Final Report: Stormwater Management Observation Program

THE JAMESTOWN PROJECT











JAMESTOWN, VIRGINIA

SUBMITTED TO

National Park Service
Colonial National Historical Park, Jamestown Unit

Association for the Preservation of Virginia Antiquities
Jamestown National Historic Site



THE JAMESTOWN PROJECT

JAMESTOWN, VIRGINIA





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ACRONYMS AND ABBREVIATIONS

APVA – Association for the Preservation of Virginia Antiquities
CBPL – Collections Building Parking Lot
CFS – cubic feet per second
DCP/EIS – Development Concept Plan/Environmental Impact Statement
DO – dissolved oxygen
E&S – erosion and sediment
EC – electrical conductivity
HDPE – high-density polyethylene
mg/L – milligrams per liter
NPS – National Park Service
NTU - nephelometric turbidity unit
PVC – polyvinyl chloride
ROD – Record of Decision
µS/cm – microSiemens per centimeter

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INTRODUCTION

In May 2003, the Record of Decision (ROD) was signed for the Jamestown Project *Final Development Concept Plan/ Environmental Impact Statement* (DCP/EIS) (NPS/ APVA 2003). This was a significant accomplishment in a joint effort by the Association for the Preservation of Virginia Antiquities (APVA) and the National Park Service (NPS) to present a unified Historic Jamestowne. Part of this effort included construction of a new Visitor Center, Collections Building, and exhibit building (Archaearium), as well as improvements to other buildings and the circulation of both vehicular and pedestrian traffic on Jamestown Island and at the Neck of Land area.

In accordance with the mitigation and compliance conditions of the ROD, the NPS implemented a Stormwater Management Observation Program to insure that the quality of runoff from newly constructed facilities at Historic Jamestowne met or exceeded state water quality standards. Routine site visits were conducted during rainfall events before, during, and after project construction was completed. This approach insured that any post-construction deviation in stormwater quality could be identified, explained, and addressed. Moreover, overall vigilance during construction and qualitative, photodocumented memorandums helped to insure that lapses in erosion and sediment control measures were quickly rectified and thus posed no threat to the receiving waters of the Pitch and Tar Swamp and the Back River.

The signing of the ROD on March 2003 cleared the way for these projects to begin the construction phase of the Jamestown Project. Groundbreaking occurred shortly thereafter and continued in earnest through April 2007, completed well before the Jamestown 400 celebrations. Over this period of time, 53 site visits were conducted. This Final Report summarizes the results from these visits, provides a summary of current conditions onsite, and recommends future monitoring and maintenance activities.

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METHODOLOGY

PROJECT AREA AND SAMPLE SITE LOCATION

New facilities constructed at Historic Jamestowne include the Collections Building, Archaearium, new Visitor Center and associated parking lot (including a small lot dedicated to staff working in the Collections Building), and a new pedestrian bridge linking the new Visitor Center to the improved grounds at the Tercentennial Monument. Off-island construction includes the Intermodal Transportation Terminal and its parking lot, located in Neck of Land. The locations of each of these features are presented on Figure 1.

Because of the lack of topographic relief and proximity of stream and wetland systems to each of these improvements, water quality sampling stations were established at existing and proposed stormwater outfalls and other potential vectors for stormflow conveyance to jurisdictional waters. Monitoring commenced at nine stations, the locations of which are depicted on Figures 2, 3, and 4. These stations were named in simple numeric fashion from Site 1 to Site 9. In some cases, construction activities had already commenced prior to the first sampling visit, so pre-construction baseline conditions could not be cataloged. This was especially true of the Collections Building, which was framed up by October 2004.

Five months into the first year of monitoring, staff from the NPS, United States Geologic Survey (USGS), and Vanasse Hangen Brustlin, Inc. (VHB) convened to reevaluate the locations of each of these sampling stations. At this point, it was decided to abandon those areas where discrete stormwater outfalls were not present. Examples include Sites 1 and 2 at the Collections Building (Figure 3). These represented unconstrained (non-point source) sampling locations within or immediately adjacent to the Pitch and Tar Swamp that were correspondingly less sensitive barometers of potential water quality concerns within the construction site itself. Similar examples include Sites 5 and 6 in the vicinity of the New Visitor Center (Figures 2 and 3). To address these concerns, six new stations were established at more discrete stormwater outfalls. Sites 1 and 2 were replaced by sampling at the input and outfall pipes of the stormwater basin at the Collections Building (Bio In and Bio Out, Figure 3). However, most of these sites were located at outfalls from the new Visitor Center and its parking lot, and include the Collections Building Parking Lot, the Bus Stop Site, Site E, and the Trench Site (Figure 2).

During the coordination meeting, it was also agreed that spot sampling should be conducted as necessary to characterize any visually obvious and questionable discharge. This included pooled areas around active construction sites, temporary access areas, areas around drop inlets, and those areas that typically only discharge water during significant rain events (e.g., ditches around the Bronze Trough and Hunt Shrine, Figure 3). Lastly, new and permanent sampling stations were established as new stormwater infrastructure



Association for the Preservation of Virginia Antiquities (APVA)

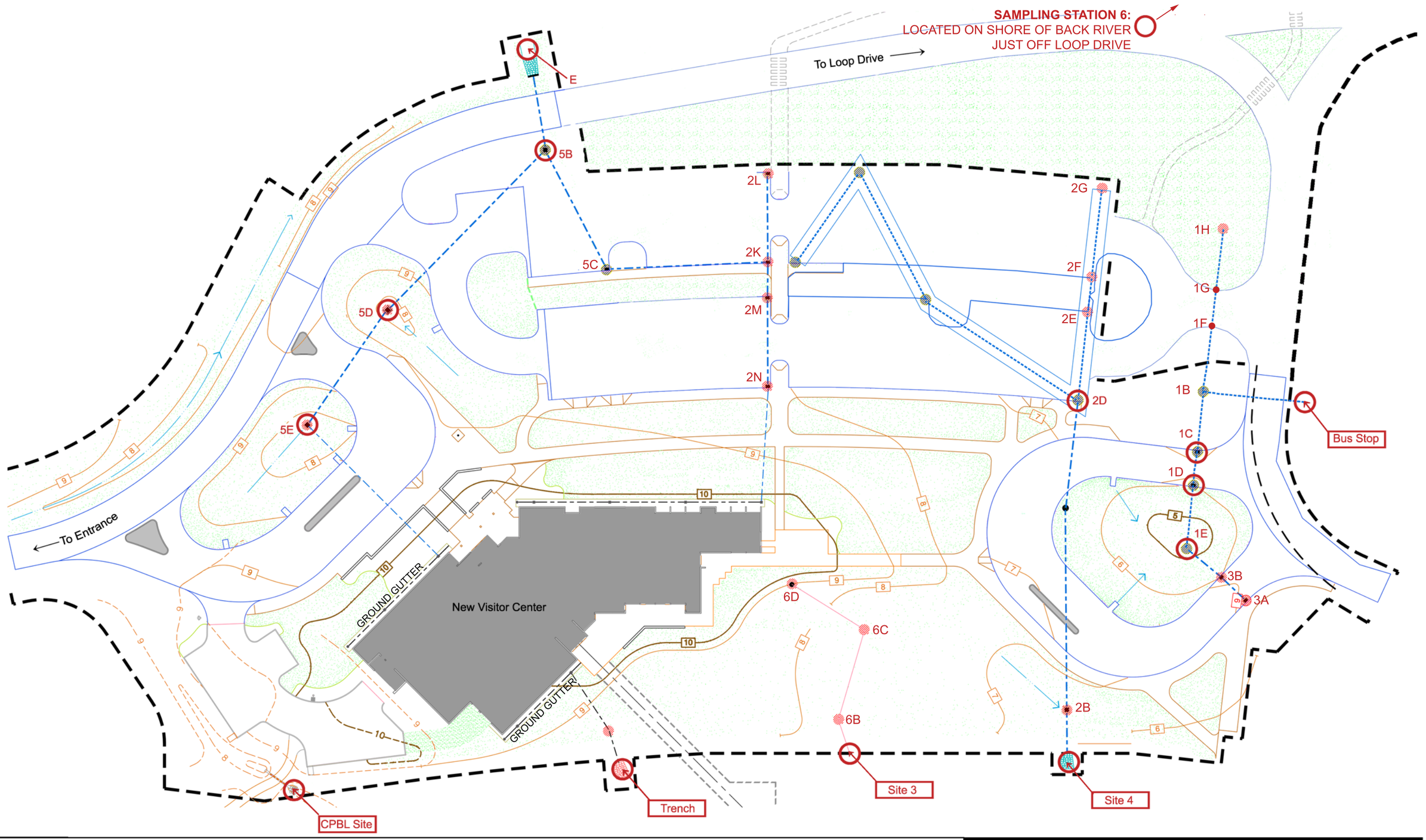
Colonial National Historical Park

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Vanasse Hangen Brustlin, Inc.

Historic Jamestowne

Figure 1
Stormwater Management Observation Sites: Project Location



N

stormwater monitoring stations

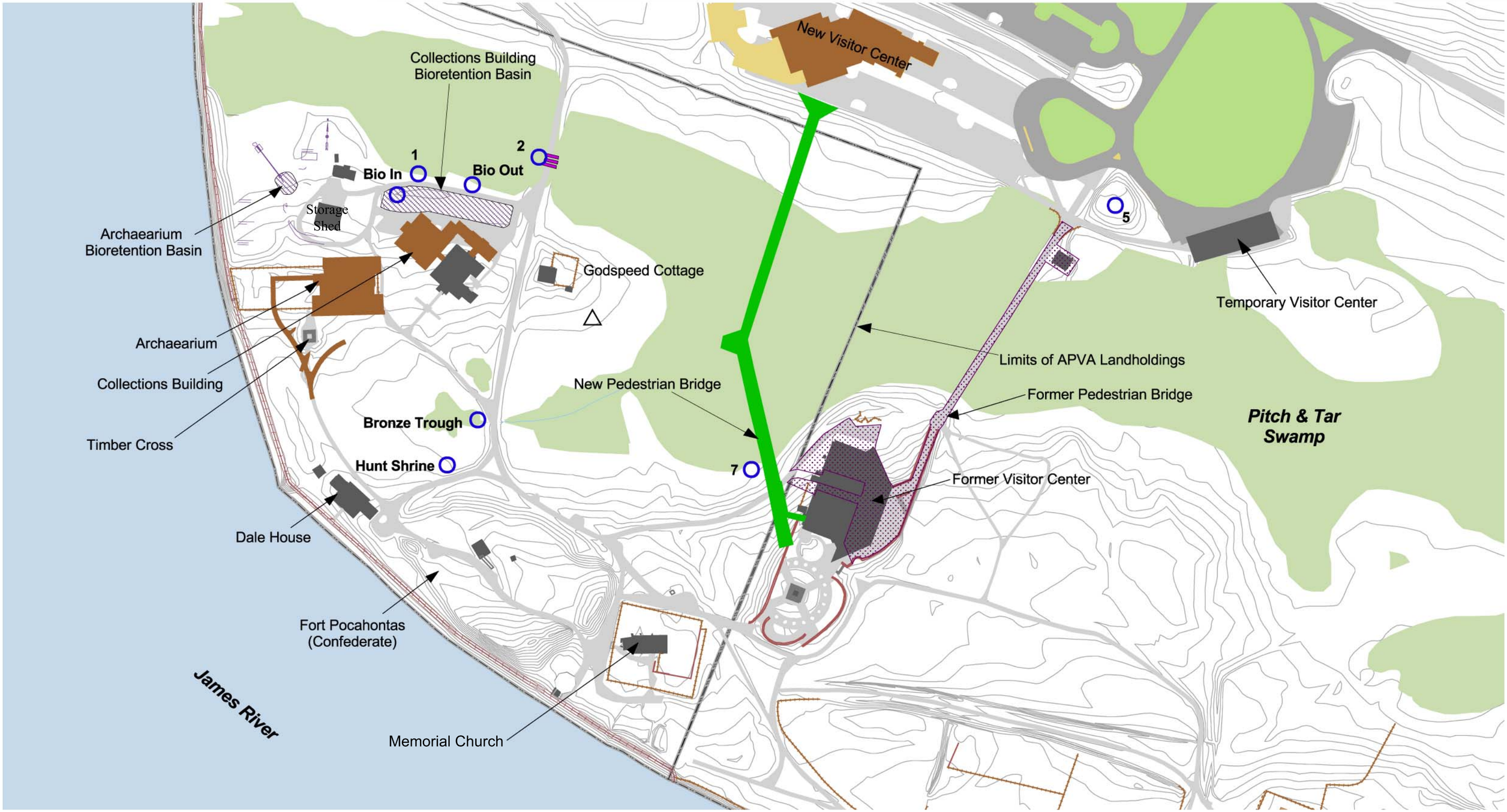
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Figure 2
Stormwater Management Observation Sites:
Vicinity of New Visitor Center

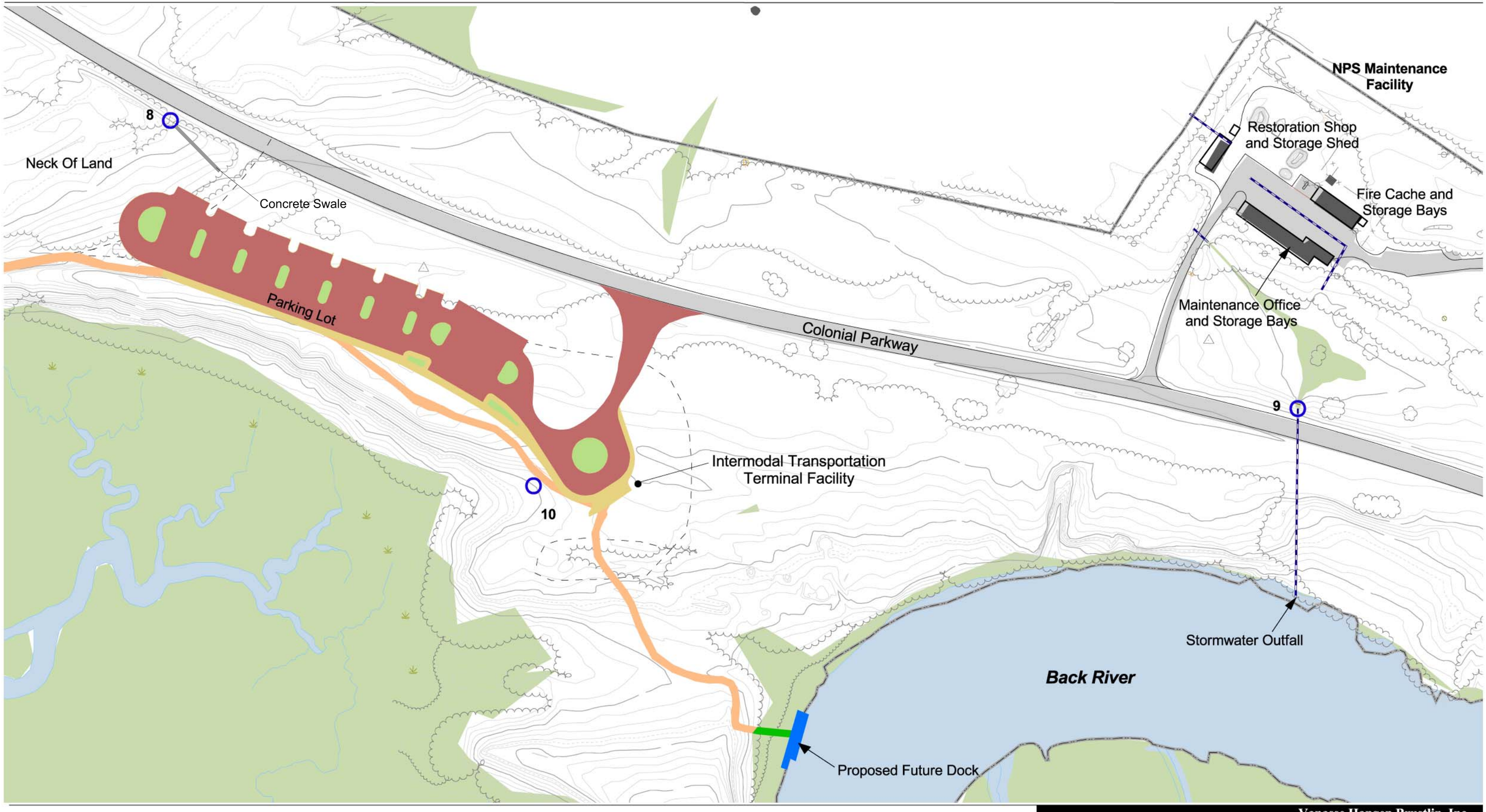


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Figure 3
Stormwater Management Observation Sites:
APVA Landholdings



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APVA

Historic Jamestowne

Figure 4
Stormwater Management Observation Sites:
Neck of Land Area

was completed, such as the outfall pipe and forebay at the Intermodal Transportation Terminal (Site 10, Figure 4).

Stations at the New Visitor Center

The following sections describe the location and nature of drainage at the sampling stations in the vicinity of the new Visitor Center. Each of these stations and its contributing drainage network is shown on Figure 2.

Bus Stop Site

The Bus Stop Site is located to the far west side of the new Visitor Center parking lot. The sampling point is located at the outfall to the forested area which drains water from three drop inlets and yard drains (1B, 1E, and 1H) and six curb inlets (1C, 1D, 1F, 1G, 3A, and 3B) at the easternmost side of the new Visitor Center parking lot area (Photo 1).



Photo 1: Bus Stop Site.

Site E

Site E is located at the outfall pipe to the Back River northwest of the new Visitor Center parking lot (Photo 2). This pipe drains three drop inlets (5B, 5D, and 5E) and five curb inlets (2L, 2K, 2M, 2N, and 5C) in the northern and western portions of the parking lot, as well as rooftop runoff from the north side of the building via a ground gutter system.

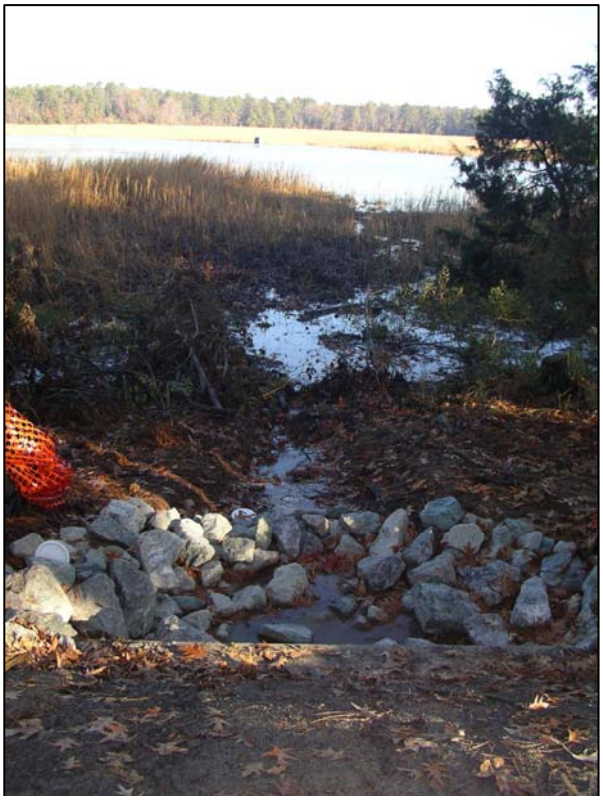


Photo 2: Site E.

Collections Building Parking Lot Outfall

The Collections Building Parking Lot (CBPL) is located just west of the new Visitor Center and drains to an adjacent, small stormwater basin and ditch. Samples were drawn from the downstream side of a culvert at the south end of the ditch, where runoff flows overland towards the Pitch and Tar Swamp (Photo 3). The main source of water for this basin is the CBPL itself, with minor amounts being contributed by the undeveloped, grassed area to its west.



Photo 3: Collections Building Parking lot outfall.

Trench Site

The Trench Site is located to the south of the new Visitor Center and west of the new pedestrian bridge. The sampling location is at a pipe outfall that discharges runoff from nearby grassy areas via a single drop inlet at the edge of the words near the north end of the new pedestrian bridge, as well as rooftop runoff via a ground gutter system (Figure 2, Photo 4).



Photo 4: Trench.

Site 3

Site 3 is located at a stormwater outfall south of the new Visitor Center and to the east of the sidewalk leading from the building to the new pedestrian bridge (Photo 5). This outfall conveys runoff from grassy areas southeast of the Visitor Center, collected via three drop inlets (6B, 6C, and 6D, Figure 2).



Photo 5: Site 3

Site 4

Site 4 is located at a pipe outfall east of Site 3, abutting a grassy area south and west of the east circle drive at the new Visitor Center (Photo 6). This outfall discharges water collected from four curb inlets and one drop inlet into the Pitch and Tar Swamp. Field investigations of water level fluctuations revealed that this location is occasionally backflooded by brackish water during high tides.



Photo 6: Site 4

Site 5 (abandoned)

Site 5 was located further east of Site 4 in the shallow depression near the temporary Visitor Center (Figure 3). The area is connected to the Pitch and Tar Swamp by a culvert that passes underneath a sidewalk. Water quality sampling was abandoned at this location when it was determined that the source of any significant amount of impounded water was typically the Pitch and Tar Swamp and was not stormwater derived.

Site 6 (abandoned)

Site 6 was located on the shoreline of Back River near the location of the proposed New Dock and New Bridge (Figure 2). This sampling station was abandoned due to its considerable distance from the construction site and the lack of a point-source(s) of runoff.

Stations in APVA Landholdings

The following sections describe the location and nature of drainage at the sampling stations outside of the boundaries of the Jamestown National Historical Site. They are located on APVA property south of the Pitch and Tar Swamp in the vicinity of the Collections Building, Archaearium, and Tercentennial Monument. Each of these stations is shown on Figure 3.

Collections Building Bioretention Basin

The stormwater basin immediately adjacent to the north side of the Collections Building is in fact a dry pond, low-impact development system called a “bioretention basin.” This facility was designed to accept rooftop runoff and that from surrounding ground and road surfaces. Stormwater pools within this basin and slowly infiltrates through its base, filtering potential pollutants before they reach the water table. The water level within the bioretention basin is regulated by a two-stage concrete control structure on its north bank. When the prescribed capacity is exceeded, water drains north under the neighboring access road and into the Pitch and Tar Swamp via three PVC pipes (Photo 7).



Photo 7: Collections Building Bioretention Basin Outfall

Archeaerium Bioretention Basin

A similar bioretention basin is located northwest of the Storage Shed and Archeaerium (Photo 8). It accepts rooftop runoff from the Archeaerium routed through a drainage swale running west behind the Storage Shed and then north into the basin. The areas surrounding the basin (open field to the west and north and gravel parking area to the east) also drain into this facility.



Photo 8: Archeaerium Bioretention Basin

Site 7

Site 7 was located just northwest of the Tercentennial Monument on the southern edge of the Pitch and Tar Swamp. The sampling point was located at the base of a culvert formerly linked to the drainage system of the original Visitor Center (Photo 9). This location is also proximal to the southern terminus of the new pedestrian bridge. This site was selected to monitor potential water quality concerns related to the demolition of the original Visitor Center and to the construction of the new bridge. However, like Site 2, interpretation of the results of sampling was constrained by the fact that this area is routinely inundated by tidal backflooding. Thus, the provenance of sampled water was frequently difficult to ascertain. Nevertheless, Site 7 also functioned as a fixed point at which qualitative observations could be gathered.



Photo 9: Site 7

Bronze Trough Site

The Bronze Trough is located on the west side and at the approximate midpoint of the access road between Godspeed Cottage and the Dale House. The sampling site named after this historic feature is located at a nearby culvert in the road, representing its intersection with the southwest tributary of the Pitch and Tar Swamp. Numerous ditches converge at this low point in the landscape, most of which provide drainage for the surrounding gravel road surfaces (Photo 10).



Photo 10: Bronze Trough Site

Water quality samples from the Bronze Trough Site were seldom collected for formal lab processing, as the complex provenance of such water precluded any deductive analysis. However, informal observations at the site were important from a qualitative standpoint. Visually characterizing the water clarity at this location was often a useful barometer of local conditions. On one the occurrence of particularly turbid water was traced to the pumping of sediment-laden water from the excavation at Fort Pocahontas.

Hunt Shrine Site

The Hunt Shrine sampling station is located in the ditch on the east side of the access road leading from Godspeed Cottage to the Dale House (Photo 11). A pipe outfall is located in this ditch, connected to a drain in the bowl-like area around the Hunt Shrine. This pipe typically discharged water only during high-intensity rain events.



Photo 11: Hunt Shrine Site

Site 1 (abandoned)

Site 1 was located just north of the Collections Building and adjacent bioretention basin. The sampling point was located on the wetland (north) side of the silt fence that lined the access road. This station served to monitor the quality of water being discharged from the construction areas around the Collections Building. Specifically, one of the pump hoses dewatering the foundation of the Collections Building was positioned at Site 1. This site was abandoned once the bioretention basin was completed.

Site 2 (abandoned)

Site 2 was located in the upper portion of the Pitch and Tar Swamp at the culvert in the private access road leading from the main road to the Collections Building. Routine sampling at Site 2 was abandoned for reasons similar to those at Site 6 on the Back River (e.g., distance from active construction, water quality and level fluctuations affected by tides and perhaps reflecting off-site conditions).

Stations in Neck of Land Area

The following sections describe the location and nature of drainage at the sampling stations in the Neck of Land area. Each of these stations is shown on Figure 4.

Site 8

Site 8 is located at a culvert under the Colonial Parkway immediately west of the new parking lot for the Intermodal Transportation Terminal. This culvert provides drainage relief for an intermittent stream flowing in a northeasterly direction (Photo 12). This stream now accepts runoff from the western half of the parking lot via a curb drain and concrete flume.



Photo 12: Site 8

Site 9

Site 9 is located on the upstream end of the culvert draining the grassy area between the NPS Maintenance Facility and the Colonial Parkway, just east of the new Intermodal Transportation Terminal (Photo 13). As this culvert discharges directly to the Back River, a sampling station was established at this location to monitor any potential change in water quality related to the installation of nearby utility trenches servicing the Intermodal Transportation Terminal.



Photo 13: Site 9

Site 10

Site 10 is located at the outfall of the stormwater pipe that discharges runoff from the circle drive in front of the Intermodal Transportation Terminal. Overflow from a small, riprap-lined detention basin downstream of the pipe follows a grassy swale towards marshy tributaries of the Back River (Photo 14). During typical rain events, all water dissipates within the forested area between just beyond the structure before reaching the Back River.



Photo 14: Site 10

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DESIGN OF THE MONITORING PROGRAM

WATER QUALITY PARAMETERS

Several commonly used parameters were selected to monitor water quality at the established stations. These metrics included pH, electrical conductivity (EC), dissolved oxygen (DO), and turbidity, and are described in Table 1 below. This broad-spectrum approach allowed for the identification of a variety of potential contaminants. Another important consideration in choosing each of the four parameters is that as industry standards, they can be measured using equipment that is cost-effective, reliable, easy to maintain and portable, while at the same time providing reasonably accurate results in a field or office laboratory setting.

Table 1: Description of Water Quality Parameters

Parameter	Definition	Units
pH	Measurement of hydrogen-ion activity. An indication of a given solution's acidity or alkalinity.	dimensionless (pH scale is an inverse logarithmic representation of hydrogen proton (H^+) concentration)
Electrical Conductivity (EC)	The ability of water to conduct an electric current. The relative measure of the total dissolved solids.	microSiemens per centimeter (µS/cm)
Dissolved Oxygen (DO)	The amount of oxygen in the water. Low levels can be harmful to aquatic organisms.	milligrams/liter or percentage (mg/L or %)
Turbidity	A measure of the optical properties of water that cause light to be reflected or scattered. Causes of high turbidity include organic matter, algae, sediment, and solids.	Nephelometric Turbidity Unit (NTU)

STORMWATER CHEMISTRY

pH

Pristine, unpolluted rainfall has a pH of approximately 5.6. This slightly acidic condition is caused by the combination of atmospheric carbon dioxide and rainwater, producing carbonic acid. The typical pH of rainfall in Virginia is 4.6, or about 10 times more acidic (VCTU 2007). This is a result of the solution of oxidized sulfur and nitrogen emitted from burned fossil fuels and metal refining operations. Geographically, the pH of rainfall is generally uniform and greater than 5.1 across the western states to the Mississippi River. Continuing east, it increases sharply through the eastern states. This is the combined effect of a heavy industry in the Midwest and the prevailing weather direction. The nature of the soil or surface upon which this precipitation falls can greatly affect the resulting pH of the stormwater runoff. Fresh concrete surfaces and basic soils tend to buffer rainwater, resulting in runoff approaching neutral. A variety of soils underlie the construction areas at Historic Jamestowne, each of which ranges from slightly to greatly acidic (USDA 1985). Therefore, the buffering ability of the native soil is not pronounced and the pH of runoff is expected to be somewhat acidic, especially where it is generated over undisturbed, natural surfaces.

Electrical Conductivity (EC)

By its very nature, rainwater is very dilute. Pristine rainfall in theory should approximate distilled water, and thus have very low EC (less than 1.0 µS/cm). However, the same pollutants that cause acid rain, coupled with other sources of anions such as soil dust and smoke from forest fires, will result in some dissolved compounds in rainwater. Rainfall is typically less than 100 to 150 µS/cm (CWT 2004).

Dissolved Oxygen (DO)

The level of DO in stormwater runoff is typically high. As rainwater courses of a variety of surfaces, it tends to entrain oxygen. Therefore, anomalously low readings for DO may indicate the presence of anaerobic conditions at some location above the sampling point. These include areas of organic-rich, stagnant water or water tainted by sewage, in which microbial activity consumes DO.

Turbidity

For the purpose of this study, precipitation is considered to be optically clear. As a product of evaporation and plant transpiration, this is a reasonable assumption. Therefore, any measurable turbidity is a function of the availability of loose sediments to be entrained between the point at which rainwater falls and the sampling station.

Summary

Significant fluctuations in turbidity are common during the land-disturbance phase of any site construction, as soils are graded and sediment is transported by stormwater. Of the four metrics, turbidity

typically experiences the most deviation from baseline conditions. However, pH and EC can also be important indicators of soluble pollutants, such as accidental chemical spills.

TIMING OF SITE VISITS

Rather than be scheduled at fixed intervals, site visits were conducted during times of moderate to heavy rainfall, when runoff was most likely to happen. Field scientists carefully followed weather forecasts and consulted weather radar via the Internet. When possible, personnel arrived at Jamestown prior to the onset of rainfall in order to capture the "first flush" of stormwater through the system. This initial pulse of water can contain a chemical signature that provides insight into the character of the watershed within which it originated. As rainfall intensifies, surficial contaminants such as loose sediment, isolated chemical spills, and so on, are quickly mobilized and washed through the drainage system. After this flush of pollutants moves past the sampling station, the quality of subsequent discharge is relatively improved. Depending on the length of the path over or through which the runoff must flow, it can quickly begin to resemble that of the source rainwater itself. This illustrates the importance of sampling the first flush. Field scientists typically stayed onsite through peak rainfall intensity, collecting multiple samples from certain stations to characterize their watersheds. When climatic conditions permitted, at least one such field trip was conducted per month.

Due to daylight constraints and personnel availability, not all candidate storms could be sampled from inception through peak intensity. In such cases, site visits were conducted after the fact. On occasion, samples were collected from those sites with persistent flow in order to document conditions on the falling limb of the storm hydrograph. Oftentimes, important qualitative observations were made at these times, such as the presence of failed erosion and sediment control measures or fresh gully erosion on cleared land. Similar visual assessments were chronicled when candidate storm events failed to yield runoff due to low-intensity rainfall.

SAMPLE COLLECTION

Discrete grab samples were obtained from those stations with flowing water and from any special areas of concern during site visits. The samples were collected in 125 ml high-density polyethylene bottles, obtaining virtually zero headspace so as to preserve the water for later analysis. Turbidity samples were collected in the same manner in 20 ml glass vials. Duplicate samples were taken from at least one station during each field outing to validate data processing.

Due to the inclement conditions during sample collection and the need to move quickly between multiple and distance stations, all samples were brought back to the office for analysis in a controlled environment. Samples were typically processed immediately upon returning to the office. If this was not possible, samples were preserved in a refrigerator until they could be processed.

RAINFALL DATA

Rainfall data for each event were obtained for the nearby Williamsburg Airport, a station reporting to the National Weather Service (MRCC 2007). In May 2006, a tipping-bucket rain gauge equipped with an

electronic data logger was installed in the lawn behind Godspeed Cottage (Figure 3). This logger was downloaded following the conclusion of each documented rain event. Bird droppings fouled the gauge on numerous occasions, and resulted in some data loss.

SAMPLE PROCESSING

Each water sample was processed using equipment manufactured by Hach Company. A Sension156 Portable Multiparameter Meter was used to measure pH, EC, and DO. The meter is capable of reading these parameters through the use of three interchangeable electrodes.

A Hach Portable Turbidimeter Model 2100P was used to measure turbidity, having a resolution from 0.01 to 1000 NTU. For each sample, three readings were measured consecutively and then averaged to provide an overall number (as recommended by the manufacturer). Samples exceeding the instrument's maximum range were diluted with equal amounts of distilled water as necessary to produce an in-range reading. The resulting reading was multiplied by the number of dilutions to interpolate the actual turbidity.

Prior to sample analysis, each piece of monitoring equipment was calibrated according to the manufacturer's specifications. Standard laboratory practice was carefully followed. All probes and beakers were cleansed with distilled water between each sample analysis, and sample bottles were cleaned with an anionic detergent such as Alconox® and placed on a drying rack post analysis. All sensors were cleaned and inspected for signs of wear or damage and refurbished or replaced as necessary.

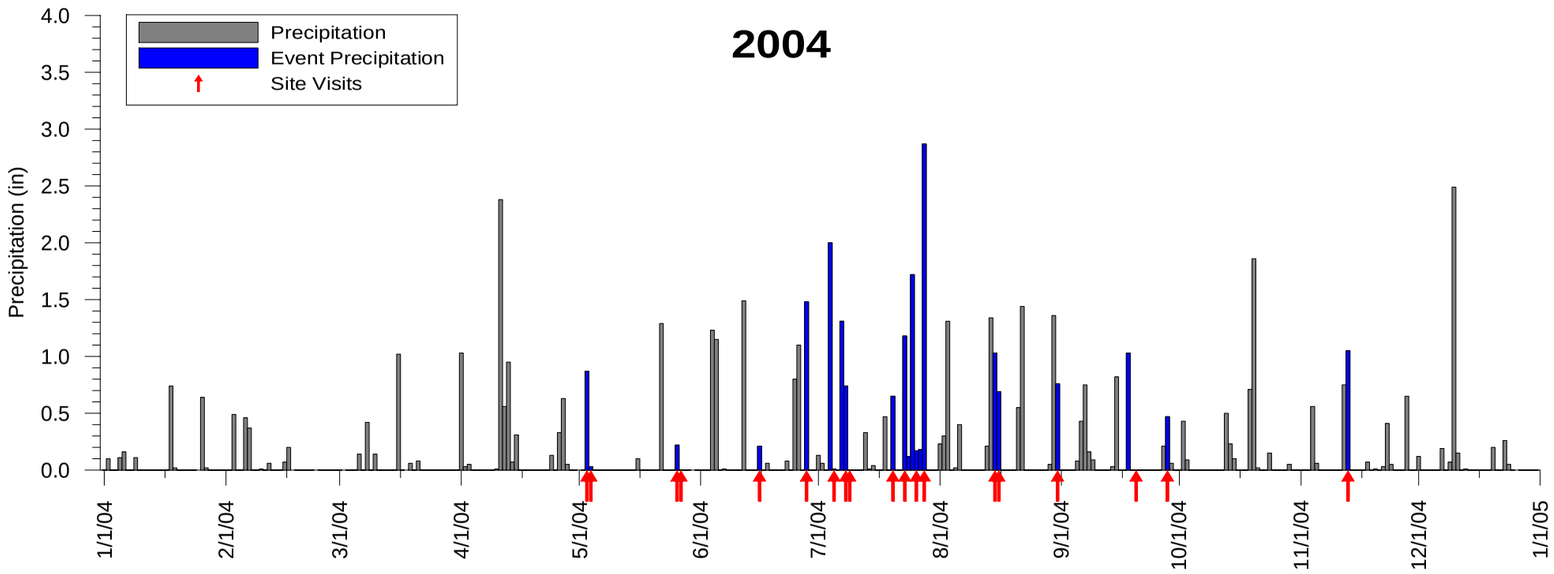
DATA ANALYSIS

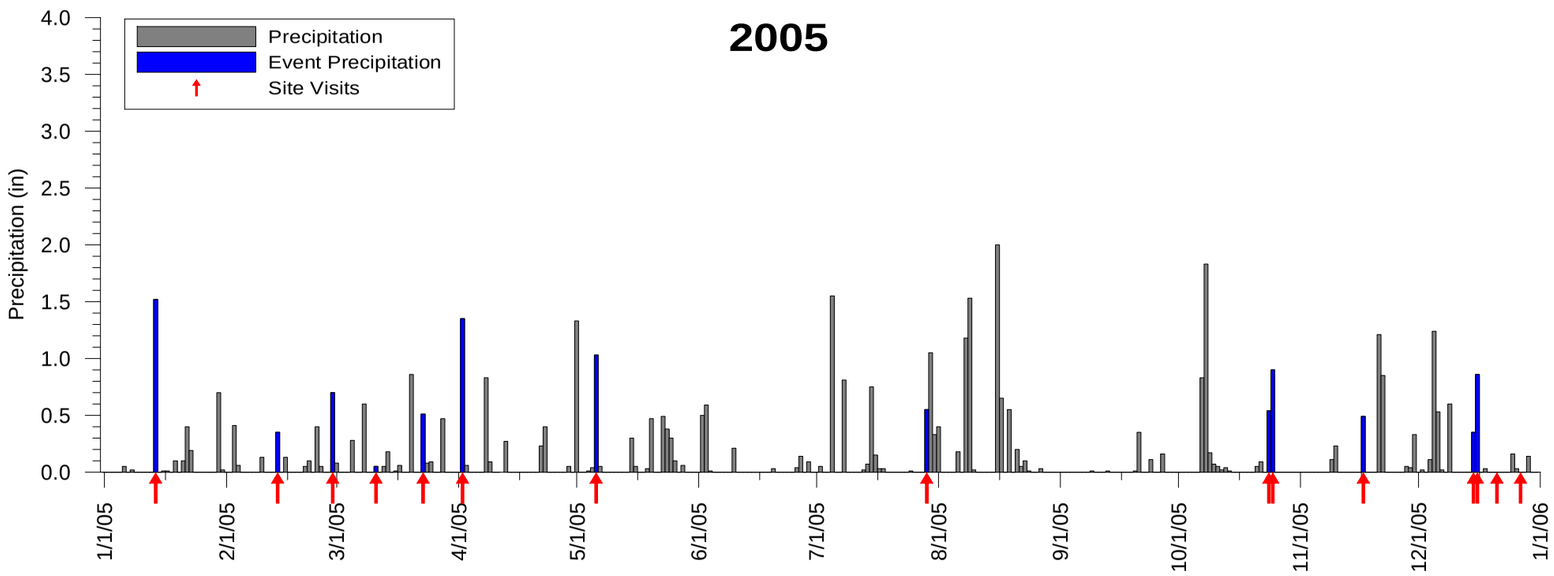
After processing each water sample, results were compiled electronically both within an event-specific spreadsheet (i.e., including results for all stations sampled during that event) and within a station-specific spreadsheet. Data were also broadly categorized accordingly to when the samples were collected relative to peak rainfall intensity: pre, during, and post. All data were then further examined and averaged to determine baseline conditions (if possible) and deviations from the norm during and after construction.

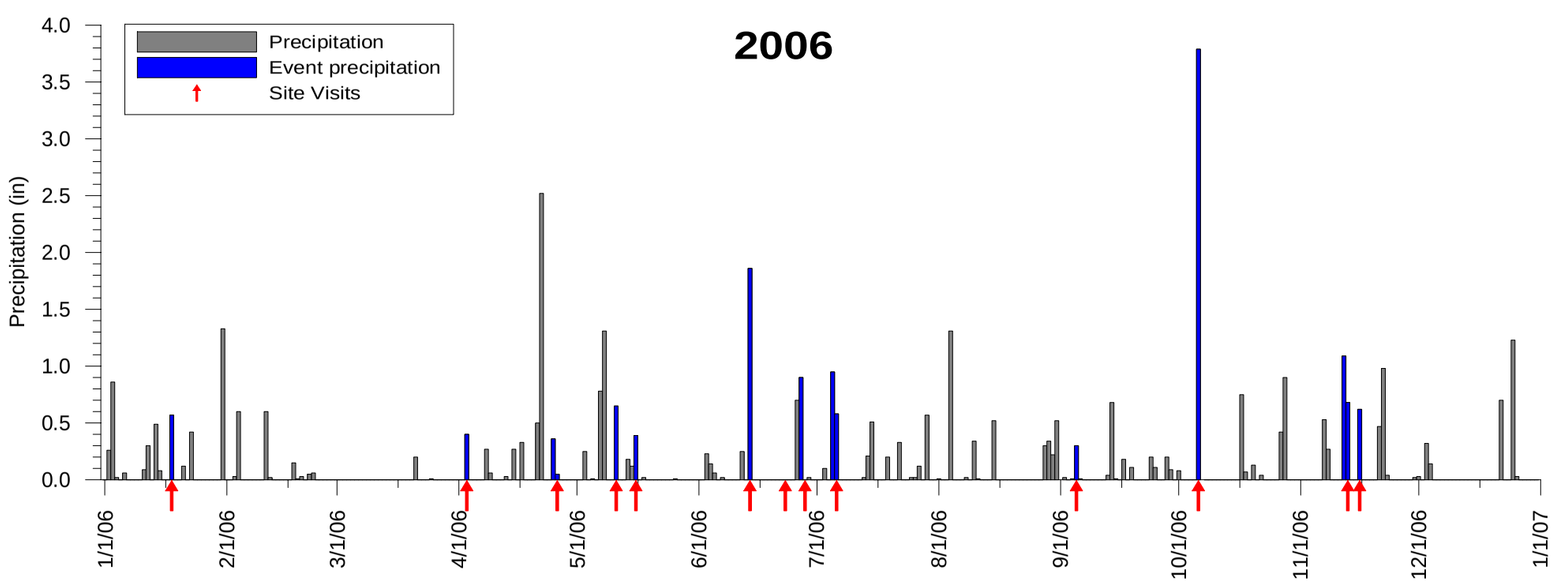
REPORTING

Stormwater monitoring at Historic Jamestowne commenced in May of 2004 and continued through May of 2007. In total, field scientists conducted 53 site visits. Conditions were suitable for stormwater sampling on 40 occasions. Figure 5 presents the rainfall record for the entire monitoring period. Daily total precipitation as recorded at both the Williamsburg Airport and on site is depicted in four separate graphs arranged by calendar year. Rainfall associated with a site visit is labeled as "Event Precipitation". The dates of all site visits are denoted by a red arrow just below the horizontal (date) axis on each graph.

Brief field reports were distributed electronically to the NPS and APVA following each of these events, summarizing the results, chronicling consultations with the general contractor, photo-documenting site conditions, and providing recommendations for remediation as necessary.







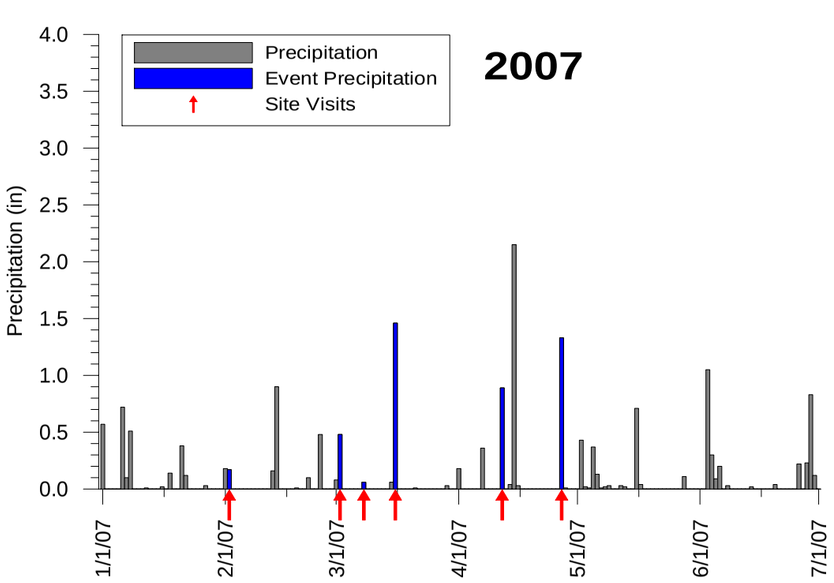


Figure 5.
Rainfall Records: Periods I, II, and II (2004-2007)

Historic Jamestowne
The Jamestown Project
Stormwater Management Observation Program

4
RESULTS

BASELINE CONDITIONS

Baseline water quality data do not exist for most of the sites, as site preparation or construction had commenced prior to the initiation of water quality sampling. The asphalt surface of the old Visitor Center parking lot had been removed, and the foundation of the Collections Building installed. The north and west sides of the Collections Building consisted of bare soil and were heavily trafficked by construction vehicles and equipment. The former Visitor Center had been largely demolished, with some remnant debris left onsite. Only Sites 8 and 9 in the Neck of Land area have sufficient pre-construction data to characterize baseline conditions.

Sites 8 and 9

Pre-construction conditions at Sites 8 and 9 are provided in Table 2. Water quality at both stations was predictably nondescript, with pH just below neutral, and very low turbidity and EC. DO varied somewhat between sites, with lower average DO at Site 8. This is because any water present at Site 9 is a direct result of stormwater runoff, and ponding is uncommon. Thus, water is typically well oxygenated. At Site 8, stagnant water conditions are more common, providing more opportunity for oxygen consumption by microbial activity.

Other Sampling Stations

While quantitative baseline data are lacking, prior work performed by VHB at Jamestown and associated field notes and observations suggest that all monitoring locations were in stable condition with regards to land cover. Furthermore, no known water quality concerns had been identified at or adjacent to the construction sites before the onset of land disturbance. As such, it is reasonable to assume that all water quality parameters for stormwater runoff fell within state guidelines.

CONDITIONS DURING AND AFTER CONSTRUCTION

As anticipated, fluctuations were observed in the values for each of the four water quality parameters at virtually each sampling station when construction was occurring in their contributing watersheds. The most significant departures from normal were experienced with respect to turbidity, reflecting the mobilization of loose sediment from disturbed or denuded soil surfaces, utility trenches, or stockpiled

TABLE 2: WATER QUALITY SUMMARY:
NECK OF LAND AREA

PRE-CONSTRUCTION (JULY 2004 - AUGUST 2005)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Site 8	10	6.80	5.44	6.19	0.46	10	93	4	27	27	6	130	45	79	31	10	86	38	61	16
Site 9	9	7.50	6.27	6.77	0.41	9	24	5	10	6	5	130	84	97	19	9	423	45	119	120

CONSTRUCTION (AUGUST 2005 - JUNE 2006)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Site 8	5	8.49	6.39	7.26	0.78	4	3475	6	887	1725	5	78	47	66	12	5	407	151	244	102
Site 9	4	7.12	6.67	6.88	0.19	5	52	5	16	20	4	74	61	68	6	4	101	75	88	11
Site 10	8	10.01	6.83	8.79	1.32	7	744	89	269	254	6	103	25	80	29	6	342	69	162	126

POST-CONSTRUCTION (JUNE 2006 - APRIL 2007)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Site 8	6	7.01	6.35	6.72	0.24	7	146	11	45	47	6	125	73	94	17	6	227	63	144	64
Site 9	2	6.74	6.55	6.65	0.13	2	92	10	51	58	2	83	78	81	3	2	78	46	62	23

N = Number of historical values used for statistical anaylsis
σ = standard deviation

earth. The conveyance of suspended sediment to receiving waters was generally abated by erosion and sediment (E&S) controls such as silt fencing and by having stormwater drains protected by hay bales or geofabric coverings. Given the limited efficacy of standard E&S practices, some degree of sediment transport was unavoidable and not considered deleterious to receiving waters. However, spikes in the data record sometimes coincided with the failure or lack of implementation of such measures and highlighted the need to redress. Such needs were identified in the site-visit reports provided to the NPS and APVA.

While some results did pinpoint construction-related and avoidable water quality concerns, more benign and natural trends were generally observed in each parameter. EC typically peaked early in a storm event and decreased through peak storm intensity, reflecting the increasing contribution of relatively dilute rain water. Turbidity also tended to increase during the onset of precipitation, retreating back to lower, steady concentrations as the storm progressed. DO readings often increased over the same span, as turbulent stormflow entrained oxygen. Each of these trends is attributed to the "flushing" of residual water within nascent stormwater pipes or stored in surface depressions of work sites during the rising limb of the storm hydrograph. Water quality issues were only apparent when that residual water that was being flushed was outside a normal range for a specific parameter or the new water was being overly enriched by construction materials or chemicals as it navigated towards a discharge point. Once site construction ceased and disturbed surfaces were stabilized with vegetation or paved for parking and/or walkways, water quality improved at all monitoring sites.

Conditions at each sampling site during and after the construction phase are described below. Water quality data are summarized in Tables 2, 3 and 4. Individual data points are provided for each sampling station in Appendix A.

Stations at the New Visitor Center

Bus Stop Site

Even during intense storm events, discharge was typically not readily discernable at the Bus Stop Site due to its very low, backwater setting. Rather, water stages up slowly in a small pool about the pipe outfall, eventually spilling over a low crest and into the forested wetland area to the west.

During the construction process at the new Visitor Center and associated parking area, turbidity readings taken from the samples collected from this location tended to be elevated during high-discharge events. The sediment appeared to be coming from a number of sources in the eastern portion of the parking area, which consisted of bare earth for a considerable period of time before the asphalt surface was applied. Frequent vehicular traffic exacerbated the disturbance and mobilization of sediment. Turbid water was often observed accumulated around the curb inlets draining to the Bus Stop Site, including 1C, 1D, 1F, 1G, 3A, and 3B (Figure 2). Activity and bare ground conditions at drop inlets 1B and 1E released the bulk of the sediment to the drainage system. The maximum reading for turbidity at the Bus Stop Site was 642 NTU, recorded on 1/18/06.

Each of these inputs was fitted with filter fabric during construction to impede sediment transport, but it was easily torn by heavy discharge events. By VHB's recommendation, hay bales were placed around

TABLE 3: WATER QUALITY SUMMARY:
NEW VISITOR CENTER

CONSTRUCTION (OCTOBER 2004 - NOVEMBER 2006)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Site 3	24	7.97	6.38	7.04	0.36	25	1483	5	**343**	374	15	128	48	81	23	25	235	31	97	49
Site 4	34	8.04	6.11	6.85	0.42	33	**1000**	1	160	283	21	131	20	78	25	34	5187	29	280	882
Site E	16	12.00	5.97	7.97	1.74	14	509	14	139	151	13	93	25	74	18	14	2400	24	520	681
CBPL	19	9.87	6.08	7.34	0.78	19	3225	25	**321**	732	17	113	45	80	17	19	415	44	133	84
Trench Site	8	7.71	6.44	7.16	0.49	8	758	9	265	249	8	91	63	80	9	8	222	37	81	60
Bus Stop Site	24	10.55	5.96	6.99	1.10	23	642	9	112	150	21	116	30	75	22	22	2853	14	285	590

POST-CONSTRUCTION (NOVEMBER 2006 - APRIL 2007)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Site 3	4	7.30	6.40	6.85	0.37	4	300	25	149	118	4	107	82	93	12	4	305	68	184	104
Site 4	4	7.28	6.18	6.93	0.51	4	70	15	31	26	3	108	80	94	14	4	85	27	64	25
Site E	7	7.60	6.56	7.13	0.32	7	90	21	36	24	6	111	73	90	13	7	338	49	128	105
CBPL	1	6.08	6.08	6.08	N/A	1	172	172	172	N/A	0	N/A	N/A	N/A	N/A	1	126	126	126	N/A
Trench Site	6	7.56	6.68	7.15	0.36	6	32	11	22	9	5	101	75	94	11	6	204	39	89	59
Bus Stop Site	7	7.26	7.07	7.19	0.08	7	209	5	46	73	6	99	76	89	8	7	483	80	220	157

N = Number of historical values used for statistical anaylsis
σ = standard deviation
Average Turbidity strongly influenced by outlier maximum reading.
Maximum turbidily equal to instrument max range (1000 NTU). Reflects sample taken before dilution processing initiated in lab environment.

some of the inlets, and additional silt fence was placed roughly 8 feet downstream of the Bus Stop Site outfall. Construction in the parking lot was completed in the fall of 2006, but somewhat turbid discharge persisted at the outfall. VHB determined that this was the result of the remaining unvegetated ground surface around drop inlet 1E (Photo 15). Grass finally began to take hold in this area in the spring of 2007, and turbidity readings subsequently decreased. Post-construction turbidity averaged 46 NTU, as opposed to 112 NTU during construction.



Photo 15. View of poorly vegetated surface around drop inlet 1E draining to the Bus Stop Site.

Average values for DO varied little between construction and post-construction periods, calculated at 75% and 89%, respectively. The slightly lower average value for the construction period is most likely a reflection of the larger number of post-event measurements taken during this time, when relatively slack or even stagnant water was present at the sampling station. The fewer number of post-construction measurements were generally taken at the onset of or during the event, thus capturing more oxygenated water. Similarly, average EC varied little, from 285 µS/cm during construction to 220 µS/cm afterwards. The average during construction is artificially inflated by the inadvertent sampling of backflooded tidal waters, which being brackish, have a naturally high EC. For example, on October 28, 2007, a reading of 2,853 µS/cm was recorded. Readings subsequent to the first flush (i.e., rising limb of hydrograph through to peak discharge) were typically below 100 µS/cm both during and after construction, indicating the transmission of relatively dilute and untainted stormwater.

While trends in DO and EC readings were predictable, water quality sampling at the Bus Stop Site documented high pH readings during the construction phase. A sample collected on December 15, 2005 exhibited a pH reading of 10.55, which exceeds the Virginia water quality standard of 9.0 for pH. A site meeting was called to determine the source of the contaminated runoff and an appropriate remediation plan. Personnel from the NPS, VHB, USGS, Alpha Corporation (general contractor), and THR, Inc. (subcontractor) met onsite on December 22, 2005, to discuss the matter. It was determined that the spike in pH was a by-product of the process used to create exposed-aggregate concrete finishes on both road and pedestrian surfaces. The concrete retardant Rugasol® was sprayed onto these surfaces to prevent the set of surface mortar. The day following initial pouring, the retardant and unset mortar were sprayed off and the resulting wash water directed towards drop inlets discharging into the Back River. During the site

meeting, a remediation plan was developed and implemented for the remainder of the construction process as explained in Appendix B. Subsequently, pH values returned below the state threshold and remained close to background levels for the remainder of the monitoring process.

Site E

The Site E outfall came online in the spring of 2005, during the construction period for the new Visitor Center and associated parking lot. Flow was almost always observed at this site, even well after a precipitation event. This is perhaps due to the extensive network of pipes connected to Site E and the correspondingly larger possibility for storage within the system itself. Turbidity readings remained consistently low during the monitoring process, with the exception of two anomalous peaks in January and November of 2006. Those readings were determined to be a result of a persistent lack of vegetation and subsequent erosion of the ground surface around contributing drop inlets 5D and 5E (Figure 2, Photo 16). As grass took hold in these areas, sediment transport to the outfall decreased. Post-construction turbidity averaged just 36 NTU, as opposed to 139 NTU during construction (Table 3).



Photo 16. View of unvegetated ground surface around drop inlet 5E.

As with the Bus Stop Site, pH spiked at Site E in December of 2005. Again, this was the result of exposed aggregate work around the entrance to the new Visitor Center. However, unlike the Bus Stop Site, maximum pH was notably higher: 12.00 versus 10.55. Because the pH scale is logarithmic, this means that discharge at Site E was actually 32 times more alkaline than at the Bus Stop Site. Furthermore, EC spiked along with pH, reaching peak values of 2,400 µS/cm and 1,131 µS/cm on December 15 and 16, 2005. The disparity between results at the two sampling sites is thought to lie chiefly in the fact that wash water from surfaces around the new Visitor Center entrance was routed more directly to drop inlets than it was at the eastern circle drive near the Bus Stop Site. In fact, abundant ponding was routinely noted at the former location. In addition, much of the circle-drive entrance was completed by mid-December 2005, whereas the eastern circle drive had not been installed. The lack of subsequent peaks in pH at both sites suggests proper implementation of the wash-water remediation plan during final paving. All post-construction water quality parameters at Site E were improved, with near-neutral average pH, low average EC and turbidity, and high DO (Table 3).

Unlike the Bus Stop Site, Site E is a new stormwater structure. As such, the pipe outfall was carefully monitored to insure receiving waters were not adversely affected by erosional scour and that the structure itself remained stable. Several lengths of timbered logs were observed in early 2007 within the rip-rap splash apron. VHB informed the NPS and proposed that these be removed to forestall any channel erosion at this location. At the time this document was prepared, these logs remained in place, and minor erosion was noted on their downstream side (Photo 17).



Photo 17. View of logjam below the Site E outfall.

CBPL Stormwater Basin

Though the drainage area for the CBPL stormwater basin is limited, it was nevertheless highly disturbed during construction of the new Visitor Center. The open space to its west was used to stage construction materials and equipment and to house trailers for contractors. Bare soil conditions and vehicular traffic around the new Visitor Center resulted in persistent muddy conditions on the east side of the basin. Hay bales were placed on the upstream side of the basin culvert to prohibit the transport of excess sediment to the offsite woods. The bales remained well after the completion of work in the new Visitor Center area and parking lot, as the land to the west of the ditch was still unvegetated. Because of the hay bales and the slightly elevated invert of the culvert relative to the basin floor, impounded water was typically observed.

No abnormal conditions were observed at this site during the construction process. Turbidity readings were elevated at times due to the high sediment load from adjacent and very active work sites, and peaked at 3,225 NTU in January 2006 (Photo 18).



Photo 18. Highly turbid water at CBPL Site.

However, as staged materials and work trailers were removed and the surrounding ground surfaces stabilized, subsequent turbidity readings were appreciably lower. With the exception of slightly elevated pH during the installation of exposed-aggregate surfaces, pH readings typically fell between 6.9 and 7.4. Maximum EC was 415, coincident with the most intensive exposed-aggregate work in December 2006. Otherwise, EC never exceeded 200 µS/cm. The ground surfaces around the CBPL stormwater basin and the flanks and base of the basin itself are currently highly stable (Photo 19). This fact, coupled with the considerable overland distance through which runoff from this facility must flow before reaching the open-water surface of the Pitch and Tar Swamp makes for a highly effective, low-impact stormwater treatment scenario.



Photo 19. View of stabilized CBPL Basin and surrounding ground surfaces.

Trench Site

Similar to the other sampling locations on the south side of the new Visitor Center, monitoring activities did not begin until construction was already underway. Flow was typically difficult to observe at the outfall of the Trench Site due to the very shallow gradient of the ditch leading away from the pipe and into the adjacent woods.

At the onset of monitoring at the Trench Site in the spring of 2005, turbidity readings were relatively high, coinciding with active construction of the building nearby. However, they were still far less than observed elsewhere, peaking at a relatively low maximum value of 758 NTU. These readings began to moderate significantly as construction and grading were completed and grass began to grow in the drainage area contributing to the Trench Site's sole drop inlet (Figure 2, Photo 20).

Much of the discharge at the Trench Site is rooftop runoff from the new Visitor Center, collected via a ground gutter inlet at the rear of the building (Figure 2). As such, EC was typically very low and DO high. As a pre-existing



Photo 20. View of stabilized ground surface around drop inlet draining to Trench Site

conveyance retrofitted to accept a minor amount of additional runoff, the outfall at the Trench Site and the downstream channel were predictably stable throughout the monitoring period.

Site 3

Water quality samples collected from Site 3 exhibited an elevated turbidity throughout the construction process. This was caused by poor seed germination and persistent bare soil in the areas around the contributing drop inlets. Once grass began to provide dense ground cover, a downward trend in turbidity was observed in water quality samples (Photo 21).



Photo 21. View of stable ground surface at middle drop inlet draining to Site 3.

DO was highly variable at Site 3. Low readings may have been a reflection of the flushing of stagnant water stored either in shallow depressions at surface or within the pipe system. Another possible explanation for low DO readings is the setting. Like the Trench Site, Site 3 is a long-standing drain. Because it discharges to a very low-gradient ditch and flow is not readily discernable, water quality samples may have often consisted of slow-moving or stagnant water. Readings ranged from 48% to 128%. Alternately, pH and EC were relatively static throughout the construction and post-construction monitoring periods.

Site 4

Monitoring at the Site 4 outfall commenced in January 2005, after construction of the new Visitor Center had already begun. Initially, not all contributing drop inlets were online, specifically the one closest to the outfall: drop inlet 2B. Site work in the vicinity of Site 4 continued for some time after the main construction on the building was completed, including paving of the east circle drive and fine grading of the green space between the drive and the Visitor Center.

As expected, elevated turbidity readings were recorded during the construction and grading process. Similar to the Bus Stop Site, some of the contributing curb inlets from the parking lot, specifically, curb inlet 2D (Figure 2), drained visibly cloudy water during precipitation events. However, after the parking lot was resurfaced and grass cover in the vicinity of drop inlet 2B began to stabilize the ground surface, turbidity readings at the outfall diminished. Post-construction turbidity at Site 4 averaged just 31 NTU. This outcome was expected, as the bulk of runoff to this outfall is collected from impervious surfaces. As Site 4 did not directly drain any areas of exposed aggregate concrete, pH spikes were not observed.

The range of readings for all other water quality parameters at Site 4 was considered nominal. However, rare instances of elevated EC readings did occur. A maximum value of 5,187 µS/cm was recorded at Site 4. This and other high EC readings were a product of backflooding of brackish water from the Pitch and Tar Swamp during high tide cycles and were not indicative of a construction-related problem.

While water quality issues were relatively benign, two potential problems were noted regarding the physical components of the stormwater system. First, the invert of drop inlet 2B appeared to be too high relative to the surrounding ground surface. Visual observations during multiple storm events concluded that overland runoff from the green space west of drop inlet 2B was not entering the drain (Photo 22). Runoff would instead be directed around the drop inlet where it would flow downgradient and against the headwall of the pipe outfall, where it began to create erosional gullies in the unvegetated slope. To correct this developing instability and at VHB's recommendation, fill material was placed behind the Site 4 headwall and the area regraded in 2006. While the establishment of grass cover has reduced the potential for soil erosion, the invert of drop inlet 2B remains too high to collect overland flow. Gully formation on the slope leading to the Pitch and Tar Swamp thus remains a possible outcome (Photo 23).



Photo 22. View of runoff flowing overland away from drop inlet 2B near Site 4.



Photo 23. View of minor gully erosion at Site 4 outfall at photo left.

Stations in APVA Landholdings

Collections Building Bioretention Basin

By January of 2005, construction of the Collections Building bioretention basin was complete, as was most of the exterior work on the building itself. From this point on, the basin received stormwater runoff from the rooftop of the Collections Building, surrounding parking areas and road surfaces, and small areas of green space between the Collections Building and Archaearium (Figure 3). The chief input to the basin is a pipe located at its western end. This water quality monitoring station was referred to as the "Bio-Basin In" (Photo 24). Stormwater leaves the basin through infiltration into the underlying substrate. Excess runoff is relieved by a drain connected to the Pitch and Tar Swamp via three PVC culverts under the APVA access road which runs along its north perimeter (Photo 7). This station is called "Bio-Basin Out."



Photo 24. View of "Bio-Basin In" sampling location.

With the exception of pH, all other water quality parameters fluctuated significantly over the monitoring period. Heavy vehicular traffic and bare-ground surfaces during the construction phase led to frequent spikes in turbidity at Bio-Basin In through the summer of 2005. Localized instabilities were noted on the slopes of the basin. Small gullies formed where downspout discharge from the Collections Building entered the basin. Nevertheless, much of this turbid water converging on the basin was mediated therein, as readings from at Bio-Basin Out were notably lower than Bio-Basin In during the same storm event. In fact, the maximum turbidity recorded at Bio-Basin Out is the third lowest of all monitoring stations at just 503.7 NTU. This indicates that the basin provides an important water quality function in addition to attenuating stormwater runoff from impervious surfaces. Following site construction, surrounding ground surfaces and the flanks of the basin itself became increasingly well vegetated. Turbidity values dropped correspondingly. Nevertheless, persistent but localized gully erosion marks the basin flanks and warrants continued vigilance. These have been caused and are exacerbated by continued discharge from Collections Building downspouts (Photo 25).

TABLE 4: WATER QUALITY SUMMARY:
APVA LANDHOLDINGS

CONSTRUCTION (OCTOBER 2004 - JANUARY 2006)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Site 1	18	8.80	6.55	7.22	0.61	4	941	24	363	404	17					18	940	253	480	187
Site 2	19	7.90	5.24	6.81	0.52	19	919	2	86	216	19					20	2050	345	835	497
Collections Bldg Bio Basin (In)	16	7.82	6.47	7.24	0.37	13	1546	59	380	488	15	101	5	47	36	14	1729	84	404	408
Collections Bldg Bio Basin (Out)	14	7.64	6.38	7.08	0.32	14	504	7	162	158	13	84	9	49	29	13	1321	118	492	298
Site 7	8	7.74	6.65	7.06	0.34	8	878	3	191	292	4	84	76	81	4	8	396	105	229	105
Hunt Shrine	3	7.27	7.02	7.11	0.14	3	2653	158	1190	1302	3	97	42	76	30	2	54	32	43	16
Bronze Trough	3	7.70	6.74	7.23	0.48	3	**1000**	81	458	481	3	94	71	82	12	3	289	116	203	86

POST-CONSTRUCTION (JANUARY 2006 - APRIL 2007)

	pH					Turbidity (NTU)					Dissolved Oxygen (%)					Electrical Conductivity (µS/cm)				
Sampling Location	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**	**N**	**Max**	**Min**	**Avg**	**σ**
Collections Bldg Bio Basin (In)	6	7.48	6.86	7.15	0.24	5	330	24	150	132	5	98	83	89	6	6	317	84	180	103
Collections Bldg Bio Basin (Out)	6	7.49	6.92	7.22	0.24	4	50	6	23	19	6	98	58	84	15	6	660	105	385	194
Site 7	2	8.85	6.77	7.81	1.47	2	38	13	25	17	2	82	49	66	23	1	5303	5303	5303	N/A
Hunt Shrine	5	7.68	6.22	6.86	0.53	4	277	33	135	104	5	93	48	77	17	5	1756	53	414	751
Bronze Trough	6	7.03	6.28	6.69	0.26	5	299	16	173	142	6	88	57	76	11	6	1987	50	450	756

N = Number of historical values used for statistical anaylsis
σ = standard deviation
Maximum turbidily equal to instrument max range (1000 NTU). Reflects sample taken before dilution processing initiated in lab environment.

DO readings also improved after construction ceased and as the flanks and bottom of the basin itself were colonized by vegetation. Initial low values for DO are thought to be the result of the combination of persistent inundation in the basin and an abundance of organic material in the form of mulch applied liberally as erosion control. An anaerobic condition arose as microbial activity decomposed the flooded mulch. Average DO rose roughly 40% at both the Bio-Basin In and Bio-Basin Out between the construction and post-construction phases. This is thought to be the combined effect of the exhaustion of the mulch supply and the establishment of dense emergent plant cover within the basin that is facilitating nutrient recycling and stabilizing the substrate.

EC did not manifest a particular trend over the monitoring period. Readings sometimes varied appreciably between visits. This unpredictability and the relatively high average EC was attributed to water of mixed provenance; stormwater runoff and backflooding from the Pitch and Tar Swamp or upwelling of brackish groundwater.

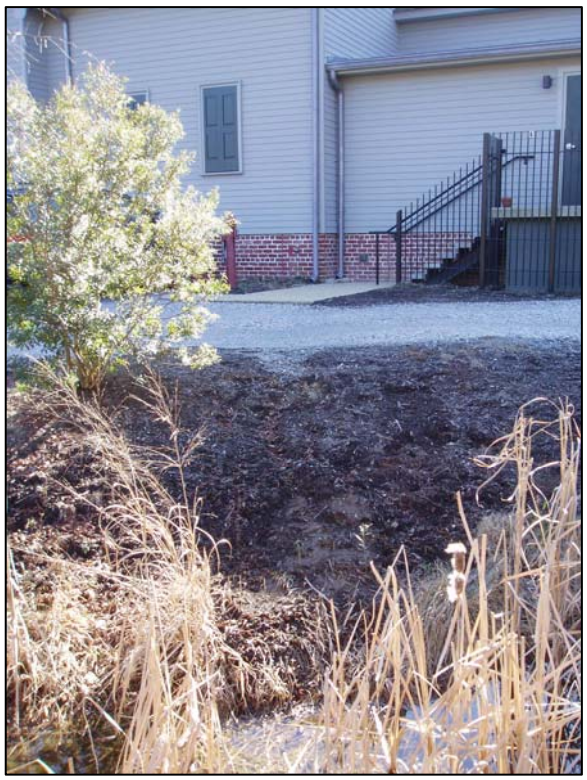


Photo 25. View of gully erosion of south flank of Collections Building Bioretention Basin, caused by discharge from downspouts visible in photo background.

Archeaerium Bioretention Basin

Earthwork behind the Archeaerium and adjacent to the Pitch and Tar Swamp commenced in 2006 with the installation of a geothermal well field. On several occasions, this area was significantly disturbed, containing large piles of excavated material and deep trenches where the wells and interconnecting pipelines were being placed. Despite the disturbed condition, the silt fence separating the job site from the swamp prevented sediment transport during storm events (Photo 26). When the well field was completed in late 2006, a new bioretention basin was installed above it.



Photo 26. View of silt fence during installation of geothermal well field.

The principal stormwater contribution to this basin is rooftop runoff from the Archeaerium, directed northwesterly via a drainage swale installed behind the Storage Shed. Routine evaluation of this swale during storm events revealed worsening channel erosion (Photo 27). The rock weir installed as a grade-control measure where the swale meets the basin was rendered ineffective as erosion caused the channel to circumvent the structure. The NPS was notified of this outcome, and in the summer of 2007, a length of HDPE pipe was connected to the Archaearium downspout and routed through the swale to the basin. Held in place by a veneer of coarse stone, this retrofit has effectively stopped channel erosion in the swale (Photo 28).



Photo 27. View of erosion caused by rooftop drainage from the Archaearium.

Site 7

Water quality records from Site 7 are limited due to the difficulty of obtaining discrete samples from this site. All parameters range broadly in value, reflecting the fact that water provenance and residence time in emergent, tidally connected wetlands are inherently variable. For example, EC ranged from 105 to 5,303 µS/cm, the highest value recorded during the three-year monitoring period (Table 4). Thus, the primary objective of this sample location was to visually identify potential vectors for water quality degradation associated with the construction of the new pedestrian bridge and the removal of the original Visitor Center. Photo documentation and field notes were often the only means of recording conditions at Site 7.



Photo 28. View of gravel covering an HDPE pipe that joins the Archaearium downspout to Archaearium Bioretention Basin.

Silt fence was in place both during the removal of the original Visitor Center and for the construction of the new pedestrian bridge, and no obvious water quality concerns were observed throughout these processes at Site 7. All silt fencing was removed from these areas as construction activities ceased, though the decision to do so was premature based on the sparsely vegetated condition of the site of the original Visitor Center. This was caused in part by trenching for the installation of new utilities and surface disturbance by vehicular traffic. During moderate to heavy storm events early in 2007, plumes of very turbid water were observed entering the Pitch and Tar Swamp from the site of the original Visitor Center. In advance of the Jamestown 400 celebration, this area was stabilized by grass cover and is currently well vegetated (Photo 29).



Photo 29. View of stabilized ground surface at location of the original Visitor Center.

Hunt Shrine and Bronze Trough Sites

Water quality sampling at the Hunt Shrine and Bronze Trough Sites was initiated in response to observations of turbid water at both locations, apparently derived from site excavation at Fort Pocahontas. Flowing water was only observed at the Hunt Shrine Site during significant rain events, and thus the record is relatively scant. Maximum turbidity was recorded at 2,653 NTU. However, because of the appreciable distance from the Hunt Shrine Site to the nearest receiving water (Pitch and Tar Swamp), these pulses of turbid water posed little threat to downstream water quality. Furthermore, once the drainage area contributing to the Hunt Shrine drain was stabilized, turbidity readings diminished appreciably (Table 4).

The Bronze Trough Site accepts stormwater from the Hunt Shrine outfall via a ditch and culvert system, and thus had correspondingly high turbidity readings. These were occasionally diluted by backflooding water from the Pitch and Tar Swamp during super-elevated tides. The open field adjacent to the Bronze Trough also flooded frequently during rain events, further diluting the water at the sample location. Like the Collections Building bioretention basin, water samples collected from the Bronze Trough Site were frequently of mixed provenance, explaining the range of values for each water quality parameter. However, no significant departures from expected conditions were observed during the monitoring period.

Stations in Neck of Land Area

Site 8

Site 8 is located on the upstream end of a culvert that conveys discharge from an intermittent stream northwards under the Colonial Parkway just west of the parking lot at Neck of Land (Figure 4). The culvert is partially blocked by accumulated silt (Photo 12). Because of this obstruction and because stream flow is discontinuous through this low-gradient channel, sampling at Site 8 would occasionally capture water with a long residence time. This was especially true of pre-construction and construction samples, as reflected by relatively low average DO (Table 2). As the concrete swale conveying parking lot runoff to Site 8 came online, average DO increased markedly. This reflected the addition of oxygen-rich stormwater, coursing down the relatively high-gradient swale (Photo 30).



Photo 30. View of concrete swale leading from the west end of the Neck of Land parking lot to intermittent stream at Site 8.

Pre-construction samples collected from Site 8 tended to have a slightly acidic pH. Stormwater sampled from within the concrete swale was predictably slightly alkaline. When combined at the culvert, the result was that the pH of post-construction runoff at Site 8 is somewhat higher than natural conditions, but is nevertheless almost neutral (Table 2). Only one anomalous pH reading was recorded at Site 8. In January 2006, a sample collected at the culvert had a pH of 8.49. Though the concrete swale was not in place at this time, parking lot construction was well underway, and downslope runoff to Site 8 was plentiful in response to an intense storm event. Record turbidity for Site 8 was recorded during this event (3,475 NTU). Concrete retardant used to create exposed-aggregate surfaces was likely responsible for this minor and singular spike in pH. Following this event, all water quality parameters resumed their comparative stability through to the end of site monitoring.

Site 9

Site 9 was added to the monitoring network to insure that proposed utility installation on the south side of the road did not introduce potential contaminants to the upstream end of a culvert discharging directly to Back River (Figure 4). However, conditions at Site 9 remained undisturbed throughout the monitoring period. In fact, turbidity never exceeded the relatively low value of 92 NTU, and all other parameters exhibited little variability (Table 2).

Site 10

Site 10 was added to the monitoring network shortly after the installation of the stormwater pipe draining the circle drive at the new Intermodal Transportation Building at the Neck of Land parking lot (Figure 4). Construction here involved in the installation of exposed-aggregate concrete surfaces. VHB personnel first sampled this location on March 2, 2007, one day after these surfaces were completed. Though the area had been washed after construction, and the sample was taken during the recession limb of a rain event, the pH of the water was 9.60.

This outcome was brought to the attention of the NPS and the general contractor, the latter explaining that all exposed aggregate work in the area had been completed. It was therefore assumed that residual retardant in the stormwater network had caused the elevated pH reading. During a storm event on March 16, 2007, high pH was again recorded, peaking at 10.01. After being notified of persistent high pH at Site 10, the NPS asked the site contractor to thoroughly flush the system with clean water and provide evidence that the pH of subsequent discharge fell within state limits. This was accomplished in early April of 2007 and site visits on April 12 and 27, 2007, found pH readings of 7.06 and 6.83, respectively.

STORMWATER DESIGN AND POLLUTANT LOADING

While establishing the degree of pollutant removal attributable to the new stormwater infrastructure at Historic Jamestowne was beyond the scope of this study, the following engineering information is provided to summarize the degrees to which the bioretention basins at the Collections Building and Archaearium reduce nutrient loading and attenuate the stormwater hydrograph.

Collections Building Bioretention Basin

The drainage area for the Collections Building Bioretention Basin is approximately 1.09 acres, comprised of building surfaces and paved areas as well as landscaped areas. About 0.36 acres of this total was impervious before construction commenced, yielding a pre-development nutrient loading of 0.90 pounds per year. The post-development loading based on a slight increase in impervious area to 0.43 acres is 1.05 pounds per year. The design of the bioretention facility effectively reduces the post-loading rate by 0.63 pounds which yields a net loading of just 0.42 pounds. This rate is less than half of the original rate of 0.90 pounds. In addition to reducing nutrient loading, the Collections Building Bioretention Basin also attenuates the peak rate of stormwater discharge from the site. The 2-year rainfall event rate is reduced from 3.3 CFS to 1.7 CFS, and the 10-year event from 6.8 CFS to 3.6 CFS.

It should also be noted that the location of the Collections Building Bioretention Basin is coincident with a former septic tank for the original facility. The associated septic field extended out into the wetland area immediately north. Planning for the new Collections Building represented an opportunity to phase out this potential source of contamination. The tank was removed in its entirety, but the branches of the septic field were left in place so as to avoid unnecessary disturbance of the wetland. Wastewater from the

Collections Building is pumped offsite via a new sanitary system consisting of a force main and grinder pump.

Archaearium Bioretention Basin

The drainage area to the Archaearium Bioretention Basin is approximately 0.43 acres, consisting of existing and proposed building and paved areas as well as green space. The pre-development nutrient loading for this facility is based on the default percent impervious surface of 16%, resulting in 0.20 pounds per year (16% rate applied when the existing impervious rate is less than the 16 % default rate). The post-development loading based on the increase in the percent of impervious surface to 30% is 0.33 pounds per year. The bioretention facility effectively reduces the post loading rate by 0.17 pounds which yields a net loading of 0.16 pounds. Again, this rate is below the original rate of 0.20 pounds. The Archaearium Bioretention Basin similarly attenuates the peak rate of stormwater discharge from its watershed. The 2-year rainfall event rate is reduced from 0.7 CFS to 0.4 CFS, and the 10-year from 1.7 CFS to 1.3 CFS.

5
SUMMARY AND RECOMMENDATIONS

Site visits conducted for the Jamestown Stormwater Management Observation Program gathered both qualitative and quantitative information to chronicle surface water quality before, during, and after the construction of new facilities at Historic Jamestowne. Qualitative observations identified obvious potential threats to the receiving waters of the Pitch and Tar Swamp and Back River. These included failed silt fencing, inadequate filtration at drop and curb inlets, exhausted or offline filter bags at pump outfalls, and poor stabilization of disturbed or recently graded ground surfaces. Though making such visual observations was not originally conceived during project scoping, initial site visits determined that the failure of standard erosion and sediment control measures represented the most potent threat to water quality and also the easiest to remedy. Conversely, quantitative records of measured water quality parameters helped identify a less obvious source of contamination: the flushing of high pH wash water associated with the installation of exposed aggregate surfaces.

This two-pronged approach provided a comprehensive assessment of site conditions. Routine status reports drafted for both the NPS and APVA synthesized the results of site monitoring and recommended specific action to remediate problem areas. The NPS shared reports with the general contractor as necessary, who could then use them as a task list for corrective measures. This proactive system was very successful in quickly identifying and redressing all concerns, avoiding costly mitigation associated with the clean up of neglected or overlooked vectors for water pollution.

After the completion of site construction and the stabilization of disturbed ground surfaces via reseeding, the water quality of runoff at all sampling stations returned to pre-construction conditions (where baseline data are available). In areas where baseline data are not available, all post-construction water quality metrics exhibited a pronounced improvement over construction conditions and remained within state guidelines. This indicates the overall stormwater system has been installed and is functioning per design. The installation of low-impact development facilities such as the two bioretention basins provides a water quality benefit previously absent at Historic Jamestowne. When these basins are empty or at low stage, runoff from minor storm events can be retained completely, infiltrating slowly into the basin substrate rather than being discharged directly to wetlands of the Pitch and Tar Swamp. This new stormwater management strategy, coupled with the removal of the septic tank at the Collections Building, has resulted in an overall decrease in pollutant loading to adjacent wetlands.

RECOMMENDATIONS

Site-Specific Issues:

The following points have been determined to be unresolved site-specific issues. Though they do not pose a significant threat to receiving waters, they may warrant either eventual correction or at the very least continued vigilance:

- Remove the logjam at the outfall of Site E to prevent channel scour and eventual undermining of the foundation of the riprap outfall protection.
- Evaluate possible options for stabilizing the gullies on the south flank of the Collections Building bioretention basin. This should include assessing the feasibility of piping discharge from the downspouts directly to the base of the basin. This could be accomplished using HDPE pipe installed in a trench in the road surface and slope of the basin and subsequently backfilled. Once the source of the erosion is removed, the slope could then be stabilized via the installation of additional plant material.
- Drop inlet 2B at Site 4 remains too high to effectively collect overland stormflow. This has resulted in some minor gully erosion on the west side of the outfall pipe. However, at this point, disturbing the local ground surface to retrofit this drop inlet may only incite further erosion. It is therefore recommended that the slopes around Site 4 be routinely monitored for developing instabilities, with the invert of drop inlet 2B corrected only if conditions worsen appreciably.

Wastewater Remediation Plan: Application of Concrete Retardants

The application of the concrete retardant Rugasol® resulted in anomalously high pH at the Bus Stop Site and Site E in December 2005. At that time, the NPS apparently did not have a formal remediation plan that could be quickly implemented. Thus, the installation of exposed-aggregate surfaces was temporarily discontinued while an acceptable water quality monitoring and treatment plan could be developed. As this particular type of concrete finish is implemented at a number of NPS facilities, it is recommended that such a remediation plan be developed and applied wherever these exposed-aggregate surfaces are installed or repaired. This will help avoid unintended contamination of receiving waters and costly downtime while pollutant sources are identified and an ad hoc treatment plan devised.

SELECTED BIBLIOGRAPHY

Clean Water Team. 2004. *Electrical conductivity/salinity Fact Sheet, FS-3.1.3.0(EC)*, in: *The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0.* Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA.

Midwestern Regional Climate Center. June 2007. *Midwestern Climate Information System (MICIS).* http://mcc.sws.uiuc.edu/prod_serv/prodserv.htm

National Park Service, U.S. Department of the Interior, and Association for the Preservation of Virginia Antiquities. June 2003. *Final Development Concept Plan & Environmental Impact Statement: The Jamestown Project.* Washington, D.C.

United States Department of Agriculture, Soil Conservation Service. April 1985. *Soil Survey of James City and York Counties and the City of Williamsburg, Virginia.* Washington, D.C.

Virginia Council of Trout Unlimited. 2007. *Back the Brookie: The Challenges.* http://207.121.125.32/council/btb_challenges.htm

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APPENDIX A

WATER QUALITY DATA

WATER QUALITY SAMPLING STATIONS:
NEW VISITOR CENTER

SITE 3					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
5/3/2004	13:00	375.67	--	87.1	7.21
5/4/2004	9:50	--	--	--	--
5/26/2004	10:45	--	--	--	--
5/27/2004	10:20	--	--	--	--
6/16/2004	15:00	--	--	--	--
6/28/2004	14:47	143.00	--	62.8	7.00
7/5/2004	10:00	--	--	--	--
7/8/2004	9:30	5.23	--	72.8	7.00
7/9/2004	8:42	70.80	--	81	6.38
7/20/2004	9:45	--	--	--	--
7/23/2004	10:30	--	--	--	--
7/26/2004	9:00	range	--	113	6.97
7/28/2004	8:34	185.67	--	81.8	7.97
8/15/2004	10:30	83.00	--	106.6	7.70
8/16/2004	--	79.43	--	82	7.30
8/31/2004	--	231.33		98.4	7.10
9/20/2004	--	--	--	--	--
9/28/2004	9:15	--	--	--	--
11/13/2004		--	--	--	--
1/14/2005	9:55	1000*	--	42.3	
2/14/2005	13:12	--	--	--	--
2/28/2005	15:12	111.00	128.2	82.5	7.21
3/11/2005		207.0	104	110.3	6.89
3/23/2005		317.7	85.1	62.8	6.69
4/2/2005	10:32	150.0	63.7	146.2	6.93
4/2/2005	11:44	573.0	87.5	43.1	7.27
4/2/2005	12:31	920.7	93.4	30.9	7.37
5/6/2005	11:37	89.8	103.5	50.5	7.31
5/6/2005	12:33	106.0	103.6	40.9	6.86
7/29/2005		592	55.8	67.7	6.79
10/25/2005		948.3	50	178	7.11
11/17/2005	7:18	1482.7	--	--	--
12/15/2005	10:40	47.0	47.7	235	6.57
12/16/2005	9:57	89	64.2	160.9	6.69
1/18/2006	--	227	68.8	131.1	7.06
6/14/2006	10:10	285	67.3	110.2	6.94
10/6/2006	9:20	252	85.6	153.6	6.59
11/16/2006	--	25	106.6	305	6.40
2/2/2007	--	300	82.0	227	7.30
3/2/2007	8:25	176	83.6	136.6	6.87
3/16/2007	13:25	95	99.6	67.8	6.82

* sample at maximum range, sample collected before commencement of dilution processing

WATER QUALITY SAMPLING STATIONS:
NEW VISITOR CENTER

SITE 4					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
5/3/2004	13:00	82.00	--	29.1	6.53
5/4/2004	10:20	15.03	--	133.7	7.03
5/26/2004	11:00	82.10	--	71.6	6.18
5/27/2004	13:16	1.24	--	70	6.6
6/16/2004	14:50	6.25	--	--	--
6/28/2004	14:57	45.33	--	56.1	6.63
7/8/2004	9:40	25.43	--	78.1	6.7
7/9/2004	8:55	--	--	--	--
7/20/2004	10:00	--	--	46.6	6.42
7/23/2004	9:45	--	--	700	6.9
7/26/2004	9:20	18.67	--	113	6.94
7/28/2004	8:45	34.77	--	50.8	8.04
8/16/2004	--	34.70	--	66	7.1
8/31/2004	--	--	--	--	--
9/20/2004	--	10.37	--	297	7.6
9/28/2004	9:45	14.40	--	98.5	6.11
11/13/2004	8:00	394.67	55.9	147.3	6.57
1/14/2005	10:00	1000	131.2	30.5	6.81
2/14/2005	13:12	10.73	53.8	89.5	6.56
2/14/2005	15:09	73.47	52.3	71.8	6.36
2/14/2005	15:50	92.67	48.5	71.9	6.41
2/28/2005	12:05	126.33	121.2	66.7	6.66
3/11/2005		8.7	85.9	599	7.21
3/23/2005		133.0	83.5	49	6.3
4/2/2005	10:29	82.7	77.5	120.5	6.52
4/2/2005	11:48	1000	86.8	46.6	7.22
4/2/2005	12:34	1000	92.2	30.6	7.23
5/6/2005	8:41	17.3	92.8	35.3	6.99
5/6/2005	11:41	97.2	99.2	38.6	7.22
5/6/2005	12:37	88.3	99.4	34.5	6.81
7/29/2005		17.4	68.6	40.6	6.72
10/25/2005		31.7	62.8	5187	6.91
12/16/2005	10:00	48	20.2	522	7.51
1/18/2006	--	328	72.7	216	7.09
6/14/2006	10:15	118	69.4	139.4	6.89
6/14/2006	11:35	84	73.0	127	6.96
10/6/2006	9:15	154	88.9	38.1	7.07
3/2/2007	8:05	70	79.9	71.7	7.28
3/16/2007	10:55	15	94.0	85.1	7.01
3/16/2007	13:30	16	108.4	26.9	7.23
4/27/2007	14:20	22	--	70.7	6.18

* sample at maximum range, sample collected before commencement of dilution processing

WATER QUALITY SAMPLING STATIONS:
NECK OF LAND AREA

SITE 8					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
7/28/2004	10:00	13.33	--	42.2	6.80
8/16/2004		12.60	--	38.4	6.60
9/28/2004	--	48.70		86.2	5.55
1/14/2005	--	--	--	--	--
2/14/2005	--	--	--	--	--
2/28/2005	--	--	--	--	--
3/11/2005	--	11.4	129.6	64.8	6.07
3/23/2005		15.2	87.4	64.1	5.98
4/2/2005	8:51	17.8	44.8	84.2	6.29
4/2/2005	13:09	41.0	82	57.1	6.20
5/6/2005	13:06	93.2	84.4	50.9	6.27
7/29/2005		4.2	48.3	54.7	6.74
10/25/2005		697.0	44.9	177	7.02
11/17/2005	6:40	51.7	--	--	--
12/16/2005	8:50	49	47	150.6	6.39
1/18/2006	8:30	3475	71.8	177.3	8.49
4/26/2006	10:46	--	62.3	275	6.88
6/14/2006	9:00	6	69.9	210	7.23
6/14/2006	12:07	19	78.2	407	7.30
7/6/2006	--	12	--	--	--
10/6/2006	8:40	39	92.0	62.5	7.01
11/16/2006	--	27	124.5	207	6.60
2/2/2007	--	11	87.2	147.4	6.76
3/2/2007	7:30	57	73.3	131.6	6.35
3/16/2007	10:20	146	91.0	227	6.65
3/16/2007	11:50	26	93.6	91	6.95

WATER QUALITY SAMPLING STATIONS:
NECK OF LAND AREA

SITE 9					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
7/26/2004	10:30	6.83		65.6	6.59
7/28/2004	10:00	8.50		53.2	7.50
8/16/2004	11:00	6.15		65.7	7.10
9/28/04	--	--	--	--	--
11/13/2004	7:02	5.39		80.7	6.27
3/11/2005		5.5	130.2	423	7.23
3/23/2005		8.4	88.6	83.1	6.55
4/2/2005	13:15	14.4	84.3	45.4	6.46
5/6/2005	8:13	24.1	87.7	178.3	6.80
5/6/2005	13:12	9.0	95.8	76.9	6.48
10/25/2005		4.0	52.4	105	6.81
12/16/2005	11:13	5	73.9	90.7	6.90
1/18/2006	--	7	65.8	75.1	7.12
4/26/2006	--	--	--	--	--
5/11/2006	--	--	--	--	--
6/14/2006	8:55	8	60.9	100.9	6.67
6/14/2006	12:10	7	72.5	84.2	6.81
10/6/2006	8:37	10	82.8	45.7	6.74
3/2/2007	7:20	92	78.2	78.4	6.55

SITE 10					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
3/2/2007		165.00	81.9	74.9	9.60
3/16/2007	9:00	122	24.9	342	7.91
3/16/2007	10:05	89	74.6	305	9.16
3/16/2007	11:50	505	102.5	104.6	10.01
3/16/2007	12:40	131	95.9	79.0	9.96
3/16/2007	14:50	124	99.1	68.6	9.75
4/12/2007	9:20	--	--	--	7.06
4/27/2007	13:50	744.0	--	--	6.83

WATER QUALITY SAMPLING STATIONS:
NEW VISITOR CENTER

BUS STOP SITE					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
1/14/2005	10:25	56.70		24.80	6.15
2/14/2005	13:08	37.87	55.2	177.30	6.49
2/14/2005	15:30	22.90	54.1	106.90	6.27
2/28/2005	12:10	9.82	115.60	58.70	6.53
3/11/2005	--	10.5	92	378	6.31
3/23/2005	--	23.6	88.1	48.6	5.96
4/2/2005	10:25	46.9	52.4	388	6.29
4/2/2005	11:53	146.0	92.6	19.99	7.00
4/2/2005	12:39	52.2	97.1	13.78	6.32
5/6/2005	8:37	9.3	30.3	144.9	6.82
5/6/2005	11:44	14.8	101	22.4	6.87
5/6/2005	12:41	19.9	99.8	22.4	6.60
7/29/2005	--	44.7	55.30	75.2	6.66
10/25/2005		203.3	51.5	2853	6.57
11/17/2005	6:50	349	--	--	--
12/16/2005	9:15	106	63.2	290	10.55
12/21/2005**		--	--	--	9.54
1/18/2006	8:57	642	82.2	103.4	8.16
4/26/2006		--	70.1	213	7.27
6/14/2006	10:25	38	62.6	275	7.96
6/14/2006	11:30	52	73.2	203	7.35
7/6/2006	--	187	--	--	7.06
10/6/2006	9:10	271	96.8	66.2	6.75
11/16/2006	--	13	73.0	365	6.05
11/16/2006	--	221	65.7	422	6.11
2/2/2007	--	29	98.8	113.7	7.10
3/2/2007	8:00	209	76.0	129	7.07
3/16/2007	9:50	5	87.7	334	7.19
3/16/2007	10:35	6	85.9	315	7.25
3/16/2007	13:05	21	90.1	87.2	7.25
3/16/2007	14:40	29	92.9	80.4	7.23
4/27/2007	14:30	20	--	483	7.26

WATER QUALITY SAMPLING STATIONS:
NEW VISITOR CENTER

SITE E					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
4/2/2005	12:52	33.7	93.4	24.1	5.97
5/6/2005	8:32	76.4	91.7	215	7.04
7/29/2005		16.9	24.7	1426	6.49
11/17/2005	8:25	167	--	388	7.47
12/15/2005	10:10	55	63.8	2400	12.00
12/16/2005	9:00	79	72.8	1131	11.84
12/21/2005**		--	--	--	9.37
1/18/2006	8:44	422	81.9	83.3	8.80
4/26/2006	10:15	--	69.5	304	7.38
5/11/2006	--	14	69.8	495	7.61
6/14/2006	9:20	33	80.6	130	7.63
6/14/2006	11:20	50	80.8	104	7.69
7/6/2006	--	121	--	--	7.04
10/6/2006	9:00	204	89.8	45	7.42
11/16/2006	--	157	76.4	378	6.93
11/16/2006	--	509	68.7	155	6.85
2/2/2007	--	29	82.3	338	7.60
3/2/2007	7:55	90	73.2	106	7.10
3/16/2007	9:45	21	87.7	194	7.11
3/16/2007	10:30	32	89.9	82	7.00
3/16/2007	12:50	28	111.3	50	7.24
3/16/2007	14:30	25	95.7	49	7.28
4/27/2007	14:35	25	--	74	6.56

WATER QUALITY SAMPLING STATIONS:
NEW VISITOR CENTER

CBPL					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
1/14/2005	9:12	414.00	--	118.40	7.26
2/14/2005	14:14	60.63	52.1	158.10	7.02
2/14/2005	15:36	106.33	45.2	138.50	6.91
2/28/2005	12:26	40.00	112.8	193.40	7.27
3/23/2005		24.8	78.9	101.6	7.12
4/2/2005	10:37	86.0	88.7	43.6	7.13
4/2/2005	11:41	284.3	82.3	46.5	7.39
5/6/2005	8:50	110.0	94.3	66.6	6.91
5/6/2005	11:32	50.2	99.6	51.5	7.45
7/29/2005		76.8	57.6	131.6	7.29
11/17/2005	7:39	887.3	--	--	--
12/15/2005	10:30	34.0	71.7	415	7.79
1/18/2006	--	3225	76.9	143.1	8.46
10/6/2006	9:35	167	89.3	104.4	9.87
11/16/2006	--	--	85.9	114.8	6.41
3/2/2007	8:15	221	68.3	220	7.28
3/16/2007	10:00	27	77.5	160.7	7.37
3/16/2007	10:45	37	92.3	69.1	7.12
3/16/2007	13:15	77	90.3	117.4	7.31
4/27/2007	14:00	172	--	126	6.08

TRENCH SITE					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
3/23/2005		441.7	71.2	102.9	6.49
4/2/2005	12:29	758.0	85.6	61.7	7.38
5/6/2005	12:30	366.7	90.8	48.7	6.44
11/17/2005	7:30	150.3	--	--	--
12/15/2005	10:34	28.0	81.2	67.9	7.71
12/16/2005	9:45	--	62.6	222	7.22
1/18/2006	--	157	80.4	54.1	7.65
6/14/2006	10:00	9	83.6	56.3	7.41
10/6/2006	9:27	208	85.6	37	6.97
11/16/2006	--	13	93.0	87.4	6.86
3/2/2007	8:20	32	75.0	204	7.00
3/16/2007	10:05	11	101.2	88.3	7.30
3/16/2007	10:50	19	97.5	56	7.52
3/16/2007	13:20	27	100.8	38.8	7.56
4/27/2007	14:15	30	--	61.1	6.68

WATER QUALITY SAMPLING STATIONS:
APVA LANDHOLDINGS

BIO-BASIN IN					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
1/14/2005	8:05	out of range	97.7	267	7.62
1/14/2005	11:00	out of range		--	7.40
2/14/2005	13:55	106.10	7.0	423	6.76
2/14/2005	15:30	88.10	6.9	403	6.47
2/28/2005	10:48	73.47	14.7	414	7.02
3/11/2005		211.7	25.7	493	6.92
3/23/2005		177.3	4.6	376	7.02
4/2/2005	11:26	121.3	14.1	555	7.26
4/2/2005	11:29	1000*	25.8	244	7.64
4/2/2005	12:19	out of range	45.9	151.2	7.45
5/6/2005	9:05	1062.0	101.1	177	7.82
5/6/2005	11:24	1546.0	99.8	141.8	7.38
7/29/2005		143	74.8	--	6.84
10/25/2005		58.7	45.6	1729	7.26
12/16/2005	10:31	86	69.9	200	7.57
1/18/2006	--	269	76.2	83.8	7.44
6/14/2006	11:10	90	88.0	113	7.48
6/14/2006	12:00	330	83.1	86.8	7.27
10/6/2006	10:00	--	86.6	84.1	6.86
3/16/2007	11:05	24	98.0	317	7.15
3/16/2007	13:55	60	90.7	193.4	7.26
4/27/2007	15:00	246	--	286	6.87

* sample at maximum range, sample collected before commencement of dilution processing

WATER QUALITY SAMPLING STATIONS:
APVA LANDHOLDINGS

BIO-BASIN OUT					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
2/14/2005	14:00	75.40	22.2	434	6.59
2/14/2005	15:30	67.63	13.1	436	6.38
3/23/2005		90.4	16.4	371	7.08
4/2/2005	11:34	131.3	23.6	656	7.06
4/2/2005	12:17	161.7	8.9	597	7.14
5/6/2005	11:26	397.0	72.8	470	7.21
5/6/2005	12:23	427.0	81.1	332	6.91
5/6/2005	12:54	503.7	84.1	324	6.93
7/29/2005		53.7	75.9		7.34
10/25/2005		84.0	49.1	448	7.08
11/17/2005		67.3		1321	7.64
12/15/2005	10:55	7.0	42.6	689	7.04
12/16/2005	10:33	138	69.7	117.7	7.31
1/18/2006	--	60	71.2	205	7.36
6/14/2006	12:03	--	77.6	450	7.42
10/6/2006	9:55	--	90.3	104.5	6.92
11/16/2006	--	6	92.9	660	6.97
3/2/2007	8:40	17	57.6	368	7.19
3/16/2007	11:07	50	89.2	482	7.34
3/16/2007	13:57	20	97.5	245	7.49

WATER QUALITY SAMPLING STATIONS:
APVA LANDHOLDINGS

SITE 7					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
7/28/2004	9:11	5.41		105	7.74
8/16/2004	10:00	2.67		330	7.2
11/13/2004	9:30	877.67		396.0	6.65
3/23/2005		83.0	80.3	269	6.77
4/2/2005	10:58	198.3	75.5	242	6.99
4/2/2005	12:05	261.0	83.8	110.1	7.02
5/6/2005	9:49	46.0	83.4	235	7.25
5/6/2005	12:02	53.5	--	144.8	6.87
7/29/2005		37.6	82.4	--	8.85
10/25/2005		13.0	49.4	5303	6.77

BRONZE TROUGH					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
3/23/2005		81.4	81.4	289	6.74
4/2/2005	10:52	1000*	70.7	202	7.26
5/6/2005	9:42	292.3	94	116.4	7.70
10/25/2005		24	56.9	1987	6.6
12/16/2005	10:14	16	72.2	256	6.59
1/18/2006	--	299	77.9	125.9	7.03
6/14/2006	11:50	234	75.0	127.5	6.73
10/6/2006	10:30	--	87.5	50.3	6.28
3/16/2007	13:47	292	87.6	151.8	6.88

* sample at maximum range, sample collected before commencement of dilution processing

HUNT SHRINE SITE					
Date	**Time**	**Turbidity** (NTU)	**DO** (mg/L)	**EC** (µS/cm)	**pH**
4/2/2005	12:11	759.3	89.5	32.3	7.04
5/6/2005	11:17	157.7	97	54.3	7.27
7/29/2005		2653	41.5	--	7.02
10/25/2005		33.3	47.9	1756	6.68
1/18/2006	--	277	84.7	82.1	7.68
6/14/2006	11:52	92	75.9	66.4	6.22
10/6/2006	10:25	--	81.8	112.3	6.77
3/16/2007	13:45	139	93.4	53.3	6.95

WATER QUALITY SAMPLING STATIONS: SUPPLEMENTARY DATA

DATE	SITE ID	AVERAGE TURBIDITY (NTU)	DO (%)	DO (mg/L)	ELECTRICAL CONDUCTIVITY µs/cm	pH
3/23/2005	Triple Culvert	253.7	52.9	6.1	462	7.25
	Ponding (3/Trench)	2.1	84.5	9.8	137.9	6.85
4/2/2005	NW VC PL	33.7	93.4	8.6	24.1	5.97
5/6/2005	Triple Culvert	158.7	63	6	1152	7.52
10/24/2005	Swamp	--	53.3	6.5	--	7.06
11/17/2005	New Bridge Ditch	1758.7	--	--	--	--
	CBPL in	388	--	--	--	--
	Basin Outfall	45.7	--	--	1565	7.67
12/15/2005	New VC Runoff	595	82.7	8.5	115.9	6.72
12/16/2005	Site 8 upstream	49	47	4.5	150.6	6.39
	Site 8 downstream	50	53.3	5.0	144.4	6.65
	Site E up	N/A	77.1	7.2	1063	11.82
	Site E mid	79	72.8	6.8	1131	11.84
	Site E down	135	74.8	7.0	1038	11.83
	Back River	25	84.3	7.9	835	7.64
	Drain 5D	N/A	79.9	7.5	232	10.91
	Drain 5E	N/A	86.6	8.2	1336	12.01
	Thermal Well Site	563	72.1	6.8	504	7.49
	Bio-Outfall	122	69.9	6.6	150.6	7.29
12/21/2005	Site E culvert					9.37
	Site E downstream (at Back River)	--	--	--	3700	6.4
	Bus Stop culvert	--	--	--	--	9.54
	Bus Stop downstream	--	--	--	--	8.5
	Oval Cut Out (East)	--	--	--	--	11.45
	Oval Cut Out (West)	--	--	--	--	11.42
	Curb drains (1C & 1D) in road near BS site	--	--	--	--	12.53
	Puddle on unfinished road near temp. VC	--	--	--	--	9.37
	Pond near temp. VC	--	--	--	--	6.33
	Ponded area along curb just north of new VC	--	--	--	--	12.36
	Disturbed area in front of new VC	--	--	--	--	11.63

WATER QUALITY SAMPLING STATIONS: SUPPLEMENTARY DATA

DATE	SITE ID	AVERAGE TURBIDITY (NTU)	DO (%)	DO (mg/L)	ELECTRICAL CONDUCTIVITY µs/cm	pH
1/18/2006	Site E hole	--	75	7	108.7	8.28
	Site E (Back River)	--	72.3	6.6	287	7.20
	5D	557	77.5	7.2	109.6	8.62
	5E	177	76.1	7	136.1	9.85
	CBPL input	4171	68.2	6.3	118.9	8.00
	1D	--	70	6.5	105.4	9.69
	2D	529	78.2	7.3	97.2	9.24
	Runoff	819	72.4	6.7	44.7	7.09
4/26/2006	DI 5D	--	79.7	7.0	278	--
	Concrete	--	69.9	6.1	213	--
5/11/2006	Powerwash Area	--	78.2	6.9	840	11.02
	Concrete	--	74.6	6.6	351	9.37
6/14/2006	Site 8 (concrete swale)	4	81.2	7.2	455	7.60
	Site E (beyond silt fence)	44	81.6	7.2	148.5	7.37
	DI 5D	109	78.7	7.0	122.8	8.91
	Road cutout by cones	--	80.6	7.1	511	10.06
	Sidewalk cutout by VC door	--	71.7	6.4	181.5	8.90
	DI 5E	67	78.4	6.9	148.1	9.07
	CBPL drainage into utility hole	501	78.6	6.9	229	7.45
	CBPL drainage into utility hole	--	79.8	7.0	--	7.39
	Eastern oval cutout	--	83.3	7.4	305	10.80
	Curb Inlet 1C	--	81.3	7.2	127.5	9.09
	Archeaerium outfall	2	90.2	8.0	8.3	6.83
	Archeaerium swale	46	81.6	7.3	45	6.11
	Archeaerium swale dark spot	--	70.0	6.2	50.2	5.54
	New Bio Basin	52	81.1	7.2	53.8	6.47
	New Bio Basin dark spot	45	46.1	4.1	384	6.31
	Curb Inlet 2D	--	80.9	7.1	128.9	8.2
	DI 1E	194	80.8	7.1	134.6	7.99

WATER QUALITY SAMPLING STATIONS: SUPPLEMENTARY DATA

DATE	SITE ID	AVERAGE TURBIDITY (NTU)	DO (%)	DO (mg/L)	ELECTRICAL CONDUCTIVITY µs/cm	pH
10/6/2006	Site 8 (concrete swale)	--	93	8.3	102.3	8.24
	Site 4 (flow around silt fence)	670	--	--	--	--
	bridge swale	1639	--	--	--	--
	Archaerium Swale	--	93.9	8.6	3.99	5.79
	New Bio	--	84.8	7.7	81.4	6.42
11/16/2006	CBPL (from Parking Lot)	--	86.4	8.2	135.8	7.03
	Archaearium Swale	2	96.5	9.1	14.04	5.44
	Concrete Swale	27	115.8	11.3	105.3	7.03
		--	--	--	--	--
3/2/2007	Site 8 (concrete swale)	--	79.4	--	264.0	--
	New Bio Basin	--	75.0	--	63.8	6.36
3/16/2007	Site 8 (concrete swale)	33	90.2	--	121.0	7.33
	Swale near pedestrian bridge	142	83.5	--	45.5	7.18
	Archeaerium outfall	181	100.0	--	22.8	6.63
	Old VC Area Runoff	1959	78.5	--	229.0	6.88

APPENDIX B

PROPOSED REMEDIATION PLAN FOR WASTEWATER FROM EXPOSED-AGGREGATE SURFACES

Vanasse Hangen Brustlin, Inc.
Transportation | Land Development | Environmental Services

351 McLaws Circle
Suite 3
Williamsburg, VA 23185-6316
757 220-0500
www.vhb.com

Memorandum

To: Charles D. Rafkind
Natural Resource Manager
Colonial NHP, NPS, USDI

Date: 01/04/2006

Project No.: 31005.41

From: Brad Ketterling

Project Name: Jamestown Stormwater Management Observation Program

RE:
Site Meeting and Follow-Up Correspondence Regarding the Source of High pH of Stormwater Runoff from the Site of the New Visitor Center and Determined Course of Action

Site Meeting:

Date/Time: 12/22/05, 13:00 – 14:00

Attendees:

National Park Service (NPS):
P. Daniel Smith, Superintendent, Colonial NHP
Charles D. Rafkind, Natural Resource Manager, Colonial NHP
Tom C. Nash, Chief Ranger, Colonial NHP
Bob Holt, Acting Chief of Maintenance, Colonial NHP

THR Enterprises, Inc. (THR):
Victor Leone, Project Manager
Alex Elliot, Site Superintendent
Dick Wrobel, QA/QC

Alpha Corporation (AC):
John D. Glass, Construction Manager
Donovan Cole

United States Geological Survey (USGS):
Gary Speiran, Research Hydrologist, Water Resources Division

Vanasse Hangen Brustlin, Inc. (VHB):
Brad Ketterling, Environmental Scientist

Findings:

A meeting was held at the location of the New Visitor Center (VC) at Historic Jamestown to discuss the potential sources of anomalously high pH readings of runoff sampled at stormwater outfalls draining the VC grounds and parking lot areas, as described in a report produced by Vanasse Hangen Brustlin, Inc (VHB) dated 12/16/05.

Brad Ketterling provided the latest figures for pH recorded the previous day at stormwater outfalls and in areas of pooled water within the construction site, all of which were greater than 9.0.

Victor Leone and Alex Elliot from THR explained that the technique used to achieve the exposed aggregate texture on road and walking surfaces at the VC was the most likely cause of the high pH of runoff. The concrete retardant Rugasol© is sprayed on the surface to prevent the set of surface mortar. The day following initial pouring, the retardant and unset mortar are sprayed off and the resulting wash water directed towards drop inlets discharging into the Back River. Between the beginning of November and December 13th, 18,000 gallons of potable water were consumed to complete roughly 80% of the concrete work at the VC.

The procedure for exposing aggregate was specified in construction plans approved by the NPS and THR did not deviate from specifications to perform this work. THR also indicated that cement trucks were cleaned onsite, but no wash water was directed towards stormwater drop inlets.

Chuck Rafkind and Daniel Smith expressed their satisfaction with the steady progress made at the VC and were confident a resolution to the stormwater problem could be found same day via group consensus. Mr. Rafkind also remarked that though the pH was above upper limit of the State standard of 9, because most aquatic and plant life are currently dormant, little or no permanent impacts are expected.

Mr. Rafkind suggested some means of capturing and neutralizing or at least lowering the pH below 9.0 be employed before the wash water is discharged to natural waterways. Otherwise, the current means for exposing the concrete aggregate (*i.e.* use of Rugasol© and wash water) is to be continued. Alex Elliot indicated he could fill a series of 55-gallon drums and use muriatic acid to bring down the pH. Gary Speiran of the USGS instructed THR to determine the mixing ratio of acid to wash water for each drum by slowly acidifying a known volume of the wash water and noting the amount of acid required to achieve a pH below 9. THR will acquire a handheld pH sensor and use their personnel to perform this task. The mediated wash water will then be discharged into the stormwater network.

THR raised the issue of existing residuum within the drainage network possibly accounting for some increase in pH even after the pH of the wash water had been effectively neutralized or lowered below 9. Drop inlets have recessed areas below the pipe that may retain sediment, which according to Gary Speiran may result in a minor increase in pH before the outfalls due to mixing within the drainage network itself. THR may elect to flush the system with potable water in advance of further concrete work. VHB agreed to monitor the pH of runoff that the outfall to the Back River.

Daniel Smith noted a favorable outcome of the stormwater monitoring at the VC is that the resulting precautions employed at this location will be used for the Neck of Land parking lot site, currently under construction.

Post-Meeting Correspondence

During the site meeting, Dick Wrobel suggested the possibility of using shallow, excavated basins adjacent to future work areas to facilitate the collection of wash water by gravity drainage. Post-meeting correspondence between NPS specialists and VHB staff determined that due to Section 106 concerns (*i.e.* possibilities of disturbing historic artifacts at depth) this method would not be pursued.

In addition, Roy Irwin of the NPS Water Resources Division was consulted regarding the selection of an appropriate acid to lower the pH of the wash water. Mr. Irwin indicated that muriatic acid (HCl) is acceptable unless the addition of chloride / salinity to the receiving waters is of concern. As the Back River is already brackish, muriatic acid is deemed suitable for use. Muriatic acid is also readily available and relatively inexpensive.

On December 30th, John Glass of AC asked Victor Leone of THR to provide a written procedure for wash-water treatment and allow one week for review before recommencing concrete operations. Mr. Rafkind also requested the opportunity to review and comment on the plan before implementation, indicating that an e-mail with appropriate attachments would suffice.

Mr. Glass requested the written description of the procedure incorporate the following points:

- list of equipment to be used;
- proposed locations where the wash-water collection system will be placed (*e.g.* barrels, buckets, bladders, other closed system etc.);
- means of disposal for concrete truck wash water;
- means of protection for roadway surfaces outside the contract area.

Mr. Glass also indicated that he would like the opportunity to review and approve the equipment noise level before mobilization.





As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for Native American reservation communities and for people who live in island territories under U.S. administration.

March 2008

United States Department of the Interior – National Park Service