Bloede Dam Removal

60% Design Report

SUBMITTED TO

American Rivers

Maryland Department of Natural Resources

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I. Executive Summary

American Rivers, Maryland Department of Natural Resources (DNR), National Oceanic and Atmospheric Administration (NOAA), and Friends of the Patapsco Valley State Park have successfully restored upstream segments of the Patapsco River through the removal of the Union and Simkins dams. The next dam planned for removal is the Bloede Dam— a 34-ft high concrete dam within the Patapsco Valley State Park approximately two miles east of Ellicott City, Maryland (Figure 1). The Bloede Dam, downstream of the former Union and Simkins dam sites, will be the third dam removed on the Patapsco River, and will help to achieve the goals for the Patapsco River restoration effort. These goals include providing passage for diadromous fish (Alewife, Blueback Herring, American Eel, and American and Hickory Shad) and other aquatic species; restoration of free-flowing river morphology, riparian and in-stream habitat; and will eliminate a hazard to public safety by removing an attractive nuisance that has taken several lives and caused many injuries.

This report outlines the major design elements of the Bloede Dam removal, including data collected and analyzed, recommended design approach, and a short- and long-term impact assessment. Important considerations in designing this project include an existing 42-inch diameter sanitary sewer pipe routed through the dam and the sediments that are impounded by the dam. Based on data from subsurface investigations, the existing sewer line could be undermined as a result of dam removal and subsequent sediment evacuation, and thus portions of the sewer line must be relocated prior to the removal of Bloede Dam. Sediment evacuation could also threaten existing mature trees rooted in the exposed sediment accumulation upstream of the dam. These trees must be cleared prior to dam removal to prevent their transport downstream.

To date, Inter-Fluve and the project partners have conducted the following efforts as part of the design process:

- Engineering site investigations
- Sediment contaminant sampling and testing
- Topographic surveying
- Hydrologic and hydraulic modeling
- Geomorphic investigation
- Alternatives analysis
- Soil borings
- Concept design plans (30%)
- Draft Sediment Management Plan

Based on data collected and analyzed for the Alternatives Analysis and Draft Sediment Management Plan, the dam removal with passive sediment management option has been selected as the preferred alternative. The preferred alternative includes breaching the dam

and allowing natural transport of approximately 312,000 cubic yards of impounded sediments. The decision to pursue a passive sediment management approach was based on review of sediment transport model data, regulatory and regional expert opinions regarding sediment release, and by comparison of channel response and sediment monitoring data collected as part of the post-removal evaluation of the Simkins removal.
This decision also takes into consideration the impact of the selected approach on recreational use of the popular Patapsco Valley State Park. Short-term impacts of the removal include sand deposition in the channel, overbank sediment deposition, temporary trail impacts, disturbance of River Road during construction, and ecological impacts to low gradient reaches lasting about 6 years depending on river flows. Long-term benefits include fish passage restoration, improved fish and wildlife habitat in the former impoundment, elimination of an attractive nuisance, improved park safety, improved kayak and canoe passage, and the uncovering of a picturesque boulder and cobble step pool channel with bedrock outcrops. The project partners have concluded that these long-term positive benefits outweigh the short-term impacts to the system.

The following design report details the methods used in data collection, analysis tools used in design, and the general approach for dam removal. This report provides documentation of design development for this 60% design.

INTRODUCTION

The Bloede Dam is located within the Patapsco Valley State Park approximately 11 miles upstream of Chesapeake Bay (Hanover Street) and 0.51 miles downstream of the Ilchester Road Bridge crossing the Patapsco River (Figure 1). American Rivers, on behalf of the Project Management team including the Maryland Department of Natural Resources and National Oceanic and Atmospheric Administration, contracted with Inter-Fluve to design the removal of Bloede Dam. This design report provides documentation of the 60% design submittal development.

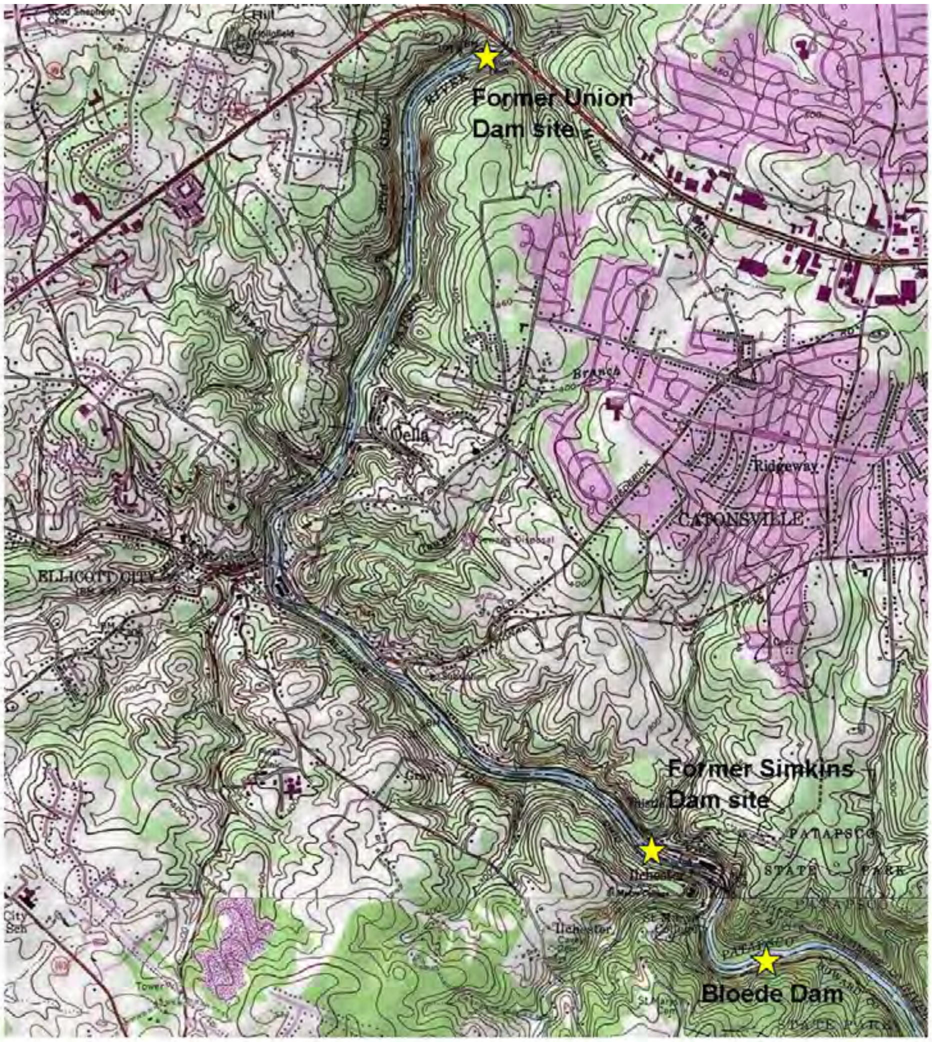

Figure 1- USGS Topographic map of the Patapsco River at Ellicott City, MD showing the location of the Simkins, Bloede and Union dams.

SITE DESCRIPTION

The Bloede Dam is a hollow-core slab and buttress dam built in 1907 by the Ambursen Hydraulic Construction Company of Boston, Massachusetts. A buttress dam is a reinforced concrete structure characterized by an inclined flat slab upstream face supported by vertical buttresses. The spillway is 34-feet high and 160-feet long, with a 40-foot wide base and adjacent concrete abutments that span a total distance of 220 feet across the river valley. The turbines, which were once housed inside the dam, have been removed, and the current structure is filling with sand. The dam drains an area of approximately 304 square miles and impounds roughly ten acres. The original structure had three seven-foot diameter steel penstocks routing water to turbines, but only two were ever used. During 1912 and 1913, the intakes were replaced with gates operated from two motor houses on top of the spillway, and a sluice gate was added to one of the turbine bays. The design of the Bloede dam is unique, featuring water intakes below the crest that fed internal turbines. This design was also the reason for the dam's dysfunction, as large amounts of sediment deposited upstream of the dam and clogged the intake pipes. Dredging in the early 1920s temporarily restored power generation to the dam, but subsequent flooding brought more sediment. Hydropower generation was finally discontinued in March 1932 (Figure 2).

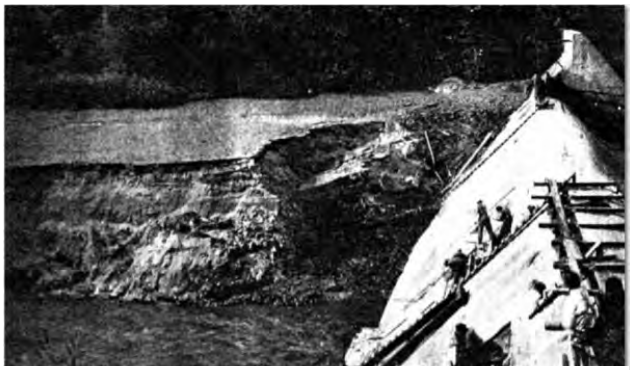

Figure 2- Dredging upstream of Bloede Dam (ca 1920)

Since that time, the dam has functioned only as a run-of-river dam. In 1972, river flows from Tropical Storm Agnes resulted in extensive damage and the removal of the No. 1 and No. 2 motor houses. Inspections conducted in the late 1970s recommended reinforcement of the dam's interior. The dam was rehabilitated in 1991 when concrete was added to the buttresses and upstream slab to improve weathering resistance and strengthen the dam to resist the added loads caused by silt accumulation. In 1992, a concrete Denil-type fish ladder was installed by the Maryland DNR on the right abutment.

The dam and abutments are an attractive nuisance and a safety hazard; several people have been killed or injured at the Bloede Dam site. The dam has been inspected thoroughly numerous times, including Century (1980), Synergics (1989), Wheelock (1993), and Gannett Fleming (2012). These were either dam inspection reports or engineering analyses related to fish passage, repairs, or demolition.

FIELD DATA COLLECTION

Existing Data Collection

Historic and archeology

Although a cultural resources consultation is being conducted by the project partners, Inter-Fluve conducted a cursory investigation into historic conditions at the site and also the history of the watershed. This information has been used to create a wider picture of how the dam came to be, its construction, abandonment and finally removal. A comprehensive review of local history is found in Patapsco River Valley (Sharp, 2001) and The Patapsco - Baltimore's River Of History (Travers, 1990).

Maps

Historic USGS topographic maps were obtained for 1890, 1908, 1953, 1966, 1974, 1982, 1984, and 2000. No other historic maps were obtained. Flood Insurance Rate Maps (FIRM) are also available for the area. The most recent FIRM for the Baltimore County side of the river is dated September 26th, 2008 (Map #24001000485F). The Howard County FIRM was updated November 6, 2013 for the southerly side of the river (Map #24027C0160D).

Aerial Photographs

Aerial photographs from the MDDNR (1m resolution) and USGS (0.5m resolution) were used for the creation of field maps and analyses in GIS.

River-Section Monitoring Data

American Rivers has an ongoing program to collect data downstream from the former Simkins Dam site following its removal. This monitoring data includes geomorphic monitoring, biological monitoring, and hydrologic modeling including measuring turbidity and discharge.

GIS Coverage

GIS data in the form of shapefiles and digital elevation models (DEMs) were obtained from the MD DNR Geospatial Data clearinghouse website. A DEM with 1 m resolution was obtained from 2005 LIDAR data. LIDAR has been updated with 2011 data through the project site. Contour lines were extracted from the DEMs and topographic data was merged with the total station survey data to create a basemap. A shapefile of FEMA flood data from 1996 shows the 100-yr flood prone area along the Patapsco River. Another shapefile created in 1998 shows the watersheds within the state of MD based on third-order stream drainages.

Reports

Three main reports examining conditions at the Bloede Dam were reviewed: Century (1980), Synergics (1989) and Gannett Fleming (2012). Other reports reviewed include: Dewatering of Bloede Dam (Associated Engineering Sciences, 1987), Deep Run and Patapsco River Stream Corridor Survey (MDNR, 2005), Bankfull Discharge and Channel Characteristics in the Coastal Plain Hydrologic Region (USFWS, 2003), Maryland Stream Survey: Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region (USFWS, 2002), Patapsco River Stream Corridor Assessment Survey in Howard County (Maryland DNR, 2003), Site Characteristics for Selected USGS Gage Stations in the Coastal Plain Physiographic Province (USFWS, 2003). As part of the hydrologic investigation, Flood Insurance Studies for Howard County (FEMA, 2013) were also reviewed, as was Technique for Simulating Peak-flow Hydrographs in Maryland (Dillow, 1998).

A dam removal alternatives analysis was compiled outlining potential removal and sediment management scenarios (Inter-Fluve, 2012). Additionally, sediment management plans for this project include Bloede Dam Removal Draft Sediment Management Plan (Inter-Fluve, 2013) and Final Sediment Transport in the Patapsco River, Maryland following Bloede Dam Removal (Stillwater Sciences, 2014).

Survey

Topographic and bathymetric survey data compiled for this project includes initial river and bridge surveying along with as-built and cross-sectional surveys associated with Simkins Dam removal monitoring (McCormick Taylor, 2012) that have been augmented by river and sewer pipe surveys (Inter-Fluve and A&B Consultants) performed at the Bloede Dam site. Topographic and bathymetric data was integrated with other existing survey and topographic data, including Baltimore County 2005 LIDAR.

Geomorphology

Geomorphic field investigations for this project started prior to the Simkins Dam removal and have included observations of the river from the former Union Dam site downstream to Chesapeake Bay. Multiple site visits since 2008 have provided opportunities to observe pre- and post-dam removal and pre- and post-flood channel response. These include initial geomorphic reconnaissance, sediment sampling, topographic and bathymetric surveying, sediment depth probing, post construction site inspections and reconnaissance during design. Regular monitoring associated with the Simkins Dam removal has provided valuable understanding of geomorphic response following dam removal with passive sediment release (McCormick Taylor, 2012) on the Patapsco. See the “Sediment Monitoring Results” section of this report for additional information relative to the ongoing monitoring. Historical photographs and subsurface investigations have provided additional understanding of anticipated post-dam removal conditions.

Sediment Investigations

In 2011, Maryland Geological Survey (MDGS) performed subsurface investigations using vibrocoring, ground penetrating radar, and acoustic seismic equipment. MDGS vibrocores did not penetrate through the entire impounded sediment profile but did provide grain size information at the bore locations (Ortt, 2012). Two rounds of subsurface investigations performed by Triad Engineering on September 6, 2012, and December 11, 2012, included a total of 17 bores. An additional floodplain geoprobe and coring operation was performed by Triad Engineering/Green Services on July 24th and July 25th, 2013 Followed by an additional 12 borings completed along the Grist Mill Trail by Triad Engineering on January 14, 2014 to assess sanitary sewer constructability and slope stability.

A total of 14 sediment samples were taken behind Bloede Dam and analyzed for inorganic and organic contaminants (Figure 3). Eleven of the samples were taken from six cores collected by Maryland Geological Survey (MGS) between December 17, 2011, and February 1, 2012 (MGS, 2012). Contaminant analyses were run on Core #1 (upper and lower halves), Core #3, Core #5 (upper and lower), Core #6 (upper and lower), Core #8 (upper and lower), and Core #9 (upper and lower). The three remaining samples were taken from three separate cores on July 29, 2013. Analytical results for the sediment samples as compared with regulatory standards and screening levels are summarized in Bloede Dam Removal Draft Sediment Management Plan (Inter-Fluve, 2013).

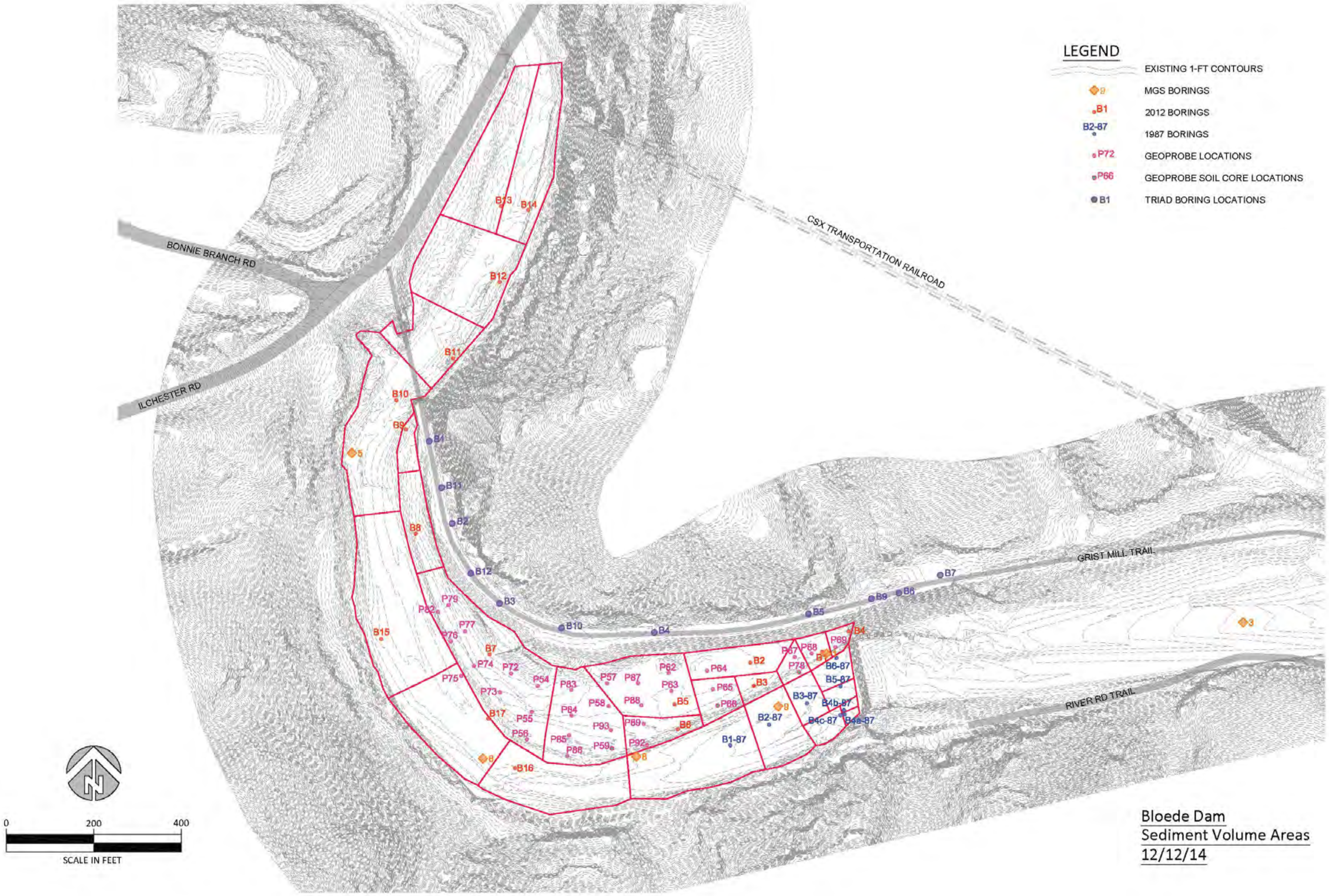

Figure 3 - Sediment Core Locations.

II. Data Analysis

IMPOUNDED SEDIMENT VOLUME

Impoundment sediment volume was estimated by combining sediment depth and character information provided in the subsurface investigations and borings described above. Several subsurface investigations were used to develop sediment volume estimates. The earliest of these was conducted by Associated Engineering Sciences, Inc., for the Dewatering of Bloede Dam report prepared in July 1987, which includes seven bores. Maryland Geological Survey performed subsurface investigations using vibrocoring, ground penetrating radar and acoustic seismic equipment. MDGS vibrocores did not penetrate through the entire impounded sediment profile, but did provide grain size information at the bore locations. Three rounds of subsurface investigations were performed by Triad Engineering on September 6, 2012, December 11, 2012, and January 14, 2014 that included a total of 29 bores. Also, a floodplain geoprobe probing and coring operation was performed on July 24, 2013 and July 25, 2013. Data obtained from these efforts is summarized in *Bloede Dam Removal Draft Sediment Management Plan* (Inter-Fluve, 2013). The cores were used to estimate the extent, stratification, and character of sediment deposition within the channel and within the left (north) bank sediment deposit. The left bank deposit was determined to be a significant portion of the impoundment volume based on geotechnical investigation, which indicated the original main river channel is located there.

Figure 4 - Left Bank Impoundment Deposit Location

During the Simkins Dam Removal, sediments were characterized as almost exclusively uncontaminated sands. Consequently, passive sediment management was elected, which allowed sediment to mobilize downstream during baseflow and flood conditions. Subsurface investigations indicate that the Bloede Dam impoundment contains a higher fraction of silt isolated within stratified layers, which is due to difference in dam height between the Simkins and Bloede dams. The silt is located predominantly within the left bank sediment deposit and is overlain by the sand. The smaller Simkins Dam impoundment did not provide adequate residence time for fine grained material (silt) to settle and these sediments consequently passed over the Simkins Dam and were transported to the Bloede Dam impoundment, where they settled within the larger impoundment. Over time, the Bloede impoundment depth was diminished by the silt to a point where the reduced residence time prevented further settling of additional silt material. The silt was then overlaid with heavier sand material, which is evidenced in the soil borings.

The sediment volume estimates are based on analysis of two-dimensional surfaces developed for the existing ground, proposed river bed, and silt/sand interface – all founded on the 29 soil boring cores collected. Using computer aided design (CAD) software, a volume estimate was completed for the site. Core data within the existing channel footprint and within the left bank sediment deposit and the volume analysis polygons are shown in **Error! Reference source not found.**3. For the purposes of the sediment volume estimate, sediments classified as silty sands were considered sand, and sediments classified as sandy silts were considered silt. Sediments in the existing channel footprint and within the left bank sediment deposit were segregated. This segregation of sediments in the existing channel footprint and left bank sediment deposit is based on Bloede Dam operations, which included periodic sediment flushing to facilitate hydroelectric power generation. The calculations indicate an estimated total quantity of 312,000 CY of sediment impounded behind Bloede Dam. Approximately 225,000 CY of sand is impounded, overlaying approximately 87,000 CY of silt.

METALS

A suite of 23 metals were analyzed for 14 sediment samples. The samples were analyzed using USEPA Method 6020A which quantifies total metals in the sample. The Toxicity Characteristic Leaching Procedure (TCLP) analysis was used on select samples to test the potential mobility of metals bound in the sediments to leach into the water column. Considering the volume and fate of the sediment per Environmental Protection Agency guidance, the TCLP Method (1311) will result in concentrations that are at least 20 times lower than the corresponding total metals concentration due to a 20:1 dilution factor involved in the TCLP test. Applying this dilution factor, the adjusted metal concentrations were compared with the following regulatory standards and screening levels:

- Maryland Department of the Environment (MDE) Cleanup Standards for Soil and Groundwater for three categories: residential clean-up, non-residential clean-up, and protection of groundwater (MDE, 2008)
- NOAA Screening Quick Reference Tables (SQuiRTs) that lists Threshold Effects Concentrations (TEC) and Probable Effects Concentrations (PEC) for inorganic and organic contaminants in freshwater soils (Buchman, 2008)
- US EPA Region 3 Freshwater Sediment Screening Benchmarks (US EPA, 2006)

The data was sent to MDE's Land Management Agency (LMA) for comments by William Seiger of MDE. Arthur O'Connell from LMA replied in November 2013 via email: “[We] don't see anything of concern. The metals are all within normal concentrations for the area and there was no mercury or PCBs detected. The organic analysis was unremarkable."

NUTRIENT LOADING

Research on the limiting factors impacting phytoplankton growth in the Chesapeake Bay have been completed based on samples collected between 1989 and 1994. The report indicates seasonally based nutrient limitations, which:

> appeared to be caused by temperature, mixing, river discharge, and sediment P fluxes. At high salinity stations, we also observed winter N limitation (caused by DIN depletion prior to spring nitrate delivery), and at lower salinity stations there was fall P limitation (caused by reaeration of bottom sediments). At tidal fresh stations, turbidity and nutrient concentrations resulted in continuous light limitation, except at some stations in summer. Interannual decreases in light limitation and increases in N and P limitation appear to represent improvements in water quality. (Fisher et al., 1999)

The impacts resulting from additional total phosphorus (TP) loads potentially released from Bloede Dam are subject to regulation by Maryland Department of the Environment (MDE). The TP can be evaluated based on the 2006 established Total Maximum Daily Load (TMDL) for Baltimore Harbor, for which the Patapsco River watershed provides the greatest hydrologic input. The approved TMDL lists a target load of 324,309 lb/year for TP. TP loading within the watershed is estimated at 354,888 lbs/yr based on the published TMDL. Based on the analysis completed, the TP load associated with the silt within the Bloede Dam impoundment is approximately 85,000 lbs (based conservatively on 90,000 CY of silt, rounded up from 87,000 CY). Under the preferred design alternative of passive sediment release, the TP loading would be released over approximately six years (based on average statistical rainfall events) after removal is complete (Stillwater Sciences, 2014). The total amount of Bloede Dam impoundment sediment represents approximately 26% of the annual TP load allocation for the Patapsco River.

Estimates of total nutrient loads of Total Nitrogen, Total Kjeldahl Nitrogen (TKN) and Phosphorous are associated with: 1) the impounded material within the channel; 2) within the left bank deposit; and 3) total based on three core samples taken during the 2013 sampling event given in **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**. A TMDL of 4.3 million pounds per year is allocated from the Patapsco River into the Chesapeake Bay. The one-time release of up to approximately 180,00lbs of Nitrogen is approximately 4.2% of the allocated load.

Table 1 - Estimated Soil Nutrient Loads for Impounded Silt (P59)

	P59			
	Concentration (mg/kg)	**Left bank load (lb)**	**Channel load (lb)**	**Total Load (lb)**
Phosphorus	390	77,527	2,420	***79,947***
Nitrogen, Total (NO2, NO3, TKN)	880	174,933	5,460	180,393
Nitrogen, Total Kjeldahl	880	174,933	5,460	180,393

Table 2 - Estimated Soil Nutrient Loads for Impounded Silt (P66)

	P66			
	Concentration (mg/kg)	**Left bank load (lb)**	**Channel load (lb)**	**Total Load (lb)**
Phosphorus	410	81,503	2,544	***84,047***
Nitrogen, Total (NO2, NO3, TKN)	540	107,345	3,351	110,696
Nitrogen, Total Kjeldahl	540	107,345	3,351	110,696

Table 3 - Estimated Soil Nutrient Loads for Impounded Silt (P78)

	P78			
	Concentration (mg/kg)	**Left bank load (lb)**	**Channel load (lb)**	**Total Load (lb)**
Phosphorus	420	83,491	2,606	***86,097***
Nitrogen, Total (NO2, NO3, TKN)	500	99,394	3,102	102,496
Nitrogen, Total Kjeldahl	500	99,394	3,102	102,496

Note: Laboratory analysis uses dry weight. All calculation therefore assumes a silt soil density of 1.4 g/cm3

HYDROLOGY

Hydrologic Analysis

To be consistent with gage-derived hydrologic modeling completed for the Simkins Dam removal project (Inter-Fluve, 2010), Inter-Fluve recalculated return interval flows based on gage data. Flood frequency estimates were determined from peak flow data recorded at the USGS Hollofield gage (USGS# 01589000) using a Log Pearson Type 3 distribution following guidelines of Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The Hollofield gage provides data for 57 (noncontiguous) annual peak flow events between 1933 and 2013. The data set provided input for Log Pearson Type 3 distribution analysis to determine return interval flows for the entire period of record.

Since the Log Pearson Type 3 was calculated to a drainage point of a smaller watershed compared to the Bloede project site, a gage transfer was applied. To account for the difference in watershed size from the Hollofield gage site of 285 sq mi. to the project site of 303 sq mi. a scaling factor of 1.06 was used for gage transfer.

Table 4- Estimated recurrence floods for Patapsco River based on Log Pearson Type 3

	Recurrence Interval										
Years (yrs)	1.11	1.43	1.67	2	5	10	25	50	100	200	500
Annual Exceedance Percentage (%)	90%	70%	60%	50%	20%	10%	4%	2%	1%	0.5%	0.2%
Entire Period of Record (cfs)	1,906	3,346	4,191	5,232	11,891	19,256	33,558	49,172	70,445	99,204	152,829

Fish Passage Flows

To ensure that fish passage would be possible under post-dam removal conditions, channel velocities were analyzed under the 5% (716 cfs) and 95% (56 cfs) exceedance flows. The 5% exceedance flow during the migration period is the daily average flow that is equaled or exceeded 5% of the days in the period the selected fish species are moving. The 95% annual exceedance flow is the daily average flow that is equaled or exceeded 95% of the days through the noncontiguous period of record from 1944 to 2014. Daily flow data was generated from gage data for the migration period of February 1 – June 30 to encompass herring and shad migration windows. The actual migration period for anadromous clupeids varies depending on species, temperature and other factors, so we used a conservative window based on reported values in the literature and as reported by Maryland DNR Fish Facts (http://dnr2.maryland.gov/Fisheries/Pages/fishfacts-index.aspx). The migration window used encompasses reported migration periods for alewife, blueback herring and American shad in the North Atlantic or Chesapeake Bay area (Davis 1970, Greene et al. 2009, Klauda et al. 1991, Kocik 2000, Loesch 1987, Mansueti and Hardy 1967, O’Connell and Angermier 1997).

Fish passage flows are typically calculated from average daily flows during the migration period. Zero flow recordings were assumed to be erroneous or a result of former dam operation practices that are no longer applied at the site since decommissioning of power generation equipment. Thus, zero values were removed from the data set. The 95% exceedance probability is commonly used for low flow fish passage and the 5% exceedance probability is often used for high flow fish passage design (Furniss, 2006) Searcy (1959) recommends a minimum of 10 years of record be used to develop exceedance probability values. The Hollofield gage provides the equivalent of over 58 years of daily flow data.

Base Flow

The Hollofield gage daily flow data were also used to develop an estimate of base flow. For base flow, the 95% exceedance probability was used for noncontiguous daily flow data recorded from 1944 through November 2014. The 95% exceedance probability differs from the fish passage flow since it includes data from all months of the year, not just the fish migration period. Zero flow recordings were assumed to be erroneous, or a result of former dam operation practices that are no longer valid. Thus, zero values were removed from the data set. Average daily flows that were higher than the annual exceedance flood were also removed from the data set to avoid skewing base flow calculation with flood flows. The resultant base flow is estimated to be 30 cfs. It should be noted that the base flow estimate does not change if flood flows remain in the data set.

Ordinary High Water (OHW) Flow

The OHW elevation downstream of the dam was estimated from field indicators including: the lower limit of large trees, top of bank or point of incipient flooding, and stain lines on adjacent infrastructure. Although woody species can be found at or near the observed summer base flow elevations, these plants were less than 10 years of age and were not used as indicators. Only trees greater than 10 inches in diameter were used. The OHW elevation was estimated in the field at four feet above the proposed channel thalweg based on cross-sections downstream of the Bloede Dam. The two-year (Q2) discharge (5,464 cfs) inundation pattern in the hydrologic/hydraulic model matches the elevation observed in the field at the downstream location. Typical bankfull indicators such as the lower limit of smaller woody vegetation and the top of depositional bars were not used to estimate the OHW due to the complicating factors of recent flooding, highly impacted hydrology within the watershed, and sediment deposition from upstream dam removals.

HYDRAULICS

Summary of Data Collected

Initial topographic survey data was collected via total station and GPS-RTK surveying equipment in 2011. These data were taken at 20 cross-sections within the impoundment and were augmented by ground shots throughout the project area, as well as Baltimore County 2005 LIDAR data outside the project area and Howard County 2011 LIDAR data within the project area. Where applicable, cross-sections were revised and updated with survey data collected in November 2012 for Simkins Dam removal monitoring and for the existing conditions model. Subsurface data to predict proposed conditions was obtained through a combination of seismic reflection surveying (MDGS), soil borings and probes, conducted by both the MDGS and Inter-Fluve's geotechnical engineering partner, Triad. Soil boring and MDGS seismic cross-sections used in the design are provided in the *Bloede Dam Removal Draft Sediment Management Plan* (Inter-Fluve, 2013). Additional detail can be found in Associated Engineering Sciences Inc., (1987), Triad Engineering (2012a, 2012b, 2013), and Ortt (2012). Tree cores were taken to determine the age of large trees (>12 in. dbh) on the subaerial reservoir deposit just upstream of the dam. Historic maps and aerial photographs, as well as historic ground photos were used to help determine pre-dam conditions and estimate pre-dam channel boundary locations and hydraulic roughness. The Bloede Dam removal analysis incorporates and expands upon the hydrology and hydraulic analysis gained from the Simkins Dam Removal project completed in spring 2011.

Existing Conditions Model

Hydraulic modeling was performed using HEC-RAS v. 4.1.0. Cross-sections were located to model pertinent hydraulic conditions for the reach. McCormick Taylor, Inc. developed the existing conditions model for the project reach and development of the model can be referenced in detail by reviewing *Hydrology and Hydraulics Study Bloede Dam Removal and Patapsco River Restoration* (McCormick Taylor, 2012). The existing model required some modifications based on the updated hydrology along with the additional cross-sections. As mentioned above, flows were revised based on gage data, and the HEC-RAS model was run with the updated flood frequency flow estimates. Additional cross-sections were developed for direct comparisons with the cross-section locations associated with proposed channel slope breaks. Augmented cross-sections are shown in Table 5 - HEC-RAS cross-section additions and removals to the McCormick Taylor existing hydraulic model. Cross sections were sampled from the Inter-Fluve survey, McCormick Taylor cross-section surveys, and LIDAR.

Table 5 - HEC-RAS cross-section additions and removals to the McCormick Taylor existing hydraulic model.

Added	Removed
190+30	
188+46	
181+64	
	180+94
179+20	
177+58	
	177+38
175+19	
172+91	
	172+89
170+63	

169+04	
167+98	
	167+68
167+28	
166+65	
166+02	
165+56	
-13-20	
-19-43	
-33-40	
-41-45	
-64-74	

Based on field indicators, channel roughness was estimated at 0.035 and floodplain roughness was estimated at 0.08 under existing conditions. These channel roughness values are consistent with the Simkins Dam removal studies.

Since the existing conditions model was updated within the project reach with more recent survey data, the model was calibrated with water surface elevation data from McCormick Taylor's cross-section surveys. The results of the calibration are provided in **Error! Reference source not found.**. The results of the calibration appear to provide acceptable results at relatively low flows.

Table 6- Existing Conditions model calibration from 2013 survey data.

M&T Section	IFI Model Section	Date Surveyed	Survey Day Flows		Water Surface	
			Flow Hi (cfs)	Flow Lo (cfs)	Obs. El (ft)	Modeled El (ft)
6	185+25	10/16/2013	133	120	74.89	75.67
7	182+68	10/16/2013	133	120	74.96	75.4
8	169+04	10/21/2013	92	90	74.93	75.18
10	124+39	10/21/2013	92	90	36.2	36.14

Anticipated Conditions Model

Anticipated hydraulic model cross-sections were developed from existing conditions cross-sections and modified by extrapolating data from subsurface investigations, and are considered approximations of the likely future channel condition. Depth of refusal from probes and boring data was used to develop proposed channel cross-sections. A photo of the pre-dam Patapsco River channel is provided in **Error! Reference source not found.**, and shows two people standing next to a large boulder across the channel. **Error! Reference source not found.** illustrates the variability that may be associated with developing channel shape based on depth of refusal data.

Figure 5 - View of the Patapsco River prior to dam construction.

Hydraulic model cross-section locations within the project reach are indicated by the existing and anticipated channel alignment stations shown on the design drawings. The channel thalweg is anticipated to shift to the north in the lower impoundment. Infrastructure locations can be determined relative to hydraulic model cross-section and their station on the design drawings. Roughness values for anticipated conditions were not changed from the existing values for the floodplain. However, roughness values were increased from 0.035 to 0.050 in channel based on an anticipated change from a sand bed channel to a large boulder bed channel, as shown in **Error! Reference source not found.**. Hydraulic model output is provided for the anticipated and existing conditions in the project reach in the form of profile graphs, below. The profile graph in **Error! Reference source not found.** demonstrates the modeled water surface elevations along with channel bottom elevations under the existing conditions and anticipated conditions.

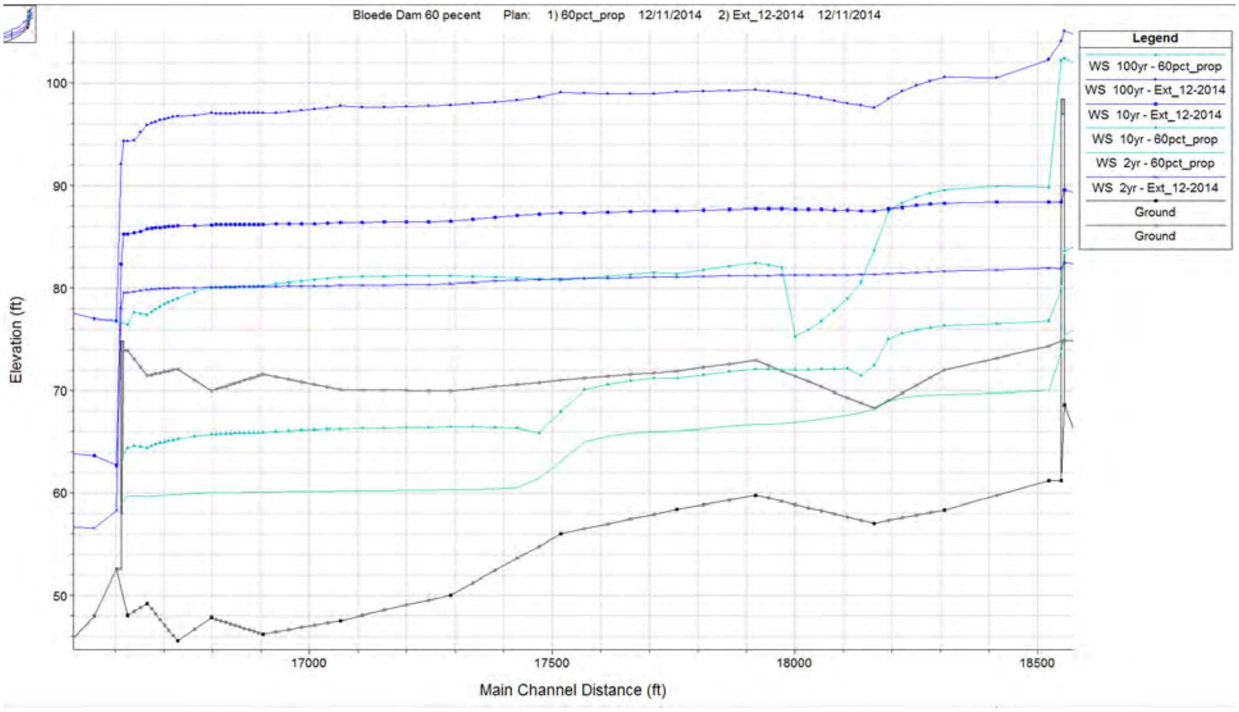

Figure 6 - Excerpt from HEC-RAS model output showing water surface elevations for existing (dark blue) and anticipated conditions (light blue) in the impoundment area.

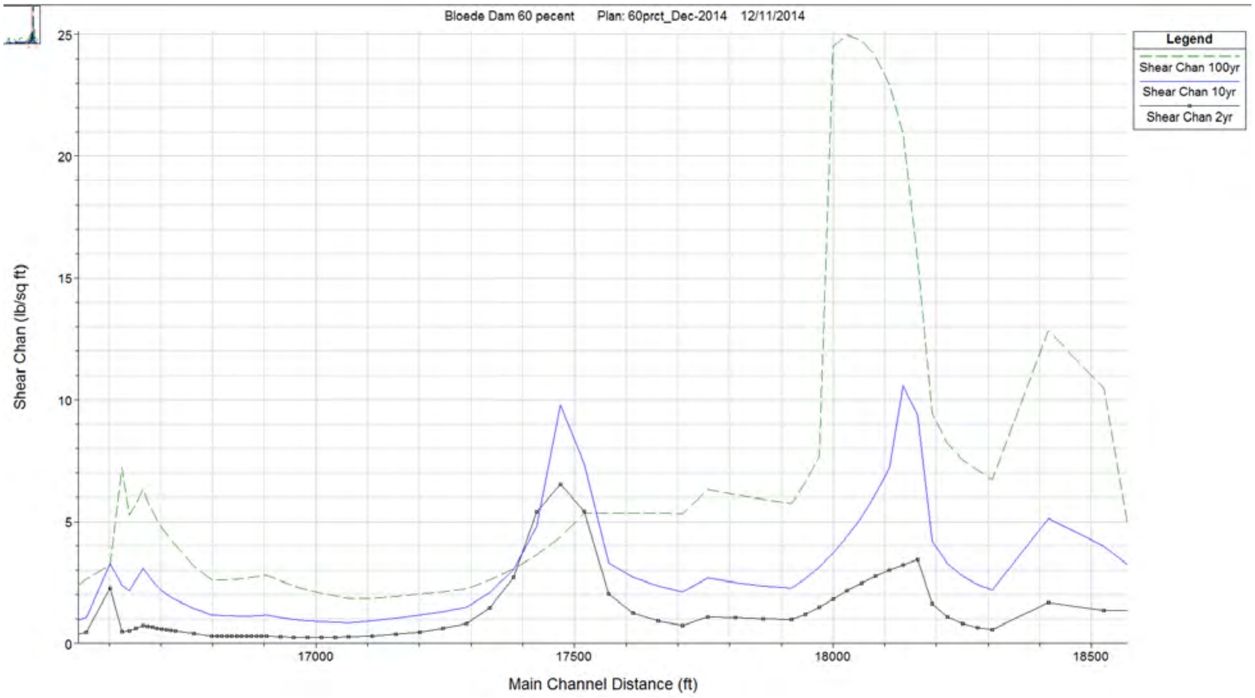

Figure 7 - Excerpt from HEC-RAS model output showing shear stress values (lb/ft2) associated with the 2-, 10-, and 100-yr recurrence flood for anticipated conditions.

The results from the HEC-RAS model indicate very high shear stresses at STA 180+00 where hydraulic jumps occur (See **Error! Reference source not found.** and **Error! Reference source not found.**). These are likely due to a valley wide flow constriction and downstream drop in channel elevation near STA 179+20. The proposed conditions model has been developed based on limited subsurface data; therefore, channel conditions following dam removal may vary. The channel exposed following dam removal and sediment evacuation should closely match the pre-dam channel. As such, if severely erosive conditions exist, the exhumed channel should have the erosional resistance to withstand severe hydraulics. The greater concern may be for fish passage, and an adaptive management approach may be necessary to assure fish passage.

Fish Passage Hydraulic Analysis

The fish passage flows were input into the HEC-RAS proposed conditions hydraulic model to determine resultant velocities and evaluate fish passage conditions. Velocities downstream of the dam plunge pool, outside the project area, approach 11 and 15 feet per second (ft/s) at the low and high fish passage flows, respectively, for both existing and anticipated conditions. The highest velocity modeled at the high fish passage flow through the project site is 6.68 ft/s, and the highest velocity modeled at the low fish passage flow is 3.88 ft/s. HEC-RAS velocities are an average velocity across the entire cross-section. Thus, higher and lower velocities will occur within a cross-section, especially near the channel bed where turbulent eddies can provide resting areas for fish. The boulder, bedrock, and pool channel that is anticipated to be exhumed within the Bloede Dam impoundment will likely provide frequent velocity breaks where fish may hold and rest during migration. While velocity is typically the concern for fish passage at high flow, depth is usually the critical parameter at low flow. For the purposes of this analysis, a minimum depth equivalent to an estimated fish body width of approximately six inches (based on Alewife and Blueback Herring) was utilized as the minimum flow depth to achieve fish passage. All modeled depths at the low fish passage flow were six inches except at STA 187+47 (approximately midway between the Ilchester Road Bridge and pedestrian bridge) where critical depth flows are modeled at three inches depth at 95% exceedance flow during the migration period. It should be noted that we cannot determine exact channel dimensions or flow characteristics at this time. An adaptive management approach may include creating a low flow channel coupled with boulder placements where necessary to provide sufficient flow depth at low flow.

Modeled velocity results were compared to documented cruising and darting swimming speeds (Bell, 1991) (Haro, 2004). According to Chapter 6.3 of Bell (1991 – USACE Fisheries Handbook), the following are listed as relative swimming speeds for our species of interest:

- Alewives 2.5 – 3 inches in length demonstrate darting speeds up to 4 ft/s. Haro (2004) has recorded Alewives passing at velocities up to 11.5 ft/s for short distances. As with any fish, performance (distance) increases with decreased velocity.
- American Shad 12-14 inches in length demonstrate cruising and sustained speed up to 8 ft/s, and darting speeds up to 15 ft/s. This correlates well with Haro (2004).

- Blueback Herring 6-11 inches in length demonstrate cruising speed up to 5 ft/s, and darting speed up to 10 ft/s. Haro (2004) has recorded slightly higher passable velocities for Blueback Herring.
- Eel of varying lengths from 2 – 8 feet, and elvers are able to pass velocities up to 7 ft/s. Eels and elvers make use of interstices and marginal habitat and are able to pass under a wide variety of conditions.

There are no published guidelines for fish passage conditions following dam removal, as natural river conditions and species requirements vary widely. Fish passage is dependent on fish size, swimming and leaping ability as they relate to water depths, water velocities, and grade drops that may hinder or prevent passage. Fish swimming speed also varies by species, swimming mode (e.g. burst or coast), size of the fish, and the duration of the activity (Bell 1991, Dow 1962, Haro 2004, Stringham 1924, Weaver 1965). Natural rivers have in-stream roughness elements that create turbulent flow and macroeddies that create variable water velocities, as well as quiescent conditions used as resting habitat. Fish in these conditions are able to use this variability to aid their movements (Hinch and Rand 2000, Pavlov et al. 2000). Flood conditions also alter depth, velocity, and barrier hydraulics, and can create passable conditions at varying flows. Considering the fish passage water depth threshold and the above data for fish swimming performance, the hydraulic conditions under the post-removal scenario may require adaptive management to provide fish passage. However, the proposed channel conditions in the computer model do not fully account for microhabitat, interstitial spacing, local turbulence, and changes in velocity across the cross-section. The post-removal condition will likely have low velocity conditions in boundary layers, interstitial spaces, and backwater areas to provide additional hydraulic diversity to facilitate migration.

It is likely that bedrock outcrops exist near the dam and within the impoundment. However, observations of existing, visible bedrock, suggest that there will be gaps in the bedrock outcroppings that may allow for full fish passage. It is important to note that the most severe hydraulics affecting fish passage currently exist downstream of the dam, with velocities there that are higher than 10 ft/s at fish passage flows; in contrast, modeled velocities are less than 7 ft/s through the project area following dam removal.

Hydraulic model output is provided for proposed and existing conditions in the project reach in the form of tabular output under Tab 4.

SEDIMENT TRANSPORT

Transport will be partially controlled by flow, but sediment transport did occur during baseflow conditions following the Simkins Dam removal as a consequence of the base level change (Collins et al., 2013). Following dam breach, the Patapsco River will immediately begin incising through sediments impounded by the Bloede Dam. A headcut will form that will migrate upstream as impounded sediments are liberated. As was the case with the Simkins Dam, this headcut will contain sand and will likely be a diffuse headcut spread over a long profile. Even at low flow, sand and silt from the face of the headcut will be transported. The design team has compiled the results of two parallel tasks to provide estimates of downstream sediment transport due to the removal of the Bloede Dam. The first analysis includes the results of sediment transport modeling completed using the Dam Removal Express Assessment Model-1 (DREAM-1). In addition to the modeling results, the team has also compiled the most recent findings of the sediment transport monitoring which has been ongoing since the removal of the Simkins Dam in 2011.

SEDIMENT TRANSPORT MODELING

A DREAM-1 sediment transport simulation was performed by Stillwater Sciences (2014) who concluded that the most likely outcome is that 250,000 CY will be transported during wet and average hydrologic conditions and the pre-dam channel profile will be exhumed in one to 6.5 months, respectively. Suspended sediment concentrations are anticipated to peak up to 6,000 to 7,000 mg/l, with elevated concentrations (>1000 mg/l) persisting for approximately 11 of the 23 weeks immediately following removal with average hydrologic conditions, and less than three weeks with wet hydrologic conditions (Stillwater, 2014). Channel aggradation may be up to seven feet thick immediately downstream of the dam, and channel accretion of two-to-five feet of thickness may persist for up to six years in downstream reaches (Stillwater Sciences, 2014).

Additional key findings include:

- Although there is approximately twice the sand in the Bloede impoundment than was within the Simkins impoundment, the higher volume of sediment does not result in twice the deposition depths downstream.
- The maximum impounded silt release is equivalent to the suspended solids transported in the river over a one day period during an eight-year recurrence flow event.

SEDIMENT MONITORING RESULTS

Detailed monitoring of the Simkins Dam removal broadly supports the DREAM-1 modeling results that suggest sand will be excavated rapidly from the Bloede impoundment and the largest downstream accretions will be in the Gun Road area (Collins et al., 2013).

BIOTIC IMPACTS

The Patapsco River dams have had many impacts to the river systems. A summary of impacts is provided in the following sections and how they have affected biotic communities associated with the Bloede impoundment. Additional information regarding the biotic impacts of Bloede Dam and its removal can be found in alternatives analysis documents and in monitoring reports for the Simkins Dam removal (MBSS, 2013).

Biotic Impacts of the Patapsco River Dams

Construction of the Bloede Dam in 1906 created an impoundment where some of the sediment and nutrients normally transported downstream have been retained and accumulated. The covering of pre-dam river channels by thick layers of sediment reduces habitat diversity and functional living space for benthic, or bottom-dwelling, organisms (Waters, 1995). Fine sediment deposition upstream of the Bloede Dam has buried the pre-dam channel under many feet of silt and sand. Prior to burial, the pre-dam channel likely had habitat diversity including bedrock outcrops, riffle, and pool features. The current channel through the impoundment is a flat, featureless, coarse sand bed with minimal heterogeneity of habitat.

Overall reduction in habitat diversity within impoundments results in the loss of species diversity and a greater abundance of organisms tolerant of altered conditions (Allen, 1995).
Stream invertebrates and fish are replaced by more tolerant or adaptable species typically associated with reservoir or lake environments (Ross, 1991; Kanehl et al., 1997). Studies of sediment deposition from dam construction, logging, and mining show that deposited sediment negatively impacts macroinvertebrate and mussel populations (Benke et al., 1984; Cordone and Kelly, 1961; Hughes and Parmalee, 1999).

Perhaps the most important impact of the Bloede Dam has been to aquatic organism passage. Bloede Dam has been a barrier to the migration of both resident fish and migratory fish for over 100 years. Secondary effects of the fish migration barriers include reduced spawning, outmigration, and living space for these fish in the upper Patapsco River system. Migratory and resident fish will immediately have access to 64 miles of upstream habitat following the removal of Bloede Dam. This project is expected to improve biological connectivity in the Patapsco River, partially restore anadromous/catadromous fish migration, and increase the similarity of resident fish species composition above and below the dam. The Patapsco River monitoring surveys (McCormick Taylor, 2012) and previous Maryland DNR (MDDNR) surveys found American Eel (*Anguilla rostrata*) above Bloede Dam and anadromous or semi-anadromous fish species below the Bloede Dam, including Blueback Herring (*Alosa aestivalis)*, Hickory Shad (*Alosa mediocris*), Sea Lamprey (*Petromyzon marinus*), Striped Bass (*Morone saxatilis*), White Perch (*Morone americana*), Yellow Perch (*Perca flavescens*) and Quillback (*Carpiodes cyprinus*). These anadromous fish are either in decreased abundance or absent above the Bloede Dam. Resident fish species found in the MDDNR studies included: Bluegill (*Lepomis macrochirus)*, Brown Trout (*Salmo trutta*), Channel Catfish (*Ictalurus punctatus)*, Common Carp (*Cyprinus carpio)*, Fallfish (*Semotilus corporalis)*, Gizzard Shad (*Dorosoma cepedianum*), Northern Hogsucker (*Hypentelium nigricans)*, Rainbow Trout (*Oncorhynchus mykiss)*, Redbreast Sunfish (*Lepomis auritus)*, Rock Bass (*Amboplites rupestris)*, Smallmouth Bass (*Micropterus dolomieu)*, White Catfish (*Ameiurus catus)*, and White Sucker (*Catostomus commersonii)*. These fish are expected to have unrestricted passage from the reaches below Bloede Dam until they encounter Daniels Dam several miles upstream, and this allows for spatial and diel migration which should improve their abundance and survival.

Short-Term Bloede Dam Removal Impacts

This section deals with the short-term biotic effects of dam removal with passive transport of sediment downstream. A comprehensive review of the short (and long-term) impacts of dam removal has been completed by Baxter (1977) and more recently by Bednarek (2001). The immediate and most visible impact of the Bloede Dam removal is associated with the clearing and grubbing of the trees in the left bank deposit area. The left bank impoundment deposit has matured with vegetation since 1987, when the State of Maryland dredged the impoundment and placed hydraulic fill in the left bank area. The current forest cover will be extracted to allow removal of the sanitary sewer located within the left bank deposit, and to minimize impact of large trees on downstream infrastructure if they were allowed to mobilize with the sediment. The other short term impact will be the passive hydraulic release of sediment that has accumulated behind the dam and its resulting impacts to downstream areas. The preferred dam removal approach calls for the natural transport of between an estimated 220,000 – 312,000 cubic yards of sediment. Final Design analysis and post-removal activities of the Simkins removals included an assessment of potential impacts to Patapsco River ecology downstream and within the impoundments, and long-term monitoring of sediment movement. We summarize those impacts here within the context of the Bloede Dam removal.

Once the Bloede Dam is fully breached, fine organic and inorganic sediments can be expected to mobilize and increase bedload and turbidity downstream of the dam (Stillwater, 2014). The planned implosion of the dam at a low elevation will result in the mobilization of the overlying sand within the river channel, followed by evacuation of the lower silt deposits. The remaining left bank deposit will be transported as the river migrates north towards the pre-dam thalweg. Increased bedload and turbidity impacts are expected to be of short duration, with bedload impacts persisting for about 6 years, and turbidity impacts on the order of weeks. The DREAM-1 sediment transport model predicts that silt and sand deposits will migrate through the system within 5-10 years (Stillwater Sciences, 2014). Based on the post-Simkins monitoring results, the Patapsco River appears to have naturally mobilized large amounts of the Simkins impounded sediments during low and high flows and has been gradually transporting it downstream (Collins et al., 2013).

The impact of increased turbidity on aquatic species depends on the concentration and exposure time, both of which can vary dramatically in a dam removal. Suspended sediment occurring with every flood event in natural streams typically does not produce mortality in fish as river fish are adapted to tolerate periodic increases in turbidity due to flooding. However, it is anticipated that short-term ecological impacts will likely include "an increased sediment load that may cause suffocation and abrasion to various biota and habitats" (Bednarek, 2001).

While relatively immobile communities like mussels and some other invertebrates can suffer significant impacts downstream of dam removals, fish are able to move upstream or downstream of the impact zone and thus avoid many of the negative impacts of temporary sediment deposition. Fish species can readily respond to temporary changes in turbidity, bedload and temperature following dam removals. Fish readily move to improved habitat conditions, which can include those restored and formerly inaccessible areas upstream of the removed dam. Removal of the Simkins Dam on the Patapsco has resulted in increased habitat complexity through exposure of bedrock outcrops, boulder and cobble habitat, deep scour pools, depositional bars, riffle and pool sequences and potential gravel spawning substrates in riffles and pool tailouts (glides). Short-term fish assemblage changes observed following the Simkins Dam removal are similar to those seen in other studies, with a decline in benthic species downstream of the removal, but with a corresponding increase in species upstream due to passage barrier removal (MBSS, 2013). These same short-term effects are expected to accompany the Bloede Dam removal, followed by an overall increase in fish abundance and diversity of riverine species as the fine sediment moves through the system.

Fish can become stranded during the drawdown of an impoundment. Consequently, fish rescue and relocation is often part of the dam removal process. Fish rescue in isolated water pockets within the immediate work area should be included in the construction contract, or coordinated through the MDDNR Fisheries. It should be noted that no mussels were found downstream of Bloede Dam prior to or after the Simkins Dam removal, and it is unlikely that they will be found there until after the Bloede Dam is removed, the evacuated sand sediments have transported out of the lower Patapsco River, and fish migration has been re-established (Watters, 2001).

Sand and silts are readily mobile, and it is likely that the material not actively excavated from the Bloede impoundment will transport downstream within the first few weeks or months following removal (Stillwater Sciences, 2014). As former streambed materials become exposed and new channels are formed in the exposed sediment, more heterogeneous habitat will likely become available (Bushaw-Newton et al., 2002; Calaman and Ferreri, 2002; Hart et al., 2001; Pollard and Reed-Anderson, 2001).

Given the larger volume of silts likely to be made available with the removal of the Bloede Dam, the project team also engaged researchers with the University of Maryland Center for Environmental Science in an effort to understand the potential biogeochemical impacts of the Bloede Dam removal. Drs. Walter Boynton and Jeffrey Cornwell considered “worse-case scenarios” for the maximum potential phosphorus release from sediments released from dam removal, the magnitude of phosphorus loading rates to the Patapsco system, and the like. Assuming “…that the dam associated sediments are spread over a larger area (full Patapsco River estuarine system; 99 x 106 m-2) the release rate (assuming 50% of all phosphorus would be released from sediments during a single year) would be about 0.2 g phosphorus m-2 year -1. This is a very modest phosphorus loading rate.” Sediment phosphorus fluctuations that would support phytoplankton production are also relatively low (about 0.3 g C m-2 day -1 as compared to the typical range of 2 – 3 g C m-2 day-1 during summer periods (Boynton and Cornwell, 2014).

While there is a reasonable expectation that release of Bloede Dam sediment could result in 1) the deposition of inorganic phosphorus in sediments of the tidal Patapsco River and that 2) under saline, and especially low oxygen conditions, a portion of that phosphorus could become bio-available for the growth of algae, this will depend on the area over which the materials is deposited and the timing of when those materials reach the estuary. Boynton and Cornwell concluded that, either way, they do not expect significant phosphorus releases from deposited sediment except during summer (Boynton and Cornwell, 2014).

Research in other river systems has shown immediate decreases in abundance and diversity of macroinvertebrates downstream of dam removals, but these studies did not examine long-term community changes or recovery (Johnson, 2001; Sethi et al., 2004; Thomson et al., 2005; Stanley et al., 2002). Decreases in organism abundance in these studies were attributed to the change in the streambed substrates downstream of the dam with release of sediment from the former impoundment. Similarly, short-term monitoring conducted by the MDDNR showed an increase in burrowing macroinvertebrates and a decline in Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa) macroinvertebrate habitat quality in the areas monitored downstream of the former Simkins Dam, but showed an increase in habitat quality in areas monitored upstream of the dam. Coarse substrate dependent EPT taxa macroinvertebrates increased in diversity upstream of the dam as the sand transported and more cobbles and gravels were exposed. Lentic or burrowing macroinvertebrate diversity decreased in the impoundment with the flushing of sand, as expected. This short-term trend is expected following the removal of Bloede Dam. Both upstream and downstream macroinvertebrate communities are likely to exhibit similar changes in abundance to those observed at the Simkins Dam as sediment is flushed out of the system (MBSS, 2013).

Long-Term Removal Impacts

The return of a natural flow regime, sediment transport, and channel forming processes with removal of the Bloede Dam will help to restore natural habitat formation in the reach, as has been observed in the Simkins impoundment. River bottom substrate typically increases in size as impounded sediments are transported and riffle and pool habitat is exposed. In the case of Bloede Dam, the channel immediately upstream of the dam will convert from a sand substrate to a boulder, bedrock and cobble substrate. Immediately downstream, the bedrock channel will aggrade in some locations in the short term. Long term, the sediment will be transported downstream and the channel is anticipated to return to its current character. Approximately five kilometers downstream, the Patapsco River is naturally a sand bed and bank channel, the long-term substrate conditions of the downstream portion of the channel are not likely to change following the short-term (approximately six years) adjustments to sediment distribution discussed above. The channel will aggrade and may assume a braided condition in the lower gradient reaches, but the channel will return to a single thread with a meandering character after the evacuated sediment has transported through.

The long-term habitat effects of dam removal on the Chesapeake Bay are contingent upon the eventual deposition of sediments that have been detained behind the dam. Much of the lower eight to nine miles of the Patapsco River are partially braided or a gently meandering river with considerable sand bedload. It is believed that the channel downstream of Patapsco Valley State Park is an actively transporting sand bed. This segment has the ability to accommodate incoming sand from the Bloede Dam removal without significant change to the channel morphology or available habitat. Deposition within the Bay itself is not likely to be detectable.

The short-term impacts to fish and macroinvertebrate populations, including filling of pools and fining of substrates, will reverse in time. Fish and macroinvertebrate populations should return to pre-removal levels following return of stable channel morphology.

RECREATIONAL AND SOCIAL IMPACTS

The project will result in several recreational and social impacts within the Patapsco Valley State Park. Park users will have restricted access for approximately one calendar year due to construction activity. Restricted access will generally be along the river corridor from Ilchester Road downstream to the Orange Grove area of the Patapsco Valley State Park. The relocation of the sanitary sewer will impact Grist Mill Trail use within the project area during construction. However, the trail will be repaved and restored upon completion of the project. The River Road trail between the Orange Grove area and Bloede Dam will also be impacted. This impacted length of the River Road trail is currently a combination of rough asphalt and gravel surface, which will be improved as part of this project.

In the short-term, increased park maintenance associated with sand removal along trails and roads should also be anticipated. The existing sandy shores of the impoundment are utilized by recreational park users. Long term, the dam removal will result in the evacuation of the sediment and elimination of the current sandy beach areas. As this sediment is transported through the downstream reaches over a 6-year period following removal of the dam, temporary sandy beach areas will likely be created or enhanced (Stillwater, 2014). Current recreational fishing opportunities will be changed from the current lentic species to lotic species including Striped Bass and herring. It is likely that whitewater kayaking usage will increase following dam removal.

OTHER IMPACTS

The short-term increase in bedload downstream of the dam site could cause aggradation of the channel bed and potentially influence projected flood elevations downstream, at least temporarily until the sediment moves through. The short-term impacts are anticipated for approximately six years. Initially, sediment will deposit relatively deep over a short distance. Over time, as the sediment is transported downstream, the depth of sediment will reduce and the length of sediment deposits will increase. To be conservative, it should be anticipated that complete transport/distribution of impounded sediments could take six to 10 years; therefore, an adaptive monitoring and management plan is being developed to support the project. The plan should be followed to assess and manage potential changes to flood elevations. Based on the movement of bed material during and after Tropical Storm Lee in 2011, changes to flood elevation and flood risk resulting from Simkins Dam removal are minimal. Sediment impounded by Bloede Dam will be transported during ordinary flow events. During large flood events, sediment transport will be much more effective. Thus, impacts to flood elevations may occur, but they will be transient and temporary.

An increase in sediment supply can also result in a temporary increase in bank erosion. Channel stability downstream of the Bloede Dam should be monitored and adaptive management strategies implemented such as bank stabilization or sediment removal in critical areas. Monitoring of potential impact locations identified in the Simkins post-removal monitoring should be continued, including: the Grist Mill Trail (for sediment deposition), Gun Road (for erosion and sediment deposition), Thomas Viaduct area, and the bus facility downstream of the viaduct.

Infrastructure Summary

Upstream

The upstream suspension bridge is termed the Cable Stay Bridge in engineering design plans. The Cable Stay Bridge abutments were built in the early to mid-1800s as part of the original railroad bed, and have withstood numerous large tropical storm events for over the last 150 years. It is assumed that removal actions at Bloede Dam will not affect Cable Stay Bridge abutment stability. Figure 8 shows that the bridge appears to be founded on bedrock.

Figure 8 - Pre-dam photo of Railroad Bridge that has been converted to the Grist Mill Trail Cable Stay pedestrian bridge.

The Grist Mill Trail alignment was once also the alignment for the railroad prior to the construction of the Bloede Dam. The railroad was realigned to reduce bends in its alignment with construction of the existing railroad bridge and tunnel.

The main tributary channel in the Bloede impoundment is the Bonnie Branch, discharging just downstream of the suspension bridge near the upper end of the impoundment. Base level change translated through the Patapsco River will not cause headcutting at the Bonnie Branch confluence. Bonnie Branch currently discharges under Ilchester Road through three culverts, which are perched above the Patapsco River, resulting in no accessibility at current and projected baseflow elevations. Since soil borings were not completed at the outfall location, incision of the short reach between the culvert outlets to the Patapsco River cannot be ruled out. The design team anticipates minor downcutting of the Bonnie Branch reach from the culvert outlets to the Patapsco River, but field evidence indicates that underlying bedrock will prevent incision of more than a few feet. This conclusion is based on historical photos of the location (Figure 8), which indicate a bedrock waterfall just below the existing Patapsco River water elevation, and the existing rock energy dissipation basin, which would lower with incision, yet remain within its current location. Consequently, the culverts are anticipated to remain stable.

Existing sanitary sewers will be impacted by dam removal and solutions are identified in the subsequent design section of this report.

Downstream

Downstream of the dam, in the Avalon Park area, there is currently a turnaround parking lot area at the Swinging Bridge and a well-used parking lot/picnic area at Gun Road. The effect of sediment deposition on these areas is a consideration in the design process by the development of a HEC-RAS model to assess potential flood and deposition elevations. Along the left (north) bank of the river, a paved path (Grist Mill Trail) is maintained by the State Park and is used by hikers, runners, and bikers. Deposition of sand and silt on the trail during floods will occur, and occasional clearing of deposited sand may be needed.

Along the right (south) bank up to Bloede Dam, a paved road allows for park user access to the Swinging Bridge area and maintenance access up to Bloede Dam. Gabion walls support portions of River Road downstream of the Swinging Bridge area. The road upstream of Bloede Dam was damaged during Tropical Storm Agnes and is currently impassable. Park users and employees access the Avalon picnic area, Swinging Bridge, and Bloede Dam areas via the Gun Road crossing. The effect of sand deposition at this crossing will be important to monitor. Mitigation measures could include dredging at the crossing and removal of fines if deposition becomes problematic. Built in 1835, the downstream Thomas Viaduct is the world's oldest multiple arched stone railroad bridge and is still in use today. Sand transported from the Simkins Dam removal will be deposited in the Thomas Viaduct area, and it is expected that Bloede Dam sediment will deposit in that location also. The Thomas Viaduct area should be monitored following the Bloede Dam removal to determine if sand needs to be removed from park roads.

Cultural Resources

The Bloede Dam is eligible for the National Register of Historic Places, primarily due to its unique design and association with early hydropower development. As such, dam removal designs provide consideration for Maryland Historic Trust and National guidelines. A portion of the dam will remain to address Section 106 of the National Historic Preservation Act.

Since there has been alteration to the original dam, the value of the structure as a historic site is lessened. The dam has been modified since hydropower was discontinued. None of the original turbines or power generating equipment remain, and the ceiling of the interior was removed. Large amounts of concrete support were added to the original concrete slab and buttresses, so the interior does not resemble the original design. The gateworks were damaged or completely washed away by the 1972 tropical storm, and since then, a large concrete fish ladder, fences, and signage, have been added to the dam. Removal of the dam will include removal of all of the appurtenant structures with the exception of a portion of the right bank abutment and construction of an overlook. This overlook will contain signage and information about the history of Bloede Dam.

III. Design

RECOMMENDED DESIGN APPROACH

The following section outlines the sequence of construction for the 60% design and describes the reasoning behind each step in the sequence.

Access

Site construction access was examined by engineers from Inter-Fluve and Hazen and Sawyer, along with potential contractors and project partners. Access to the dam site must be gained via two routes that approach the dam from both upstream and downstream. Access must be gained to the downstream side of the dam to remove the dam structure following dam breach. The downstream access route will be along River Road located on the right bank that approaches the downstream side of Bloede Dam. The dam is 2.7 miles from the Gun Road crossing and 4.0 miles from the main park entrance at South Street. There is a bridge that crosses the Patapsco River on Gun Road leading to River Road. The last bridge inspection was performed in 2010. The 2010 bridge inspection report lists the design load for the Gun Road Bridge as HS20 with a Gross Vehicle Weight of 36 tons. The existing road embankment is stable, and the road is wide enough for truck traffic directly to the dam site. There may be damage to the road caused by heavy truck traffic, and the road may need to be repaved upon project completion. The park impacts will occur over one calendar year and truck traffic will be minimized through the creation of a construction access directly to Ilchester Road.

Upstream access must be established to relocate the existing 42-inch diameter sewer prior to dam breach. The upstream access route has been selected after considering several alternative temporary river crossings – with assigned risk, including:

1. Culvert crossing with stone (design would be for the Q_2) – medium risk
2. A steel bridge span (design for greater than Q_2) – low to medium risk
3. Access mats on sandbags – high risk
4. Flow diversion (build a controlled channel on the flood plain) – medium risk
5. Create a riffle ford (drive in the wet) – low risk
6. Pump-around (drive in dry channel with flow going through piping) – medium risk

The preferred access is located just downstream of the Cable Stay Bridge, but is not feasible due to an uncooperative landowner. A proposed access is available upstream, beginning at Ilchester Road downstream of the CSX Railway Bridge on river right. The proposed upstream access is routed within the shallowest part of the Patapsco River to reduce impacts and crosses underneath the Grist Mill Trail pedestrian bridge. An alternative access alignment, closer to the Grist Mill Trail, has also been designed if required due to unforeseen issues at the primary access location. The primary access point is preferred since it reduces clearing of riparian forest cover.

Both temporary construction access alignments will require construction crossings of the existing 12-inch and 42-inch sanitary sewer, downstream of the pedestrian cable bridge. The sanitary sewers are both buried at the crossing locations. The contractor will be required to provide a plan for the crossing locations and a spill prevention and containment plan. The specifications will require that the contractor protect and monitor the sewer lines during construction.

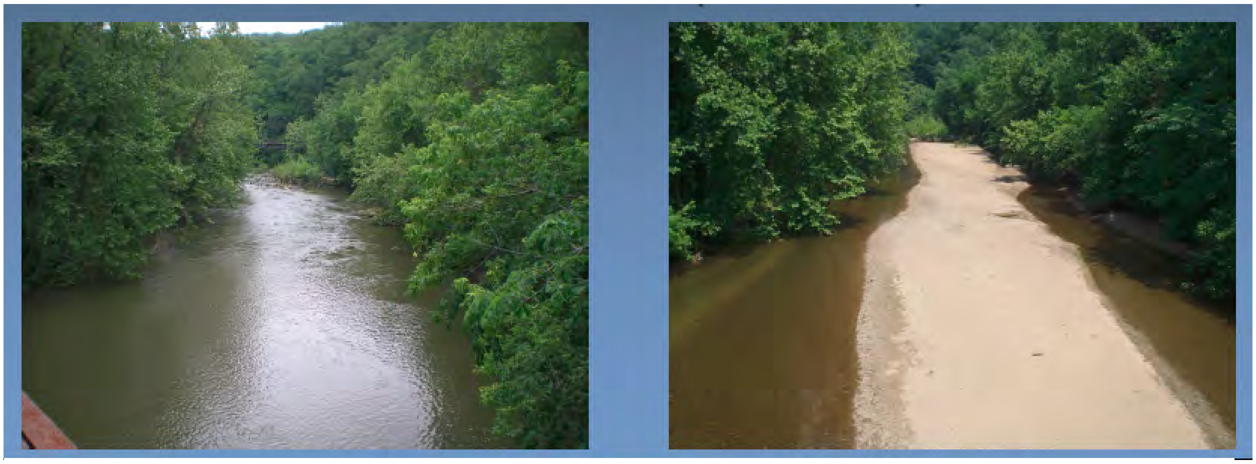

Figure 9- Proposed In-river Alignment (Pre- and Post-Simkins Dam Removal).

The upstream access routes were selected while acknowledging relative impacts and risk of flooding during construction. There will be temporary impacts to aquatic organisms in the riverbed due to the construction traffic. The proposed in-river alignment is located in the shallowest area, which was also the area that exhibited sand aggradation after the Simkins Dam removal (**Error! Reference source not found.**). Long term impacts are anticipated to be negligible based on the extensive channel bedrock along the alignment. Because Ilchester Road has moderate traffic, and proposed upstream access points are partially blind to oncoming traffic, temporary traffic lights are proposed for Ilchester Road. Both potential site access routes will require proper signage. Baltimore and Howard Counties will require prior notification to consider temporary road closure to local traffic only. Construction entrances will be erected, minimizing the damage to curbs and road edges during ingress and egress. Pads will be constructed of 4-6 inch stone. The design follows standard MDE specifications for traffic control and erosion control.

Staging

A staging area will be established downstream of the dam on the right bank. There will need to be road improvement and widening of the staging area downstream of the dam, but removal of the fish ladder will greatly increase the available staging space. The staging area is directly adjacent to the dam near the fish ladder area. This area is generally on a slope, but a staging area can be established with temporary fills. Temporary fills can be placed with concrete rubble obtained by demolishing the existing fish ladder and then removed and hauled off-site upon completion of the dam demolition.

The existing 42-inch diameter sewer is routed through impounded sediments on the left bank upstream of the dam. Based on subsurface investigations and hydraulic modeling, the impounded sediments supporting portions of the 42-inch sewer will mobilize following dam removal. The existing left bank upstream of the dam is covered in mature trees growing in sediments that will evacuate following dam removal. The existing trees will be cleared prior to dam removal to avoid downstream impacts of mature trees being transported and deposited in the downstream channel. Since the trees must be cleared and the existing 42-inch diameter sewer must be relocated prior to dam breach, the cleared area on the left bank upstream of the dam can be used as a staging and stockpile area for the 42-inch diameter relocation. This dam breach will not occur until after completion of the sanitary work, so conflict with the use of the area is not anticipated. The former Simkins Mill site will also be used for staging and stockpile associated with the existing 42-inch diameter sanitary sewer relocation.

Existing 42-Inch Diameter Sanitary Sewer Relocation

A 42-inch diameter sewer main extends along the north side of the river channel and penetrates the

Figure 10- Existing 42-Inch Diameter Sewer.

dam on the left side at the foundation contact. The pipe is exposed downstream of the dam and upstream of the impoundment, passing through the left abutment of the pedestrian bridge and into impounded sediments that will be mobilized following dam removal. Downstream of the dam, the pipe is supported by concrete piers mounted on bedrock outcrops at the toe of the left valley wall (Figure 10). Upstream of Bloede Dam, near the upper end of the impoundment, the interceptor is exposed along the left bank. The sanitary sewer pipe will be relocated from downstream of the existing pedestrian bridge to downstream of the Bloede Dam and moved within the Grist Mill Trail alignment (Figure 11).

Figure 11- Grist Mill Trail alignment.

As discussed, this will require access to the left bank of the Patapsco River upstream of Bloede dam, and trees will be cleared between the Grist Mill Trail and the Patapsco River downstream of the existing pedestrian bridge and upstream of the dam. Trees will also need to be cleared downstream of the dam to facilitate the relocated sewer into the existing sewer. Construction of the pipe reroute will require temporary shutdown of the Grist Mill Trail for a period of up to twelve months. Long-term stability of the Grist Mill Trail and the associated proposed pipe alignment has been evaluated by geotechnical engineers as a part of the Final Design process. The geotechnical engineer (Triad Engineering) has determined that the slope conditions during construction are stable at the proposed 2:1 (H:V) slopes. For ultimate conditions, which are anticipated to include slopes as steep as 1.6:1, the slopes will require compaction in 4-foot lifts and a geotechnical engineer will be required on-site to assess material as it is placed. Based on soil borings completed, adequate dense material is available within the project area for construction of the proposed Grist Mill Trail slopes. It is anticipated that some temporary erosion protection may be required as vegetation is re-established on the exposed south slopes of the trail.

For construction of the new interceptor, it is also anticipated that a temporary construction road, located south of the Grist Mill Trail, will be required to allow for safe construction of the new interceptor. The temporary construction road that extends along the Grist Mill Trail may be constructed in phases with the first phase including the removal of four-to-eight vertical feet of material. This material would then be used to widen the access path along the Grist Mill Trail, where necessary. Excavation would continue in the next phase to approximately one foot below the proposed invert of the new interceptor, which would result in total excavation depths ranging from a minimum of seven feet to a maximum of 28 feet. It is anticipated that excavation support would likely be provided through the use of double stacked eight-foot trench boxes (16 feet of total vertical support).

An access road turnaround located downstream of the Bloede Dam and at the end of the construction access path will be erected for construction access to the sanitary sewer tie-in point and hauling materials upstream and downstream along the alignment. It is anticipated the turnaround, which is anticipated to have a road elevation nearly equivalent to the two-year storm elevation, would be left in place, at a minimum, for the duration of the sewer construction, which is anticipated to take 12 months to complete. The area will also likely be utilized during dam demolition to allow access during the initial dam breach as well as provide an alternative haul route for trucks during the dam demolition phase of the project. The turnaround would be removed upon completion of the work.

Design of the new interceptor will require approval from Baltimore County. The 60% design has been laid out in accordance with past Baltimore County large diameter sewer projects. The new interceptor is proposed to be constructed out of pre-stressed concrete cylinder pipe (PCCP) and will be laid in 16-foot sections. All joints will be bonded, harnessed, and have testable ports to ensure the pipe is leak-tight. Two access manholes are proposed along the new interceptor alignment for maintenance purposes and as potential air release valve locations. The new interceptor will be buried at depths between approximately four feet and 23 feet. Large concrete thrust blocks will be constructed at both the upstream and downstream tie-in points along the new interceptor alignment. The concrete thrust blocks will be covered with large rip rap for additional protection and aesthetic integration along the stream bank. Sandbags will be placed around the upstream connection point temporarily (placed to a height equivalent to the two-year flood elevation) to allow for the construction of both the wet tap and line stop that will be required to allow for the new interceptor to be connected to the existing interceptor without the need for bypass pumping. These concrete thrust blocks are required to transfer large forces to the subsurface bedrock and protect the piping from decoupling. Following construction of the new interceptor alignment the existing sewer will be removed between the upstream and downstream tie-in points. Prior to the removal, the sewage that is stored between the upstream and downstream tie-in points will be removed and either pumped to the downstream sewer or hauled offsite. The removal method of the sewage stored in the pipe to be eliminated (pumped downstream or hauled off-site) will be left to the Contractor's discretion, subject to the Engineer's approval of his disposal method, to allow for the Contractor to assess during the Bid phase what is the most economical solution for removing the sewage.

Bonnie Branch Sanitary Sewer (12-inch Sewer)

A 12-inch diameter, concrete encased sanitary sewer connection from Bonnie Branch Road to the existing 42-inch sanitary sewer is located in the project area. The sewer is currently configured as a siphon with the low point located below the stream bed. The sewer's river crossing point begins on the downstream side of the right Cable Stay Bridge abutment and crosses Northeast to connect into the 42-inch sewer on the left bank, upstream of the Cable Stay Bridge. Based on conversations with Howard County, the 12" pipe will be reconstructed below the anticipated channel bottom prior to dam removal. The new pipe will be trenched into the bedrock, while the flows are temporarily bypassed over the Cable Stay Bridge by installing a temporary pump at the existing manhole located along Ilchester Road. The sewer will likely be constructed of HDPE and sized to convey the County's peak wet weather flows. The HDPE pipe is economical and will allow for improved hydraulics given the smooth internal surface of the pipe. The pipe will be buried at a depth in accordance with Howard County standards and protected above from erosion by the installation of riprap.

Dam Breaching

Typically, construction contracts do not dictate means and methods for project implementation. This stifles creativity on the part of the contractor and can potentially discount innovate solutions. In the case of dam removal in general, and this dam in particular, it is important to discuss potential means and methods so that the stakeholders understand what is involved and construction impacts are minimized. This exercise is more for the elimination of certain methods that are not in the best interests of the Patapsco Valley State Park, the public at large, or the project partners.

Dam breaching must include security and exclusion measures prior to dam breach and the evacuation of impounded sediments. This may include patrols, fencing, warning signs, log booms, or other measures to reduce public safety risks during drawdown of the impoundment.
Initial dam breach is proposed to allow blasting of a left segment of the dam. This method has been used on dam removals around the country including the Edwards Dam, Maine (1999); the Embry Dam, Virginia (2004); the Marmot Dam, Oregon (2007); and the Condit Dam, Washington State (2011). The design team has engaged several qualified contractors to evaluate breach alternatives

and provide guidance for the 90% design process. Creating an initial breach is based on the following technical and safety analysis:

Issue 1: Safety - This is the primary concern of the design team.
Mechanical demolition of the dam would result in a longer-duration, phased drawdown of the impoundment. Low stability of the impounded sediment during the work is anticipated due to the silty material at the base of the impoundment and saturated sand/silt within the work area. Site access during this phase is at an increased risk due to the material instability.

This dam is a unique design in which the combination of intact slabs and buttresses provide stability. During dam breach, the combination of fully saturated impounded sediment, breaching flows, and partially demolished slabs and buttresses create dangerous instability near the breach. Thus, no one should be near the breach when it initially occurs. A phased dewatering would require equipment and operators be located within the impoundment as well as downstream of the dam. The flashy nature of the flows within the Patapsco puts both equipment and operators at higher risk the longer they are required to work within the channel/impoundment. Drilling and blasting of one segment of the dam would result in a short term, large-scale release of sediment.

Contractor personnel would require access within the dam and on the downstream face to drill, place charges, and place blasting mats. Breaching and dewatering would be completed without people in the vicinity, reducing the risk associated with creating the breach. Blasting would create a void at or near the base of the impounded sediment, ideally siphoning out the silt initially, followed by the sand. The remaining sand would dewater relatively quickly (on the order of days), allow it to be mechanically moved into the channel with lower risk to the equipment operators.

Issue 2: Sediment Transport
Due to the ability to create an immediate breach to bedrock at the dam using blasting, the event will ideally be timed with a predicted moderate rainfall event, which would expedite sediment evacuation and transport. This would not be feasible with mechanical demolition.

Issue 3: Sanitary Sewer Stability
Initial design analysis considered the existing sanitary sewer, located within the left abutment, as the controlling factor impacting the demolition alternatives. Given the relocated position of the sanitary line, a wider range of demolition methods are available to the contractor. The plans and specifications will require vibration monitoring of the proposed sanitary line, to identify and prevent any damage to the system during dam demolition.

Issue 4: Dewatering for access
The proposed blasting method would require containment and dewatering of the downstream face of the dam at the drilling/blasting location. Based on the 60% design plans for the sanitary sewer, access to that location will be required for sewer installation. Consequently, the same access will be

available to create the containment area required for completing the drilling and blasting for dewatering. The closer the dam breach is to the anticipated thalweg location the easier it will be to access and remove the remainder of the dam structure. The blasting technique is deemed the safer and likely most cost effective method to create a breach and dewater the impounded sediment.

Because natural sediment transport of the impounded sediment is proposed, we do not propose any major dewatering via pumping, piping or other diversion. Water flow is critical to the success of the approach, and diversion is not required to complete construction. Once the initial breach is completed, the impounded sand will rapidly dewater, allowing for safe equipment access to the dam from upstream and downstream of the dam. Trucks will be able to access the right bank via the stabilized apron surface, and demolition material will be loaded directly on to trucks for removal. The selected contractor may have suggestions for more efficient removal of material. Alternative sequencing plans will be considered, but must be approved by the Engineer prior to implementation.

Dam Demolition

Following dam breach, the contractor can begin removal of the dam with the exception of the right abutment and dam section which are planned to be left in place for historical purposes. The approximately 2,400 cubic-yard concrete dam structure can be reduced to rubble using an excavator mounted rock hammer, and concrete rubble and steel reinforcement bar can be removed from the channel with an excavator. The right abutment affords access to the toe of the dam. Concrete rubble will be transported to the staging area on river right, where concrete rubble will be stockpiled and separated from reinforcement bar. It is proposed that the concrete be crushed on site and the crushed concrete reused to improve access to the former dam site. Reused crushed concrete may be placed in compacted lifts along River Road between the former dam site and the downstream gate and parking area for Patapsco Valley State Park.

Overlook

The overlook is designed to provide park users a view of the dam remnants as well as restored river at the dam location. The overlook will be constructed at the completion of the dam removal, prior to seeding and demobilization from the site. The overlook location is on the right bank, downstream of the dam, at the exiting fish ladder, and will be within the area of disturbance required for dam removal. The overlook is intended to provide a venue for informational signage as well as a destination for those seeking to visit the former Bloede Dam site.

Disturbed Area Restoration

Seeding and planting

After dam removal and evacuation of sediment, areas with exposed soils will be seeded in accordance with MDE Sediment and Erosion Control Standards. The staging and access road materials will be removed and all disturbed areas will be seeded and mulched. All seeding will be with a single mix of native regional grasses and sedges. Containerized shrubs and trees will be planted, with most concentrated in areas with retained soils in the impoundment. Silt fence will be removed once vegetation has become established.

Long-Term Stabilization

Post-dam removal sediment dynamics are not always predictable and are partially dependent upon precipitation. Monitoring the site for changes in channel size and location is recommended. After 1 year of monitoring, selected hand seeding of exposed floodplain areas can be done to ensure the growth of native species on banks and exposed floodplain surfaces. Tree and shrub planting of exposed impoundment sediment surfaces can also be examined, but an assessment of geomorphic stability should be conducted to minimize the risk of long-term erosion. The success of plants and seed in constructed bank areas will be guaranteed by the contractor for a minimum of three years.

Schedule

The sanitary sewer must be relocated prior to breaching the dam. Currently, it appears that sanitary sewer construction will begin in late 2015. It is likely that dam removal will not begin until late 2016, in which case the dam structure would be removed by February 2017. Planting would occur in the spring of 2017. Monitoring downstream sediment impacts and adaptive management may be required up to 5 years following dam removal.

Estimated Opinion of Cost

1	Mobilization & Demobilization	LS	$700,000	1	$700,000
2	Traffic Control	LS	$40,000	1	$40,000
3	Temporary River Crossing	EA	$145,000	1	$143,805
4	Temporary Access Road	LS	$115,000.00	1	$115,000
5	Clearing and Grubbing	AC	$10,000	4.3	$43,000
6	Dam Demolition	LS	$500,000	1	$500,000
7	Sand Handling	CY	$2	170,000	$340,000
8	Gabion Wire Removal	LS	$40,000	1	$40,000
				Subtotal	$1,921,805
Baltimore County Sanitary Sewer Interceptor Construction					
No.	**Bid Item**	**Unit**	**Unit Price**	**Quantity**	**Subtotal**
9	Pre-Drill Alignment for Mechanical Excavation (I	LF	$200	1,700	$340,000
10	Excavation (8,100 CY of Soil/2,200 CY of Rock)	CY	$25	10,300	$257,500
11	Class 57 Stone Bedding	Ton	$70	1,704	$119,280
12	Haul & Dispose Excess Excavated Material	CY	$25	1,533	$38,325
13	Backfill & Compaction	CY	$15	8,100	$121,500
14	CR-6 Aggregate (Access Ramp & Turnaround)	Ton	$50	3,012	$150,600
15	HMA Pavement Restoration Grist Mill Trail	Ton	$125	500	$62,500
16	Concrete Encasement for Manhole Base	CY	$400	30	$12,000
17	42" PCCP & Fittinqs (Interior Coating)	LF	$338	1,700	$573,750
18	48" Diameter Manhole Riser (1xARV, 2xMH acce	Vertical Foot	$2,000	45	$90,000
19	42"x36" Wet Tapping System	LS	$85,000	2	$170,000
20	42" Line Stop System	LS	$140,000	2	$280,000
21	Thrust Blocks at Line Stop/Wet Tap Locations	EA	$17,500	2	$35,000
22	Pipe Supports with Straps (Exposed Pipe)	LF	$300	50	$15,000
23	Dispose of Sewage Stored in Pipe (Including Tap	LS	$50,000	1	$50,000
24	Existing Pipe Removal	LF	$100	1,500	$150,000
25	Temporary Retaining Walls for Grading	SF	$35	1,350	$47,250
26	Support of Excavation, Sheetinq	SF	$30	49,500	$1,485,000
27	Borrow Exc. w/On-Site Disposal of Unsuitable M	CY	$50	1,500	$75,000
28	Geotechnical Stabilization of Grist Mill Trail Slop	LS	$100,000	1	$100,000
				Subtotal	$4,172,705
Howard County Sanitary Sewer (Bonnie Branch) Construction					
No.	**Bid Item**	**Unit**	**Unit Price**	**Quantity**	**Subtotal**
29	Rock Excavation	CY	$180.00	96	$17,333.33
30	Soil Excavation	CY	$25.00	337	$8,425.92
31	Haul & Dispose Excess ExcavatedMaterial	CY	$25.00	337	$8,425.92
32	Gravel - Trench Backfill	CY	$100.00	209	$20,864.18
33	CR-6 Aggregate, stone bedding	CY	$78.68	48	$3,788.45
34	Concrete Encasement for pipe	CY	$267.98	53	$14,336.54
35	16" HDPE	LF	$30.00	100	$3,000.00
36	Access structure for 16" siphon	LS	$27,650.00	1	$27,650.00
37	42"x16" Wet Tapping System	LS	$35,442.00	1	$35,442.00
38	12" CI Line Stop System	LS	$10,527.00	1	$10,527.00
39	12" Bypass (0.5MGD), 800 ft bypass, 45psi	LS	$15,000.00	1	$15,000.00
40	Existing Pipe Removal	LF	$100.00	100	$10,000.00
41	Support of Excavation, Sheetinq and Trench Box (Mix)	SF	$30.00	1620	$48,600.00
42	Diversion Sandbag Dike (up to 4' in Height)	LF	$78.00	400	$31,200.00
43	Temporary Dewatering Device (excludes dewatering and drainage for Sewer Pipe and Manhole Installation and Rehabilitation work incidental)	Month	$10,000.00	3	$30,000.00
				Subtotal	**$284,593**
Site Erosion Control					
44	Super Silt Fence	LF	$12	6,900	$82,800
45	Construction Entrance	EA	$5,000	2	$10,000
46	Diversion Sandbag Dike - tie-in locations	LF	$55.50	150	$8,325
47	Diversion Sandbag Dike - Pipe Removal	LF	$70	300	$21,000
48	Filter Logs	LF	$110	100	$11,000
49	Temporary Dewatering Device	Month	$10,000	12	$120,000
50	Flow Management	LS	$50,000	1	$50,000
51	Vegetative Mitigation	AC	$21,780	4.3	$93,654
52	Site Vegetative Establishment	AC	$30,000	5	$150,000
53	Miscellaneous E&SC Measures	LS	$50,000	1	$50,000
				Subtotal	**$596,779**
Overlook					
54	Composite Decking	ea	1	$6,560.00	$6,560.00
55	Deck Railing	ea	1	$1,920.00	$1,920.00
56	Wooden Deck Frame Structure	ea	1	$7,925.00	$7,924.50
57	Decking Inlay	ea	1	$4,000.00	$4,000.00
58	Park Benches	ea	3	$1,250.00	$3,750.00
59	Crushed Gravel Trail	ft^2	700	$11.50	$8,050.00
			Subtotal		**$32,204.50**
			PROJECT	**SUBTOTAL**	**$7,008,087**
Contingency & Construction Oversight					
	Contingency		15%		$1,051,213
	Construction Oversight and Administration		10%		$700,809
			Project Total		**$8,760,109**
				Total	**$8,760,000**

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Appendix A: Hydraulic Model Results

(See Binder Tab 4)