ECCLESTON MITIGATION SITE

DESIGN REPORT

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1. INTRODUCTION

This document is presented to provide a basis for the assessment, design, and implementation of restoration, enhancement, and preservation work at the Eccleston Mitigation Site, a proposed permittee responsible mitigation (PRM) site located in the Upper Jones Falls River catchment area within the Gunpowder-Patapsco Watershed (Hydrologic Unit Code (HUC) 02060003) in Baltimore County, Maryland. The Eccleston site is adjacent to the intersection of Greenspring Valley Road and Park Heights Avenue (**Figure 1**). The project limits include the Jones Falls (main stem) from Spring Hill Road to Park Heights Avenue and four significant unnamed tributaries. The project site was selected following the Site Selection Criteria (**Appendix A)**.

The overall design approach for the site is to create an environmentally diverse and self-sustaining stream and riparian system which is resilient, reestablishes a natural valley bottom ecosystem, promotes improved biological and ecological functions, provides long-term protection to adjacent infrastructure, and provides significant sediment and nutrient reductions. Of utmost importance in this project is the preservation and enhancement of a brown trout (*Salmo trutta*) population which utilizes this reach; goals for the project include the restoration of impacted and degraded habitats as well as the preservation of critical spawning habitats on the reach. Every aspect of the data collection and restoration practices emphasizes this project goal. The site description, reach descriptions, objectives, and baseline conditions of the site are described in Sections 1-11. The proposed compensatory mitigation activities are described and supported through Sections 12-14. The requirements for the mitigation work plan and conceptual plans are stated in the conclusion of the document in Sections 15 and 16.

The streams within the project are classified as a Use Class III (Nontidal Cold Water) waterway. As such in-stream work is prohibited during a closure period from October 1 through April 30. Proposed crediting for this project is outlined in Tables 1, 2, and 3, and further detailed in the Mitigation Credit Map (**Appendix B).**

Table 1: Proposed Eccleston Stream Mitigation Credits

Linear Feet	Proposed Mitigation Activity	Ratio	Proposed Credit
8,462	Restoration	1:1	8,462
1,499	Preservation	1:10	150
N/A	Out-of-Kind Mitigation (High-Quality Floodplain Wetland Restoration)	See Table 6	4,500
CREDIT SUM			**13,112 LF**

Table 2: Proposed Eccleston Wetland Mitigation Credits

Acres	Proposed Mitigation Activity	Ratio	Proposed Credit
4.95	Wetland Restoration	1:1	4.95
3.32	Wetland Enhancement	1:3	1.11
5.71	Wetland Preservation	1:10	0.57
22.82	Buffer Enhancement	1:15	1.52
15.59	Buffer Preservation	1:20	0.78
-0.06	Wetland Removal	1:1	-0.06
CREDIT SUM			**8.87 AC**

Table 3: Proposed Eccleston Out-of-Kind Stream Mitigation Credits

SF	AC	Proposed Mitigation Activity	Ratio	Proposed Credit	
				SF	LF*
405,000	9.30	High-Quality Floodplain Wetland Restoration	1:10	40,500	4,500
CREDIT SUM					**4,500 LF**

*Roadway impacts to streams average 9 feet wide; therefore, 40,500 SF of credit converts to 4,500 LF of credit

Assessment and analyses conducted by the design team for the project site include review of previously conducted studies, historic and geologic data collection, stream corridor investigation, natural resource inventories, habitat assessments, geomorphic data collection and analysis, basal gravel analysis, BEHI and NBS stability analysis, hydrologic analysis utilizing GISHydro and TR-20, hydraulic analysis, and a sediment mobility study.

The assessments and analyses have been performed to develop an understanding of the existing impacts within the stream corridor, current geomorphic processes, and causes of instability to develop potential restoration recommendations. To make recommendations specific objectives first had to be met. The specific objectives of this report include:

1. Determining potential causes and impacts to the current state of the project site
2. Determining the principle and secondary sources of habitat impairment
3. Determining sediment sources, morphological conditions, and existing hydraulic parameters of the existing channels
4. Recommending design measures that promote long-term sustainability and environmental uplift within the project reach

These objectives were achieved through the following tasks:

1. Determining historic and other anthropogenic influences on the current stability
2. Determining areas of high-quality habitat as well as those with departure from that reference condition
3. Performing hydrologic/hydraulic data collection and analyses
4. Obtaining and analyzing site specific geomorphic data to characterize bankfull conditions, hydraulic parameters, bedload composition, stream type, and sediment competence
5. Developing a design approach based upon conditions specific to the sediment supply and current stability state of the project site

The proposed restoration of the site will focus on remediating impairments to the site which compromise the existing habitat in the stream channel as well as the adjacent floodplain.

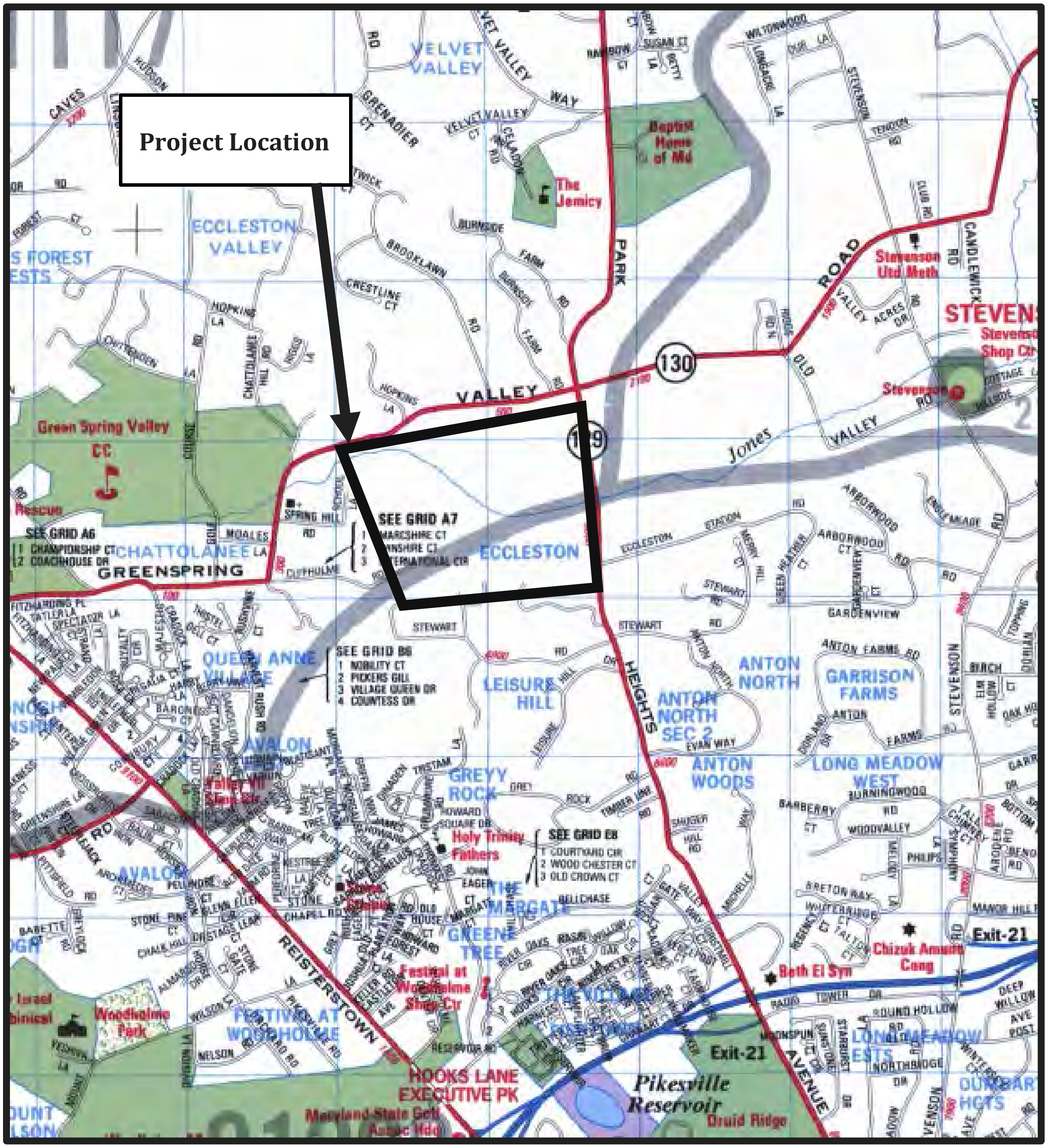

Figure 1: Project Location Map

2. PHYSIOGRAPHIC REGION, SURFACE GEOLOGY, AND WATERSHED CHARACTERISTICS

The Jones Falls and its tributaries are located within the Gunpowder-Patapsco Watershed and are classified as Use Class III waters. In-stream work is prohibited from October 1 through April 30 inclusive, during any year. The reach in question is a natural reproduction brown trout stream as supported with data from Maryland Department of Natural Resources (MD DNR). Although brown trout are an introduced species native to Europe, they are an indicator species, occupying a top predator position in the ecosystem, and are tolerant of more degraded conditions than the native brook trout of the piedmont which would have originally occupied these waters prior to impairment. They are also an important game fish which are managed specially by the MD DNR.

The drainage area to the lower end of the project site is 2.78 square miles (**Appendix C**). The Jones Falls and its tributaries are listed as water quality limited segments per Maryland Department of the Environment (MDE), and the watershed has been prioritized for restoration to reduce sediment and nutrient sources to downstream receiving waters and the Chesapeake Bay.

The project site is located within the Timonium Valley District of the Piedmont Province. The environmental landscape and topography associated with this area is characterized by a broad flat-bottomed valley underlain by Cockeysville Marble per the Maryland Geologic Survey. Where the marble outcrop becomes narrow, the valley disappears. Chemical weathering of the marble produces a distinctive dolomite sand and numerous pinnacles and residual boulders.

The weathered layers of Cockeysville Marble and the corresponding saprolite and sand layering are a critical resource, responsible for the abundant and clean groundwater which is observed through the site and was historically utilized for the Chattolanee Spring Water Company as well as for a “clean milk” dairy operation. A historic waterwheel, pumps, piping, dam, and conduits are still present on the site and visible to this day.

The Piedmont Province is composed of hard, crystalline igneous and metamorphic rocks. Bedrock in the eastern part of the Piedmont, where the project is located, consists of schist, gneiss, gabbro, and other highly metamorphosed sedimentary and igneous rocks of probable volcanic origin.

The surface soils within the stream restoration corridor mainly include Melvin silt loam (MmA). The Melvin series consists of deep, poorly drained, nearly level soils in depressions and on flats of floodplains. These soils are nearly level to depressed parts of floodplains and in upland depressions. Slopes range from 0 to 2 percent. These soils formed in silty alluvium derived from soils formed from limestone, shale, siltstone, sandstone, and loess, which meet the definition of hydric soils.

The mitigation site and its tributaries are located within a suburban watershed with an impervious cover of approximately 22.7%, and an overall urban area of approximately 54.4%. The stream flow is perennial and driven by rainfall and occasionally by snowmelt. Bankfull flows may occur as a result of a variety of rain events, including rain or snow, frontal storm events, and tropical storms.

3. PRINCIPLE AND SECONDARY IMPAIRMENTS OF THE SITE

Investigation of the site has revealed several principle impairments to the wetlands and waterways on the site:

- Straightening of Streams
  - Historic aerial investigation reveals streams were channelized multiple times. Streams are low sinuosity.
- Impairment of Stream Substrates
  - Channelization has disrupted the natural sediment transport processes. In many locations, the stream is perched above or incised below the native basal gravel layer, which is the original gravel substrate of the stream prior to impairment.
- Impoundments and Associated Legacy Sediment
  - Existing impoundments as well as historic and now-breached impoundments have disconnected the stream from its floodplain, leaving high banks of sediment less than 400 years old.
- Diversion of Stream Baseflow
  - Channel baseflow remains diverted from the Jones Falls mainstem for approximately 1,500 LF, impairing base flow habitat.
- Deforestation of Stream Buffer
  - The entire site was deforested within the last 60 years as shown in historic aerial photos. A lack of channel shade is evident on much of the site.
- Draining of Wetlands
  - Multiple existing tile locations have been noted, draining existing wetlands. Some small tributaries appear to be draining from wetland areas; these were likely excavated to drain wetlands.

These impacts are in addition to the principle watershed impacts of deforestation, urbanization, and climate change, which imperil resources throughout the state.

Secondary impacts to the site, resulting from the site specific and watershed principle impacts, include the following:

- Loss of Water Quality/Increased Temperature
  - Historic regional trends in water quality, from a variety of causes, have increased conductivity, decreased pH, and increased water temperature from pre-colonial conditions. Nutrients from agriculture on the site likely contribute to algal blooms and apparent eutrophication of the stream channel.
- Loss of Physical Habitats
  - Lack of stable riffle habitats, lack of in channel overhead cover, and lack of bed diversity have been noted for the restoration portions of the project.
- TMDL Pollution Sources
  - On-going loss of sediment from erosion causing various impairments within the project reach and downstream.

Top-Level Functional Losses resulting from these impacts include:

- Trophic impacts/ecosystem simplification
- Dominance of invasive species
- Loss of surface soil carbon and impairment of soil biology

The study plan and supporting data are geared toward examining the relationship between observed disturbances and the associated thermal conditions, habitats, and biological communities present on the site. With this information, a restoration plan and respective restoration potential can be evaluated, as well as an approach which avoids and minimizes impacts to existing resources and compensates for temporal loses of those resources.

4. HISTORICAL SITE USES INVESTIGATION

The principle impairments to the project site are directly a result of human activity. MDTA conducted a historical records search as an initial basis to determine any existing impairments to the stream and wetland systems at the Eccleston site. This included a detailed analysis of historic aerial photos, historical records, title and deed searches, as well as a review of historic maps of the area.

Historic aerials of the site show that the channel has been altered significantly, with meanders being straightened and adjusted throughout the aerial period. Aerials from 1927 and 1953 were consulted along with historic maps (**Figures 2 and 3**).

Figure 2: 1927 Aerial image of the site. Note extensive ditching, draining, and lack of forest cover

Figure 3: 1953 aerial image of the site

Historic maps show further alteration. Although all the maps consulted are hand drawn, based upon the relative position of the streams on the site with roads, intersections and other features, the channel has been moved, adjusted, and straightened (the sinuous stream is later drawn as straight-line ditches) multiple times as depicted in these sources.

Visual inspection of the site confirms that ditching and channel alteration are present. This includes streams with a sinuosity of approximately 1.0, as well as visual side cast on the banks of channels, indicating spoiled material adjacent to the channel. In addition to side cast, multiple pieces of clay drain tile, culverts, and a former waterworks and two dams were discovered on the project site. Downstream of the site on the adjacent parcel exists a breached dam and pump house which, per local interviews, was used to pump drinking water to the farmhouses within the Greenspring Valley.

Additional historical accounts were consulted for the project assessment. Sources from the Maryland Historical Society describe the historical African American settlement of Chattolanee which was settled by freed slaves. This location is just upstream of the project site and was once the site of the Chattolanee Spring Water Company, which commercially provided bottled spring water. Additional accounts describe the cool, clear, and high-quality nature of the spring and mineral water obtained from this portion of the valley; accounts even describe the water as being such high quality as to have a blue cast as observed in a bathtub.

The former quarry located on the project is the source of the stone for the English country style home on Greenspring Valley Road. Per the current owners, the site owner built the home in the 1870s for his Irish mistress and servants on the farm, basing the design on his mistress' country home.

In 1915, the project site owners completed the dam and waterworks project still observed on the site, which still uses hydropower to pump groundwater to a former “clean milk” dairy operation. Additional diversions of channel flow are found in support of the dairy operation; however, the diversion and dam which still exist and are presently diverting water have the most profound impact on the Jones Falls, diverting at times more than half of the base flow of the mainstem Jones Falls into pipes for the majority of the project reach. This base flow diversion powered an overshot water wheel which turned two, three-piston pumps used to pump groundwater from wells up the hill to the dairy operation. Easements and maintenance agreements are still found in the title record regarding this pressured water infrastructure; however, these have been long abandoned. The dam is still fully intact, as is the flow diversion; however, the other infrastructure has fallen into disrepair. The dam poses a potential aquatic organism passage problem particularly for small young of year trout and other small species.

An additional dam is found upstream in the preservation reach. This dam is fully breached but based upon its construction it is likely to pre-date the clean milk process dam by more than 50 years, as it is made of masonry and soft lime mortars. Multiple log grade controls which are saw-cut with sheathing nailed to them exist upstream of this dam within the preservation reach. This dam is of unknown purpose, as is the wooden structure above it, but it is theorized it may have been used for mining as part of a gravel or stone washing operation or as a flow diversion of some sort. No historical documents have been found relating to its purpose.

5. DAMMING AND TRENCHING INVESTIGATION

Damming of the Jones Falls and tributaries is evident on the project site. Historic damming of the Jones Falls may not be limited to those observed in the present day. All of the historic indicators of Legacy Sediments as described in the works of Robert Walters and Dr. Dorothy Merritts at Franklin and Marshall College are present throughout the main stem of the project site. A dense, relatively impervious layer of sediment is located above a hydric soil layer containing wood, seeds, and other evidence of a previously thriving floodplain wetland complex. Below this hydric soil layer exists a basal matrix-supported gravel layer, indicative of the periglacial processes which formed the present-day landscape following the last ice age in Maryland, when this area was a tundra ecotype (**Figure 4**).

To verify these geologic findings, a trenching investigation was conducted August 13-15, 2018. MDTA utilized a permit-approved trenching plan and operators from Meadville Land Service to dig multiple trenches perpendicular to the channel and on each side of the channel. A surveyor was on hand to survey the position and elevation of geologic features. The purpose of this investigation was to document the elevation and the extents of the hydric soil layer as well as the basal gravel layer in the floodplain valley. This information is used to understand the vertical position of the stream so that the invert elevation of the channel is established in the appropriate gravel substrates to support the fishery and to determine the extents of the valley to inform the restoration and re-establishment of wetlands in the floodplain.

Without this investigation, it would be impossible to determine the extent of the buried hydric soil in the floodplain and therefore any wetland restoration footprint depicted would not be well supported. Hydric soil is one of the three parameters required for a successful wetland.

The basal gravel layer is composed of subangular quartz constituents in a sandy/clay matrix indicative of the breakdown of the Cockeysville Marble complex; pockets of clean uniform sand are also below the hydric soil layer. This layer is important because it provides all of the gravel substrates in a well-graded mixture necessary for a complex fishery and benthic community. The existing channel does not contain the same size distribution of gravel substrates as it has been channelized and altered, and through sediment transport processes has transported away many of the smaller size classes that smaller forage-type fish species require for reproduction. Size distributions of the basal gravel layer as well as riffles in the existing channel are provided in Table 4 below.

Table 4: Eccleston Stream Restoration – Size Distribution of Basel Gravel Layer and Riffle Materials

	Basal Gravel Layer Combined Sample Distribution	Combined Main Stem Riffle Pebble Count Distribution
D16 (mm)	0	2.53
D35 (mm)	13.81	21.63
D50 (mm)	26.84	37.02
D84 (mm)	66.44	89.22
D95 (mm)	79.86	139.85
D100 (mm)	86	361.98
Silt/Clay (%)	0	4.26
Sand (%)	18.75	11.3
Gravel (%)	68.13	54.25
Cobble (%)	13.12	29.63
Boulder (%)	0	0.56
Bedrock (%)	0	0

Figure 4: Buried basal gravels, below hydric soil observed at base of stream banks

Through the trenching investigation, MDTA was able to observe a very strong hydric soil layer and basal gravel geology through the entire main stem Jones Falls stream valley (**Figures 5 and 6**). This layer had minor disturbances, presumably from agriculture. MDTA has also observed that the majority of the main stem of the Jones Falls has been trenched and relocated to the right side of the valley (right as observed looking downstream). The final approximately 600 LF of the main stem approaching the Park Heights Avenue culvert appears to be trenched and located centrally in the valley, with geologic indicators occurring strongly on both banks. Groundwater was strongly observed in trenches, with trenches rapidly filling with groundwater and commonly associated with pockets of buried clean sands.

Tributaries to the Jones Falls do not exhibit a strong hydric soil and basal gravel layer geology. The railroad tributary (UT-1) is perched, meaning that trench groundwater is observed far below the elevation of the stream in this area. The stone house tributary (UT-2) exhibits similar conditions and lack of groundwater connectivity with the floodplain.

Figure 5: Trench along the main stem of the Jones Falls showing where layers of hydric soil and basal gravel were found

Figure 6: Trench along the main stem of the Jones Falls showing where layers of hydric soil and basal gravel were found

With this information in mind, MDTA can characterize the thermal characteristics of any proposed restoration on the project site. The main stem of the Jones Falls has a strong probability for an increase in base flow input from the connected groundwater resources and therefore a stronger probability for thermal buffering and decreasing stream temperature through restoration, once its floodplain is connected with groundwater. The main stem of the Jones Falls, once restored, has a greater potential for increased hyporheic interactions within the project site. The smaller tributaries which are perched do not exhibit the same type of restoration potential, as their base flow conditions will be governed more by surface water input from offsite, and not through hyporheic interactions within the project site.

6. EXISTING CONDITIONS VISUAL ASSESSMENT

As part of developing design strategies for the site, a visual assessment of the original project site and further upstream and downstream environments was conducted on multiple occasions through 2017 and 2018, as well as assessments by MDTA staff since 2008. The visual assessment serves to characterize existing conditions, habitat, sediment and debris sources, degradation/depositional areas, influences and regional and localized impacts throughout the stream corridor that may influence long-term stability of the stream and wetland habitats. The assessment of the main stem of the Jones Falls began at the Park Heights Avenue culvert and extended to a point 3,900 feet (existing channel length) upstream of the culvert directly downstream of the Spring Hill Road crossing. All streams are Rosgen B4/B4c streams as differentiated by their slope. Sinuosity is sufficiently low that they do not classify as C4 streams, due to straightening.

The visual assessment of the project site has been separated into multiple reaches which represent discrete habitat units. These areas can be seen in the site assessment map located in **Appendix D** of this report:

- ***Jones Falls - Reference Area:*** Main stem starting at the upstream project limits and being used as a reference area
- ***Jones Falls - Middle Jones:*** Straightened section of the main stem starting from the Jones Falls Reference Area to the Jones Falls Walnut-Horse Chestnut
- ***Jones Falls - Walnut-Horse Chestnut:*** The sparsely forested portion of the Jones Falls just above “Downstream Forested” dominated by a sparse walnut and horse chestnut overstory
- ***Jones Falls - Downstream Forested:*** Downstream reach of the main stem that ends at the 22.5’ x 9.2’ culvert which flows under Park Heights Avenue
- ***Railroad Tributary (UT-1):*** Unnamed Tributary 1 starting at a bridge flowing underneath the BGE right-of-way at the south side of the property and ending at the location of an existing wetland prior to tying into Jones Falls
- ***Stone House Tributary (UT-2):*** Unnamed Tributary 2 that ties into the Jones Falls at the downstream end of the Middle Jones portion of the main stem from the north side of the channel
- ***Braided Tributary (UT-3):*** Unnamed Tributary 3 that ties into the Jones Falls directly upstream of the Walnut-Horse Chestnut Tributary portion of the main stem from the south side of the channel

- ***Intersection Tributary (UT-4):*** Tributary that runs parallel to Park Heights Avenue before crossing underneath the roadway. Tributary ties into the main stem on the east side of Park Heights Avenue.

6.1 JONES FALLS – REFERENCE AREA

Figure 7: Key map of Jones Falls Reference Area

The upstream limits of the Jones Falls Reference Area (**Figure 7**) begins at the Spring Hill Road culvert and flows approximately 1,315 feet downstream along the main stem. This area of the project site includes an existing trout spawning area, a bald cypress wetland, and the location of two basal gravel sample areas, one point bar sample, two cross sections, and one longitudinal profile. An existing stone wall also exists directly upstream of the Middle Jones reach. Although some previous impacts are observed in this reach, such as damming and legacy sediment, drain tile, and similar disturbance, a dense native tree canopy is observed as well as connection to floodplain wetlands. Minor bank erosion is present, but stability and channel substrates appear relatively unimpacted by those sediment sources. The existing channel is already connected to the surrounding floodplains and wetlands are present. Strong in-channel habitat is present as assessed by MDTA in 2017 and 2018, including a diversity of pool depths, overwintering deep pools, frequent submerged overhead cover, frequent and stable woody debris, clean channel gravel substrates, and trout observed throughout the year. Trout spawning was surveyed in October and November 2017 and has been monitored in 2018. This area is proposed to be protected as a preservation area.

Figure 8: Trout overwintering location (looking downstream)

Figure 9: Trout spawning location (approximate, looking upstream)

Figure 10: Basal gravel sample #5 (facing left bank)

Figure 11: Basal gravel sample #4 (facing left bank)

Figure 12: Upstream end of longitudinal profile in 7-2 in Reference Area (looking downstream)

Figure 13: Downstream end of longitudinal profile 7-2 in Reference Area (looking upstream)

Figure 14: Point bar sample within project site

Figure 15: Existing channel bar within Reference Area

Figure 16a and b: Existing stone wall at downstream end of Reference Area

6.2 JONES FALLS – MIDDLE JONES

Figure 17: Key Map of Jones Falls Middle Jones

The Middle Jones section (Figure 17) of the main stem is the straightened section of the channel which begins at the end of the Jones Falls Reference Area and ends at the start of the Jones Falls Walnut-Horse Chestnut Tributary approximately 150 feet downstream of UT-3. The total length of this section of stream is approximately 1,400 LF and includes very few/subtle meander bends throughout the entirety of its length. This area of the project site also includes existing concrete walls, an existing dam, a stream crossing and the location of one basal gravel sample area, four cross sections, and two longitudinal profiles. The existing dam dewaters approximately 40-60% of the baseflow of the reach, depending on the time of year, diverting it to approximately the end of the Walnut-Horse Chestnut reach. The slope of the channel is approximately the same as the valley slope as it has been straightened due to trenching. The right bank of the stream is at the valley wall, and has the densest forest observed. Much of the canopy through the 2016-2018 period has been impacted by the emerald ash borer, and multiple trees that were living in the 2016 observation period have been killed as of fall

2018. Minimal pool diversity is present; the channel has been significantly straightened and only long, shallow pools are present with little or no opportunity for overwintering. In-channel overhead cover is small and infrequent, and very little stable woody debris is present in the channel. Broken drain tile and other debris are present in the channel. An existing stream crossing is present which is poorly maintained and unstable. Trout are seasonally observed here and have not been observed in pools during the summer months. The concrete dam used for the clean milk process is located here. Depending on the quantity of debris jamming below the dam, the dam is approximately a 1- to 2-foot change of hydraulic head and presents an obstacle to young of year and smaller fish in the reach, disconnecting the upstream spawning and refugia reference reach from the rest of the Jones Falls.

Figure 18: Concrete wall in channel upstream of concrete dam in Middle Jones

Figure 19: Concrete dam in Middle Jones

Figure 20: Existing stream crossing in Middle Jones

Figure 21: Downstream end of longitudinal profile 3-2 in Middle Jones (looking upstream)

Figure 22: Looking upstream at cross section 3-1 in Middle Jones

Figure 23: Basal gravel sample #2 (facing right bank)

6.3 JONES FALLS – WALNUT-HORSE CHESTNUT

Figure 24: Key Map of Jones Falls Walnut-Horse Chestnut Reach

The Walnut-Horse Chestnut Reach (Figure 24) is a shorter section of the main stem that begins at the end of the Middle Jones section and extends approximately 510 LF downstream. This section is surrounded on both sides by farmed lands with minimal buffer of invasive European horse chestnut (*Aesculus hippocastanum)* and black walnut (*Juglans nigra*). Black walnut, although native, is one of the latest trees to come into leaf and the lose their leaves beginning in late August; as such they represent a poor canopy species with the additional impact of suppressing understory below them due to their allelopathic traits. The reach is marginally more sinuous, but still has evidence of trenching and straightening. Multiple drain tiles have been observed here. The lower end of the reach contains the outfall from the concrete dam diversion. The channel is more confined in this section which is most likely a result of the adjacent farmlands constricting the limits of the channel and floodplain. Other features within this section of the channel include a debris jam and persistent overhead cover at the upstream end. Aside from that jam and resulting pool, there is small and infrequent overhead cover throughout the reach and minimal pool diversity. The reach contains predominantly short and shallow pools. Adult brown trout are consistently observed in this reach from October through April; however, they have not been observed in pools through the summer months. Channel substrates are relatively large in this reach, a likely result of the winnowing of smaller substrates due to the entrenched condition. One longitudinal profile and three cross sections were also taken within this section of the main stem.

Figure 25: Debris jam at upstream end of Walnut-Horse Chestnut Reach

Figure 26: Marginal canopy cover at upstream end of Walnut-Horse Chestnut Reach

Figure 27: Upstream end of longitudinal profile 2 in Walnut-Horse Chestnut Reach (looking downstream)

Figure 28: Downstream end of longitudinal profile 2 in Walnut-Horse Chestnut Reach (looking downstream)

6.4 JONES FALLS – DOWNSTREAM FORESTED

Figure 29: Key Map of Jones Falls Downstream Forested Reach

The Downstream Forested Reach (Figure 29) is the furthest downstream section of the Jones Falls within our project that begins at the end of the Walnut-Horse Chestnut and flows 650 feet downstream to a 22.5-foot-by-9.2-foot culvert that flows underneath Park Heights Avenue. The culvert may represent a seasonal trout blockage in low base flow conditions as it has a wide, flat concrete bottom, and therefore it is a logical habitat unit boundary. The study area reach begins where the buffer increases and the diversion pipe from the concrete dam re-enters the stream. This area of the main stem is moderately forested and has exposed stream banks on both sides of the channel. The channel is mostly straight throughout this reach and only begins to meander approximately 300 feet upstream of the existing culvert. Two large debris jams and a trout spawning area were observed at the downstream end of the reach. The reach has consistent diversity of in-channel pools and a potential overwintering pool. Directly below the Park Heights culvert is a very large overwintering pool which while not part of this project, is an important resource for the Jones Falls. Pool diversity is excellent here and in-channel overhead cover is abundant and frequent, though not as plentiful as in the Reference Area. The loss of some trees through 2017 has exposed a central portion of the reach to mid-morning sun, but overall canopy coverage is good through the year, dominated by maples (*Acer spp.*), walnuts, horse chestnut and locust. Trout are observed here consistently year-round in the lower half of the reach. The upper half of the reach is slightly over widened and has transverse riffle/bar features which indicate a potential oversupply of bed materials from the upper reaches. Work will only be proposed in the upper half of this reach as the lower end is in a Maryland Department of Transportation - State Highway Administration (MDOT SHA) easement. One longitudinal profile and two cross sections were also taken within this section of the main stem.

Figure 30: Upstream end of longitudinal profile 1 in Downstream Forested Jones (looking upstream)

Figure 31: Upstream end of longitudinal profile 1 in Downstream Forested Jones (looking downstream)

Figure 32: Debris jam within Downstream Forested Jones (upstream of trout spawning area)

Figure 33: Trout spawning area within Downstream Forested Jones (directly upstream of debris jam at culvert)

Figure 34: Debris jam at downstream end of Downstream Forested Jones

6.5 RAILROAD TRIBUTARY (UT-1)

Figure 35: Key Map of Railroad Tributary Reach

The Railroad Tributary (Figure 35) begins at a bridge crossing that flows underneath a BGE right-of-way where an overheard electric utility line exists. The first 250 feet of the channel is sparsely forested up until the point where the channel is constrained by an existing farmland at the stream edge to the north that redirects the channel down-valley. Overall in-channel habitat is poor, with poor pool variability and marginal base flow. A highly exposed and eroded stream bank exists at the location where the channel is being redirected due to a significant change in direction of flows during storm events. The tributary flows for an additional 350 feet following the redirection through a straightened channel with very minimal overhead coverage. The channel then outfalls into an existing wetland which bleeds into another tributary that begins approximately 200 feet south of the main stem of the channel; this tributary is considered an extension of the Railroad Tributary (UT-1). The tributary ties into the Middle Jones section of the main stem approximately 50’ downstream of stone house tributary (UT-2). One longitudinal profile and one cross section were also taken in this tributary.

Figure 36: Upstream end of longitudinal profile 4 in Railroad Tributary

Figure 37: Downstream end of longitudinal profile 4 in Railroad Tributary (looking downstream)

6.6 STONE HOUSE TRIBUTARY (UT-2)

Figure 38: Key Map of Stone House Tributary Reach

The Stone House Tributary (Figure 38) begins at an existing 16-foot wide stone wall flowing north to south and tying into the Jones Falls at the downstream end of the Middle Jones portion of the main stem from the north side of the channel. The channel flows in and out of a forested area and is adjacent to a cultivated field that is located to the west of the channel. A drainpipe inflow exists within the active channel approximately 200 feet downstream from the stone wall; this pipe diverts all flow from the Stone House Tributary into a separate channel to the west, leaving the rest of the Stone House Tributary completely dry. The channel is periodically diverted; MDTA has observed the pipe inlet clogged with flow occurring in the original bed location, but for this assessment flow was not present. This diversion occurs irregularly due to the pipe being clogged with debris and is not predictable. The tributary downstream of the drainpipe inflow is completely dry and only conveys flow during storm events when diverted. The total length of the channel downstream of the drainpipe to the tie-in with Jones Falls is approximately 900 feet. One longitudinal profile and one cross section were also taken in this tributary.

Figure 39: Drain pipe inflow located in active channel (facing right bank)

Figure 40: Upstream end of longitudinal profile 6 in Stone House Tributary (looking upstream)

Figure 41: Downstream end of longitudinal profile 6 in Stone House Tributary (looking downstream)

6.7 BRAIDED TRIBUTARY (UT-3)

Figure 42: Key Map of Braided Tributary Reach

The Braided Tributary (Figure 42) ties into the Jones Falls directly upstream of the Walnut-Horse Chestnut portion of the main stem from the south side of the channel. It is a continuation of the Railroad Tributary. It is a perched system, periodically losing base flow due to the alluvial sandy and gravely deposits it flows on. Its canopy is predominantly immature green ash trees. When flowing, it has some in channel habitat sourced from flow diversity and small shallow pools, but it does not have aquatic organism passage for finfish to the Jones Falls.

6.8 INTERSECTION TRIBUTARY (UT-4)

Figure 43: Key Map of Intersection Tributary Reach

The Intersection Tributary begins at a 60-inch RCP outfall on the south side of Greenspring Valley Road and runs parallel to Park Heights Avenue before it leaves the project site when it crosses underneath the roadway through a 60-in. CMP. The tributary is a straightened channel that runs for approximately 750 feet and contains multiple debris jams and has little to no facet features. Habitat is poor. The steep existing slope of the channel has resulted in a channel that is actively eroding and contains exposed banks in multiple locations. One longitudinal profile and one cross section were also taken in this tributary.

Figure 44: Downstream end of longitudinal profile 8 in Intersection Tributary with debris jam

Figure 45: Upstream end of longitudinal profile 8 in Intersection Tributary with debris jam

Figure 46: Channel erosion within Intersection Tributary

7. WATERSHED HYDROLOGY STUDY

To determine peak discharge rates, a hydrologic analysis was performed using GISHydro2000 and WinTR-20. The peak discharge rates were determined for key Points of Investigation (POI). The locations of the POIs, along with soil type and land use, are shown on the Drainage Area Maps provided in **Appendix C.** The proposed design reaches referred to herein are provided on the Preliminary Design Plans provided in **Appendix J**. POI-1 is located along the main stem immediately upstream of the Park Heights Avenue Culvert. POI-1 will be used for the design of the main channel downstream of the braided tributary. POI-2 is located on the main stem immediately upstream of the stone house tributary and will be used for the design of the main stem in this upstream area. POI-3 is located at the downstream end of the Stone House Tributary that ties into the main stem from the north side of the channel, and POI-4 is located at the downstream end of the Braided Tributary that ties into the main stem from the south side of the channel. POI-3 and POI-4 will be used for the design of each of the tributaries they are located on, respectively. POI-5 is located along the intersection tributary that flows from Greenspring Valley Road to Park Heights Avenue and ties in with the main stem outside of the project site on the east side of Park Heights Avenue. The POI is located on the upstream end of the culvert under Park Heights Avenue and will be used to design the associated tributary.

MDTA modified the TR-20 output from GISHydro200 to compute discharge values at the various POIs using both the existing and ultimate condition land uses. The peak discharges for existing and ultimate conditions can be seen in **Table 5** following:

Table 5: Eccleston Stream Restoration – Peak Discharges (Q2, Q10, Q100)

Location	*Drainage Area (mi^2)*	*Q2 (Existing)*	*Q10 (Existing)*	*Q100 (Existing)*	*Q2 (Ultimate)**	*Q10 (Ultimate)**	*Q100 (Ultimate)**
POI-1	2.783	593.4	1438.7	3050.4	655.4	1520.5	3144.3
POI-2	1.323	317.9	736.5	1526.6	363.3	798.4	1593.4
POI-3	0.920	161.4	439.0	998.8	175.5	459.7	1025.9
POI-4	0.450	151.7	322.2	622.1	151.7	322.2	622.1
POI-5	0.139	62.2	133.9	256.2	66.3	138.9	261.2

*Discharge values to be used in the proposed design

The ultimate condition discharge values for the furthest downstream POI of the main stem (POI-1) was compared to the Fixed Region Regression Equation for the Piedmont Region. The discharge values for this analysis can be seen in ***Table 6*** below:

Table 6: Eccleston Stream Restoration – POI-1 Discharge Analysis

Storm Events (24 hr)	*Lower Limit Standard Deviation Discharges (cfs)*	*Fixed Region Regression Equation Discharges (cfs)*	*Upper Limit Standard Deviation Discharges (cfs)*	*POI-1 WinTR-20 Ultimate Conditions Discharges (cfs)*
2-year	300	434	628	655.4
5-year	611	838	1150	1121.1
10-year	920	1230	1660	1520.5
25-year	1430	1900	2530	2103.7
50-year	1930	2590	3480	2609.6
100-year	2500	3430	4690	3144.3

The discharge value expectation per the *Introduction to GISHydro2000 Training Manual, November 2007* is as follows: "Calibration of TR-20 is expected for the [Fixed Region Regression Equation] between the best estimate and the best estimate plus one standard deviation" (Moglen, 24). The analysis for this project shows that the computed two-year discharge falls slightly above the plus one standard deviation of the Fixed Region Equation and the 100-year discharge falls slightly below the plus one standard deviation. MDTA has decided to proceed with the ultimate conditions discharge values for all POIs associated with this WinTR-20 output (POI-1 through POI-4) since any adjustments to the model would cause either the two-year or 100-year to fall even further out of compliance with the expectation of the manual.

A separate GISHydro2000 analysis was performed at POI-5 since the tributary ties into the main stem downstream of the Park Heights Avenue culvert and outside of the project site. However, unlike previously done for POI-1 through POI-4, the Fixed Region Regression Equation for the Piedmont Region was not used for calibration of TR-20 since the drainage area to POI-5 (0.139 square miles) is smaller than the recommended drainage area criteria of 0.28-258.07 square miles for the Fixed Region Regression Equation for the Piedmont Region as stated in the *Introduction to GISHydro2000 Training Manual, November 2007*. Instead, the WinTR-20 discharges computed for POI-5 using the ultimate land uses were compared to the TR-20 output discharges from the GISHydro2000 program to determine if the WinTR-20 values are appropriate for use in design. The discharge values for this analysis can be seen in **Table 7** below:

Table 7: Eccleston Stream Restoration – POI-5 Discharge Analysis

Storm Events (24 hr)	*GISHydro2000 TR-20 Discharges (cfs)*	*POI-5 WinTR-20 Ultimate Conditions Discharges (cfs)*
2-year	59	66.3
5-year	100	106.0
10-year	135	138.9
25-year	187	186
50-year	228	223.3
100-year	272	261.2

Because of this analysis, MDTA concluded that the ultimate condition discharge values computed using WinTR-20 and the ultimate land uses are acceptable since the values fall in line with the TR-20 discharges that were computed from GISHydro2000.

Additional information on the WinTR-20 model hydrologic input and output data and GISHydro2000 output data are provided in **Appendix C**.

8. DETAILED GEOMORPHIC SITE ASSESSMENTS

To document existing geomorphic, hydraulic and sediment competence characteristics of Jones Falls and its tributaries, detailed channel cross sections, profiles, pebble counts, and bulk sediment samples were surveyed and collected within the project reach. This section of the report will characterize the hydraulic parameters of the cross sections to the top-of-bank and bankfull elevations. Please note that due to the impaired channel characteristics, bankfull indicators such as an inset bench feature, depositional bar or low bank appear to be temporary and not likely to form under consistent, stable conditions. The detailed site assessments also include a bank erosion estimate to be utilized to compute potential Total Maximum Daily Load (TMDL) credits and an analysis of the particle size distribution and elevation of the buried hydric soil and basal gravel layers.

8.1 GEOMORPHIC ASSESSMENT DATA

The data presented herein provides a means to assess the existing morphological properties of the project site. The geomorphic assessment of the existing valley conditions will provide the basis for the proposed stream restoration design. The design will include a detailed analysis of the upper watershed and the sediment being contributed for these conditions, substrate analysis of basal gravels to estimate and predict the proposed streambed substrate, and an understanding of the full range of geomorphic conditions (more specifically floodplain width and channel geometry) necessary to convey the full range of flow events through the stream corridor under stable conditions.

During our geomorphic field assessment of the project site, a total of 14 existing conditions cross sections (XS) on riffle and pool features and nine longitudinal profiles were surveyed using laser-level equipment to characterize existing channel conditions throughout the project site. The data collected at the sections (Figures 47-60) represent average existing channel conditions found throughout the project reach. The locations of the cross sections can be found on the Site Assessment Map located in **Appendix D**.

Figure 47: XS 1-1 riffle cross section looking downstream (Jones Falls)

Figure 48: XS 1-2 pool cross section looking downstream (Jones Falls)

Figure 49: XS 2-1 riffle cross section looking downstream (Jones Falls)

Figure 50: XS 2-2 Pool cross section looking downstream (Jones Falls)

Figure 51: XS 2-3 riffle cross section looking upstream (Jones Falls)

Figure 52: XS 3-1 pool cross section looking downstream (Jones Falls)

Figure 53: XS 3-2 riffle cross section looking downstream (Jones Falls)

Figure 54: XS 3-3 riffle cross section looking downstream (Jones Falls)

Figure 55: XS 4-1 riffle cross section looking downstream (Railroad Tributary)

Figure 56: XS 6-1 riffle cross section looking downstream (Stone House Tributary)

Figure 57: XS 7-1 riffle cross section looking downstream (Jones Falls)

Figure 58: XS 7-2 riffle cross section looking downstream (Jones Falls)

Figure 59: XS 7-3 riffle cross section looking downstream (Jones Falls)

Figure 60: XS 8-1 riffle cross section looking downstream (Intersection Tributary)

In addition, eight pebble counts were conducted on riffle features at cross sections 1-1, 3-2, 3-3, 4-1, 6-1, 7-1, 7-2 and 8-1. A point bar sample was also taken in between XS 7-3 and XS 7-2. A bulk sample of the native basal gravels was also collected and wet sieved for particle distribution at three separate locations. Locations of the assessment cross sections, profiles, pebble counts, and bulk sediment sample are shown on the site assessment maps in **Appendix D.** The survey of the existing conditions cross sections will also serve to compute the estimated erosion rates utilizing the BANCS method for TMDL credits**.**

8.1.1 Pebble Counts and Bulk Sediment Analysis

Within the project reach, pebble counts were conducted on riffle sections at XS 1-1, XS 3-2, XS 3-3, XS 4-1, XS 6-1, XS 7-1, XS 7-2 and XS 8-1. All field data has been entered into Rivermorph and data plots are included in **Appendix D.** The representative D35, D50 and D84 sediment sizes are based on the average grain sizes from the eight pebble counts conducted. The pebble counts are summarized in **Table 8** following.

Table 8: Summary of Eccleston Pebble Count Data

Size Fraction (mm)	*XS 1-1* *(100 count)* Jones Falls	*XS 3-2* *(117 count)* Jones Falls	*XS 3-3* *(100 count)* Jones Falls	*XS 4-1* *(134 count)* UT-1	*XS 6-1* *(113 count)* *UT-2*	*XS 7-1* *(117 count)* Jones Falls	*XS 7-2* *(106 count)* Jones Falls	*XS 8-1* *(104 count)* UT-4
D35	21.5	35.67	18.48	18.94	14.64	15.93	26.96	3.89
D50	32	53.91	26.87	37.42	26.67	33.77	37.91	10.75
D84	86.75	139.93	180	126.53	102.77	115.14	65.93	40.73

The results of the pebble counts were used for several purposes. They are used to evaluate the mobile particles in the riffle, the bed stability as compared to a 1D HEC-RAS derived shear stress, and to compare to the native basal gravel samples in order to determine the suitability of this material as gravel substrate when salvaged. As a detailed channel analysis was developed and this section will be updated with further detailed results. In terms of habitat, these substrates are of suitable size to be useful for benthic habitats, and typical of piedmont freestone gravel streams; however, the D35 of these samples is higher than those typically seen in region trout streams such at the East and West Branches of Codorus Creek, Pierceville Run in southern Pennsylvania, and smaller tributaries to the Gunpowder, as observed through MDTA staff experience and documented in multiple Growing Greener grant projects in York County.

To determine the typical mobilized bedload within the existing main stem, bulk sediment samples of point bar features were collected and analyzed for particle size distribution using a wet sieve method. The purpose of this analysis is to determine what size particles are being routinely transported by the channel in the existing conditions. These materials are either delivered to the project site via upstream sources or sourced via bank erosion from within the study reaches. The sediment distribution data is included in **Appendix D**. A summary of the data is provided in Table 9 below.

Table 9: Bulk sediment sample analysis along Long Profile 7-2

Particle Size (mm)	Bar in between XS 7-3 and XS 7-2
D35	25.6
D50	38.0
D84	68.5

Where point bars are not located, it is an indicator of excessive shear stress or minimal delivered bed load to a reach as a depositional feature cannot be formed. As the upstream smaller tributaries are highly impaired outside of the study area, it can be assumed that excessive shear stress in the channel is leading to the sorting of material and transport of bedload outside of the reach. This is further supported when viewing cross sectional data and entrenchment ratios. In this instance, channel geometry will likely widen until a depositional feature can be formed, and through this deposition meander form and channel enlargement/floodplain reestablishment processes will force the channel to change Rosgen stream type.

To determine the sediment transport characteristics of the buried basal gravels, a bulk sample totaling approximately 4 gallons in size was collected from the exposed basal gravel layer at the base of several stream bank locations along the Jones Falls. The samples consisted of mostly quartz angular particles which is consistent with periglacial processes and underlying geology of the region, previously described. The particles were separated using a wet sieve sampling in USGS standard sieves. The sediment size distribution data is included in **Appendix D.** A summary of the data is provided in **Table 10** below. Locations of the basal gravel sampling areas can be seen in the Site Assessment Mapping in **Appendix D**.

Larger cobble and even small boulder quartzite particles were observed to be part of the historic substrate material where samples were collected. The largest particles observed within the system will likely provide an additional armoring component within the restored valley bottom (Figure 61).

Table 10: Bulk sediment sample analysis of basal gravels observed within the streambanks

Particle Size (mm)	Basal Gravel Sample #2	Basal Gravel Sample #4	Basal Gravel Sample #5
D35	14.77	6.80	29.71
D50	27.38	17.59	43.12
D84	56.97	46.27	72.28

Figure 61: Portion of the basal gravel sample #2

Figure 62: Portion of the basal gravel sample #4

Figure 63: Portion of the basal gravel sample #5

Figure 64: Larger particle found at basal gravel sample #5

This analysis will help define the morphological attributes of a channel design that will be sustainable based upon the existing sediment regime and sediment supply from the upper watershed*.* The sizing of this material indicates that larger particles are being retained within riffle features on the reach and smaller particles are becoming part of the bedload delivered through the reach or delivered to that reach. Larger basal material is located closer to valley walls, consistent with understanding of colluvium in relation to the other valley bottom materials (i.e. the material as the side of the valley wall has been transported and weathered less than that in the center).

Sizing of the proposed bankfull channel is based upon analyzing existing hydraulic characteristics of the channel (cross sectional area, width, and depth) and developing a channel design or low transport channel that will minimize streambed substrate mobility of the basal gravels, yet maintain the competency to mobilize finer sediments being contributed to the design reach from the upper watershed.

Channel Roughness

Channel roughness values were determined using the USGS guide for selecting Manning's *n*-values for natural channels and floodplains and verified from field observations. Channel roughness is caused primarily by the roughness of the channel bed and the shape of the channel. Estimates of Manning roughness coefficient, n, are based on the Cowan (1956) relation given here as

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m$$

Where:
$n_b = a\ base\ value\ of\ n\ for\ a\ straight, uniform\ smooth\ channel\ in\ natural\ materials$
$n_1 = a\ correction\ factor\ for\ the\ effect\ of\ surface\ irregularities$
$n_2 = a\ value\ for\ variations\ in\ shape\ and\ size\ of\ the\ channel\ cross\ section$
$n_3 = a\ value\ for\ obstructions$
$n_4 = a\ value\ for\ vegetation\ and\ flow\ conditions$
$m = a\ correction\ factor\ for\ meandering\ of\ the\ channel$

The pebble counts provided in our geomorphic analysis were used to evaluate the median size of the bed materials and determine the base value of *n* for each reach. Each reach was then evaluated for adjustment factors to calculate the existing conditions Manning's *n*.

Boundary Shear Stress

The average boundary shear stress produced by a discharge over each riffle was computed as:

$T_b = \gamma\ R\ S_f$

where T_b is the cross section average boundary shear stress (psf), R is the hydraulic radius, and S_f is the energy slope. Because backwater effects on the steep riffles were considered to be minor, the average boundary stress was considered to be a conservative approximation for the average stress on the wetted perimeter of the cross-sectional area. To assess the maximum boundary shear stress which may be asserted on the streambed at any single point within the cross section, R or hydraulic radius has been approximated using D(max) or the maximum channel depth. The energy slope (friction slope), S_f, for each reach has been estimated from the top-of-bank slope that flood flows would experience at the existing valley flat stage.

8.1.2 Existing Cross Section Data

The purpose of the following hydraulic analysis is to determine the existing conditions top of bank shear stresses within the project reach. The data collected provides a means to assess streambed and bank sediment mobility and in turn the stability of facet features in relation to the top of bank discharges and the estimated frequency of these hydraulic conditions. This has direct relation to the stability of not only the banks from a TMDL sediment reduction standpoint, but an analysis of the stability of channel bed substrates and the ability to have a temporal availability of channel facet habitats within the stream reach. Many sensitive macroinvertebrate types require more than one year of their life cycle to be spent in in-channel habitats, and the stability of these facet features directly relates to their potential to be present or potential to re-establish following restoration (assuming they are present in a suitability connected habitat to allow for that colonization).

The top of bank represents the point of incipient flooding or when flows contained within the channel make a hydraulic connection to the surrounding floodplain or valley flat. This analysis is not performed to determine what flow event correlates to the mobilization of particles under "bankfull" conditions, but rather to understand the largest particles being mobilized in this system when the channel is flowing at full capacity for a peak shear stress regardless of magnitude of discharge.

For the purposes of this analysis, the 11 geomorphic riffle cross sections surveyed on riffle features along the main stem and tributaries have been utilized. The slope at each area has been derived for each section and reach, measured during the laser level survey of the project site conditions and compared with the surveyed contours. The existing geomorphic channel conditions within the project site for use in identifying the top-of-bank hydraulic parameters without backwater conditions is summarized in Table 11 following.

Table 11: Summary of Top-of-Bank Hydraulic Data at Representative Cross Sections of Jones Falls

	XS 1-1 (Jones Falls)	XS 2-1 (Jones Falls)	XS 2-3 (Jones Falls)	XS 3-2 (Jones Falls)	XS 3-3 (Jones Falls)	XS 7-1 (Jones Falls)	XS 7-2 (Jones Falls)
Top of Bank Elevation (ft)	354.32	359.76	361.00	365.91	373.16	375.18	383.26
Width (ft)	18.15	11.5	18.47	15.77	15.02	14.29	12.41
Average Depth (ft)	1.45	1.49	1.31	1.42	1.09	1.25	1.12
Maximum Depth (ft)	1.9	2.07	2.23	1.87	1.36	2.06	1.6
Cross Sectional Area (sf)	26.28	17.17	24.2	22.43	16.35	17.89	13.89
Hydraulic Radius, R	1.33	1.26	1.2	1.32	1.03	1.13	0.99
Width/Depth Ratio	12.52	7.72	14.1	11.11	13.78	11.43	11.08
Slope (ft./ft.)	0.00126	0.013	0.013	0.011	0.014	0.017	0.013
D50 (mm) (pebble count)	36.89*	36.89	36.89*	36.89	36.89*	36.89	36.89*
D84 (mm) (pebble count)	91.61*	91.61	91.61*	91.61	91.61*	91.61	91.61*
‘Manning’s N	0.049	0.049	0.049	0.049	0.049	0.049	0.049
~Discharge (cfs)	34.23	86.88	91.86	88.6	62.49	79.3	47.72
Velocity (fps)	1.30	3.95	3.88	3.87	3.68	4.29	3.44
****Avg. Boundary Shear Stress (psf)**	0.10	0.99	0.97	0.92	0.91	1.2	0.8
*****Max. Boundary Shear Stress (psf)**	0.15	1.68	1.81	1.28	1.19	2.19	1.30
+Mobile Particle (mm) at Average Boundary Shear Stress	7	77	76	71	71	94	62
+Mobile Particle (mm) at Max. Boundary Shear Stress	11	134	145	101	93	176	102

*Using the entire reach values
**Using hydraulic radius (r)
***From maximum depth at cross section
+ Based upon the Shields Diagram (Leopold et al.)
~Computed using Manning’s Equation.
^Discharges exceed 100-yr values.
‘Computed using USGS Manning’s Roughness Coefficients for Natural Channels and Flood Plains

Table 12:Summary of Top-of-Bank Hydraulic Data at Representative Cross Sections of Tributaries

	XS 4-1 (UT-1)	XS 6-1 (UT-2)	XS 8-1 (UT-4)
Top of Bank Elevation (ft)	381.46	370.10	196.76
Width (ft)	4.82	13.76	17.21
Average Depth (ft)	2.07	1.04	2.19
Maximum Depth (ft)	2.58	1.95	3.51
Cross Sectional Area (sf)	10	14.26	37.66
Hydraulic Radius, R	1.19	0.93	1.97
Width/Depth Ratio	2.33	13.23	7.86
Slope (ft./ft.)	0.017	0.036	0.008
D50 (mm) (pebble count)	37.42	26.67	10.75
D84 (mm) (pebble count)	95.4	65.98	40.73
‘Manning’s N	0.057	0.061	0.046
~Discharge (cfs)	38.53	64.09	170.29
Velocity (fps)	3.82	4.28	4.54
****Avg. Boundary Shear Stress (psf)**	1.26	2.00	0.98
*****Max. Boundary Shear Stress (psf)**	2.74	4.28	1.75
+Mobile Particle (mm) at Average Boundary Shear Stress	99	161	76
+Mobile Particle (mm) at Max. Boundary Shear Stress	223	355	140

*Using the entire reach values
**Using hydraulic radius (r)
***From maximum depth at cross section
+ Based upon the Shields Diagram (Leopold et al.)
~Computed using Manning’s Equation.
^Discharges exceed 100-yr values.
‘Computed using USGS Manning’s Roughness Coefficients for Natural Channels and Flood Plains

This 1D analysis shows that in the existing conditions and real-life, 3D flow conditions, all reaches within the project site, including the unnamed tributaries are capable of mobilizing non-cohesive sediments much larger than the typical bed substrates found on site. When considering that also secondary shear stresses exceed the 1D modeled stresses, and that debris and other naturally occurring flow obstructions can additionally magnify shear stress, there is enormous potential to mobilize bed substrates and degrade important habitat features derived from the channel geometry and substrate, (i.e. riffle, run, pool and glide facet features of the channel). The channel’s geometry, specifically the high banks and lack of connectivity to the floodplain for small magnitude discharges, produces the hydraulic effect of magnifying shear stress.

Given this information, channel enlargement and further entrenchment of the channel, transport of excessive bed material to maintain channel habitats, and overall degradation of the stream channel habitats is anticipated to continue if left un-restored.

8.2 BANK EROSION ESTIMATE

MDTA performed a Bank Erosion Hazard Index (BEHI) and Near Bank Shear Stress (NBS) analysis of all stream banks along the mainstem of the Jones Falls and tributaries to be restored. The BEHI methodology uses field data to determine expected erosion rates at a specific stream bank. The BEHI is computed on banks by analyzing the following properties: exposed bank height, stratification of materials, root depth, root density and bank angle. Near Bank Shear Stress (NBS) predicts the amount of energy distributed to streambank which can accelerate erosion. These methods are described in by the U.S. Environmental Protection Agency (EPA) in the *Watershed Assessment of River Stability and Sediment Supply (WARSSS)* manual (Rosgen 2006). NBS methods 1, 2, and 5 were utilized. Method 1, a level I validation tool according to WARSSS, obtains NBS values ranging from high to extreme based on the presence of transverse bars, central bars, extensive deposition, chute cutoffs, down valley meander migration, and/or converging flow. Method 2, a level II validation tool according to WARSSS, obtains NBS values based on the ratio of radius of curvature to bankfull width. Method 5, a level III validation tool according to WARSSS, obtains NBS values based on the ratio of near bank maximum depth to bankfull mean depth. The NBS values have been obtained from field observations and the riffle cross sections surveyed during our geomorphic site assessment.

These measured properties have been used to predict the amount of lateral bank erosion from empirically derived *Steam Bank* Erodibility curves produced by the U.S. Fish & Wildlife Service (USFWS) in Maryland (Hickey Run). Ultimately, these predictions provide a quantity of expected mass wasting or surface erosion from the analyzed stream bank. This provides a useful comparison tool to establish a prioritization for stabilization measures based on rates of expected erosion from various stream banks.

Within the limits of the proposed restoration site, 5,564 feet of existing channel will be restored. The BANCS data accounts for all streambanks within the project site limits. Based upon the BANCS data reported in **Appendix E** the erosion rate along the main stem and tributaries through the project reach is as follows:

- (2024.8 tons/yr) / (12754 ft) = 0.1588 tons/yr/ft

The computed total annual stream bank erosion rates from the existing stream bank erosion estimates based on actual length of the existing channel to be restored is as follows:

- 5,564 ft * 0.1588 tons/yr/ft = 883.3 tons/yr

Table 13: Summary of TMDL Credits

	Total Nitrogen (TN) *(lbs/year)*	Total Phosphorus (TP) *(lbs/year)*	Total Suspended Sediment (TSS) *(lbs/year)*
Protocol 1	596.25	196.56	883,329.70
Protocol 2	1202.7	-	-
Totals	**1,798.9**	**196.56**	**883,329.70**

8.3 RAPID BIOASSESSMENT PROTOCOL

To assess habitat, the EPA Rapid Bioassessment Protocols chapter 5 habitat assessment field data sheet for low gradient perennial streams was used. Low gradient perennial streams in Maryland typically fall within Rosgen C4, B4, and B4c classified streams. The purpose of rapidly assessing habitat is to quickly determine level of health (optimal, suboptimal, marginal, and poor) of the stream system and identify impairments. The habitat structure is broken into 10 categories to analyze riparian overbanks, streambanks, and in-stream habitat.

1. Epifaunal substrate/available cover – percentage of natural structures in streams like cobble, large rocks, fallen trees/logs/branches, undercut banks, and areas for fish, macroinvertebrate, and amphibian refuge.
2. Pool substrate characterization – rating of how diverse pool substrate is with more diverse substrate (grave, sand, aquatic plant roots, etc.) supporting better habitat than poor mud or bedrock pools.
3. Pool variability – rating of mixture of pool types that vary in width and depth. Higher diversity of pool types supports higher diversity of habitat and are generally associated with more meandering streams
4. Sediment deposition – rating of amount of sediment deposited in stream. High sediment deposition seen through islands or point bars or amount of sediment covering stream bottom. High sediment is indicative of unstable or changing streams and greatly reduces in stream habitat.
5. Channel flow status – rating focused on the width of channel. Optimal conditions include water reaching from bank to bank with minimal streambed exposed as opposed to over-widened poor streams.
6. Channel Alteration – degree of which channel sinuosity has been straightened and disrupted. Poor streams also see artificial embankments, riprap, dams, and bridges.
7. Channel Sinuosity – a measure of meandering of the stream compared to a straight line. Optimal meandering length would be 3-4 times longer than a straight line. Higher sinuous streams can dissipate storm surges and create diverse habitat.
8. Bank stability – rating of individual bank shape and cover with gently sloping banks with vegetation being optimal. Sheer banks with potential to collapse and unvegetated banks are poor and disconnect the habitat.

9. Bank vegetative protection – measure of amount of vegetation protection on the bank. Vegetation stabilizes stream bank soils and prevent erosion and instability.
10. Riparian vegetative zone width – measurement of riparian buffer from streambank out through riparian zone. Buffers of 4x the bank-to-bank stream width area optimal for habitat and flood and pollutant buffering.

The 10 categories are totaled to provide an overall rating of the system. The results of the habitat assessment can be found in **Appendix E**.

9. DETAILED HABITAT ASSESSMENTS AND METHODOLOGY

MDTA conducted spawning surveys (redd counts) for the Jones Falls and tributaries in fall 2017 and additional studies in fall 2018. It is anticipated this level of survey will occur through the monitoring period of the project for all restored or enhanced stream reaches. Survey times were coordinated with MD DNR and a period of late October through November was selected. The survey period for spawning is highly dependent upon precipitation, water temperature, and light conditions, and therefore varies with each year.

MDTA staff examined the stream channel for locations of probable spawning and redd development. These are observed as clean, bright patches of gravel typically in riffle, head of riffle, or glide conditions following pools; however, the entire channel including runs and pools was examined for activity.

Two reach locations had active spawning. The Reference Area near the cypress wetland had the most conclusive and active redd creation, with multiple redds and bed disturbance found in multiple locations through the November period. Just before the Park Heights Avenue culvert, an additional single active redd location was found.

Given the level of disturbance in the MDOT SHA right of way, as well as pruning of trees, debris, and debris removal associated with that right of way and the BGE power right of way, MDTA found the spawning in that area to be unexpected, but none the less present. Spawning in the fully canopied Reference Area was expected, particularly given the clean and well-graded nature of the gravel substrates there. MDTA does not know how successful spawning was in these locations, only that it was present. Trout spawning for the purposes of this project is considered the highest tier biological function. Therefore, these locations are proposed to be protected through easement from future disturbance, with no proposed grading, clearing, or other disturbance in their vicinity.

Specific measurements of habitat features are required to develop goals for functional uplift and fisheries goals. These measurements and assessments exceed what is typically used in the USFWS methodology and focus on specific components of physical habitat. The qualitative descriptions of the habitat properties of specific reaches has already been built into the existing conditions reach descriptions of each assessment reach.

MDTA surveyed the available in-channel overhead cover associated with the main stem of the Jones Falls and its tributaries. This study was conducted via staff measuring with a pocket rod the size of overhead cover features while in channel. A very detailed assessment was conducted for the reference portions of the project which exhibited spawning, measuring, and quantifying cover in the main stem. Tributaries, which have other factors such as diverted base flow, disturbance, etc., which limit their habitat value, were evaluated based on the relative frequency and quantity of cover. Tributaries scored poorly with infrequent and small quantities of cover. Dewatered tributaries scored as having no overhead cover available.

In trout fisheries, multiple types of overhead cover are utilized. Reference quality C and E Rosgen type streams have the ability to have overhanging sod mats, and stable undercut and vegetated banks serve as suitable trout cover. This type of cover is minimally present in the main stem of the Jones Falls and only occurs in reference areas, where cypress roots/sod mat are the dominant substrate and cover in the channel. Generally, in-channel debris and logs compose the other dominant cover type in piedmont streams utilized by trout. In reference locations, logs, debris, and overhanging shrubs make up the other observed cover in the reaches, though some of the debris jams, particularly above the Park Heights Avenue culvert, appear to be unstable, and have shifted with storm flows through the observation period. These cover features are more ephemeral than those from embedded logs and root wads in the channel and adjacent banks.

A third type of overhead cover is of geologic origin, and includes crevasses and overhangs of bed rock, boulders and other rock often associated with pools in the channel. Boulders in riffles also contribute to this type of cover, as they may create micro-scour features and associated overhead cover. This cover type is not dominant nor present in the assessment reach but is available within the watershed and Piedmont trout streams in the region, as observed on the Gunpowder in this watershed. The geology appears to not support this type of feature, or that stone has been dredged and removed from the channel. This type of overhead cover is utilized in trout streams which are above the tree line or where woody debris isn't prevalent or available, such as many high-altitude western U.S. native trout streams or high-latitude streams such as the River Laxá í Aðaldal in Iceland, which is a renowned stream for anglers of brown trout. Neither of these stream system types have an associated forested buffer. Here, flow diversity and cover from geologic sources provides important foraging habitats for adult fish.

In addition to fostering ambush foraging habits for larger mature fish, these pool and overhead cover areas are also often thermal refugia for trout, providing relief from high water temperatures in summer and overwintering opportunities in winter. Pools may be thermally stratified. It is generally accepted through literature and discussed and agreed with MD DNR through coordination on this project that brown trout become stressed at approximately 68-70 degrees Fahrenheit and mortality may occur after 80 degrees, depending on other conditions in the stream reach. In terms of restoration, each meander bend should be considered an opportunity to restore overhead cover and thermal refugia.

10. FISHERIES AND BENTHIC ASSESSMENT

MD DNR provided historical fisheries data for the site. MDTA mimicked the data collection method and format and use this to monitor fisheries in the future, with the first fish sampling event occurring in July 2019. This data has not been finalized at this time, however data collection is complete. Similarly, benthic sampling occurred in Spring of 2019 with data not yet finalized. Historical data is presented below:

Table 14: 1998 August 6th Data Collection Relative Abundance

Common Names	**Scientific Name**	**Maturity**	**Count Estimation**
Blacknose Dace	*Rhinichthys atratulus*	Adult	Common - 26-100 individuals (standardized to 100 meters or 600 sec.)
Brown Trout	*Salmo trutta*	Adult	Abundant - >100 individuals (standardized to 100 meters or 600 sec.)
Brown Trout	*Salmo trutta*	YOY	Abundant - >100 individuals (standardized to 100 meters or 600 sec.)
Creek Chub	*Semotilus atromaculatus*	Adult	Scarce - 6-25 individuals observed (standardized to 100 meters or 600 sec.)
Largemouth Bass	*Micropterus salmoides*	YOY	Rare 1-5 individuals observed (standardized to 100 meters or 600 sec.)
Longnose Dace	*Rhinichthys cataractae*	Adult	Scarce - 6-25 individuals observed (standardized to 100 meters or 600 sec.)
Rosyside Dace	*Clinostomus funduloides*	Adult	Rare 1-5 individuals observed (standardized to 100 meters or 600 sec.)
White Sucker	*Catostomus commersoni*	Adult	Scarce - 6-25 individuals observed (standardized to 100 meters or 600 sec.)

Table 15: 2014 June 27th Data Collection Relative Abundance

Common Names	Scientific Name	Maturity	Count Estimation
Blacknose Dace	*Rhinichthys atratulus*	Unknown	Common - 26-100 individuals (standardized to 100 meters or 600 sec.)
Brown Trout	*Salmo trutta*	Adult	Common - 26-100 individuals (standardized to 100 meters or 600 sec.)
Brown Trout	*Salmo trutta*	YOY	Common - 26-100 individuals (standardized to 100 meters or 600 sec.)
Creek Chub	*Semotilus atromaculatus*	Unknown	Common - 26-100 individuals (standardized to 100 meters or 600 sec.)
Green Sunfish	*Lepomis cyanellus*	Unknown	Scarce - 6-25 individuals observed (standardized to 100 meters or 600 sec.)
Longnose Dace	*Rhinichthys cataractae*	Unknown	Scarce - 6-25 individuals observed (standardized to 100 meters or 600 sec.)
White Sucker	*Catostomus commersoni*	Unknown	Rare 1-5 individuals observed (standardized to 100 meters or 600 sec.)

Although representing only two data collection events, when looking at the sum of species collected, a trend can be observed that the fishery is warming and becoming more suitable for tolerant species. Brown trout populations decrease from abundant to common. Similar cold water species such as white sucker and rosyside dace also decrease from scare to rare or absent, though these fish are more tolerant of warmer temperatures than brown trout. Corresponding tolerant species such as blacknose dace and creek chub increase their populations. If this had been observed in a single species, the data would not be nearly so conclusive as that seen in corresponding cold and warm water species.

Fisheries data will continue to be collected through the term of the monitoring period. It is encouraged that MD DNR also collect data to continue their data set; not as a substitute for bank monitoring, but to provide an independent account of the fishery for the greater Jones Falls.

No site-specific benthic baseline exists for the site prior to 2019, though MD DNR provided extensive regional and watershed benthic data.

11. THERMAL DATA COLLECTION

MDTA installed temperature sensors to evaluate in-channel temperatures within the Jones Falls and tributaries. There are multiple mechanisms of temperature exchange on the site, and collecting data was viewed as the best way to evaluate the effectiveness of these measures. One such measure is hyporheic exchange of the stream base flow with the attached ground water aquifer. Hyporheic exchange should buffer stream temperatures and keep surface base flow temperature cooler as it exchanges with a relatively stable 55-degree Fahrenheit aquifer.

In the absence of hyporheic exchange, canopy cover should have a direct relation to stream temperature. Canopy cover can include overhead trees, shrubs, but also herbaceous vegetation in small streams. Canopy should serve to limit solar temperature gain through a study reach.

Warm or cool water pipe inputs also can be a factor in evaluating stream temperature. While there are no industrial or commercial inputs into this stream in our study area, there are inputs from tile drains, and reductions in channel base flow due to stream diversion and damming. Damming increases the amount of stagnant pool water, which can increase solar gain. Diversion of water into pipes reduces the amount of water in the channel, which means relatively less depth and potential to increase solar gain.

MDTA installed six monitoring devices to track temperature and evaluate these parameters of the Jones Falls and tributaries. HOBO U020 devices were installed, which are an optically-read data logger with capacity to read temperature and absolute pressure. The absolute pressure function of these devices was recorded, however not used for our analysis.

Temperature is measured in critical locations that represent reference, spawning, flow diversion, and tributary thermal input locations. Hourly data is being collected, sensitive enough to detect storm events and rapid changes in temperature. Each tributary was monitored. Key locations following tributary or pipe diversion input was monitored. Each monitoring gauge is located in riffle facet features; this specific placement is intended to capture the temperature of moving water in the stream in potential trout foraging locations. The monitoring stations and temperature gauge information is included in **Appendix I**.

In the analysis of this data, daily average temperatures are computed, as well as station by station graphs showing the daily minimum and maximum temperature. Daily average temperatures are not useful in this project when viewed in context with daily extreme temperatures to determine suitability of the stream for trout. Daily average temperatures would only be a useful analysis tool if the range between minimum and maximum temperature was small, however our data show exceedances of temperature which seasonably make portions of the stream unsuitable for trout. Daily average temperatures can, however, be viewed to determine when large precipitation evets occur. In these instances, the average temperature for all gauges approaches a singular value, due to watershed runoff being the primary flow component in the stream.

Data indicate that reference sites have a lower range between minimum and maximum daily temperature as compared to tributary and mainstem Jones Falls stations within the area where flow is diverted. Data also indicate that despite any existing canopy, the temperature of the stream increases through the site, yielding that solar gain is still very much an issue and hyporheic exchange may be limited. Tributary and impacted mainstem locations display larger swings in temperature as relating to daily weather conditions; in many cases in early spring, the water temperature is lower than the relatively constant groundwater/earth temperature of 55 degrees Fahrenheit. Temperature is much higher in the summer and closely related to daily air temperatures. Consequently, we can conclude that these stations exhibiting rapid changes and large daily temperature ranges are disconnected from the groundwater aquifer's relatively constant temperature. This reinforces that these reaches have poor hyporheic exchange and are perched and/or otherwise disconnected from the shallow groundwater table.

12. RESTORATION AND UPLIFT OPPORTUNITY IDENTIFICATION

This section will describe the strategies of proposed design elements to be utilized in the proposed restoration as outlined in the *Final Draft Function-Based Rapid Stream Assessment Methodology* developed by the U.S. Fish and Wildlife Service (Starr et al. 2015) and the ecological benefits or functional uplift they may provide. The assessment methodology is largely based on the Stream Functions Pyramid as described in *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al. 2012) (Figure 66). The pyramid consists of a hierarchal relationship of five (5) critical categories that evaluate the health and function of a stream.

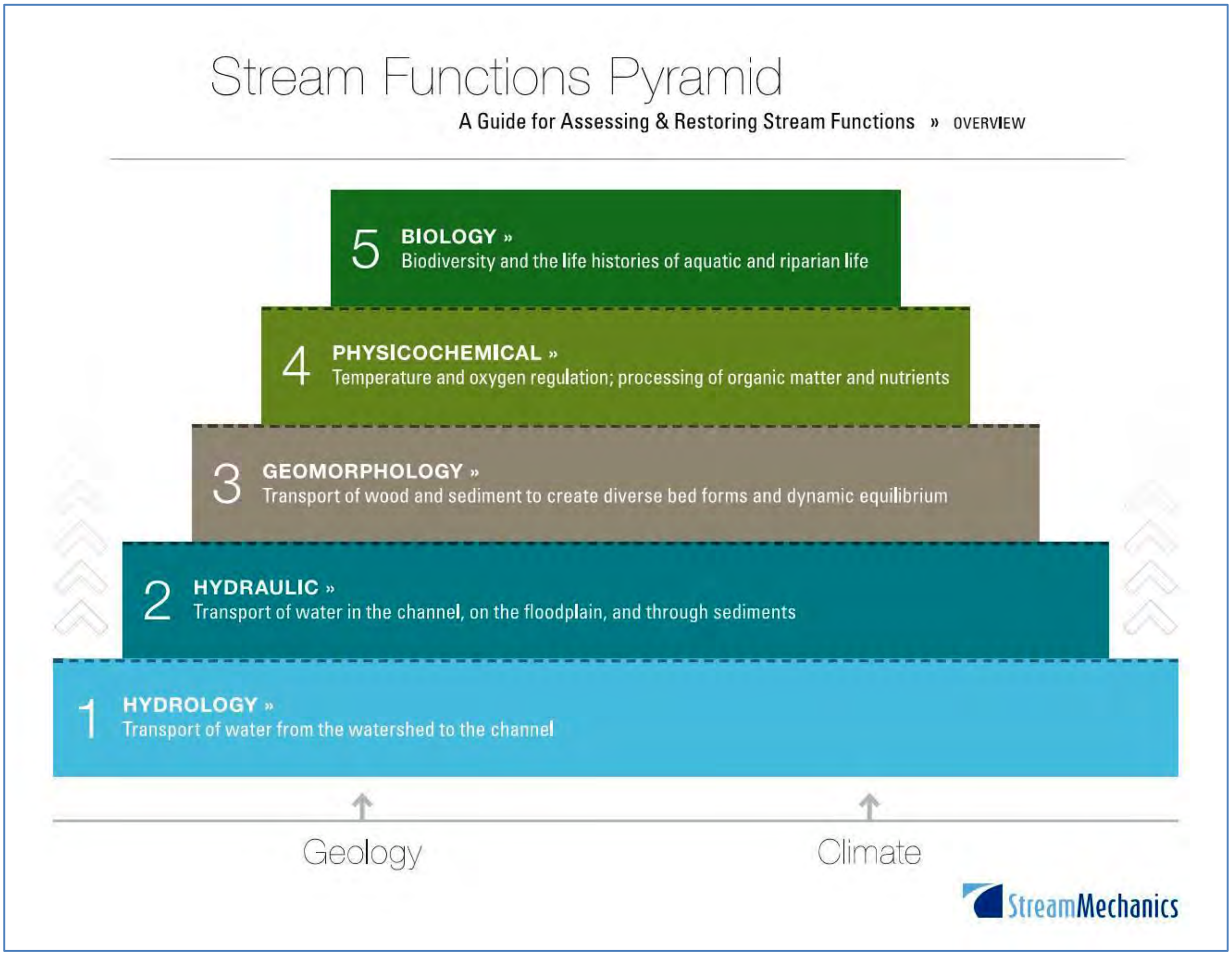

Figure 65: Stream Functions Pyramid (Harman et al., 2012)

The foundation of the proposed design for the project site is based on the supporting premise of the Stream Functions Pyramid, that lower functions of the Pyramid support and form the foundation for higher level functions. If a proposed restoration project cannot fully or only partially improve the hydrology, hydraulics and geomorphology, higher chemical and biological functions may be inadequate and may never become established at all.

Because of the importance of top-level biological functions at this site in regard to a brown trout fishery, goals of this project focus on all levels of the pyramid. Multiple practices are included in this restoration proposal which impact upland and riparian parameters as a means of enhancing in-channel habitats.

Hydrology

Hydrology is primarily driven by land use within the upstream and adjacent watershed to the project site. During large storm or run-off events, land use and soil types dictate the amount of water delivered to the project site. Land use also dictates the quality of that water delivered. Upstream of the site, the project cannot impact the existing land uses, which include residential, golf course, road ways, and agricultural uses. This project can change the land uses on the site, however, from agriculture to more sustainable cover types, such as grassland, forest, or managed timber uses.

The following hydrologic changes are proposed at this site to meet the challenges of the primary impairments to hydrology of the study area:

- Grading to reduce overburden on floodplains and expose the groundwater table, enhancing baseflow.
- Removing/reducing the scope of agriculture on the site, to change runoff curve numbers, reduce runoff, and increase the quality of runoff.
- Increase the quantity and quality of wetlands on site to improve groundwater recharge and enhance base flow.

Hydraulics

Hydraulics are the velocity, depth, shear stress, and associated fluid dynamic relations associated with flow. Channel hydraulics are one of the most critical parameters for supporting top level functions. The hydraulic conditions at differing discharges dictate the sediment transport conditions, the potential for erosion, and the stability of benthic substrates. Channel hydraulics form and maintain channel facets; for example, without plunging flows, scour pools cannot be maintained, overhead cover would fill with sediment, and essential fisheries habitat would not sustain itself.

The following hydraulic changes are proposed at this site to meet the challenges of the primary impairments to hydrology of the study area:

- Alterations to channel size, shape, slope, and proportion (geomorphology) to limit the in-channel peak shear stress, peak velocity, and sediment transport dynamics to sustain benthic substrates and channel facets.
- Alterations to floodplain grading to increase connectivity of frequent storms to the floodplain and reduce velocity and shear stress to foster a depositional environment for suspended sediments and organic matter.

Geomorphology

In a restoration project, excavation and grading is used to create a geomorphic framework of stream facets features and pattern to start the basis of a self-forming and self-maintaining dynamic equilibrium. ecosystem. Ultimately, the goals of the equilibrium are to foster top-level biological and physiochemical functions in a sustainable environment which minimizes the probability of ecosystem simplification as stressors such as time, climate change, and catastrophic events change the boundary conditions on the study reach. The enablers of this dynamic system maintenance are flow hydraulics, sediment transport / geomorphology, and biology. These factors provide the ecosystem services which incrementally contribute to watershed health.

Typically, in stream and wetland restoration practices, geomorphology is best articulated in terms of expressing the difference between a high-quality reference system and the one which is to be uplifted. Using the Rosgen classification system and series of dimensionless ratios, these geomorphic differences are expressed.

Reference parameters which have been tested through restoration projects is being utilized for this project. The sources of these reference parameters include Deer Creek (PA), Muddy Creek (PA), Codorus Creek (PA), Gunpowder River Tributaries (MD) as well as the related watershed parameters of land cover, impervious area, biology, and geology to ensure they are appropriate. The reference parameters used for geomorphology are all thriving natural reproduction brown trout streams. Where references are deficient, species specific knowledge of geomorphic principles are used for design validation. The following geomorphic changes are proposed at this site to meet the challenges of the primary impairments to hydrology of the study area:

- Alterations to channel size, shape, slope, and proportion to limit the in-channel peak shear stress, peak velocity, and sediment transport dynamics to sustain benthic substrates and channel facets. This is the same technique to meet hydraulic goals.
- Changes to stream length, sinuosity, dimension, pattern and profile to more closely match reference conditions from the site and from related functioning and similar sites.
- Changes to the sediment transport competency of the channel to promote the retention of native substrates found in the basal gravel layer.
- Removal of dams and structures, armoring, and straightening which have negatively impacted site geomorphology and caused instability, facet simplification, and flow simplification.

Physiochemical

Physiochemical parameters are a combination of unchangeable boundary conditions coming from upstream in the watershed, and factors that can be changed in the project boundaries. They are the constituent properties of the hydrology, such as temperature, dissolved solids, and dissolved nutrients. They additionally are the biochemical processes which process nutrients, alter temperature, and affect overall water quality through a reach. Those processes can be impacted through work on a site.

In the constraints of this project, we cannot change the temperature of water flowing into the site, nor the quality of that water. We cannot change the atmospheric deposition of nutrients and contaminants upon the landscape. What can be changed, however, is how those parameters are processed on the project site. We can change land uses which contribute non-point source pollutants, and change land uses which limit nutrient and sediment processing. The following physiochemical changes are proposed at this site to meet the challenges of the primary impairments to hydrology of the study area. They principally act to improve hyporheic exchange, process or sequester sediment and nutrients, lessen solar gain, and reduce non-point source pollutant sources:

- The reduction of agricultural land uses on the site. These locations will be selected based upon highly erodible land criteria and extended riparian buffer due to slopes and erodible soils. These lands will be placed into meadow and forest land covers.
- Additional property will be leased to negate the need for agricultural best management practice immediately adjacent to the stream, and limit point outfalls of agricultural runoff which are viewed as potentially increasing stream temperature.
- Promote infiltration of runoff through wetland restoration and forest re-establishment.
- Invasive species will be removed and a robust native buffer will be installed.
- Green ash dominated forest, most of which is now dead due to emerald ash borer as surveyed in 2018, will be replaced with vigorous, fast growing canopy species.
- The connection of the stream with the historic floodplain and shallow groundwater table, and associated Cockeysville Marble geology to enhance hyporheic exchange and promote base flow.
- The connection of carbon-rich hydric soils with the floodplain surface, to promote nutrient processing as well as increase contact/detention time of floodwater in the floodplain.
- The lowering of the floodplain to connect frequent discharges to the floodplain surface, thus exposing frequent flood flows to an increased surface area of floodplain and floodplain vegetation.
- The use of woody structures and debris, and a low energy floodplain environment which accumulates leaves and other cellulosic debris whose decomposition denitrifies and increases soil carbon.

Biology

Biology is the highest possible response for a project. All improvements in a restoration plan should have biological uplift as the primary goal of the project, supported through robust and consistent monitoring protocol.

The following biological changes are proposed at this site to meet the challenges of the primary impairments to hydrology of the study area:

- The removal and management of invasive plant species, and replacement of those communities with planted or seeded native species.
- The monitoring of those plant communities for success, and assurance of success through an adaptive management process.
- The installation of stone and woody substrates, and facets as part of specific habitats for brown trout as well as the other native fishery species.
- The removal of barriers to aquatic organism passages, and the monitoring of those biological communities for response.
- The recommended continued stewardship by MD DNR, Trout Unlimited, other NGO partners, and this bank to monitor the Jones Falls trout resources and use their genetics as part of programs to promote trout fisheries in the state.

- The protection of the restored habitats and reference habitats in perpetuity from development and impact via a conservation easement, supported through long term monitoring and maintenance funding.
- The removal of pipe diversions / drain tile and establishment of wetland and canopy to reduce thermal impact and solar gain to the base flow of the Jones Falls, and continued monitoring of thermal conditions within the project area with the goal of a long-term reduction in daily range of temperature and maintenance of thermal conditions suitable for trout and other sensitive species.

13. RESTORATION DESIGN

13.1 DESIGN APPROACH

The proposed restoration design for improvements within the project area is based upon the watershed assessment; a historical perspective and understanding to the causes of current channel instability, project site and assessment reach geomorphic data and evaluation, soils assessment and validation and the sediment transport analyses. All of these studies have been utilized to provide guidance to the proper channel and floodplain dimensions which will serve to maintain sediment equilibrium and long-term stability without the need to import large quantities of unnatural materials. The proposed design will focus on providing restoration approaches to address the principle impairments of the reach via the pyramid functions and specific detailed assessments previously outlined.

The basis for the design is to develop a stable design, dimension, pattern, and profile that will promote stable geomorphic function to both the proposed channel and the proposed floodplain. In addition, the proposed design aims to slow floodplain velocities to the extent of accreting organic debris and suspended sediments for treatment on the floodplain. To understand the long-term stable condition of the proposed design, an understanding of the upstream sediment supply and fully understand the condition of the proposed/native streambed substrate. The foundations of the proposed design have been previously outlined.

The design approach to this system is a modified Rosgen/Floodplain Restoration approach. The methodology utilizes both present day as well as historical references, and historic site soils to meet top level physiochemical and biological goals for the project. Additional details of the approach include:

- A proposed streambed profile located within the native valley basal gravels identified throughout the valley bottom and furnished substrates of geologically appropriate composition and size in the event of a lack of native material or where needed for transitional reaches.
- A hydrologic and hydraulic regime where the stream floods frequently in a non-erosive manner order to maintain geomorphic and biological functions.
- Developing a low-energy floodplain environment with maximum shear stresses not to exceed 2.0 lbs./sq. ft., and average channel shear stress much lower than this. A variety of woody

debris structures have been placed for minor grade control and specific habitats. This is fully sustainable with a surface treatment of native herbaceous and woody plant species through the full range of the ultimate conditions hydrograph.

The proposed design is intended to restore conditions which once existed prior to settlement disturbances, as seen through the historic hydric soil profile and confirmed through regional sampling of preserved seeds within that profile. The evidence of suitability was discussed in the historic and trenching investigations for the site. During our geomorphic investigation of project site conditions, additional survey shots of the basal gravel layer were taken throughout the Jones Falls valley to more accurately determine the elevation of the proposed streambed and floodplain and supplement trenching investigation. In areas where the basal gravel and hydric soil layers were exposed in the streambanks, survey shots were taken and tied to the site datum elevation control at the project site.

The locations of this investigation of shown on the Site Assessment Map provided in **Appendix D.**

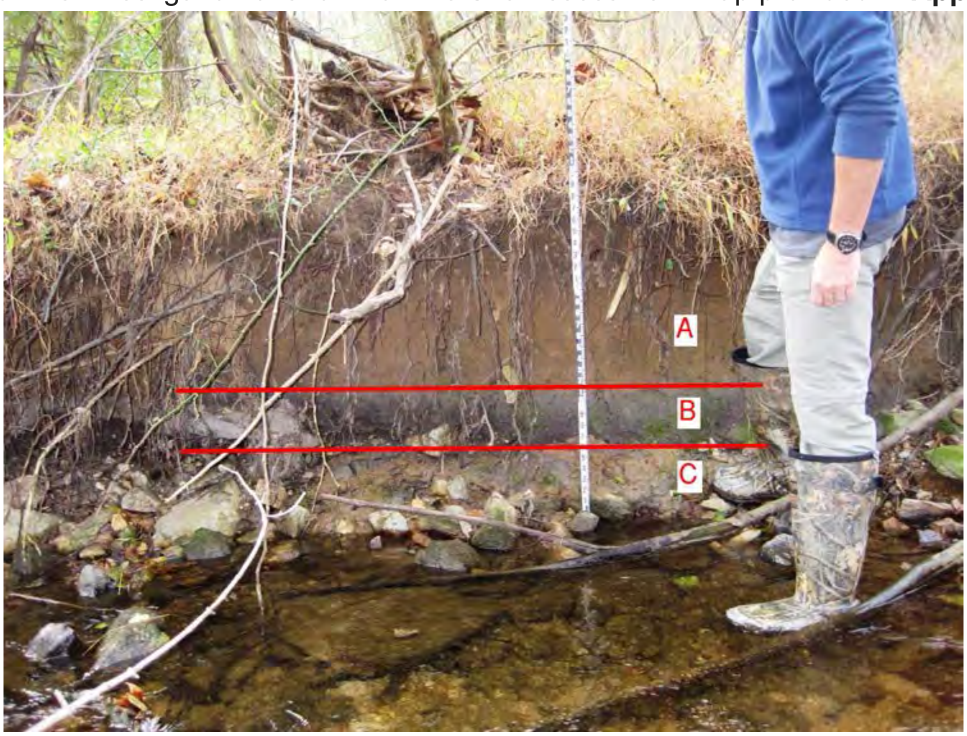

Figure 66: Representative soil profile including the Upper Streambank consisting of fine grained silty-loam material deposited during the colonial to industrial period, above the (B) historic, organic-rich hydric soils that permeated throughout the valley bottoms, above (C) the valley bottom sub-angular, quartz-rich, matrix supported basal gravels

The materials, shown as layers B and C in the above photo are consistent with the historical wetland soils that are described by Walter and Merritts (Walter & Merritts, 2008) that dominated the Piedmont valley bottoms prior to colonial times. This organic-rich soil layer overlays the valley bottom basal gravels that moved into the valley bottoms from periglacial and fluvial processes during the Pleistocene. It is these angular basal gravels that overlay the bedrock within the valley bottom that provided the long-term stability of the valley bottom in the current Holocene up until the colonial period beginning in the early 1700's.

13.2 DESIGN ELEMENTS

Specific design elements of this project are proposed to restore top level biological and physiochemical functions. Descriptions of these elements are included here.

Geologic Substrates:

Where possible, materials native to the site will be re-used for the benefit of the restoration project. This includes the use of site soils and gravels in the foundation of the stream and floodplain.

- The channel will be situated, where geology dictates, upon the matrix-supported basal gravel layer as identified or a suitable furnished substitute where those materials are available. Native geologic materials for the site are calcium based, making limestone a suitable component for substitution on this site and appropriate for a trout fishery. The native basal gravels are of a well-graded mixture with multiple size classes useful to biology. Furnished materials shall mimic that size mixture.
- Furnished and native materials larger than gravel, such as cobble and boulder, will be utilized in the design for channel flow diversity and the pinning of woody debris structures.
- Floodplain surfaces shall be composed of native hydric soils uncovered through excavation, or suitable salvaged site top soil.

No bank armoring of any type is proposed, including imbricated riprap, rock toe, or other stone bank practices purported by other practitioners as beneficial. Stone usage is limited to substrates and flow alteration structures as described in the plans. Armoring practices reduce habitat, generate instabilities, are not long-term sustainable, and do not qualify for mitigation credit. They are unable to be sustained in perpetuity, nor demonstrate any uplift other than a temporary reduction in sediment sources. These practices are directly in conflict with the requirements of the 2008 Final Mitigation Rule.

Channel Form, Facet, and In-Channel Habitat Formation:

The channel form will be modified to be in accordance with known reference parameters and to sustain a self-forming and self-maintaining geomorphic system, capable of maintaining top-level biological and physiochemical functions and values. The channel will be altered to correct principle impairments previously identified in this document.

- Increase channel sinuosity to facilitate the stable formation and maintenance of diverse pools for in-channel cover and refugia. Add meander bends within stable known reference parameters for Piedmont streams. Construct new channel offline to limit impact to existing resources.
- Re-size and re-shape channel for improved baseflow habitat and within reference parameters for floodplain restoration, Rosgen C4 and B4 restored streams.

- Increase frequency of channel flooding to leave the base flow channel for flows beyond the 1-year storm discharge for the majority of the site.
- Provide in-channel overhead cover in each meander bend.
- Provide micro pools and other flow diversity features in each riffle, through the addition of random boulders and other substrates.
- Provide compound and diverse pools, including side pools as seen in the reference locations on the site.
- Provide greater pool variability, including the addition of at least ten additional thermal refugia / overwintering pools greater than three feet static depth.
- Preserve existing habitats identified in reference locations.

Woody Substrates:

Trees and other woody materials removed during excavation of the proposed lower floodplain will be fully repurposed to provide numerous grade control and habitat features throughout the proposed channel and floodplain. Trees are sustainable, renewable resources. These materials provide critical organic value to the system for both fish and wildlife. The extensive use of wood sequesters an available carbon source vital to both floodplain and in-channel nutrient processing. Wood structures/habitat features to be implemented include:

- In channel log placements will be installed throughout the project reach to provide grade control and to generate low magnitude flow shear stress to aid in the formation and maintenance of pools. Logs from trees removed during construction within the project site limits of disturbance will be salvaged and repurposed for use. The use of these in riffles will be used for substrate variability and minor grade control, and to generate flow diversity. Log vanes and J-Hooks will utilize logs for similar flow manipulation.
- Toe wood will be utilized as cover and substrate in meander bends. This material is not an armoring process, but rather a means of creating a varied channel edge with cover opportunities. Its use in outer meander bends is to ensure shear stress adequately maintains voids between twigs and branches of debris to sustain cover. Because of its placement, it is commonly confused with an armoring practice.
- Woody debris to be utilized in the proposed design includes the repurposing of smaller branches, saplings, tree tops and stumps removed during grading operations. The woody debris will be placed randomly throughout the project site as directed by an on-site designated stream specialist. Woody debris in the channel and floodplain provides organic food content, critical cover for fish and wildlife and a source and trapping mechanism of finer organic materials. Broken and exposed wood also provides habitat for insects. Standing dead wood provides habitat for cavity nesting birds and roosting sites for bats. The woody debris will also aid in constructing a floodplain with varied micro topography and habitat diversity. The inclusion of woody stream bed materials and log grade controls will likely increase the capture and deposition of leaf litter and course organic material for macroinvertebrate processing. These habitat enhancements will positively benefit fish communities by increasing habitat refugia and food sources for fish and are expected to have significant benefits to young fish.

Herpetological Habitat Enhancements:

Reptiles and amphibians require complex habitats and diverse hydrology at their various life stages; as a result, many species are imperiled due to a variety of environmental factors, including habitat loss. Breeding habitats, for example, require varying induration periods for proper hydrology depending on the species, isolation from predatory species such as fish, and presence of appropriate substrates, namely organic matter such as leaves, twigs, and other woody or herbaceous debris. Multiple aspects are included in the design to enhance these habitats:

- Vernal pool features: Broader areas of the floodplain, out of the immediate belt width of the proposed channel can be excavated to create additional open water habitat and add to the diversity of the floodplain environment. Vernal Pools may experience periodic drying in summer months, effectively creating isolated habitats removed from fish predation. Log, pools, and muddy pools will provide potential hibernacula which may remain relatively frost-free due to their connection to groundwater. The vernal pools can provide refuge for bird species and food sources for a variety of herpetofauna species. The recreation of the floodplain, very near the groundwater elevation will support a constant supply of water. The vernal pools will be excavated to varying depths below floodplain elevation and in areas which will predominantly receive surface runoff.
- Flow velocity reduction and depositional attributes: The proposed restoration design will create velocities slow enough to deposit significant leaf and woody material into the floodplain, providing substrate for herpetological function. Sedges, logs, and rough grading and other vegetated hummocks will provide basking locations.

Vegetation:

The principle improvement to the project watershed will include the removal of agricultural land uses from all presently cultivated areas with exception of the portion of the site at the corner of Greenspring Valley Road and Park Heights Avenue, and a portion of the field adjacent to Spring Hill Road. Approximately one half of the 73 tillable acres of the site will be converted to woodland and meadow usage. Historic agriculture uses on the site are suspected to be one of the principle impairments impacting thermal and other water quality parameters, and the previous tenant had repeated instances of spraying adjacent to the stream, stream crossings, and other detrimental usages (though likely legal uses of the land).

All areas adjacent to the channel are proposed to be forested, though these areas may meet the reforestation standard for stems rather than that of forested wetland standards in Maryland. Throughout the project site in the existing conditions much of the vegetation found of the surface of the higher floodplain are drier, upland and/or invasive plant species. Wetlands exist in areas; however, they are predominantly supported by a perched aquifer, hillside seeps or surface run-off, and are of limited functions and values. These wetlands are not hydraulically or hydrologically well-connected to the channel and provide little to no processing of fine sediment and nutrients transported by the active channel. Due to the high elevation of the present-day floodplain these wetlands remain perched and disconnected. Much of the degradation of stream and floodplain biota can be attributed to the disconnection of channel base flows from groundwater aquifers as a result of alluviation (Bravard et al. 1999). Thus, species diversity and wildlife food sources and habitats suffer.

In the proposed conditions, the entire floodplain area will be seeded with a robust native seed mix, which contains numerous native herbaceous plant species. Tree plantings are proposed throughout the floodplain area and adjacent upland areas. In the proposed conditions, the channel and floodplain vegetation will be highly connected to groundwater, providing year-round thermal stability. In addition, due to the small size of the proposed channel, the proposed herbaceous and grass community along the channel will accomplish or surpass the shading processes of trees during initial stability. The combination of a restored hyporheic connection and improved shade will enhance year-round temperature regulation. The use of trees on restored floodplains is not necessary to achieve long-term stability. Research from respected academia suggests that many stream valleys remained stable for thousands of years as sedge dominated, emergent wetland systems, largely devoid of trees. However, since the existing forest will be temporary disturbed and existing trees repurposed, it is very appropriate to restore the proposed valley bottom to a forested condition.

Additional aspects of the restoration of vegetation include:

- Enhancement of Natural Vegetation and Pollinator Habitats: At present, the stream corridor is largely open with sporadic trees, or forest with dead and dying ash trees and high concentrations of invasive species, such as English ivy, which is choking many canopy trees. While some wetland systems are present with a limited variety of native vegetation, overwhelmingly, non-native, upland, and invasive species dominate the existing project area. The finished project should foster a variety of native vegetation, including herbaceous pollinator habitats fostered by a seed mix which permits foraging for nectar and pollen through the entire growing season.
- Utilization of known historic species on the site. This includes Bad Cypress, Atlantic White Cedar, and River Birch which are either present in reference portions of the site, or historically known to be present on the site.

Small Order Streams:

The purpose of smaller order streams on the project site is to restore the braided and small order stream habitats lost in the watershed as well as on the project site from agricultural impacts. These streams are habitat for young trout as well as small forage species, amphibians, and macroinvertebrates. The serve as refugia in high flow conditions and as direct conduits for groundwater input into the mainstem and tributaries of the Jones Falls. They are a specific / specialist habitat represented in the overall restoration plan and credited to take this into account. They are based on natural reference data of 1.2-1.5 sinuosity and are narrow enough to permit canopy from herbaceous plants alone in initial years as regular tree canopy develops.

Aquatic Organism Passage:

MDTA proposes to remove the concrete dam which diverts the Jones Falls. This dam is intact and dates to 1915 and is an approximately 3' high structure which presents varying degrees of fish passage blockage for trout depending on the debris jams accumulated downstream of it. MDTA has observed between 6" and 3' of elevation change in this location during the study period. While this dam does not represent a barrier to larger mature fish in most circumstances, it is a barrier at nearly all flow and debris conditions for small fish species and young of year and juvenile trout. It additionally serves to divert flow from the mainstem, impacting the ecological potential of those areas diverted.

Soils:

The project site has a visible, buried sequestered carbon wetland soil, evidence that wetland conditions persisted at the site for thousands of years. A noted comparative absence of carbon is visible in the more recent sediment horizons, indicating drier conditions with less carbon sequestration noted. Given this, MDTA estimates that the present-day project conditions do not sequester carbon as effectively as historic conditions. The proposed shallow floodplain will improve wetland functions and aid in the creation of a wetland soil which rapidly sequesters carbon.

- Vegetation Selection to Foster Sequestration of Soil Carbon: Tree and wetland species which create large amounts of biomass are proposed. This includes sycamores, maples, and other species which rapidly grow, producing leaves, bark, seeds and other organic detritus. Increasing the organic carbon content of soils has multiple benefits, including enhancing infiltration rates, promoting plant growth, and reducing atmospheric carbon. Submerging woody debris in wetlands not only sequesters carbon but creates subsurface structure and texture characteristics found in high quality wetlands. Submerged woody debris typically has an extremely long life span and is commonly found in piedmont systems well in excess of 200 years old and preserved, sometimes thousands of years old.

13.3 BEDLOAD SEDIMENT TRANSPORT ANALYSIS

A major determining factor in the sizing of the bankfull channel for the restoration of the Jones Falls is to analyze the existing hydraulic characteristics of the channel (cross sectional area, width, and depth) and developing channel morphology that will minimize streambed substrate mobility of the native basal gravels, yet maintain the competency to mobilize finer sediments being contributed to the design reach from the upper watershed. In the proposed conditions, the intended design is to reestablish the vertical elevation of the Jones Falls channel on the native basal gravels observed within the project limits to be able to transport and provide vegetative treatment of finer sediments which may be delivered to the project reach from upstream streambank erosion and maintain a stable equilibrium with the native basal gravels within the valley bottom. Based on geomorphic assessment of watershed condition, we anticipate the average size of these sediments to be no more than 5mm to 8mm in size. To accomplish this objective the proposed channel dimensions must be sized to provide a frequent hydraulic connection to the surrounding floodplain and maintain a low transport condition during bankfull flow events.

The dimensions of the proposed channels are based upon providing stability of the proposed channel bed by maintaining the D50 of the historic basal gravel layer though the entire hydrograph of flow events. The D50 and larger materials analyzed in the basal gravel bulk sediment sampling will provide protection of the smaller fine-grained sediments analyzed in the sample and those delivered to the project reach from upstream sources. Based on our observations and analyses only fine-grained sediments (sand and fine gravel) will be delivered downstream to the project reach in the proposed conditions. As previously stated, larger sediments (gravels and cobbles) are being sourced from erosion occurring within the project reach and should not be considered part of the long-term, sustainable supply of sediment. The following analysis will utilize the Andrews (1995) marginal bed load transport function to analyze critical shear stresses necessary to initiate partial movement of the finer sediments. The data presented herein will be used as a guide to help establish a range of proposed channel parameters which considers the sustainable size fraction and load of sediments through which the project reach must transport and the stability of the native basal gravels or other materials which will form the bed of the proposed channels.

Due to a variety of past and present influences, the project site conditions and the sediment regime of the project reach and upper watershed has been greatly altered. Therefore, the existing data provided here will serve as a general guide to help establish channel parameters that promote long-term stability of the active channel and floodway in the restoration design.

13.3.1 Principles

A major premise of the sediment mobility analysis is that threshold conditions defined by any critical shear stress method represent a condition of very low transport rate (Wilcock 1988). Secondly, smaller grains within a mixture of sizes tend to be harder to move than they would in a bed consisting of uniform size sediments, and larger grains tend to become easier to move in a mixture of sizes. Based upon the data presented from the bulk basal gravel samples, approximately thirty to forty percent of the bed materials consist of fine gravel or smaller sediment sizes, which will be mobilized during the full range of complex flow events and would therefore coarsen the remaining riffle bed substrate in the existing condition. Very large particles from colluvial material, large fragments of bedrock plucked from the streambed or bank during infrequent high flows or very large particles within the basal gravel sediment matrix may not be mobile although they can effectively hide or shelter other smaller particles. The largest particles on the bars or in the sub-surface represent the maximum size present in the bedload.

Methods considered in this report for the computation of the critical dimensionless shear stress condition for marginal transport of a specific size fraction in mixed-grain sediments (Andrews et al 1995) have the form:

$$\tau^*_{ci} = a\,(D_1/D_2)^b$$

where τ^*_{ci} is the critical dimensionless shear stress for a very low transport rate for the specific size fraction in the matrix armor layer. This equation is used to estimate the conditions under which marginal transport will exist in the channel. An assumption is made that the minimum shear stress under bankfull conditions in the assessment riffle should be that which mobilizes the largest particles in the bed load. The variables D_1 and D_2 are representative sizes of the sediment samples. Using Andrews' 1995 equation, D_1 is equal to D_i identified below, and D_2 is the mean diameter particle size of the riffle surface using the Wolman Pebble Count method. Coefficient 'a' and exponent 'b' are 0.0376 and –0.994, respectively, for the 1995 equation.

The critical shear stress for marginal transport rate of the largest size fraction in the bed load corresponding to τ^*_{ci}, which relates shear stress to bed load material, is given as:

$$\tau_{ci} = \tau^*_{ci} (s-1) \gamma D_i$$

where τ_{ci} is the critical shear stress required to mobilize D_i , which represents the largest size fraction that is considered to be mobile; s is the specific gravity of the sediment (typically 2.65); and γ is the specific weight of water (62.4 psf).

The average boundary shear stress produced by a discharge over each riffle is expressed as:

$$\tau_b = \gamma R S_f$$

where τ_b is the cross section average boundary shear stress (psf), R is the hydraulic radius, and S_f is the energy slope. Because the channel depth on riffle features is relatively shallow (bank resistance considered minor at bankfull conditions) and backwater effects from downstream bends or other blockages will be minor in the proposed conditions, the average boundary stress, using the proposed average riffle depth was considered to be a good approximation for the average stress on the wetted perimeter of the cross-sectional area. To assess the maximum boundary shear stress which may be asserted on the streambed at any single point within the cross section, R or hydraulic radius has been approximated using D (max) or the maximum channel depth. The energy slope (friction slope), S_f, for each reach is the proposed bankfull slope of the proposed channels.

The use of critical shear stress (τci) and boundary shear stress (τb) methodologies provides a sound approach for calibrating the threshold and recommended bankfull parameters at the riffles studied and for establishing the proper and/or threshold values for the depth and width-to-depth ratio in the natural channel design process. The proper dimensions of the proposed channel must be sized to both maintain stability on the basal gravel layer and have the competency to mobilize finer sediments transported to the project reach from upstream erosion. This design strategy may be appropriate to encourage the deposition and treatment of very fine sediment on the proposed floodplain surface. Although the supply of fine sediment from upstream sources is not significant enough to affect future channel stability, the fine sediment supplied from upstream reaches may actually create biodiversity in the proposed floodplain and create critical habitats. This is based on the design team's geomorphic assessment of watershed conditions. The proposed bankfull channel will need to be sized to maintain a near-equilibrium condition with the finer size fractions of the sampled basal gravels. The methodology used for this analysis were derived by Andrews from specific bed-load data sets for similar stream types located in the western United States and therefore may not be directly applicable to the project site; however, they provide a conservative estimate of the expected shear stress required for sediment mobility.

13.3.2 Entrainment Analysis

A thorough entrainment analysis detailing the mobile particle fractions during the final design.

13.4 DESIGN DISCHARGE AND BASE FLOW DESIGN ESTIMATE

As previously discussed, the Jones Falls remains highly entrenched with significant stream power. Under these conditions, the channel will continue to erode both laterally and vertically, and mobilize sediment much larger then is sustainable in the long-term. Even utilizing USFWS bankfull discharge relationships, boundary conditions remain too high to be sustainable without the need to import large volumes of non-native materials. Sizing a larger channel through bank grading which has the competency to mobilize the native streambed and larger materials will require armoring of the channel bed and does not address the stable sediment regime of the system. Adding “hard’’ structures and imported bed materials, pins or forces the channel into a defined geometry and does not account for a higher risk of maintenance or failures because water will always find a way to erode around and through the fine alluvial sediments they are founded on. In addition, these methods may increase boundary roughness within the channel and increase existing flood elevations.

Being that the primary volume of sediment which is transported to downstream receiving waters consists of fine gravel, sand and silt generated from bank erosion, the design discharge of the proposed channel must remain at levels which can both transport and treat fine sediment from upstream sources and remain stable on native streambed materials. Based on our assessment of watershed and project site conditions, the sustainable supply of sediment from upstream sources are anticipated to be less than approximately 10 mm in size. As previously stated, the larger basal gravels and colluvial materials being transported for short distances within the highly-incised channel are creating additional lateral and vertical instability and should not be considered part of the stable bed load. Identifying what should be considered the long-term sustainable supply of sediment in highly impacted eastern stream systems should be considered the primary objective of a design discharge.

As part of the geomorphic assessment of existing site conditions, the design team surveyed multiple cross sections to characterize the base flow regime. As this is the regime most commonly observed in a stream, it is important to characterize it to assess habitat and flow characteristics, which is vital to demonstrating functional uplift of the reach through restoration. As typical for streams in the region consistent with floodplain restoration, base flow makes up the predominance of the channel bankfull volume.

Base flow for the Jones Falls mainstem was estimated to be between 2.0 cfs to 4.0 cfs (seasonally). Tributaries are estimated to have base flow discharges less than 1 cfs typically, though this has been frequently exceeded due to the usually wet conditions in the summer of 2018.

This base flow analysis in conjunction with reference material was utilized to develop the proposed channel geometry. The proposed design, as it is more connected with the groundwater than the existing condition, is anticipated to augment the seasonal base flow condition and buffer against seasonal loses due to precipitation variation and evapotranspiration.

13.5 ALTERNATIVES ANALYSIS – RESTORATION AREAS

For the purposes of agency review, the alternatives analysis is utilized to determine the Least Environmentally Damaging Practicable Alternative (LEDPA) which achieves the goals of the compensatory mitigation site and the functional uplift as mandated by the U.S. Army Corp of Engineers (Corp) and MDE. These goals represent what MDTA believes to be the greatest possible ecological uplift of the site, and the preferred restoration alternative for this project is that which MDTA feels best meets this goal.

As tree canopy and its purported thermal effects on the Jones Falls is the primary resource of concern per agency comment, design alternatives which limit disturbance of canopy and leave most existing trees in place are discussed as a singular alternative, despite that this can be accomplished in several ways. A no-action alternative is also included in this analysis, which details the projected fate of the biological and physiochemical functions and values on the project site in relation to the identified principle impairments of the site and watershed. All analysis relates to the proposed alternative, which is the preferred alternative accomplishing the most goals in the long term when compared to other alternatives.

For the purposes of this alternative, goals must be considered in the long term, in-perpetuity context which is set forth in the 2008 Final Mitigation Rule. To determine only short-term goals and attainment does not meet the mitigation standard, although it is industry standard when considering projects set forth with the intent to meet MS4 / TMDL program sediment and nutrient reduction goals.

The no action alternative assumes that watershed and site pressures and impairments continue to act on the site as they do currently, or with the same relative rates of change as historically seen. The following effects are anticipated at the project site:

- **A loss of approximately 70% of the mature tree canopy in areas of the site presently proposed for restoration within the next ten years.**

Much of the existing tree canopy of the site is made up of mature green ash, except for reference portions of the project site where maples and bald cypress dominate the canopy. This analysis accounts for green ash only and does not consider other species lost through smothering of porcelain berry and English ivy as is also seen on the site. Between 2016 and 2018, significant losses due to emerald ash borer were observed by MDTA, and this is expected to continue as no effective biological or other means of control has been adopted by the State of Maryland. Control measures in other states, such as Michigan, have included the cutting of ash trees to prevent the spread, which would also result in a loss of canopy on the site.

- **Minor channel enlargement and no significant increase in channel sinuosity for the next five to 10 years.**

MDTA staff has observed this site since approximately 2008. Barring a catastrophic event and given the high degree of channel entrenchment in its present straightened condition, it is likely the channel will remain in its relative position for the foreseeable future, remaining as a B4/B4c stream with some channel enlargement. BEHI and NBS analysis demonstrates moderate instability; the channel is certainly not the most unstable in the watershed in terms of the position of its bed and banks. Therefore, existing poor habitat conditions will persist as there is little mechanism for plan and profile change to add stream length or rebuild facet features. As canopy dies and influx of woody debris from green ash are introduced, there is a greater chance for channel evolution and pattern change, however this comes at the cost of smothering gravel substrates with fine sediment and abandoning, filling, or otherwise impacting what good habitats remain.

- **Flow diversion, damming, and agricultural uses are anticipated to continue for the foreseeable future.**

The landowners have expressed that agriculture is the sustaining income which pays for taxes and other expenses for the property. Agriculture is a major contributor to forest disturbance, poor water quality, and loss of canopy. Channel dams are in good condition with no major structural deficiency, as are flow diversions. These diversions are anticipated to continue without alteration, making the majority of the project reach less resilient to watershed urbanization and climate change.

- **A continued decrease in trout populations and increase in tolerant warm water fishery species, in accordance with the existing trends observed in MD DNR data.**

MD DNR data, as previously discussed, is showing an approximately 16-year trend of decreasing trout populations. While there are many factors accounting for this, a lack of site protection, increase in intensive agricultural use, damming and flow diversion, and a natural decrease in canopy are projected to significantly reduce the trout population and corresponding functions and values of the site, particularly with continued pressures of urbanization and climate change.

A no action alternative does not significantly meet any goals of this project in the short or long term.

<u>Limited Canopy Disturbance Alternatives (Uplift, Patch Work, Stabilize in Place Techniques):</u>

Restoration alternatives which limit disturbance to the canopy would include practices which keep the existing stream channel in place. This includes alternatives which would lift the channel profile or armor / stabilize the channel in place.

Stabilizing the channel in place and adding habitat structures within the existing channel would not meet the goals of the 2008 Final Mitigation Rule; channel deficiencies in hydraulics, excess shear stress, and impaired substrates would continue to operate and degrade channel habitats. Habitat and substrate placement would be jeopardized by frequent high shear stress discharges within the channel, as floodplain relief would not lessen these stresses for frequent discharges. Additionally, and most importantly, stone armoring practices and patchwork repair of the channel does not provide any significant sustainable habitat uplift. Repair and maintenance of the reach would be frequent and releasing credit from the project would be difficult to justify for the given performance criteria. Armoring of instabilities in the reach would be required, which is entirely inappropriate for a fishery of this potential quality. Simply stated, uplift cannot be provided to meet the mitigation standard using the stabilization practices which have been locally implemented to meet TMDL goals alone. These practices in the long term do not even meet sediment and nutrient source reduction goals particularly well, nor economically.

An alternative which lifts the channel using riffle grade controls, sheet pile, or similar perching techniques would create a new floodplain at a higher elevation. This alternative would definitively meet many hydraulic goals. It would have the distinct disadvantage, however, of disconnecting the active channel from the existing gravel substrates as well as the buried basal gravel and hydric soil substrates present on the site. Benthos is anticipated to suffer in such an instance, as artificial substrates replace native ones and channel facets are altered drastically. Administrative hurtles, such as increases in the 100-year water surface and potential floodplain impacts to upstream property owners would also complicate the project. Continued disturbance due to loss of green ash would continue. Ecosystem functions and values would none the less be lifted, however the entire ecosystem type would change to more closely favor a warm water fishery versus a cold-water fishery, as disconnection to the sands and gravels of the Cockeysville Marble geology and groundwater table would occur, favoring a perched groundwater system. Hyporheic exchange would likely not increase definitively as dense in-situ sediments would remain in the floodplain. Inundation of existing canopy tree roots may result in additional temporary canopy impacts. Expansive open water systems, as we see in similar restorations of in Howard or Anne Arundel County would promote increased water temperatures. This type of approach does not meet the full extent of project goals as the preferred alternative. Examples of this include:

- Does not utilize the in-situ native basal gravel and hydric soil layers within the design approach.
- Requires a significant amount of imported, unnatural materials to stabilize the channel.
- Only creates limited flood flow relief for smaller flooding events contained within the inset bankfull bench/floodway feature.
- Regional curves for which method is highly dependent on, does not account for stable sediment regimes and usually creates a large channel with competency to mobilize more sediment than is sustainable.
- Does not fully meet Levels 3-5 of the Stream Functions Pyramid.
- Level 3 of the Stream Functions Pyramid cannot be achieved through importing large, unnatural materials into the system.
- Structures and imported bed materials may be highly susceptible to failure due to erosion occurring around and under them.
- High risk of failure and/or routine maintenance of rock structures.

- Serves to “pin” the channel in one position.
- Large channel dimensions will create a transport reach condition which may create future downstream instability.
- Very limited organic carbon inputs, which are vital to nutrient processing and food sources, can be incorporated into the system due to the fact that in-channel energy will remain at or above existing levels and cannot rely on vegetative stability.
- Increased boundary roughness within the channel may increase flood stage.
- Additional disturbance outside the limits of the inset floodplain will be required for construction access.
- Increased cost due to importing large quantities of rock, construction of structures and erosion and sediment controls.
- The requirement for importing large rock quantities for grade and structure control.

13.6 ALTERNATIVES ANALYSIS – PRESERVATION AREAS

Preservation is the preferred alternative to meet the project goals in reference-quality portions of the study area. This practice is proposed for high quality / functional forested wetlands and nearby associated portions of the mainstem of the Jones Falls.

In 2018, these areas were assessed as part of the study plan for the project site using the same habitat assessments conducted throughout the rest of the site. Some additional emphasis was included in these areas as high-quality resources were present and their usefulness as a reference to the rest of the project site design was evident. These locations have the following properties:

- Stream reaches have trout observed throughout the year.
- In channel habitat is excellent, with strong flow diversity, flow depths suitable for fish passage, clean gravel substrates, and a mix of living and dead wood proving overhead cover.
- Stream is situated at basal gravel layer. Top of bank has legacy sediment but wetlands present.
- Stream banks have some instabilities, but strong canopy and lower bank height make them not worth disturbing to merely gain TMDL reductions.
- Stream thermal characteristics strongly favor trout.
- Wetlands have varied hydrology and have sensitive species (wood frogs, for example) present.

The stream and wetland locations identified have high functional value, however that is not to say they are pristine. Invasive species are present and potentially dominant in some portions. These locations additionally have local bank instabilities, contributing sediment and nutrients to receiving waters.

MDTA weighed multiple options for these locations, including enhancements, restoration / rehabilitation work, and no-action alternatives including not including them within the project site easement. Preservation was selected as the most viable and beneficial alterative for these locations vs. other actions for the following reasons:

- The principle impairment of these resources is a minor to moderate source of TMDL pollutants.

- Invasive species, while present, are not negatively impacting the in-channel habitat and appear to not significantly diminish value of forested wetland habitats. In some cases, invasive species provide in-channel habitat as MD DNR has identified in agency comments.
- Given the sediment source impairment, impacting habitat resources for the sole purpose of reducing TMDL sediment and nutrient sources is not justifiable given the minor uplift achievable, the risk of impacting prime habitats, and the ability to seek TMDL reductions in other locations offsite without the same risk to habitat and species of concern.
- The resources provide critical habitat and increase the value of restored resources downstream. They are therefore an integral part of the bank.
- County, State and Federal protections are inadequate for the project site; the danger of development conforming to the existing or future zoning is a significant concern for the future viability of these habitats. Lawful disturbance is a sufficient risk to these habitats, such as driveways, buffer removal, clearing, logging and other permissible uses could severely impact this habitat.
- The risk of degradation through future TMDL-oriented work through public entities or private partnerships is significant in this watershed. These TMDL-focused projects do not have habitat restoration as a principle goal and commoditize stream restoration into an impervious acre credit for the lowest price. Such projects may adversely impact this reach without the benefit of full stakeholder involvement or agency review.

It is important to note that all areas within the project site easement will be protected equally from future lawful disturbance and development via a perpetual instrument.

14. HYDRAULIC ANALYSIS

Hydrology for the restoration of the project site has been developed and is included in Section 7.

The hydraulic models in this report were created using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS), version 5.0.3, dated February 2016. There is no current Federal Emergency Management Agency (FEMA) model for the project site to be utilized. Therefore, cross sections were created to best represent the 100-year flood event within the project area. The model includes sections both upstream and downstream of our proposed restoration area and was run using a subcritical flow regime. The model will be used to compare to a proposed conditions model for the next phase of the project.

The HEC-RAS model was split into seven reaches to better characterize anticipated flooding conditions within the project site. The Jones Falls is separated into four separate reaches to account for the tributaries that flow into the main stem. These reaches are named JonesFalls, JonesFalls2, JonesFalls3, and JonesFalls4. The existing dam along the Jones Falls is not included in the existing HEC-RAS model to generate conservative and worst-case shear and velocity values. UT-2 (Reach name NorthTrib) enters the mainstem at a junction located directly downstream of JonesFalls and UT-1/UT-3 (Reach name SouthTrib) enter the mainstem at a junction located directly downstream of JonesFalls2. UT-4 (Reach name IntsTrib) enters the main stem at a junction directly downstream of JonesFalls3 at the downstream end of the Park Heights Ave culvert. The fourth reach of the Jones Falls (JonesFalls4) extends 250 feet downstream from the junction with UT-4 (Reach name IntsTrib). Please note that although UT-2 and UT-1/UT-3 tie into the main stem at locations further downstream then the junction locations. The junctions were moved to upstream cross sections as this is the location where the 100-year flood flows of the tributaries merge with those of the main stem. The following table depicts the reach names used in the HEC-RAS model as compared to the site assessment reach naming.

Table 16: HEC-RAS Reach Naming Convention Compared to Site Assessment Reach

HEC-RAS Reach Name	Site Assessment Reach
JonesFalls	Jones Falls – Reference Area & Jones Falls – Middle Jones
JonesFalls2	Jones Falls – Middle Jones
JonesFalls3	Jones Falls – Walnut-Horse Chestnut & Jones Falls – Downstream Forested
JonesFalls4	*Downstream of project site and site assessment area
NorthTrib	Stone House Tributary (UT-2)
SouthTrib	Railroad Tributary (UT-1) & Braided Tributary (UT-3)
IntsTrib	Intersection Tributary (UT-4)

Although the restoration ends at the upstream end of the Park Heights Avenue culvert, the HEC-RAS model was evaluated through the culvert and included multiple sections downstream of the project site. The HEC-RAS map showing the reaches and cross sections locations can be found in **Appendix H**.

14.1 HEC-RAS MODEL

14.1.1 Reach Boundary Conditions

The reach boundary condition at the downstream end is a normal depth with a starting water surface slope of 0.00613 ft/ft.

14.1.2 Cross Sections

Cross sections were created using data from the full topographic survey and augmented with GIS contour data acquired from Baltimore County.

14.1.3 Manning's N-values

Roughness values for the existing model were demined based on the USGS guide for selecting Manning's *n*-values for natural channels and floodplains, table 3-1 of the HEC-RAS User Manual, and verified from field observations. All values are verified from field observations. All existing Manning's *n*-values used in the model area shown in the table following:

Table 17: Existing Manning's n-values for HEC-RAS

Reach	*Channel Manning's n-value*	*Floodplain Manning's n-value range*	*Associated land use for Floodplain Manning's n-values*
JonesFalls	0.049	0.040 - 0.110	Agriculture field and Woods
JonesFalls2	0.049	0.040 - 0.110	Agriculture field and Woods
JonesFalls3	0.049	0.040 - 0.110	Agriculture field and Woods
JonesFalls4	0.049	0.040 – 0.045	Agriculture field, Woods, and 2-ac Residential Area
NorthTrib	0.061	0.040	Agriculture field
SouthTrib	0.057	0.040 – 0.045	Agriculture field, Woods, and 2-ac Residential Area
IntsTrib	0.046	0.013 – 0.045	Agriculture field, Woods, 2-ac Residential Area, and pavement

14.1.4 Contraction and Expansion Coefficients

Contraction and expansion coefficients of 0.1 and 0.3 for gradual transitions and 0.3 and 0.5 for the area directly downstream from the culvert outfall were utilized, respectively.

14.1.5 Ineffective Flow Areas

Ineffective areas at the culverts were projected to Jones Falls RS 3-6, Ints Trib RS 1-7, South Trib RS 5-8 in existing conditions. The areas were projected as an extension of the downstream wing walls or, if the structure did not have wingwalls, at a 1:1 in the direction of flow along both sides of the channel until full expansion of flow was realized. Please note that the culvert located at Park Heights Avenue has three separate culverts that were considered when determining the ineffective flow areas.

14.1.5 Steady Flow Data

The 2, 10, and 100-year design storms were evaluated in the HEC-RAS model. The design storm flows are delineated for each reach separately based on the hydrology in Section 7. The discharges for reach JonesFalls match POI-2, for reach NorthTrib match POI-3, for reach SouthTrib match POI-4, for reach IntsTrib match POI-5, for reach JonesFalls2 match POI-2 + POI-3, for reach JonesFall3 match POI-1, and for reach JonesFalls4 match POI-5 + POI-1.

Table 18: 2-Year Storm Event, HEC-RAS Summary

		Existing Conditions: Q_2						
Reach	**Discharge**	**Station**	**WSEL**	**Vel. Total**	**Shear Total**	**Shear Left**	**Shear Right**	**Shear Channel**
JonesFalls	363.3	15	384.02	3.03	0.74	0.57	0.67	1.67
JonesFalls	363.3	14	377.89	1.81	0.46	0.3	0.42	1.07
JonesFalls	363.3	13	372.42	3.46	0.84	0.59	0.28	1.76
NorthTrib	175.5	2	380.23	4.4	1.28		0.56	1.87
NorthTrib	175.5	1	373.35	3.39	0.73		0.46	1.81
JonesFalls2	538.8	12	369.72	2.13	0.31	0.28	0.16	0.81
JonesFalls2	538.8	11	368.48	2.97	0.54	0.38	0.47	1.7
SouthTrib	151.7	8	389.03	4.4	2.11			2.11
SouthTrib	151.7	7	386.87	3.13	0.75			0.75
SouthTrib	**Bridge**							
SouthTrib	151.7	6	385.93	3.75	1.03			1.03
SouthTrib	151.7	5	383.73	7.01	3.99			3.99
SouthTrib	151.7	4	381.23	4.01	1.3			1.3
SouthTrib	151.7	3	376.84	4.74	1.04	0.24	0.42	2.38
SouthTrib	151.7	2	373.05	2.1	0.28	0.24	0.03	0.66
SouthTrib	151.7	1	368.61	6.44	3.27	0.05		3.56
IntsTrib	66.3	8	392.61	4.7	1.5			1.5
IntsTrib	66.3	7	387.79	5.67	1.58		0.27	2.01
IntsTrib	**Culvert**							
IntsTrib	66.3	6	380.98	2.46	0.3	0.08	0.02	0.32
IntsTrib	66.3	5	380.08	3.77	0.88			0.88
IntsTrib	66.3	4	371.88	5	1.63			1.63
IntsTrib	66.3	3	367.28	3.47	0.62			0.62
IntsTrib	**Culvert**							
IntsTrib	66.3	2	365.47	4.46	0.78		0.24	1.36
IntsTrib	66.3	1	360.99	4.01	1.21			1.21
JonesFalls3	655.4	10	366.83	3.41	0.59	0.36	0.21	1.33
JonesFalls3	655.4	9	365.57	3.86	0.66	0.34	0.45	1.92
JonesFalls3	655.4	8	364.96	2.3	0.53	0.52	0.19	1.03
JonesFalls3	655.4	7	359.06	7.26	2.75	2.3	0.31	4.08
JonesFalls3	655.4	6	356.72	1.22	0.2	0.11	0.19	0.47
JonesFalls3	655.4	5	356.51	2.24	0.3	0.07	0.22	0.43
JonesFalls3	**Culvert**							
JonesFalls3	655.4	4	355.26	2.33	0.22	0.09	0.22	0.41
JonesFalls3	655.4	3.5	355.19	1.93	0.18	0.15	0.15	0.36
JonesFalls3	655.4	3	354.44	3.38	0.58	0.55	0.34	1.42

JonesFalls4	721.7	2	352.56	2.56	0.36	0.34	0.33	0.82
JonesFalls4	721.7	1	350.69	2.1	0.25	0.22	0.25	0.44

Table 19: 10-Year Storm Event, HEC-RAS Summary

		Existing Conditions: Q_{10}						
Reach	**Discharge**	**Station**	**WSEL**	**Vel. Total**	**Shear Total**	**Shear Left**	**Shear Right**	**Shear Channel**
JonesFalls	798.4	15	384.84	3.27	1.09	0.93	1.08	2.27
JonesFalls	798.4	14	378.68	2.14	0.72	0.5	0.71	1.44
JonesFalls	798.4	13	372.95	4.25	1.29	1.05	0.44	2.49
NorthTrib	459.7	2	380.57	1.99	0.19	0.17	0.14	0.37
NorthTrib	459.7	1	373.73	4.46	1.19		0.94	2.57
JonesFalls2	1258.1	12	370.36	2.7	0.51	0.5	0.29	1.02
JonesFalls2	1258.1	11	369.41	3.03	0.78	0.72	0.53	1.74
SouthTrib	322.2	8	389.46	5.11	2.57			2.57
SouthTrib	322.2	7	388.06	3.72	0.91		0.11	0.94
SouthTrib	**Bridge**							
SouthTrib	322.2	6	386.29	6.83	3.28			3.29
SouthTrib	322.2	5	384.8	3.8	0.68	0.46	0.48	2.06
SouthTrib	322.2	4	381.69	5.33	1.52	0.54	0.55	2.54
SouthTrib	322.2	3	377.52	4.22	0.73	0.49	0.49	2.24
SouthTrib	322.2	2	373.32	3.04	0.54	0.52	0.16	1.26
SouthTrib	322.2	1	369.47	3.81	0.7	0.51	0.3	1.95
IntsTrib	138.9	8	393.08	5.49	1.86			1.86
IntsTrib	138.9	7	390.12	1.59	0.09	0.04	0.08	0.19
IntsTrib	**Culvert**							
IntsTrib	138.9	6	381.69	3.46	0.51	0.26	0.11	0.57
IntsTrib	138.9	5	380.6	4.81	1.18	0.11		1.31
IntsTrib	138.9	4	372.41	5.87	2.03			2.03
IntsTrib	138.9	3	369.31	3.11	0.38	0.18	0.27	0.58
IntsTrib	**Culvert**							
IntsTrib	138.9	2	366.18	3.05	0.39	0.06	0.27	1.15
IntsTrib	138.9	1	361.33	4.8	1.42		0.32	1.55
JonesFalls3	1520.5	10	368.18	2.9	0.77	0.74	0.5	1.57
JonesFalls3	1520.5	9	366.76	4.02	1.32	1.09	1	3.03
JonesFalls3	1520.5	8	365.65	3.74	1.31	1.37	0.59	2.35
JonesFalls3	1520.5	7	360.51	4.09	0.84	0.66	0.68	2.47
JonesFalls3	1520.5	6	360.4	0.67	0.07	0.05	0.08	0.11
JonesFalls3	1520.5	5	360.3	1.73	0.26	0.19	0.25	0.31
JonesFalls3	**Culvert**							
JonesFalls3	1520.5	4	355.97	3.66	0.56	0.34	0.55	0.89

JonesFalls3	1520.5	3.5	355.89	2.9	0.38	0.34	0.33	0.62
JonesFalls3	1520.5	3	354.91	4.37	0.99	0.93	0.74	2.13
JonesFalls4	1659.4	2	352.96	3.45	0.56	0.56	0.51	1.05
JonesFalls4	1659.4	1	351.13	2.84	0.4	0.33	0.4	0.61

Table 20: 100-Year Storm Event, HEC-RAS Summary

		Existing Conditions: Q_{100}						
Reach	**Discharge**	**Station**	**WSEL**	**Vel. Total**	**Shear Total**	**Shear Left**	**Shear Right**	**Shear Channel**
JonesFalls	1593.4	15	385.55	2.89	1.04	1.39	0.81	2.9
JonesFalls	1593.4	14	379.49	2.2	0.79	0.56	0.82	1.72
JonesFalls	1593.4	13	373.52	5.38	1.88	1.69	0.67	3.47
NorthTrib	1025.9	2	380.59	4.37	0.91	0.84	0.68	1.77
NorthTrib	1025.9	1	374.19	5.43	1.55	0.21	1.36	2.96
JonesFalls2	2619.3	12	371.42	3.01	0.58	0.61	0.36	1.04
JonesFalls2	2619.3	11	370.81	3.08	0.8	0.82	0.57	1.53
SouthTrib	622.1	8	390.3	4.22	1.18	0.17	0.16	1.55
SouthTrib	622.1	7	389.68	4.34	1.06		0.5	1.09
SouthTrib	**Bridge**							
SouthTrib	622.1	6	387.35	7.37	2.57	1.03	0.64	4.25
SouthTrib	622.1	5	385.19	4.8	1.14	0.9	0.83	2.83
SouthTrib	622.1	4	382.24	6.7	2.24	0.96	1.38	3.86
SouthTrib	622.1	3	378	4.79	0.99	0.7	0.82	2.56
SouthTrib	622.1	2	373.49	4.7	1.2	1.22	0.41	2.89
SouthTrib	622.1	1	370.55	2.26	0.21	0.17	0.18	0.5
IntsTrib	261.2	8	394.74	2.58	0.23	0.07	0.07	0.38
IntsTrib	261.2	7	394.81	0.56	0.01	0.01	0.01	0.02
IntsTrib	**Culvert**							
IntsTrib	261.2	6	382.54	4.58	0.8	0.55	0.24	0.93
IntsTrib	261.2	5	381.01	6.42	1.8	0.43		2.31
IntsTrib	261.2	4	373.15	5.6	1.16	0.26		1.86
IntsTrib	261.2	3	371.98	0.52	0.01	0.01	0.01	0.02
IntsTrib	**Culvert**							
IntsTrib	261.2	2	366.45	3.98	0.75	0.19	0.61	1.76
IntsTrib	261.2	1	361.74	5.5	1.64		0.63	1.89
JonesFalls3	3144.3	10	369.55	3.47	1.3	1.33	0.98	2.27
JonesFalls3	3144.3	9	368.31	4.31	1.73	1.73	1.34	3.46
JonesFalls3	3144.3	8	366.09	6.43	3.66	3.92	1.79	6.35
JonesFalls3	3144.3	7	363.77	2.18	0.2	0.17	0.2	0.34
JonesFalls3	3144.3	6	363.68	0.65	0.06	0.06	0.07	0.1
JonesFalls3	3144.3	5	363.67	0.63	0.05	0.05	0.05	0.08
JonesFalls3	**Culvert**							

JonesFalls3	3144.3	4	356.78	5.52	1.21	0.87	1.21	1.74
JonesFalls3	3144.3	3.5	356.7	4.26	0.74	0.69	0.68	1.08
JonesFalls3	3144.3	3	355.45	5.65	1.56	1.54	1.25	3.05
JonesFalls4	3405.5	2	353.51	4.16	0.75	0.79	0.69	1.31
JonesFalls4	3405.5	1	351.71	3.67	0.58	0.49	0.6	0.83

14.2 HYDRAULIC MODEL ANALYSIS

As discussed in Section 7 of this report, the existing condition of the Eccleston site routes storm events through a highly incised channel.

Along the upstream end of the Jones Falls Reach, Sections 15 and 14 have existing wetlands adjacent to the channel which result in lower shear stresses and velocities for the 100-year storm due to the wide floodplain. Section 13 starts to show increases in the velocity and shear stress from the upstream reaches due to a pinch point in the valley and absence of adjacent wetland floodplains. Further downstream, Section 8 along the Jones Falls shows velocities and shears increasing as compared to the rest of the reach, and this can be expected as there is a major pinch point in the valley at this location. The triple culverts at Park Heights Avenue, along the Jones Falls Reach, are overtopped in current conditions during the 100-year storm event. The roadway embankment creates a backwater condition for the 100-year storm for approximately 552 feet, to Section 7, which attributes to a lower velocity and shear stress for the 100-year storm compared to the 10- and two-year storms for these sections.

The culvert along the Intersection Tributary, under Park Heights Avenue, also overtops during the 100-year storm in current conditions. The roadway also creates a backwater condition for the 100-year storm for approximately 250 feet.

The shear stress and velocities along the North and South Tributaries on average are larger than those along the Jones Falls due to narrower valleys and steeper slopes.

The results of the existing conditions model will be used to compare to the proposed design during the next phase of the project.

15. MITIGATION WORK PLAN (MWP)

The MWP shall include, but is not limited to:

- Grading plans at a scale of 1”=50’ and providing 0.5 ft. contour intervals in Restoration areas (or metric equivalent), or at a more detailed scale. Plans shall use the correct vertical datum, NOS in tidal mitigation areas and NGVD 88 in non-tidal areas;

- Erosion and Sediment Control (ESC) Plans, designed in accordance with General ESC Specifications approved by the Soil Conservation District, or approved directly by MDE.
- A detailed location map, including the latitude and longitude and the hydrologic unit code (HUC) at the center of the site
- Proposed construction methods and details on plans
- Timing and Sequence
- A GIS shapefile or similar exhibit depicting the location and extent of the project

The Wetland MWP shall include, but is not limited to:

- Water budget for a typical, wet, and dry year that includes, on a monthly basis:
  - Inputs
    a. Precipitation
    b. Infiltration
    c. Surface Flow Runoff
  - Outputs
    a. Evapotranspiration
    b. Exfiltration
    c. Spillway Outflow

- Vegetation schedule with plants and seeds selected based on habitat value and projected water elevation and duration. Schedule shall include, but not be limited to:
  - Expected zonation (i.e. POWZ, PEM, PSS, and PFO)
  - Species names of herbaceous and woody species
  - Herbaceous seed mix that includes at least ten (10) native species
  - Woody species list that includes a minimum of four (4) native species per strata
  - Wetland indicator status
  - Plant size and spacing
  - Wildlife value assessment

- Soil mapping, planned soil handling, soil amendments, and soil testing

- A surveyed delineation, in accordance with the USACE 1987 Wetland Delineation Manual (Manual) and the appropriate Regional Supplement to the Manual of the existing wetland areas of each Phase. A GPS survey is sufficient.

- Reference wetland data from existing wetland communities that are utilized for proposed wetland establishment, restoration, and enhancement activities. These data may include but are not limited to:
  - Reference location
  - Watershed and land use composition
  - Proximity to the site
  - Monitoring well data
  - Field data and analysis of those data including hydrology, vegetation, soils, wildlife, etc.

The Stream MWP shall also include, but is not limited to:

- The proposed stream segment restoration and/or enhancement locations, including plan views, longitudinal profiles, and cross-sections, with structure locations; Proposed detailed cross-sections should be located a minimum of every 500 feet within restoration/enhancement stream channels.
- A description of the existing watershed, valley, and channel classification, and the estimated proposed land use for that watershed (percent residential, forested, commercial, agricultural, etc.)
- A description of the existing riparian buffer (age of forested, shrub, and herbaceous strata present, utility easements, understory mowed, actively cropped, etc.)
- Phase of channel evolution
- Data table comparison of existing, reference, and proposed design morphological characteristics. Hydraulic assessment including, but not limited to, a quantification of bankfull, flood stage, stream velocity, sheer stress, and stream power
- The stream deficiencies to be addressed. Describe the causes of instability and the methods used to make determinations, existing lateral and vertical stability; and planned channel types
- The proposed restoration measures and methods (form, process, combination) to be employed, including channel measurements (bankfull elevation, cross-sectional area, slope, etc.), proposed design flows, typical design cross-sections, proposed detailed design cross-sections, and types of instream structures
- Reference stream data from existing stream and riparian buffer communities that is utilized for proposed stream restoration and enhancement activities. This may include but is not limited to: Reference location, watershed and land use composition, proximity to site, stream type, geomorphology, hydrology, vegetative and aquatic communities, etc.
- Describe any project constraints
- Plan-view location of proposed riparian buffer restoration, reestablishment, enhancement, and preservation segments
- Vegetation schedule with plants and seeds selected based on habitat, water quality, and stream stability value. Schedule may include but should not be limited to:
    - Species name
    - Wetland indicator status
    - Plant size and spacing

- Any stream crossings, roads, or other structures that will be removed, replaced, or left in place should be identified on the plans. Generally, crossings should be removed; if needed to be left in place, they should be stable and not adversely impact the stream.

16. MAINTENANCE PLAN

All maintenance requirements for this site shall follow the standards set forth in the Compensatory Mitigation Plan and the 2008 Final Mitigation Rule.

17. MONITORING REQUIREMENTS AND PERFORMANCE STANDARDS

All monitoring requirements and performance standards for this site shall follow the standards set forth in the Compensatory Mitigation Plan and the 2008 Final Mitigation Rule.

18. LONG-TERM MANAGEMENT PLAN

All long-term management for this site shall follow the standards set forth in the Compensatory Mitigation Plan and the 2008 Final Mitigation Rule.

19. FINANCIAL ASSURANCES

The MDTA, as a state agency, operates on a 5-year Transportation Improvement Program (TIP) cycle and has allocated $1.1 billion as a specific line item in its TIP budget to construct Phases I and II of the I-95 ETL Northbound Extension Project. The funding allocated for the project is inclusive of any compensatory mitigation, including required construction, monitoring, and long-term maintenance activities, for unavoidable impacts associated with the proposed improvements.

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