variations. Possibly recruit a volunteer to monitor the shoreline by walking the 1- 2 hour distance each season. Supplement these surveys with lidar, GIS surveys (such as the shoreline and marsh survey of summer, 2003, January 2004, and March 2005), and aerial photographs.
- Continue to study shoreline changes since the 1930's.
- Promote and support coastal erosion rate studies such as the Miller USGS study of the middle Potomac River in the mid- 1980's
- Study erosion rates and processes in surrounding areas and relate to the sediment budget of the Popes Creek watershed.

- Define the mappable shoreline and its scale.
- Monitor loss of islands within Popes Creek estuary.
- Monitor topographic changes due to surface and cliff erosion.
- What if any slope stability impacts exist?
- Can cliff erosion be slowed or stopped?
- Promote coastal shoreline stability measures.
- What are the effects of increased erosion on aquatic ecosystems at the monument?
- Is runoff in the monument increasing due to surrounding development? If so, are there any remedial efforts resource management can undertake to reduce this impact?

3. Connections between geology and other scientific disciplines

Geology forms the basis of any environment. Relationships between geologic features and processes and the ecosystem are complex. Shoreline erosion affects park boundaries and wildlife habitat at George Washington Birthplace National Monument. Estuarine habitat is shifting and impacting wetland species. Larger tree clumps within the wetland areas are being lost during erosive storms. These woodland areas provide vital habitat for osprey. Bald eagles also nest among the woodlands lining the Potomac River shoreline.

Archaeological sites including Native American pre- settlement campsites and plantation artifacts are threatened by erosion. In addition to the continual slope processes active along the shoreline, major storm events can remove meters of cliff face at one time. Further discussion on archaeology at the park is under item number 10, below.

Paleontological resources are constantly exposed within the monument by erosion. Paleocene to Miocene age shark teeth, duodongs, and bones from seals, whales, and porpoises are among the many fossils present in the bluffs and slope deposits. Calvert fossils are part of the Smithsonian collection. Mastodon teeth, a testament to Pleistocene ice age climate fluctuations, are also present in some subaerial deposits at the monument. Due to upland erosion and reworking of sediments, fossils tend to be concentrated along the shorelines. These specimens are attractive to collectors, but also are a unique resource within the monument that requires management.

Research and monitoring questions and suggestions include:

- Monitor paleontological exposures as they are exposed by erosion.
- Map archaeological sites.
- Establish a time estimate to cultural resource loss due to erosion processes.

4. Hydrogeologic system at Popes Creek

Resource management staff need to understand how water is moving through the hydrogeologic system into, under, and from the monument. Management also needs to understand how the water table might change over time. Several wells throughout the area could be used for monitoring of ground water quality. It would be useful to perform tracer studies in these wells to see how quickly and in what direction water is moving through the system.

Understanding the hydrogeologic system is critical to understand the impacts of human introduced contaminants on the ecosystem. The interaction between groundwater flow and the overall water quality should be quantitatively determined at the monument.

Swamp surveys indicate that land use patterns have effects on erosion and deposition within the estuary. Logging efforts aimed at increasing visibility of the commemorative obelisk seems correlative to swamp degradation and tidal channel proliferation. Erosion of the wetlands has increased due to logging over the past 100 years. Wetlands are typically considered indicators of overall ecosystem health and should be researched and monitored periodically.

Research and monitoring questions and suggestions include:

- Obtain subsurface data (depth to layers, composition, etc.) for quadrangles of interest to understand groundwater movement through layers of variable permeability. The Oak Grove core hole exists within the Rollins Fork Quadrangle. This core was 365 m (1,2000 ft) deep and was part of a 1977-1978 study by the Virginia Department of Mineral Resources (VDMR).
- Cooperate with the USGS to obtain further cores within the Popes Creek watershed to accompany cores from the delta and estuary mouth.
- Study estuarine terraces cut into the upland areas to chart fluvial changes within the watershed.
- Will an island form from the spit and Longwood swamp due to increased erosion?
- Will sedimentation trap the swamp lands, leading to increased salinity there?
- Obtain core surveys across the mouth of Popes Creek and the estuary.
- Monitor hydrologic changes of Popes Creek and its interface with the Potomac River.
- Develop a 3- D terrane model of the hydrogeologic system at the monument incorporating cliff morphological changes.
- Inventory groundwater levels.
- Perform dye tests to look at the hydrogeologic effects of local geologic structures on the watershed.

- Test for and monitor phosphate and volatile hydrocarbon levels in the groundwater at the park, focusing on areas near facilities.
- Test water quality at any existing springs.
- Comprehensively map and monitor water and soil quality at all wetlands within the monument. This creates a baseline level of ecosystem health to use for understanding future changes.
- Determine any hotspots for water contamination. Remediate and monitor results.

5. Recreational demands

Although George Washington Birthplace National Monument was not established for recreation, visitor use includes hiking, swimming, picnicking, and wildlife viewing. Fossils within the Calvert Formation are attractive to collectors. These fossils are exposed by shoreline erosion and line the shore at the base of the Potomac River bluffs. In addition to the potential loss of paleontological resources, visitor safety is at risk along and at the base of the actively eroding cliffs.

Research and monitoring questions and suggestions include:

- How can fossil specimen collecting be prevented?
- Identify weaker areas along the bluffs for targeted resource management efforts
- Warn visitors of the potential danger from spalls defined by joints within the Calvert Formation.
- Identify undercut areas vulnerable to mass wasting and attempt to keep visitors away from the potential hazard.
- Create an interpretive program discussing the inevitability of resource change due to natural processes as a means to educate the public on resource management at the monument.

6. Seismicity

The Stratford fault system, a structure deep beneath the regolith west of the monument, is considered low for seismic risk. More local faults and joints effect cliff erosion and mass wasting. The Chesapeake Bay impact structure southeast of the monument is still downloading and causes frequent small magnitude earthquakes. Earthquakes may cause significant damage to buildings, fences and other cultural features at George Washington Birthplace. Seismic waves may also undermine slope stability and increase local spalling along the cliffs.

Research and monitoring questions and suggestions include:

- Promote the development of an active seismic network for the area.

- Evaluate risk for tsunami and shoreline damage due to earthquake activity and continental slope landslides.
- Evaluate cultural features at risk for damage during infrequent seismic events.

7. Geologic outreach and cooperation

The scope and mission of George Washington Birthplace National Monument is to preserve and protect a historical landscape. This mission does not necessarily include scientific study of the monument's geology. The monument is a gateway for Chesapeake Bay related issues and depends on cooperative efforts with numerous other agencies such as the U.S. Geological Survey, the Virginia Institute of Marine Science, the Virginia Department of Mineral Resources, etc. to effectively study and manage geologic features and processes. This cooperation and outreach is essential for resource management.

Research and monitoring questions and suggestions include:
- Cooperate with the Chesapeake Gateway Network Program.
- Attempt to cooperate with other agencies studying hurricane- related issues.
- Promote studies correlating land use changes with movement of Native Americans and early settlers.

8. Geochemical characteristics of the Popes Creek watershed

Popes Creek is generally considered a low impact watershed. For this reason, monitoring the geochemical changes in the water and sediments is vital to maintaining the overall high quality. Surrounding development and agriculture add nutrients and pollutants to Popes Creek tributaries as does water entering the estuary from the Potomac River. Popes Creek is vulnerable to changes within the Chesapeake Bay and Potomac River watersheds due to influx into the estuary during high tides.

Research and monitoring questions and suggestions include:
- Promote the monument as a site to monitor continuous fluvial processes and geochemical changes in the Popes Creek watershed.
- What is the salinity gradient within Popes Creek Estuary?
- Establish a baseline for comparison of water quality at Popes Creek.
- Monitor sediments for pollutants and nutrients.
- Promote less biosolid fertilizer use in surrounding areas.

9. Surrounding development and landownership concerns

The population of the area surrounding George Washington Birthplace National Monument is growing rapidly. Increased development in the area makes conservation of existing forest, wetland, and meadow community types a critical concern. Understanding the geology beneath the biotic communities is vital to their management. Management of the landscape for historic preservation purposes compliments the preservation of these ecosystems.

As land and shoreline erodes from the surface at George Washington Birthplace, surrounding landowners also face land loss issues. These landowners often expect the monument to put measures in place to secure the shoreline instead of allowing natural processes to continue. Another issue with land loss is an increase in property value making the lands around the monument too expensive to consider attaining for inclusion within the park.

Human impacts continue today as pipelines, power lines, roads, buildings, trails, visitor use areas, invasive species, acid rain, and air and water pollution take their toll on the landscape. State Route 3 crosses the Popes Creek watershed. Associated with the Virginia Department of Transportation are a fueling plant and three dams within the watershed.

Research and monitoring questions and suggestions include:

- Perform studies to define the impact of surrounding land use patterns on the geomorphology of the landscape at the monument.
- Keep rigorous track of land use and development and create community profiles in surrounding areas. Possibly employ a GIS to monitor land use changes.
- Cooperate with local developers to minimize impact near park areas.
- Consult conservation groups regarding cooperative efforts to increase the areas of relevant parklands and protect more of the region from development.
- Promote environmentally sound methods of developing land parcels including partial clearing of trees and proper construction of stable slopes.

10. Connections between geology and the Plantation’s history

Interpreters make the landscape come alive for visitors and give the scenery a deeper meaning. Because geology forms the basis of the entire ecosystem and is directly responsible for the unique history at George Washington Birthplace National Monument, geologic features and processes should be emphasized to improve the visitor’s experience. The website for the park needs to be updated for geologic content and connections with other scientific and cultural disciplines.

Charcoal found in a ravine within the flat uplands dates from 1360 years ago. Another ravine contained a 350- year- old stump that dates the Brooks Colony slash and burn agricultural practices. Cores within the Popes Creek estuary record the transition from a relatively constant peat accumulation of a forested environment to the modern agricultural horizon.

Europeans began settling the George Washington Birthplace area in the late 1600's. Their farming and homestead activities created an unnatural landscape that persists today at the monument. Minor irrigation features, removal of soil and rocks, stone fences, grazed pastures, extensive logging, and other homestead features dot the landscape.

As part of the historical landscape at the monument, several drainage ditches were carved into the Calvert Formation. These served to drain the fields, irrigate crops, and possibly mark boundaries for neighbors and animals. As a young, practicing surveyor, George Washington surveyed the landscape near Dickweed Swamp, formerly a turnip patch within a 14 acre area.

The park is charged with maintaining the historic context of the landscape at the monument. This often means working against natural geologic changes. Many of the historical features at the monument have been lost to coastline erosion. The waterways are changing position constantly as part of natural meandering river flow. These shoreline changes threaten existing park facilities and the historical context of the landscape. From Brooks Patent Point 120 to 500 m (400 to 1,650 ft) more coastline extended into the Potomac River. Church Point, the site of Washington's baptism washed away before the site became a national monument. In 2004, the earthen dam that holds the "ice pond" blew out. Main roads and buildings are susceptible to flooding during high water storm events.

Efforts to commemorate the site are also sometimes thwarted by geologic features and processes. In 1820, William Augustum Washington's efforts to sail into the estuary failed due to the shallowness of the mouth of Popes Creek. The obelisk, a prominent feature at the monument, was carted in on railway because the estuary was too shallow to allow water transport up Popes Creek.

Research and monitoring questions and suggestions include:

- Use the park library to track the history of land use. Resources within the library include an 1891 survey of the eastern side of Popes Creek Estuary as well as historical photographs.
- Use N- alkanes to measure changes in land use through time.
- Create interpretive programs concerning geologic features and processes and their effects on the settlement history of the monument.
- Encourage interaction between geologists and the interpretive staff to come up with a list of features and programs to execute.

- Create a general interest map with simple explanatory text on geologic influences for visitors to the monument.

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References

Duffy, D.F., Whittecar, G.R., 1991, Geomorphic development of segmented alluvial fans in the Shenandoah Valley, Stuarts Draft, Virginia. Abstracts with Programs - Geological Society of America, vol.23, no.1, p.24.

Harris, A.G., Tuttle, E., Tuttle, S.D., 1997, Geology of National Parks. Kendall/Hunt Publishing Company, 759 p.

Means, J., 1995, Maryland's Catoctin Mountain parks; an interpretive guide to Catoctin Mountain Park and Cunningham Falls State Park. McDonald & Woodward Publishing Company : Blacksburg, VA, United States, 168 p.

Mixon, R.B., Pavlides, L., Powars, D.S., Froelich, A.J., Weems, R.E., Schindler, J.S., Newell, W.L., Edwards, L.E., Ward, L.W., 2000, Geologic Map of the Fredericksburg 30'x60' Quadrangle, Virginia and Maryland. U.S. Geological Survey, Geologic Investigations Series Map I- 2607, 1:100,000 scale.

Onasch, C.M., 1986, Structural and metamorphic evolution of a portion of the Blue Ridge in Maryland. Southeastern Geology, Vol. 26, Issue 4, pp. 229- 238.

Southworth, S., Brezinski, D.K., Orndorff, R.C., Chirico, P.G., Lagueux, K.M, 2001, Geology of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor, District of Columbia, Maryland, West Virginia, and Virginia; A, Geologic map and GIS files (disc 1); B, Geologic report and figures (disc 2). U. S. Geological Survey, Open- File Report: OF 01- 0188.

Whittecar, G. R., Duffy, D.F., 2000, Geomorphology and stratigraphy of late Cenozoic alluvial fans, Augusta County, Virginia, U.S.A. In: Regolith in the Central and Southern Appalachians, Clark, G.M., Mills, H.H., Kite, J.S., eds., Southeastern Geology, vol.39, no.3- 4, p.259- 279.

Map of George Washington Birthplace National Monument